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Intelligent Fiber Network Reduces Wind Energy Project Complexity and Increases Reliability

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By Lynn Hansen and Bob Landman

Utilities have long recognized the benefits of fiber-optic communication systems. In particular, fiber optics provide immunity from electrical interference caused by lightning and adjacent high-voltage power lines, and isolation that protects equipment and personnel against ground potential rise during faults.

Self-healing fiber network designs have evolved, allowing redundant loop protection for mission critical applications. When a fiber interruption is detected in the network, these systems automatically reroute traffic around the failed fiber or device. In addition, advanced networks incorporate network management systems (NMS) to allow monitoring and management of the fiber communications network. The NMS runs in the overhead data stream independent of the network traffic.

Until recently, these advanced capabilities were only available for relatively high-capacity, low-node-count, fiber networks. Utilities needing low-capacity, high-node-count fiber networks for distribution SCADA applications have had to build networks without the advanced capabilities the high-capacity users have enjoyed for years. This is no longer the case.

SeaWest, a San Diego, Calif.-based wind energy developer, is one company that is seeing many of the benefits normally associated only with high-capacity fiber networks from a much simpler fiber network. Utilizing intelligent fiber-optic controllers and transceivers in the communications system has greatly increased the safety, reliability and survivability of one of the company`s wind energy projects. In addition, the technology reduced excavation costs, helping offset the additional costs of using fiber optics. The system`s simplicity and the use of a built-in NMS has also reduced downtime and maintenance costs.

The Project

Wind energy projects utilize large wind turbines to generate commercial power from renewable energy, often referred to as "green power." One of SeaWest`s latest projects, Foote Creek Rim, is a 69 unit project located near Arlington, Wyo. At this site, each wind turbine has the capacity to generate 600 kW of energy feeding a combined output of more than 40 MW to the power grid. Each turbine has a controller located at the base of its tower. The controller is involved in all aspects of the turbine`s operation, including starting and placing the unit on-line, turning the nacelle into the wind as it shifts, adjusting the blade pitch for maximum generation based on the current wind conditions and taking the unit off-line when wind speed goes above or below preset speeds.

Each controller also performs the functions of a remote terminal unit (RTU), providing important operating parameters to a SCADA master computer located in a 34.5 kV/230 kV substation. Operations & maintenance (O&M) personnel, in an off-site facility linked to the substation via microwave, monitor wind and generation conditions for the entire plant.

The site also includes five meteorological towers (METs) that independently monitor wind speed, direction, temperature and barometric pressure. Data from these units are also sent to the central SCADA computer where it is used with data collected from the turbine controllers to monitor and evaluate the turbines` performance.

Design Considerations

The Foote Creek Rim facility is located on one of the windiest ridges in North America and is subject to lightning strikes. Due to of the possibility of lightning, and the fact that SeaWest had tried radio in other projects (where scan times even with multiple channels were too long), it was determined that a fiber-optic communications system to link the turbines and MET stations to the SCADA master computer in the substation would be the most reliable and cost effective. Sixty of the 69 turbines are symmetrically spaced 300 feet apart along a 3.5-mile ridge. Nine other turbines form a back row near the south end of the project.

CC&E Engineers, Salt Lake City, Utah, was selected to evaluate various fiber-optic options and design a simple yet robust fiber network that would connect the turbines and the MET stations to the SCADA master located at the 230 kV/34.5 kV substation at the north end of the project. Several topologies were studied including simple fiber loops, fiber bus modems, fiber multiplexers, redundant loop modems and intelligent fiber network controllers. Because the turbine and MET stations use different communication protocols, at least two communication channels were required. Consideration was also given to the required fiber count, physical complexity, overall reliability and future expandability.

The Fiber Loop II System from H&L Instruments, North Hampton, N.H., was selected because it greatly simplified the fiber network`s physical complexity and provided many benefits previously available only in high-capacity fiber networks. Benefits include multiple data channels (four virtual channels), self-healing redundant-loop operation with support for sub-loop configurations, and NMS.

Fiber Cable Configuration

The entire fiber network was deployed using multimode, six-fiber, tight-buffered "DX" style fiber-optic cable supplied by Optical Cable Corp. The cable was pulled from turbine to turbine in underground innerduct in a daisy-chain fashion. Inside each turbine control cabinet, two fibers from each direction were directly terminated with Siecor Unicam no epoxy/no polish connectors, while the remaining two active fibers (that bypass the turbine) were fusion spliced. In essence, four fibers interconnect the entire project with the remaining two fibers acting as spares. A Panduit multi-media fiber box mounted at each turbine was used to provide protection and slack storage for the fiber. This method of construction proved to be very economical.

Fiber Network Topology

The fiber network topology consists of a self-healing redundant main fiber loop with two sub-loops. Because of the symmetrical radial nature of the wind project, all fiber loops are of the "collapsed" or "hairpin" style, meaning the loop is carried in the same cable. Routing the fiber in the same trench as the underground 34.5 kV high-voltage feeder cables greatly reduced excavation costs compared to a copper system that would have required a separate trench. The fiber duct was spaced a minimum of three feet away from the primary cable to avoid problems should a primary fault occur. While this design somewhat compromises the redundant nature of the loop--a cut cable would isolate the downstream units on the system--it was felt that because access to the site is controlled by SeaWest and fiber locations are well documented, dig-ins would be rare. Since most fiber runs are less than 350 feet long, should a dig-in occur, the damaged fiber could be pulled out, the duct repaired, and the fiber replaced.

Fiber sub-loops were incorporated in the design to provide additional protection for the fiber network. The primary high-voltage distribution system consists of six feeders, each connecting groups of turbines to S&C Electric Co.`s sectionalizing switches that feed the substation. Because the fiber controllers operate on commercial AC power, eliminating the cost and maintenance of battery backup, the fiber network is designed so that each fiber loop services turbines on two feeders. A failure of any feeder (which will cause all fiber controllers on that feeder to go off-line) will not affect the traffic on the fiber communication system. The affected fiber loop will automatically revert to "radial" mode and continue to carry traffic from the remaining turbines. In fact, all but one feeder can fail and the fiber network will remain operational to the turbines on the in-service feeder.

MET stations are not included in the protected loop system. They are spurs, interfaced with inexpensive point-to-point fiber modems to the nearest fiber controller where they enter the fiber network via one of the virtual channels.

Fiber-optic Controllers and Transceivers

The H&L Fiber Loop II system consists of three components; the Model 560 Fiber-optic Network Controller, the Model 562 Fiber-optic Transceiver, and the Model 564 Fiber-optic Transceiver/Sub-net Controller. All units have two fiber transmitters and receivers so there is a redundant path in the loop. In addition, dual fibers make two multi-drop radials possible if both fibers at one location fail or one or more units fail.

The 560 Fiber-optic Network Controller is the "brain" of the system. The controller is located in the substation and manages the entire fiber network, while providing the interface to the SCADA master. It has four serial ports, each of which can be dynamically assigned to one of four virtual channels on the fiber network. Maximum baud rate on each channel is 19.2 kbits/s.

The 562 Fiber-optic Transceivers are located at each turbine site except for the two sites where the sub-loops originate. They also have four serial ports, each of which can be dynamically assigned to any one of the four virtual fiber channels.

At the sub-loop origination turbine sites, the 564 Fiber-optic Transceiver/Sub-net Controllers are used. The 564 combines the functions of the 562 Fiber-optic Transceiver with those of the 560 Fiber-optic Network Controller. It incorporates dual-ported, shared memory and two microprocessors. The transceiver side interfaces to the main loop, providing four serial ports to access the four virtual channels on the fiber similar to a standard 562. The controller side of the 564 controls a sub-loop and conveys network traffic to and from the main loop. DC battery backup systems are used to power the two 564`s in this system so they will remain in service should the primary power supplying those turbines fail. This allows the affected sub-loop to remain in service while repairs are made.

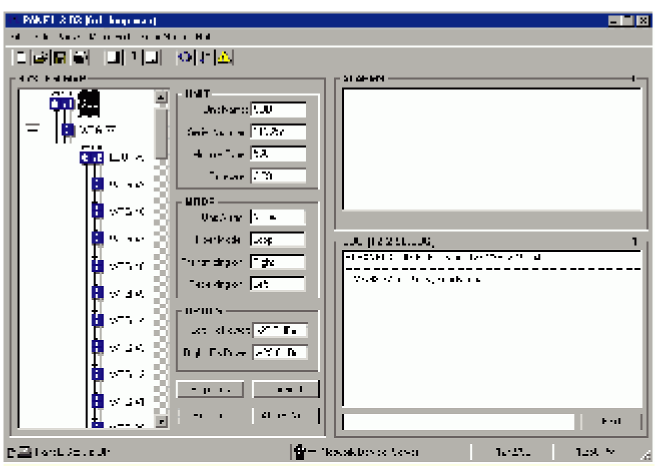
Additional Benefits

The configuration chosen for the project required only two virtual fiber channels. Two additional channels are available for future expandability. For instance, a power quality monitor or other diagnostic equipment can be easily placed at any turbine and monitored from the substation or O&M building.

The fiber system contains an NMS channel that allows the entire fiber network to be monitored from the 560 in the substation. The NMS channel is used for system maintenance. The alarm status and receive optical power levels of each unit in the fiber network are monitored and displayed to the service personnel using an HMI Windows 95/NT program running on a local computer. Should an outage occur, the NMS system provides the information needed to locate and repair the problem. Intermittent problems are easily identified and repaired because each alarm on the fiber network is date and time stamped and saved in a log file.

The NMS system provides tools to perform predictive maintenance on the communication system. For example, indication of low optical power levels, even though not yet creating a failure or intermittent problem, can enable service personnel to schedule maintenance. n

Foote Creek Rim, a 69 unit wind project provides a combined output of more than 40 MW to the power grid.



The alarm status and receive optical power levels of each unit in the fiber network are monitored and displayed on a local computer.

Robert Landman is president, founder (1979) and director of R&D at H&L Instruments, North Hampton, N.H. He has authored papers on SCADA and communications and was published in the 13th Edition of McGraw-Hill`s "Standard Handbook for Electrical Engineers."

Lynn Hansen joined Communications, Controls, & Electrical Engineers (CC&E Engineers) in 1996 where he has been assigned several SCADA projects. Prior to CC&E Engineers, he worked as an electronic technician for PacifiCorp. Hansen has authored and presented technical seminars relating to SCADA and stationary battery maintenance and testing.