CASE STUDY

Consumers Energy—Jackson, Michigan

Making the Switch—How One Utility Is Transitioning Seamlessly From Leased Analog to Ethernet

Jackson, MI—North American electric utilities have long relied on leased analog lines for deterministic, low-latency communication for critical protection schemes. These analog circuits typically rely on time-division multiplexing (TDM) technologies, such as T1 and SONET, that provide a circuit-switched path and dedicated bandwidth to each communications circuit. The result is deterministic, low-latency, and low-asymmetry communication with guaranteed synchronous performance that is unaffected by other network traffic.

However, telecommunications carriers have begun phasing out analog services due to carrier equipment obsolescence and the increasing costs of maintaining these services. These carriers are focusing on providing digital services based on Ethernet that better address the growing consumer demand for high-bandwidth, internet-based services.

The digital alternatives to analog services are based on technologies such as Multiprotocol Label Switching (MPLS) and Carrier Ethernet. In contrast to analog circuits carried over TDM, they offer neither the guaranteed latency nor the synchronous performance required for power utility protection schemes. Moreover, Ethernet-based circuits are incompatible with the analog 4-wire circuit interfaces used by utility equipment, potentially necessitating extensive and costly equipment upgrades.

Many utilities are beginning to feel the impacts of this change. Consumers Energy, a Michigan-based electric utility, has 35 leased analog copper circuits in their system. Faced with rising analog lease costs and the need to ensure service reliability, they knew it was time to make a switch.

Solution Requirements

Consumers Energy purchases power from several third-party cogeneration facilities and uses direct transfer trip (DTT) protection schemes to take generators offline when there is a fault rather than risk the generator islanding with a Consumers Energy load. They also use permissive overreaching transfer trip (POTT) and current differential for system coordination. They rely on leased analog circuits for all of these applications.

Availability and restoration speed are the highest priorities for these applications. A replacement for their analog services had to provide point-to-point connectivity with a service agreement similar to that of the existing analog IEEE 487 SPO Class A circuit with uninterruptable service performance. It also needed to be available before, during, and after a fault with high reliability; to support existing substation equipment and schemes; and to match the existing DTT scheme latency of 13.1 ms. In addition, a replacement could not allow any misoperations as the result of channel delay or interference.

Consumers Energy further required:

- Substation-hardened devices.
- Support for 48 Vdc or 125 Vdc.
- Cost-effectiveness.
- Ease-of-use.
- Simple maintenance with excellent manufacturer support.
- Industry-standard interfaces.

A local Ethernet carrier was able to offer Consumers Energy the low latency (5 ms), limited jitter (3 ms), and reliability (99.995% packet delivery rate) they required, so they began exploring an Ethernet-based solution in earnest.

The Search for Alternatives

Consumers Energy decided to start testing alternatives with a simple DTT contact transfer scheme. They first evaluated a direct Ethernet solution but found that standard industrial equipment provided insufficient contact power voltage ratings (125 Vdc is rare); required auxiliary relays and other additional equipment; had questionable tolerance to heat, cold, and surges; and still only provided variable, nondeterministic latency and best-effort packet delivery.

Direct serial-to-Ethernet DTT solutions also proved inadequate for their protection scheme. While data transceivers were able to establish a link, they lost synchronization and went into an alarm state within seconds. Standard converters could not maintain a synchronized, deterministic path; jitter caused packet queuing delays that compounded until synchronization was lost.

Consumers Energy needed to actively keep jitter in check and synchronize data coming in with data going out using a known latency. Fortunately, TDM multiplexers already on the market were able to meet this need and, with some modification, run over packet networks.

The answer finally came in the form of the SEL ICON® multiplexer with virtual synchronous networking (VSN) technology (Figure 1). The ICON is a wide-area-networking multiplexer optimized for industrial and utility applications. It provides deterministic packet transport that preserves the performance characteristics of TDM when converting to Ethernet.

The SEL ICON uses VSN technology to maintain a synchronous network connection across an MPLS or Carrier Ethernet network. It transports serial-based teleprotection traffic with performance levels on par with TDM.

Leased Ethernet Implementation

Consumers Energy began testing the ICON VSN solution in their labs using leased Ethernet and a pair of SEL ICON multiplexers with support for various analog and serial interfaces (see Figure 1). Consumers Energy evaluated multiple interfaces to prove that this solution could do all of the following via an Ethernet fiber carrier service connection:

- Act as a direct replacement for an analog line.
- Simulate a point-to-point serial link.
- Directly connect protective relays to exchange relay teleprotection data.
- Simply transfer contacts.

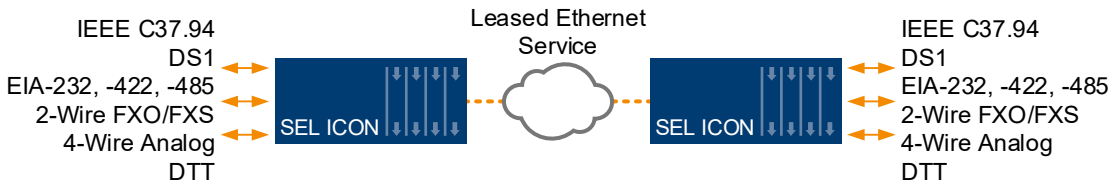

Figure 1—ICON VSN Supports Substation Circuits

ICON VSN uses a TDM engine to provide the synchronous interface to the protective relay. The relay data are efficiently packetized in standard, Layer 2 Ethernet packets and transmitted at regular intervals. As long as the telecommunications Carrier Ethernet network transports the packets within an acceptable packet delay variation, the system maintains synchronous operation. To manage packet delay variation through the carrier network, ICON VSN requires much smaller jitter buffer sizes (400 µs) than typical packet-based systems.

ICON VSN required the best service class offering from the local carrier, which was a real-time class of service with a 5 ms guaranteed latency. The relationship between the carrier and their network equipment vendor was key to establishing the service level agreement needed to support this requirement.

Live Trials

After three months of consistent lab results, Consumers Energy began live trials over an Ethernet circuit between their Parnall lab and Churchill substation, which are approximately 19 miles apart. The company placed ICON multiplexers at both ends of the leased Ethernet circuit. To minimize the physical equipment needed, Consumers Energy used an integrated transfer trip module that allowed them to connect inputs and outputs directly to the ICON. A test set measured the round-trip delay by injecting a contact closure at the lab ICON and measuring the return contact from the Churchill substation.

Consumers Energy monitored the channel performance for seven months. During that time, only one carrier network outage occurred. Measurements showed a total contact transfer latency of 4.5 to 5 ms, less than half that of the existing leased analog scheme. This was the complete communications time, including receiving the analog contact input, adding a debounce buffer and transmit delay for security, packetizing the event, sending the data over the Ethernet circuit, receiving and depacketizing the data, and generating the analog contact output (see Figure 2).

These results validated ICON VSN as a migration solution for the company's DTT and POTT leased circuit schemes. As shown in Figure 3, the lower costs of the leased Ethernet service allowed the ICON VSN system to pay for itself in just over 2 years.

For more information on these trials, refer the SEL technical paper "Addressing Analog Leased Line Obsolescence by Preserving Protection Channel Performance Over Ethernet."

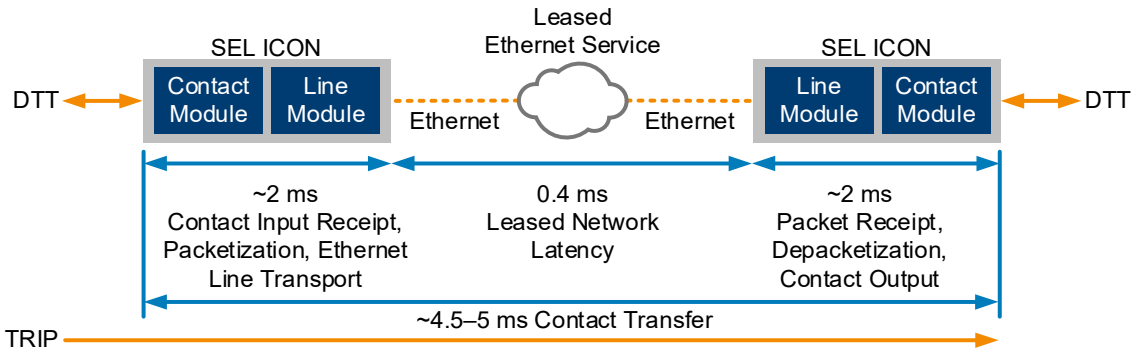

Figure 2—Live Circuit Substation Results

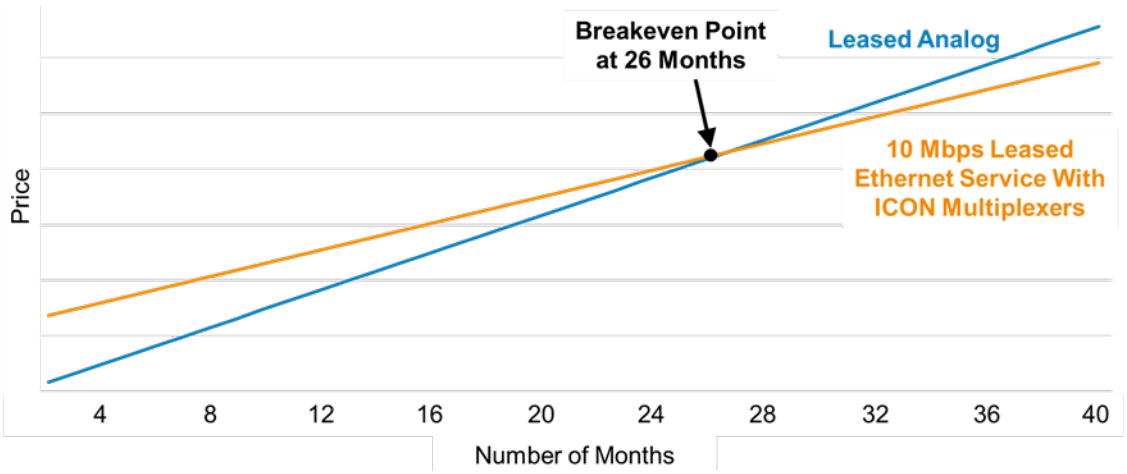

Figure 3—Breakeven Point to Migrate Single Leased Analog Circuit to 10 Mbps Ethernet

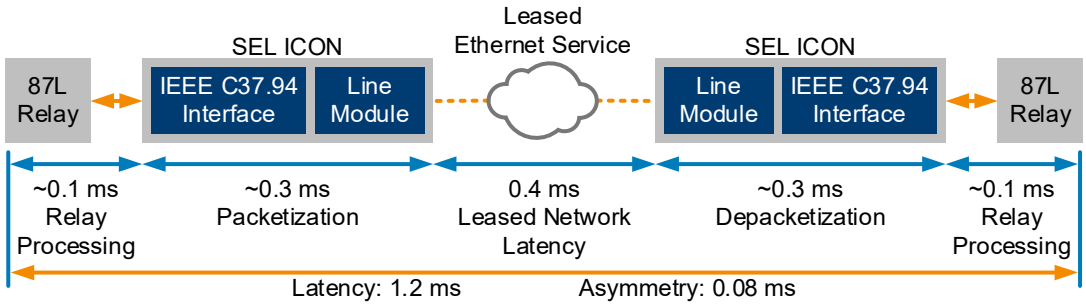

Figure 4—Substation Test Results for Line Current Differential

Going Beyond Transfer Trip

From a communications channel perspective, line current differential is the most challenging type of teleprotection scheme to support because of its tight latency and asymmetry requirements. As such, utilities avoid using leased circuits to support such schemes. However, the channel performance of the ICON during DTT testing, along with its interface capabilities, prompted Consumers Energy to consider using ICON VSN technology to support a line current differential circuit over leased Ethernet.

To evaluate the long-term performance of the channel and the feasibility of the scheme, Consumers Energy installed a pair of protective relays and ran a live line current differential (87L) protection channel across the leased Ethernet circuit. Table 1 and Figure 4 show the optimized performance results from a four-month trial.

The results were impressive. The performance was very close to what could be expected from a private fiber network using TDM equipment. The implications to the electric power utility industry are significant because these results demonstrate that leased services can be used for a range of critical services, including line current differential schemes.

Table 1 Line Current Differential Test Results

Parameter	87L Channel Performance (ms)
Round-trip delay	2.3 ms
Transmit delay	1.2 ms
Receive delay	1.1 ms
Asymmetry	0.08 ms
Dropped packets*	0

*Not counting packets lost during leased network outage.

ICON VSN Holds the Key to Critical Communications Transport Over Ethernet

Identifying an alternative to leased analog circuits is important not only to Consumers Energy but to the broader electric power utility industry. ICON VSN technology has proven its viability for transporting serial circuit information and is providing Consumers Energy with a cost-effective migration path for leased analog DTT and POTT circuits. By maintaining the synchronous principle of SONET, ICON VSN can transport serial circuit information with nearly the same performance as a native SONET network.

Until recently, electric power utilities had cause to worry about the telecommunications industry's decision to discontinue analog. Ethernet alone cannot meet the tight latency, determinism, and asymmetry requirements of critical communications. But Ethernet with ICON VSN can.

Consumers Energy experienced this firsthand—along with improvements in performance, reliability, and costs—when they moved their protection circuits from analog to digital leased lines using ICON VSN.

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About Consumers Energy

Consumers Energy, founded in 1886, is an electric and natural gas utility that provides electric generation, transmission, and distribution. They serve 6.7 million of Michigan's 10 million residents across 68 counties.

About SEL

Schweitzer Engineering Laboratories, Inc. (SEL) has been making electric power safer, more reliable, and more economical since 1984. SEL serves the electric power industry worldwide through the design, manufacture, supply, and support of products and services for power system protection, control, and monitoring.

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