WHITE PAPER

Get Substation Automation In Sync With IEEE 1588v2 Precise Timekeeping

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As the marine chronometer demonstrated, simply keeping accurate time is a huge competitive advantage: it allows you to precisely coordinate complex systems.

In the age of exploration, the British Empire was able to achieve great maritime feats thanks to a modest new invention: the marine chronometer, a clock that could keep accurate time while at sea. By setting the chronometer to the local time in the port city of Greenwich, then comparing that time to the position of the sun in the sky, British captains could calculate their longitude to extraordinary levels of accuracy. The chronometer was nothing less than a paradigm shift: a revolutionary advantage that allowed British explorers to surpass their contemporary competitors. Though the British Empire no longer spans the globe, the British marine chronometer's lasting influence can be seen in Greenwich Mean Time (GMT), the benchmark against which all other local time zones are set.

For industrial networks, accurate timekeeping offers similar advantages. This is especially true of power distribution networks, which need accurate timekeeping and network synchronization in order to coordinate the activities of widely distributed equipment and regulate power transmissions. Higher levels of precision allow power grids to unlock their own revolutionary advantages: a "Smart Grid" that can achieve new levels of efficiency, security, and reliability by autonomously and intelligently distributing power to end users in response to changes in demand.

This white paper explores some of the limitations that current industrial systems, especially power substations, face in synchronizing their networks. It also provides an overview of today's commonly used timekeeping technologies, such as NTP and GPS, and identifies how IEEE 1588 v2 precision time protocol (PTP) can transform how your current industrial network is run.

An Overview of Historical Time Synchronization Technologies

In an industrial data network, time synchronization allows all of the different devices on that network to use a common clock to coordinate their activities. Network integrators currently have a number of different time synchronization options available. Each has its own advantages and disadvantages, but not all of them are optimal for use in industrial networks.

Inter-range Instrumentation Group (IRIG): The IRIG standard defines a serial time code format for use with serial communications networks. First standardized in 1956, IRIG signals are a legacy technology used with older serial systems. IRIGB 205-87 is the latest update of this standard.

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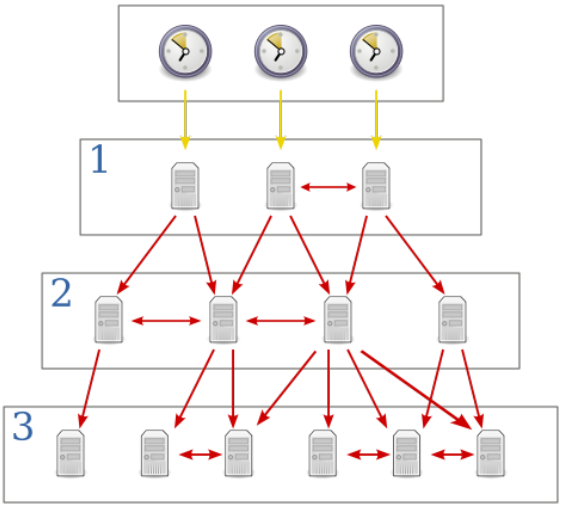
Network Time Protocol (NTP): NTP is a time protocol for data networks, first established in 1985. NTP relies on a hierarchical, layered system to promulgate the current time throughout the network. NTP imposes a hierarchical tree architecture on the network to avoid cyclical dependencies.



NTP divides the network into different strata
(source: B.D. Esham for Wikimedia Commons)

Global Positioning System (GPS): GPS satellites are highly accurate atomic clocks placed in orbit around the earth. Satellite signals carrying timekeeping information can travel at light speed to receivers on the ground. These light-speed signals are also corrected according to the principles of general relativity, which gives each receiver on the ground highly accurate time information.

Potential Time Synchronization Pitfalls

Many existing time synchronization systems are either too inaccurate, or too costly.

Industrial systems, such as substation automation networks, rely on accurate time synchronization in order to coordinate activity across many different subsystems and devices. However, many existing technologies are inadequate for the needs of industrial automation measurement and control systems.

Accuracy: For industrial networks, every nanosecond counts—but most legacy technologies are simply unable to deliver that level of performance. For example, a substation automation network needs nanosecond-level accuracy on raw data sampled values in order to better support mission-critical applications such as fault recording, remote monitoring, and remote control. IRIGB and NTP are an order of magnitude too slow to achieve nanosecond accuracy. Even under ideal, local conditions, NTP's accuracy can be measured in the hundreds of microseconds.

Cost: The GPS network provides highly accurate time data measured by extremely precise atomic clocks, but in order to access that information the network must have a GPS receiver at each node. This is a prohibitive cost that is impractical for industrial networks where each device needs time information and its own GPS receiver. GPS would become more practical if there was some way to reduce the number of nodes in the entire network, or more efficiently use a fewer number of GPS receivers so that the entire network can benefit from the accuracy of GPS timekeeping.

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A Time Protocol for Industrial Networks

IEEE 1588v2 was designed specifically so industrial systems could achieve high accuracy at a reasonable cost.

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

An IEEE 1588v2 system needs just one GPS receiver to provide highly accurate time information to many devices

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

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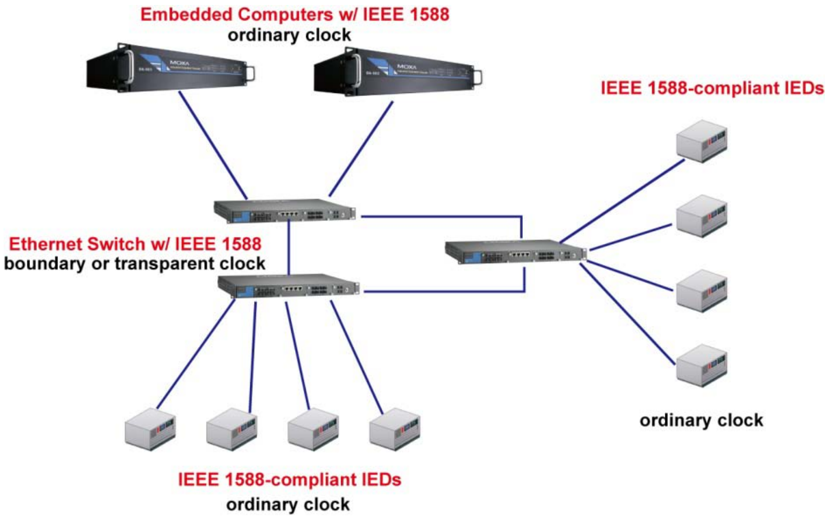

To be in sync all of the system components, including the embedded computers, should support IEEE 1588v2

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

Blackout prevention through early detection of grid problems, early location of disturbances, and real-time power islands.

Accurate fault recording and event loggers that enable precise event analysis thanks to event loggers that can be scrutinized down to the nanosecond level.

More efficient use of assets through congestion relief and equipment condition monitoring.

Demand response through time-of-use billing, virtual power generators, and outage management.

IEEE 1588v2's cost-effective nanosecond-level accuracy gives substation and other power utility networks a competitive edge just as formidable as the one Britain's chronometer-equipped navy possessed over its peers. As part of a "Smart Grid," highly synchronized substations are more efficient, more economical, more sustainable, and more responsive. These advantages allow electricity providers to increase the profitability of their operations and decrease their impact on the environment.

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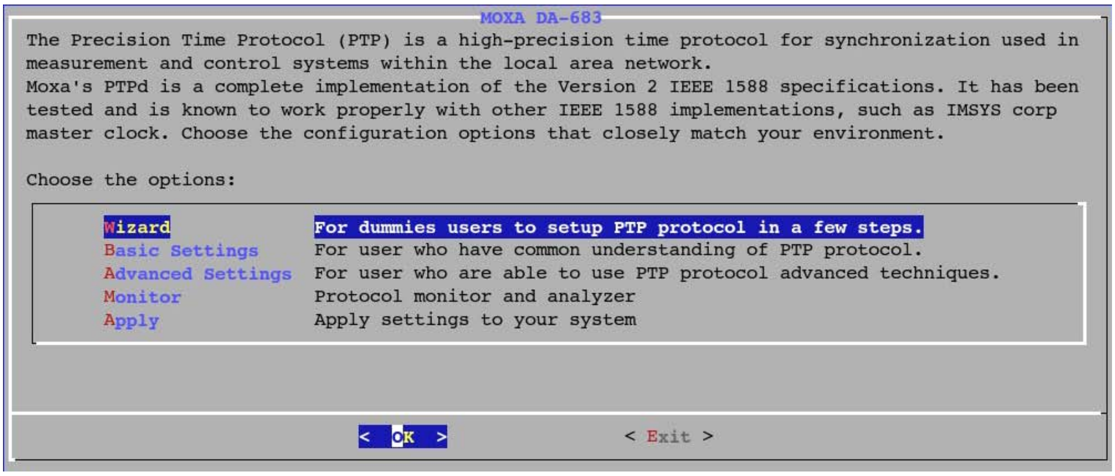
The Moxa Advantage: Getting Substation Operations In Sync

Moxa's **PTP-7728-PTP IEC 61850-3 Fast Ethernet switches** support the latest version of IEEE 1588v2 technology to deliver precise time synchronization for substation network and related applications. The PT-7728-PTP offers:

• Up to 14 100BaseFO (Multi-mode ST connector) or 100BaseTX, ports and 1 BNC connector, support for IEEE1588 v1 and v2 hardware time stamping on each port, and pulse outputs (pps) on one BNC port.
• 1 and 2-step for both transparent and boundary clock operation with accuracy under 1 μs in End to End mode.
• 2-step for both transparent and boundary clock operation with accuracy under 1 μs in Peer to Peer mode.
• Network clock synchronization accuracy in the nanosecond range.
• Clock synchronization to support large and distributed substation networks.
• Low-cost implementation in multicast messaging networks such as Ethernet.
• Fast re-synchronization when system changes occur.
• Simple installation and maintenance.

To complete your system, Moxa's **DA-683-LX embedded computers** also support IEEE 1588v2. The DA-683-LX offers:

• Low power consumption of under 40 watts for a very industry-friendly deployment profile.
• An industrial all-in-one board design that does not use fans or cables for highly stable operations.
• IEC 61850-3 certification for verified suitability for substation and power automation applications.
• Modular design with two independent slots for cost-effective future system expansion, such as with an 8-port RS-232/422/485 module, an 8-port RS-422/485 module, a 4-port 10/100 Mbps LAN module, an 8-port 10/100 Mbps switch module, or a universal PCI expansion module.
• User-friendly Linux-based IEEE 1588v2 configuration interface, for a no-hassle setup process that saves deployment and maintenance time and costs.



Configure IEEE 1588v2 on a DA-683 in just a few steps with a setup wizard

You can quickly find a product that matches your network's time synchronization requirements or request a price quote at the Moxa web site: www.moxa.com. USA customers can quickly order evaluation units at store.moxa.com.

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