Transforming Power Grid Communication

Solutions for substation networking

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Introduction

Many power grids throughout the world are in dire need of upgrade to accommodate clean energy production. Also, extreme weather can cause major disruptions to power transmission, just when it is needed most desperately by people. Modernizing the electricity grid is essential to achieving a future with fewer blackouts, more energy and economic security, and healthier communities.

For reliable and efficient operation of the grid, power substations which transform, switch, and distribute electrical power to users are interconnected not only electrically, but also by a network of communication links and control systems. These networks are designed to enable real-time monitoring, control, and protection of the power system, allowing operators to respond quickly to changes in power demand or disruptions to the grid. A modern substation communication network follows the IEC 61850 Standard to provide interoperability between various equipment, and enables advanced functionalities such as wide-area protection and control, fault location, and disturbance recording. But even in legacy substations that are not yet ready to make a total leap to this standard, ATOP and partners can help you upgrade and retrofit for optimal reliability and security.

This brochure is a compilation of ATOP's *Transforming Powergrid Communication* article series, published on atoponline.com. The series offer basic knowledge as well as application insights, to help you make informed decisions on how to build efficient, secure, and sustainable communication networks for power systems. We encourage you to learn from this thoughtfully prepared content, but also welcome you to reach out directly to our experts for the latest and personalized technology and information.

Substation digitalization based on the IEC 61850 standard

The IEC 61850 Standard defines substation communication in three levels: *Process Level* functions interface with electricity processes like switching and monitoring. These processes are controlled from the *Bay Level* by intelligent electronic units (IEDs), such as protection relays, meters, and controllers. Data acquired from the process level also passes through the bay level to inform station actions at the *Station Level*, or to be further aggregated and sent to monitoring systems like SCADA.
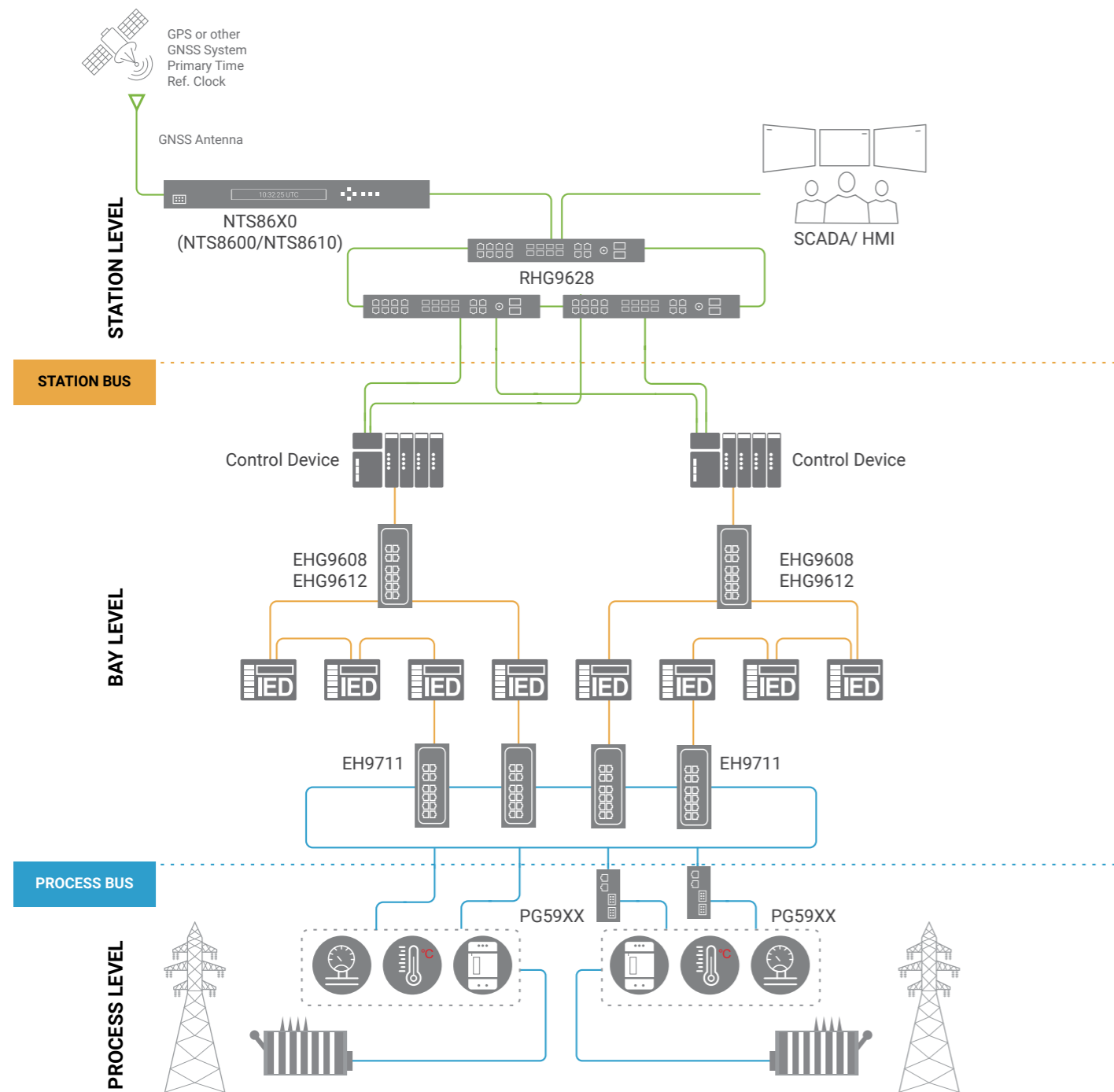
Several aspects must be considered to achieve maximal substation network reliability:

Electromagnetic compatibility (EMC) is definitely one of the first priorities to think about when building a substation network. Situated near power equipment and cables, devices in substations require better EMC than normal industrial facilities do. IEC61850-3 defines the construction, design and environmental conditions that substation devices must meet, and only when fully compliant and certified does ATOP present a device as "for substations."

Rugged housing that withstands demanding weather and heavy use is also indispensable in power applications. Especially with the rise of clean energy, substations are often located in remote and severe environments, so ATOP IEC 61850-3 certified devices make sure to deliver optimal performance even under harsh temperature and humidity conditions.

Redundancy is important to ensure that the substation network can continue to operate even if some equipment or systems fail. This can be achieved through the use of redundant power supplies, redundant control systems, and backup communication systems.

ATOP switches designed specifically for substation access may enable both power and communication redundancy through dual power inputs as well as ring topology support. In the event of node failure, ring topologies like RSTP and ERPS allow traffic to self-recover in milliseconds. In addition to RSTP and ERPS, HSR/PRP support guarantees zero packet loss for critical substation information.

Interoperability is one of the key points of IEC 61850. Substations contain a variety of devices that use different protocols to communicate with each other. Some may even be legacy or proprietary. Protocol gateways act as a bridge between these different protocols, allowing devices to exchange information and operate together seamlessly. ATOP takes this concept a step further with diverse media options, such as optional SFP slots or cellular connections.

Precise timing, as first mention, may not seem closely related to power transmission—what is a nanosecond's difference in receiving electricity? But in truth, acccurate synchronization of devices enables control systems to operate more efficiently and effectively, reducing the risk of errors or failures. Following the IEEE 1588 v2 Precision Time Protocol (PTP), all events on the network are logged with the same time reference, and protection devices can operate in the correct sequence, regardless of where they occur. This not only maintains the safety and reliability of operations, but also allows determination of the exact sequence of events, which is crucial in performance control and troubleshooting.
ATOP offers comprehensive solutions for precise timing in the nanosecond level, from grandmaster clocks which sync with a GNSS reference, to a range of powerful switches that support precise hardware-based boundary and transparent clocks, assuring the accuracy of events throughout the network.

Cybersecurity has been a growing focus of substation networks in recent years, as the more interconnected and digitized these systems grew, the more vulnerable they became to cyberattacks which could potentially cause significant damage. High availability requirements, wide geographic spread, and often legacy equipment pose unique challenges in securing power networks.
ATOP products are developed and created with the highest awareness of cyber-risk consequences, referencing the IEC 62443 and 62351 standards. Our substation solutions encompass numerous forms of protection including access control, network segmentation, and encryption, to serve different scenarios and needs.

Finally, a reliable network benefits from **remote management** and monitoring. ATOP solutions come with user-friendly management software that allow real-time visualization of topologies, remote control and troubleshooting, smart alarms, and more. Operators can quickly and easily onboard new devices, scale network systems, find bugs and errors, and resolve issues from off site, which is particularily helpful in large sites and multi-sites. Automated configuration through secure multi-platforms improve efficiency while lowering costs of maintenance.
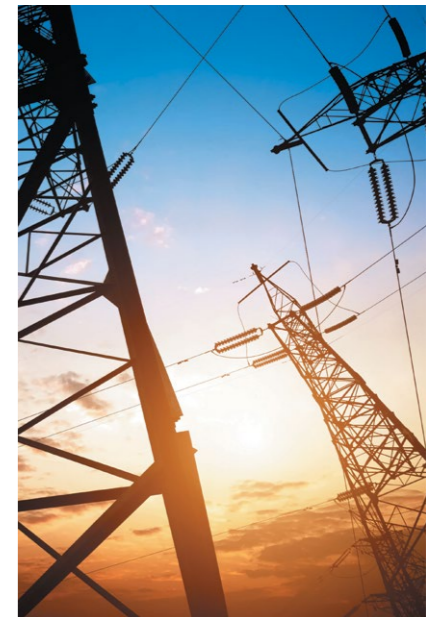
Precision Timing Protocol in power substations

Precise time synchronization is essential for the safe and reliable operation of power systems. Network faults can occur at any time, but especially for critical utilities, fault detection and isolation need to be fast and accurate to minimize the risk of damage. This is why ATOP places utmost emphasis on support of IEEE 1588 v2 Precision Time Protocol as well as the C37.238 Power Profile.

Even under normal operation, the stability and control of power systems depend on coordination and synchronization of various devices and systems, such as generators, transformers, and switches. Precise time synchronization allows for coordinated operation and control of these devices, ensuring grid stability and minimizing the risk of power outages. For renewable energy sources such as solar and wind power, where energy resources are often distributed, time synchronization is particularly important for coordination of multiple sources to maximize their contribution to the grid.
Monitoring and analysis of power grids also require precise time synchronization to accurately correlate data from various sources, such as sensors and meters. With event data in the correct sequence, managers can perform real-time and offline analysis of grid performance and faults.

Why use Precision Time Protocol?

IEEE1588 v2 Precision Time Protocol (PTP) is a protocol that is used to synchronize clocks in a network to a common time reference. Key features of PTP include:

⏱ High accuracy

PTP's most defining feature is its ability to provide sub-microsecond accuracy, by exchanging hardware timestamped packets between devices. Because packets are timestamped when they enter and leave a device, inaccuracies that arise from software processing time are eliminated. The process doesn't require additional processing overhead, which can introduce jitter and delay in the time synchronization process. Thus PTP is suitable for applications that require precise timing, such as power systems and industrial automation, as well as for telecommunication networks and financial trading systems.

📈 Dynamic adaptability

PTP is able to dynamically adjust its synchronization rate and algorithm to adapt to changes in network conditions, such as latency or packet delay variation. Accumulated delay calculations are used to provide an accuracy with 1 μs.

⚠ Fault tolerance

PTP includes mechanisms for fault tolerance and redundancy, such as backup grandmasters and boundary clocks, to ensure that the network continues to operate in the event of failures or disruptions.

⚙ Scalability

PTP can support large-scale networks with thousands of devices, making it suitable for power systems, which have many interconnected devices that require synchronized timing. A single grandmaster clock can synchronize the time of multiple devices on the network, so the cost of deploying and maintaining multiple timing sources is low.
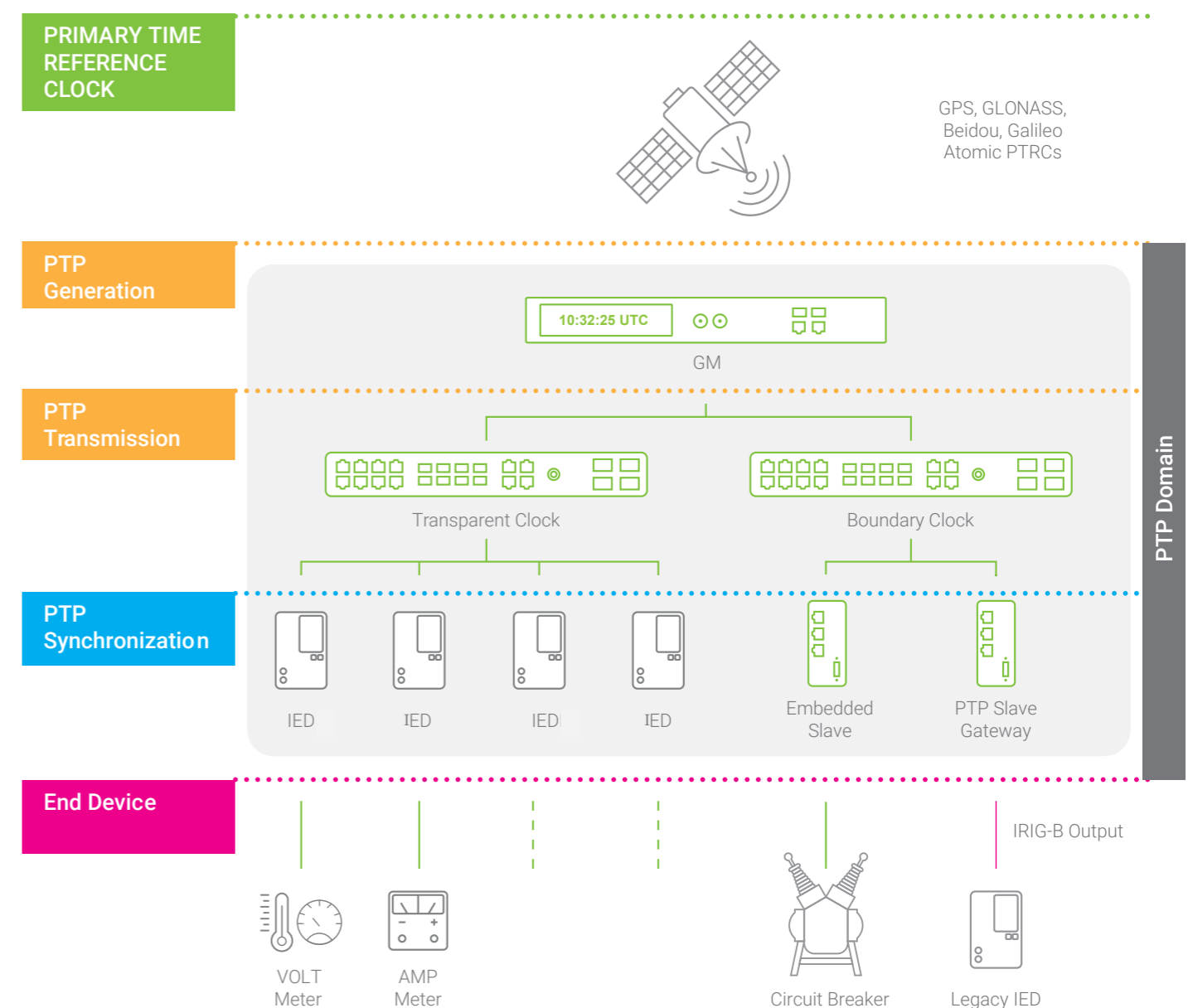
$ Cost effective

PTP can operate over Ethernet networks, eliminating the need for dedicated timing hardware. Therefore, it is a cost-effective solution to install and to maintain.

How does PTP work?

The architecture of a PTP network involves a hierarchical system of master and slave clocks. Masters serve as the source of time, distributing the time to different segments, while slave clocks receive PTP messages from masters and adjust their own time to synchronize with the network time. This strata system allows for easier network management and troubleshooting of issues when they arise.
A common substation PTP network includes a grandmaster (GM) clock, boundary clocks (BC) and transparent clocks (TC) as intermediary slaves, and end slave clocks, as depicted in the following figure. Below we will take a deeper look into the features and requirements of each clock type.

PRIMARY TIME REFERENCE CLOCK — GPS, GLONASS, Beidou, Galileo Atomic PTRCs

PTP Generation — 10:32:25 UTC — GM

PTP Transmission — Transparent Clock — Boundary Clock

PTP Synchronization — IED, IED, IED, IED, Embedded Slave, PTP Slave Gateway

End Device — VOLT Meter, AMP Meter, Circuit Breaker, Legacy IED — IRIG-B Output

PTP Domain

+ 886 - 3 - 5508137
+ 886 - 3 - 5508131
info@atop.com.tw
www.atoponline.com

The grandmaster clock

The ATOP state-of-the-art NTP Server and IEEE 1588 PTP Grandmaster NTS86X0 is fully certified to IEC 61850-3 HV & IEEE1613 standards, ensuring robust performance and reliability in harsh substation environments. Designed to deliver precise time synchronization across your entire power grid infrastructure, this device offers superb accuracy and stability. The IEC 61850-3 HV & IEEE 1613 certification guarantees that the NTP Server & PTP Grandmaster can withstand electromagnetic interference, temperature fluctuations, and other environmental stresses typical of substation settings, ensuring uninterrupted performance and enhanced system reliability.

NTS8600

NTS8610

Boundary clocks

Boundary clocks receive time information from the grandmaster clock and act as new masters to redistribute it to other devices in the network. They also perform time stamping and packet forwarding functions. Boundary clocks reduce the load on the grandmaster clock and improve time accuracy by minimizing the propagation delay of PTP messages.

Capacity is an important feature of boundary clocks, as they are often used to connect multiple PTP domains or in complex network topologies. The ATOP RHG9X28 hardware-based boundary clock supplies up to 24 Gigabit ports to handle large numbers of PTP clients with simple architecture, while additional 10G uplinks allow fast transmission to upper level management. Its modular configuration provides flexibility and scalability. Support for multiple profiles ensure compatibility with various PTP devices.

RHG9528

RHG9728

Transparent clocks

Transparent clocks also receive PTP time packets from the grandmaster, but while they measure the propagation delay of PTP messages and compensate for it, they do not modify the PTP messages in any way—they forward the messages transparently between network segments. Transparent clocks are used in large networks with multiple network segments, and provide a way to mitigate the effects of network latency and delay variation.

A good transparent clock, like ATOP EHG9508 and EHG9512, supports multiple network segments to provide accurate time synchronization across large networks. It integrates easily into existing network infrastructure without causing disruption, and its low latency minimizes propagation delay to establish accurate time synchronization.

Transparent clocks calculate link delay time within a network by two methods, end-to-end (E2E) or peer-to-peer (P2P). With E2E, timestamps for delay calculation are collected when the clock receives the time packet from the grandmaster, and when the packet reaches the end of the network. Any other transparent clocks in between simply forward the packet, achieving maximal efficiency. ATOP EHG95xx and EHG96xx series are of this type.

With P2P, timestamps are collected and the delay calculated from each transmission (or hop) between a sequence of transparent clocks. ATOP RHG9X28 series can work as this type of transparent clock, which, compared to E2E, may generate higher loading but also higher accuracy.


EHG9508

EHG9512
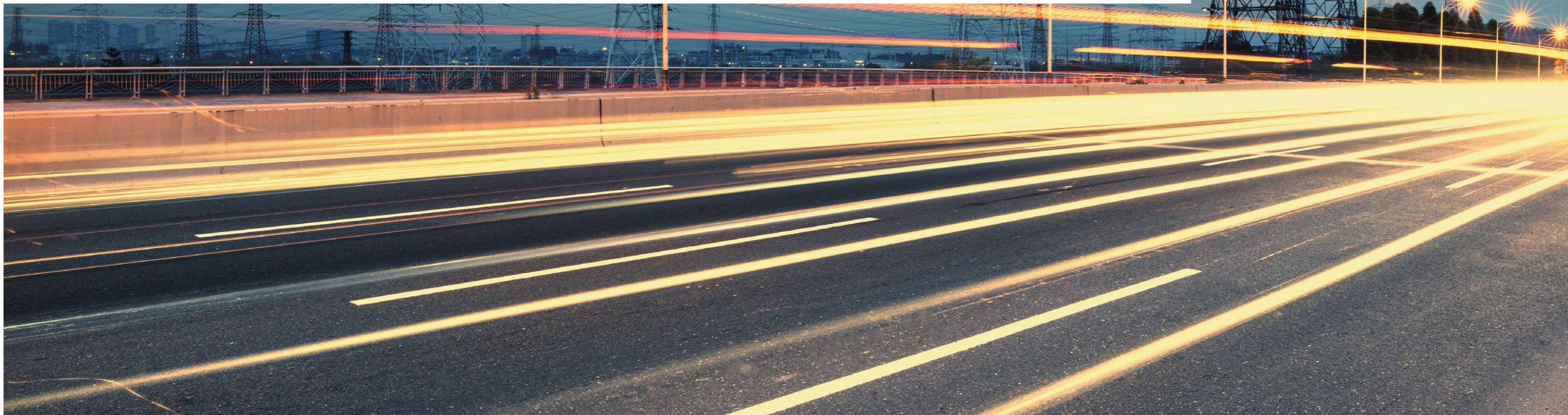
HSR and PRP: what high-availability means for power substations

To avoid errors and blackouts, substation automation must ensure strict data integrity and the least latency or downtime. Therefore, the IEC 61850 Standard adopts High-availability Seamless Redundancy and Parallel Redundancy Protocols to achieve fault-tolerant communication between devices within the power grid infrastructure. These redundancy techniques are known as hot redundancy, where redundant links are simultaneously active, thus enabling minimal switchover time.

High-availability Seamless Redundancy (HSR; IEC 62439-3 Clause 5) enables zero-packet-loss communication through a ring topology, where each device connects via two ports. Packets are duplicated and sent in both directions, with the first correct packet received being processed and duplicates discarded. This ensures seamless communication even during network failures, supporting sub-millisecond switchover crucial for real-time control and protection functions. HSR's deterministic transmission also makes it suitable for applications requiring strict timing and data integrity, such as protection relay coordination and substation equipment control.
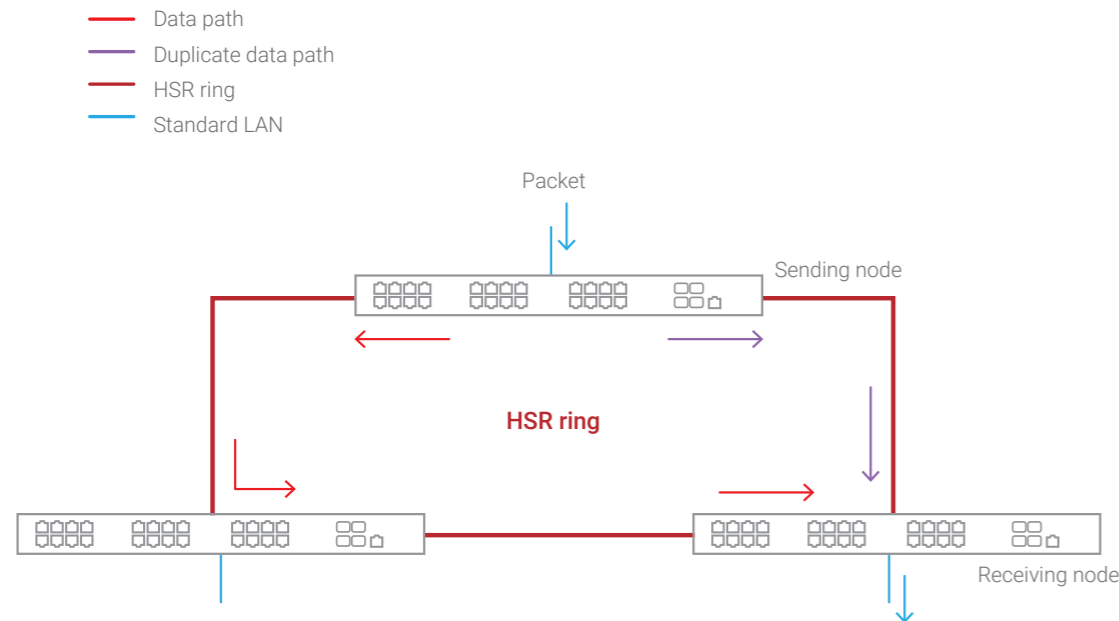
Parallel Redundancy Protocol (PRP; IEC 62439-3 Clause 4) is another redundancy protocol used in power grid communications. It also creates a redundant network topology, but instead of rings, it uses a double star topology to send duplicate data packets over two independent network paths.
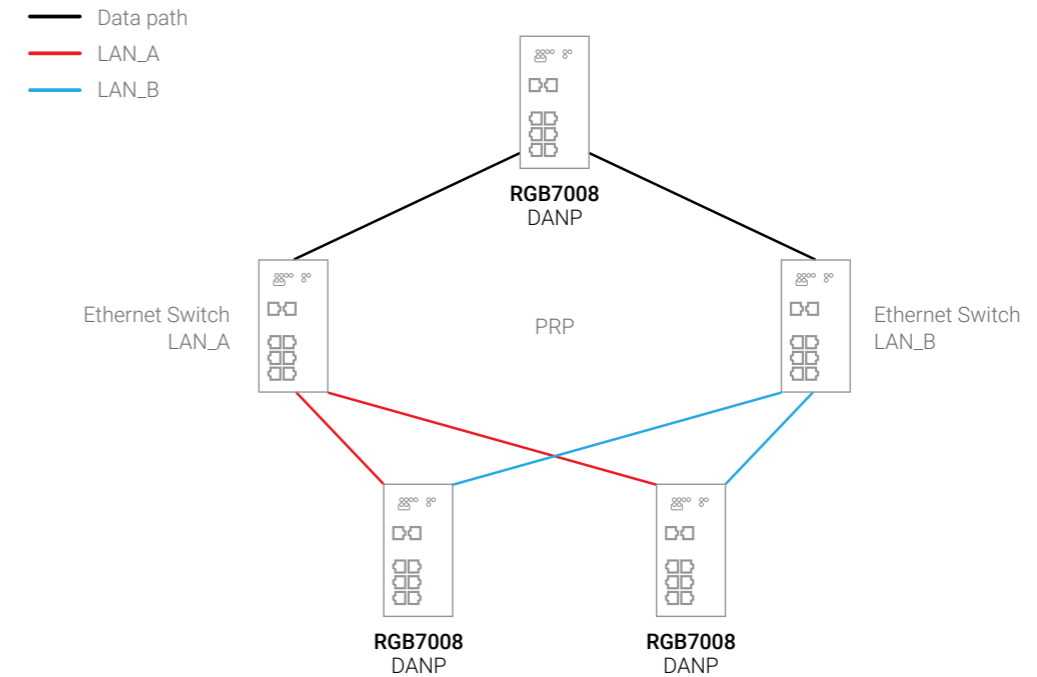
Both HSR and PRP can coexist within the same network, operating independently of application protocols and supporting most Industrial Ethernet standards. However, building a compliant IEC 61850 network with HSR and PRP requires careful device selection. Devices must support redundant interfaces, packet duplication, and seamless switchover. Additionally, Precision Time Protocol (PTP) is often needed to maintain accurate timing across redundant paths, especially when time-triggered operations are critical.

Scalable Redundancy Solutions: RHG and RGB Series

For substation backbone communication, ATOP's RHG9628 and RHG9528 High-Availability Managed Gigabit Switches provide robust nodes with HSR/PRP ports, PTP support, and advanced management features. These switches offer plug-and-play high-availability functions and modular slots for building large-scale, flexible networks.

For connecting IEDs that do not support HSR or PRP, the RGB7004 and RGB7008 series managed RedBox devices are ideal solutions. Fully compliant with IEC 61850-3, these devices support up to four HSR or PRP instances, including RedBox and QuadBox topologies. The ATOP RGB7004 and RGB7008 offer hardware-based IEEE 1588v2 PTP support, dual power supply options, and reliable operation in temperatures ranging from -40°C to +75°C, ensuring seamless integration and uninterrupted performance in digital substations.

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Protocol gateways in substation application
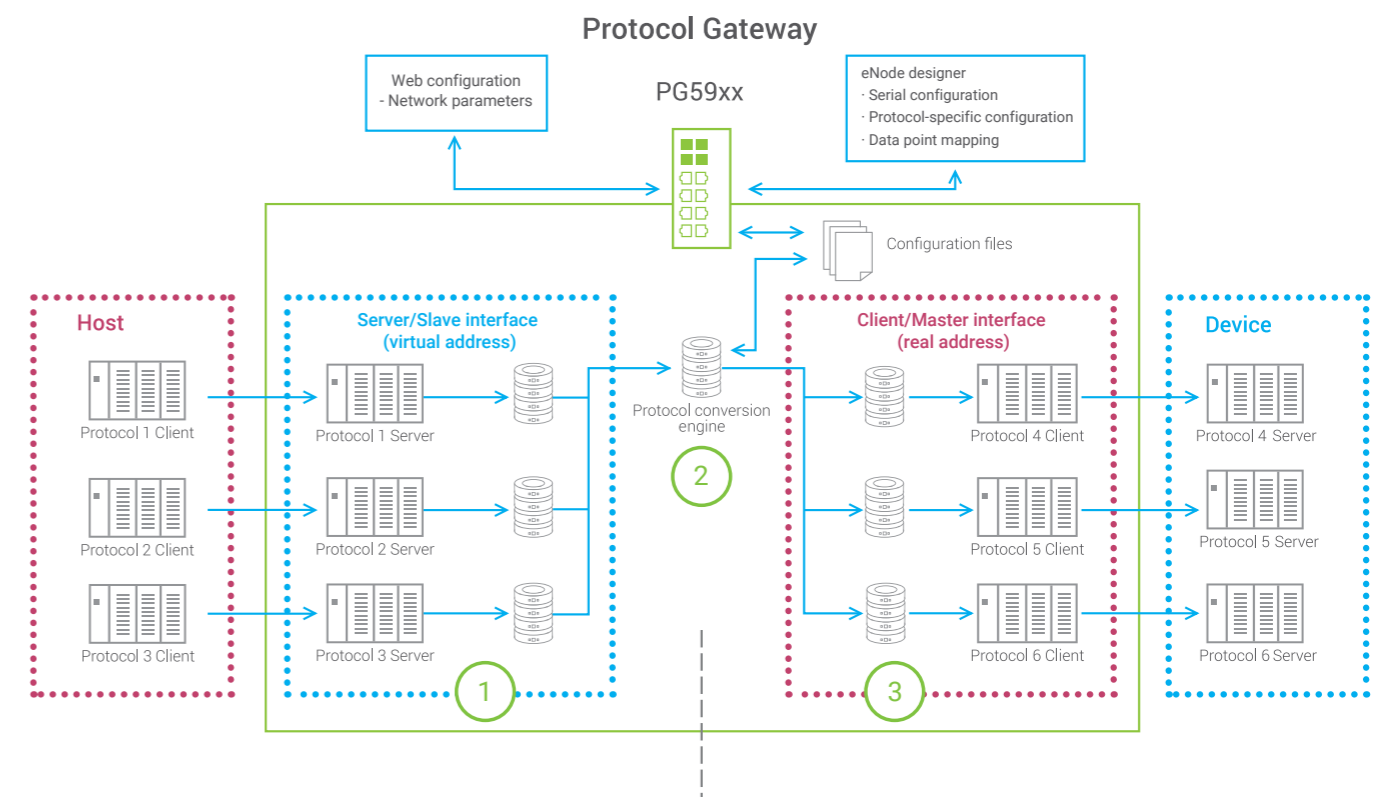
At the time of building, power utilities typically invest in the latest available technologies. Yet, equipment in the grid system has a long lifespan, lasting over 50 years. As a result, often both legacy and new technologies are present in the power grid. A challenge of implementing IEC61850, therefore, is to integrate all technologies seamlessly to enable this enhanced system.

For substations utilizing legacy process protocols such as through IEC 60870, DNP 3.0, and Modbus, ATOP provides protocol gateways of powerful hardware platforms paired with stable software, for protocol-to-protocol translation that is transparent, highly reliable, and fault-tolerant. These gateways allow the high availability, reliability, and security that modern power grids need, without the cost and hassle of a full system renewal.
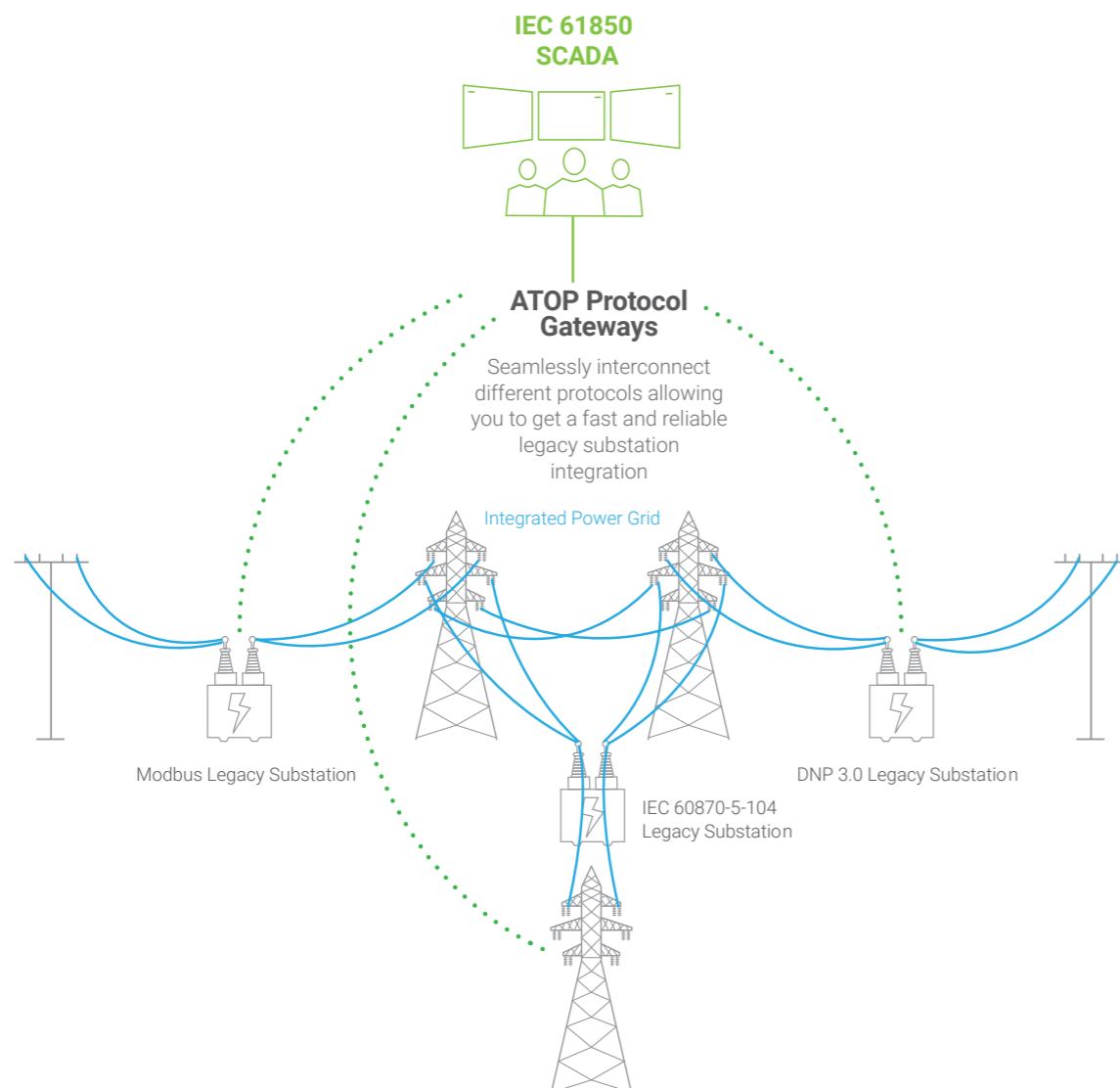
The pivotal role of protocol gateways lies in their ability to act as translators, allowing devices from different eras and communication paradigms to understand each other. Specifically, this involves the translation of data points, mapping of attributes, and normalization of data formats to ensure a coherent and standardized communication flow. Architecture of a protocol gateway consists of three parts:

① A **server/slave interface**, which listens to an external host client/master, such as a PLC or SCADA. The protocol gateway will act towards the host as a slave device according to the protocol used.

② A **protocol engine**, the core of the unit that moves, translates, and maps the data points, commands, and events between the client and server sides. Here, data, commands, and events are stored and mapped to other protocols. ATOP protocol gateways allow protocol mapping to any Serial or Ethernet port. Using the friendly eNode Designer tool, users can assign different protocols to different ports, configure serial port settings and protocol-specific parameters, and define real IDs or virtual addresses for the Master/Client or Slave/Server to work with, respectively.

③ A **client/master interface**, which actively polls or issues commands to an external server/slave device.

IEC 61850
SCADA

ATOP Protocol Gateways

Seamlessly interconnect different protocols allowing you to get a fast and reliable legacy substation integration

Integrated Power Grid

Modbus Legacy Substation

IEC 60870-5-104 Legacy Substation

DNP 3.0 Legacy Substation

IEC 60870

Protocol Gateway

Web configuration
- Network parameters

PG59xx

eNode designer
· Serial configuration
· Protocol-specific configuration
· Data point mapping

Configuration files

Host | Server/Slave interface (virtual address) | Client/Master interface (real address) | Device

Protocol 1 Client — Protocol 1 Server — Protocol conversion engine — Protocol 4 Client — Protocol 4 Server

Protocol 2 Client — Protocol 2 Server — Protocol 5 Client — Protocol 5 Server

Protocol 3 Client — Protocol 3 Server — Protocol 6 Client — Protocol 6 Server

Users can choose and set up protocol gateways according to the host and equipment protocols in place. At the device level, a protocol gateway might sit between process equipment and management servers, facilitating the communication of equipment data and commands. The below figure illustrates how a Modbus gateway, a protocol gateway specifically for the Modbus protocol family, may work in a real application.

```
Management  ⟷ Modbus TCP (Ethernet) ⟷ Modbus Gateway  ⟷ (serial) ⟷ Modbus RTU / Modbus ASCII ⟶ Operations
```
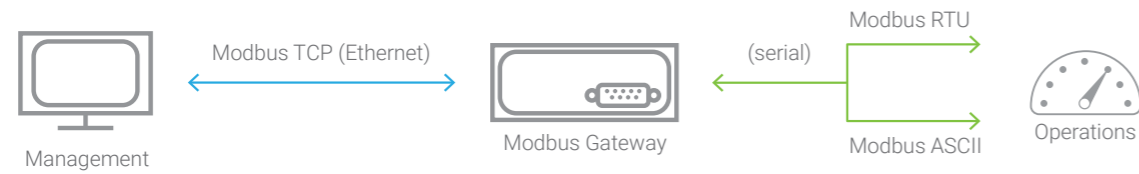
To support the varied needs of different scenarios, ATOP offers more than 80 protocol combinations that are available on a range of hardware platforms, empowering users whichever protocols their current system runs on. For IEC 60870-5-101 to 104 and DNP 3.0 Serial to Ethernet, ATOP also offers a transparent function that allows direct conversion without mapping, providing enhanced efficiency.

Protocol	Interface	Function
Modbus RTU	RS-485 ; RS-232 ; RS-422	Master/Slave
Modbus TCP	Ethernet	Client/Server
DNP 3.0 over Serial	RS-485 ; RS-232 ; RS-422	Master/Slave
DNP 3.0 over Ethernet	Ethernet	Client/Server
IEC 60870-5-101	RS-485 ; RS-232 ; RS-422	Master/Slave
IEC 60870-5-103	RS-485 ; RS-232 ; RS-422	Master
IEC 60870-5-104	Ethernet	Client/Server
IEC 61850	Ethernet	Client/Server

Not all protocol gateways are created the same

ATOP protocol gateways can serve more than simple protocol conversion. While protocol names may be the first specification to look at, efficiency and cybersecurity are two more subjects that require utmost attention to when integrating legacy substation systems.

In an automated substation, various devices need to exchange data seamlessly and in a timely manner. The resulting network is complex and often the overall traffic is heavy. **Routing** functions direct the flow of information, acting as a traffic controller within the network. By efficiently managing data traffic, protocol gateways ensure that information reaches its intended destination swiftly, enhancing overall network performance.

Filtering functions, on the other hand, allow selective passage of relevant information, refining traffic and preventing unnecessary data from clogging the network. This not only conserves bandwidth, but also enhances the security and efficiency of data transmission.

Data mapping is a feature that assigns data points into memory, organizing and aligning data in a structured manner. With data mapping, exchange between devices is more swift and accurate. This streamlined approach reduces latency and ensures that the right information is delivered promptly, further optimizing the overall communication process.

Hardware		Mount	Ethernet Ports	RS-485 RS-232 RS-422 ports	Additional features
	PG5901	Din-Rail	2 (RJ45)	1 (TB5 or DB9)	can be PoE-powered [optional]
	PG5901B	Din-Rail	1 (RJ45)	1 (DB9 vers.) / 2 (TB14 I/O vers.)	4G LTE or 3G connectivity
	PG5904D-4P	Din-Rail	2 (RJ45 or SFP)	4 (TB5 or DB9)	can be PoE-powered [optional]
	PG5908	Rack-Mount	2 (RJ45)	8 (RJ45)	
	PG5916	Rack-Mount	2 (RJ45)	16 (RJ45)	
	PG5900A	Rack-Mount	6 (SFP or RJ45)	-	
	PG5908A	Rack-Mount	6 (SFP or RJ45)	8 (TB5 or DB9)	
	PG5916A	Rack-Mount	6 (SFP or RJ45)	16 (TB5 or DB9)	

Like any critical infrastructure, IEC61850 networks are susceptible to vulnerabilities such as unauthorized access, data manipulation, and denial-of-service attacks. Every link and node in the network has to be safeguarded, and protocol gateways are no exception—indeed, they must understand the security protocols of both legacy and IEC61850 systems. ATOP PG5904, 08, and 16 series also offer **port isolation** and **VPN** support. The segmentation of devices and subsystems prevent issues in any part of the network from propagating across the gateway to critical connected devices. Any potential issues are confined in the smallest range possible to await handling by the administrator, who is alerted by network management software such as **BlackBear NIMBL**.

To summarize, the concept of a protocol gateway may be simple to comprehend, but the possibilities of this device is endless. With their unique functions and key positioning, protocol gateways are indispensable to the upgrade to IEC61850 substations, or for any industrial digitalization and modernization. From facilitating smooth data exchange to enhancing cybersecurity measures, a good protocol gateway shapes the future of automation.

Getting the most out of Modbus gateways and concentrators

Modbus is a widely used communication protocol in industrial automation and control systems. Its simplicity and versatility have contributed to its continued use in various applications, notably in power substations where voltage is transformed, controlled, and distributed.

Common variants of the Modbus protocol include Modbus RTU, Modbus ASCII, and Modbus TCP. The first two are serial-based, facilitating communications with operational devices such as relays, meters, controllers, and protection equipment. Modbus RTU is a compact binary protocol known for its efficiency and compactness, well-suited for applications with lower data rates. Modbus ASCII uses human-readable ASCII characters for data transmission. It is less efficient than Modbus RTU due to the overhead of ASCII character encoding, but can be useful for debugging and testing purposes.
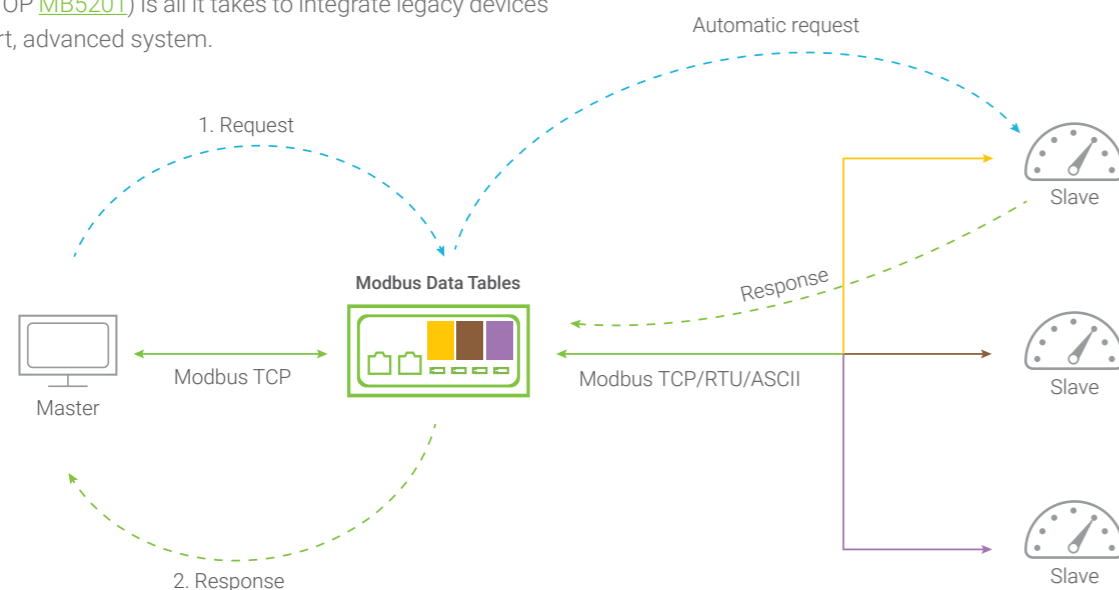
Modbus TCP, on the other hand, works with Ethernet, enabling higher data rates as well as more advanced control and monitoring features. It is the key to bridging legacy devices with modern Ethernet systems, such as those based on the IEC61850 standard.

By converting Modbus RTU and ASCII to Modbus TCP, Modbus serial devices can continue to play active roles in substation operation, while newer Ethernet-based SCADA and cybersecurity measures are brought in to ensure the high availability, reliability, and security that modern power grids need. No need to upgrade the whole communications network—a good Modbus gateway (such as ATOP MB5201) is all it takes to integrate legacy devices with a smart, advanced system.

Meanwhile, Modbus gateways can serve more than simple protocol conversion. Port isolation and VPN features (such as provided by ATOP MB5901 and MB5904D) protect against potential failures and attacks by ensuring that issues on one side of the gateway do not propagate across to critical devices. Routing and filtering functions help control the flow of information, managing data traffic and optimizing communication between devices. Data mapping assigns data points into memory, further improving communication efficiency.

A Modbus concentrator, in particular (such as the ATOP MB5916-CT and MB5916A-CT), is an advanced machine suitable for frequent polling requests from multiple devices. It performs pre-defined Modbus commands to read/write data automatically from slave devices. It then mirrors the obtained slave device data to its own memory, compartmenting those from different slaves in separate tables for easy access. Thus, requesting masters can receive responses in a shorter period, achieving better overall efficiency, even with a high density of devices.

Modbus concentrator register mapping can be customized for optimal performance where different masters need to access different data structures. Link status and data timestamp access allow high-level management, and for the most mission critical applications, redundant architecture can achieve automatic link recovery in case of Ethernet or serial link failure.

Modbus Data Tables

Master — Modbus TCP — Modbus Data Tables — Modbus TCP/RTU/ASCII

1. Request
2. Response
Automatic request
Response
Slave
Slave
Slave

Case study: Robust and secured networking for substations

Requirements

To provide a full turnkey industrial networking solution for up to 32 substations, many which are far from each other. The overall network must comply with industrial cyber security standards as well as ensure high reliability. Some other required standards include:

- Traffic optimization and packet prioritization according to IEEE 802.1p/q
- Precision Time Protocol—time synchronization according to IEEE 1588v2
- HSR-PRP zero packet loss redundancy protocol

Solution

- A comprehensive solution was provided by ATOP along with partners BlackBear TechHive and BlackBear Cyber Security. In total, more than 150 ATOP switches are used throughout these 32 substations. Built with industrial-grade hardware and design, the whole system is able to perform reliably under harsh environments for a long period of time.
- All devides are managed via BlackBear TechHive's network management tool. Specifically designed for efficient, portable, scalable, secure and consistent management of network communications systems, the BlackBear NIMBL is capable of, among other features, automatic device discovery, device monitoring and diagnostics, and alarm notifications in case of any anomalies.

Security

- The **BlackBear Intelligent Gateway (BIG)** is an FPGA-based data diode solution by BlackBear Cyber Security that provides hard defense through network segmentation between the operational technology (OT) side and information technology (IT) side. As IT is exposed to external environments and hence more susceptible to cyber-attacks, the BIG ensures strict data flow from OT to IT only, blocking any traffic from IT to OT in its entirety. In contrast to firewalls, data diodes do not rely on known malware signatures to operate, so keeps safe from zero day vulnerabilities.
- Moreover, data traffic must be **encrypted** to avoid eavesdropping. ATOP switches use MACsec to encrypt data from RTUs/VOIPs/AMRs/recorders to the central SCADA room, and the BIG encrypts data from and through SCADA. Therefore, SCADA data can be sent securely to uplinks via FTP/sFTP.
- All networking devices are **IEC62443 compliant** to ensure sufficient cybersecurity robustness. Especially in critical environments like substations where the stakes are high, this feature is important indeed.

+ 886 - 3 - 5508137
+ 886 - 3 - 5508131
info@atop.com.tw
www.atoponline.com

Topology of an IEC 61850-3 substation

Secure, Compact & Robust

Precision Timing

Zero Packet Loss

IEC 62443 IEC 61850-3 Compliance

Protocol Conversion

Simple Network Management by NIMBL

BlackBear
Cyber Security

BIG9000

Unidirectional Gateway

No incoming route

SCADA
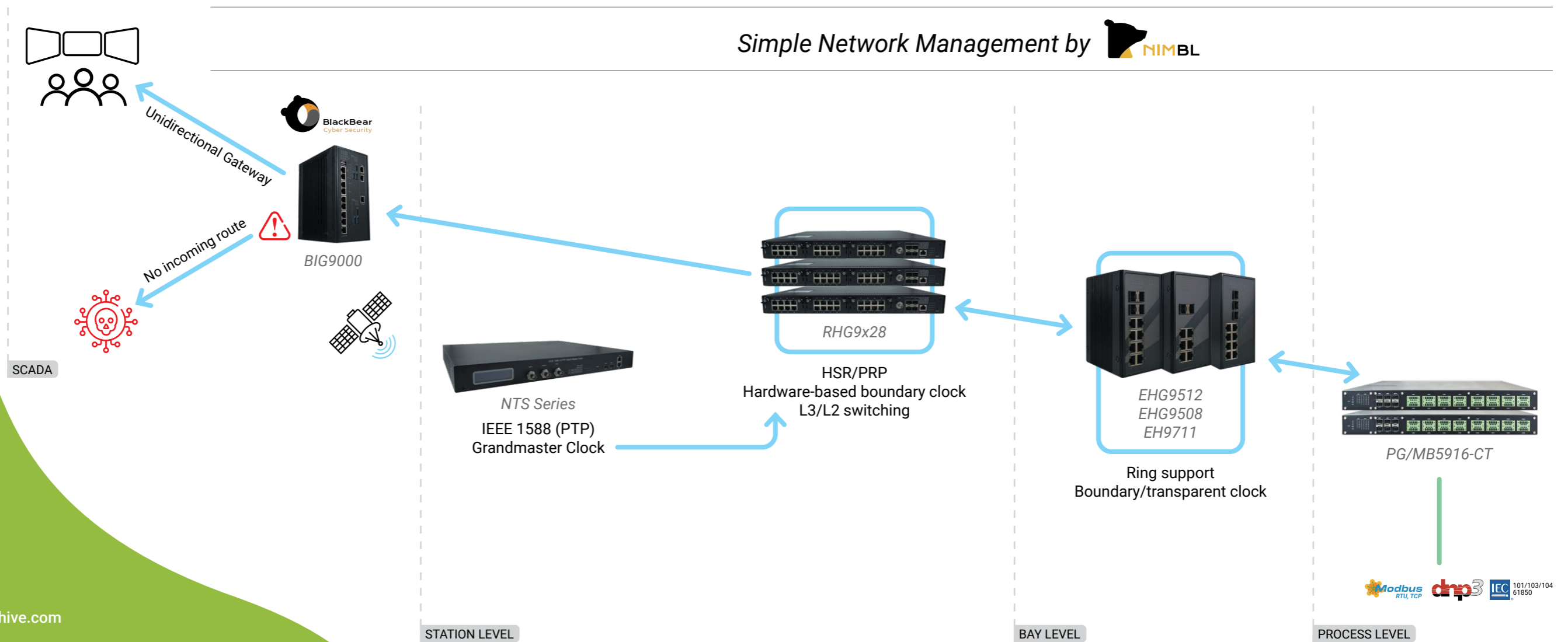
ATOP Technology and BlackBear Cyber Security are close partners specializing in industrial networking and OT cybersecurity. Both companies are part of BlackBear TechHive, an international provider of industrial digitalization.

Learn more at
https://www.blackbeartechhive.com

NTS Series

IEEE 1588 (PTP)
Grandmaster Clock

STATION LEVEL

RHG9x28

HSR/PRP
Hardware-based boundary clock
L3/L2 switching

EHG9512
EHG9508
EH9711

Ring support
Boundary/transparent clock

BAY LEVEL

PG/MB5916-CT

Modbus RTU, TCP   dnp3   IEC 101/103/104 61850

PROCESS LEVEL

RoHS COMPLIANT

IEC 62443

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+ 886 - 3 - 5508131

info@atop.com.tw
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