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. With over 30 years of industry experience, Moxa has connected more than 50 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 industry with reliable networks and sincere service for industrial communications infrastructures.

© 2018 Moxa Inc. All rights reserved.
The MOXA logo is a registered trademark of Moxa Inc. All other logos appearing in this document are the intellectual property of the respective company, product, or organization associated with the logo.

The Americas
Moxa Americas
Tel: Free 1-888-MOXA-USA
Toll Free: +1-714-526-6777
Fax: +1-714-526-6778
usa@moxa.com

Moxa Brazil
Tel: +55-11-2362-4555
Fax: +55-11-2362-4555
brazil@moxa.com

Europe
Moxa Germany
Tel: +49-89-37033-50-0
Fax: +49-89-37033-59-09
eurpe@moxa.com

Moxa France
Tel: +33-1-30-85-47-80
Fax: +33-1-30-47-45-91
france@moxa.com

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Asia-Pacific
Moxa Asia-Pacific and Taiwan
Tel: +886-2-8919-1230
Fax: +886-2-8919-1231
asia@moxa.com
japan@moxa.com
taiwan@moxa.com

Moxa India
Tel: +91-80-4172-9088
Fax: +91-80-4132-1046
india@moxa.com

Moxa Russia
Tel: +7-495-287-0000
Fax: +7-495-289-0009
russia@moxa.com

Moxa Korea
Tel: +82-2-6368-4048
Fax: +82-2-6368-4044
korea@moxa.com

Moxa Beijing
Tel: +86-10-5976-6122
Fax: +86-10-5976-6122
china@moxa.com

Moxa Shenzhen
Tel: +86-755-8368-4754
Fax: +86-755-8368-4748
china@moxa.com

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

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Europe
Moxa Germany
Tel: +49-89-37033-50-0
Fax: +49-89-37033-59-09
eurpe@moxa.com

Moxa France
Tel: +33-1-30-85-47-80
Fax: +33-1-30-47-45-91
france@moxa.com

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Asia-Pacific
Moxa Asia-Pacific and Taiwan
Tel: +886-2-8919-1230
Fax: +886-2-8919-1231
asia@moxa.com
japan@moxa.com
taiwan@moxa.com

Moxa India
Tel: +91-80-4172-9088
Fax: +91-80-4132-1046
india@moxa.com

Moxa Russia
Tel: +7-495-287-0000
Fax: +7-495-289-0009
russia@moxa.com

Moxa Korea
Tel: +82-2-6368-4048
Fax: +82-2-6368-4044
korea@moxa.com

Moxa Beijing
Tel: +86-10-5976-6122
Fax: +86-10-5976-6122
china@moxa.com

Moxa Shenzhen
Tel: +86-755-8368-4754
Fax: +86-755-8368-4748
china@moxa.com

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

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Europe
Moxa Germany
Tel: +49-89-37033-50-0
Fax: +49-89-37033-59-09
eurpe@moxa.com

Moxa France
Tel: +33-1-30-85-47-80
Fax: +33-1-30-47-45-91
france@moxa.com

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Asia-Pacific
Moxa Asia-Pacific and Taiwan
Tel: +886-2-8919-1230
Fax: +886-2-8919-1231
asia@moxa.com
japan@moxa.com
taiwan@moxa.com

Moxa India
Tel: +91-80-4172-9088
Fax: +91-80-4132-1046
india@moxa.com

Moxa Russia
Tel: +7-495-287-0000
Fax: +7-495-289-0009
russia@moxa.com

Moxa Korea
Tel: +82-2-6368-4048
Fax: +82-2-6368-4044
korea@moxa.com

Moxa Beijing
Tel: +86-10-5976-6122
Fax: +86-10-5976-6122
china@moxa.com

Moxa Shenzhen
Tel: +86-755-8368-4754
Fax: +86-755-8368-4748
china@moxa.com

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

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Europe
Moxa Germany
Tel: +49-89-37033-50-0
Fax: +49-89-37033-59-09
eurpe@moxa.com

Moxa France
Tel: +33-1-30-85-47-80
Fax: +33-1-30-47-45-91
france@moxa.com

Moxa UK
Tel: +44-1844-355-601
Fax: +44-1844-355-655
uk@moxa.com

Asia-Pacific
Moxa Asia-Pacific and Taiwan
Tel: +886-2-8919-1230
Fax: +886-2-8919-1231
asia@moxa.com
japan@moxa.com
taiwan@moxa.com

Moxa India
Tel: +91-80-4172-9088
Fax: +91-80-4132-1046
india@moxa.com

Moxa Russia
Tel: +7-495-287-0000
Fax: +7-495-289-0009
russia@moxa.com

Moxa Korea
Tel: +82-2-6368-4048
Fax: +82-2-6368-4044
korea@moxa.com

Moxa Beijing
Tel: +86-10-5976-6122
Fax: +86-10-5976-6122
china@moxa.com

Moxa Shenzhen
Tel: +86-755-8368-4754
Fax: +86-755-8368-4748
china@moxa.com

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

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.

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.
IEC 61850 Makes Substations Smarter

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

**MMS:** Substation status information used for monitoring purposes is sent using the Manufacturing Messaging Specification protocol.

**GOOSE:** Critical data such as control signal and warnings are sent using the Generic Object Oriented Substation Event protocol.

**SMV:** Power line current and voltage measurements are sent using the Sampled Measured Values protocol.

### 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

<table>
<thead>
<tr>
<th>Transfer time class</th>
<th>Transfer time (ms)</th>
<th>Type of transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT0</td>
<td>&gt;1000</td>
<td>Files, events, log contents</td>
</tr>
<tr>
<td>TT1</td>
<td>1000</td>
<td>Events, alarms</td>
</tr>
<tr>
<td>TT2</td>
<td>500</td>
<td>Operator commands</td>
</tr>
<tr>
<td>TT3</td>
<td>100</td>
<td>Slow automatic interactions</td>
</tr>
<tr>
<td>TT4</td>
<td>20</td>
<td>Fast automatic interactions</td>
</tr>
<tr>
<td>TT5</td>
<td>10</td>
<td>Failures, status changes</td>
</tr>
<tr>
<td>TT6</td>
<td>3</td>
<td>Trips, blockings</td>
</tr>
</tbody>
</table>

Reference: IEC 61850-5

### The Architecture of an IEC 61850 Substation

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

- **Process Level:** The process level comprises devices such as circuit breakers and data acquisition equipment used to measure the current, voltage, and other parameters in different parts of the substation.

- **Bay Level:** The bay level consists of the IEDs that collect the measurements provided by the process level. The IEDs can make local control decisions, transmit the data to other IEDs, or send the data to the substation SCADA system for further processing and monitoring.

- **Station Level:** The station level is where you’ll find SCADA servers and HMIs, as well as the human operators (if needed) who monitor the status of the substation.

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

### IEC 61850 Communication

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

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

Substation Automation with IEC 61850 Station Bus

Substation Automation with IEC 61850 Station and Process Bus

PRP/HSR: The Next Wave of IEC 61850

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

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.

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

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.
IEC 61850 Makes Substations Smarter

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?
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.

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.
Certification Standards Can Make or Break the Deal

IEC 61850-3 Class C3 Certified

The IEC 61850-3 and IEE 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

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

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.

A Platform Is Not Just a Platform

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

Native Compilation Support

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

Operating Systems

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

Wireless Capability

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

Performance and Security

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

**Reduced Costs**

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

**Application Isolation**

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

**Extend the Life of Your Legacy Applications**

You can use VMs to run your legacy applications and OS on computers with new hardware platforms or operating systems. However, don’t assume that every computer platform works well with VMware. Be sure to use products that display the VMware-ready logo, which indicates that a product meets the criteria for VMware integration and interoperability.

Troubleshooting Communication Errors

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

Troubleshooting System Crashes

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

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

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

Troubleshooting Communication Errors

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

Prioritizing Modbus Messages

In a control and monitoring system (CMS), commands that track important data and emergency requests are considered critical. Regular metering commands are non-critical in nature. The CMS generates an alarm or error if a critical function is not addressed immediately. You can find products with features that can prioritize critical commands, such as Modbus messages, to solve this issue.
Performance
One of the major concerns of experienced substation engineers is how the performance of an Ethernet-based substation compares with the performance of a more traditional peer-to-peer, hardwired substation. The concern is understandable, particularly since in an Ethernet-based network, thousands of information packets are constantly competing for a spot in the substation network’s main trunk line. Someone unfamiliar with how an advanced IEC 61850 substation network prioritizes packets to ensure that critical information is passed quickly to the correct devices is likely to be skeptical.

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

► Performance
► Reliability
► Manageability

Background
Will the performance of an IEC 61850 Ethernet-based substation compare favorably with that of a hardwired peer-to-peer substation?
The answer is, yes. In general, engineers have three major concerns:
1. Will the transfer time between applications be fast enough?
2. Can we expect communication via an Ethernet network to be the same or better than a hardwired peer-to-peer substation?
3. What kind of protocol can be used to ensure that event timestamps are accurate across different locations for efficient operational diagnostics.

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.

Start off on the right foot with IEC 61850

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

► Performance
► Reliability
► Manageability

Background
Will the performance of an IEC 61850 Ethernet-based substation compare favorably with that of a hardwired peer-to-peer substation?
The answer is, yes. In general, engineers have three major concerns:
1. Will the transfer time between applications be fast enough?
2. Can we expect communication via an Ethernet network to be the same or better than a hardwired peer-to-peer substation?
3. What kind of protocol can be used to ensure that event timestamps are accurate across different locations for efficient operational diagnostics.

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.

Start off on the right foot with IEC 61850

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

► Performance
► Reliability
► Manageability

Background
Will the performance of an IEC 61850 Ethernet-based substation compare favorably with that of a hardwired peer-to-peer substation?
The answer is, yes. In general, engineers have three major concerns:
1. Will the transfer time between applications be fast enough?
2. Can we expect communication via an Ethernet network to be the same or better than a hardwired peer-to-peer substation?
3. What kind of protocol can be used to ensure that event timestamps are accurate across different locations for efficient operational diagnostics.
IEC 61850 Makes Substations Smarter

IEC 61850 QoS: Critical Packet Prioritization

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

**Standard QoS**

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

IEC 61850 QoS

In IEC 61850 substation communication, GOOSE and SMV are 2 critical packet types that require high-priority attention. To ensure that these messages are not corrupted, they are transmitted with the highest priority, regardless of what other messages each device needs to process.

### Time Synchronization Technology: Enabling Efficient and Reliable Communication

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

#### VLAN Technology: Enabling Efficient and Reliable Communication

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

- **Trunk traffic reduction**
- **Traffic filtering**

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

**Packet-type inspection** guarantees higher critical packet types that require high-priority attention. For example, with this method, GOOSE packets are critical, and hence always given the top priority in the sending queue.

#### VLAN Technology: Enabling Efficient and Reliable Communication

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

- **Trunk traffic reduction**
- **Traffic filtering**

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

**Packet-type inspection** guarantees higher critical packet types that require high-priority attention. For example, with this method, GOOSE packets are critical, and hence always given the top priority in the sending queue.

**Reliability**

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

**Background 1**

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

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

**Background 2**

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

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

---

**IEC 61850 QoS: Critical Packet Prioritization**

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

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

IEC 61850 QoS

In IEC 61850 substation communication, GOOSE and SMV are 2 critical packet types that require high-priority attention. To ensure that these messages are not corrupted, they are transmitted with the highest priority, regardless of what other messages each device needs to process.

### Time Synchronization Technology: Enabling Efficient and Reliable Communication

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

#### VLAN Technology: Enabling Efficient and Reliable Communication

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

- **Trunk traffic reduction**
- **Traffic filtering**

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

**Packet-type inspection** guarantees higher critical packet types that require high-priority attention. For example, with this method, GOOSE packets are critical, and hence always given the top priority in the sending queue.

**Reliability**

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

**Background 1**

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

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

**Background 2**

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

Fiber port performance is measured by the length of time the port operates successfully. Preventing fiber malfunctions using a pre-fault predictive maintenance mechanism is extremely important. Most substations currently support only SFP-type optical-fiber monitoring. Moxa FiberCheck™ can be used by substation switches to monitor ST/SC (as well as SFP) connectors, and notify the power SCADA system via SNMP or MMS when abnormalities are detected, allowing operators to quickly initiate maintenance procedures. Reports and alarms can be transmitted using any one of the following methods: a network port, a serial console, CLI, MMS reporting, SNMP traps, digital relay, entries written to the system log file. The FiberCheck™ function also allows system operators to monitor transmission and reception power, temperature, and voltage/current along optical-fiber connections in real time.
Background 3
Time-critical data transmitted through the process bus can only tolerate delays up to 4 ms (IED interlocking). Is there a redundancy technology that can meet this requirement?

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

Background 4
Stable system operation is important for ensuring reliable substation management. However, when the system is unstable, how do you restore the system to normal operation as quickly as possible?

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

**Fully Automated Recovery Tool**
- Special design for unmanned or remote substations that can automate the recovery process.

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

Background 5
How do you improve CPU performance, memory usage, storage, and system temperature performance, which can severely impact real-time management and monitoring?

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

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

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

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

**Storage Drive Alerts**
Thresholds may be configured for SM A R T values, including demanding storage capacity.

**Predefined Event Threshold**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Min.</th>
<th>Max.</th>
<th>Default</th>
<th>Action</th>
<th>Output to the Relay</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>CPU usage alert: When CPU usage reaches the predefined threshold.</td>
<td>7%</td>
<td>100%</td>
<td>80%</td>
<td>Disabled</td>
<td>CPU Loading Warning</td>
</tr>
<tr>
<td>Memory</td>
<td>Memory usage alert: When memory usage reaches the predefined threshold.</td>
<td>7%</td>
<td>100%</td>
<td>80%</td>
<td>Disabled</td>
<td>Memory Usage Warning</td>
</tr>
<tr>
<td>Disk</td>
<td>Disk usage alert: When disk usage reaches the predefined threshold.</td>
<td>7%</td>
<td>100%</td>
<td>80%</td>
<td>Disabled</td>
<td>Disk Usage Warning</td>
</tr>
<tr>
<td>Temperature</td>
<td>Temperature alert: When the temperature exceeds the predefined threshold.</td>
<td>0°C</td>
<td>0°C</td>
<td>120°C</td>
<td>Disabled</td>
<td>High Temperature Warning</td>
</tr>
<tr>
<td>Network</td>
<td>Network status alert: When network status (link down).</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Disabled</td>
<td>Link Down Warning</td>
</tr>
<tr>
<td>Power</td>
<td>Power failure alert and alerts for power failures.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Disabled</td>
<td>Power Failure Alarm</td>
</tr>
</tbody>
</table>

Background 6
Extreme temperatures ranging from -40 to 75°C, dust, and restricted airflow are conditions commonly found in substation environments that can greatly affect the performance of substation computers. Computers that rely on fans to keep their CPU cool are particularly vulnerable to these kinds of conditions. Many substations are now turning to fanless computers designed to operate in the extreme conditions found in substation environments.

A substation computer should be fully sealed from the outside environment and not require any type of fan. Not requiring a fan extends a computer’s life significantly, provided the computer is able to survive in the extreme heat often experienced in substation environments. Engineers must therefore work to situate the PCB’s highest thermal concentration in the very center of the device, so that heat has the largest immediate area available to dissipate into. With fanless systems, generally the entire outer shell is utilized as one large heat sink, with fins heights, gaps, thicknesses, and points of contact carefully analyzed and adjusted to further optimize dissipation. All of these factors must be carefully evaluated and adjusted to achieve maximum dissipation efficiency. What this means is that designing a fully fanless computer is a nontrivial engineering challenge, with fanless computers inevitably more expensive than fan-cooled solutions. But the additional cost is more than justified by the huge increase in reliability, as well as the additional benefits of reduced size, complexity, and protection against dust, heat, and corrosion.
IEC 61850 Makes Substations Smarter

Manageability

Background 1
Configuring network devices correctly can be a major headache for substation engineers, particularly since incorrect configurations can result in an unstable or nonfunctional communication infrastructure.

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

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

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

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

Extend the Life of Your Legacy Applications
You can use VMs to run your legacy applications and OS on computers with new hardware platforms or OSs.

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

Background 2
A powerful and secure management platform is crucial to substation automation. However, with a variety of applications operating on a single system, overall performance can experience significant degradation. What substation engineers would like to avoid is the need to maintain multiple management platforms, which can be costly and difficult to implement and maintain.

That’s where Moxa’s proprietary Substation Configuration Wizard makes managing the Ethernet switch the same as managing IEC-61850 electrical devices.

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

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

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

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

Background 3
Upgrading multiple peer-to-peer communication connections on the same network, and finding communication errors can be an extremely complicated exercise. One of the main concerns of substation engineers is that they may need to hire network experts to work onsite, resulting in long system downtimes.

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

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

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

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

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

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

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

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

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

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

Enabling Efficient and Visually Represented PRP/HSR Network Management

Background 4
Decentralized management with multiple protocols (MMS, PRP/HSR supervision frame, SNMP) increases complexity and decreases efficiency. One of the main concerns is that if substation engineers are not able to efficiently analyze the communication status of a PRP/HSR network, it will be harder to implement a preventive maintenance strategy when only one communication path is operational.

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

The PRP/HSR management middleware supports both SNMP and MMS interfaces, allowing the connection of various substation devices that run different communication protocols, including PRP/HSR devices. The supervision frame from the PRP/HSR devices is converted to SNMP or MMS format at the device level and then sent to the middleware for analysis. The integration of the middleware and Power SCADA system enables all data to be effortlessly used and read in the substation Power SCADA system via the MMS protocol. Substation operators find it easy to manage all devices on the PRP/HSR system via the Power SCADA visual tools. In addition, troubleshooting can be easy since any single-point-of-failure can be shown on the Power SCADA system, making the PRP/HSR application more reliable and stable.
Over 1,000 Successful Transmission and Distribution Deployments Worldwide

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.
### Background and Requirements

**Substation Voltage:** 110/220 kV

**Type of Substation:** Transmission Substation

**Customer Needs:**
- Build an EIC 61850 digital substion on a state grid in Jiangsu province that utilizes the IEC 61850 GOOSE/SMV and IEEE 1588 standards.
- Implement ESS (Energy Storage System) to enable remote monitoring of the state of the energy stored.

**Why Moxa?**
- Consulting service for substation networking design
- PT-7728-PTP is IEC 61850-3 and IEEE 1588 compliant
- IEEE 1588 nanosecond-level accuracy
- HSR HSR HSR

### China

#### World’s First IEC 61850 3-Layer 220 kV Substation

- **Protection Devices:**
  - PT-7728-PTP Ethernet Switch
  - PT-7728-PTP Ethernet Switch
  - PT-7728-PTP Ethernet Switch

- **Analysis:**
  - GPS
  - 4 Main Stations

- **Sending Data:**
  - SCADA/HMI
  - Telemetry

- **Environments:**
  - Station Level
  - Bay Level

### Background and Requirements

**Substation Voltage:** 200 kV

**Substation Type:** Transmission Substation

**Customer Requirements:**
- Build the world’s first IEC 61850 substation networking design
- PT-7728-PTP is IEC 61850-3 and IEEE 1583 compliant
- IEC 61850 GOOSE/SMV and IEEE 1588 standards.

**Why Moxa?**
- Comprehensive PRP/HSR offering
- PT-7728-PTP Ethernet Switch
- PT-7728-PTP Ethernet Switch

### Why Moxa?

- Easy-to-configure HSR solution
- PT-5033 has one dedicated Ethernet port for monitoring and troubleshooting
- PT-G503 has one dedicated Ethernet port for monitoring and troubleshooting
- PT-7728 provides the best communications solutions
- PT-7728-PTP is IEC 61850-3 and IEEE 1583 compliant
- PT-7728-PTP has 4 fiber gigabit ports to form a redundant ring

### India

**Substation Voltage:** 110 kV

**Substation Type:** Transmission Substation

**Customer Requirements:**
- Build an EIC 61850 digital substation with a PRP/HSR network
- PT-7728 Ethernet Switch
- PT-7728 Ethernet Switch

**Why Moxa?**
- EIC 61850-3 and IEEE 1583 compliant
- Total computing and communications solutions
- PT-7728 provides the best cost-performance ratio

### Background and Requirements

**Substation Voltage:** 765 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?**
- 02

### Korea

**Substation Voltage:** 345 kV

**Type of Substation:** Generation Substation

**Customer Needs:**
- IEC 61850 makes substations smarter

**Why Moxa?**
- 01

### Background and Requirements

**Substation Voltage:** 161 kV

**Type of Substation:** Transmission Substation

**Customer Needs:**
- Flexible port configuration with 4 fiber gigabit ports to form a redundant ring

**Why Moxa?**
- PT-7728 provides the best communications solutions
- PT-7728-PTP is IEC 61850-3 and IEEE 1583 compliant
- HSR HSR HSR

### Taiwan

**Substation Voltage:** 110 kV

**Substation Type:** Transmission Substation

**Customer Requirements:**
- Build an EIC 61850 digital substation with a high-reliability design including IEEE 1583 Class 2 devices and a zero packet loss network
- Protection devices (SAN and DAN) should be connected redundantly to SCADA, through MMS

**Why Moxa?**
- 04

### Background and Requirements

**Substation Voltage:** 150/320 kV

**Type of Substation:** Transmission Substation

**Customer Requirements:**
- Implement ESS (Energy Storage System) to enable remote monitoring of the state of the energy stored.

**Why Moxa?**
- 03

### World’s First IEC 61850 3-Layer 220 kV Substation

- **Protection Devices:**
  - PT-7728-PTP Ethernet Switch
  - PT-7728-PTP Ethernet Switch

- **Analysis:**
  - GPS

- **Sending Data:**
  - SCADA/HMI
  - Telemetry

- **Environments:**
  - Station Level
  - Bay Level

**Why Moxa?**
- KEMA certification for IEC 61850-3
- Good consulting and technical support
- Comprehensive PRP/HSR offering
- Solution includes MMS communication

**Why Moxa?**
- 03

### Why Moxa?

- Easy-to-configure HSR solution
- PT-5033 has one dedicated Ethernet port for monitoring and troubleshooting
- PT-G503 has one dedicated Ethernet port for monitoring and troubleshooting
- PT-7728 provides the best communications solutions
- PT-7728-PTP is IEC 61850-3 and IEEE 1583 compliant
- PT-7728-PTP has 4 fiber gigabit ports to form a redundant ring

### India

**Substation Voltage:** 765 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?**
- 01

### Background and Requirements

**Substation Voltage:** 345 kV

**Type of Substation:** Generation Substation

**Customer Needs:**
- IEC 61850 makes substations smarter

**Why Moxa?**
- 01
The Largest State Grid Substation in Colombia
Integrated with Leading PSCADA Provider

Background and Requirements
- **Substation Voltage:** 380/132 kV
- **Type of Substation:** Transmission Substation
- **Customer Requirements:**
  - High-performance and reliable IEC 61850-3 compliant devices
  - Quick adaptation to latest IEC 61850 standard requirements and fast response to specific firmware needs

Why Moxa?
- **A complete PRP/HSR portfolio.**
- **High-performance, fanless, IEC 61850-3 compliant, fanless, and high-performance computers**
- **IEC 61850 Rackmount Computer.**

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 forward various HV data workloads from the MB and IEC platforms to a centralized SCADA system.

Why Moxa?
- **Total IEC 61850-3 computing and communication solution PT-7528’s main management features that can be used on the DA-820.

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

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 with Moxa’s IED device server, enabling easy maintenance.**

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 forward various HV data workloads from the MB and IEC platforms to a centralized SCADA system.

Why Moxa?
- **Total IEC 61850-3 computing and communication solution PT-7528’s main management features that can be used on the DA-820.

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 with Moxa’s IED device server, enabling easy maintenance.**

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 with Moxa’s IED device server, enabling easy maintenance.**
ADNOC (Abu Dhabi National Oil Company) Substation

**Background and Requirements**
- **Substation Voltage:** 33 kV/11 kV
- **Type of Substation:** Distribution
- **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 voltages range up to 60 V
- Customized Firmware: Customized web navigator to monitor the status of Ethernet switches (MAC Address, FW, Serial Number)

China Southern Power Grid Distribution

**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

Enterprise Substation: PRP/HSR Solution for Factory DCS

**Background and Requirements**
- **Substation Voltage:** Mito or low level
- **Type of Substation:** Enterprise Substation
- **Customer Needs:** Integration of IEC 61850 Ethernet switches 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**
- Wide range of expertise in computing, fieldbus, and I/O, and can provide prompt and customized service
- Consulting service: To fine tune configuration solutions

**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?**
- Ethernet switches that can be easily integrated into existing RSTP ring based on Turbo Chain technology
- PT-508 supports voltages range up to 60 V
- Customized Firmware: Customized web navigator to monitor the status of Ethernet switches (MAC Address, FW, Serial Number)
IEC 61850 Makes Substations Smarter

Background and Requirements
- **Type of Substation:** Enterprise Substation
- **Substation Voltage:** 15 or 35-kV
- **Customer Needs:**
  - Ability to monitor the heating temperatures of the contact points in the busbar/circuit breaker.
  - The heating temperature can be caused by a loose screw or by oxidation. The computer that measures the temperatures uses Modbus RTU by default, which needs to interface with a PROFIBUS DP network.

Why Moxa?
- Reliable hardware platform with wireless design
- Flexible modular design for easy expansion (LON communication protocol)
- Customized consulting service

10 kV Semiconductor Substation

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

Why Moxa?
- Total computing and serial-to-Ethernet communication solutions
- Flexible and scalable computers
- Embedded remote device server for quick, cost-effective networking

35 kV Steel Factory Substation

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

Why Moxa?
- Total computing and serial-to-Ethernet communication solutions
- Flexible and scalable computers
- Embedded remote device server for quick, cost-effective networking

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

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

Why Moxa?
- Successful deployment in the manufacturing substation using ABB’s MicroSCADA for data acquisition and analysis, fault recording, protection parameter configuration, event alarms, and event lists.

Switchgear Busbar Temperature Monitoring

13 Brazil

14 Korea

15 Taiwan

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

### IEC 61850-3 Ethernet Switches

<table>
<thead>
<tr>
<th>Number of Ports</th>
<th>PT-G7828/G7928</th>
<th>PT-7828</th>
<th>PT-7728</th>
<th>PT-7728-PTP</th>
<th>PT-7528</th>
<th>PT-7710</th>
<th>EDS-510E</th>
<th>EDS-518E</th>
<th>EDS-528E</th>
<th>EDS-610GE</th>
<th>EDS-610SE</th>
<th>EDS-620GE</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Max. Number of Ports PTP</td>
<td>28</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Max. Number of Hardware PTP Ports</td>
<td>28</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gigabit Ethernet, 10/100/1000 Mbps</td>
<td>Up to 28</td>
<td>Up to 4</td>
<td>Up to 4</td>
<td>Up to 2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast Ethernet, 10/100 Mbps</td>
<td>Up to 28</td>
<td>Up to 28</td>
<td>Up to 28</td>
<td>Up to 10</td>
<td>8 or 10</td>
<td>7</td>
<td>14</td>
<td>24</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Supply</td>
<td>24 VDC, isolated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>48 VDC, isolated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>24/48 VDC, isolated</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>12/24/48 VDC</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Installation Options</td>
<td>Rack Mounting</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Wall Mounting</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>DIN-Rail Mounting</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40 to 85°C (-40 to 185°F)</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-40 to 75°C (-40 to 167°F)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Standards and Certifications

- **IEEE 1613** (Power Substation)
- **IEC 61850-3** (Power Substation)
- **EN 50121-4** (Wayside Applications)
- **EN 50155** (Railway Applications)
- **NEMA TS2** (Traffic Control System)
- **CE/FCC**
- **UL/cUL 60950-1**
- **UL 61010-2-201**
- **IEC 61850 QoS**
- **NTP/SNTP**
- **Software-based IEEE 1588v2 PTP**

---

**www.moxa.com/SmartGrid**

---

**www.moxa.com/substation**
### Power Computers

#### Specifications

- **CPU Speed**: 1.4 GHz dual core, 1.2 GHz dual core, 2.6 GHz dual core
- **RAM**: 16 GB (204-pin SO-DIMM DDR3 memory at 1333 MHz)
- **Display**: 2048 x 1536 at 75 Hz
- **Graphics Controller**: Intel® HD Graphics 4000
- **System Memory**: 8 GB (204-pin SO-DIMM DDR3 memory at 1333 MHz)
- **Resolution**: 1920 x 1200 @ 60 Hz
- **CPU Speed**: 1.6 GHz dual-core
- **Computer**: Windows 7 Professional

#### Physical Characteristics

- **Dimensions**: 440 x 315 x 90 mm (17.32 x 12.40 x 3.54 in)
- **Weight**: 14 kg (31.11 lb)
- **Display Interface**: 2 VGA outputs (DB15 female connector)
- **Operating Temperature**: -40 to 60°C (-40 to 140°F)
- **Storage Expansion**: 1 x SATA 3.0 interface
- **Input/Output Channels**: –
- **Storage**: 32 GB capacity, 4 GB for Linux preinstalled; 1 slot of 4 GB SD or 2 GB MicroSD card preinstalled
- **Input Voltage**: 100 to 240 VAC; 110 to 240 VDC auto-ranging
- **Input Current**: 4.7 A
- **Input Power**: 60 W

#### Environmental Limits

- **Ambient Relative Humidity**: 5 to 95% (non-condensing)
- **Power Consumption**: 25 W
- **Power Consumption**: 30 W (full loading)
- **Power Consumption**: 5.4 W
- **Environmental Certification**: RoHS, CRoHS, WEEE
- **Safety Certification**: UL 60950-1, IEC 60950-1

#### Standards and Certifications

- **IEC 61850 Makes Substations Smarter**
- **IEC 61850-3, IEC 60255, IEEE 1613**
- **IEC 61850-3, IEEE 1613, IEC 60255**
- **IEC 61850-3, IEEE 1613, IEC 60255**

#### Warranty

- **Warranty Period**: 3 years
- **Warranty**: See www.moxa.com/warranty
- **Warranty**: See www.moxa.com/warranty
- **Warranty**: See www.moxa.com/warranty
Device Server Gateways for Substations

IEC 61850 Makes Substations Smarter

- Driver Support
- Rated Voltage
- Power Requirements
- Communication
- Configuration Options
- Storage
- Ambient Relative Humidity 5 to 95% (non-condensing)
- Connectors 8-pin RJ45 CN2610/2650: 8-pin RJ45
- Security Protocols DES, 3DES, AES, SSH, SSL RADIUS, HTTPS, SSH, PAP,
- Software
- Reliability
- Dimensions (mm)
- RS-485 Data Direction
- Online Port Buffering 64 KB
- Standards and Certifications
- 10/100BaseT(X) Ports 1 port
- Protocol – – Modbus TCP, DNP3 TCP Modbus TCP Client/Server
- Baudrate 50 bps to 921.6 Kbps
- Secure Operation Modes
- Serial Interface
- Offline Port Buffering 64 KB
- Advanced Features
- 39
- Rated Voltage
- Power Requirements
- Communication
- Configuration Options
- Storage
- Ambient Relative Humidity 5 to 95% (non-condensing)
- Connectors 8-pin RJ45 CN2610/2650: 8-pin RJ45
- Security Protocols DES, 3DES, AES, SSH, SSL RADIUS, HTTPS, SSH, PAP,
- Software
- Reliability
- Dimensions (mm)
- RS-485 Data Direction
- Online Port Buffering 64 KB
- Standards and Certifications
- 10/100BaseT(X) Ports 1 port
- Protocol – – Modbus TCP, DNP3 TCP Modbus TCP Client/Server
- Baudrate 50 bps to 921.6 Kbps
- Secure Operation Modes
- Serial Interface
- Offline Port Buffering 64 KB
- Advanced Features
- 39

Many Successful Deployments in Power Projects Worldwide

Create rock-solid and future-proof power networks by partnering with Moxa. Moxa is a Collective Member of CIGRE and has delivered solutions in over 1,000 successful substation transmission and distribution networking and computing applications around the world. Moxa is now the leading solar energy monitoring supplier in North America with many diverse projects in advanced metering infrastructures worldwide. You can rely on our 30 years of expertise in providing proven solutions for a range of industrial applications.