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MOXA®
Reliable Networks ▲ Sincere Service

IEC 61850 Communication and Computing Solutions for Substation Automation Systems Guidebook

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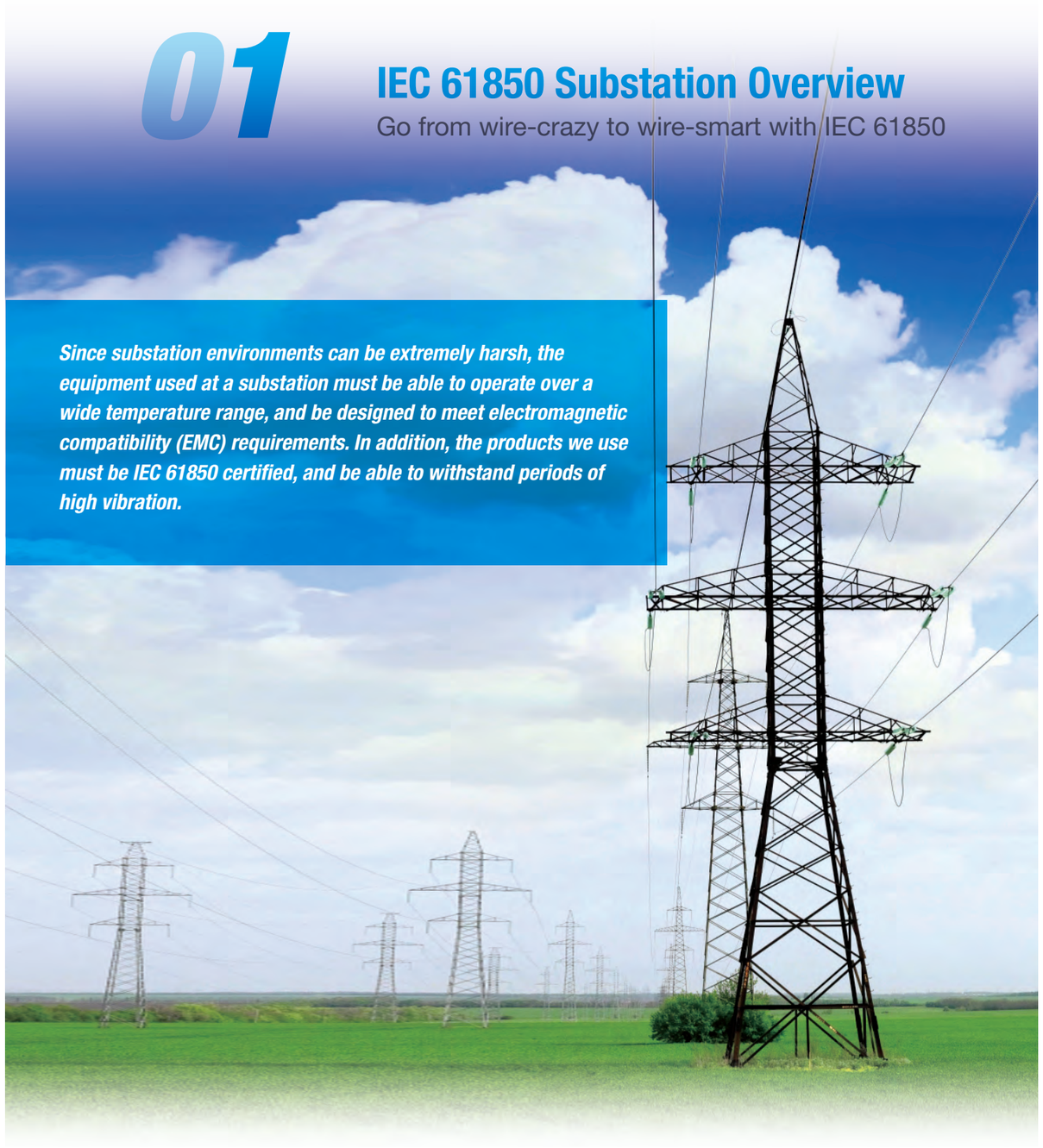
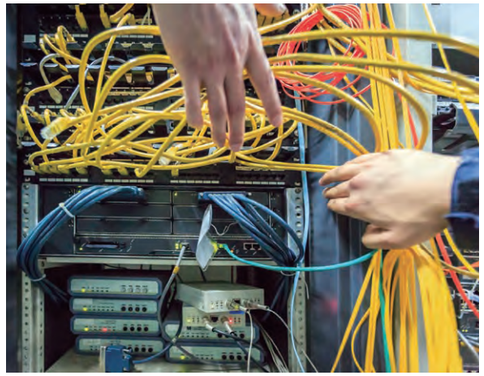
Moxa is a global leader in IEC 61850 and IEEE 1588 smart substation solutions and provides a wide range of networking and computing products for substation automation. As an active participant in Work Group 10 of the IEC TC57, a Collective Member of CIGRE, and Director-General of the Taiwan Smart Grid Industry Association, Moxa is applying its innovative technological expertise to the creation of practical, market-specific networking and computing solutions for the smart substation industry. With over 30 years of experience in industrial networking, Moxa solutions now manage over 500 successful substation applications around the world, including the world's first fully ntegrated IEC 61850 and IEEE 1588 smart substation.

01 IEC 61850 Substation Overview

Go from wire-crazy to wire-smart with IEC 61850

Since substation environments can be extremely harsh, the equipment used at a substation must be able to operate over a wide temperature range, and be designed to meet electromagnetic compatibility (EMC) requirements. In addition, the products we use must be IEC 61850 certified, and be able to withstand periods of high vibration.





Introduction

Power substation technology has evolved considerably since the first power distribution system went into service in the late 1800's. Today, several hundred thousand substations of various sizes and varieties are in operation around the world, with both retrofit and new substation projects being initiated with increasing frequency. To get a better handle on the enormity of the situation, one study (Pike Research) estimates that 150,000 substations are expected to be fully automated by the year 2020.

Let's take a close look at the benefits and advantages offered by the IEC 61850 standard. While the prospect of implementing such a complex set of rules, regulations, and stringent specification requirements may at first seem daunting, the advantages by far outweigh the disadvantages. For example, whereas the thousands of devices making up a traditional substation use hard-wired device-to-device connections running relatively low speed serial connections over copper wiring, the IEDs (intelligent electronic devices) in a modern IEC 61850 substation connect to a high-speed Ethernet bus, making it relatively easy to implement a comprehensive management, maintenance, and control strategy via a centralized power SCADA system.

Why Invest in an IEC 61850 Substation?

Whether you're looking to retrofit an existing substation, or build a new one from the ground up, the advantages of implementing the IEC 61850 standard are the same:

Simplified Architecture: The thousands of IEDs in a modern substation use localized intelligence to handle much of the decision making required at the local site, and communicate with other devices via Ethernet switches which themselves are connected to the substation's Ethernet network.

Greater Reliability: By design, the IEC 61850 standard places great emphasis on reliability. Not only are many of the devices required to be rugged enough to withstand extreme environmental conditions, you can expect the network itself to be redundant on many different levels.

Future-Proof Design: One of the major advantages of implementing an Ethernet network is that it is easy to expand when the need arises. In addition, any new products that connect to an existing IEC 61850 substation are required to be fully compatible with what's already there.

Vendor-Independence: The fact that IEC 61850 products produced by different companies are all required to speak the same language gives substation system integrators (SIs) a huge advantage, since they can pick and choose the best products from different vendors.

What is IEC 61850?

The non-proprietary IEC 61850 standard uses modern object-oriented programming principles to define a complete virtual model of the substation, which can be tested and tweaked in a computer model before being implemented with actual devices. Since the standard is open, any hardware vendor can provide IEC 61850 compliant products, giving substation engineers the freedom to pick and choose the best products for their particular project. Highlights of the standard include:

- The main data pathways use Ethernet-based communication, with high bandwidth trunk lines used to transmit data packets from/to multiple devices connected to the substation network.
- Guaranteed compatibility with IEC 61850-compliant products from different vendors, making it much easier to expand a substation's operation when the need arises.
- The IEC 61850 standard makes heavy use of the XML-based substation configuration language (SCL) to define the configuration parameters of the multitudes of IEDs used in the substation.
- High speed IED-to-IED communication with transfer times guaranteed using priority tagging of the Ethernet frames.

The transfer time requirements for different types of transfers

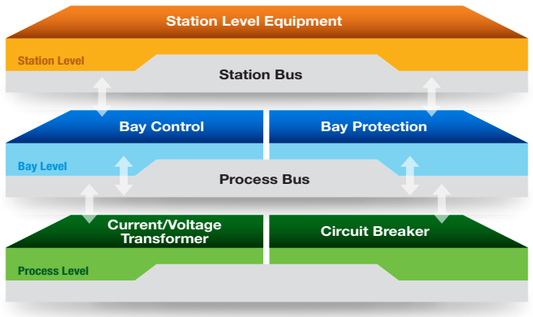
Transfer time class	Transfer time (ms)	Type of transfer
TT0	>1000	Files, events, log contents
TT1	1000	Events, alarms
TT2	500	Operator commands
TT3	100	Slow automatic interactions
TT4	20	Fast automatic interactions
TT5	10	Releases, status changes
TT6	3	Trips, blockings

Reference: IEC 61850-5

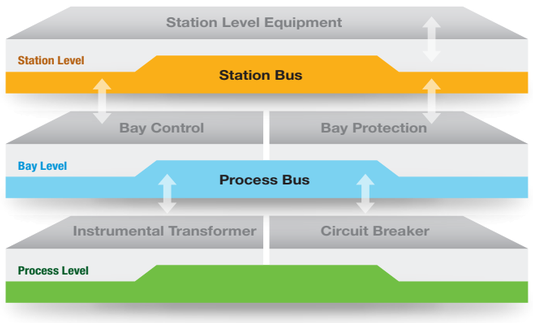
The Architecture of an IEC 61850 Substation

The IEC 61850 standard divides substation operation into three distinct levels:

Process Level: The process level comprises devices such as circuit breakers and data acquisition equipment used to measure the current, voltage, and other parameters in different parts of the substation.
Bay Level: The bay level consists of the IEDs that collect the measurements provided by the process level. The IEDs can make local control decisions, transmit the data to other IEDs, or send the data to the substation SCADA system for further processing and monitoring.
Station Level: The station level is where you'll find SCADA servers and HMIs, as well as the human operators (if needed) who monitor the status of the substation.



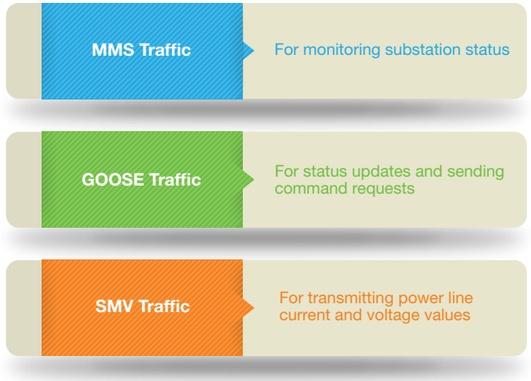
Furthermore, the IEC 61850 standard defines a Process Bus and Station Bus, as illustrated in the following diagram. The Process Bus handles communication between the Process Level and the Bay Level, and the Station Bus handles communication between the Bay Level and Station Level.



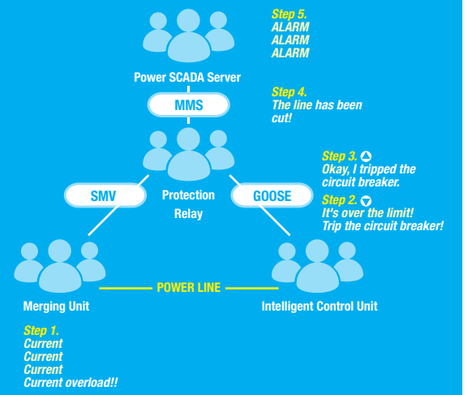
IEC 61850 Communication

IEC 61850 is a substation automation standard that is part of the International Electrotechnical Commission's (IEC) Technical Committee 57 (TC57) reference architecture for electric power systems. The transmission protocols used to handle specific types of data transfer are one of the main aspects of the IEC 61850 standard. The abstract data models defined in IEC 61850 can be mapped to a number of protocols, including MMS (Manufacturing Message Specification), GOOSE (Generic Object Oriented Substation Events), and SMV (Sampled Measured Values). These protocols can run over high speed TCP/IP networks to ensure the fast response time (< 4 ms) needed for protective relays.

MMS: Substation status information used for monitoring purposes is sent using the Manufacturing Messaging Specification protocol.
GOOSE: Critical data such as control signal and warnings are sent using the Generic Object Oriented Substation Event protocol.
SMV: Power line current and voltage measurements are sent using the Sampled Measured Values protocol.



The example in the following figure illustrates how the three protocols contribute to substation communication.



Step 1: After sensing that the current in the power line is too high, a merging unit sends a message using the SV protocol to a protection relay.

Step 2: The protection relay uses the GOOSE protocol to notify the intelligent control unit to trip the circuit breaker.

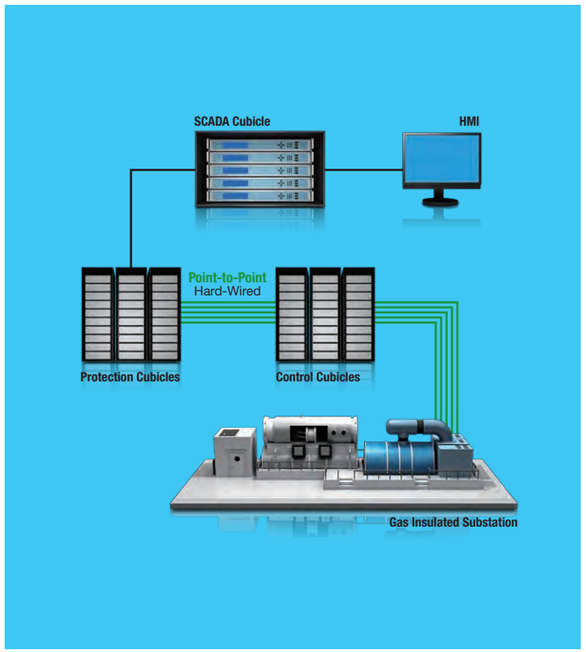
Step 3: After switching the power off, the intelligent control unit uses the GOOSE protocol to notify the protection relay that the power has been cut.

Step 4: The protection relay uses the MMS protocol to notify the power SCADA server that the power line has been cut.

Step 5: The power SCADA server issues an alarm.

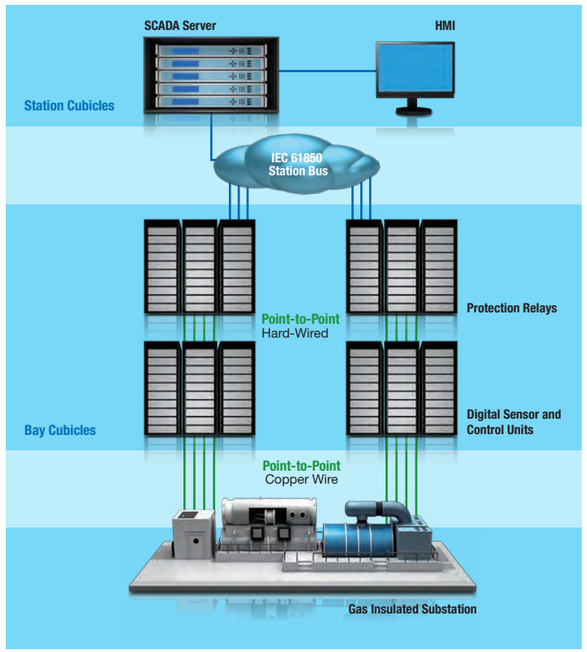
The Evolution of Substation Automation

Conventional Substation Automation



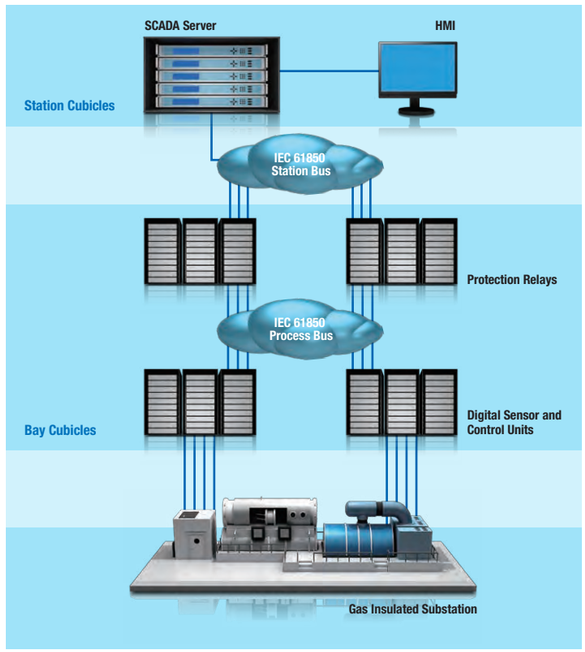
In the 1960's a conventional substation was rather bulky, with copper or fiber wiring used to hard-wire one device to another.

Substation Automation with IEC 61850 Station Bus



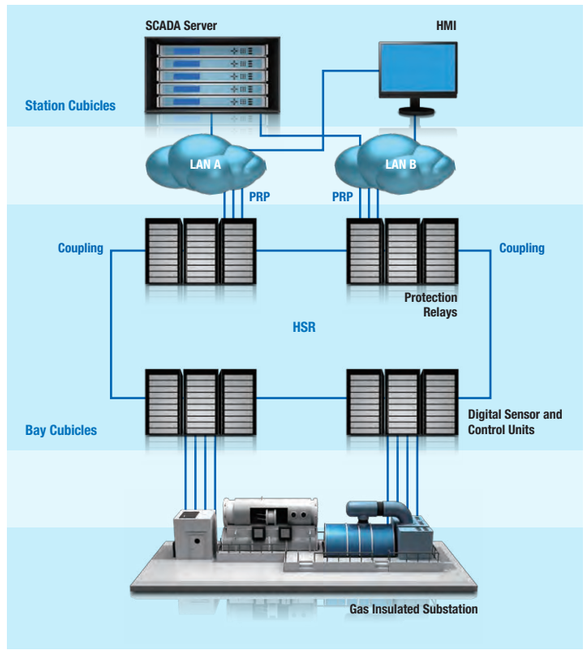
The release of the IEC 61850 Station Bus protocol in the 1980's was a big first step forward on the way to implementing a substation-wide all-purpose network.

Substation Automation with IEC 61850 Station and Process Bus



In 2005, the IEC 61850 standard was greatly improved by defining a Process Bus to connect the Process Level with the Bay Level.

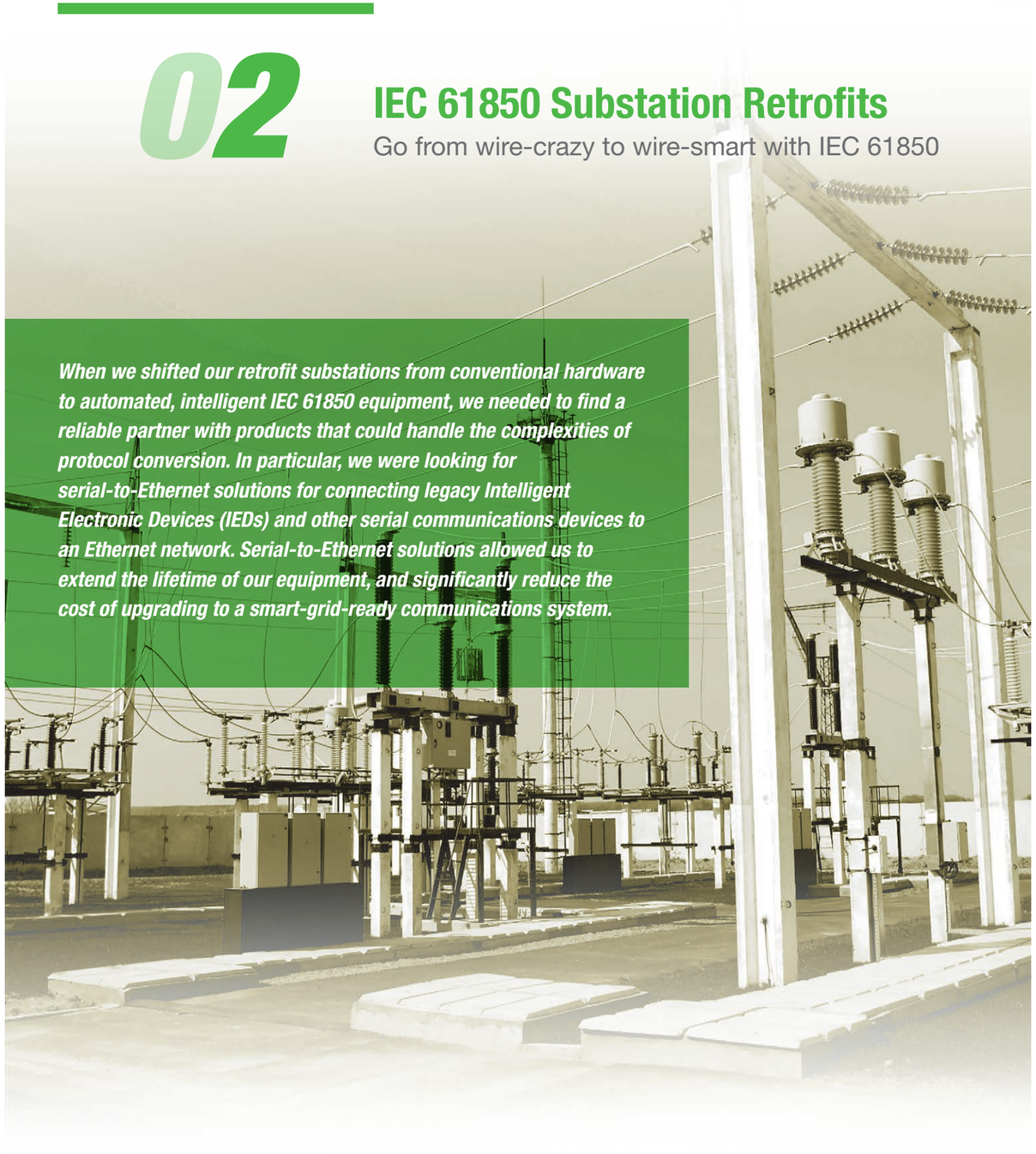
PRP/HSR: The Next Wave of IEC 61850



The latest development in the IEC 61850 standard was the inclusion of the PRP/HSR protocol in 2010. PRP/HSR (parallel redundancy protocol/high-availability seamless redundancy) specifies how to use two Ethernet networks to ensure seamless failover if one of the redundant networks fails.

02 IEC 61850 Substation Retrofits

Go from wire-crazy to wire-smart with IEC 61850



When we shifted our retrofit substations from conventional hardware to automated, intelligent IEC 61850 equipment, we needed to find a reliable partner with products that could handle the complexities of protocol conversion. In particular, we were looking for serial-to-Ethernet solutions for connecting legacy Intelligent Electronic Devices (IEDs) and other serial communications devices to an Ethernet network. Serial-to-Ethernet solutions allowed us to extend the lifetime of our equipment, and significantly reduce the cost of upgrading to a smart-grid-ready communications system.

Substation Retrofitting

Existing substations that use hundreds or thousands of legacy serial devices, some of which could be as much as 20 or 30 years old, can benefit greatly from an IEC 61850 facelift. However, executing such a facelift requires connecting the legacy devices to a modern TCP/IP network, as well as implementing the protocol conversion functionality needed to enable the devices to communicate with each other.

Let's look at the three main challenges engineers face during the process of retrofitting a substation, and how to handle them.

▸ Device Variety

Existing systems may have been developed over the years, at different time periods, making it difficult to migrate legacy devices to a single system.

▸ Integration

Substation system engineers may have limited communication domain knowhow or less time to bridge devices for system integration.

▸ Operation

How can I optimize, perform daily maintenance on, and troubleshoot an established system?

▸ Device Variety

One of the main aspects of modernizing an existing substation involves disconnecting legacy devices from a serial network (which could be as simple as “one or more serial devices connected directly to one or more PCs”), and then re-establishing the connections through a modern TCP/IP network. The goal may sound simple enough, particularly with the plethora of serial-to-Ethernet device servers available on the market today, but the fact that so many options are available also complicates the process since you need to identify which devices are suitable for your particular application.

From One Protocol to Another

One of the problems you'll face is that legacy devices from different vendors will undoubtedly use different communication protocols. We can classify the problem into three distinct categories:

Devices that use standard industrial protocols

In this case, the precise structure of the data packets sent into and out of the device is known. Vendors like Moxa can develop reliable "industrial Ethernet gateways" whose sole purpose is to convert back and forth between two or more types of data packet structures, typically between serial format and Ethernet format. A common example is Moxa's MGate MB3000 Series, which converts between the Modbus RTU/ASCII and Modbus TCP protocols. Gateways that convert between fieldbus protocols and IEC 61850 are in great demand.

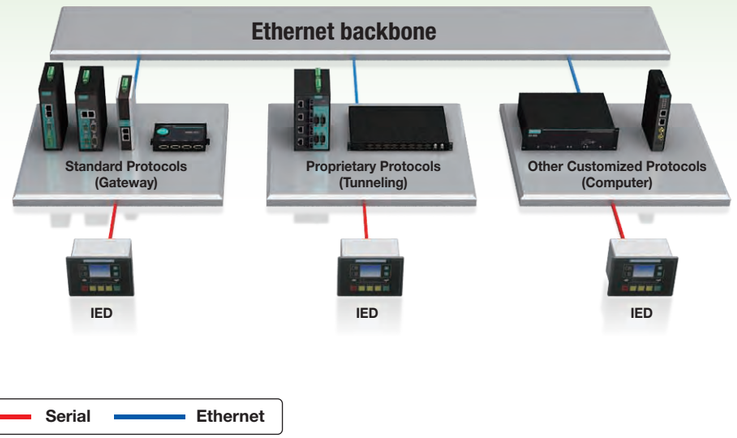
Devices that use proprietary protocols

In this case, the precise structure of the data packets is known only to the owner of the protocol. To handle this kind of situation, Moxa's serial-to-Ethernet products like NPort S9000 Series support what is referred to as "tunneling," which simply involves packing data from the device into TCP/IP data packets and then sending the data packets over the network to a computer. A Moxa driver installed on the computer intercepts the TCP/IP packets, unpacks the proprietary data packets, and then presents the data to the proprietary software. In effect, the NPort S9000 Series device works together with the driver server to fool the proprietary software running on the computer into thinking that it's still connected directly to the proprietary device.

Devices that optimize performance with custom software applications

If your organization has invested in customized software applications to add value to and optimize the substation system, then you'll need a special-purpose computer positioned between the network and your devices to run the applications. In some retrofitted substation systems, operators use their own customized protocols instead of standard or proprietary protocols. In such cases they will require fanless embedded open computing platforms to develop unique applications for these customized protocols. The data acquired through the customized protocols must also be stored in a meaningful way.

Existing Devices Use a Variety of Protocols



Different Specs for Different Folks

Depending on the size of your operation and the performance requirements of your system, the specification for the devices installed can vary from one system to another. For example, the input voltage range can be defined in AC (100 to 240 V) or in DC (12 to 48 V, up to 300 V). The Ethernet connection interface could be either copper or fiber, depending on EMC and distance requirements, and whether DIN-rail mounting or rack mounting is used could also vary from one project to another.

Time Is of the Essence

SCADA systems used to monitor and manage a modern substation work by continuously collecting and analyzing huge quantities of data from the many devices and computers making up the substation system. There are two time-related aspects of this process that are extremely important:

Meaningful timestamps

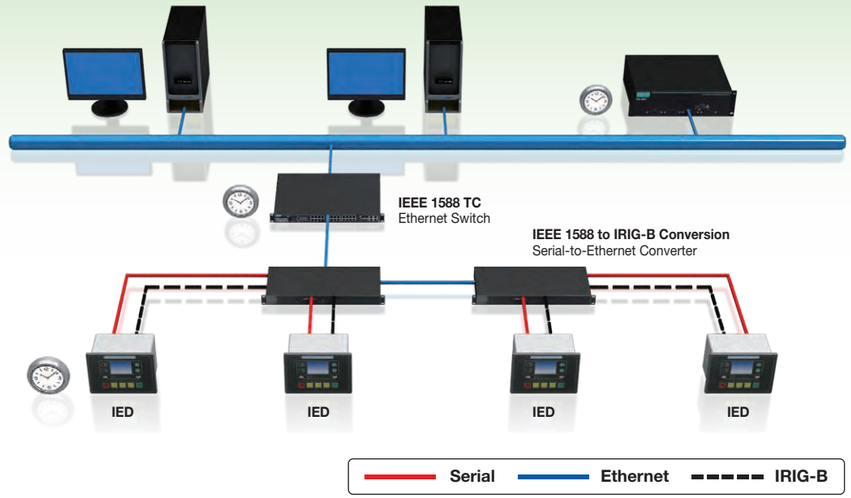
As events occur at different locations throughout a substation, the local device that records an event will add a timestamp, based on the local time of the device, before sending the event information for analysis. For this reason, it is extremely important that timestamps coming from different parts of the system are based, essentially, on the same clock. To achieve this, time synchronization protocols are used to keep all of the clocks in the system in sync.

Real-time data transmission

We all know that information, even when travelling at the speed of light, takes a finite amount of time to get from point A to point B, so "real time" generally refers to keeping the transmission time at the millisecond level. This is particularly important for control systems; any significant delay in getting control signals to the controller in response to sensor-readings can throw the entire system out of whack.

In a retrofit project, existing serial-based devices will probably be using the IRIG-B serial time synchronization protocol. In contrast, an IEC 61850 network will be using Ethernet-based IEEE 1588 time synchronization protocol. To get around this problem you should use devices that are able to convert between the two protocols as the time sync signals make their rounds.

A Mix of Time-Synchronization Protocols



Certification Standards Can Make or Break the Deal

IEC 61850-3 Class C3 Certified

The IEC 61850-3 and IEEE 1613 standards precisely define EMC and communication requirements for network equipment used in substations. Substation computers and Ethernet switches must have IEC 61850-3 and IEEE 1613 certifications to guarantee adequate protection against a variety of environmental conditions. These minimum requirements include:

- Level-4 EMC for strong protection against electrical interference
- -40 to 75°C ambient temperature tolerance
- High tolerances for constant vibrations and shocks

IEC 61850-3
Communications Networks and Systems in Substations — Part 3: General Requirements

IEC TS 61000-6-5
Electromagnetic Compatibility (EMC) — Part 6-5: Generic Standards;
Immunity for Power Station and Substation Environments

IEC TS 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, AC Power Supplies)
61000-4-12 (Damped Oscillatory Transients)
61000-4-16 (Mains Frequency Voltage)
61000-4-17 (Ripple on DC Power Supplies)
61000-4-29 (Voltage Dips, DC Power Supplies)

IEC 870-2-2
Telecontrol Equipment and Systems — Part 2: Operating Conditions;
Section 2: Environmental Conditions

Class A: Air-conditioned locations (indoors)
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

Integration

Engineers who manage power substations earmarked for retrofitting may be good at their job, but may not have the communication domain knowhow needed to convert their substation to a full-fledged IEC 61850-compliant system, or may have limited time to bridge devices for system integration. When deciding how to proceed, including which products to invest in for the transition to IEC 61850 status, you should keep the following points in mind:

Dealing with Configuration Issues

A common issue seen in the installation phase is the configuration of serial-to-Ethernet devices. Especially in retrofit projects, engineers would prefer to spend more time on performing system functional tests, rather than deal with communication issues. Therefore, making the configuration as simple as possible would definitively improve the configuration efficiency of the entire project.

Easy Configuration in Three Steps

1 Operating Mode

2 Network Settings

3 Serial Settings

Wide Range of Operating Systems

Engineers who deal with retrofit projects have always faced a wide variety of operating systems due to the fact that existing substations were built over a period of time. Sometimes, the limitation comes from needing to retain the legacy operating systems because the drivers used to read the end devices only works on these systems. Sometimes, end users might want to use up-to-date operating systems because of their longevity. Therefore, an IEC 61850 solution must support a wide range of drivers for serial-to-Ethernet devices on multiple operating systems.

Moxa provides drivers for more than 20 Operating Systems
We guarantee a continuous driver/OS support for the best system interoperability and flexibility

Windows 10 x86/x64	Windows 7/8 x86/x64	Windows Server 2008 x86/x64	Windows Server 2003 x86/x64	Windows Vista x86/x64	Windows XP x86/x64	Windows XP Embedded
Windows CE 5/6	Windows 2000	Windows NT 4.0	Windows ME	Windows 98 SE	DOS	Linux 3.0 x86/x64
Linux 2.6 x86/x64	Linux 2.4	SCO OpenServer 6	SCO OpenServer 5	Unixware 7	FreeBSD	QNX 6 QNX 4

A Platform Is Not Just a Platform

Since embedded computers are often used for customization, optimization, and multitasking, choosing a suitable hardware platform is extremely important.

Native Compilation Support

Engineers have to deal with specific tool chains, source code, and binaries to compile software for multiple platforms. A platform that supports a native compiler will make things much easier.

Operating Systems

The embedded computer used in a serial-to-Ethernet solution is expected to do more than just protocol conversion. The operating system and the packages supported will determine the time required to develop any solution.

Wireless Capability

For geographically-distributed substations, wireless solutions are usually chosen to provide communication and redundancy. However, there are no rigorous certification processes to identify the stability of wireless solutions. Some wireless companies have defined their own criteria for choosing a wireless platform for IEC 61850 substations.

Native Compiler
- Programming environment similar to Linux
- Development is much easier without cross-compilation

Scalable OS & Software Packages
- Debian ARM support
- Over 48,575 stable, ready-to-use packages, including IPSec and NetSNMP

Ready-to-Run Wireless Computer with Data Acquisition Capability
- Supports wireless-enabled functions and related development
- Ethernet-to-cellular
- Serial-to-cellular

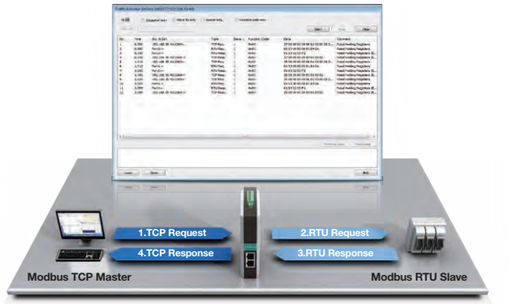
verizon at&t

Operation

Once your IEC 61850 retrofitted substation is up and running, problems are bound to pop up, so you'll need to be on your toes. Here are some things you should watch out for:

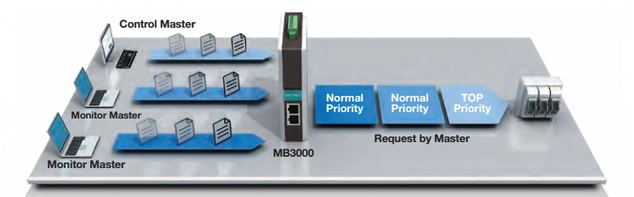
Troubleshooting Communication Errors

Because of insufficient domain know-how, troubleshooting communication issues is always a nightmare for substation engineers. In a retrofit substation, dealing with serial communication errors (e.g., Modbus errors) can be even more daunting because engineers often need to use time-consuming trial-and-error methods to solve problems. Products that support data traffic monitoring and protocol inspection can help you identify serial communication errors and thereby decrease the impact of system downtime.



Prioritizing Modbus Messages

In a control and monitoring system (CMS), commands that track important data and emergency requests are considered critical. Regular metering commands are non-critical in nature. The CMS generates an alarm or error if a critical function is not addressed immediately. You can find products with features that can prioritize critical commands, such as Modbus messages, to solve this issue.



Performance and Security

Protocol conversion is only one of the functions sought while choosing embedded computers for a retrofit substation project. Most of the time, embedded computers in a substation are used to run many different applications and operating systems. In such cases, engineers would prefer to use virtualization technology such as VMware to run independent virtual machines (VMs) with the following benefits:

Reduced Costs

VMs increase the efficiency and utilization level of your existing x86 hardware platform.

Application Isolation

Depending on the capability of your hardware platform, you can run each application on a separate VM for complete isolation of the applications. You can also run critical and non-critical application workloads on separate VMs to ensure that if one set of applications fails, the other applications will continue to run.

Extend the Life of Your Legacy Applications

You can use VMs to run your legacy applications and OS on computers with new hardware platforms or operating systems.

However, don't assume that every computer platform works well with VMware. Be sure to use products that display the VMware-ready logo, which indicates that a product meets the criteria for VMware integration and interoperability.

Troubleshooting System Crashes

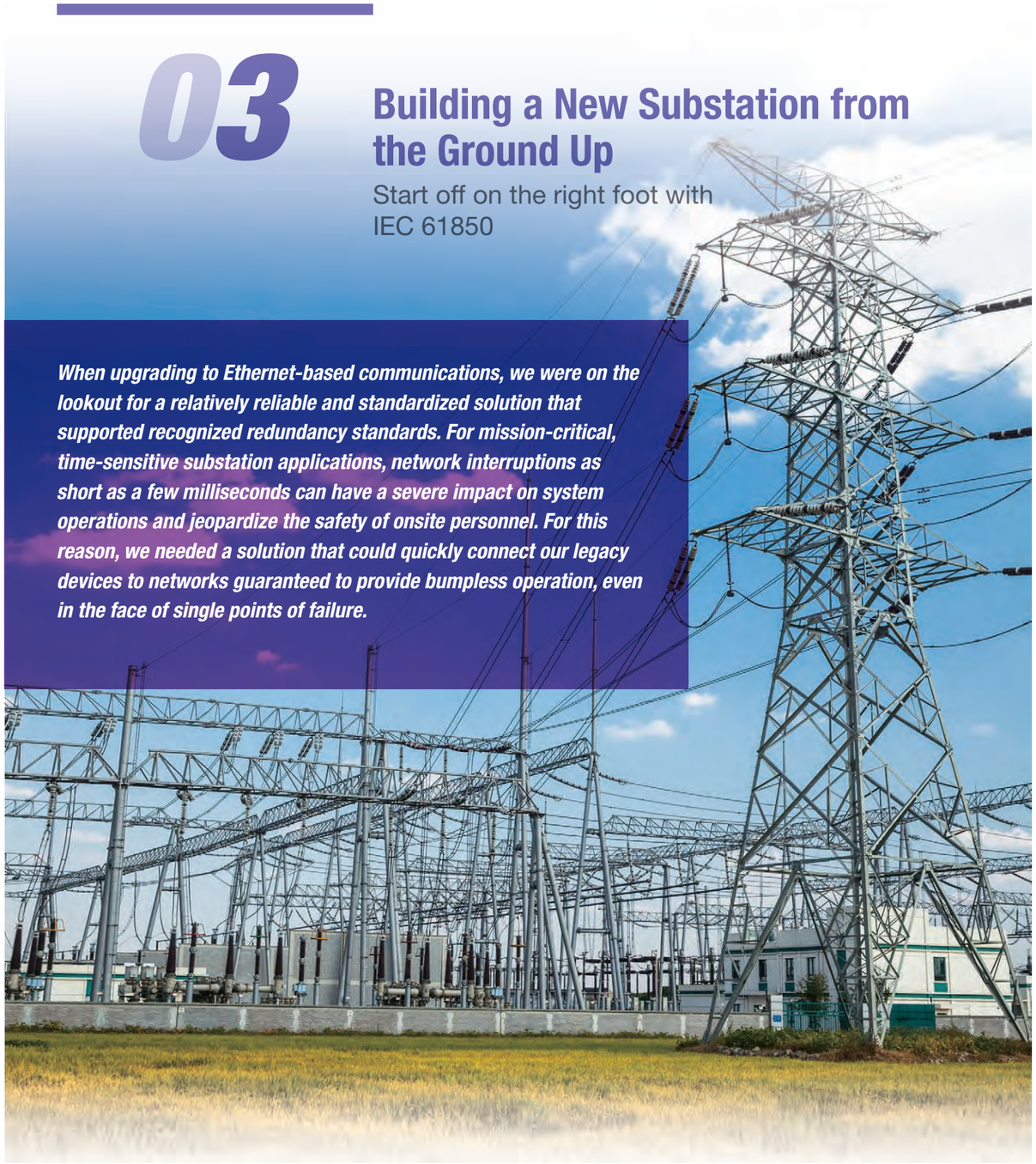
A smart OS recovery system is an essential function in a remote substation. Without an OS recovery system, corruption of system software—whether in the OS or in local substation applications—can mean catastrophic failure. According to some estimates, the percentage of computer failures attributable to software corruption is as high as 30%. However, most of the substation engineers who are experts in their field do not have enough computer domain knowledge on troubleshooting and fixing operating system problems. To minimize downtime, an automated BIOS-level software recovery system is an extremely valuable addition to the design of a power substation process.

A good example is Moxa Smart Recovery™, a tool that facilitates automatic system recovery by triggering OS rewrites. The system triggers a recovery process using a tagged copy of the entire system created when the embedded computer was first deployed successfully, and which is stored locally on the computer or on an external drive. The following recovery methods are available to help ensure minimum downtime when there is a system crash:

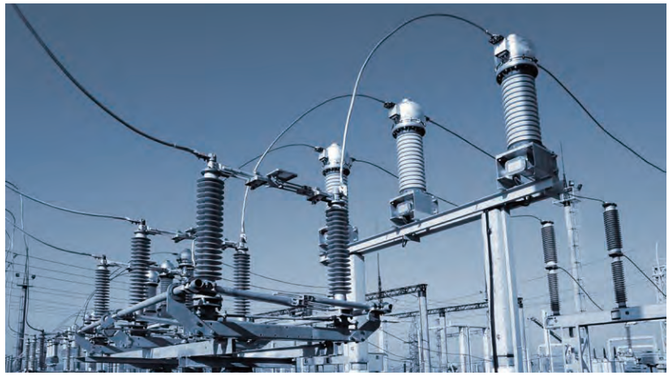
- For unmanned sites where troubleshooting is not easy, OS rewrites can be fully automated to restore the system from a tagged copy.
- For sites that are monitored by substation engineers where the requirement is to double-check the parameters before the OS-recovery process starts, engineers can provide the location of the image file and just run a power cycle to complete the process.

03 Building a New Substation from the Ground Up

Start off on the right foot with IEC 61850



When upgrading to Ethernet-based communications, we were on the lookout for a relatively reliable and standardized solution that supported recognized redundancy standards. For mission-critical, time-sensitive substation applications, network interruptions as short as a few milliseconds can have a severe impact on system operations and jeopardize the safety of onsite personnel. For this reason, we needed a solution that could quickly connect our legacy devices to networks guaranteed to provide bumpless operation, even in the face of single points of failure.



New IEC 61850 Substations

Engineers given the task of designing a new power substation have the luxury of being able to start from scratch. When comparing conventional hardwired solutions with modern IEC 61850 solutions, many power companies are opting for the IEC 61850 solution, which can provide the same performance and reliability as a hardwired solution, but with the added benefit of scalability. Let's look in detail at how to handle three of the main challenges engineers face when building a new IEC 61850 substation from the ground up:

- Performance
- Reliability
- Manageability

Performance

One of the major concerns of experienced substation engineers is how the performance of an Ethernet-based substation compares with the performance of a more traditional peer-to-peer, hardwired substation. The concern is understandable, particularly since in an Ethernet-based network, thousands of information packets are constantly competing for a spot in the substation network's main trunk line. Someone unfamiliar with how an advanced IEC 61850 substation network prioritizes packets to ensure that critical information is passed quickly to the correct devices is likely to be skeptical.

Background

Will the performance of an IEC 61850 Ethernet-based substation compare favorably with that of a hardwired peer-to-peer substation?
The answer is, yes. In general, engineers have three major concerns:

1. Will the transfer time between applications be fast enough?
2. Can we expect communication via an Ethernet network to be the same or better than a hardwired peer-to-peer substation?
3. What kind of protocol can be used to ensure that event timestamps are accurate across different locations for efficient operational diagnostics.

IEC 61850 QoS: Critical Packet Prioritization

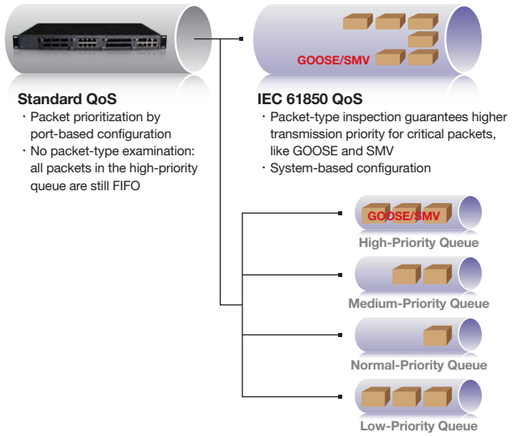
Modern IEC 61850 Ethernet networks should apply an intelligent QoS (Quality of Service) categorization method to ensure that the most critical data packets can be forwarded with highest priority.

Standard QoS

Standard QoS prioritizes packets depending on their port-based configuration and the queue level. All packets in a high-priority queue are transmitted based on a first-in-first-out sequence within each queue level without undergoing a packet-type inspection. For example, with this method, GOOSE packets with the highest priority could be transmitted after other data traffic.

IEC 61850 QoS

In IEC 61850 substation communication, GOOSE and SMV are 2 critical packet types that require high-priority attention. To guarantee that these messages are not corrupted, they are transmitted with the highest priority, regardless of what other messages are queued up in the network. When an IEC 61850 queueing scheme is used, the Ethernet switch knows that GOOSE and SMV packets are critical, and hence always gives these messages the top priority in the sending queue.



VLAN Technology: Enabling Efficient and Reliable Communication

VLAN technology is used to group network devices by IP address, instead of by physical location. That is, devices from anywhere on the substation network can be assigned to the same “virtual” LAN (abbreviated VLAN), whereas two devices located right next to each other could be assigned to different VLANs. VLANs provide substation networks with the following benefits:

Trunk traffic reduction

Traffic can be restricted to specific network domains by assigning network devices to specific VLANs, and in this way remove potential trunk traffic bottlenecks.

Traffic filtering

A network device assigned to a particular VLAN filters out packets sent from devices not on the same VLAN. This simple, yet effective filtering strategy is used to segregate traffic flow throughout the network.

Device performance improvement

Endpoint devices on the network will only process packets from the VLAN that they belong to, greatly reducing the number of messages each device needs to process.

Time Synchronization Technology: Enabling Efficient and Reliable Communication

Accurate time synchronization is required in a substation to ensure that measuring devices connected to the grid have accurate clocks. Accuracy of the clocks is measured relative to a national standard and can vary from the order of milliseconds to microseconds, depending on the application.

Time-Synchronization Protocol	Typical Accuracy in Substations	Fulfills IEC 61850 Station Bus Requirements (1 ms)	Fulfills IEC 61850 Process Bus Requirements (1 μs)
NTP/SNTP	1 to 10 ms	✓	–
IEEE 1588 V2	1 μs	✓	✓

Reliability

Reliability is extremely important for substations. If one or more devices fail, key segments of the substation could potentially go offline for a significant length of time. For this reason, reducing the amount of time it takes to detect errors, and correcting the errors once they’re detected, is an important performance indicator for substation engineers.

Background 1

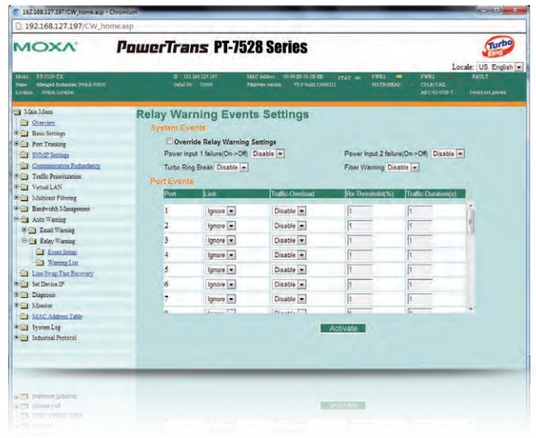
Packet losses of any kind are not tolerated in substation communication. Ensuring that critical packets are reliably transmitted is a key for any substation. With this in mind, what measures can be taken to reduce packet loss due to electromagnetic interference in a substation?

Network devices that meet IEEE 1613 Class 2 requirements are the minimum criteria to guarantee reliable communication in a high EMI environment such as a substation. To ensure better protection than IEEE 1613 Class 2 standard, Moxa’s NoiseGuard™ technology can guarantee zero packet loss under wire speed communication. NoiseGuard™ uses an optimized mechanical design with integrated housing for better conduction. Customized components can include a newly designed fiber transceiver, and an enhanced, optimized power circuit design.

Background 2

How can a mechanism that anticipates when fiber components are reaching the end of their life-cycle be implemented, allowing engineers to replace the components before they fail?

Fiber port performance is measured by the length of time the port operates successfully. Preventing fiber malfunctions using a pre-fault predictive maintenance mechanism is extremely important. Most substations currently support only SFP-type optical-fiber monitoring. Moxa FiberCheck™ can be used by substation switches to monitor ST/SC (as well as SFP) connectors, and notify the power SCADA system via SNMP or MMS when abnormalities are detected, allowing operators to quickly initiate maintenance procedures. Reports and alarms can be transmitted using any one of the following methods: a network port, a serial console, CLI, MMS reporting, SNMP traps, digital relay, entries written to the system log file. The FiberCheck™ function also allows system operators to monitor transmission and reception power, temperature, and voltage/current along optical-fiber connections in real time.



Background 3

Time-critical data transmitted through the process bus can only tolerate delays up to 4 ms (IED interlocking). Is there a redundancy technology that can meet this requirement?

Engineers are concerned that meeting redundancy requirements when upgrading to Ethernet-based communication will be too costly. In fact, a “standard” solution does not exist, and consequently the cost will depend on the type of solution that is adopted. Moxa's zero-switchover-time PRP/HSR solution adheres to the IEC 62443-3 standard to provide a scalable, integrated solution for the communication infrastructure and management platform. See the PRP/HSR section for details.

Background 4

Stable system operation is important for ensuring reliable substation management. However, when the system is unstable, how do you restore the system to normal operation as quickly as possible?

Engineers are often stymied by a lack of domain knowledge and unfamiliarity with what could be a long list of complicated recovery steps. Moxa Smart Recovery™ is an automated BIOS-level software recovery tool that allows engineers to automatically trigger OS recovery to minimize downtime.

Fully Automated Recovery Tool

- Special design for unmanned or remote substations that can automate the recovery process.

Two-Step Manual Recovery Process

- Supports an easy 2-step recovery process either from the tool or using a USB storage device, which helps the engineer to quickly restore system operations.

Background 5

How do you improve CPU performance, memory usage, storage, and system temperature performance, which can severely impact real-time management and monitoring?

Proactive Monitoring, Moxa’s revolutionary software visualization tool for industrial computers, monitors the computer’s health by keeping an eye on CPU usage, memory usage, storage partition usage, the operating temperature of the CPU and motherboard, and the redundant power monitor, and can trigger relay outputs to provide either visual or audio alarms. What’s more, you can configure the tool to trigger these alarms based on user-defined criteria.

CPU Usage Alert
When CPU usage exceeds a threshold over a period of time (usage threshold and time period defined by the user).

Temperature Alert
When the system temperature exceeds a user-defined threshold over a configured time period.

Memory Usage Alert
When memory usage exceeds a specified threshold over a configured time period.

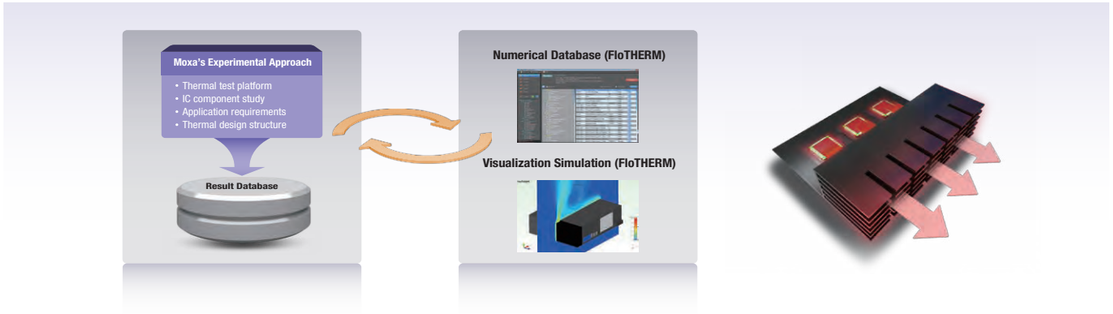
Storage Drive Alerts
Thresholds may be configured for S.M.A.R.T. values, including dwindling storage capacity.

Predefined Event		Threshold			Default Activation	Action
Item	Description	Min.	Max.	Default		Output to the Relay
CPU	**CPU usage alarm:** When the CPU usage reaches the predefined threshold.	1%	100%	80%	Disabled	CPU Loading Warning
Memory	**Memory usage alarm:** When memory usage reaches the predefined threshold.	1%	100%	80%	Disabled	Memory Usage Warning
Disk	**Storage partition usage alarm:** When storage usage reaches the predefined threshold.	1%	100%	80%	Disabled	Disk Partition Usage Warning
Temperature	**CPU temperature alarm:** When the CPU temperature exceeds the predefined threshold.	0°C	120°C	100°C	Disabled	High Temperature Warning
	Mainboard temperature alarm: When the mainboard temperature exceeds the predefined threshold.	-40°C	0°C	-15°C	Disabled	Low Temperature Warning
		0°C	120°C	100°C	Disabled	High Temperature Warning
Network	**Ethernet status alarm:** When an Ethernet port link is down, a relay is triggered.	N/A	N/A	N/A	Disabled (by port)	Link Down Warning
Power	**Redundant power monitor and alarm:** When one of the power modules malfunctions (dual-power models only).	N/A	N/A	N/A	Disabled	Power Failure Alarm Default: Disabled

Background 6

Extreme temperatures ranging from -40 to 75°C, dust, and restricted airflow are conditions commonly found in substation environments that can greatly affect the performance of substation computers. Computers that rely on fans to keep their CPU cool are particularly vulnerable to these kinds of conditions. Many substations are now turning to fanless computers designed to operate in the extreme conditions found in substation environments.

A substation computer should be fully sealed from the outside environment and not require any type of fan. Not requiring a fan extends a computer’s life significantly, provided the computer is able to survive in the extreme heat often experienced in substation environments. Engineers must therefore work to situate the PCB’s highest thermal concentration in the very center of the device, so that heat has the largest immediate area available to dissipate into. With fanless systems, generally the entire outer shell is utilized as one large heat sink, with fin heights, gaps, thicknesses, and points of contact carefully analyzed and adjusted to further optimize dissipation. All of these factors must be carefully evaluated and adjusted to achieve maximum dissipation efficiency. What this means is that designing a fully fanless computer is a nontrivial engineering challenge, with fanless computers inevitably more expensive than fan-cooled solutions. But the additional cost is more than justified by the huge increase in reliability, as well as the additional benefits of reduced size, complexity, and protection against dust, heat, and corrosion.

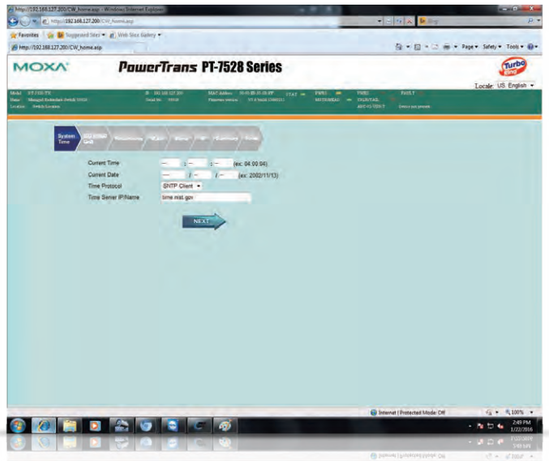


▸Manageability

Background 1

Configuring network devices correctly can be a major headache for substation engineers, particularly since incorrect configurations can result in an unstable or nonfunctional communication infrastructure.

That's where Moxa's proprietary Substation Configuration Wizard can make all the difference. Because substations are such a specialized environment, IT setups will only require a few key features. For this reason, it makes a lot of sense to simplify and streamline the configuration process. By reducing the configuration interface to only the relevant network features, setup and maintenance becomes much more efficient. As is illustrated in the accompanying graphic, engineers can use Moxa's browser-based configuration wizard to deploy our network devices in as few as 7 steps.



Background 2

A powerful and secure management platform is crucial to substation automation. However, with a variety of applications operating on a single system, overall performance can experience significant degradation. What substation engineers would like to avoid is the need to maintain multiple management platforms, which can be costly and difficult to implement and maintain.

Performance and Protection

Protocol conversion is only one of the functions sought while choosing embedded computers for a retrofit substation project. Most of the time, embedded computers in a substation are used to run many different applications and operating systems. In such cases, engineers would prefer to use virtualization technology such as VMware to run independent virtual machines, with the following benefits:

Reduced Costs

VMs increase the efficiency and utilization level of your existing x86 hardware platform, thereby saving the cost of acquiring new hardware.

Application Isolation

Depending on the capability of your hardware platform, you can run each application on a separate VM for complete isolation of the applications. You can also run critical and non-critical application workloads on separate VMs to ensure that if one set of applications fails, the other applications can continue to run.

Extend the Life of Your Legacy Applications

You can use VMs to run your legacy applications and OS on computers with new hardware platforms or OSs.

However, don't assume that every computer platform works well with VMware. Be sure to use products that display the VMware-ready logo, which indicates that a product meets the criteria for VMware integration and interoperability.

Background 3

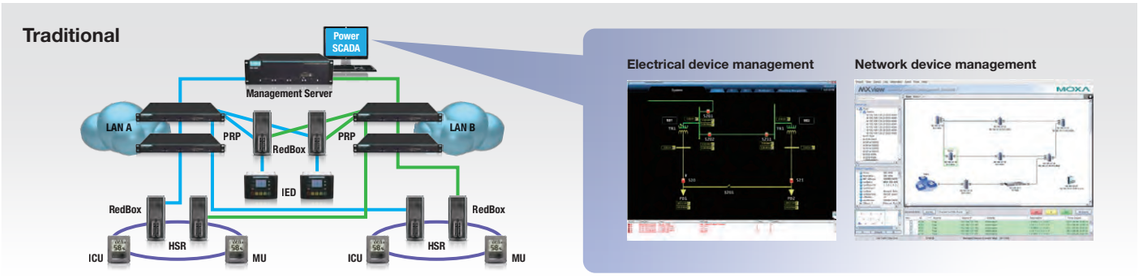
Upgrading multiple peer-to-peer communication connections on the same network, and finding communication errors can be an extremely complicated exercise. One of the main concerns of substation engineers is that they may need to hire network experts to work onsite, resulting in long system downtimes.

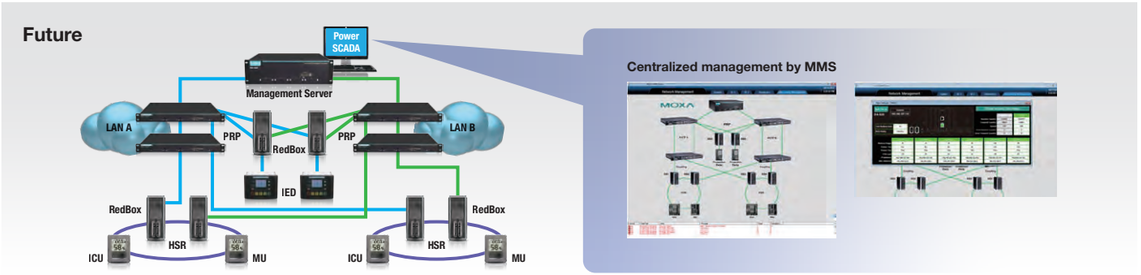
With fully integrated MMS (Manufacturing Message Specification) support based on IEC 61850-90-4 modeling, Moxa's PowerTrans substation Ethernet switches give substation engineers a huge management advantage by way of its simple PSCADA integration, which makes managing the Ethernet switch the same as managing IEC-61850 electrical devices.

With MMS-capable hardware, substation SIs and automation engineers can display their entire network of automation devices right alongside process-level information, all in a single SCADA view. Since you will no longer need to install and configure separate NMS software for IT devices on your substation system, station operators can enjoy the combined benefits of more thorough automation integration, improved management efficiency, and savings on deployment costs.

Integrating IT devices via MMS makes substation networks more controllable, more flexible, and more responsive. Administrators can use MMS to:

- Monitor and control IEDs, switches, embedded computers, device servers, and process data from a single power SCADA interface
- Eliminate redundant SNMP systems for IT hardware while decreasing network congestion
- Configure devices for event triggers, polling reports, or both
- Precisely locate devices relative to other devices within the network hierarchy in a single software view
- Directly configure and control IT hardware from the SCADA system





Enabling Efficient and Visually Represented PRP/HSR Network Management

Background 4

Decentralized management with multiple protocols (MMS, PRP/HSR supervision frame, SNMP) increases complexity and decreases efficiency. One of the main concerns is that if substation engineers are not able to efficiently analyze the communication status of a PRP/HSR network, it will be harder to implement a preventive maintenance strategy when only one communication path is operational.

A native PRP/HSR computer is the best choice when it comes to ensuring high reliability while monitoring a PRP/HSR network. With some specially designed PRP/HSR management middleware built in, the PPR/HSR management server can enable the Power SCADA system to collect and analyze the raw data from various distributed devices. The current redundant network status can be fully monitored, and the single-point-of-failure can be immediately discovered. This makes real-time troubleshooting a simple task.

The PRP/HSR management middleware supports both SNMP and MMS interfaces, allowing the connection of various substation devices that run different communication protocols, including PRP/HSR devices. The supervision frame from the PRP/HSR devices is converted to SNMP or MMS format at the device level and then sent to the middleware for analysis. The integration of the middleware and Power SCADA system enables all data to be effortlessly used and read in the substation Power SCADA system via the MMS protocol. Substation operators find it easy to manage all devices on the PRP/HSR system via the Power SCADA visual tools. In addition, troubleshooting can be easy since any single-point-of-failure can be shown on the Power SCADA system, making the PRP/HSR application more reliable and stable.

Benefits of Moxa's Integrated PRP/HSR Technology

Flexible and Modular PRP/HSR Switch

- IEC 62439-3 Clause 4 (PRP) and Clause 5 (HSR) compliant
- Modular design provides flexible deployment and lower mean-time-to-repair
- MMS server built-in for power SCADA integration
- Designed for NERC CIP-compliant system development

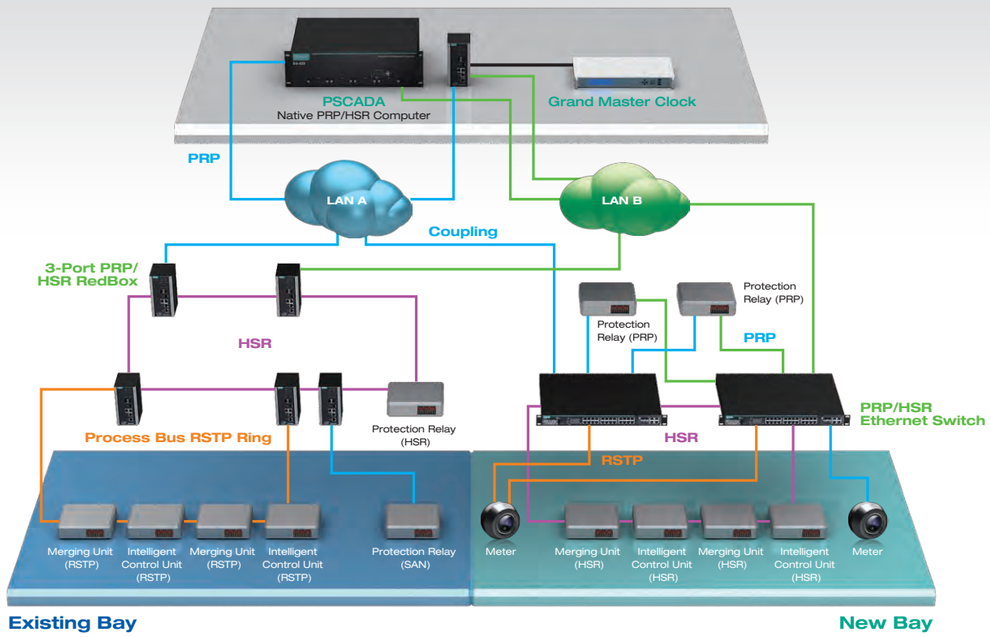
Versatile and Scalable PRP/HSR Redundancy Box

- IEC 62439-3 Clause 4 (PRP) and Clause 5 (HSR) compliant
- All-in-one device supporting Gigabit, Coupling, QuadBox, and PTP for maximum scalability
- MMS server built-in for power SCADA integration

Native PRP/HSR Computer

- Power SCADA host without single link failure
- Built-in PRP/HSR management middleware for monitoring and troubleshooting redundant network
- Visual representation of PRP/HSR devices to enable efficient network management

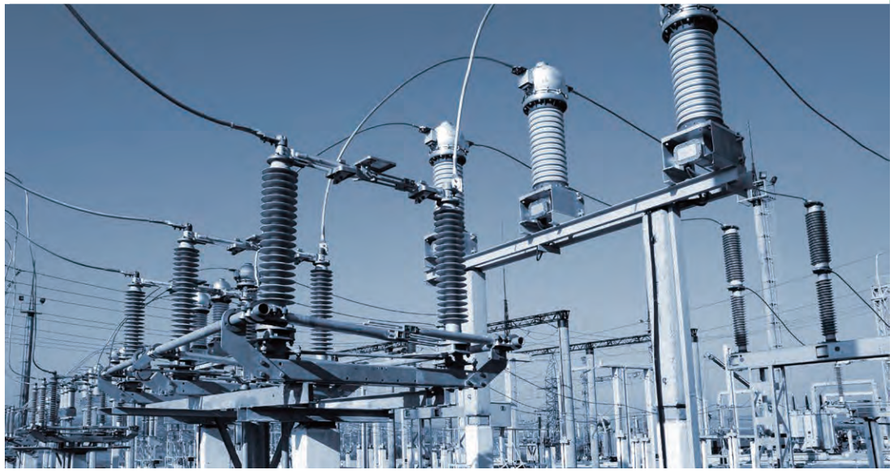
High Interoperability from Communication Backbone to Management Platform



04 Over 1,000 Successful Transmission and Distribution Deployments Worldwide

General Substations: **Cases 1 and 2**

Transmission Substations: **Cases 3, 4, 5, 6, 7, and 8**



Distribution Substations: **Cases 9, 10, and 11**

Enterprise Substations: **Cases 12, 13, 14, 15, and 16**

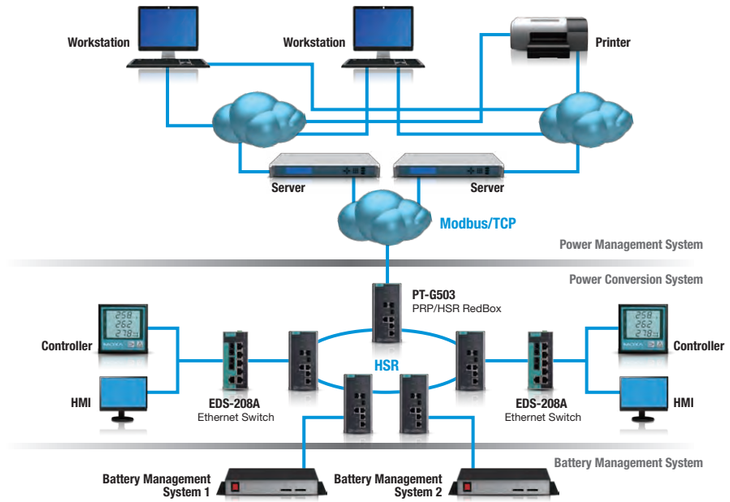
Create rock-solid and future-proof substation networks by partnering with Moxa. With years of expertise in the substation industry, we have delivered digital solutions to over 1,000 substation communication and computing projects worldwide.

In this chapter we share success stories from all over the world. The success stories are grouped into four categories: Generation Substations, Transmission Substations, Distribution Substations, and Enterprise Substations. Take a close look at these success stories to see how Moxa can help you overcome critical issues that arise when you're building your own smart substation.

01
Korea

HSR Solution for an Energy Storage System

Power Conversion System in Korea



Background and Requirements

- **Substation Voltage:** 345 kV
- **Type of Substation:** Generation Substation
- **Customer Needs:** Implement ESS (Energy Storage System) to enable remote monitoring of the state of the energy stored

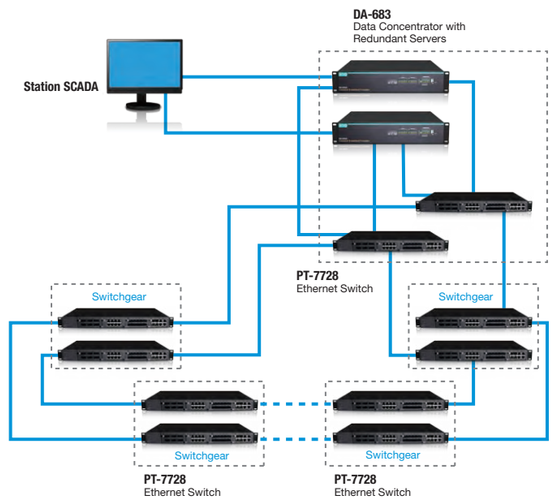
Why Moxa?

- Easy-to-configure HSR solution
- PT-G503 has one dedicated Ethernet port for monitoring and troubleshooting

02
India

Thermal Plant IEC 61850 Terminal Substation

India's Biggest Thermal Plant with Redundant Network Design



Background and Requirements

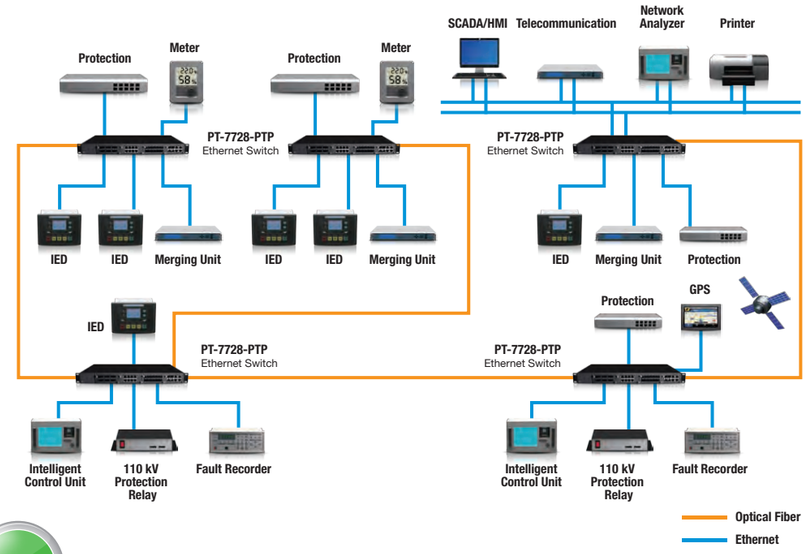
- **Substation Voltage:** 765 kV
- **Type of Substation:** Generation Substation
- **Customer Needs:** Flexible port configuration with 4 fiber gigabit ports to form a redundant ring

Why Moxa?

- IEC 61850-3 and IEEE 1613 compliant
- Total computing and communications solutions
- PT-7728 provides the best cost-performance ratio

03
China

World's First IEC 61850 3-Layer 220 kV Substation



Background and Requirements

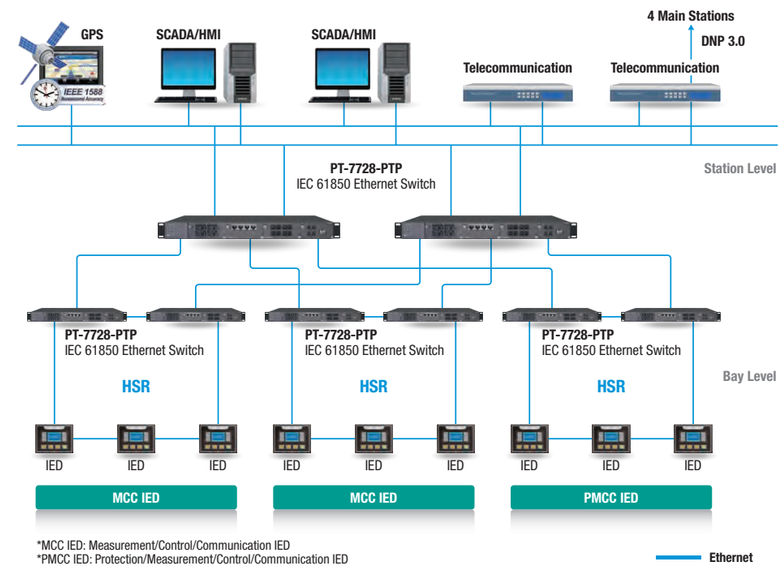
- **Substation Voltage:** 110/220 kV
- **Type of Substation:** Transmission Substation
- **Customer Requirements:** Build the world's first IEC 61850 digitalized substation on a state grid in Jiangsu province that utilizes the IEC 61850 GOOSE/SMV and IEEE 1588 standards.

Why Moxa?

- Consulting service for substation networking design
- PT-7728-PTP is IEC 61850-3 and IEEE 1613 compliant
- IEEE 1588 nanosecond-level accuracy

04
Taiwan

IEC 61850 161 kV Substation with a PRP/HSR Network



Background and Requirements

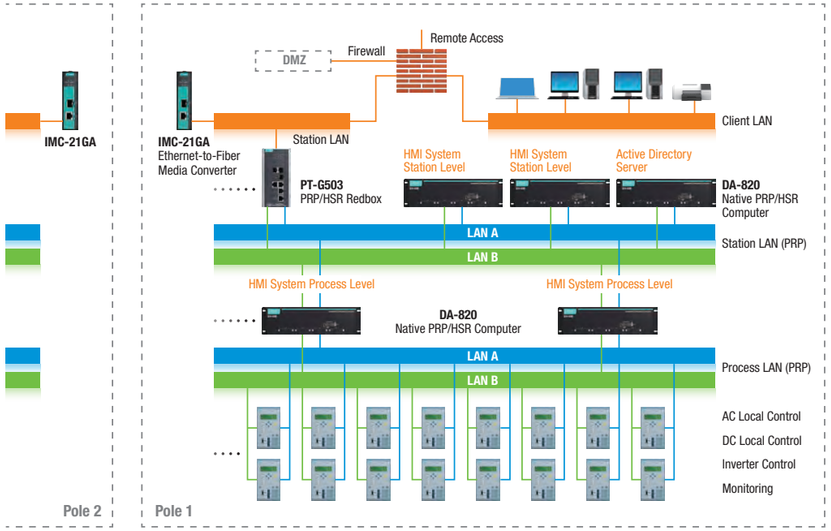
- **Substation Voltage:** 161 kV
- **Substation Type:** Transmission Substation
- **Customer Requirements:**
  - Build an IEC 61850 substation with a high-reliability design including IEEE 1613 class 2 devices and a zero packet loss network
  - Protection devices (SAN and DAN) should be connected redundantly to SCADA through MMS

Why Moxa?

- KEMA certification for IEC 61850-3
- Good consulting and techincal support
- Comprehensive PRP/HSR offering
- Solution includes MMS communication

05
Germany

PRP Network for Station & Process Bus



Background and Requirements

- **Substation Voltage:** 380 kV
- **Substation Type:** Transmission Substation
- **Customer Requirements:**
  - Converter stations for a 340 km 380 kV HVDC link with a transmission capacity of 2 Gigawatt.
  - PRP/HSR box with coupling mode support and management and monitoring functions
  - State-of-the-art PTP support
  - IEC-61850-3 compliant, fanless, high-performance computers

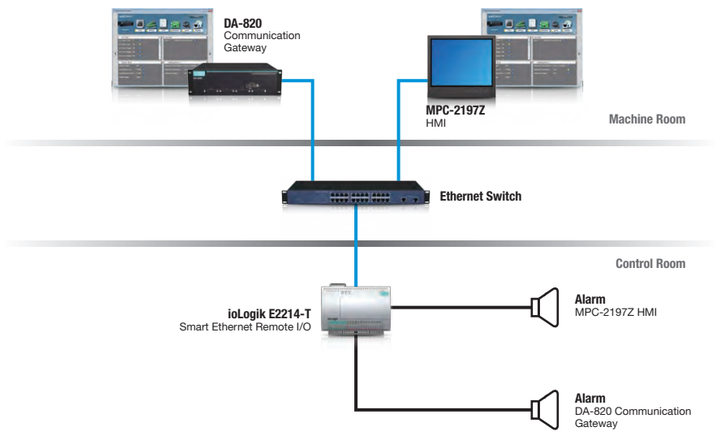
Why Moxa?

- A complete PRP/HSR portfolio.
- High-performing and reliable IEC 61850 compliant computers.
- PTP feature support for PRP/HSR coupling mode
- Quick adoption of latest PRP/HSR standard requirements and fast response to specific firmware needs

06
Colombia

The Largest State Grid Substation in Colombia

Integrated with Leading PSCADA Provider



Background and Requirements

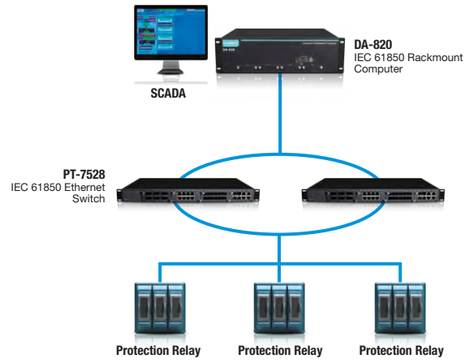
- **Type of Substation:** Utility Substation (Transmission)
- **Customer Needs:**
  IEC 61850-3 and IEEE 1613 compliant communication gateway and remote alarm solution.

Why Moxa?

- Moxa provides the toughest embedded computer for substations
- IEC 61850-3 and IEEE 1613 compliant
- High performance, fanless, cableless computers
- Proactive Monitoring: Moxa's exclusive centralized remote-alarm solution

07
Italy

Electrical Grid Monitoring Solution for Italy's State Grid



Background and Requirements

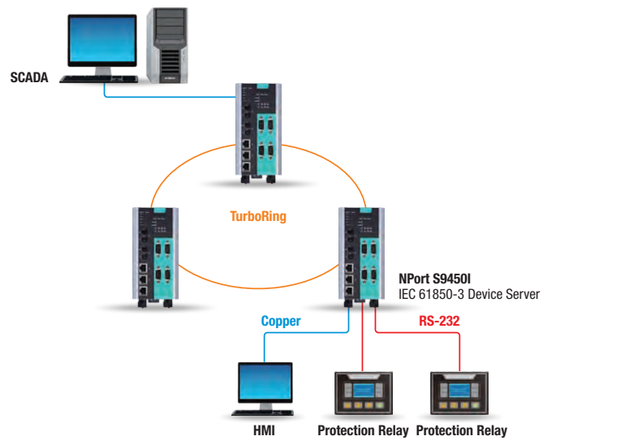
- **Substation Voltage:** 380/132 kV
- **Type of Substation:** Transmission Substation
- **Customer Needs:**
  A solution that can enhance remote asset management and monitoring, and transmit various HV data workflows from the MBI and PSE platforms to a centralized SCADA system.

Why Moxa?

- Total IEC 61850-3 computing and communication solution
- PT-7528's main management feature: Diagnostic data (port status, power supply) via MMS or SNMP
- Proactive Monitoring: Predictive maintenance function supported on the DA-820

08
Italy

Medium-Level Unmanned Substation Retrofit



Background and Requirements

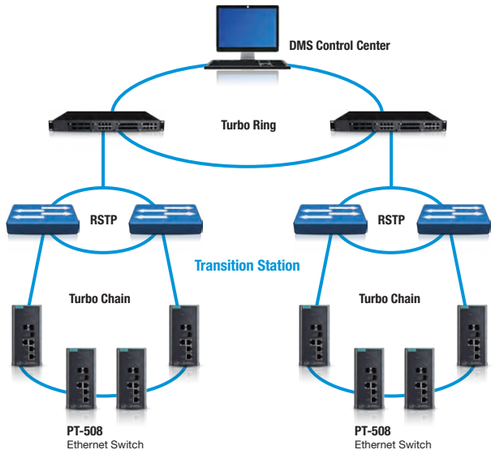
- **Substation Type:** Transmission Substation
- **Customer Requirements:**
  - Protection relay should only have serial interface (RS-232)
  - IEC 61850-3 compliant devices for substation application
  - Ethernet-to-fiber interface for long-distance communication

Why Moxa?

- Ethernet and fiber ports to set up a redundant network backbone using Moxa's Turbo Ring technology
- Two-in-one solution that replaces a switch and a device server, enabling easy maintenance
- DIN-rail mountable devices that save space in installation cabinets
- Real COM mode driver support for Windows 7 & Windows 2012

ADNOC (Abu Dhabi National Oil Company) Substation

09
United Arab Emirates



Background and Requirements

- **Substation Voltage:** 33 kV/11 kV
- **Type of Substation:** Distribution FRTU
- **Customer Needs:**
  Ethernet switches that are secure and that can be integrated into legacy systems with many restrictions.

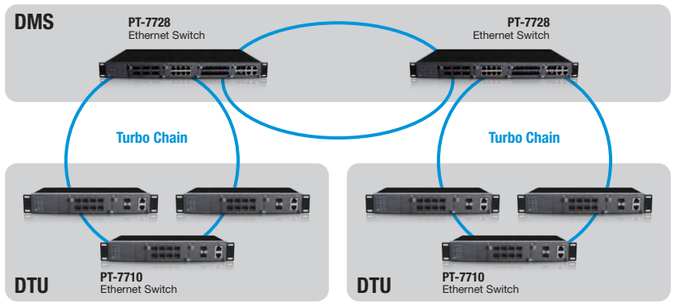
Why Moxa?

- Ethernet switches that can be easily integrated into existing RSTP ring based on Turbo Chain technology
- PT-508 supports voltage range up to 60 V
- Customized Firmware: Customized web navigator to monitor the status of Ethernet switches (MAC Address, FW, Serial Number)

Ethernet

China Southern Power Grid Distribution

10
China



Background and Requirements

- **Deployment:** 700 units
- **Type of Substation:** Distribution
- **Customer Needs:**
  - Scalable and flexible mass deployment
  - Interoperability with existing power network
  - Interoperability of various Ethernet equipment

Why Moxa?

- Turbo-chain technology that provides easy mass-deployment capability with the ability to expand the network based on system requirements.
- Easy integration with Turbo Chain and RSTP backbone
- Cost-effective with Turbo Chain deployment

Ethernet

Background and Requirements

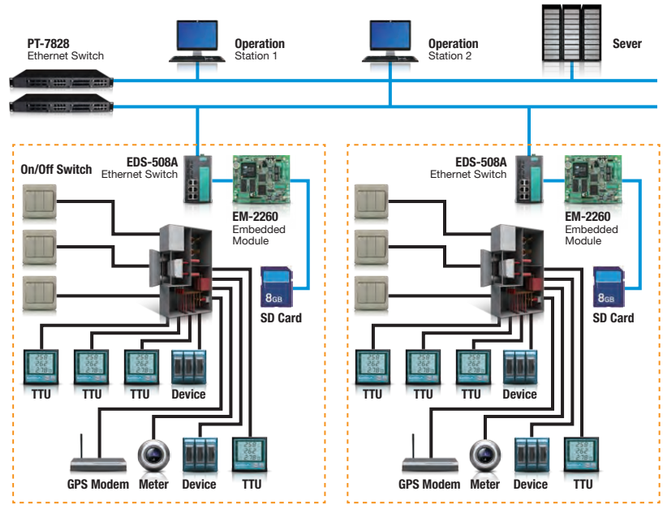
- **Feeder Voltage:** 10 kV
- **Type of Substation:** Distribution
- **Customer Requirements:**
  - An embedded platform capable of handling multiple devices running on CANbus, DI/DO, AI/AO, serial, and Ethernet
  - Consulting service for easy integration

Why Moxa?

- Wide range of expertise in computing, fieldbus, and I/O, and can provide prompt and customized service
- Consulting service: To fine tune system performance and integrate various drivers

11
China

One Embedded Computing Module Simplifies Power Distribution Systems



Ethernet

Background and Requirements

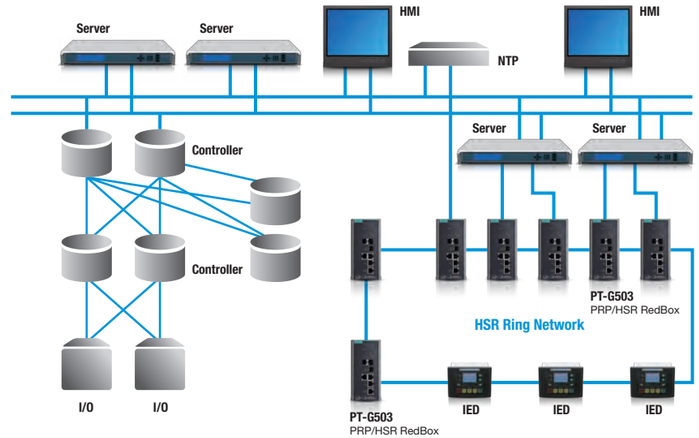
- **Substation Voltage:**
  Mid to low level
- **Type of Substation:** Enterprise Substation
- **Customer Needs:**
  Integration of IEC 61850 Ethernet switch and RedBox into the Experion process server and IEC 61850 SCADA server

Why Moxa?

- PT-G503 supports both PRP and HSR for flexible configuration solutions

12
USA

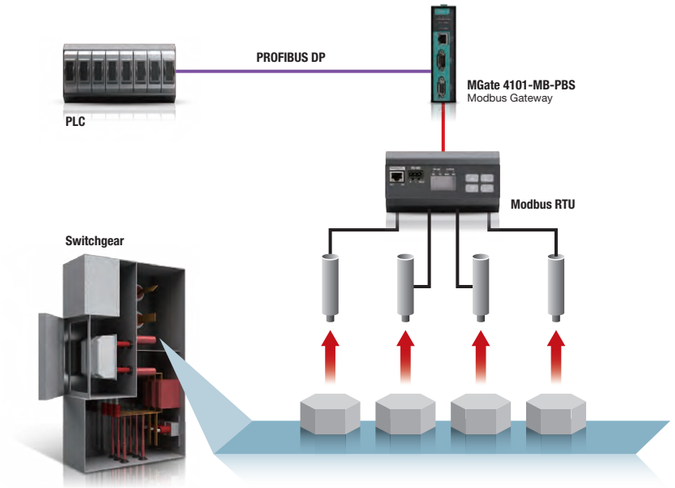
Enterprise Substation: PRP/HSR Solution for Factory DCS



Ethernet

13
Brazil

Switchgear Busbar Temperature Monitoring



Background and Requirements

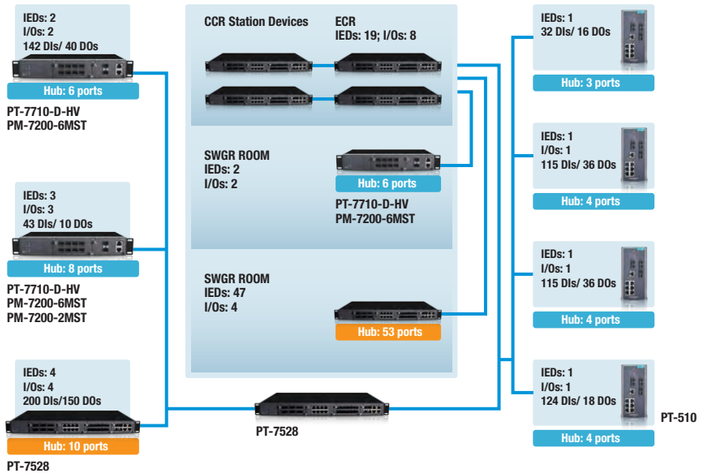
- **Type of Substation:** Enterprise Substation Monitoring
- **Customer Needs:**
  Ability to monitor the heating temperature of the contact points in the busbar/circuit breaker. The heating temperature can be caused by a loose screw or by oxidation. The computer that measures the temperatures uses Modus RTU by default, which needs to interface with a PROFIBUS DP network.

Why Moxa?

- Windows utility with graphical visualization for ease of configuration, saving up to 50% of the configuration time.

14
Korea

Electrical Equipment Control and Monitoring System (ECMS) for Power Substation with 780 MW Capacity



Background and Requirements

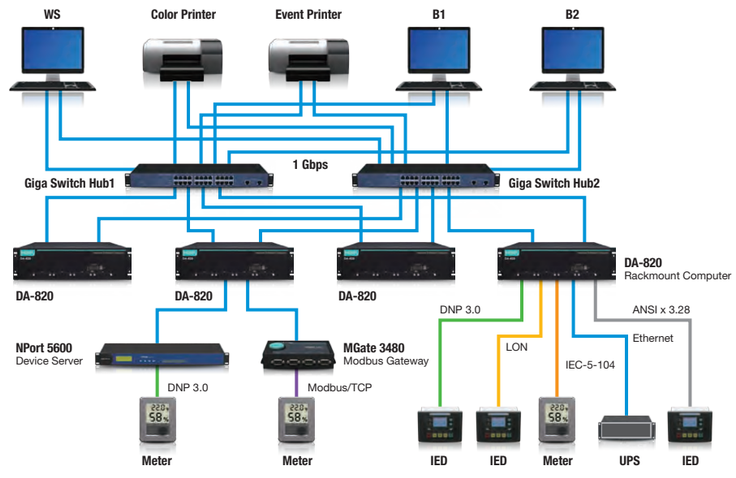
- **Substation Voltage:** 345 kV
- **Type of Substation:**
  Enterprise Substation
- **Customer Needs:**
  - Compact hardware that can fit in a small cabinet
  - IEC 61850-compliant solution

Why Moxa?

- Variety of hardware platforms to meet customer requirements
- Proven track record in providing solutions for IEC 61850 substations
- Rugged design

15
Taiwan

10 kV Semiconductor Substation



Background and Requirements

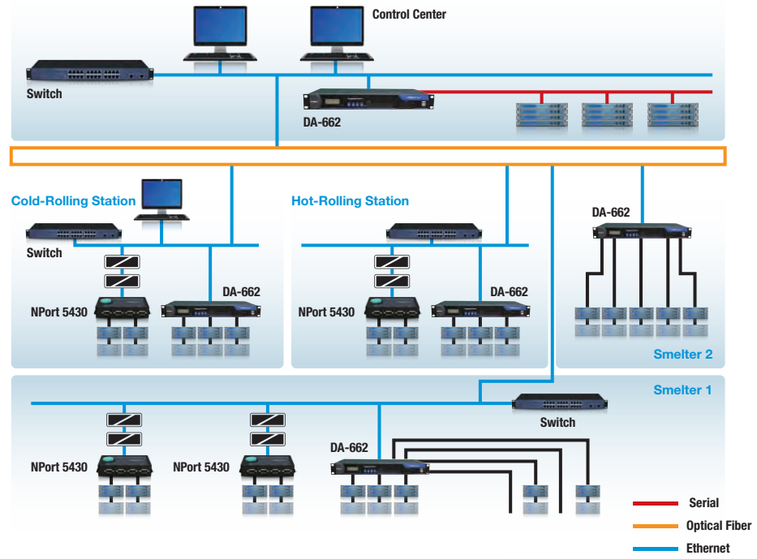
- **Substation Voltage:** 10 or 35 kV
- **Type of Substation:**
  Enterprise Substation
- **Customer Needs:**
  The manufacturing substation uses ABB's MicroSCADA for data acquisition and analysis, fault recording, protection parameter configuration, event alarms, and event lists.

Why Moxa?

- Reliable hardware platform with fanless design
- Flexible modular design for easy expansion (LON communication protocol)
- Customized consulting service

16
China

35 kV Steel Factory Substation



Background and Requirements

- **Substation Voltage:** 35 kV/10 kV
- **Substation Type:**
  Enterprise Substation
- **Customer Needs:**
  Powerful, rugged industrial computers to serve as the core control and processing units for data acquisition and protocol conversion for a large number of serial devices that need to be connected.

Why Moxa?

- Total computing and serial-to-Ethernet communication solutions
- Fanless and cableless computers
- Onboard remote device server for quick, cost-effective networking

05 Product Selection Guide

Moxa products are specifically designed for substation transmission and distribution systems. Moxa's solutions include the advanced technologies that are fueling the power revolution. For example, PRP/HSR for seamless redundancy, SNMP/MMS management for power SCADA integrated network monitoring, IEEE 1613 and IEC 61850 certifications for substation applications, and IEEE 1588 compliance for precision time synchronization are key features that upgrade large-scale electric power networks to the next level of reliability and efficiency. All of Moxa's products are toughened to overcome harsh environments, ensuring consistent operations even in the most demanding conditions. Tap into Moxa's expertise in communication and computing to easily build an efficient and effective power grid.

IEC 61850-3 Ethernet Switches

	PT-G7728/G7828	PT-7828 PT-7728 PT-7728-PTP	PT-7528	PT-7710	PT-508/510	EDS-510E	EDS-518E	EDS-528E	EDS-G516E EDS-G512E EDS-G508E	PT-G503-PHR-PTP
Number of Ports										
Max. Number of Ports	28	28	28	10	8 or 10	10	18	28	16	3
Max. Number of Hardware PTP Ports	28	–	–	–	–	–	–	–	–	3
Gigabit Ethernet, 10/100/1000 Mbps	Up to 28	Up to 4	Up to 4	Up to 2	–	3	4	4	16	3
Fast Ethernet, 10/100 Mbps	Up to 28	Up to 28	Up to 28	Up to 10	8 or 10	7	14	24	–	3
Power Supply										
24 VDC, isolated	–	✓	–	–	✓	–	–	–	–	–
48 VDC, isolated	–	✓	–	–	✓	–	–	–	–	–
24/48 VDC, isolated	✓	–	✓	–	–	–	–	–	–	✓
12/24/48 VDC	–	–	–	✓	–	–	–	–	–	–
12/24/48/-48 VDC	–	–	–	–	–	✓	✓	✓	✓	
88-300 VDC or 90-264 VAC,isolated	✓	✓	✓	✓	✓	–	–	✓	–	✓
Installation Options										
Rack Mounting	✓	✓	✓	✓	–	–	–	–	–	–
Wall Mounting	–	–	–	✓	With optional kit	With optional kit	With optional kit	With optional kit	With optional kit	With optional kit
DIN-Rail Mounting	–	–	–	–	✓	✓	✓	✓	✓	✓
Operating Temperature										
-40 to 85°C (-40 to 185°F)	✓	✓	✓	✓	✓	–	–	–	–	✓
-40 to 75 (-40 to 167°F)	–	–	–	–	–	✓	✓	✓	✓	–
Redundancy and Backup Options										
STP/RSTP	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
MSTP	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
PRP/HSR (Zero Recovery Time)	–	PT-7728-PTP	–	–	–	–	–	–	–	✓
RSTP grouping	✓	PT-7728-PTP	–	–	–	–	–	–	–	✓
Turbo Ring/Turbo Chain Recovery Time: Fast Ethernet<20 ms; Gigabit Ethernet<50 ms	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
Automatic Backup Configurator	ABC-02	ABC-01	ABC-02	ABC-01	ABC-01	ABC-02	ABC-02	ABC-02	ABC-02	ABC-02
Console Port	Micro-B USB	RS-232	USB	RS-232	RS-232	USB	USB	USB	USB	Ethernet
Network Management and Control										
Layer-3 Switching	PT-G7828	PT-7828	–	–	–	–	–	–	–	–
IPv6	PT-G7728	PT-7728, PT-7728-PTP	✓	✓	✓	✓	✓	✓	✓	✓
DHCP Option 66/67/82	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
VLAN	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
QoS	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
IEC 61850 QoS	✓	✓	✓	–	–	–	–	–	–	–
NTP/SNTP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Software-based IEEE 1588v2 PTP	–	PT-7828, PT-7728	✓	✓	✓	✓	✓	✓	✓	–
Hardware-based IEEE 1588v2 PTP	✓	PT-7728-PTP	–	–	–	–	–	–	–	✓
IGMP/GMRP	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
Port Trunking	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
IEEE 802.1X	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
TACACS+/RADIUS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LLDP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Port Mirror	✓	✓	✓	✓	✓	✓	✓	✓	✓	console port
SNMP/RMON	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MMS server	✓	✓	✓	–	–	–	–	–	–	✓
Modbus TCP	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
EtherNet/IP	✓	✓	✓	✓	✓	✓	✓	✓	✓	–
Relay Warning	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Standards and Certifications										
CE/FCC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UL/cUL 60950-1	–	✓	✓	✓	–	–	–	–	–	–
UL 508	–	–	✓	–	✓	✓	✓	–	✓	✓
UL 61010-2-201	✓	–	–	–	–	–	–	✓	–	–
IEC 61850-3 (Power Substation)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IEEE 1613 (Power Substation)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
EN 50121-4 (Wayside Applications)	✓	PT-7728, PT-7828	✓	✓	–	✓	✓	✓	✓	✓
EN 50155 (Railway Applications)	–	PT-7728, PT-7828	–	✓	–	–	–	–	–	–
NEMA TS2 (Traffic Control System)	–	PT-7728, PT-7828	✓	✓	–	✓	✓	✓	✓	–

Power Computers



	DA-820	DA-720	DA-682A-DPP
Computer			
CPU Speed	1.4 GHz dual-core 1.6 GHz dual-core 2.5 GHz dual-core 2.1 GHz quad-core	2.4 GHz, dual-core 2.6 GHz, dual-core	1.4 GHz dual-core 1.6 GHz dual-core 1.7 GHz dual-core
OS (Preinstalled)	–	Linux Debian 8 (preinstalled)	Linux Debian 8
OS (Optional by CTOS)	64-bit Linux Deb ian 7 64-bit Windows Embedded Standard 7 64-bit Windows 7 Professional	Windows 10 Enterprise LTSB 64-bit	Windows Embedded Standard 7
System Memory	16 GB capacity (204-pin SO-DIMM DDR3 memory at 1333 and 1600 MT/s, 8 GB Max.)	32 GB capacity, 4 GB for Linux Debian 8 preinstalled; 2 slots for DDR4 SO-DIMM	8 GB capacity, 1 GB (LX) / 2 GB (W7E) preinstalled: 1 slot of 4 GB DDR3-1066/1333 SO-DIMM SDRAM
Expansion Bus	5 slots (standard PCIe and PCI)	3 slots for expansion modules	PCI/104 onboard & 2 slots for expansion modules
USB	USB 2.0 hosts x 6, type A connector	4 USB hosts, system bootable, type A connector Front: 2 USB 2.0 hosts Rear: 2 USB 3.0 hosts	USB 2.0 hosts x 2, type A connector
Storage			
Built-in	CFast socket: Optional CFast card to store optional OS	8 GB for Debian 8 Linux OS (Preinstalled in mSATA)	2 GB for Linux (preinstalled industrial DOM)
Storage Expansion	4 x SATA 2.0 interfaces, supporting RAID 0, 1, 5, 10, hot-swappable	1 x SATA 3.0 interface	2 x SATA 2.0 interface
Display			
Graphics Controller	Intel® HD Graphics 4000	Intel® HD Graphics 520	Intel® HD Graphics (Integrated)
Display Interface	2 VGA outputs (DB15 female connector)	1 VGA output (DB15 female connector) and 1 DVI-D	1 VGA output (DB15 female connector)
Resolution	CRT display mode with pixel resolution up to 2048 x 1536 at 75 Hz	• VGA: CRT display mode with pixel resolution up to 1920 x 1200 @ 60 Hz • DVI-D: Display mode with pixel resolution up to 1920 x 1200 @ 60 Hz	CRT display mode with pixel resolution up to 2048 x 1536 at 75 Hz
Ethernet Interface			
LAN	10/100/1000 Mbps ports x 4	10/100/1000 Mbps ports x 14	10/100/1000 Mbps ports x 6
Magnetic Isolation Protection	1.5 kV built-in	1.5 kV built-in	1.5 kV built-in
Serial Interface			
Serial Standards	2 RS-232/422/485 ports (DB9 male)	2 RS-232/422/485 ports (terminal block)	–
ESD Protection	8 kV contact, 15 kV air	8 kV contact, 15 kV air	–
Surge Protection	2 kV line-to-line and 4 kV line-to-ground surge protection, 8/20 µs waveform	2 kV line-to-line and 4 kV line-to-ground surge protection, 8/20 µs waveform	–
Serial Signals			
RS-232	TxD, RxD, DTR, DSR, RTS, CTS, DCD,GND	TxD, RxD, RTS. CTS, GND	–
RS-422	TxD+, TxD-, RxD+, RxD-, GND	TxD+, TxD-, RxD+, RxD-, GND	–
RS-485-4w	TxD+, TxD-, RxD+, RxD-, GND	TxD+, TxD-, RxD+, RxD-, GND	–
RS-485-2w	Data+, Data-, GND	Data+, Data-, GND	–
Digital Input/Digital Output			
Input/Output Channels	–	–	–
Input Voltage/Output Current	–	–	–
Physical Characteristics			
Housing	SECC sheet metal (1 mm)	SECC sheet metal (1 mm)	SECC sheet metal (1 mm)
Weight	14 kg (31.11 lb)	6.5 kg (14.33 lb)	7 kg (15.56 lb)
Dimensions	361 x 440 x 133 mm (14.23 x 17.32 x 5.24 in) (without rackmount ears)	440 x 301 x 90 mm (17.32 x 12.20 x 3.54 in) (without rackmount ears)	440 x 315 x 90 mm (17.32 x 12.40 x 3.54 in) (without rackmount ears)
Environmental Limits			
Operating Temperature	• DA-820-C8: -40 to 60°C (-40 to 140°F) • DA-820-C1/C3/C7: -40 to 75 °C (-40 to 167°F)	-25 to 55°C (-13 to 131°F)	-25 to 60°C (-13 to 140°F)
Storage Temperature	-40 to 85°C (-40 to 185°F)	-40 to 85°C (-40 to 185°F)	-20 to 80°C (-4 to 176°F)
Ambient Relative Humidity	5 to 95% (non-condensing)	5 to 95% (non-condensing)	5 to 95% (non-condensing)
Power Requirements			
Input Voltage	• High Voltage: 100 to 240 VAC/VDC, 50/60 Hz, 1 A • Low Voltage: 24 to 110 VDC, 4.7 A	100 to 240 VAC; 110 to 240 VDC	100 to 240 VAC auto-ranging (47 to 63 Hz for AC input)
Multiple Power Supplies	Single/dual power supplies	Dual power supplies	Dual power supplies
Power Consumption	60 W	70 W	30 W (full loading)
Standards and Certifications			
Safety	UL 60950-1, IEC 60950-1, EN 60950-1	UL 60950-1, IEC 60950-1, EN 60950-1	UL 60950-1, IEC 60950-1, EN 60950-1
Electrical Substation	IEC 61850-3, IEC 60255, IEEE 1613	IEC 61850-3, IEEE 1613, IEC 60255	IEC 61850-3, IEEE 1613, IEC 60255
Protection Relay	IEC 60255	IEC 60255	IEC 60255
Rail Wayside	–	EN 50121-4	EN 50121-4
EMS	IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-6, IEC 61000-4-8, IEC 61000-4-11		
Green Product	RoHS, CRoHS, WEEE	RoHS, CRoHS, WEEE	RoHS, CRoHS, WEEE
Warranty			
Warranty Period	3 years	3 years	3 years
Details	See www.moxa.com/warranty	See www.moxa.com/warranty	See www.moxa.com/warranty

Power Computers



	DA-681A-DPP	DA-662A Series	UC-8100 Series
Computer			
CPU Speed	1.4 GHz dual-core	500 MHz	300/600/1000 MHz
OS (Preinstalled)	Linux Debian 8	Embedded Linux (preinstalled)	–
OS (Optional by CTOS)	Windows Embedded Standard 7	–	–
System Memory	8 GB capacity, 2 GB for Linux preinstalled; 1 slot of DDR3-1066/1333 SO-DIMM SDRAM	128 MB DRAM onboard, 32 MB Flash onboard	256 or 512 MB DDR3 SDRAM
Expansion Bus	PCI/104 onboard	–	–
USB	USB 2.0 host x 4, type A connector	–	USB 2.0 host x 1, type A connector
Storage			
Built-in	8 GB for Linux (preinstalled in mSATA)	–	–
Storage Expansion	1 x SATA 3.0 interface	–	1 GB SD or 2 GB MicroSD card preinstalled
Display			
Graphics Controller	Intel® HD Graphics (Integrated)	–	–
Display Interface	1 VGA output (DB15 female connector)	–	–
Resolution	CRT display mode with pixel resolution up to 2048 x 1536 at 75 Hz	–	–
Ethernet Interface			
LAN	10/100/1000 Mbps ports x 6	Auto-sensing 10/100 Mbps ports (RJ45) x 4	Auto-sensing 10/100 Mbps ports (RJ45) x 2
Magnetic Isolation Protection	1.5 kV built-in	1.5 kV built-in	1.5 kV built-in
Serial Interface			
Serial Standards	• 2 RS-232/422/485 ports (DB9 male) • 10 RS-485 ports (terminal block)	8 to 16 RS-232/422/485 ports, software selectable (8-pin RJ45)	RS-232/422/485 ports, softwareselectable (5-pin terminal block connector) x 1 or 2
ESD Protection	15 kV for all signals	8 kV contact, 15 kV Air ESD protection for all signals	–
Surge Protection	2 kV line-to-line and 4 kV line-to-ground surge protection, 8/20 µs waveform	2 kV line-to-line and 4 kV line-to-ground surge protection, 8/20 µs waveform (DA-662A-I-8/16-LX only)	–
Serial Signals			
RS-232	TxD, RxD, DTR, DSR, RTS, CTS, DCD, GND	TxD, RxD, DTR, DSR, RTS, CTS, DCD, GND (DA-662A-I-8/16-LX only: TxD, RxD, RTS, CTS, GND)	TxD, RxD, RTS, CTS, GND
RS-422	TxD+, TxD-, RxD+, RxD-, GND	TxD+, TxD-, RxD+, RxD-, GND	TxD+, TxD-, RxD+, RxD-, GND
RS-485-4w	TxD+, TxD-, RxD+, RxD-, GND	TxD+, TxD-, RxD+, RxD-, GND	TxD+, TxD-, RxD+, RxD-, GND
RS-485-2w	Data+, Data-, GND	Data+, Data-, GND	Data+, Data-, GND
Digital Input/Digital Output			
Input/Output Channels	–	–	–
Input Voltage/Output Current	–	–	–
Physical Characteristics			
Housing	SECC sheet metal (1 mm)	SECC sheet metal (1 mm)	Polycarbonate plastic
Weight	4.5 kg (10 lb)	4.3 kg (9.56 lb)	224 g (0.50 lb)
Dimensions	440 x 315 x 45 mm (17.32 x 12.40 x 1.77 in), 19 inch 1U height	Without ears: 440 x 45 x 237 mm (17.32 x 1.77 x 9.33 in) With ears: 480 x 45 x 237 mm (18.90 x 1.77 x 9.33 in)	101 x 27 x 128 mm (3.98 x 1.06 x 5.04 in)
Environmental Limits			
Operating Temperature	DPP Models: -25 to 55°C (-13 to 131°F) DPP-T Models: -40 to 70°C (-40 to 158°F)	-10 to 60°C (14 to 140°F)	-10 to 60°C (14 to 140°F) or -40 to 75°C (-40 to 167°F)
Storage Temperature	-40 to 85°C (-40 to 185°F)	-20 to 80°C (-4 to 176°F)	-40 to 80°C (-40 to 176°F)
Ambient Relative Humidity	5 to 95% (non-condensing)	5 to 95% (non-condensing)	5 to 95% (non-condensing)
Power Requirements			
Input Voltage	100 to 240 VAC; 100 to 240 VDC	100 to 240 VAC auto ranging (47 to 63 Hz for AC input)	12 to 24 VDC (3-pin terminal block, V+, V-, SG)
Multiple Power Supplies	Dual power supplies	Single power supply	–
Power Consumption	25 W	20 W	5.4 W
Standards and Certifications			
Safety	UL 60950-1, IEC 60950-1, EN 60950-1	UL 60950-1	UL 60950-1, EN 60950-1
Electrical Substation	IEC 61850-3, IEEE 1613, IEC 60255	–	–
Protection Relay	IEC 60255	–	–
Rail Wayside	–	–	–
EMS	IEC 61000-4-2, IEC 61000-4-3, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-6, IEC 61000-4-8, IEC 61000-4-11		–
Green Product	RoHS, CRoHS, WEEE	RoHS, CRoHS, WEEE	RoHS, CRoHS, WEEE
Warranty			
Warranty Period	3 years	5 years	5 years
Details	See www.moxa.com/warranty	See www.moxa.com/warranty	See www.moxa.com/warranty

Device Server Gateways for Substations






	NPort 6600 Series	CN2600 Series	NPort S9650I	NPort S9450I	MGate MB3660	MGate 5109
LAN Interface						
10/100BaseT(X) Ports	1 port (8-pin RJ45 connector)	2 ports (2 IPs, 8-pin RJ45 connectors)	2 ports (8-pin RJ45 connector with the option for 2 more RJ45/fiber ST/SC ports)	5 ports (8-pin RJ45 connector with the option for fiber ST/SC ports)	2 ports (8-pin RJ45 connector)	2 port (8-pin RJ45 connector)
Magnetic Isolation Protection	1.5 kV					
Protocol	–	–	Modbus TCP, DNP3 TCP	Modbus TCP, DNP3 TCP	Modbus TCP Client/Server	Modbus TCP Client/Server, DNP3 TCP Client/Outstation
Serial Interface						
Protocol	–	–	Modbus RTU/ASCII, DNP3 Serial	Modbus RTU/ASCII, DNP3 Serial	Modbus RTU/ASCII Master/Slave	Modbus RTU/ASCII Master/Slave, DNP3 Serial Master/Outstation
RS-232/422/485 Ports	8/16/32	8/16	8/16	4	8/16	1
Connectors	8-pin RJ45	CN2610/2650: 8-pin RJ45 CN2650I: DB9 male	DB9 male/DB9 female/multi-mode ST	DB9 male	DB9 male	DB9 male
Communication Parameters	Data Bits: 5, 6, 7, 8; Stop Bits: 1, 1.5, 2; Parity: None, Even, Odd, Space, Mark	Data Bits: 5, 6, 7, 8; Stop Bits: 1, 1.5, 2; Parity: None, Even, Odd, Space, Mark	Data Bits: 5, 6, 7, 8; Stop Bits: 1, 1.5, 2; Parity: None, Even, Odd, Space, Mark	Data Bits: 5, 6, 7, 8; Stop Bits: 1, 1.5, 2; Parity: None, Even, Odd, Space, Mark	Data Bits: 7, 8; Stop Bits: 1, 2; Parity: None, Even, Odd, Space, Mark	Data Bits: 7, 8; Stop Bits: 1, 2; Parity: None, Even, Odd, Space, Mark
Flow Control	RTS/CTS, DTR/DSR, XON/XOFF	RTS/CTS, DTR/DSR, XON/XOFF	RTS/CTS, XON/XOFF	RTS/CTS, XON/XOFF	RTS/CTS, DTR/DSR, RTS Toggle (RS-232 only)	RTS/CTS, RTS Toggle (RS-232 only)
Baudrate	50 bps to 921.6 Kbps	50 bps to 921.6 Kbps	50 bps to 921.6 Kbps	50 bps to 921.6 Kbps	50 bps to 921.6 Kbps	50 bps to 921.6 Kbps
2-kV Isolation Protection	–	Optional (CN2650I)	Yes	Yes	Optional (MB3660I)	Yes
RS-485 Data Direction Control	ADDC® (automatic data direction control)					
RS-232 Console Port	Yes	Yes	Yes	Yes	Yes	Yes
Advanced Features						
Serial Data Log	64 KB	–	–	–	–	–
Offline Port Buffering	64 KB	–	–	–	–	–
SD Slot	Yes	–	–	–	Yes	Yes
Software						
Security Protocols	DES, 3DES, AES, SSH, SSL	RADIUS, HTTPS, SSH, PAP, CHAP	RADIUS, HTTPS, SSH, PAP, CHAP	RADIUS, HTTPS, SSH, PAP, CHAP	RADIUS	HTTPS, SSH
Configuration Options	Web Console, Telnet Console, Serial Console, Windows Utility	Web Console, Serial Console, Telnet Console, Windows Utility	Web console, Serial console, Telnet console, Windows Utility	Web console, Serial console, Telnet console, Windows Utility	Web console, Serial console, Telnet console	Web console, Serial console, Telnet console
Driver Support	Windows Real COM Drivers, Linux Real TTY driver, Fixed TTY driver	Windows Real COM Drivers, Linux Real TTY driver, Fixed TTY driver	Windows Real COM drivers, Linux Real TTY drivers, Fixed TTY drivers	Windows Real COM drivers, Linux Real TTY drivers, Fixed TTY drivers	–	–
Management	SNMP MIB-II, SNMPv1/v2c/v3, Turbo Ring	SNMP MIB-II	SNMP MIB-II, SNMPv1/v2c/v3, IEC 61850 MMS, Turbo Ring, Turbo Chain 2	SNMP MIB-II, IEC 61850 MMS, Turbo Ring, Turbo Chain 2	SNMPv1 (read only)	SNMPv1/v2c/v3
Standard Operation Modes	Real COM, TCP Server, TCP Client, UDP, Pair Connection, RFC2217, Terminal, Reverse Telnet, Ethernet Modem, Printer, PPP, Disabled	Real COM, TCP Server, TCP Client, UDP, RFC2217, Terminal, Reverse Telnet, PPP, DRDAS, Redundant COM	Real COM, RFC2217, TCP Server, TCP Client, UDP, DNP3, DNP3 Raw Socket, Modbus, Disable	Real COM, RFC2217, TCP Server, TCP Client, UDP, DNP3, DNP3 Raw Socket, Modbus, Disable	Transparent Mode, Intelligent Mode, Agent Mode	Transparent Mode, Agent Mode
Secure Operation Modes	Secure Real COM, Secure TCP Server, Secure TCP Client, Secure Pair Connection, SSH, Reverse SSH	–	–	–	–	–
Physical Characteristics						
Housing	Metal	Metal	Metal, IP30	Metal, IP30	Metal, IP30	Metal, IP30
Dimensions (mm)	440 x 195 x 44 mm	440 x 195 x 44 mm	Without ears: 440 x 363 x 44 mm	Without ears: 160 x 80 x 109 mm	440 x 45 x 198 mm	36 x 105 x 140 mm
Environmental Limits						
Operating Temperature	Standard Models: 0 to 55°C Wide Temp. Models: -40 to 75°C High Voltage Wide Temp. Models: -40 to 85°C		-40 to 85°C (-40 to 185°F)		0 to 60°C (32 to 140°F)	Standard Models: 0 to 60°C Wide Temp. Models: -40 to 75°C
Storage Temperature	Standard Models: -40 to 75°C Wide Temp. Models: -40 to 75°C High Voltage Wide Temp. Models: -40 to 85°C		-40 to 85°C (-40 to 185°F)			-40 to 85°C (-40 to 185°F)
Ambient Relative Humidity	5 to 95% (non-condensing)	5 to 95% (non-condensing)	5 to 95% (non-condensing)	5 to 95% (non-condensing)	5 to 95% (non-condensing)	5 to 95% (non-condensing)
Power Requirements						
Rated Voltage	AC Models: 100 to 240 VAC DC Models: ±48 VDC (20 to 72 VDC, -20 to -72 VDC), 110 VDC (88 to 300 VDC)	AC Models: 100 to 240 VAC DC Models: 110 VDC (88 to 300 VDC)	WV models: 24/48 VDC (20 to 125 VDC) HV models: 110/220 VAC/VDC (88 to 300 VDC, 85 to 264 VAC)	WV models: 24/48 VDC (20 to 125 VDC) HV models: 110/220 VAC/VDC (88 to 300 VDC, 85 to 264 VAC)	DC models: Dual 20 to 60 VDC (1.5 kV isolation) AC models: Dual 100 to 240 VAC, 47 to 63 Hz	12 VDC to 48 VDC
Standards and Certifications						
Safety	UL 60950-1, EN 60950-1	UL 60950-1, EN 60950-1	UL 60950-1, EN 60950-1 (LVD)	UL 60950-1, EN 60950-1 (LVD)	UL 60950-1, EN 60950-1 (LVD)	UL 508, EN 60950-1
EMC	CE, FCC	CE, FCC	EN 61000-6-2/-6-4	EN 61000-6-2/-6-4	EN 55022/24	EN 55032/24
Reliability						
MTBF	NPort 6610-8: 135,891 hrs NPort 6610-16: 102,373 hrs NPort 6610-32: 68,707 hrs NPort 6650-8: 135,370 hrs NPort 6650-16: 101,783 hrs NPort 6650-32: 68,177 hrs	CN2650I AC models: 99,320 hrs CN2650I-8-HV-T: 191,326 hrs CN2650I-16-HV-T: 116,924 hrs	NPort S9650I-8B-2WV-T: 229,273 hrs NPort S9650I-8B-2HV-T: 230,955 hrs NPort S9650I-8F-2WV-T: 315,727 hrs NPort S9650I-8F-2HV-T: 312,507 hrs NPort S9650I-16B-2WV-T: 156,676 hrs NPort S9650I-16B-2HV-T: 161,039 hrs NPort S9650I-16-2WV-T: 171,642 hrs NPort S9650I-16-2HV-T: 165,308 hrs NPort S9650I-16F-2WV-T: 262,382 hrs NPort S9650I-16F-2WV-ET-T: 237,113 hrs NPort S9650I-16F-2HV-T: 264,628 hrs NPort S9650I-16F-2HV-E-T: 262,639 hrs	347,436 hrs	MGate MB3660-8-2AC: 716,647 hrs MGate MB3660-8-J-2AC: 616,505 hrs MGate MB3660-8-2DC: 706,783 hrs MGate MB3660I-8-2AC: 224,851 hrs MGate MB3660-16-2AC: 487,416 hrs MGate MB3660I-16-2AC: 114,595 hrs MGate MB3660-16-2DC: 482,835 hrs MGate MB3660-16-J-2AC: 437,337 hrs	859,422 hrs
Warranty	5 years	5 years	5 years	5 years	5 years	5 years

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