Improving data throughput on a wireless IED network

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1. Abstract

The Chattanooga Electric Power Board (CEPB) is a municipal electric utility, serving the city of Chattanooga, Tennessee, with a service area of 600 square miles and a population of approximately 350,000. The initial 900 MHz radio system was installed by MDS in 1992 as the primary communications medium for CEPB's large SCADA system, which provides extensive monitoring and control capabilities at 25 transmission, and approximately 150 distribution substations along with critical switching devices. The network was comprised of a 6-hop link backbone point-to-point radio system, feeding 6 Multiple Address System (MAS) master radios for substation communications. CEPB's business model emphasizes excellent customer service and zero outages, making the company's supervisory control and data acquisition (SCADA) system a critical component when it comes to meeting these goals with both reactive and proactive measures.

Although the company was satisfied with the performance of its existing PTP-MAS radio system, CEPB was looking to evolve its communications to include an IP data path for end devices. Specifically, CEPB has a project underway to upgrade the RTUs to fully support IP communications end-to-end and then deploy DNP/IP protocol as a replacement for DNP Serial. Increased data speeds and bandwidth supported by the LEDR-iNET upgrade were required to elevate RTU communications beyond the present baud rate. Once fully implemented, SCADA Master – RTU communications will more closely resemble a flat network with significantly increased communication speeds and improved data throughput. From a system maintenance perspective, the ability to interrogate, configure, upgrade and manage all components comprising the entire radio network via the inherent Ethernet connectivity was extremely attractive as a practical method to improve diagnostic and troubleshooting techniques from the desktop, reduce or eliminate site travel time and increase overall productivity. Embedded SNMP traps provide a good snapshot overview of the health and performance of all radio components for casual review, while providing a method to quickly determine any area of the system which may require more in-depth analysis or inspection. New generation components would also further ensure high availability and redundancy of the radio infrastructure.

2. Evolving to support the digital future

When CEPB installed its large radio system in the early 1990s, they made a significant investment in the hardware infrastructure. For example, the existing MAS is comprised of six tower sites strategically located on the geographic boundaries of CEPB's customer service area.

The original analog point-to-point (PTP) backhaul system originated from the utility's control center, emanating to each of the six tower sites where the MAS equipment was located. This provided six distinct areas of radio coverage, designated by unique frequencies and the equipment within those areas. The six communications channels provided by the six MAS sites provided an organized method of polling 170-plus RTUs by the SCADA master.

Microwave Data Systems (MDS) and their full-service partner Edison Automation, worked together with CEPB to upgrade their system while re-using the legacy infrastructure and equipment.

This included:

- replacing the aging licensed system consisting of 960 MHz analog PTP backhaul and 928 MHz digital MAS master equipment and remote radios
- acquiring faster communication speeds with an immediate path to support end-to-end IP-capable equipment (typically RTUs, IEDs, cameras and SCADA master)
- consolidating all radio and network components for single-point management and monitoring of performance
- reusing existing infrastructure (antennas, coax, etc) at all master and remote radio sites
- performing installation, staging, testing and cutover with minimal downtime

The final step was probably the most significant. The existing radio system was operational and supporting full communications for a large SCADA system, therefore, it was imperative that the construction, configuration, testing, and commissioning of the new system occur with minimal interruptions to the existing system.

3. Evolve, Consolidate, Accelerate: The IP Solution

To preserve CEPB's investment in its legacy network and existing infrastructure, existing antennas, coax, and support equipment were retained and retrofitted to the new electronic equipment to provide a stable, operational system without having to make a "forklift" upgrade of the support infrastructure. Components of the new system include:

- 4 head-end MDS LEDR radios (Figure 1) with routers at the control center, with two LEDR links supporting two independent hops over the same LEDR backhaul link

Fig 1.
The LEDR Digital Radio

- 6 tower sites comprising a redundant LEDR PTP backhaul radio
- 6 MDS iNET Access Points (APs) each with router and network switch (Figure 2)

Fig 2.
MDS iNet 900™

- 170+ remote MDS iNET radios
- PC for remote configuration, control and performance monitoring of all radio equipment through SNMP trap services and remote telnet administration
- firmware in the radio equipment that can be upgraded across the network
- Ethernet network routing, which allows the communications network to better manage bandwidth at each tower and for all remotes associated with the network

CEPB took advantage of replacing an aging analog point-to-point/multiple address system with the new technology offered in digital point-to-point solutions and frequency hopping spread spectrum radios. MDS replaced the analog PTP backhaul system with LEDR radios while the MAS system was replaced with the MDS iNET 900, an unlicensed, frequency hopping spread spectrum radio.

With the IP based radio infrastructure, CEPB has migrated to the new radios via a temporary DNP3 serial connection from the RTU to the MDS iNET radio at the substation. The iNET radio came equipped with both a serial and Ethernet port to make future migration easier. At the time of migration to an IP end-to-end system, only reprogramming of the iNET radio to activate the Ethernet port will be required. From the iNET to the access point, through the LEDR radios to the headend router, DNP3/IP can be supported. Currently at the headend, the data must be converted back to DNP3 serial for interfacing with the SCADA Master front-end-processor (FEP). RTU components and the SCADA master are currently being upgraded to provide full Ethernet connectivity. Once this is accomplished within the next 2-3 years, end-to-end IP will be fully operational in the CEPB network.

With the new MDS LEDR-iNET radio system and MDS NETview MS™, CEPB can now monitor and manage the entire radio system from the desktop. Full-featured SNMP traps provide a real-time overview of system health and performance while remote configuration and firmware updates are fully supported at the desktop--often eliminating road trips to the site for these activities.

4. Greater throughput, bandwidth, and real-time monitoring

Unlicensed spread spectrum allows higher speeds and faster data rates, which coupled with the end-to-end IP connectivity offered by the MDS iNETs, were enticing elements of the upgrade design.

RTU/substation data capacity (bandwidth) of the system was increased by virtue of the new LEDR-iNET radio system, to prepare for future needs required for DNP/IP communications. Once the serial-to-IP conversion presently used is eliminated, the end-to-end transit should be virtually transparent with no latency. With an approximate cost of $450k to establish an IP infrastructure to serve 170 locations, and $3,500 per location, CEPB is convinced this migration is the most cost-effective way to replace legacy equipment and gain many benefits including increased data bandwidth and faster RTU communication response.

The new MDS iNET/LEDR network provides the primary communication medium for a new fault isolation - automation scheme on CEPB's 46kV subtransmission system. CEPB has developed automated software running on the SCADA master servers, to automatically detect faults, identify the path of the fault, implement automatic sectionalization and load recovery. Pole-mounted PT/CT sensors are used to detect fault currents through specific nodes on the circuit, thus identifying the passage – or lack of – of fault current at that node. The goal of the automated process is to reduce customer outages for improved SAIDI/SAIFI, while automatically identifying and isolating suspected faulted line segments between controllable nodes (motor-operated switches) on the circuit.

CEPB targeted deployment of the automated schemes on its 46kV subtransmission system to gain significant reduction of the total customers impacted by a permanent outage. The 46kV automated isolation/recovery process, typically accomplishes fault isolation and load recovery within 1-2 minutes after feeder lockout, compared to 10-15 minutes typical with system operator involvement. The automated system logic is designed to closely mimic standard operating procedures, operations and decisions normally executed by system operators, only much faster. Logic is built into the automation scheme computer code to incorporate and fully support all safety requirements including lockout/tagout procedures, device clearances, equipment availability and/or malfunction and other business processes applied to the electrical system. From a business case standpoint, the cost/benefit quickly adds up by taking the minutes of outage time saved, times the number of incidents per year, times the number of customers per feeder. Currently 20 46kV circuits are automated, with a plan to do 20 per year for the next 2 to 3 years.

Major benefits realized from the 46kV Automation Scheme have been significant reductions in the total number of customers affected by a permanent outage on 46kV subtransmission feeders. Typical customer counts on any given 46kV circuit can range from a low of 2000 customers to a high of 8000 – 10000 customers. The automation logic is implemented such that once the faulted circuit segment has been identified and isolated, the majority of the remaining unfaulted circuit can be recovered via the original source feed or other alternate feeds. Oftentimes, the entire customer load is recoverable with only an unloaded portion of the circuit isolated as faulted. The resolution of recoverable circuit segments – i.e. customer load – is enhanced by the addition of remotely controlled motor-operated switches at key nodes in the circuit. The ability to either totally isolate historically problematic circuit segments is possible or the ability to provide multiple alternate feeds into the affected area is greatly enhanced, ultimately increasing the chances of maximum load recovery.

Historically, system conditions are most affected by prevalent thunderstorms of the spring and fall seasons which tend to be the most violent and destructive. It is in these times of system disruptions that the automation schemes provide a deterministic solution to fault isolation – load recovery "in the background" as the storm rages around everything else. Since the automation scheme closely follows normal manual switching of the circuits, safety is reinforced and maintained throughout. With approximately 20 circuits thus far having such automated recovery abilities, the potential numbers of customers that can be quickly restored from an outage increases dramatically.

5. Seamless transition to new system

All of the equipment for the new system was configured, staged, and made operational on a test bench prior to the actual installation. In the end, the actual cutover occurred one channel (LEDR/AP frequency) at a time while the legacy PTP/MAS equipment was left intact with the new LEDR/AP equipment installed side-by-side.

6. Lessons learned

The most significant lesson to be learned from CEPB's conversion/upgrade product was the necessity of detailed and exact planning for both the physical conversion and the required RF changes. Other lessons:

- ensure AP-iNET RSSI coverage is robust for one watt unlicensed spread spectrum radio system before replacing five watt MAS system
- remember that environmental conditions change. Be sure to check and recheck antenna height near obstructions (buildings, trees, terrain) for remote sites
- complete intermodulation studies to ensure adjacent channel and/or intermod interference won't diminish remote RSSI/SNR characteristics
- develop a flexible, robust, network/IP-addressing scheme before deployment to permit separation and management of numerous radios and other IP equipment

7. The results: One year later

CEPB has successfully operated its LEDR/MDS iNET system for over one year. They have the newest radio technology available today and an IP data path from their substation to the Operations Center for various IP devices in the future. CEPB is enjoying the ease of single-point management and performance monitoring of all radio and network equipment, they can perform self-documentation of system performance, errors, or problems.

Most important: CEPB has maintained and even enhanced its excellent customer service and record for zero unplanned outages.