Modernizing grid communications in the heart of South America

With a fully redundant IP/MPLS network, ELFEC increases grid reliability in Bolivia

Overview

For over one hundred years, ELFEC S.A. has been distributing electricity in Bolivia. One of the company's early achievements was a small hydroelectric plant with 200kVA of power. Built in 1909, it powered the new electric tram for urban public transport. Much has changed since then.

Today, ELFEC is Bolivia's second largest electricity distribution company, and has 523MVA of installed power. ELFEC owns and operates the only electrical distribution system in Cochabamba. Cochabamba is the most densely populated of the nine 'departments' that Bolivia is divided into. The department covers an area of 55,621 km^2 and has a population of about 2 million.

To manage today's grid, reliable communications are vital. When ELFEC began to modernize its grid in 2014, the company realized it also needed to rethink its communications.

Previously, ELFEC had relied on several telecom providers for connectivity to remote branches. The latency on these leased lines was too high to support applications such as billing and video surveillance. ELFEC also sourced wireless communications for 26 SCADA remote terminal units (RTUs) from telecom providers.

To reach four of its hub substations, ELFEC deployed optical ground wire (OPGW), using a star topology. "On these links we were running teleprotection between substations, and the SCADA data without Quality of Service (QoS), plus services like video surveillance and telephony directly connected to the substation switches," said Alvaro Guilarte, Substation Manager, ELFEC. Without QoS, there was no delivery assurance for critical operational traffic, such as teleprotection and SCADA, which should have priority.

This communications infrastructure had no redundancy protection. A network failure would disrupt grid communications.

ELFEC S.A. Grid

- 620,000 homes and businesses served
- 3,900km of electrical lines
- 523MVA of installed power
- 16 substations
- Seven 115kV high voltage lines in the central zone
- Two 230kV lines in the tropics zone
- 74 medium voltage feeders (10kV, 24.9kV and 34.5kV)
- 340 reclosers and sectionalizers

elfec

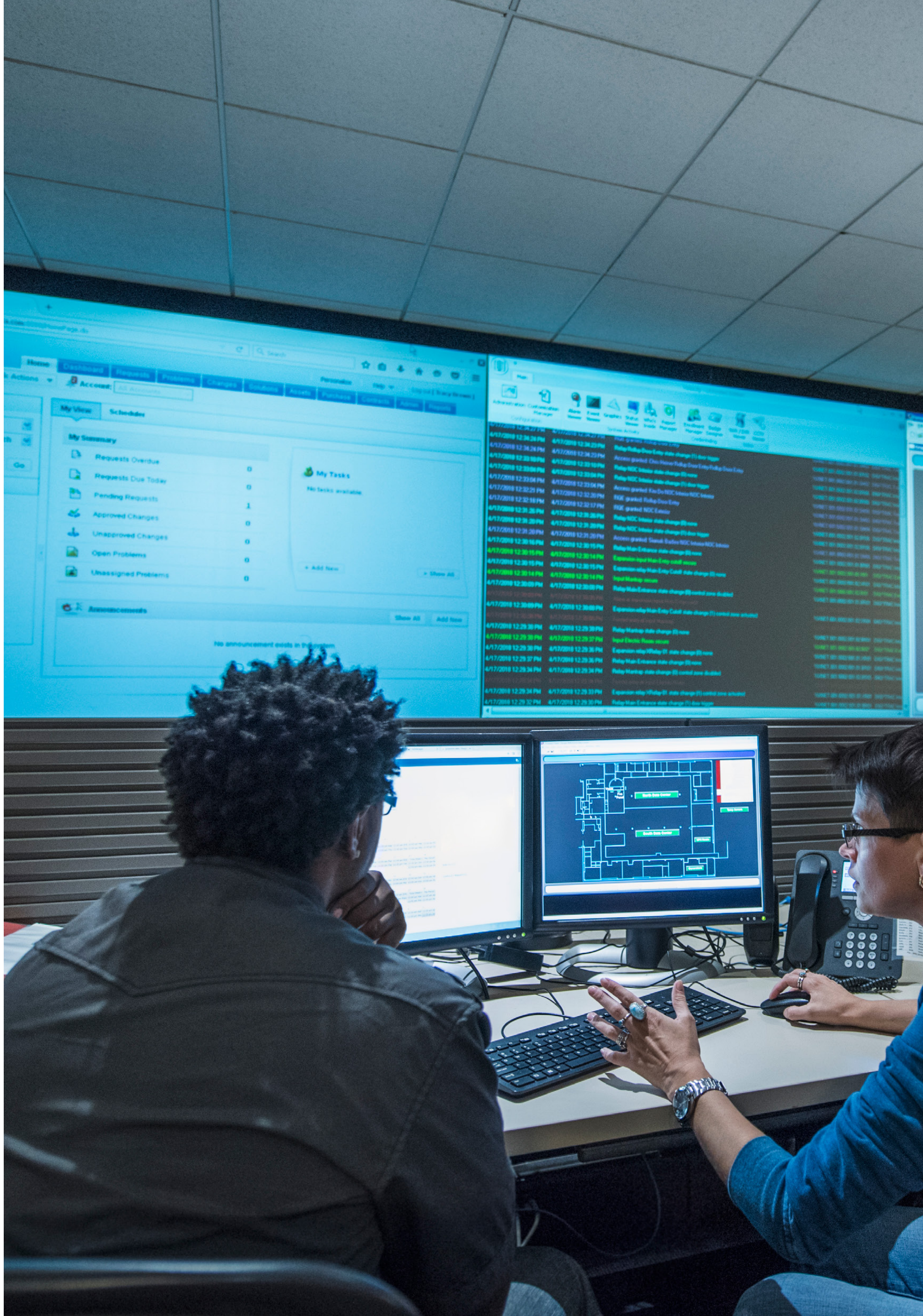
Empresa de Luz y Fuerza Eléctrica Cochabamba

The need for a new communications network

To manage the grid effectively, ELFEC needed a number of communications systems:

- Connectivity to 32 remote branch offices in provinces with high customer concentration
- VHF radio for taskforce and dispatch communications with field crews
- SCADA communications with substations and with RTUs deployed on the electrical lines
- Teleprotection communications between substations
- Video and voice communications for remote substation surveillance
- Synchronous and asynchronous communications between Intelligent Electronic Devices (IEDs) within substations

ELFEC wanted to set up a modern, robust, and flexible communications platform that could be used for all of its systems and assets, including those used for voice and video. That platform was to deliver a resilient transport backbone network for ELFEC’s communications needs, both today and in the future. Importantly, there was to be a secondary fallback network based on a different transport medium. This would add redundancy in the event of the primary network going down, so ELFEC could maintain visibility and control of the grid. ELFEC wanted the flexibility to extend its new network to capture SCADA data in substations and RTUs in the distribution grid.



Building the transport infrastructure

Optical fiber was chosen as the primary transport medium. It is field proven as the transmission technology best able to provide immense bandwidth with high reliability. Fiber is well suited for both SCADA transport and voice and video data. ELFEC was already using fiber to connect to four hub substations.

The new fiber optic backbone was built on the existing electrical grid infrastructure. OPGW, Optical Phase Conductor (OPPC), or All Dielectric Self Supporting (ADSS) fiber was deployed on the high and medium voltage transmission lines. The fiber connected the substations to each other as shown in Figure 1. The backbone topology was a redundant ring. If a link or node were to fail, there would be an alternative path to ensure communications were not interrupted.

On top of the fiber transport, ELFEC deployed an Internet Protocol/Multiprotocol Label Switching (IP/MPLS) network. IP/MPLS supports a wide range of applications, including SCADA, teleprotection, and video. It enables QoS, complete flexibility in network topologies, and has multi-fault resiliency.

A core router (Nokia 7705 SAR-8) was deployed in each substation, connecting to other substations with two 10 Gb/s optical links running IP/MPLS, OSPF, IEEE 1588v2 for synchronization distribution, and IEEE C37.94 for the redundant tele-protection channel. (See Figure 1).

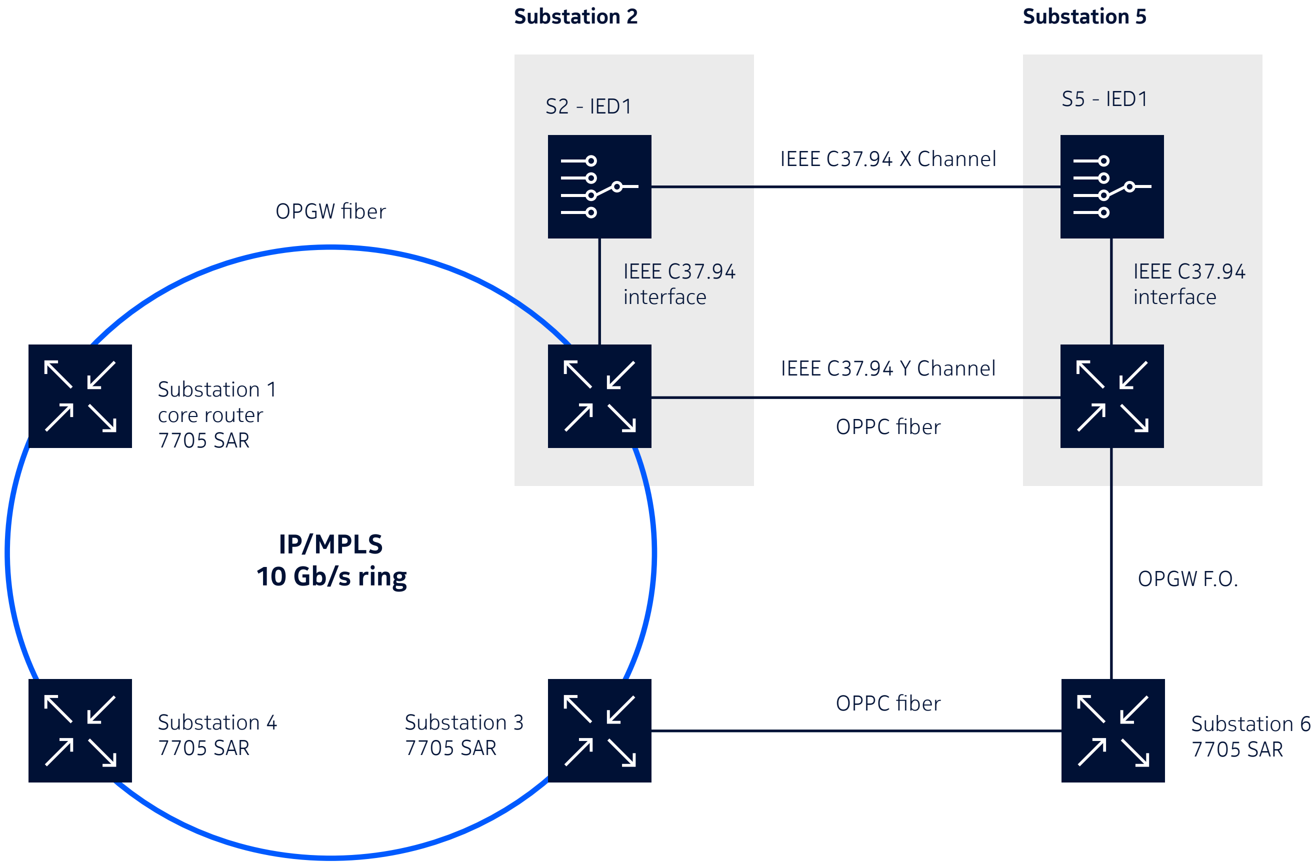


Figure 1. The IP/MPLS network topology that connects substations and grid assets over the fiber transport

For the fallback transport, ELFEC chose wireless. The capital city of the Cochabamba department is also called Cochabamba, and is the fourth largest city in Bolivia. It’s surrounded by mountains, so there are lots of high places to position wireless access points for optimal coverage. ELFEC chose the 802.11ac WiFi technology as the transport medium. It operates in the 5GHz band and offers a channel bandwidth of 20MHz. Multiple-input multiple-output (MIMO) technology was used to increase the data throughput and signal resiliency against adverse atmospheric conditions.

Parabolic and sector antennas were used to establish point-to-point and multipoint links. The location of each access point was chosen using detailed propagation studies that simulated transmitter power, sensitivity, and antenna gain. The location of the remote branches and RTUs that would connect to the antennas was also considered. High-gain antennas and power transmission engineering were used to achieve optimal results.

An IP/MPLS network was deployed on top of the wireless transport, too. A Nokia 7210 SAS-K12 switch running IP/MPLS and OSPF connects to an access point tunneling IP/MPLS traffic through the wireless link. To protect the network from wireless interference, a self-healing ring was configured with repeaters on the top of the mountains.

For security, AES-256 encryption protects all data and user management information inside the point-to-point generic routing encapsulation (GRE) tunnel. Each access point was configured to block connections that were not explicitly permitted.

The repeater is a critical point in the communications network, so each site has a battery bank system for redundant power protection. The power scheme uses AC power as the primary feed and a photovoltaic battery for backup. Both are controlled by a power monitoring application developed in-house by ELFEC’s R&D team.

IP/MPLS ring carrying Ethernet pseudowire atop a wireless bridging domain

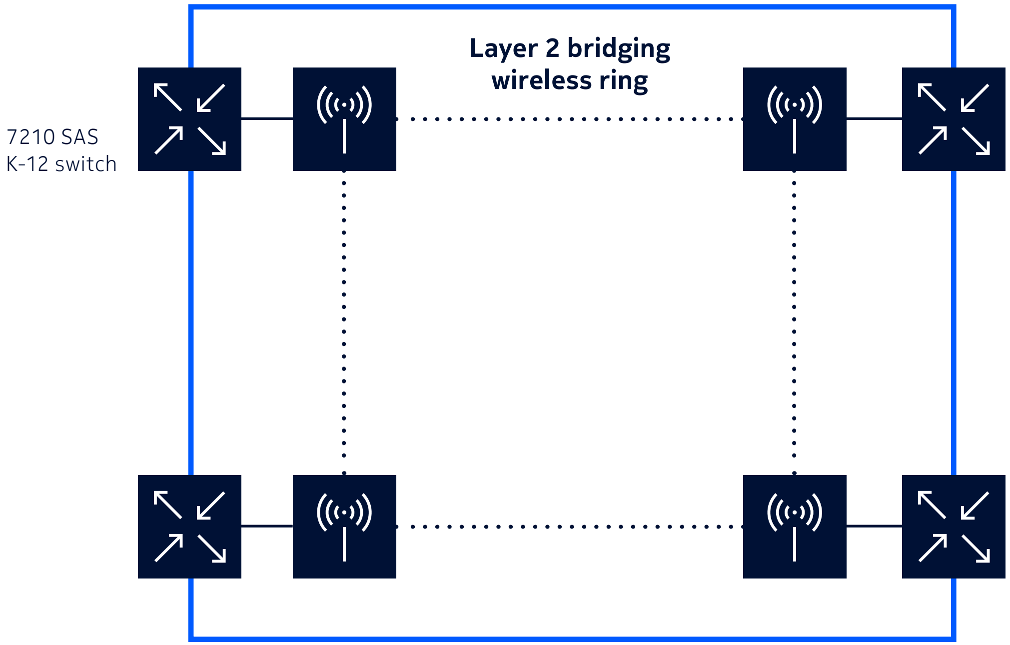


Figure 2. Topology for wireless infrastructure used for fallback connectivity

Building the communications platform

Now that ELFEC had a robust transport based on fiber and wireless, the company could deploy the communications platform for the distribution grid. There are two principal components that need communications: substations and RTUs in the field. Both need a reliable path with redundancy protection to send SCADA data to the operations center.

In the substations, industrial Ethernet switches were already installed for communications between IEDs. They were also used to send data to the main SCADA server in the datacenter in the main company building. But the switches could not segment traffic nor apply QoS when video and data traffic was running alongside SCADA data. Thanks to the Nokia 7705 SAR-8, all traffic is now segmented with QoS assurance applied on all data.

As seen in Figure 3, the Nokia 7705 SAR-8 aggregates all the multimedia traffic. The Nokia 7210 SAS-T industrial switches only need to forward the communications data from the IEDs. These switches support a highly redundant topology that uses Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR) and improves IEEE 1588v2 synchronization distribution reliability.

“With the new communications platform, all our services are segmented, and the switches work as they should, dedicated to coordination and communication between IEDs,” says Guilarte.

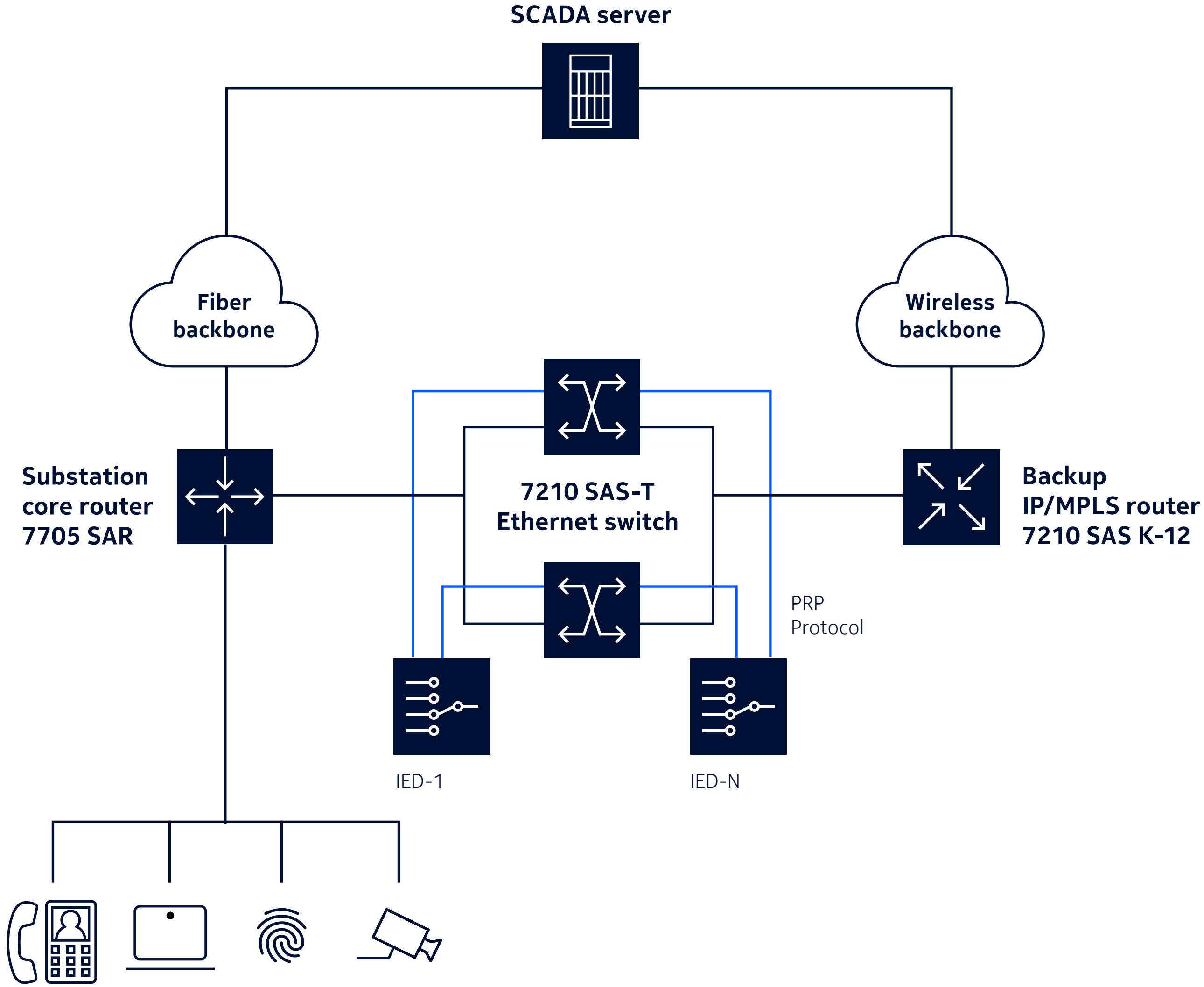


Figure 3. Redundant substation IP/MPLS networking user fiber and wireless links

The IP/MPLS network provides dedicated VPN tunnels for IEC61850-based Multimedia Messaging Service (MMS) and GOOSE message exchange between substations that are connected to each other in the grid. This enables transmission lines to be restored from a fault, using coordinated direct transfer trip (DTT) on protective relays over the IEEE C37.94 optical interface. The IP/MPLS network also supports control logic based on the IEC-61850 standard.

In the past, a RTU in the field could only send data wirelessly. Now, with IP/MPLS on top of the optical transport backbone, a field RTU sends data to the attached 7210 SAS-K12 which has connectivity using fiber. The RTU also has wireless connectivity for redundancy, similar to the substations (See Figure 4).

The IP/MPLS network also provides backhaul of VHF traffic for voice communications with the field crew. The VHF radio system was upgraded to an IP-over-radio system from an analog trunking system.

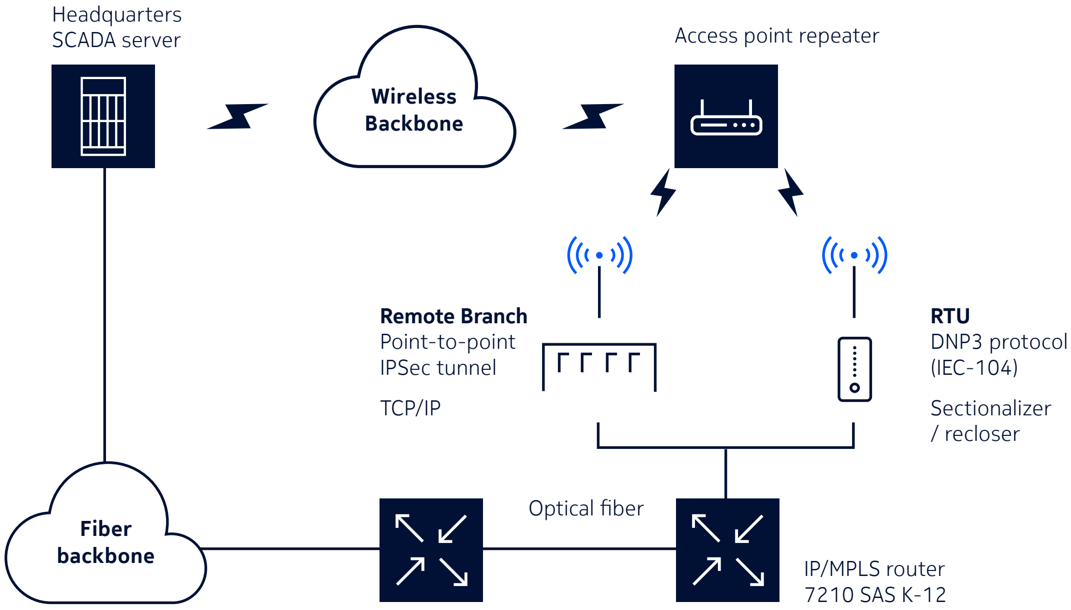


Figure 4. Redundant IP/MPLS connectivity for remote branches and RTUs

Increased grid reliability

"Substation reliability has been dramatically improved since deploying the IP/MPLS network," says Guilarte. "With the deployment of the Nokia 7705 SAR in each substation, we are running a redundant IP/MPLS ring that supports teleprotection using the IEEE C37.94 standard. The redundancy in the fiber ring is a lifesaver in case of a problem or failure on the OPGW fiber main circuit. By improving our communications reliability, we also improved our response time and reliability indicators for the grid."

He adds: "We are excited about adding this capability to all our other substations soon, so they can have the same advantages and reliability."

Alvaro Guilarte – Substations Manager at ELFEC S.A.

Multimedia for branch offices

ELFEC is also deploying commercial IT systems that require communications. For example, remote customer service branches need adequate bandwidth for data, video, and voice.

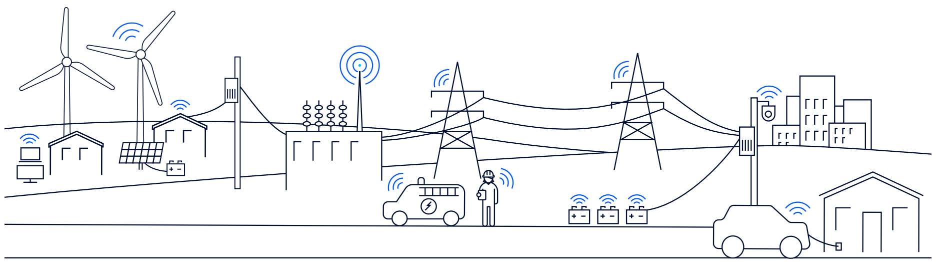
As the IP/MPLS network continues to roll out, each branch office will be provided with a dedicated 1 Gb/s link for multimedia data traffic. To provision this service, the substation core router will have a transparent tunnel originated from the attached 7210 SAS K-12 switch that connects to the office. With this dual-homing design, each office also will be able to use either the IP/MPLS network or the wireless network as a fallback communication medium.

Next steps

For ELFEC, the next step is to launch a Mobile Private Network (MPN) based on new spectrum, so the company can start connecting passive grid assets. These include capacitor banks, regulators, tripsaver fuses, and fault indicators. With the real-time grid data from these assets, the electrical grid can advance towards becoming self-healing without human intervention.

The deployment of an advanced metering infrastructure (AMI) system is also on the roadmap. The new AMI network will need to send information collected from the data concentrator units (DCU) or gateways to the servers in the datacenter. The AMI communications will be based on ELFEC's new IP/MPLS communications network.

Moreover, with the emergence of electric vehicles and charging stations, the new network will provide essential communications between machines, applications, and people for intensive grid monitoring.



Challenges

- Establish reliable, redundant communications to branch offices, substations, and RTUs on the electrical lines.
- Support video and voice traffic alongside SCADA and other operational data.
- Establish a platform for growth using flexible protocols that can support future applications.

Solution

- Optical fiber was chosen as the primary transport medium, with wireless for the fallback network.
- On both networks, IP/MPLS was used to implement a redundant ring topology.
- Nokia 7705 SAR-8 routers provide the reliable connectivity required, with a wide range of interfaces for new and legacy equipment.
- Nokia 7210 SAS-K12 switches are deployed in the wireless network.
- Nokia 7210 SAS-T industrial switches are used within substations to forward data from IEDs.

Benefits

- Services are segmented on separate VPNs and QoS is applied to all traffic.
- The redundancy in the new communications network has enabled ELFEC to increase communications reliability, and improve its response time for issues in the grid.
- Substation reliability has improved dramatically.

Conclusion

In the era of the digital utility, IP/MPLS is an important enabler for grid operations. From backhaul for voice connections with field crews, to real-time multipoint machine communications between IEDs, a versatile, reliable network is essential. ELFEC's new IP/MPLS network will play a central role in helping ELFEC to deliver a reliable electricity service, based on a modern grid architecture.

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