UTC Journal

UTILITIES TELECOM COUNCIL

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The Utility-Public Safety Partnership

- LTE and 700 MHz: Exploring the Opportunity
- The Need for Spectrum and New Technologies
- **Gulf Power Case Study: Pilot Relaying Communications Over Ethernet/IP**
- **UTC 2012 "Best Telecom Equipment" Product Award**

Gulf Power Case Study: Pilot Relaying Communications Over Ethernet/IP

There is no doubt that today's communications infrastructure for telecommunications, industrial industries, including critical infrastructure such as the Public Switched Telephone Network, are migrating toward an all-packet-based transport network. As noted by Force10 Networks in a 2009 white paper, "Once viewed solely as a new high-speed interface for data services, Ethernet is now broadly accepted as a converged-layer technology for delivering the full array of packet-based voice, video and data services."

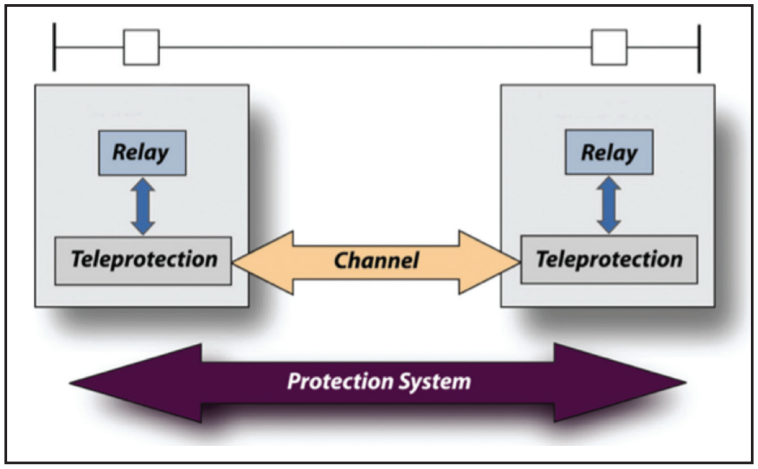
The modern substation communications system is becoming optimized for data networking, using packet-based switching and able to support multifunctional IEDs with advanced communications capabilities. Most importantly, protective relays and teleprotection devices that use data communications as part of their operating principles have very stringent requirements with regard to latency and reliability. Providing that channel over an Ethernet/IP-based infrastructure poses a challenge for these existing devices that are designed for direct fiber, T1/E1, or SONET/SDH networks.

While the development of advanced features and an understanding of the requirements are paving the way to implement pilot relaying over Ethernet/IP communications infrastructure, the big question is whether Ethernet/IP can provide the dependability and security required for pilot relaying communications.

Pilot Relaying Channel

The basic concept of pilot relaying as applied to line protection refers to the communications network implemented on the high-voltage transmission line to transmit trip signals to and from two or more substations. The intent is to compare conditions at the two line ends to determine if there is a fault on the protected line section and trip the selected few circuit breakers as fast as possible, thereby protecting the line. This is illustrated in Figure 1.

Pilot line protection has been in use for many decades. The first communication links were pilot wires and power line carrier carrying "data" in analog form. The signal generated by the pilot relays are transmitted through the power line itself by means of a line tuner. The line tuner couples the pilot relay's carrier signal to the power line's 60Hz signal. Wave traps are used to make sure the signal does not travel beyond its intended destination. For a network of substations, a communications network is used to link all the substations and serves as the communications channel between pilot relay protection segments.



▲ Figure 1: Pilot Relaying

Communications

The first telecommunication channels deployed for relaying were voice channels over analog microwave and analog phone lines. As telecommunications evolved into the digital era, relaying channels followed. There is now pilot relaying performed over digital phone lines (via CSU/DSUs); however, most

By Emmanuel Duvelson

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Gulf Power Case Study

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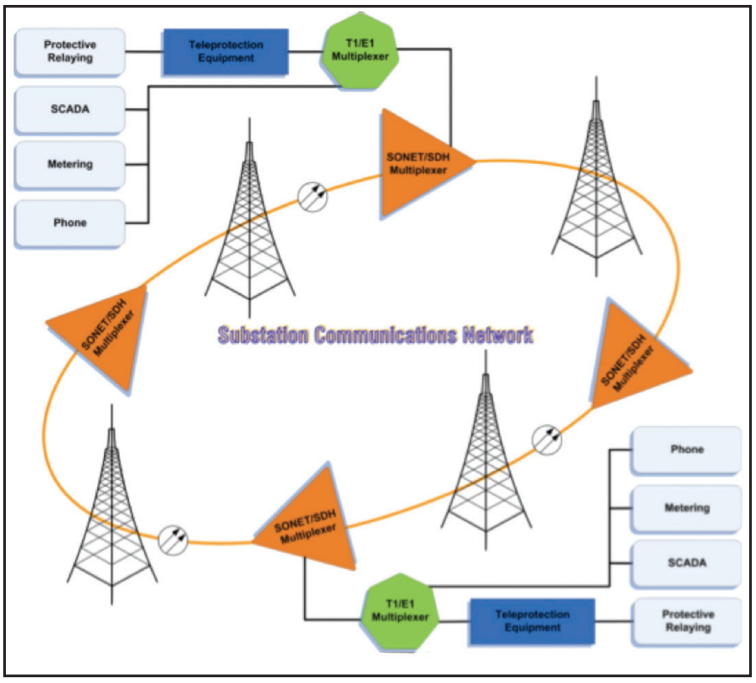

▲ Figure 2: TDM Substation Communications Network

protective relaying and teleprotection communications use T1/E1 and SONET/SDH TDM multiplexers for their pilot channel. This is illustrated in Figure 2.

Although TDM networks are not bandwidth efficient and have high cost, these types of communications networks are still deployed for two main reasons: They provide a low pre-deterministic delay between the end devices and high availability that guarantees data delivery at 99.999 percent of the time, which are ideal for real-time critical applications like pilot relaying.

Why Ethernet/IP?

The global migration toward Ethernet/IP started with the concerted effort to standardize upon a common communications architecture, which has Ethernet as the underlying technology. Ethernet is a packet-based technology that offers many advantages over the traditional TDM network. Unlike the TDM technology such as T1/E1 and SONET/SDH, messages are separated into variable-length segments and transmitted individually across dynamically created connections. The nature of this technology results in the flexible use of bandwidth providing a more-bandwidth-efficient network. Ethernet offers a flexible architecture that easily accommodates different network topologies, flexible circuit routes, and multiple protocols on the same network. Newer protocols such as multi-protocol label switching (MPLS) and technology like TDM over IP emulate SONET/SDH system attributes over a converged network. Ethernet/IP operates on a worldwide open standard ensuring interoperability between different vendors and offers procurement flexibility so that customers need not be locked into a specific supplier. Ethernet/IP networks are also less costly to build due to lower-cost equipment.

Dependability and Security

Although Ethernet provides many advantages over traditional TDM technology, it is not without its challenges. Dependability and security are major concerns when using Ethernet/IP networks in the transport of mission-critical applications.

With the implementation of Critical Infrastructure Protection (CIP) Reliability standards developed by the North American Electric Reliability Corporation (NERC) for cyber security, networks are now more secure against cyber attacks. Moreover, as stated in the 2007 UTC research report on NERC CIP standards, "Much of the technology needed to meet NERC CIP standards is embedded in most networking equipment such as switches, routers and firewalls." As also noted in the 2005 UTC research report on IP communications, "A substation communications network is a much more circumscribed environment than the public internet. Hence, issues related to cyber security can be managed with a far-greater degree of control than the term IP indicates."

While security can be easily addressed by embedded technologies in networking devices, technologies such as TDM over IP (time division multiplexing over internet protocol) provide solutions for real-time applications and overcome other challenges such as latency, high availability/reliability, and recovery time. TDM over IP is the practice of duplicating traditional TDM services over a converged network. TDM over IP can work across multiple packet-switched networks such as Ethernet, internet protocol,

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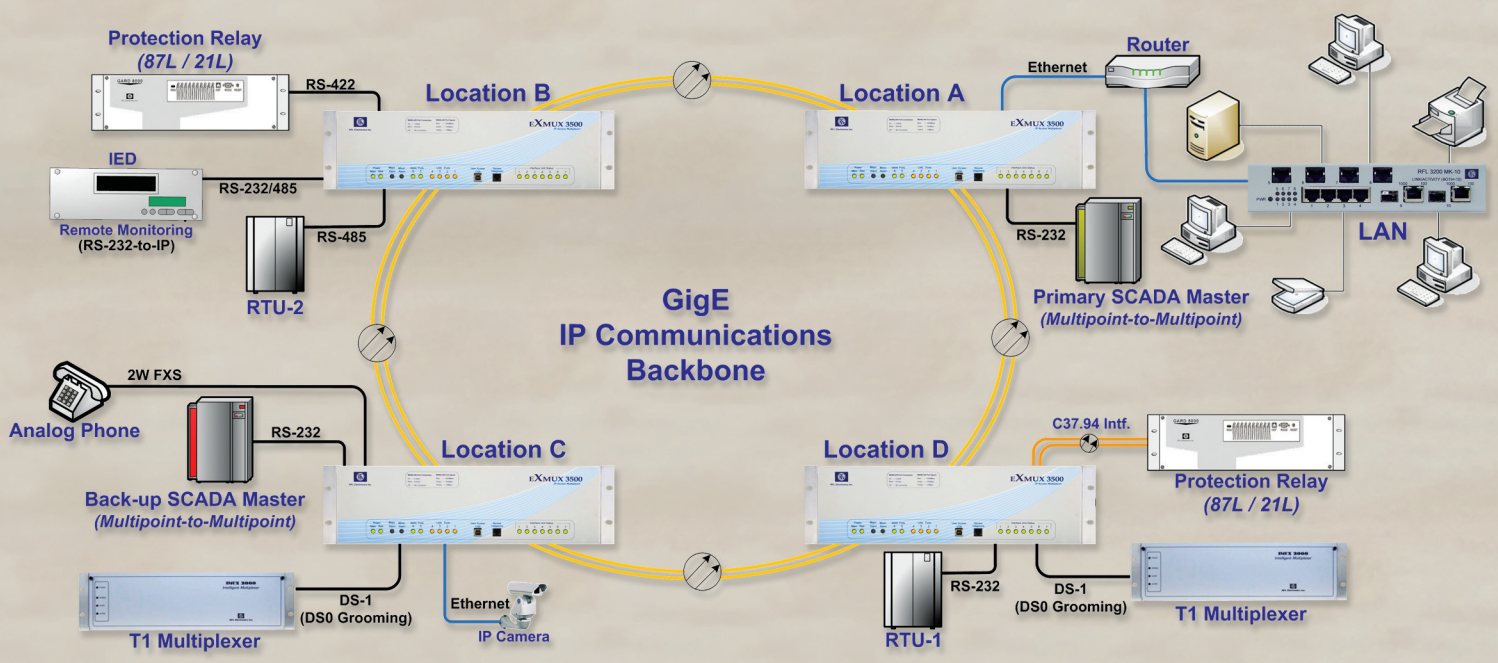
The eXmux 3500 IP Access Multiplexer was chosen for the prestigious UTC 2012 "Best Telecom Equipment" Product Award for its innovation, functionality, economic feasibility, and practicality as applied to the utility industry.

To win this award, given the competition, which includes the industry's most distinguished suppliers, is an honor for RFL and our eXmux 3500. RFL's eXmux 3500 allows customers to seamlessly migrate from TDM based Legacy Networks to a modern and secure IP-based infrastructure. The eXmux provides rock-solid communications channels ideally suited for protection and relaying schemes. The UTC Product Award is a validation of the product, its concept, and its ease of use.

The eXmux 3500 is deployed across the United States and around the world in the most challenging applications. Our customers require low-latency for protection and relaying schemes, along with ring protection that offers zero-data-loss in the event of a link failure. The eXmux 3500 is the result of over 60 years of RFL experience with relay communications and protection applications. The eXmux 3500 applies IP-based technology to provide better bandwidth management and ease of use in mission-critical protection systems.



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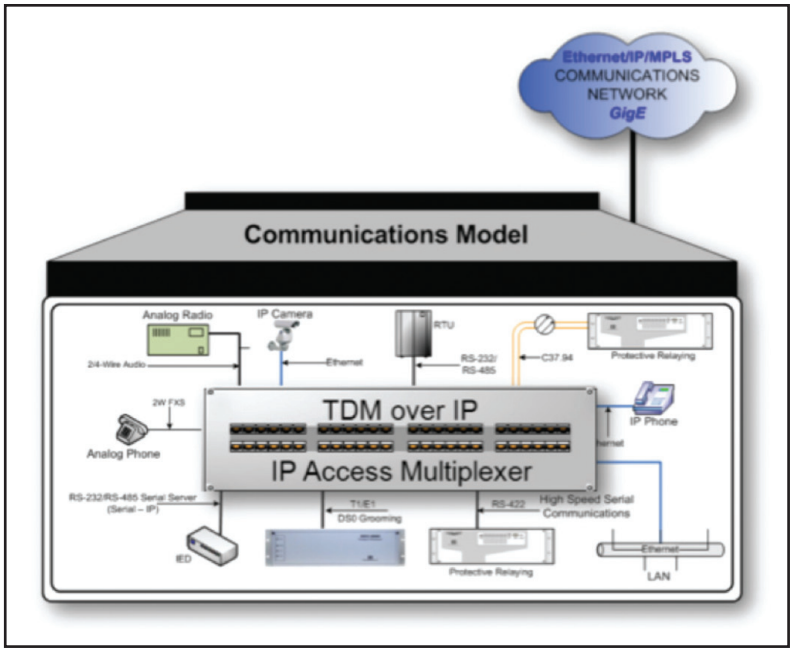

▲ Figure 3: TDM over IP Multiplexer Communications Model

and MPLS. This technology is referred to as pseudo-wire, emulating a TDM circuit-switched network, allowing synchronous TDM data such as T1/E1 services to work over an Ethernet/IP/MPLS network. As a result, every substation legacy device, whether serial data, voice, or video, can coexist with IP-based devices on the same communications platform. This is illustrated in Figure 3.

TDM over IP maps TDM octets directly into the payload with no voice compression algorithms and no resultant algorithmic delay. Therefore, the packetizing latency added by TDM over IP depends on the number of cells per packet but is typically in the single millisecond range. And by adding quality of service, where limited bandwidth is available, the high level of dependability required for critical data going across an Ethernet/IP network can also be achieved. Another feature unique to TDM over IP is the ability to send packets both ways around a redundant path network, achieving zero recovery time when a path fails, something that even traditional T1/E1 or SONET/SDH cannot achieve. These features allow real-time mission-critical applications that were traditionally designed for TDM networks to work over an Ethernet/IP/MPLS network with high reliability/availability.

Gulf Power Case Study

Many electric utilities are deploying real-time mission-critical applications such as SCADA/RTU, teleprotection, and protective relaying over Ethernet/IP/MPLS networks using TDM over IP. Gulf Power is currently deploying SCADA/RTU and pilot relaying over a packet-switched network.

Gulf Power, a Southern Company subsidiary, is an investor-owned electric utility that provides reliable, affordable electricity to more than 435,000 customers in 71 towns and communities throughout Northwest Florida. Gulf Power is headquartered in Pensacola, home to the Blue Angels flight demonstration team and the National Naval Aviation Museum. Gulf Power has three wholly owned generating plants and a co-generation facility in Northwest Florida with a generating capacity of about 2,600 megawatts of power.

Gulf Power had for many years been installing fiber throughout Northwest Florida for protective relaying and internal communications purposes and was looking to maximize the investment by upgrading its existing TDM legacy T1 network from a linear add/drop to a packet-switched network in a protected ring topology. The TDM T1 network was used mainly to transport its SCADA/RTU and pilot relaying channels between substations. The upgrade project consisted of about 60 substations and included provisions for more than 100 pilot relaying channels between the substations.

The new communications backbone network consisted of the following main requirements:

- Bandwidth capacity of 155Mbps or more
- Transport of real-time mission-critical applications: SCADA/RTU and pilot relaying channels
- Transport of corporate data network
- Integrated low-speed DS0 interface in the communications device
- Substation-hardened communications devices
- A user-friendly graphical network management software
- Low-latency and fast-recovery-ring protection protocol

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Gulf Power Case Study

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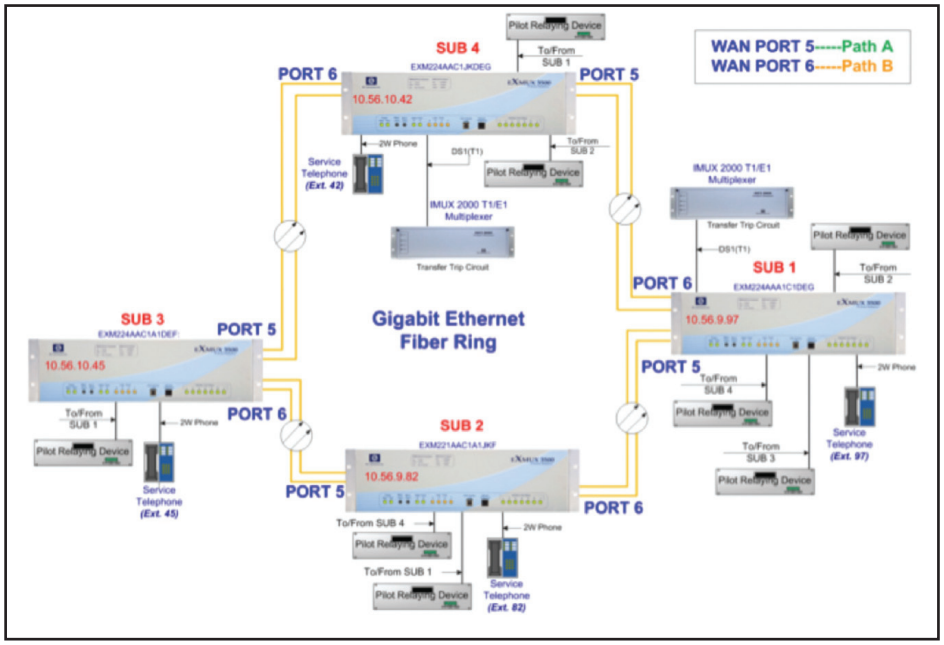

▲ Figure 4: Gulf Power TDM over IP Field Trial Communications Network

- Cyber security features meeting NERC CIP requirements

After many presentations with several vendors, a TDM over IP access multiplexer was chosen for evaluation in the upgrade project. A field trial was necessary to prove that the SCADA/RTU and pilot relaying channels could work successfully across a packet-switch network. The field trial system consisted of four nodes configured in a protected ring topology with pilot relaying channel and legacy T1 multiplexer communicating across the network. This is illustrated in Figure 4.

Figure 4 - Gulf Power TDM over IP Field Trial Communications Network

The substation-hardened TDM over IP access multiplexer chosen for the project is engineered for mission-critical infrastructures to seamlessly transport voice, serial, video, and Ethernet data communications over Ethernet/IP or MPLS networks. Designed into the TDM over IP access multiplexer is a distinctive "hitless switching" feature with zero-data-loss path recovery technology when configured in a protected ring topology. The multiplexer also includes an integrated digital access cross-connect function for cross-connecting DS0s between legacy T1 circuits, a function that will prove very useful to Gulf Power for interconnecting DS0 between rings and system timing. When setup for optimal configuration in a direct-fiber application, the latency is less than 5ms.

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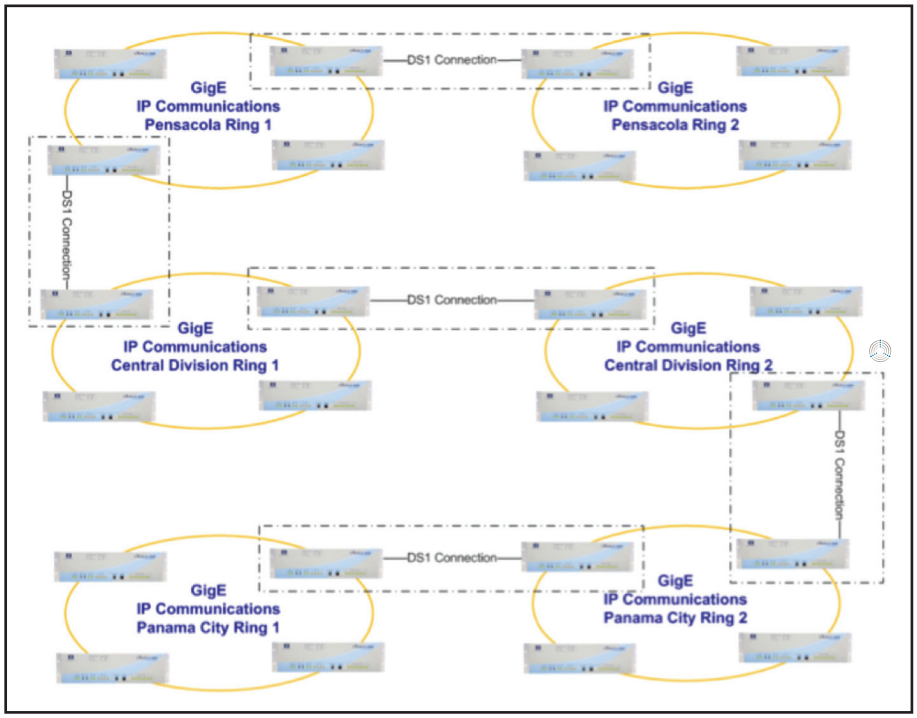
The multiplexer is also equipped with an integrated serial server interface that allows SCADA/RTU channels to work on a multipoint-to-multipoint group configuration, providing the seamless functionality of a primary and a back-up SCADA master.

After assessing the functionality of the units in a lab environment, the communications system was installed in the field at four different substations for close to a year before it was accepted by Gulf Power as the product to be used for the project. During that period, some software and hardware changes were made to correct issues found in the field, and additional features were added to accommodate Gulf Power's network topology. Among the important features proven during the trial were the hitless switching, low latency, and virtual local area network

(VLAN) functionality.

The hitless switching functionality guaranteed availability of pilot relaying communication channels in the event of a fiber failure. The low latency of this functionality, which was in the order of 5ms, ensured errorless operation of protective relays utilized in pilot relaying schemes, thus maintaining high-speed protection of the transmission line. The VLAN capability allowed the utility to segregate network traffic for a more efficient communications system and added security.

Once the field trial was successfully completed, Gulf Power began working on an overall system topology and deployment strategy. The new communications system includes about 70 TDM over IP access multiplexers subdivided into six protected rings with spur nodes. The six rings span across Northwest Florida in three different regions: Pensacola, Panama City, and Central Division. The rings are interconnected via DS1 circuits because transmission lines are protected with pilot relaying channels between rings. Firewalls are added at strategic locations for added cyber security. The communications system is illustrated with a sample network topology in Figure 5.



▲ Figure 5: Gulf Power Six Rings TDM over IP Sample Network

Conclusion

Using packet-switched networks such as Ethernet/IP and MPLS to transport real-time mission-critical applications is no longer a concept but a reality that is changing the communications landscape for both intra- and inter-substation communications. TDM over IP technology presents a migration path whereby these packet-switched networks can be used for transport, while the end-user equipment need not be replaced. As proven by the case study with Gulf Power, a packet-switched network can provide the dependability and security required by pilot relaying channel communications to protect high-voltage transmission lines. Many other power utilities are already deploying mission-critical applications over a converged network and doing it successfully. This emerging trend is allowing power utilities to build more-efficient, bandwidth rich, and smarter networks for their mission-critical communications infrastructure while costing less, achieving the best of both worlds.

Emmanuel Duvelson is the communications product marketing director at RFL Electronics Inc., a company that provides a wide range of communications and relaying products, application support, and customized systems to the electric utilities, oil and gas markets, railroad and transportation industries, government agencies, and engineering consulting firms. He is a graduate of Boston University with a BSEE degree and a member of IEEE. Duvelson not only spends his time managing the telecommunications product line, but is also involved in the design of T1/E1, SONET/DSH, and Ethernet networks for the electric utility industry. He can be reached at 973.334.3100 Ext. 275 or manny.duvelson@rflelect.com.