# Designing a LAN Communication Network For Protection Applications

**M. ZAPELLA[1], C. PIMENTEL[1], G. SILVANO[1], R. RAMLACHAN[2]**
**GE Grid Solutions**
**BR[1], US[2]**

## SUMMARY

Digital substations are at the heart of the 3 mega-trends of decentralization, decarbonization and digitalization. It allows utilities to reduce the footprint of their substations, replace oil-insulated instrument transformers for optical counterparts, harvest advanced diagnostics and analytics data from their assets and act on such data remotely and expeditiously. All these benefits have a common enabling technology, modern Ethernet networks.

Fully digital substations are already a reality, with installed base growing more and more every year and one of the biggest challenges in moving from traditional to digital is the network engineering. Not because it is difficult to manage, but because it is a completely new field of knowledge to most power system engineers, and it carries all the data needed for protection, automation and control (PAC) applications which is the fundamental of substations.

Structured in 6 sections, this paper aims to present the basic principles and techniques needed for the proper configuration, operation and maintenance of Ethernet networks in digital substations, considering practical aspects of data segregation, prioritization and redundancy for increased reliability. On the first section, a brief introduction on the benefits and core standards and technologies utilized in digital substations is presented and motivates the technology leap. On section two, we discuss the kinds of messages found on such networks and their respective priorities, introducing basic aspects of GOOSE, Sampled Measured Values and PTP messages, including specific profiles for substations applications. On section three we delve deeper in the architecture network architecture, discussing benefits and disadvantages of using topologies based on rings, stars and a mixture of both. This includes considerations on redundancy and practical aspects of the substation architecture and protection equipment available for use.

In the subsequent section, we discuss the most common set of tools used for the network configuration, these include: Quality of Service, RSTP, MSTP, VLAN and Multicast filtering. On section five, we discuss the practical application of the concepts of the previous section in real scenarios, providing the connection diagrams, device configurations and comparing traffic data with and without the many configuration options. Finally, on the last section we present our final comments and recommendations based on the scenarios assessed during the paper.

## KEYWORDS

Digital Substation, 61850 Networks, Network Architectures, Ethernet Switches, IEC 61850, PAC Communication

## 1. Introduction

A digital substation is one where all analog interfaces, such as current and voltage measurement, equipment status and alarms, and equipment control points are converted to digitized data directly at their source. This digital data, published using techniques described in the IEC 61850 standard, is then shared with other devices in the substation, and potentially beyond the substation as well. This allows substation control systems to be built faster and more efficiently, while using less materials and to unlock the value of data in the to operate the substation and its equipment better.

A digital substation therefore requires all devices in the substation to communicate with each other over Ethernet networks. These Ethernet networks must be designed to manage the various types of traffic and messages that IEC 61850 requires for sharing data between devices. This requires power system engineers to have some understanding of Ethernet networks. The design and management of large and complex networks that move large amounts of traffic is a specialized field of knowledge, which may be intimidating to power system engineers.

However, it is not necessary for power system engineers to fully understand the complexity of Ethernet networks, but to simply understand enough to design and maintain networks that support the needs of a typical substation. This is, actually, very straightforward, as the traffic on the network in the substation does not change over time, because it is based on the substation physical design, operating requirements, and equipment, which only changes rarely, as part of capital projects. This means for any specific substation, the communications network can be designed once, and the design and configuration never need to change.

In summary, the knowledge to support networking in terms of power systems, is simpler than expected. The next sections will introduce the main points on digital substation networking and present the best practices to the engineering team on how dealing with network definitions, configurations and validation, including a real case experience of Factory Acceptance Tests (FAT) for a digital substation project.

## 2. From analog to digital

In conventional substations, the task of connecting PAC equipment to signal sources requires proper engineering. Many variables are taken into account for choosing the wire infrastructure, e.g. current, signal attenuation, signal delay. When moving to a digital substation solution, wire infrastructure is replaced by network infrastructure, where data is transmitted from signal sources to PAC equipment through the Ethernet standard. Obviously, the complexity of such solution is greater because all data traffics through the same physical network, there are several protocols involved and many more variables must be considered. This means that even more care must be taken when engineering the network in digital substations.

The first thing to consider is bandwidth. Just like wire gauge is chosen based on current, link speed must be appropriate to the amount of data being transmitted. In large networks, which is usually the case for digital substations, there is a huge amount of data traffic but not all of it is required to reach every device. As most part of IEC 61850 data uses multicast destination addresses, packets are forwarded everywhere in the network, forcing every link to be dimensioned to support the total network throughput. That can be avoided using traffic segregation, allowing each device to receive only the required data. The most commonly used solutions are virtual LANs (VLANs) and multicast address filtering. VLANs are great for allowing only specific data streams to traffic through a link, blocking everything else. Multicast address filtering, in the other hand, is best suited for blocking specific data streams to be forwarded to a link, whereas everything else flows normally.

Another aspect to be considered is latency. The same way long cables will introduce signal delay, long network paths and congestions add to the time data takes to go from one point to another, usually referred to as latency. This is especially important in IEC 61850 networks, where PAC equipment must respond as soon as possible to events in the electric system. The best way to minimize latency is to ensure sender and receiver are as close as possible, i.e. reduce the number of hops between the devices, ideally being connected to the same switch. This will not only help data reach its destination faster, but also potentially reduce throughput in the so-called trunk links (connections between switches).

Prioritization is also a way of reducing latency as well as improving data delivery probability. When packets are prioritized, queueing is less likely to happen, thus ensuring that they are transmitted as fast as possible. In congestion situations when the throughput reaches the link bandwidth and packets need to be dropped, priority ensures that important data does not get lost. This can be easily done using Quality of Service (QoS) by choosing the appropriate priority level for each data stream so that the most important ones are preferable.

Moving from wire to network infrastructure raises reliability questions. In the analog world, the biggest threats against data integrity are wire damage and electromagnetic interference. In the digital world however, there are a lot more concerns, e.g. equipment failure, congestion, transmission errors. Redundancy protocols were created to address this problem. RSTP (Rapid Spanning Tree protocol), PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy) are the most commonly used and depending on the network architecture, one, two or all of them can be used simultaneously.

## 3. Performance requirements for IEC 61850 networks

General information reporting and control commands have been digitized for decades with the advent of modern SCADA systems. A fully digital substation means taking the next step, which is digitizing the interfaces between primary equipment and protective relays and bay control devices. This interface across the switchyard is generically known as "process bus". Process bus is the best way to look at and learn networking requirements in a substation, as process bus is the most demanding application in the digital substation.

Process bus requires 3 different types of messages across the Ethernet network.

**GOOSE messaging:** A GOOSE message contains a dataset of information. Individual dataset items may be used for indicating equipment status and alarms, and they may be used for control indications such as breaker trip and close flags. GOOSE messages will be published any time a dataset item changes state. GOOSE is the primary messaging between circuit breakers and protective relays and bay control units.

**Sampled Values (SV) messaging:** Sampled values are instantaneous samples of currents and voltages from instrument transformers, published by merging units (MUs) to the process bus network. Protective relays and bay control units subscribe to this data.

**Precision Time Protocol (PTP) messaging:** PTP is the other name for IEEE 1588 time synchronization through the network. PTP uses message exchanges between master and slave clocks to accurately measure and compensate for path delays between the clocks.

All three of these message types are multicast messages. This means the messages are published to the network, and any device connected to the network can subscribe to this data.

GOOSE messages, SV messages, and PTP messages will therefore be everywhere on the network. With several devices publishing network data, it is necessary to understand how this impacts the bandwidth to prevent overloading of the network, and switch ports.

## Messaging Bandwidth

GOOSE transmits a heartbeat message cyclically to prove the publishing device is still alive, typically once per second. GOOSE is intended to transmit spontaneous messages on the state change of any dataset item in the GOOSE message. To overcome possible frame loss, a GOOSE message retransmits some number of times up until the heartbeat message interval, One GOOSE application in an IED generates about 1 kbit/s of data in steady-state and about 1 Mbit/s during spontaneous messages.

The PTP message bandwidth depends on the network topology, considering the number of IEDs, the Ethernet Switch type (if it supports PTP or not) and PTP mode: peer-to-peer (P2P) or end-to-end (E2E). PTP as defined for power system applications (in C37.238 or 9-3) publishes once per second and has a bandwidth comparable to steady state GOOSE messages.

While GOOSE and PTP have similar requirements on the process bus network, SV traffic is even more demanding, but it is easily predictable. An SV frame as specified in IEC 61850-9-2LE represents 1 sample in an acquisition system with a sampling rate of 80 samples per cycle. This frame has an approximate size of 140 bytes, consuming a bandwidth of approximately 5 Mbit/s (50 Hz system) or 6 Mbit/s (60 Hz system) per stream. For measurement, the sampling rate is 256 samples per cycle, with 8 samples sent in a single frame at a lower rate, resulting in a bandwidth of up to 10Mbit/s for systems at 50 Hz and 12 Mbit/s for 60 Hz.

So as the number of devices on the network increases, messaging traffic consumes more bandwidth, which can decrease network performance. The goal must be to maintain overall substation performance, especially for protective relaying.

## Messaging Latency

The IEC 61850-90-4 Technical Report focuses on the engineering of a local network used to meet the IEC61850 requirements for substation automation. It describes the aspects related to protection, such as tripping over the network (GOOSE), the multicast data transfer from merging units with large volumes of Sampled Values and high precision clock synchronization. Among other matters, the technical report outlines different approaches to network topology and redundancy, which will be covered in a later section.

Referring to messaging performance, the technical report shows the expected IEC 61850 traffic and maximum delay of high priority messages, as below:

| *Message* | *Max. Delay (ms)* | *Bandwidth* | *Application* |
|---|---|---|---|
| GOOSE (Trip) | 3 | Low | Protection |
| GOOSE (other) | 10 to 100 | Low | Protection |
| Sampled Val. | 4 | High | Process Bus |
| PTP | - | Low | General Phasors, SVs |
| MMS (low speed) | < 100 | Low | Control |
| MMS (med speed) | < 500 | Low | Control |

Note there is not a maximum delay specified for PTP. The PTP network directly calculates and compensates for the delay over each possible path, so by definition the protocol itself defines the fastest path between the devices.

## 4. Network Design

In the substation environment, the network infrastructure must operate without the presence of operators and in some cases does not have connection to the Internet for remote management. In other words, the network infrastructure must be reliable and single failure proof, the architectures must consider redundant paths in case of link failures and the switches operating parameters must be configured to ensure the flow of information even in situations of network stress. Furthermore, whenever an unexpected situation occurs, the network infrastructure must be capable of warning/alarming the substation supervisory for attention/assistance.

Based on the application requirements, the substation infrastructure and technology definitions initiate by choosing the primary instrumentation, followed by PAC devices and its functionalities, their location on buildings and the data communications protocols (SV, GOOSE, PTP, SNMP, etc.). The network infrastructure definition is the next step, starting by selecting the networking equipment, deciding the interconnection between devices and the network topology including redundancy. The last steps would be network configuration, validation from the architectures and redesign if necessary. To illustrate this macro workflow, Figure 1 presents the engineering steps to define the network architecture from a substation.

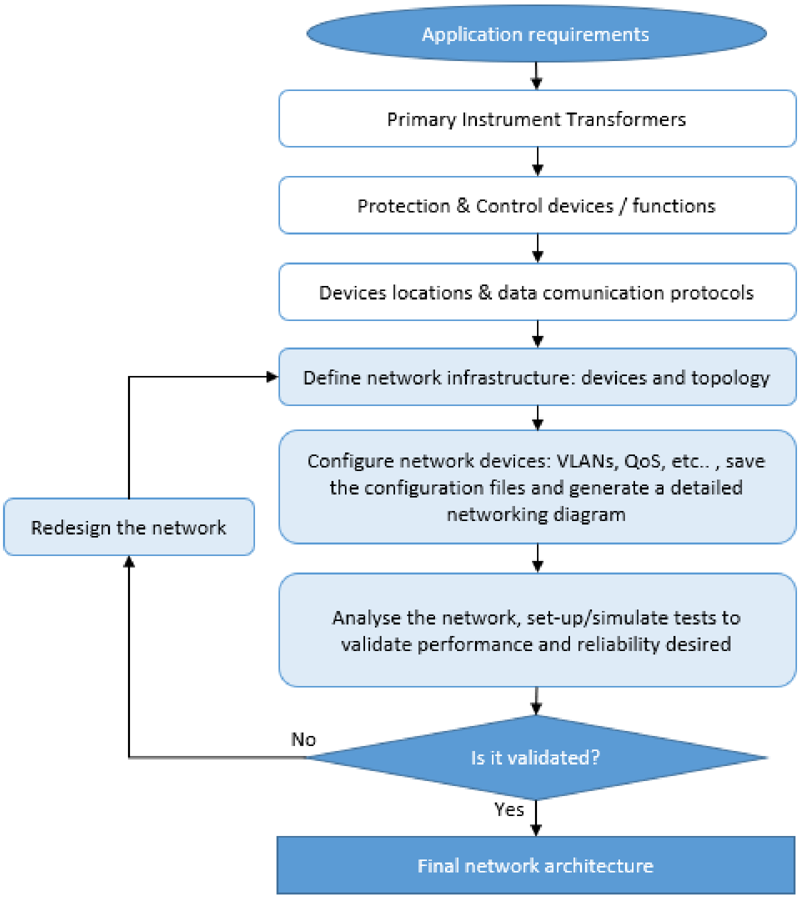


Figure 1 – Engineering steps for network communication definitions

## Network equipment selection

Although networking equipment may have a wide list of functionalities and characteristics, to fulfill the performance requirements from a 61850 network the following main points must be observed when selecting a networking equipment:

- Industry hardened design, ready to operate in harsh environment (same as relays) and preferable with redundant power supply and dry-contact relay alarm;
- Number and type of Ethernet ports, depending on interconnection required between devices;
- Ports speed and switching capacity. As previously showed IEC 61850-9-2LE sampled values usually consumes a bandwidth of 5 Mbit/s (50 Hz system) or 6 Mbit/s (60 Hz system) per stream, but it may reach up to 12 Mbit/s for measurement applications. Thus, consider trunk links (connection among switches) and a few edge links (for relays, DFRs) may transmit multiple SV stream;
- Layer 2 functionalities, such as MAC filtering and VLANs for traffic segregation;
- Switching latency and Quality of Service to ensure fast and uninterrupted data switching;
- Transparent clock operation with hardware-based time stamping, when using IEEE 1588v2 time synchronization;
- Support to desired redundancy protocols, such as RSTP, PRP and HSR.

Besides the above listed points there are many others, such as Cybersecurity features to avoid malicious attacks, SNMP for management/monitoring, IGMP for PMU applications and Layer 3 functionalities in case of large substations with multiple areas, to mention a few, but the paper's focus is on the main network concepts.

## Network topology definition

A good practice while defining the network architecture is to ensure sender and receiver are as close as possible, as this is the best way to minimize packets latency and data bandwidth in trunk links. High throughput in trunk links can also contribute to lower latency, as data from several ports is merged into a single one and queueing may be necessary, especially when devices are synchronized, and data is sent simultaneously. Figure 2 illustrates the difference between having several streams traverse a trunk link and connecting publisher/subscriber in the same switch in a way that data does not need to be forwarded to the trunk link.

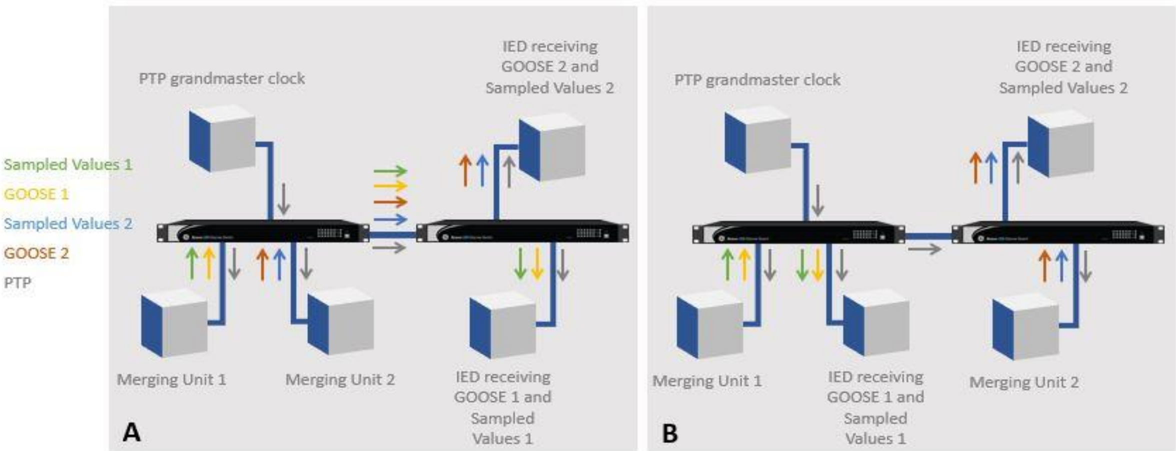


Figure 2 – Good practice on IEDs connections to avoid several streams in trunk links

In addition, redundancy is a usual requirement for network topologies to avoid any single point of failure, so it is recommended to start the network design by considering full redundancy, as it may be removed later from the parts that are do not needed. The reverse approach would require further efforts, which may even lead to a complete network reengineering. Numerous protocols provide partial or full network redundancy on the MAC layer, the most common and recommended by IEC 61850 are the RSTP, PRP and HSR; the concepts are described in IEC 62439-1.

Note that redundancy is meant to increase substation operation reliability, but it does not ensure high availability by itself. Device characteristics play a major role to ensure availability, by having a high MTBF (Mean Time Between Failure) and low MTTR (Mean Time To Repair).

RSTP is the most widely used loop breaking protocol a mechanism created to solve the problems that arise when a loop is inserted into a LAN, as it converts a meshed network to a logical tree, by blocking ports that would introduce loops and leaving only one path available between devices as shown in Figure 3. Although RSTP is widely used for loop breaking, it provides redundancy by recalculating a new path in the network if a trunk link failure occurs. In case of failure in the edge link or in the Ethernet switch itself, the RSTP will also calculate a new path but the attached devices will be isolated from the network. As RSTP is performed by Ethernet switches and takes in the order of milli-seconds to recover from a fault, it is not well suited for the process bus, but may be used for control and management on the station bus level.

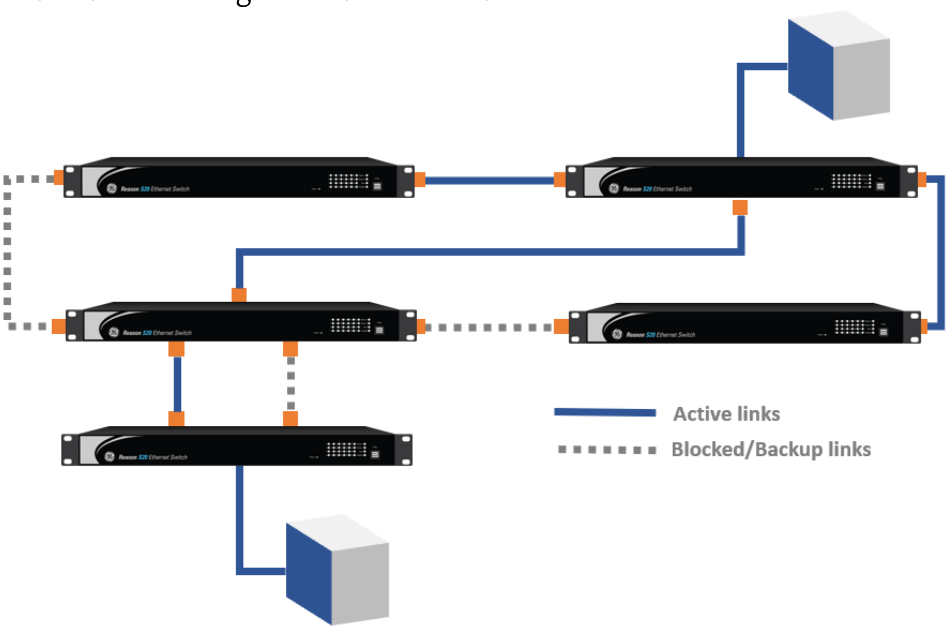


Figure 3 – Example of RSTP network topology.

Different from RSTP, the redundancy protocols PRP and HSR are implemented on the end-devices, provide seamless failover operation, and protecting the system against link (trunk or edge) or even network device failures. The PRP topology is equivalent to having two process bus networks where both operate in parallel, and in case of any failure in one, the other is used as backup. End-devices are connected to both networks, sending and receiving packets to/from both. In summary, PRP redundancy relies on a complete duplication of network devices, meaning it is the most effective redundant protocol but also the most expensive. An effective way of using PRP on substation networks is by combining the process bus and the station bus on the same physical network and segregating the buses by using virtual LANs.

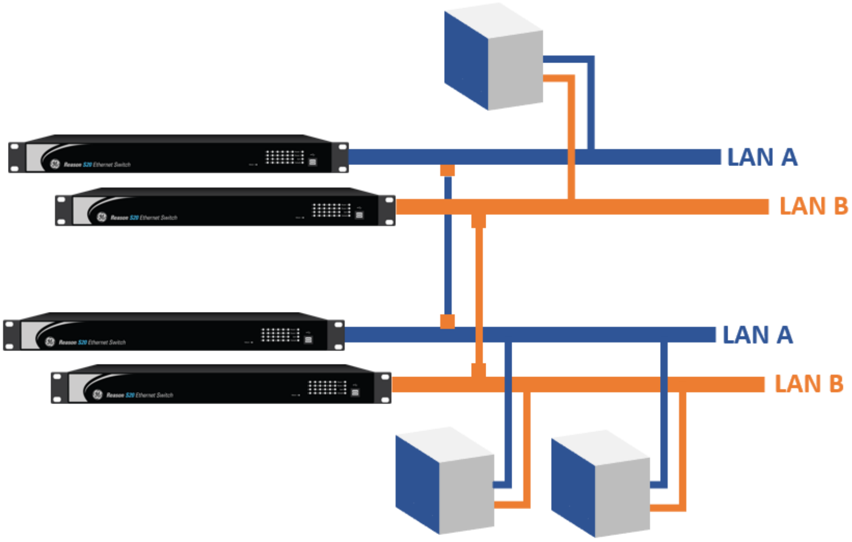


Figure 4 – Example of PRP network topology.

HSR operates in a ring topology, and as the protocol is supported by the devices, HSR can operate without dedicated Ethernet switches. On a HSR network, each device sends the same frame on both directions sail safeguarding the system against a single point of failure in the ring. Although HSR provides seamless redundancy and is cheaper than PRP, there are two main concerns when using a large ring in a process bus. The first is related to reliability, as once the ring is composed by many devices, the possibility of two failures increase, to which the network is not prepared for. The second is related to bandwidth, as all devices on the ring have to support all the data flow in the network. To avoid that, HSR networks are usually composed by multiple rings with a small number of devices each, and redundancy switches (Redbox) interconnecting them all. The interconnection may rely on other topologies, such as HSR, by creating a ring of rings (not recommended due to bandwidth limitations), or PRP (most commonly used).

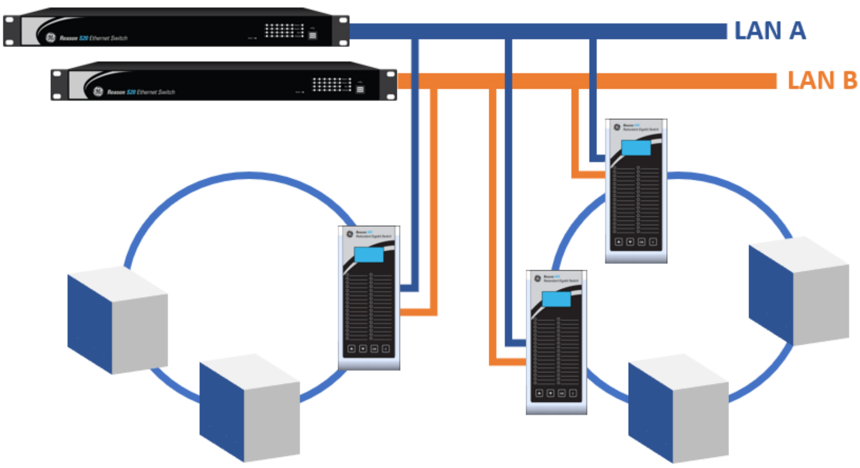


Figure 5 – Example of HSR network rings interconnected through a PRP network.

### Network configuration

In a 61850 network, special functions may be required to ensure the switches will perform appropriate treatment of substation automation traffic across the network. Defined in IEEE 802.1Q [2], functions as VLANs and Quality of Service (QoS) are designed to implement flow control, traffic shaping, or queuing differential services in the network. Class of Service (CoS) is used in support of QoS, and it assigns priority values to data messages in order to discipline the network traffic. The basic challenge is that GOOSE, Sampled Values and Precision Time Protocol messages are multicast, operating at the basic data link layer (Layer 2) of a network switch. They will pass through the entire network on a first-in, first-out basis in switch buffers unless properly managed.

Virtual LAN technology allows separation of traffic through logical networks. In power system communication, where IEC-61850 messages are expected with different priority and usage, there will be only one physical path for each IED and the packets must be separated logically.

When using VLAN traffic segregation, multicast messages are forwarded only onto the VLAN that the multicast message belongs to. Thus, GOOSE, Sampled Values and PTP traffic will flow separately from each other. Finally, as the traffic is separated, IED equipment that expects to receive only GOOSE messages will not have its network interface interrupted by Sampled Values data, for example.

An example of expected VLAN traffic segregation is shown in Figure 66. In this example, there are 3 VLAN configured, one for PTP traffic, one for Sampled Values traffic and another one for GOOSE traffic. The Merging Unit is the publisher of GOOSE and Sampled Values messages, and it is the only slave clock of PTP synchronization. Note that a ring physical topology is used for example purposes, as it is a common physical network topology in power system communication.

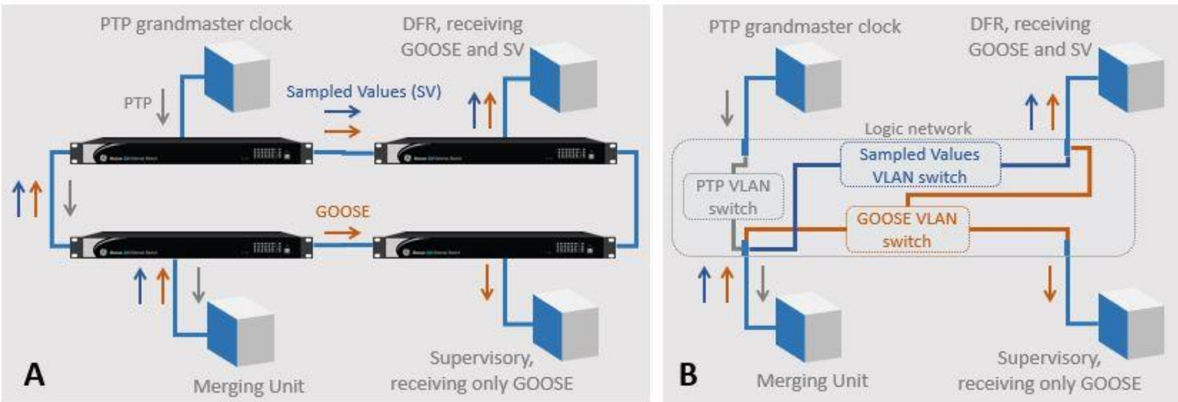


Figure 6 –Power system communication, (a) Physical network (b) logical network using VLAN.

Lastly, to make sure high priority packets will not be dropped in the case of high traffic flow, Quality-of-Service (QoS) mechanisms must be used to ensure critical data will not be lost. The QoS spares part of Ethernet port bandwidth to be used only by these messages. When using QoS, if low priority data reaches its bandwidth (which is the Ethernet port bandwidth minus the spared bandwidth to high priority messages), there will be low priority data loss. High priority data will not be affected, as it has guarantee of bandwidth. Such situation is shown in Figure 7.

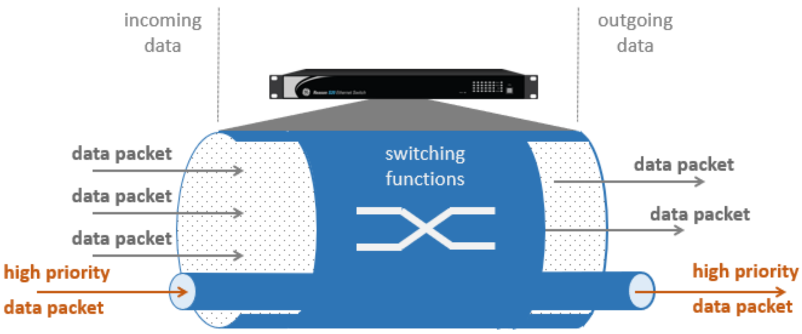


Figure 7 – Packet prioritization in a high traffic flow condition.

Overall, it is recommended to separate each Sampled Values stream, each GOOSE stream and PTP with a unique VLAN. That is the best way to ensure complete management of IEC 61850 traffic, and avoid unnecessary load where data is not required. The priorities defined for each message type in IEC 61850-90-4 should be followed when configuring QoS, which is usually done by setting appropriate PCP values in the VLAN tags.

**Table 37 – IEC 61850-5 interface traffic**

| Function Type/Message | | Interface (Table 1) | Protocol | Max. delay ms | Bandwidth | Priority | Application |
|---|---|---|---|---|---|---|---|
| 1A. Trip | GOOSE | 3,8 | L2 Multicast | 3 | Low | High | Protection |
| 1B. Other | GOOSE | 3,8 | L2 Multicast | 10 to100 | Low | Medium High | Protection |
| 2. Medium Speed | MMS | 6 | IP/TCP | <100 | Low | Medium Low | Control |
| 3. Low Speed | MMS | 6 | IP/TCP | <500 | Low | Medium Low | Control |
| 4. Raw Data | SV | 4 | L2 Multicast | 4 | High | High | process bus |
| 5. File Transfer | MMS | 6,7 | IP/TCP/FTP | >1 000 | Medium | Low | Management |
| 6. Time Sync | Time Sync | | IP (SNTP) L2 (PTP) | | Low | Medium High | General Phasors, SVs |
| 7. Command | MMS | 6 | IP | | Low | Medium Low | Control |

Figure 8 – Table 37 from IEC61850-90-4 showing the priority for each message type.

## 5. FAT for Digital Substations

A substation PAC system conceived using IEC 61850 provides benefits related to ease of equipment installation, configuration, and project execution, as most of the interconnection between equipment is made logically through a switched network. In this scenario, most of the tests related to performance, interlocking operational diagrams and protection functions can be simulated in a software-based simulator. Also, these functions can be (and should be) tested before sending the panels to the field.

Thus, in a digital substation project, by having a carefully planned, designed and executed FAT, the commissioning time should decrease drastically by weeks or even months depending on the substation size. In a conventional substation, the interconnection between primary equipment in the yard and the PAC devices are through hardwired copper cables, and most of commissioning time is on checking the interconnection of the copper cables. In a digital substation environment, these interconnections are "virtualized" through VLANs or Multicast filtering in the process bus, and QoS queues can still be used for prioritization of network packets. Thus, if the network is well tested in the FAT, the field tests during commissioning are basically checking the cabling between the primary equipment and the merging units, from which both are in the switchyard. After checking analog signals, the protection actuation and interlocking logic controls does not need to be rechecked since they were previously tested in FAT.

## Main requirements

To guarantee time savings in field services in a digital commissioning project, there are some points that utilities, end users and manufacturers should pay attention to: project drawings, FAT requirements, and scenario simulation.

The beginning of a well-executed project of a digital substation is not different from a project for a conventional one. However, as most signals in a digital substation are available to IEDs through a switched network, the network project should be much more detailed than it is generally done today. Three-line diagrams and terminal block interconnections are replaced by switch ports configuration, VLAN, multicast MAC destination, QoS class definitions, and so on. Thus, a more detailed network architecture should be represented for proper configuration afterwards. The following figure is a good example of how a network should be represented in a project for proper IED configuration.

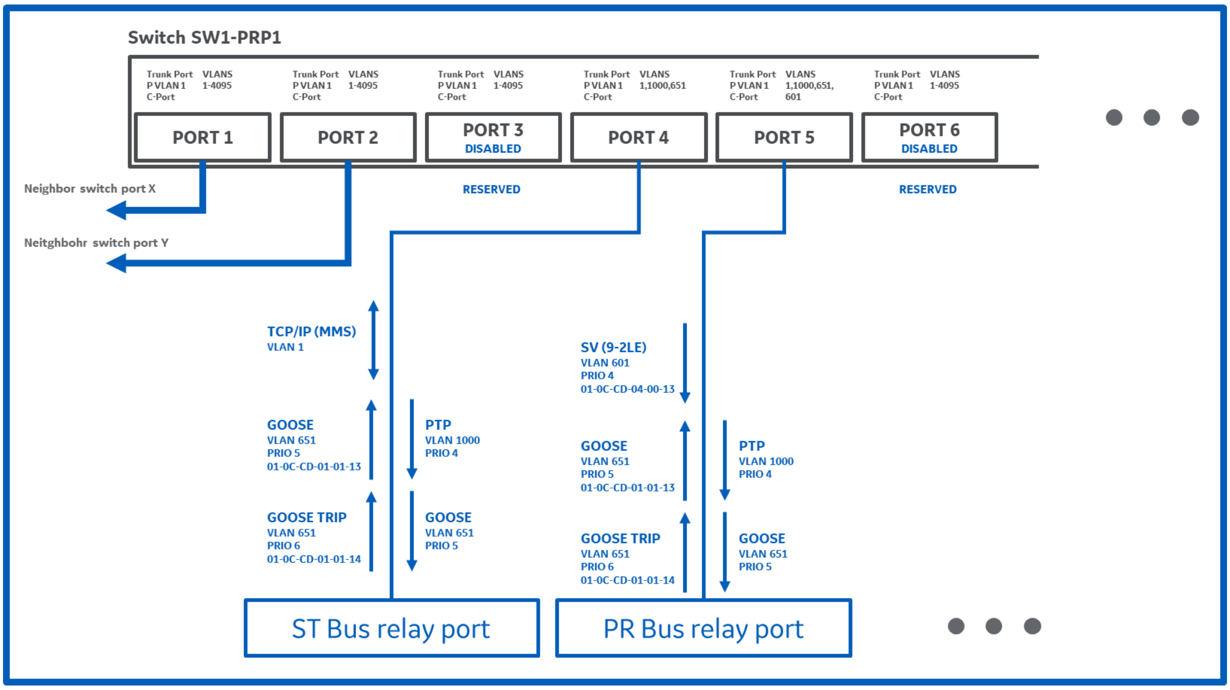


Figure 9 - Example of network project containing IED configuration information.

In addition, FAT requirements should guarantee that the system and its performance are tested in this controlled scenario. FAT plans should consider system testing not only in normal operation but also in contingencies situations, such as overload on the network or failure in IED connections. For a completely new digital substation, it is recommended that all panels are mounted and interconnected as they will be in field, so that a real simulation of the system could be performed. For a system expansion, where FAT is performed only for a few bays, utilities can use software-based traffic simulators to test network performance, and real-time power system simulation or protection test-sets to ensure protection performance. In both situations, networking load, along with IED and switch behavior must be verified for worst case scenarios such as when there's a loop in the network or when a temporary overload occurs, like broadcast storms for example.

## Real case study

The project used in this example is composed of a main substation and three additional bays in two adjacent substations. The project has in total six 220 kV bays, six 60 kV bays, one 22.9 kV bay and one 10 kV bay. There is a full PRP network, where process and station bus share the same physical infrastructure with logical traffic segregation done using VLANs.

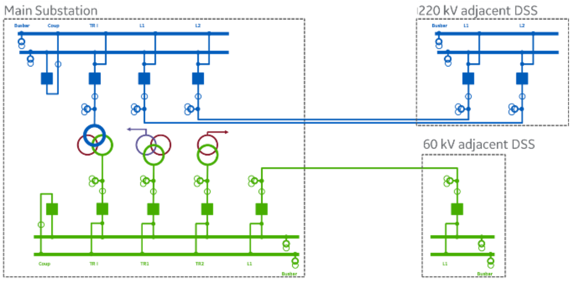


Figure 10 - Single Line Diagram from example system.

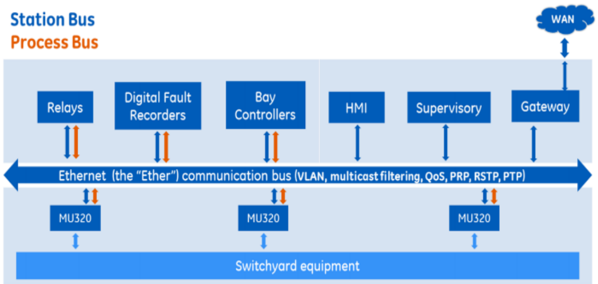


Figure 11 - Process and Station Buses strategy: single shared switched network infrastructure.

The first step on this project was the network project detailing, executed before the FAT, which inform the IEDs connected in each switch port, VLAN IDs for each stream, QoS queues, MAC destination addresses, GOOSE and SV IDs and APP IDs, were selected and described at the network project. With the detailed network design, network configuration and initial checks (equipment health and network status with all equipment connected), including GNSS clocks, Ethernet switches and all Merging Units were performed in two days of engineering work in factory during FAT.

In this FAT, protection and control equipment were not available while the network was configured and checked, so the step of having all the system running during FAT could not be performed. Even though the relays were validated separately using a dedicated process bus for FAT testing, this was a simulated check, not a complete system test, limiting the benefits of identifying possible issues before commissioning.

After FAT, the PAC system installation at site took a few days, instead of weeks, which was clearly understood as a benefit of a digital substation when compared to conventional systems. Also, as protection and interlocking functions were individually tested in FAT, commissioning efforts were basically checking primary equipment connection with merging units in the switchyard. This was performed by checking the IED measurements, which took much less time to complete in comparison to the usual approach.

On the other hand, after integrating the protection device along with the system network, some issues were identified, such as time synchronization, configuration mismatch and bad network performance. These issues could have been anticipated in FAT if the full system were available. Regardless the issues listed, the main protection and automation functions were running after using alternate time synchronization for the merging units, enabling the substation to be energized on time. In addition, as the system design implements a full PRP network, field engineers were able to perform several diagnostics in one network, while the other one was running normally.

### Final comments from real case FAT

Several advantages in digital SS project execution have been observed once the project was fully deployed and substation was under operation:

- Time for commissioning decreases from months to days or weeks, depending on substation size, given most operational functions can be tested during FAT;
- When using redundant networks, diagnosis and fixing issues can be performed in a live system, with no need to shut down transmission lines and busbars;
- PAC services are now related to network diagnosis, which is safer and easier to be performed if compared to tradition substations;

As lessons learned from this real case FAT, there are some points that utilities and manufacturers should pay attention to avoid delays on the project and unwanted execution issues:

- Network project should be detailed enough so field engineers do not need to decide or load IED parameters in the field, as it is in general done nowadays;
- FAT tests should be planned to guarantee that the system will be simulated in a real situation, with all merging units, switches, relays, clocks and others IEDs in operation, so field issues can be detected and diagnosed before commissioning at site;
- Network should be designed in a manner that a live system can be tested and diagnosed without compromising power system operation, or the operation of nearby bays.

## 6. Conclusion

Fully digital substations are already a reality, with installed base growing more and more every year. One of the most challenging parts of moving to this kind of substation is the network engineering. Although Ethernet network communication has not been so popular in PAC systems until the introduction of digital substation, the networking technology required for PAC systems is mostly on Layer 2 and require engineers to understand concepts like network architecture, redundancy, traffic segregation and prioritization, mainly.

Real projects have shown digital substation brings several benefits, starting with reduction of civil costs, including less electrical cabling for primary equipment monitoring and smaller footprint of substation. On a safety perspective, digital substations only use fiber between switchyard and relay room, avoiding the risk of opening the secondary of current transformers for instance. Lastly, it has proven the time spent on device configuration and FAT can be greatly reduced in digital substation, since a detailed network project was designed previously in order to engineers work on equipment configuration and all devices are available so operational tests can be performed using simulation tools prior SAT.

Connecting IEDs of digital substation to an Ethernet network as plug and play without a network project can lead to system failure, jeopardizing the entire substation. Even though this may sound as a barrier for adopting digital substations, learning the network concepts overcome in anyway the benefits brought by such solution. This is just a matter of getting familiar with the protocols and putting thoughtful consideration into this part of the project. Disruptive technology, such as digital substations, requires people to adapt and only then we can unleash the full potential of it.

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