Your Trusted Partner in Automation

Moxa is a leading provider of edge connectivity, industrial computing, and network infrastructure solutions for enabling connectivity for the Industrial Internet of Things (IIoT). With over 30 years of industry experience, Moxa has connected more than 57 million devices worldwide and has a distribution and service network that reaches customers in more than 70 countries. Moxa delivers lasting business value by empowering industries with reliable networks and sincere service. Information about Moxa's solutions is available at www.moxa.com.

Moxa Americas

USA
Toll Free: 1-888-MOXA-USA
Tel: +1-714-528-6777
Fax: +1-714-528-6778
usa@moxa.com

Brazil
Tel: +55-11-95261-6545
brazil@moxa.com

Moxa Europe

Germany
Tel: +49-89-37003-99-0
Fax: +49-89-37003-99-99
europe@moxa.com

France
Tel: +33-1-30-85-41-80
Fax: +33-1-30-47-35-91
france@moxa.com

UK
Tel: +44-1844-355-601
Fax: +44-1844-353-553
uk@moxa.com

Moxa Asia-Pacific and Taiwan

Asia/Japan/Taiwan
Tel: +886-2-8919-1230
Fax: +886-2-8919-1231
asia@moxa.com
japan@moxa.com
taiwan@moxa.com

India
Tel: +91-80-4172-9088
Fax: +91-80-4132-1045
india@moxa.com

Russia
Tel: +7-495-287-0929
Fax: +7-495-269-0929
russia@moxa.com

Korea
Tel: +82-2-6268-4048
Fax: +82-2-6268-4044
korea@moxa.com

Moxa China

Shanghai
Tel: +86-21-5258-9955
Fax: +86-21-5258-5505
china@moxa.com

Beijing
Tel: +86-10-5976-6123/24/25/26
Fax: +86-10-5976-6122
china@moxa.com

Shenzhen
Tel: +86-755-8368-4084/94
Fax: +86-755-8368-4148
china@moxa.com

P/N: 1900001901600

MOXA®

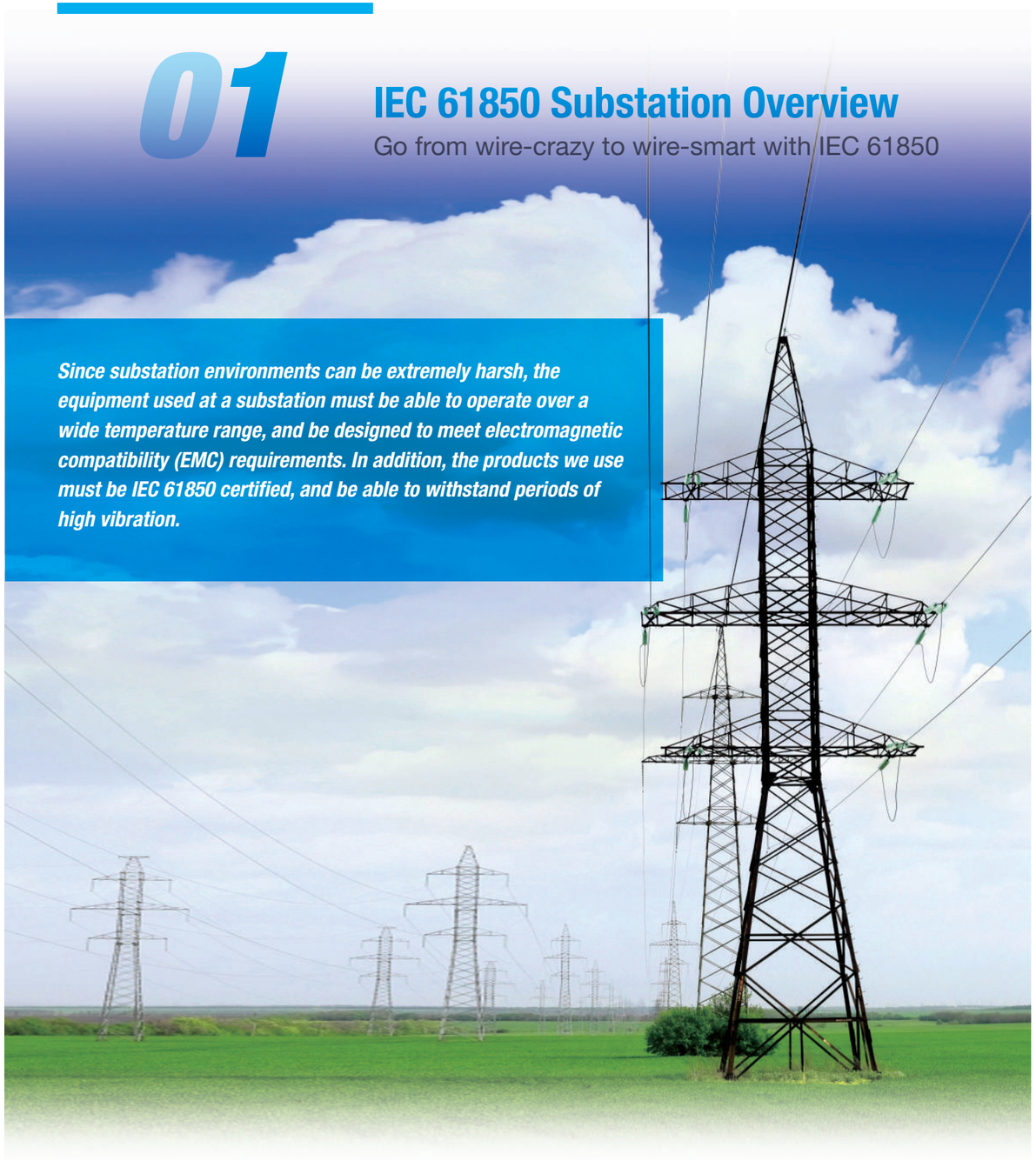
IEC 61850 Communication and Computing Solutions for Substation Automation Systems Guidebook

MOXA®

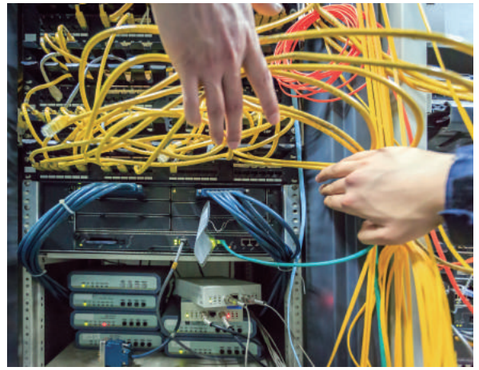
Moxa is a global leader in IEC 61850 and IEEE 1588 smart substation solutions and provides a wide range of networking and computing products for substation automation. As an active participant in Work Group 10 of the IEC TC57, a Collective Member of CIGRE, and Director-General of the Taiwan Smart Grid 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 1,000 successful substation applications around the world, including the world's first fully integrated 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

IEC61850 Substation Architecture

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 IEC 61850 standard divides substation operation into three distinct levels and two communication buses, as illustrated in the diagram on the right:

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.
Process Bus: The process bus handles communication between the process level and the bay level.
Station Bus: The station bus handles communication between the bay level and the station level.

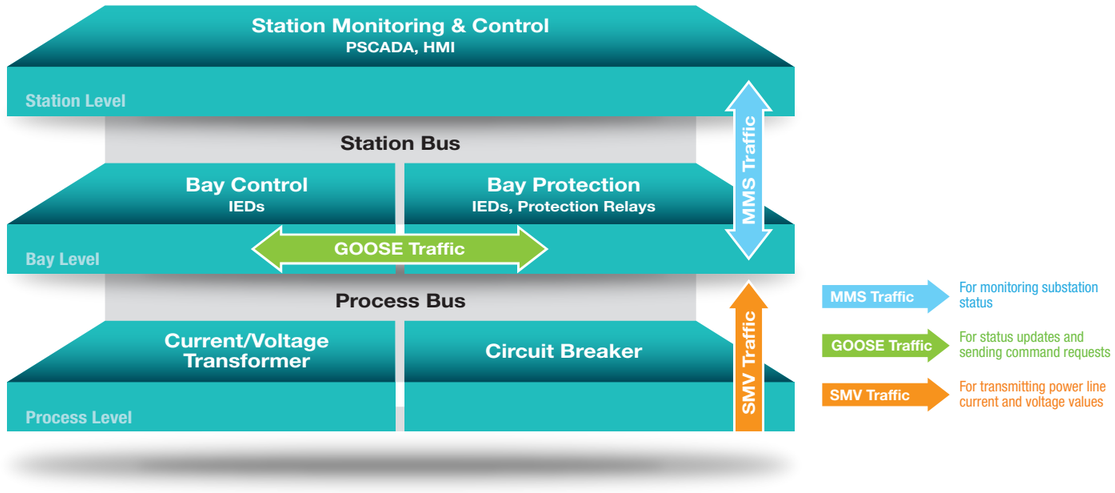
IEC 61850 Communication

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:

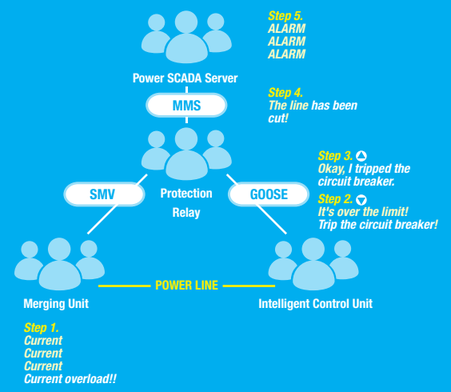
MMS: Using the Manufacturing Messaging Specification protocol to send substation status for monitoring purposes.
GOOSE: Using the Generic Object Oriented Substation Event protocol to send critical data, e.g., control signal and warnings.
SMV: Using the Sampled Measured Values protocol to send power line current and voltage values.

These protocols can run over high speed TCP/IP networks to ensure the fast response time (< 4 ms) needed for protective relays.

IEC61850 Substation Communication Architecture



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 SMV protocol to a protection relay.

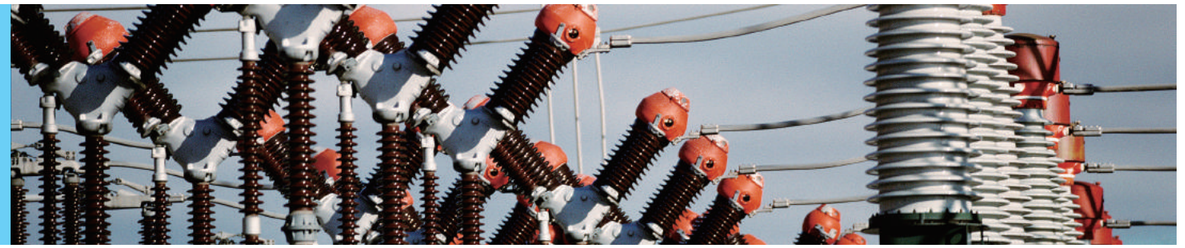
Step 2: The protection relay uses the GOOSE protocol to notify the intelligent control unit to trip the circuit breaker.

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.

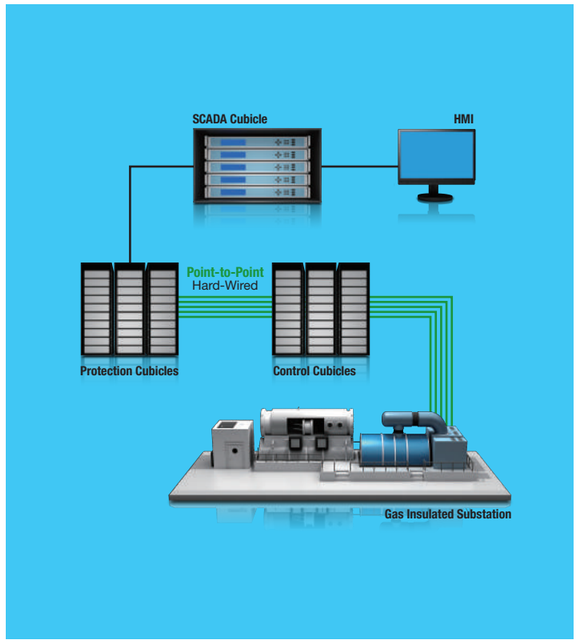
Step 4: The protection relay uses the MMS protocol to notify the power SCADA server that the power line has been cut.

Step 5: The power SCADA server issues an alarm.

The Evolution of Substation Automation

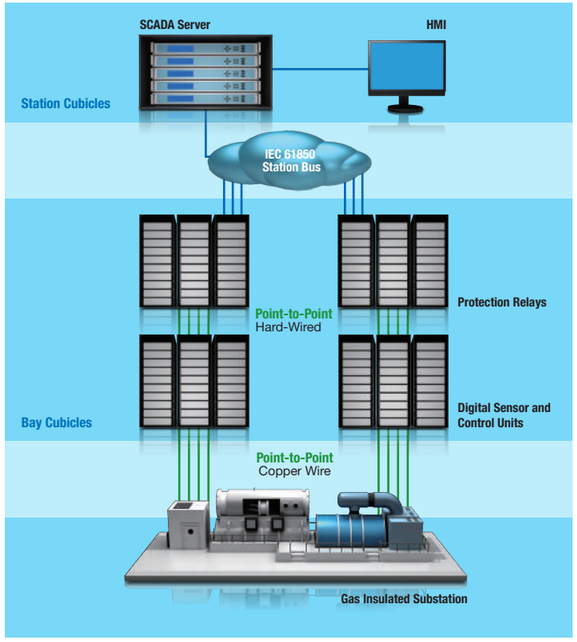


Conventional Substation Automation



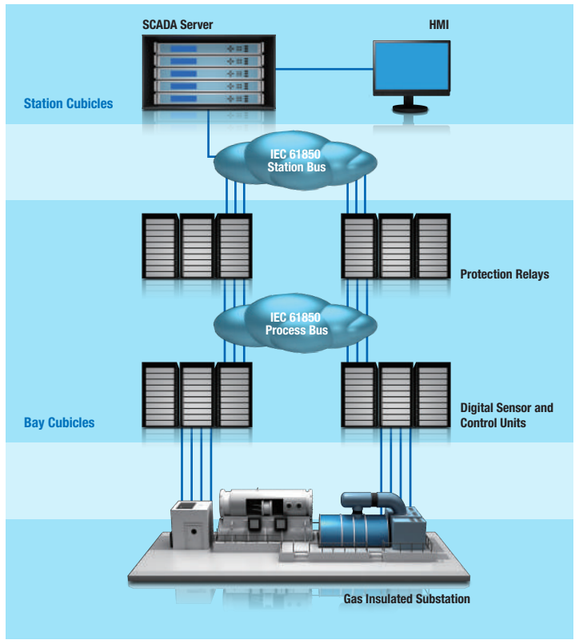
In the 1960's a conventional substation was rather bulky, with copper or fiber wiring used to hard-wire one device to another.

Substation Automation with IEC 61850 Station Bus



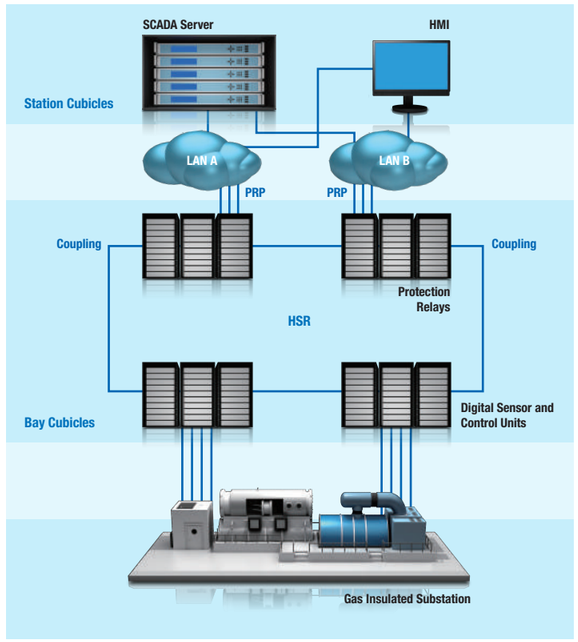
The release of the IEC 61850 Station Bus protocol in the 1980's was a big first step forward on the way to implementing a substation-wide all-purpose network.

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, such as IEC 61850, DNP3, IEC 60870-5-101, IEC 60870-5-104, and Modbus, are in great demand.

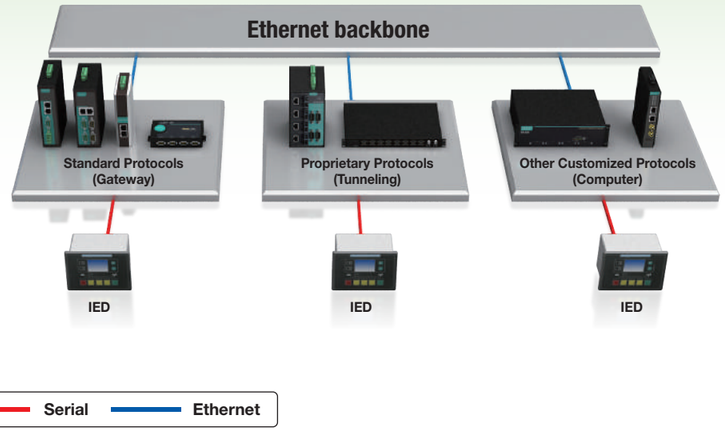
Devices that use proprietary protocols

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

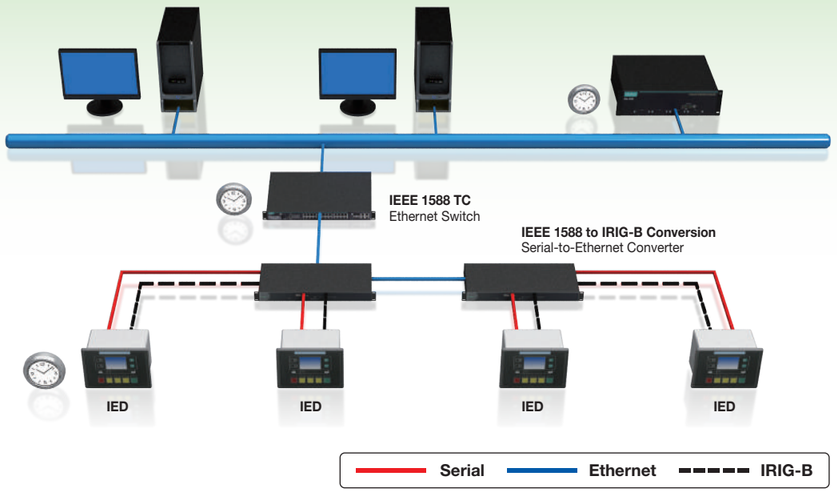
As events occur at different locations throughout a substation, the local device that records an event will add a timestamp, based on the local time of the device, before sending the event information for analysis. For this reason, it is extremely important that timestamps coming from different parts 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 870-2-2
Telecontrol Equipment and Systems — Part 2: Operating Conditions; Section 2: Environmental Conditions

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)

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

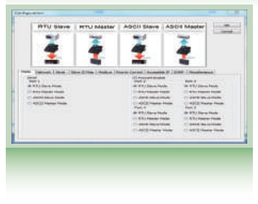
Engineers who manage power substations earmarked for retrofitting may be good at their job, but may not have the communication domain knowhow needed to convert their substation to a full-fledged IEC 61850-compliant system, or may have limited time to bridge devices for system integration. When deciding 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.

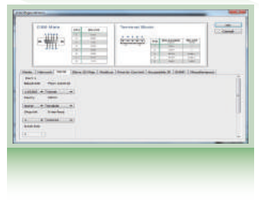
Easy Configuration in Three Steps

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	Windows 8	Windows 7	Windows Server 2016	Windows Server 2012	Windows Server 2008	Windows Server 2003	Windows Vista
Windows XP	Windows XP Embedded	Windows CE 5/6	Windows 2000	Windows NT 4.0	Windows ME	Windows 98 SE	DOS
Linux 3.0	Linux 2.6	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.

Expansion Capability

IEDs are deployed in a retrofit substation project to make the primary equipment more intelligent. A solution that provides expansion slots for installing different expansion cards to connect with a variety of devices make it easier to expand the system. The key success factor is the ability to connect to all types of devices.

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

Scalable OS & Software Packages
- Supports both Windows and Linux Debian operating systems
- Over 48,575 stable, ready-to-use packages, including IPsec and NetSNMP

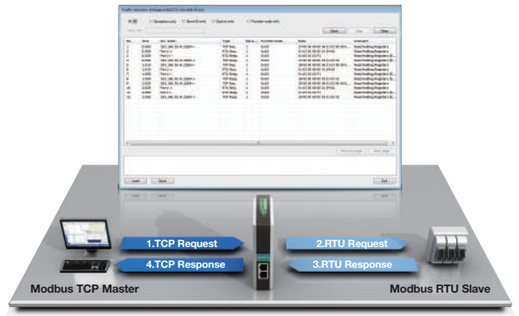
High I/O Density with Data Acquisition Capability
- IEC 61850 native computer with expansion module slots to further extend serial and LAN interfaces
- Support standard PCI/PCIe expansion cards

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

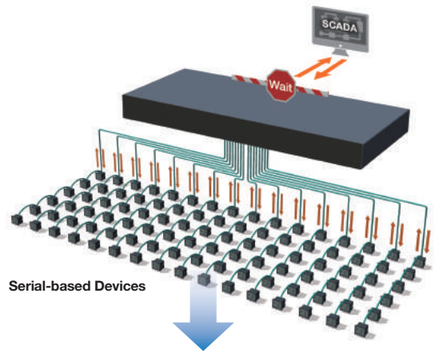
Because of insufficient domain know-how, troubleshooting communication issues is always a nightmare for substation engineers. In a retrofit substation, dealing with serial communication errors (e.g., related to Modbus, DNP3, and IEC 60870-5-101) can be even more daunting because engineers often need 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.



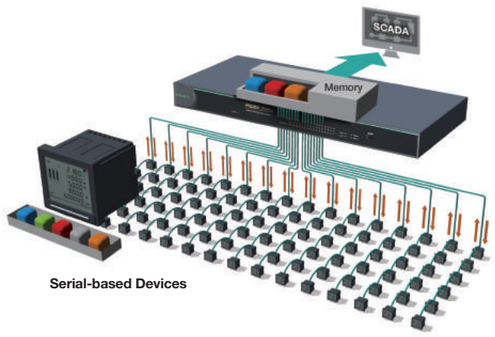
Optimizing SCADA Systems Using a Modbus Gateway

In a substation control center, one of goals for Supervisory Control and Data Acquisition (SCADA) systems is to monitor the power quality. As a complex web of electrical parameter statuses needs to be collected from numerous serial-based devices, ideally, Modbus gateways with multiple serial ports (8 or 16 ports) are required. However, traditional Modbus gateways run in the transparent mode, which has a lower data-update frequency because of a limitation in Modbus. Moxa's high-density gateways with the agent-mode technology can boost the performance of SCADA systems.

Transparent gateways can only deal with simultaneous requests and responses one by one.



Agent gateways act as data concentrators that deliver multiple requests and responses to/from PSCADA at the same time.



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 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

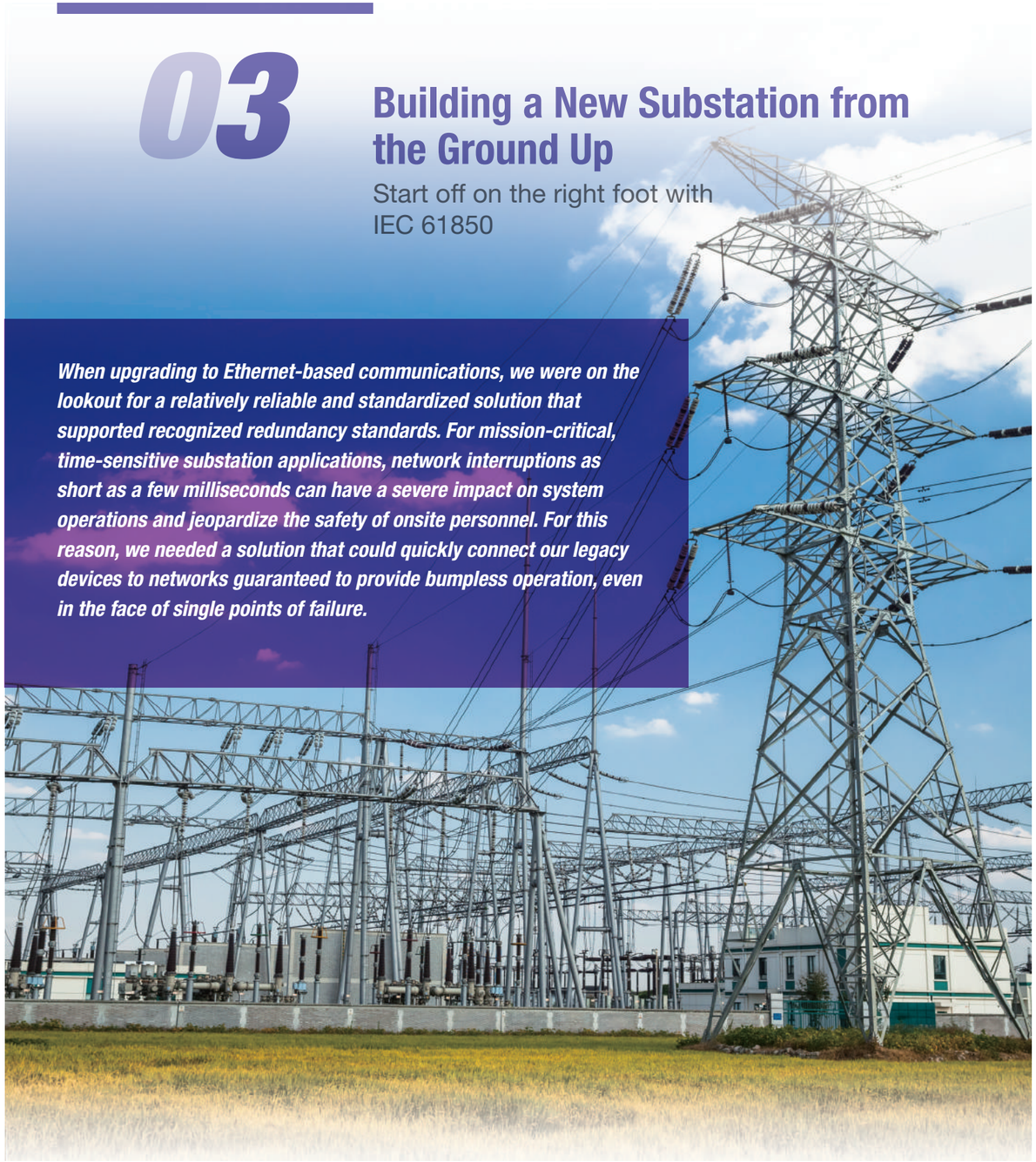
A smart OS recovery system is an essential function in a remote substation. Without an OS recovery system, corruption of system software—whether in the OS or in local substation applications—can mean catastrophic failure. According to some estimates, the percentage of computer failures attributable to 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 computer.

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 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:

▸ Determinism

Will the performance of an IEC 61850 Ethernet-based substation compare favorably with that of a hardwired peer-to-peer substation?

▸ Device, Network, and Data Reliability

Will the devices be able to operate reliably in environments with high EMI and how to implement network redundancy to ensure that critical packets are reliably transmitted?

▸ Manageability

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

▸ Determinism

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. In general, engineers have three major concerns:

1. How to ensure accurate time synchronization across different IEDs or RTUs for efficient operational diagnostics?
2. Will the transfer time between applications be fast enough?
3. How an advanced IEC 61850 substation network prioritizes packets to ensure that critical information propagates without delay?

Time Synchronization Technology: From Milliseconds to Microseconds

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	NTP/SNTP	IEEE 1588 V1	IEEE 1588 V2
Typical Accuracy in Substations	1-10 ms	1 μs	1 μs
Fulfills IEC 61850 Station Bus Requirements (1 ms)	✓	✓	✓
Fulfills IEC 61850 Process Bus Requirements (1 μs)	-	✓	✓
Scales Well with Large Number of Devices to Reduce Traffic Loading	-	-	✓

Traffic Control: VLAN Technology

Virtual Local Area Network (VLAN) technology is used to group devices by IP address, instead of by physical location. Each packet carries a VLAN ID and can be transmitted only in the permitted VLAN channel. That is, devices from anywhere on the substation network can be assigned to the same 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.

Critical Packet Prioritization: QoS

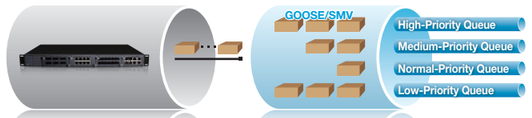
Applying an intelligent Quality of Service (QoS) categorization method to ensure that the most critical data packets can be forwarded with highest priority.

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, packets sent to a particular port with the highest priority could be transmitted before 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.

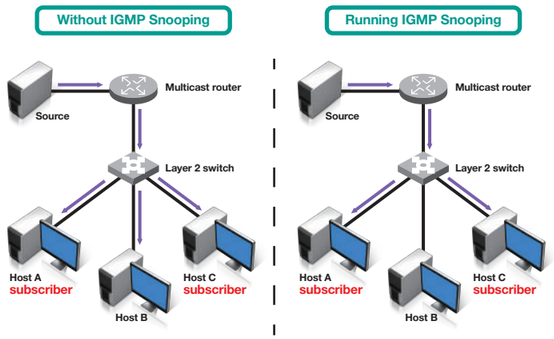


Standard QoS
- Packet prioritization by port-based configuration
- No packet-type examination: all packets in the high-priority queue are still FIFO

IEC 61850 QoS
- Packet-type inspection guarantees higher transmission priority for critical packets, like GOOSE, SMV, and PTP
- System-based configuration

Multicast Optimization: IGMP Snooping

GOOSE and SMV are multicast packets; multicast packets in the same LAN can cause unnecessary load on host devices by processing packets they have not solicited. With IGMP Snooping, the GOOSE and SMV packets will only be forwarded to the subscribers, minimizing the bandwidth wastage.



Device Reliability

Devices in a substation are constantly subject to extreme temperatures, high electricity interference, and airflow restrictions. Hence, it is critical to ensure that the devices can operate reliably in harsh operating environments.

IEC 61850-3 Compliant Devices

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

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)

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

Wire Speed Zero Packet Loss Technology: NoiseGuard™

In order to ensure no data packets (GOOSE/SMV/PTP) are lost in EMI-intensive environments, Moxa's switches are designed with NoiseGuard™ technology that can guarantee zero packet loss in most networks. NoiseGuard™ technology is an EMC-immunity technology that exceeds the requirements of IEEE 1613 Class 2 and uses an optimized mechanical design with integrated housing for better conduction. Customized components can include a fiber transceiver, and an enhanced, optimized power circuit design.

OS Recovery: Smart Recovery™ Technology

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's computers come with Smart Recovery™, which is an automated BIOS-level software recovery tool that allows engineers to automatically trigger OS recovery to minimize downtime.

Fully Automated Recovery Tool

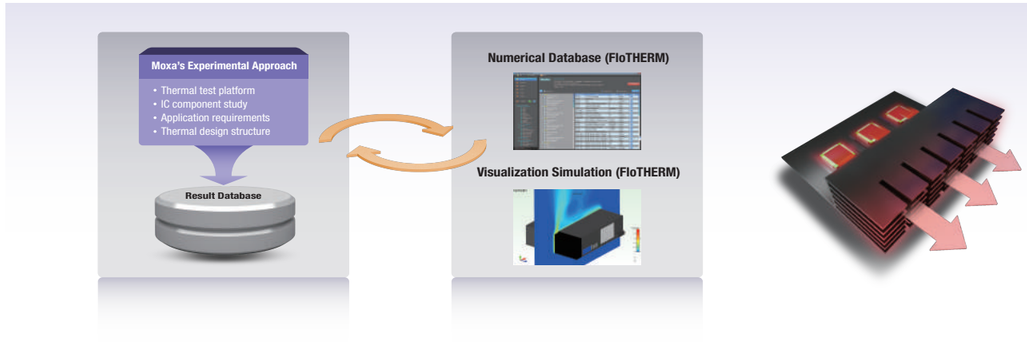
Special design for unmanned or remote substations that can automate the recovery process.

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.

Withstand Harsh Environments: Fanless Thermal Design

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. 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. 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.



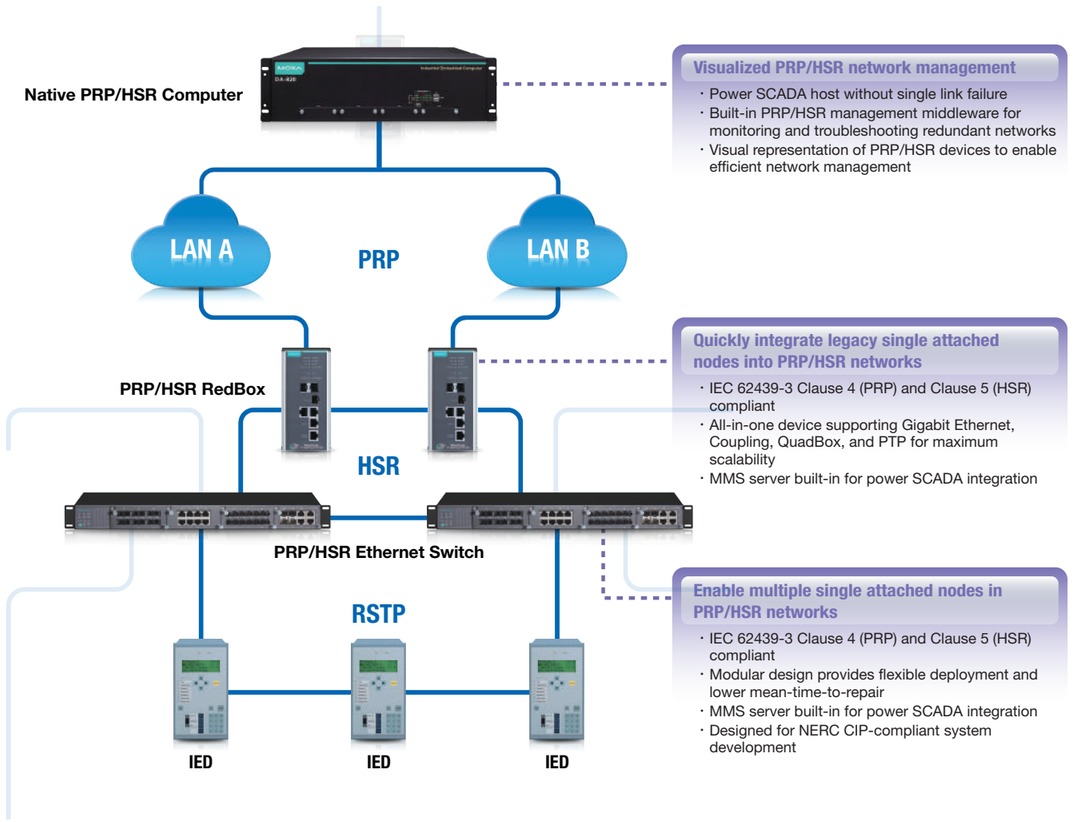
▸Network Reliability

Packet losses of any kind are not tolerated in substation communication. Ensuring that critical packets are reliably transmitted is a key for any substation, so it is critical to implement network redundancy to prevent data loss when failure occurs.

Network Redundancy Technology

Network redundancy is a method for ensuring network availability in case a network device or path is unavailable. There are many existing mechanisms that can enhance fault-tolerance in an Ethernet network. The most common ones are RSTP, proprietary ring redundancy, and PRP/HSR. However, in today's complex substation automation industry, even millisecond long network interruptions cannot be tolerated because they may severely impact system operations or jeopardize on-site safety. IEC 61850 edition 2 clearly states that the transmission of GOOSE and SMV packets in substation automation systems are required to be bumpless. Moxa also provides PRP/HSR technology for zero packet loss network redundancy technology to ensuring on-site safety and quality of service.

Moxa's Integrated PRP/HSR Technology



Visualized PRP/HSR network management

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

Quickly integrate legacy single attached nodes into PRP/HSR networks

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

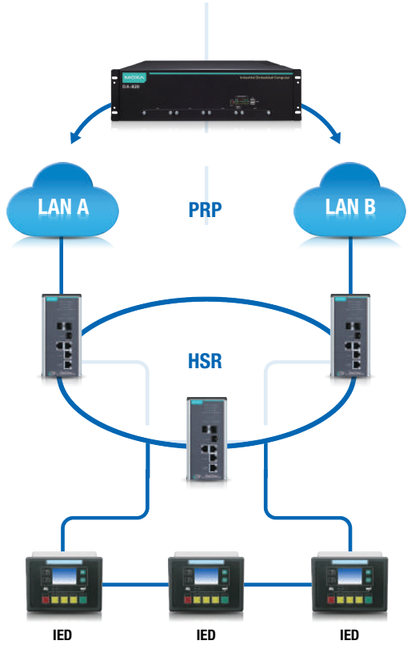
Enable multiple single attached nodes in PRP/HSR networks

- 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

Using Native PRP/HSR Computers for Efficient Network Management

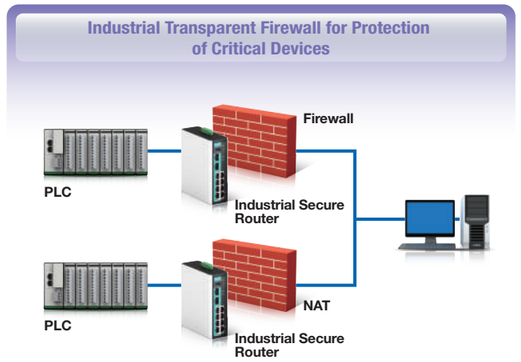
Another concern of substation engineers is that if they use PRP/HSR technology, they will have to deal with multiple protocols (MMS, PRP/HSR supervision frame, SNMP) in their system, thereby increasing the complexity of management.

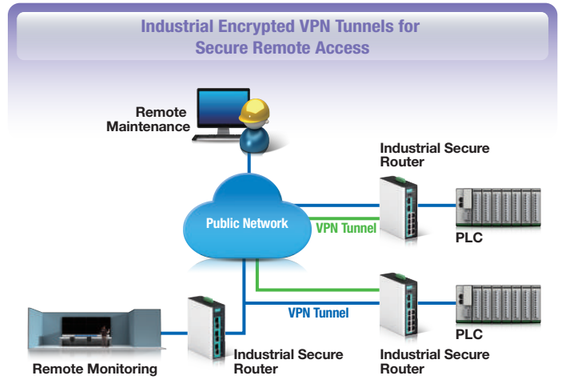
A native PRP/HSR computer is the best choice when it comes to ensuring high reliability while monitoring a PRP/HSR network with build-in PRP/HSR management middleware that supports both SNMP and MMS interface. Various substation devices that run different communication protocols, including PRP/HSR devices, can be connected to this computer. 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 PSCADA system enables all data to be effortlessly used and read in the substation PSCADA system via the MMS protocol. Substation operators find it easy to manage all devices on the PRP/HSR system via the PSCADA visual tools. In addition, troubleshooting can be easy since any single-point-of-failure can be shown on the PSCADA system, making the PRP/HSR application more reliable and stable.



Enhancing Cybersecurity in Substations

In an age where cyberattacks on public infrastructure are increasing, protection of substation networks and assets cannot be taken lightly. To protect your mission critical networks, Moxa provides a portfolio of Gigabit secure routers that provide secure remote access to field devices through public networks and facilitate layered defense-in-depth network security for substation networks.





Data Reliability

Critical data such as control signals and warnings are sent in GOOSE messages from the PSCADA to the designated IEDs. A built-in mechanism in switches to detect delay, loss, or tampering of GOOSE packets can facilitate quick troubleshooting in substation networks.

GOOSE Check Technology for Packet Monitoring

GOOSE Check is a type of packet inspection where the status of each GOOSE packet passing through the Ethernet switches is continuously monitored. Substation operators can then use MMS to send this information to a PSCADA system to visualize dropped, delayed, out-of-sequence, and tampered GOOSE packets, and trigger system alarms when the status of a packet changes.

Update Interval: every 5 secs

All	Index	APP ID	GOOSE Address	IED Name	VID	Ingress Port	Rx Counter	Status	Type
☐	1	1	01:0c:cd:01:00:00	BC_CONTCTRL	1	1-2	85	Health	Static
☐	2	1	01:0c:cd:01:00:01	BC_CONTCTRL	1	1-2	85	Health	Dynamic
☐	3	1	01:0c:cd:01:00:02	BC_CONTCTRL	1	1-2	85	Timeout	Dynamic
☐	4	1	01:0c:cd:01:00:03	BC_CONTCTRL	1	1-2	85	Health	Dynamic
☐	5	1	01:0c:cd:01:00:04	BC_CONTCTRL	1	1-2	85	Health	Static
☐	6	1	01:0c:cd:01:00:05	BC_CONTCTRL	1	1-2	85	Health	Dynamic
☐	7	1	01:0c:cd:01:00:06	BC_CONTCTRL	1	1-2	85	Tampered	Static
☐	8	1	01:0c:cd:01:00:07	BC_27_1CTRL	1	1-2	85	Health	Dynamic

Reset | Delete | Set Static

Manageability

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

Browser-based Network Device Configuration Wizard

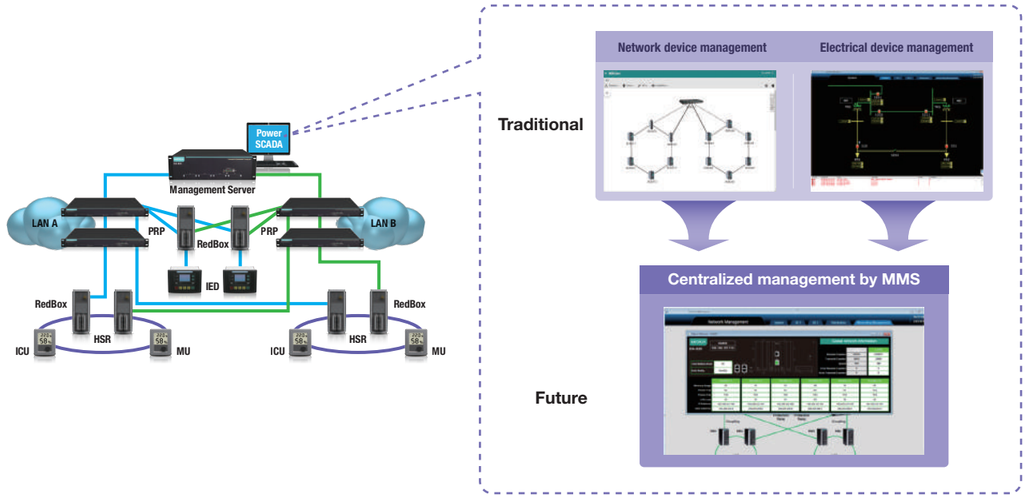
Configuring network devices correctly can be a major headache for substation engineers, particularly since incorrect configurations can result in an unstable or nonfunctional communication infrastructure. That's where Moxa's proprietary Substation Configuration Wizard can make all the difference. Because substations are such a specialized environment, IT teams will only require a few key features. For this reason, it makes a lot of sense to simplify and streamline the configuration process. Reducing the configuration interface to only the relevant network features, makes setup and maintenance 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.

Built-in MMS Server for PSCADA Integration

Upgrading multiple peer-to-peer communication connections on the same network, and finding communication errors can be an extremely complicated exercise. With fully integrated MMS support based on IEC 61850-90-4 modeling, substation SIs and automation engineers can display their entire network of automation devices right alongside process-level information, all in a single SCADA view, which makes managing the Ethernet switch the same as managing IEC-61850 electrical devices. Therefore, you will no longer need to install and configure separate NMS software for IT devices on your substation system.

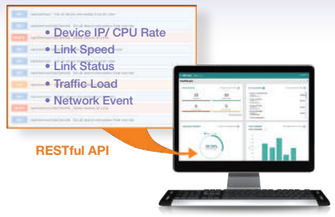
Administrators can use MMS to:

- 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



Sometimes substation networks deploy switches that do not have integrated IEC 61850 MMS, making network management more complex as these switches cannot be integrated easily into the PSCADA system. Moxa's network management software supports RESTful APIs and web widgets that enable easy integration of such devices with third-party applications (e.g., web-based SCADA).

Using RESTful APIs to embed network information into management dashboards



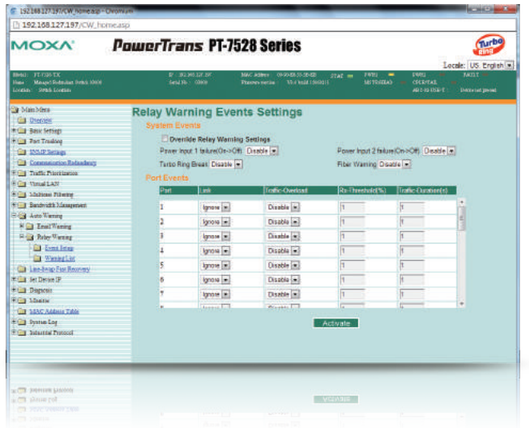
Using URL links in web widget to embed real-time network topology into web-based applications

Proactive Diagnosis of ST/SC/SFP Fiber Issues: FiberCheck™ Technology

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?

Optical fiber, which is used in substation networks to protect Ethernet connections from electromagnetic interference, may deteriorate after long years of usage. FiberCheck™ Technology uses Digital Diagnostic Monitoring technology to diagnose deterioration of signals before the signals are too weak and drop off, offering predictive maintenance for early error detection and fault isolation. 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 PSCADA 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.



Performance and Protection

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.

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 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.

Monitoring the Status of Key Components for Advance Alerts: Proactive Monitoring

How do you improve the performance of your industrial computers and get advanced alerts on the key performance indicators to help reduce unexpected equipment downtime? Proactive Monitoring, Moxa's innovative 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).

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

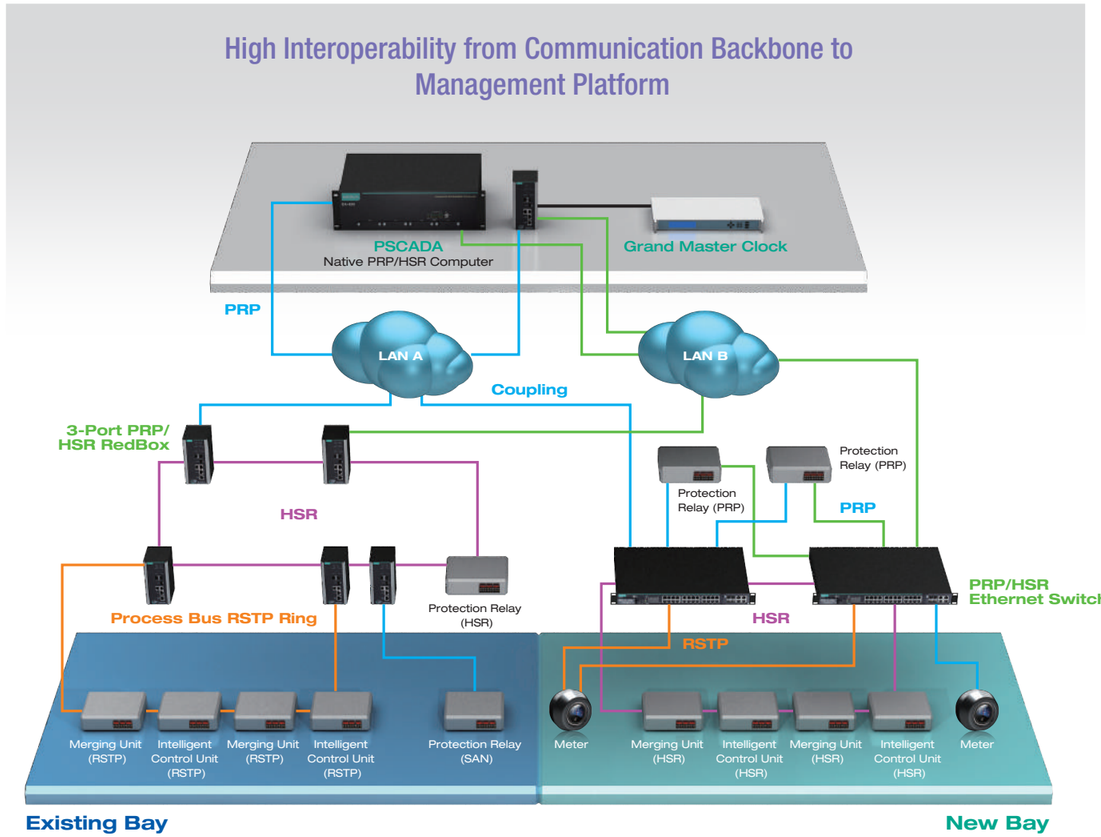
Temperature Alert
When the system temperature exceeds a user-defined threshold over a configured time period.

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

Legacy-to-hybrid Network Deployment

Substation retrofit projects require integration of existing RSTP ring networks with PRP/HSR architecture to bring DANs (dual attached nodes) to a bumpless redundant communication backbone and to enhance system availability. With Moxa's IEC 61850-compliant devices specifically calibrated for PRP and HSR redundancy, seamless control and monitoring can be achieved, to help customers construct or retrofit their network infrastructures as required for time-sensitive and mission-critical applications.



04 Over 1,000 Successful Transmission and Distribution Deployments Worldwide

Power Generation Substation: **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**

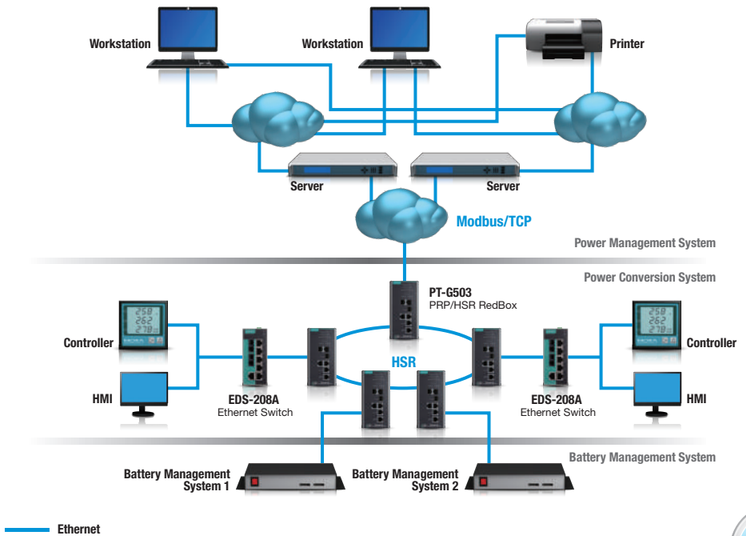
Create rock-solid and future-proof substation networks by partnering with Moxa. With years of expertise in the substation industry, we have delivered digital solutions to over 1,000 substation communication and computing projects worldwide.

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

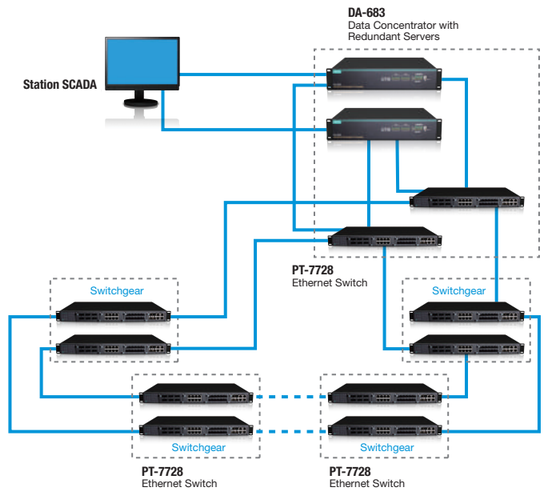
Why Moxa?

- 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

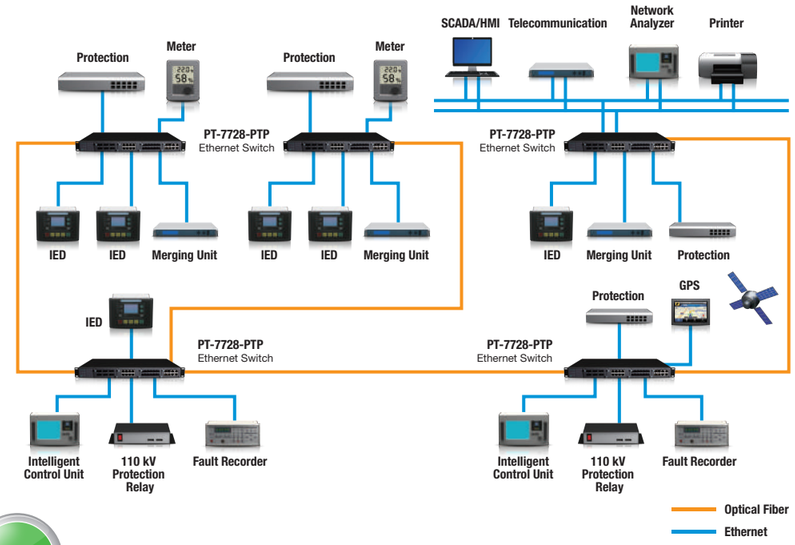
- **Substation Voltage:** 765 kV
- **Type of Substation:** Generation Substation
- **Customer Needs:** Flexible port configuration with 4 fiber gigabit ports to form a redundant ring

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

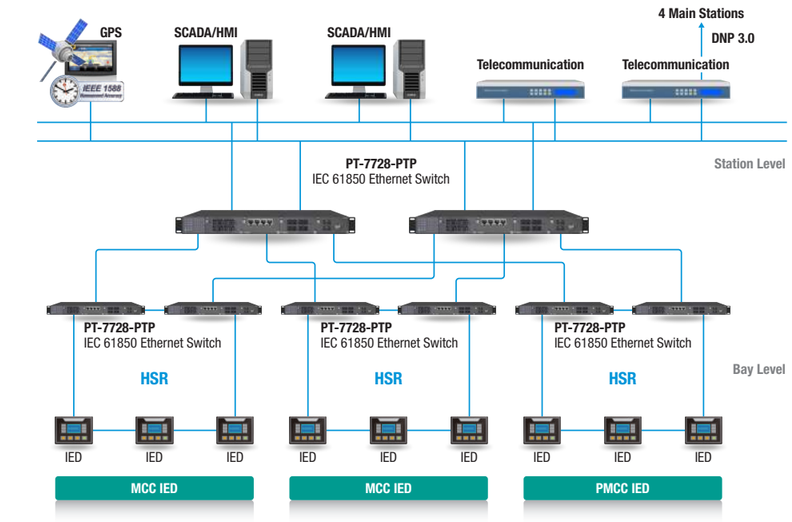
- **Substation Voltage:** 110/220 kV
- **Type of Substation:** Transmission Substation
- **Customer Requirements:** Build the world's first IEC 61850 digitalized substation on a state grid in Jiangsu province that utilizes the IEC 61850 GOOSE/SMV and IEEE 1588 standards.

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

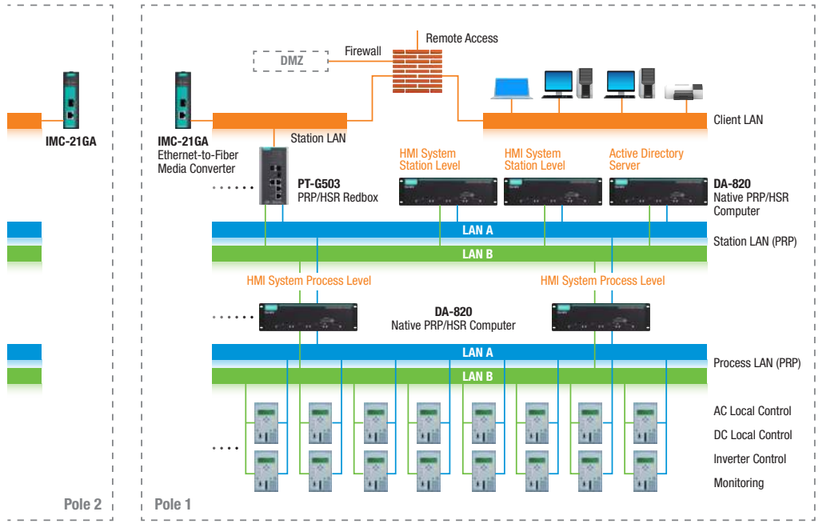
- **Substation Voltage:** 161 kV
- **Substation Type:** Transmission Substation
- **Customer Requirements:**
  - Build an IEC 61850 substation with a high-reliability design including IEEE 1613 class 2 devices and a zero packet loss network
  - Protection devices (SAN and DAN) should be connected redundantly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

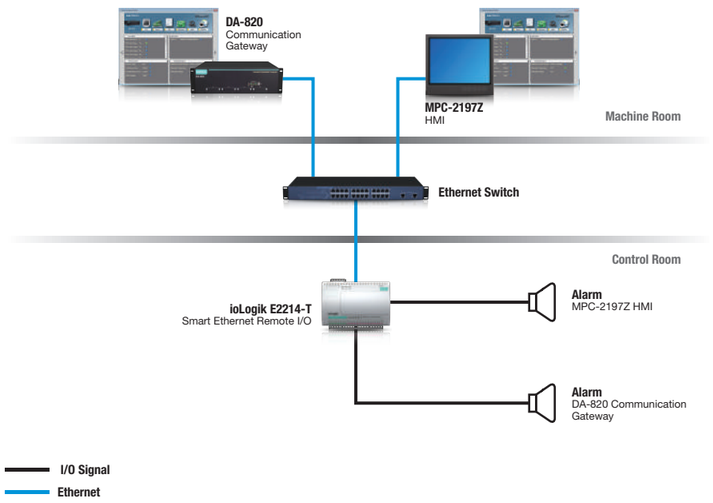
Why Moxa?

- 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

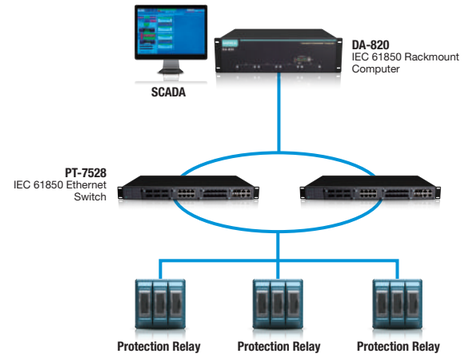
- **Type of Substation:** Utility Substation (Transmission)
- **Customer Needs:**
  IEC 61850-3 and IEEE 1613 compliant communication gateway and remote alarm solution.

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

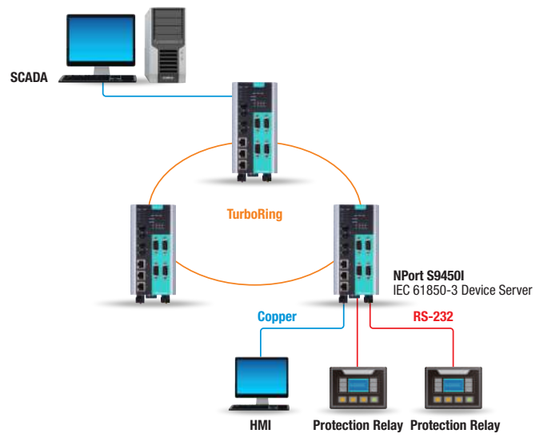
- **Substation Voltage:** 380/132 kV
- **Type of Substation:** Transmission Substation
- **Customer Needs:**
  A solution that can enhance remote asset management and monitoring, and transmit various HV data workflows from the MBI and PSE platforms to a centralized SCADA system.

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

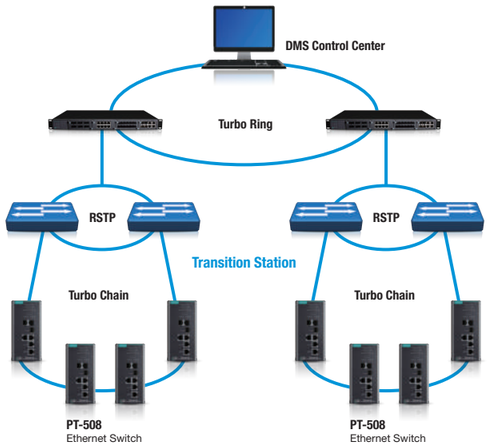
- **Substation Type:** Transmission Substation
- **Customer Requirements:**
  - Protection relay should only have serial interface (RS-232)
  - IEC 61850-3 compliant devices for substation application
  - Ethernet-to-fiber interface for long-distance communication

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.

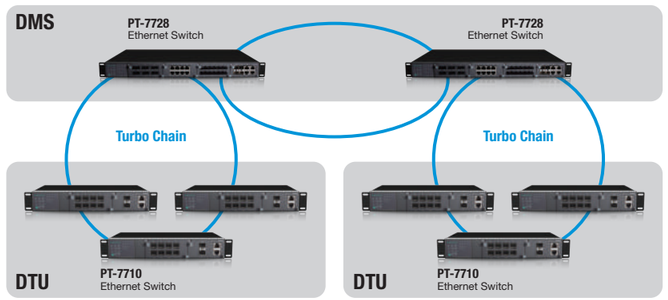
Why Moxa?

- 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

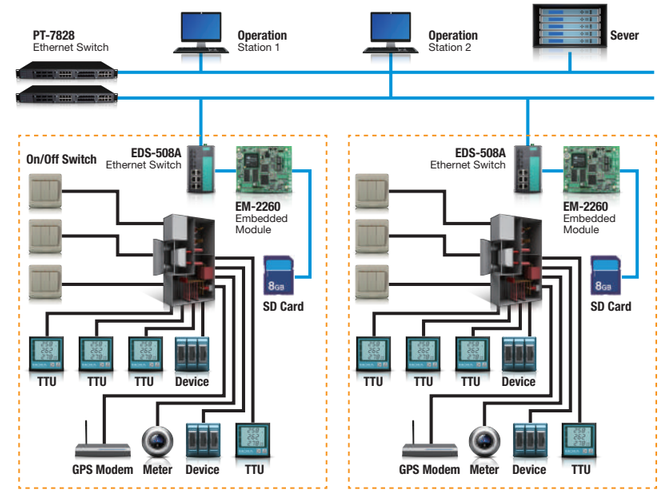
- **Feeder Voltage:** 10 kV
- **Type of Substation:** Distribution
- **Customer Requirements:**
  - An embedded platform capable of handling multiple devices running on CANbus, DI/DO, AI/AO, serial, and Ethernet
  - Consulting service for easy integration

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

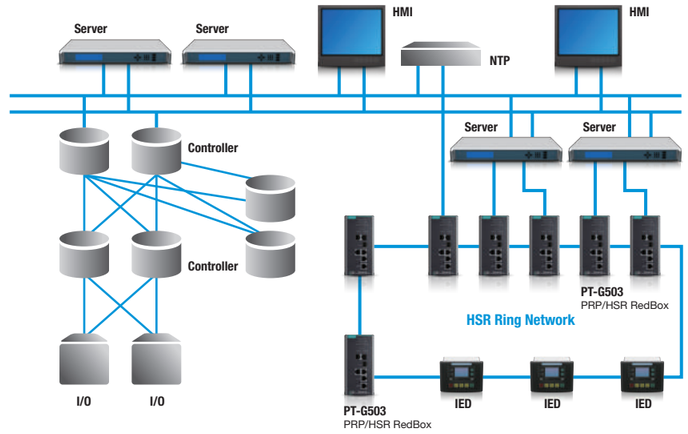
- **Substation Voltage:**
  Mid to low level
- **Type of Substation:** Enterprise Substation
- **Customer Needs:**
  Integration of IEC 61850 Ethernet switch and RedBox into the Experion process server and IEC 61850 SCADA server

Why Moxa?

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

12
USA

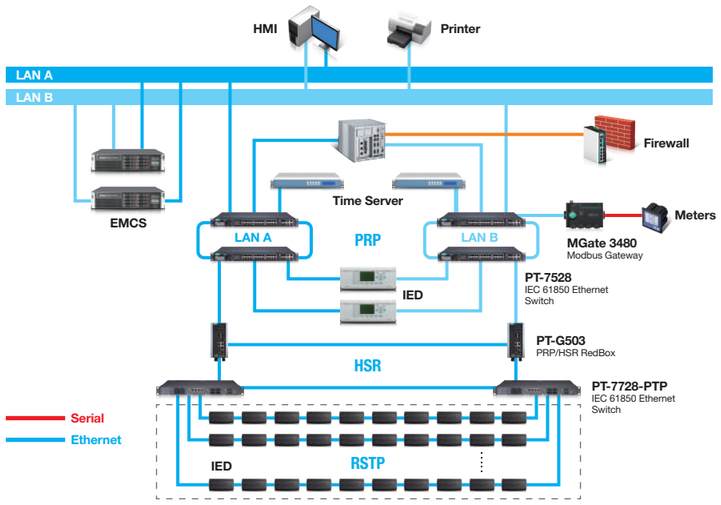
Enterprise Substation: PRP/HSR Solution for Factory DCS



Ethernet

13
Russia

RSTP Grouping for Easy Migration of Devices to PRP/HSR Networks



Background and Requirements

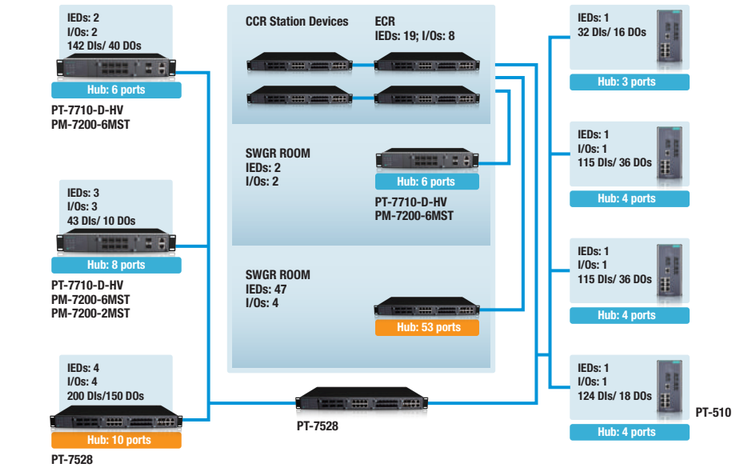
- **Substation Voltage:** 150/35 kV
- **Customer Requirements:**
  - Easily integrate RSTP-based groups with hundreds of IEDs into PRP/HSR networks
  - Convert Modbus RTU devices to Modbus TCP for easy management
  - Firewall to filter IEC 60870-5-104 packets
  - Transmit IEC 61850 packets (MMS, GOOSE) in PRP/HSR networks

Why Moxa?

- RSTP Grouping technology helps easy integration of existing IEDs into PRP network
- Four serial ports to convert Modbus RTU data to Modbus TCP
- PRP/HSR portfolio that includes switches and redbox for flexible integration
- Built-in MMS Server support in switches

14
Korea

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



Background and Requirements

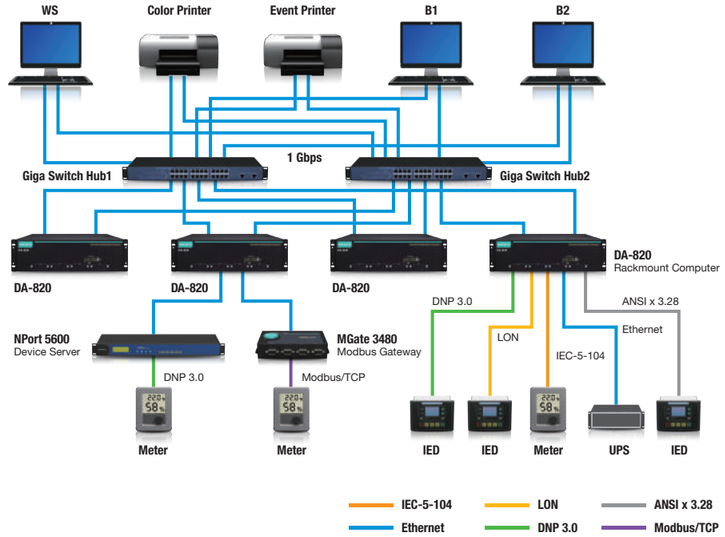
- **Substation Voltage:** 345 kV
- **Type of Substation:**
  Enterprise Substation
- **Customer Needs:**
  - Compact hardware that can fit in a small cabinet
  - IEC 61850-compliant solution

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

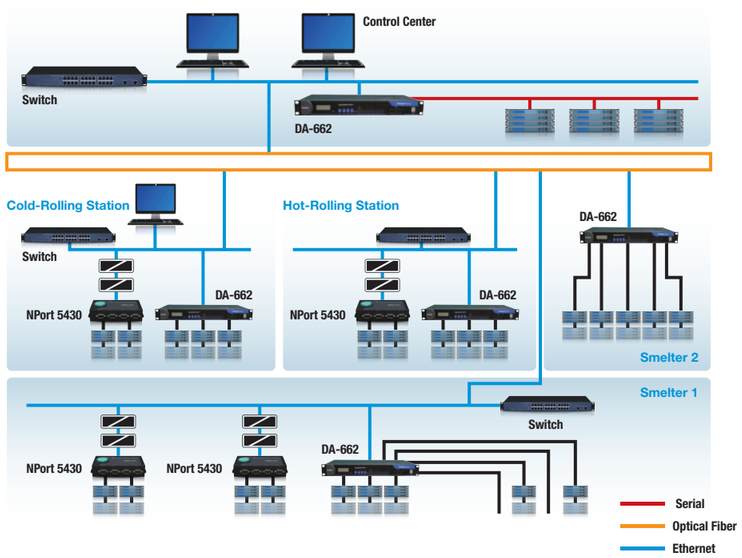
- **Substation Voltage:** 10 or 35 kV
- **Type of Substation:**
  Enterprise Substation
- **Customer Needs:**
  The manufacturing substation uses ABB's MicroSCADA for data acquisition and analysis, fault recording, protection parameter configuration, event alarms, and event lists.

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



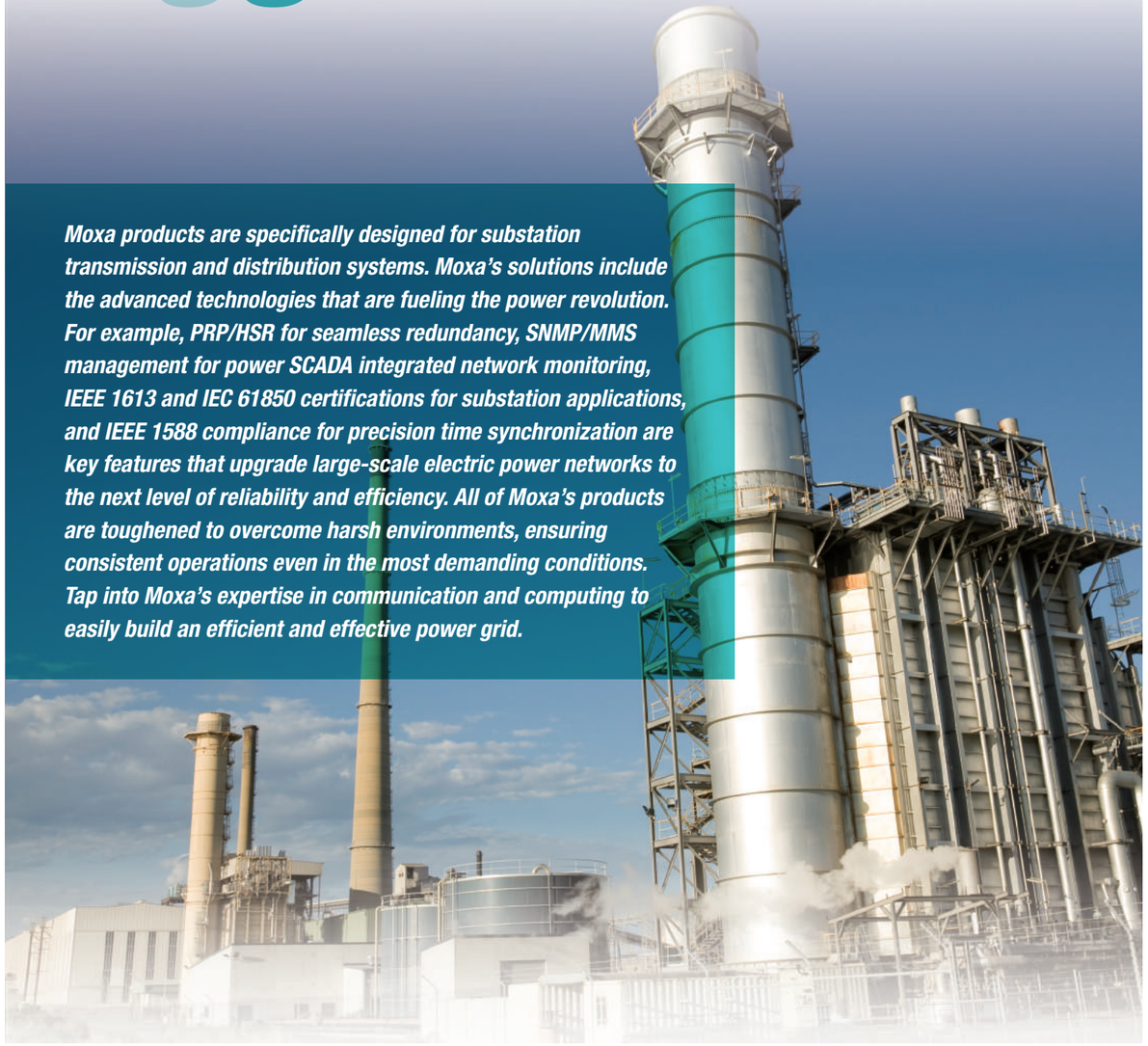
Background and Requirements

- **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.

Protocol Gateways for Substations



	MGate MB3660	MGate 5109	MGate 5114
LAN Interface			
10/100BaseT(X) Ports	2 ports (8-pin RJ45 connector)	2 port (8-pin RJ45 connector)	2 port (8-pin RJ45 connector)
Magnetic Isolation Protection	1.5 kV		
Protocol	Modbus TCP Client/Server	Modbus TCP Client/Server, DNP3 TCP Client/Outstation	Modbus TCP Client/Server, IEC 60870-5-104 Client/Server
Serial Interface			
Protocol	Modbus RTU/ASCII Master/Slave	Modbus RTU/ASCII Master/Slave, DNP3 Serial Master/Outstation	Modbus RTU/ASCII Master/Slave, IEC 60870-5-101 Master/Slave (Balanced/Unbalanced mode)
RS-232/422/485 Ports	8/16	1	1
Connectors	DB9 male	DB9 male	DB9 male
Communication Parameters	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	Data Bits: 7, 8; Stop Bits: 1, 2; Parity: None, Even, Odd, Space, Mark
Flow Control	RTS/CTS, DTR/DSR, RTS Toggle (RS-232 only)	RTS/CTS, 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
2-kV Isolation Protection	Optional (MB3660I)	Yes	Yes
RS-485 Data Direction Control	ADDC® (automatic data direction control)		
RS-232 Console Port	Yes	Yes	Yes
Advanced Features			
Serial Data Log	–	–	–
Offline port Buffering	–	–	–
SD Slot	Yes	Yes	Yes
Software			
Security Protocols	RADIUS	HTTPS, SSH	HTTPS, SSH
Configuration Options	Web console, Serial console, Telnet console	Web console, Serial console, Telnet console	Web console, Serial console, Telnet console
Driver Support	–	–	–
Management	SNMPv1 (read only)	SNMPv1/v2c/v3	SNMPv1/v2c/v3
Standard Operation Modes	Transparent Mode, Intelligent Mode, Agent Mode	Transparent Mode, Agent Mode	Agent Mode
Secure Operation Modes	–	–	–
Physical Characteristics			
Housing	Metal, IP30	Metal, IP30	Metal, IP30
Dimensions (mm)	440 x 45 x 198 mm	36 x 105 x 140 mm	36 x 105 x 140 mm
Environmental Limits			
Operating Temperature	0 to 60°C (32 to 140°F)	Standard Models: 0 to 60°C Wide Temp. Models: -40 to 75°C	Standard Models: 0 to 60°C Wide Temp. Models: -40 to 75°C
Storage Temperature	-40 to 85°C (-40 to 185°F)	-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)
Power Requirements			
Rated Voltage	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	12 VDC to 48 VDC
Standards and Certifications			
Safety	UL 60950-1, EN 60950-1 (LVD)	UL 508, EN 60950-1	UL 508, EN 60950-1
EMC	EN 55022/24	EN 55032/24	EN 55032/24
Reliability			
MTBF	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	1,140,815 hrs	1,140,815 hrs
Warranty	5 years	5 years	5 years

IEC 61850-3 Ethernet Switches

	PT-G7728/G7828	PT-7828 PT-7728 PT-7728-PTP	PT-7528	PT-7710	PT-508/510
Number of Ports					
Max. Number of Ports	28	28	28	10	8 or 10
Max. Number of Hardware PTP Ports	28	–	–	–	–
Gigabit Ethernet, 10/100/1000 Mbps	Up to 28	Up to 4	Up to 4	Up to 2	–
Fast Ethernet, 10/100 Mbps	Up to 28	Up to 28	Up to 28	Up to 10	8 or 10
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
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
Console Port	Micro-B USB	RS-232	USB	RS-232	RS-232
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	✓	✓	✓	✓	✓
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	✓	✓	–

IEC 61850-3 Ethernet Switches

	EDS-510E	EDS-518E	EDS-528E	EDS-G516E EDS-G512E EDS-G508E	PT-G503-PHR-PTP
Number of Ports					
Max. Number of Ports	10	18	28	16	3
Max. Number of Hardware PTP Ports	–	–	–	–	3
Gigabit Ethernet, 10/100/1000 Mbps	3	4	4	16	3
Fast Ethernet, 10/100 Mbps	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
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)	–	–	–	–	✓
RSTP grouping	–	–	–	–	✓
Turbo Ring/Turbo Chain Recovery Time: Fast Ethernet<20 ms; Gigabit Ethernet<50 ms	✓	✓	✓	✓	–
Automatic Backup Configurator	ABC-02	ABC-02	ABC-02	ABC-02	ABC-02
Console Port	USB	USB	USB	USB	Ethernet
Network Management and Control					
Layer-3 Switching	–	–	–	–	–
IPv6	✓	✓	✓	✓	✓
DHCP Option 66/67/82	✓	✓	✓	✓	–
VLAN	✓	✓	✓	✓	–
QoS	✓	✓	✓	✓	–
IEC 61850 QoS	–	–	–	–	–
NTP/SNTP	✓	✓	✓	✓	✓
Software-based IEEE 1588v2 PTP	✓	✓	✓	✓	–
Hardware-based IEEE 1588v2 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)	✓	✓	✓	✓	✓
EN 50155 (Railway Applications)	–	–	–	–	–
NEMA TS2 (Traffic Control System)	✓	✓	✓	✓	–

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 2.0hosts Rear: 2 USB 3.0hosts	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 2.0interfaces, 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 hostx 4, type A connector	–	USB 2.0 hostx 1, type A connector
Storage			
Built-in	8 GB for Linux (preinstalled in mSATA)	–	–
Storage Expansion	1 x SATA 3.0interface	–	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 lin e-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

Serial Device Server for Substations




	NPort 6600 Series	CN2600 Series	NPort S9650I	NPort S9450I
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)
Magnetic Isolation Protection	1.5 kV			
Protocol	–	–	Modbus TCP, DNP3 TCP	Modbus TCP, DNP3 TCP
Serial Interface				
Protocol	–	–	Modbus RTU/ASCII, DNP3 Serial	Modbus RTU/ASCII, DNP3 Serial
RS-232/422/485 Ports	8/16/32	8/16	8/16	4
Connectors	8-pin RJ45	CN2610/2650: 8-pin RJ45 CN2650I: DB9 male	DB9 male/DB9 female/multi-mode ST	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
Flow Control	RTS/CTS, DTR/DSR, XON/XOFF	RTS/CTS, DTR/DSR, XON/XOFF	RTS/CTS, XON/XOFF	RTS/CTS, XON/XOFF
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
2-kV Isolation Protection	–	Optional (CN2650I)	Yes	Yes
RS-485 Data Direction Control	ADDC® (automatic data direction control)			
RS-232 Console Port	Yes	Yes	Yes	Yes
Advanced Features				
Serial Data Log	64 KB	–	–	–
Offline port Buffering	64 KB	–	–	–
SD Slot	Yes	–	–	–
Software				
Security Protocols	DES, 3DES, AES, SSH, SSL	RADIUS, HTTPS, SSH, PAP, CHAP	RADIUS, HTTPS, SSH, PAP, CHAP	RADIUS, HTTPS, SSH, PAP, CHAP
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
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
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
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
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
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)	
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)	
Ambient Relative Humidity	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)
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)
EMC	CE, FCC	CE, FCC	EN 61000-6-2/-6-4	EN 61000-6-2/-6-4
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
Warranty	5 years	5 years	5 years	5 years

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