Integrating Utility Legacy Devices into a Modern IP-Based Communications Infrastructure

By Emmanuel Duvelson

With the increase of IP-based Intelligent Electronic Devices (IEDs) in substation automation applications, Ethernet networks are becoming more common in the substation. With the deployment of Ethernet communications infrastructure in the substation, utilities are cutting costs by eliminating the need for overlay networks that require different equipment for different service types. In general, Ethernet networks are less-costly to build, and handle data transfer more efficiently than the traditional circuit-switched, time-division-multiplexed (TDM) networks. While utilities are building new Ethernet network infrastructure to support IP based devices, they are forced to maintain the legacy substation telecommunications network to support legacy devices since the two systems are incompatible. The challenge is, how do you integrate utility legacy devices into a modern IP- based communications infrastructure and take advantage of the benefits that an IP-based telecommunication network offers?

Legacy Substation Communications

Inter-IED communications (i.e. signaling exchange of information) were typically achieved via arrangement of rigid wiring between devices and low-speed serial communications. Signaling was often attained by having outputs of one IED connected to the inputs of another. This scheme proved to be inflexible and limited in its scope of control. More-advanced inter-IED control designs required a large number of wiring interconnections between multiple IEDs and, thus, were not practical to implement. Low- speed serial communications were often limited to Master/Slave half-duplex operations and, thus, render peer–to-peer communications between IEDs unfeasible. Transporting IED data was typically done using “Plain Old Telephone Service” (POTS) leased lines. This is illustrated in Figure 1.

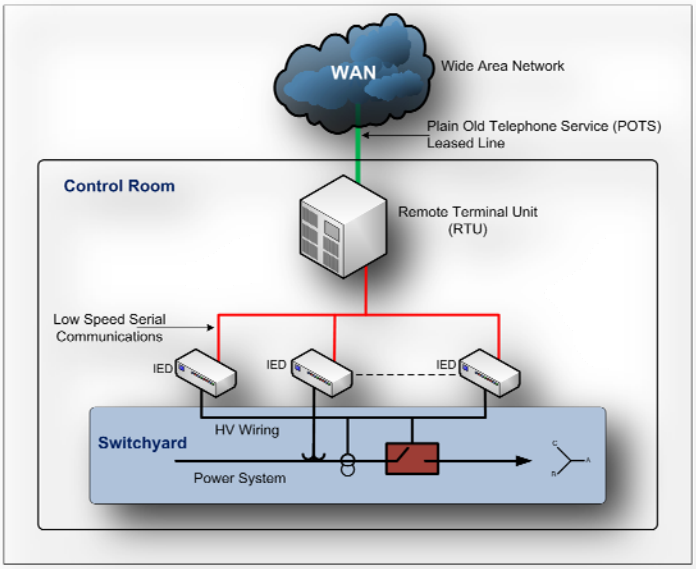

Figure 1 - Typical Legacy Substation Communications

In the 1970's, utilities began deploying communications to substations, in some cases having looped source feeds for the purpose of providing distance protection pilot schemes such as "Permissive Overreach Transfer Trip" (POTT) high-speed relaying between the substations. Early substation communications circuits used dedicated leased POTS lines as the medium of transport for "Frequency Shift Keying" (FSK) IED equipment. In the 1990's, utilities began installing fiber-optic cables between substations to enhance substation-to-substation communications, and in some cases utilizing Multiplexers on SONET using channel division at T1 speeds. Both of these methods are still in use today for two main reasons. First, they provide a low latency between devices, which is critical both for teleprotection and relaying. Second, a cost-effective solution may not be available that could be used to retrofit existing configurations without the need to replace the IEDs with more-advanced models that support a more-common communication platform such as Ethernet.

Current trends in the electric utility industry, specifically in substation automation, have converged upon a common communications architecture with the goal of having interoperability between various IEDs found in the substation. This initiative started in the late 1980s and was driven by the major North American utilities under the technical auspices of EPRI (Electric Power Research Institute). The resulting standard that emerged is known as the Utility Communications Architecture 2.0 (UCA2.0). This standard has developed into an international standard known as IEC61850, and is being adopted worldwide by utilities and IED vendors alike, and Ethernet is the underlying network technology. As a result, Ethernet communications products and applications are rapidly becoming more entrenched as the new standard for data transport to and within the substation.

Modern Substation Communications

Today, Ethernet is the predominant and most-popular networking technology used in office and home environments. As mentioned earlier, their use is quickly becoming popular for industrial and utility applications including substation automation. Originally, Ethernet networks were not developed with the intention of being used in substations and harsh environments. But in the early 2000's the need to consolidate substation communications to one common network platform was identified. The main reason for considering the change was simply to take advantage of additional benefits enabled by new technologies such as Ethernet.

The widespread use of multifunctional IEDs with advanced communications capabilities has resulted in a new trend in substation automation systems: the implementation of high-speed peer-to-peer communications-based control schemes. The IEDs exchange messages over what we today call the substation "Local Area Network" (LAN). The communication messages replace the hardwire interface between control devices in conventional substations in order to perform critical control functions as well as other user-specific distributed control or recording applications.

In order for the this new trend to be successful, the communications equipment used for the substation LAN or to interface with the utility "Wide Area Network" (WAN) need to meet the same or higher voltage withstand, environmental, and performance requirements than the existing control devices being integrated into a distributed control system. This is due to the fact that a failure of a single element of the substation LAN, such as a switch or hub, will result in loss of communications between the different IEDs.

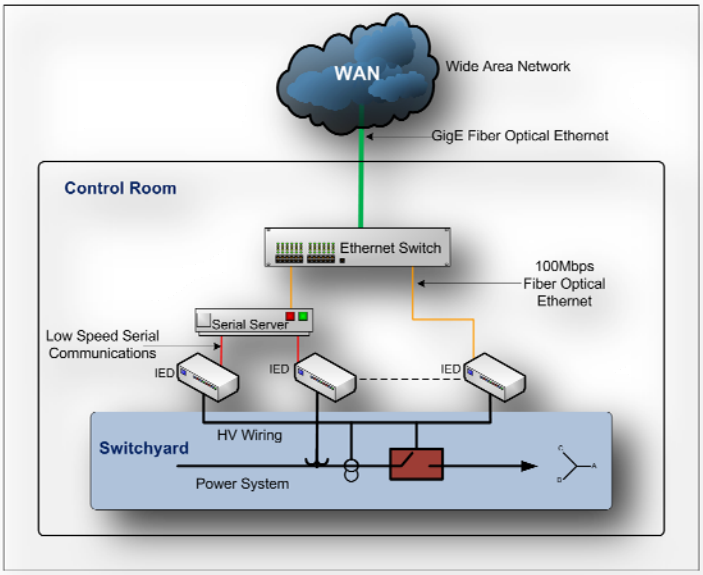

Figure 2 - Typical Modern Substation Communication

These concerns resulted in the standard known today as IEEE-1613: standards for "Electromagnetic Interference" (EMI) immunity and environmental requirements to ensure reliable operation of networking equipment in substation environments. Therefore, if Ethernet devices are to be used in substation automation applications, they should comply with IEC 61850-3 and IEEE-1613 standards.

Ethernet over fiber optics is the growing trend in substation automation and offers many advantages:

- Peer-to-peer communications
- Multiple Masters
- Client – Server vs. Master – Slave
- Reduced inter-IED wiring
- Coexistence of multiple protocols (i.e., DNP, Modbus, IEC61850) on the same physical network
- Data over IP for easy access to substation data
- Higher data transfer
- Higher bandwidth
- Faster network recovery protocols

How legacy and IP-based devices can coexist on the same communications platform

Although Ethernet is the growing trend in substation communications, unfortunately, not all IED vendors choose to follow international standards. And even if all IED vendors followed the international standards, utilities have already invested in the legacy communications infrastructure which cannot be completely replaced overnight. The cost of replacing all the legacy IEDs may not fully justify the

advantages that new, advanced IP models offer. As a result, utilities are forced to search for ways to allow the coexistence of legacy and more-modern Ethernet systems on the same communication platform, eliminating the need to build and maintain two or more separate networks.

Serial Servers which utilize Serial-to-Ethernet technology, is one of the solutions that allows integrating serial and IP devices onto one common platform. This technology creates a transparent serial tunnel over Ethernet with few changes to the existing setup. This solution, although workable, adds another level of complexity since additional equipment such as Serial Servers and Ethernet Switches are needed. Furthermore, the serial server does not address the need for connecting traditional voice and video over the same Ethernet platform. This is illustrated in Figure 2.

A more cost-effective and complete solution which is currently available uses TDM over IP (TDMoIP™). TDM over IP was developed to allow synchronous TDM data, such as T1/E1 services, to work over an IP network. TDM services can be used to transport synchronous data, asynchronous data, 4-wire telephone quality voice, POTS, high quality audio, analog telemetry, or any other low speed communications requirement. This technology allows point-to-point legacy equipment to share in the benefits of a packet switched network. Deployment and maintenance is easier than full TDM networks, and the user gets the benefits of shared bandwidth and automatic recovery of a packet network.

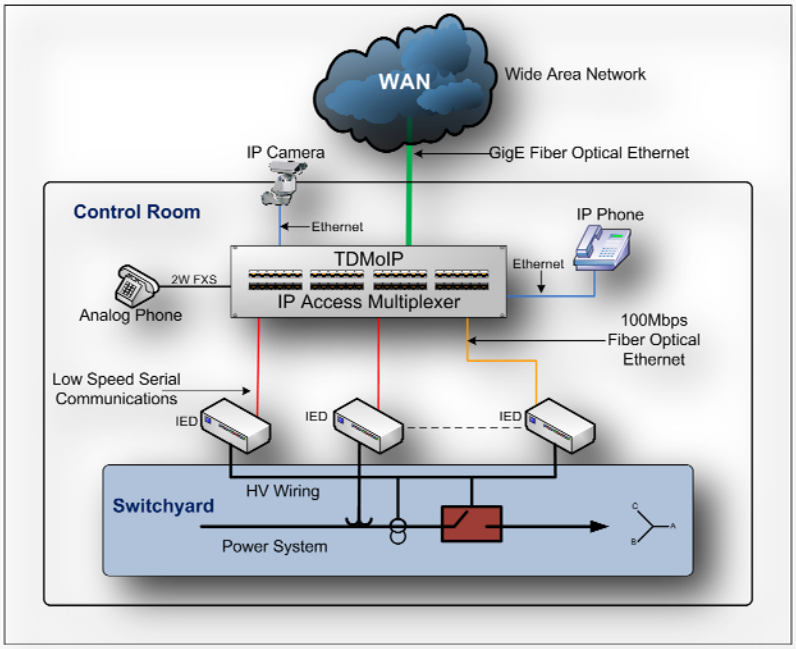

Figure 3 - Typical Modern Substation Communications with TDMoIP

With TDMoIP technology, every legacy substation device, whether serial data, voice or video, can coexist with IP-based devices on the same communications platform. Converging two important traffic types onto one infrastructure, provides the benefit of connecting traditional voice, video and data over Ethernet networks and taking advantage of the simplicity and efficiency of IP routing and Ethernet switching. These benefits have become an attractive alternative to running parallel voice and data networks. They help save money on call and leased-line service charges, while consolidating management, cutting maintenance costs, and increasing user productivity.

To render the TDMoIP solution more cost effective, manufacturers need to develop equipment that can integrate TDM DS0 legacy interfaces (such as Voice, RS-232, RS-449, V.35, G.703, C37.94 and T1/E1 interfaces) with a Layer 2 Managed Ethernet Switch that includes GigE at the WAN side. That

solution would eliminate the need for costly serial servers, managed switches, legacy multiplexers, and high-end SONET solutions. A single product solution would provide the ability to seamlessly transport Voice, Data, and Ethernet communications over Ethernet networks; providing the flexibility of backward compatibility with legacy devices and forward compatibility with IP devices on the same communications platform.

Once a substation-hardened TDMoIP-IP Access Multiplexer is chosen due to its ability to provide a stable solution over fiber at link speeds of up to 1GB, legacy IEDs, IP-based surveillance cameras, Analog Phone, IP Phone, protective relay engineering access and oscillography can be moved to the Ethernet network for integrated communications, allowing information to reach other stake holders within the Utility Enterprise. This is illustrated in Figure 3.

Conclusion

Substation communications is continually evolving as newer technologies are adopted. What started out as rigid wired arrangements between IEDs and onto the WAN via leased POTS lines is becoming a substation communication system optimized for data networking, using packed-based switching, able to support multifunctional IEDs with advanced communications capabilities.

As the telecommunications industry inevitably moves towards Ethernet, migrating technologies, such as TDMoIP, makes it possible for utility legacy devices and more-modern IP-based devices to coexist on the same Ethernet platform infrastructure, eliminating the need to maintain multiple networks. As technology continues to evolve, future demands such as Teleprotection and Relaying over Ethernet will also be possible. Telecommunications vendors are now faced with the challenge of providing a simple one-box solution that can eliminate the need to have an overlay of multiple devices for the purpose of achieving a common communications platform.

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