WHITE PAPER

Making Smart Substations Even Smarter:

Enhancing Substation Reliability, Availability, and Maintainability

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MOXA®

IEC 61850 Makes Substations Smarter

The end goal of IEC 61850 is to transform the electricity distribution industry by building more intelligence and more complete automation into power substations. With intelligent electronic devices (IED), it's possible to extend new controls and automation deep into the substation's process layer, thus allowing for real-time monitoring and management from a centralized remote control hub.
According to IEC 61850, an intelligent substation is characterized by these three basic features:

1. *All primary substation machinery (switchgear, transformers) are engineered with a relatively high level of device intelligence.*
2. *All secondary devices are networked.*
3. *All routine operations and management are fully automated.*

To meet these objectives, the IEC 61850 standard stipulates that power substations will use Ethernet switches and embedded computers for data communications and computing all throughout the station, bay, and process levels. Because commercial devices are far too frail for the demanding conditions of a power substation environment, devices specifically engineered to heavy industrial measures which are optimized for use in power substations will be required.

Gauging Customer Concerns

Power companies gauge achievement according to a number of key performance indicators (KPIs), objectives that include both technical and financial measures. The following indicators rank as among the most important KPIs for electricity suppliers:

- System Average Interruption Frequency Index (SAIFI):
  Average number of service interruptions, per customer
- System Average Interruption Duration Index (SAIDI):
  Average duration for interruptions over the last year, weighted per customer
- Energy Not Supplied (ENS):
  Total MWh not supplied to customers over the last year
- Average Interruption Time (AIT):
  Average duration of an outage weighted by the total amount of energy not supplied during the outage

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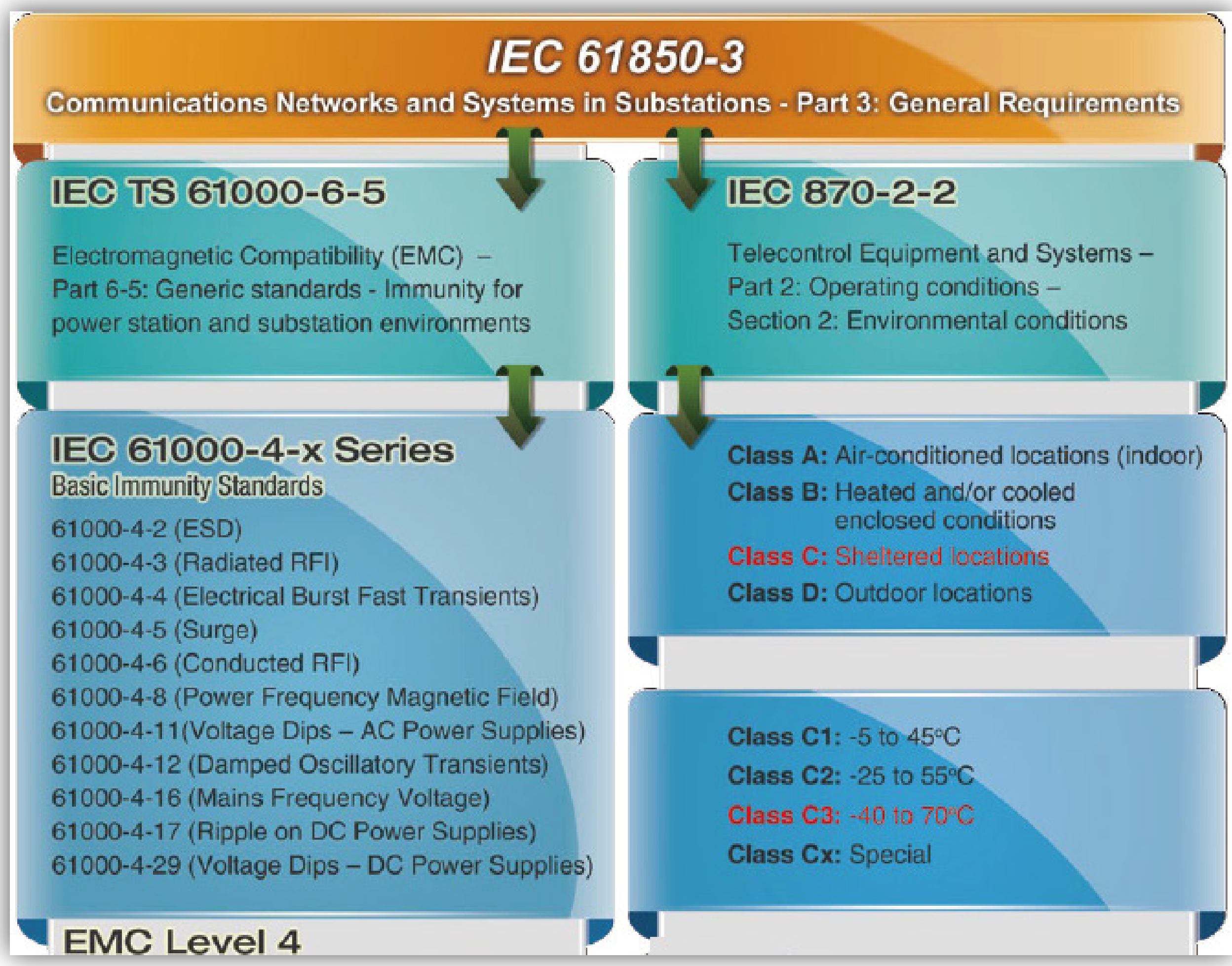
Reliable Networks ▲ Sincere Service

- Overhead Lines Maintenance Cost Index (OHLMCI):
  The maintenance cost per unit length of transmission lines, averaged over the last year
- Substation Maintenance Cost Indices (SSMCIs):
  Annual average for maintenance costs, per substation

As these KPIs indicate, the foremost concerns for electricity suppliers are substation reliability, efficiency, security, service quality, & productivity. IEC 61850 standardization addresses all of these requirements, but aims beyond them towards the establishment of full, future-proof interoperability among all IEDs, regardless of their manufacturer. IEC 61850 will, over the long run, establish a broad, free, but standardized market that substation operators may draw upon to achieve full, easy-to-maintain and economical-to-upgrade automation and remote monitoring of the power supply and delivery process, eventually divesting individual substations of any need for daily, on-site human involvement. The positive effect this achievement will have on safety, efficiency, and economy are obvious.

This paper examines some key application scenarios that sketch out a few of the more important concerns that electricity suppliers should account for when planning their substation upgrades. The focus, in each case, is always on how best to increase reliability, availability, and maintainability of power substation automation networks within the context of the IEC 61850 vision.



Enhancing Reliability, Availability, and Maintainability

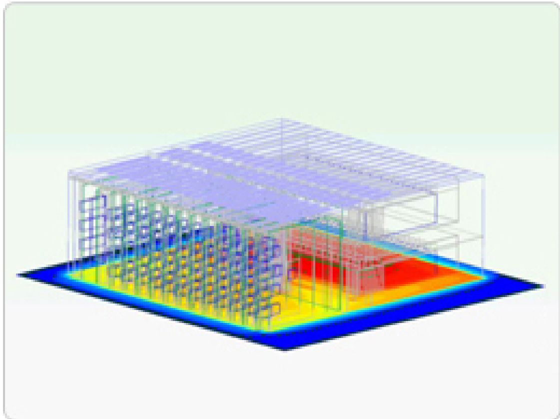
High Reliability, Rugged Dependability

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 be IEC 61850-3/IEEE 1613 certified to guarantee adequate protection against a variety of environmental conditions. These minimum requirements include:

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

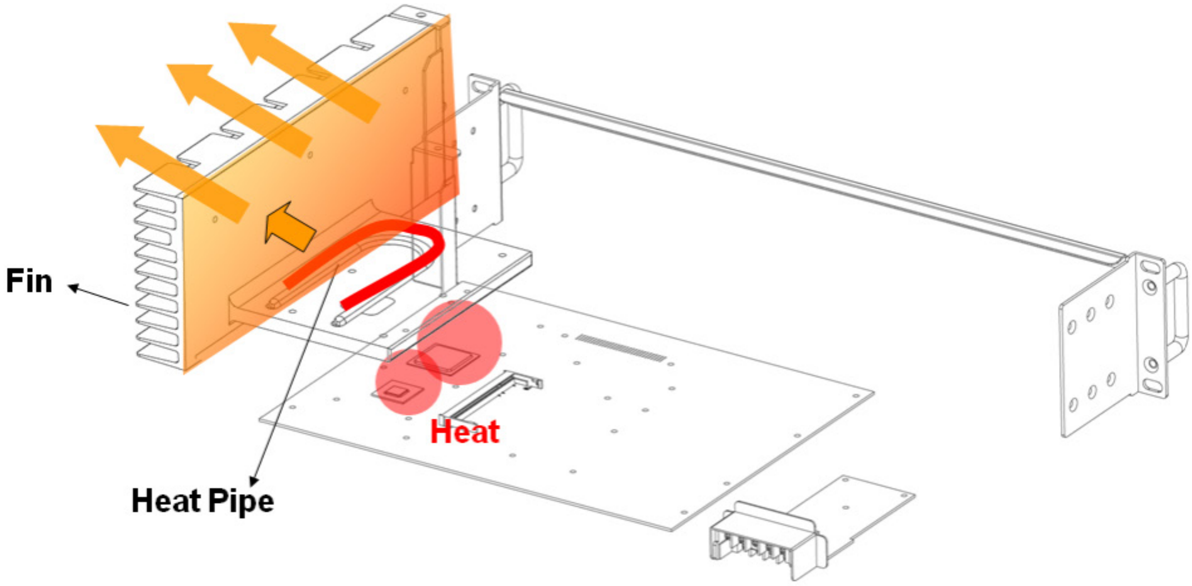
Engineering High Temperature Tolerance in Compact, Fanless Computers



A broad temperature tolerance is required in any substation environment, where temperatures may run as high as 75°C or as low as -40°C. Most computers fail when faced with these extremes. The challenge electricity suppliers face is how to guarantee that their systems will continue to function reliably and predictably even when enduring with the most extreme environmental challenges. **FloTHERM**™ computational fluid dynamics (CFD) software is the most powerful thermal simulation tool available today. It predicts airflow and heat transfer in, through, and around electronic equipment, aggregating data from individual components to create complex models of the entire system at every design level. FloTHERM™ allows engineers to predict and incorporate conduction, convection, and radiation effects within the device, clearly showing them how heat signatures shift and change at every step of operation.

By using FloTHERM's advanced modeling techniques, engineers may quickly and easily create models that allow them to test the thermal limits of proposed equipment modifications before a prototype is built. Simply put, FloTHERM™ is one of the most important tools available for engineering high heat tolerance.

A major worry for any system that depends on high performance computers are burnouts caused by failed fans or clogged grills. Ideally, a substation computer should be fully sealed from the outer environment and not require a fan in any capacity. This extends its life significantly, but is complicated by the extreme heat that is often generated 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 careful analysis and adjustment of fin heights, gaps, thicknesses, and points of contact to further optimize dissipation. All of these factors must be carefully evaluated and adjusted to achieve maximum dissipation efficiency. What this means is that fully fanless designs are not trivial to create, and overall are 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 susceptibility to dust, heat, and corrosion.



High Availability

Zero Packet Loss at Wire Speed

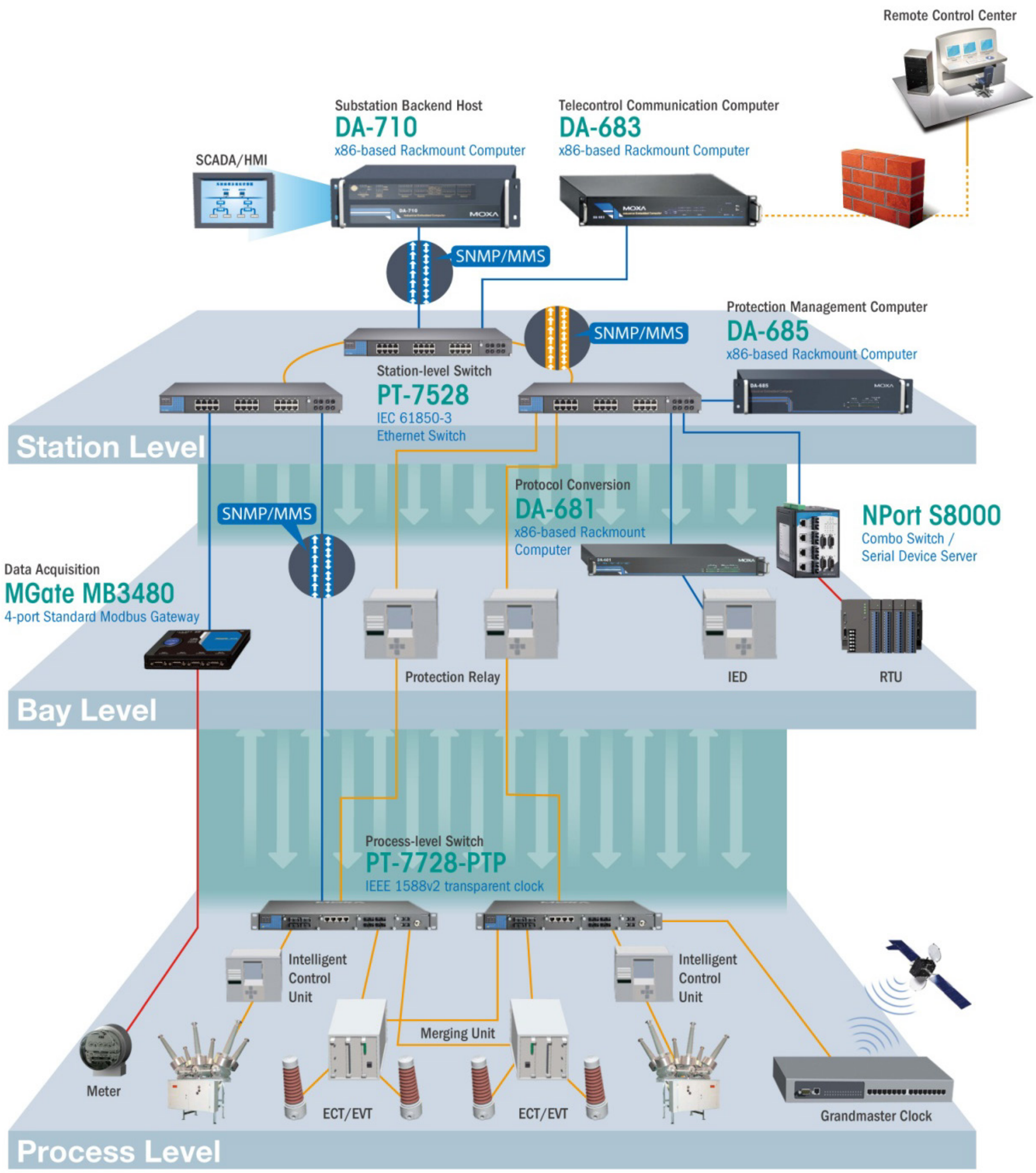
Packet loss in substation communications introduces unpredictable risk that, in worst-case scenarios, can threaten a substation system with catastrophic, permanent failure. The possibility of packet loss is even more likely in a high EMI environment than in more conventional settings, so ensuring critical packets are accurately and reliably transmitted is a key concern for any electricity supplier.

Addressing the communications integrity challenge posed by high EMI environments involves two approaches. First, network devices that meet IEEC 1613 class I requirements must have a level 4 EMC rating, to guarantee they will reliably tolerate high EMI conditions. Clever engineering may use various approaches to achieve this level of electromagnetic tolerance; for instance, hardware engineers may optimize the PCBA circuit, re-work the power supply, and use carefully customized components to achieve better EMC and surge protection. As a final measure the mechanical components themselves may be re-designed to give much better shielding and grounding than are available on commercial devices.

Second, all devices must communicate critical, low-level IEC 61850 multicasts (GOOSE/SMV) with the highest priority, without fail, to guarantee that these messages are clearly received without distortion throughout the entire network, regardless of what other communications may be currently congesting the lines. Ping-based solutions are not sufficient to achieve this. To fully satisfy IEEE 1613 Class 2 requirements, substation switches must support strong QoS traffic shaping. Traffic shaping switches scan the Ethertype field of every transmitted packet and then automatically prioritize high-importance messages to the front of the routing queue, so that critical messages are delivered within the allotted time, regardless of however much other data is being communicated along the network. To ensure stable data deliveries for critical system messages like GOOSE or SMV, substation switches must provide not only maximum EMI immunity, but also bolster it with QoS traffic shaping.

Digital Diagnostic Monitoring (DDM) for Fiber

Fiber port performance is measured by duration of successful operating time, and high temperatures reduce this significantly. Preventing fiber malfunctions with a pre-fault predictive maintenance mechanism is extremely important, but at the moment most substations only support SFP-type optical fiber monitoring. Digital diagnostic monitoring (DDM) can help with this. Using DDM, substation switches can monitor ST/SC (as well as SFP) connectors, and notify power SCADA systems via SNMP trap or MMS when abnormalities are detected, allowing operators to initiate maintenance procedures. DDM reports and alarms may be communicated over a web, CLI, or serial console; via MMS reporting or SNMP traps; by a digital relay; or in the system log. Preferably, several methods will be used to provide redundancy. This arrangement further allows system operators real time monitoring of things like transmission and reception power, temperature, and voltage/current along optical fiber connections.



An overview of an IEC 61850 compliant substation highlighting optical fiber links with DDM (in yellow) and dual SNMP/MMS monitoring

Maximal Maintainability, Minimal Downtime

SNMP and MMS Management:
Integrated Network Monitoring Solutions for Power Substation SCADA

Currently, substations are being forced into the relatively sloppy position of splitting the difference between two monitoring and communication protocols: SNMP is used for IT devices (because MMS doesn't work with IT devices), while MMS is used for everything else (because SNMP can't carry process-layer information from IEDs). This is inconvenient and expensive, not least because integrating these two systems over a single interface is a time-consuming customization that significantly increases deployment costs and system complexity.

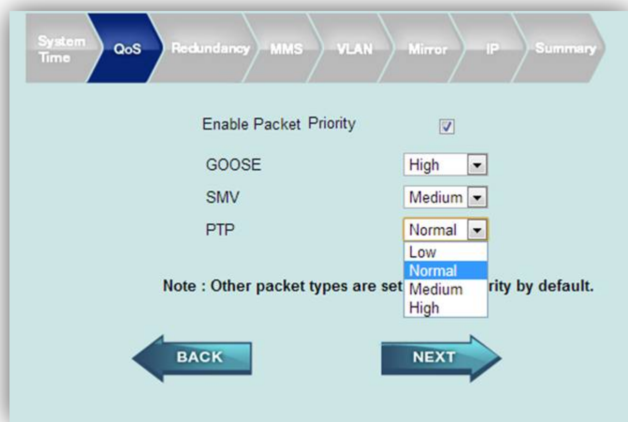
However, for manufacturers bold enough to try there is an elegant solution to this conundrum: the integration of MMS into SNMP-capable Ethernet switches and other IT hardware (like embedded computers, or panel computers used for HMIs). With MMS-capable IT hardware, substation SIs and automation engineers will be able to render a full accounting of the entire network of automation devices right alongside process layer information, all under a single SCADA view. Because substation systems will no longer need to resort to installing and configuring separate software for IT devices, station operators will achieve more thorough automation integration, improvements in management efficiency, and savings on deployment costs.

Integrating IT devices via MMS makes substation networks more controllable, more flexible, and more responsive, allowing administrators 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
- Perform batch configurations using CID (Configured IED Description) files

Streamlined Setup and Configuration

Because substations are such a specialized environment, IT setups will only require a few key features. Simplifying and streamlining the configuration process makes a lot of sense: by only including the relevant network features, setup and maintenance becomes much more efficient. Using a browser-based configuration wizard, effectively deploying an IT device can take as little as 3 steps that may be completed in less than one minute—literally!



Step 1: Using a browser, log in to the web UI
Step 2: Select the redundancy architecture
Step 3: Define the switch's role within the network (e.g., head switch, tail switch, or member switch)

That's all there is to it.

OS Smart Recovery:

Remotely or automatically trigger a computer to restore its entire software system

In the past, when IP technology was alien to industrial control networks, most automation systems could only rely on hardware or software watchdogs for hard resets whenever a failed device needed to be restored. There was very little a remote system administrator could see, or do. If the reset didn't take, then diagnosing and fixing a problem required an engineer to physically travel to the site, and of course, sending an engineer to an offshore platform or remote pumping station incurred high expense and much slower repair times that might be measured in days. For a system like a windfarm, this is often true even today.

Fortunately, IT automation now allows engineers to remotely monitor a computer's health and trigger a full software platform rewrite should a problem arise. These rewrites are made from a tagged disk image that is created when the embedded computer was first successfully configured and deployed. The methods used to achieve this sort of remote automated recovery are not new, but unless they come already combined into a ready-to- run software application then building a highly reliable, custom recovery system can be quite difficult and time consuming.

Without a smart OS recovery system, corruption of system software—whether in the OS or in local substation applications—can be catastrophic for remote industrial installations and sites with mass computer deployments. With some estimates of computer failure attributable to software corruption as high as 30%, automated BIOS-level software recovery systems are an extremely valuable design addition to power substations, whether remote or local.

In Conclusion…

In this paper we present the ideal solutions for several key customer concerns.

How to Guarantee High System Reliability?

- IEC 61850 Class 3 Certified
- Substation Automation Packet Priority
- Wire Speed Zero Packet Loss Technology
- Patented Thermal Engineering

How to Improve System Availability?

- SNMP/MMS Management
- ST/SC Fiber DDM (Digital Diagnostic Monitoring)

What Measures are Best for Reducing Maintenance and Downtime?

- Substation Configuration Wizard
- Smart Recovery

Putting these solutions together will significantly increase the reliability, availability, and maintainability of a power substation automation network, and make any smart substation even smarter.