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A Wireless Vibration Monitoring System

A 1,050 MW power plant adds a state of the art monitoring system.

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In December 2008, the Southern California Edison Co. completed installing a state-of-the art wireless vibration monitoring system at its Mountainview Generating Station in Redlands, CA.

The system was installed on all 4.16 kV critical pumps, compressors and motor drivers as well as critical 480V water treatment equipment as part of a predictive maintenance program to both maintain and improve station reliability. In addition, difficult to reach gas turbine enclosure blowers were added to the wireless monitoring list.

The 1,050 MW combined cycle power plant facility is comprised of two blocks of 2-on-1 combined cycle units using GE 7FA gas turbines as the prime movers. Each of the two blocks is rated at 525 MW net output and each contains a GE D11 condensing steam turbine. GE Power Island equipment is vibration monitored by the GE Bentley Nevada system; however, the balance of plant (BOP) equipment had little or no vibration monitoring. Critical BOP equipment such as the natural gas rotary screw compressors have a local alarm panel with a common trouble alarm signal sent to the control room DCS system. The gas compressors, boiler feedwater pumps and circulating water pumps currently only have thermocouples in the pump and motor bearing caps, which are monitored and trended in the DCS.

Proof-of-Concept Phase

The project began in June 2008 when engineering selected 10 pieces of equipment as part of the project's proof-of-concept phase along the north side of the station. The north side was selected to check for potential interference from nearby San Bernardino International Airport (formerly Norton AFB). Using the northern-most part of the station potentially addressed signal strength as well as interference issues from large steel structures such as heat recovery steam generators, concrete turbine decks and other objects obstructing line-of-sight communication. Since cell phone communication is poor throughout the plant, it was first necessary to demonstrate that the wireless system could communicate continuously and at sufficient signal strength for the project to move forward.

By late August 2008, the ITT ProSmart wireless system had provided sufficient evidence of its capability and the project moved to build-out phase. The station's technical manager, Steve Johnson, placed the order for the build-out. The goal was to use an October 2008 outage to install vibration sensors on critical equipment that could not be shut down, while less critical equipment could be shut down when the station returned to service from the outage. ITT and the station contractor completed the installation and commissioning of wireless equipment and sensors by the first week of December.

The Data Monitors

The wireless system consists of powered data modules (or DMs) that collect tri-axial vibration data, temperature, shaft speed and other analog data for 68 pieces of BOP equipment. In general, each piece of equipment requires one DM to transmit data up to a communication module, or CM.

The gas turbine enclosure fans had only one sensor installed on the lower motor bearing. Those DMs shared multiple services and reduced the total number of DMs required. In all there were 52 ProSmart DM22x's installed for this project. The recently redesigned

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DM22x is approved for Class 1, Div. 2 Group ABCD hazardous areas. The data module communicates at 2.4 GHz frequency hopping spread spectrum up to 3,000 meters in a point-to-point communication range.

ITT is developing software to allow data modules to communicate in a self-healing mesh arrangement that will allow up to 9,000-meter-long transmissions. These new DMs include an integral junction box for connecting up to three 4-20 mA signals, two digital inputs, a single form C relay and a power supply termination block. On the outside of the case are diagnostic LED's for power supply, as well as vibration warning and alarm functions. Operators making their rounds can determine if the equipment is in alarm when the red alarm light is on.

DMs are mounted four feet from the grade in an upright position with the antenna pointing up. The antenna needs to be clear of obstruction 10 inches around it and should be three feet or more apart to avoid the DM signal cancelling. Aside from that, anything goes. What surprised everyone was when four of the DMs were located inside the west end of the warehouse building adjacent to the firewater pumps. It was thought the corrugated steel building would trap the signals. However, they transmitted to the communication module on the control building several hundred feet away, with a strong signal even with the rollup door closed.

Communication Modules

The CM receives data from the DMs and provides a secure connection to the ProNet platform via LAN, DSL, cell or 802.11 wireless routers. Mountainview has two CMs on each of the steam turbine decks and one on the control building roof. The control building CM communicates to the ProNet platform through a DSL line, while the four CMs on the turbine deck have cell phone connections to the internet.

Shown in Figure 1 are two power blocks in a slide along arrangement of 2-on-1 combined cycle units. The steam turbine deck for each block is shown to the north above the two CTG-HRSG trains. There are five CM-DM circuits shown in the plant general arrangement with each circuit represented by a different color. The colored dots represent the DMs; the CMs are represented by stars. To improve communication strength, temporary cell phone CMs were added on the north side of each steam turbine deck, which are shown in white and red stars. When the mesh network software is installed later in 2009 these two temporary CMs are expected to be eliminated. Locating the CMs at a high point in the plant allows some equipment DMs to communicate via line-of-sight.

Since the signal emitted from an antenna is cone-shaped and 360 degrees around, the higher elevation prevents the bottom of the cone from being cut off if it hits the ground. This also allows for greater signal bounce from adjoining structures.

During the proof-of-concept phase of the project equipment was powered from the 110V GIFF receptacle with plug in cords, which proved to be problematic. The GIFF circuits typically will trip from heavy moisture

FIGURE 1 SENSOR OVERVIEW

or after a rainstorm. During the build-out phase the 24 VAC power supplies for the DMs and CMs were hard wired through a transformer/power supply from the 110V lighting panels. Power supplies, including fuse blocks, were attached to a D-rail inside a stainless steel NEMA 4X enclosure. The hard-wired power supply has improved the system's reliability.

Vibration Sensor

At the heart of the vibration monitoring system is a tri-axial accelerometer probe that also incorporates a temperature sensor. Four sensors are required on horizontal equipment to monitor inboard and outboard motor, pump, compressor and fan bearings. On vertical equipment, three sensors are used for monitoring the motor and the upper pump bearing. On vertical enclosure fans the utility's senior vibration analyst, Costa Yiannakakis, felt that the lower motor bearing was sufficient to determine if the fan-motor assembly was failing. These fans vibrate at 0.35 ips under normal conditions and increase to 0.6 ips as they begin to fail, so the high level of vibration is transmitted to the shutdown standby blower unit as well.

Tachometer Sensor

One of the project's more challenging aspects was installing the tachometer sensors. The original concept (and least intrusive approach) was to strap a piece of key-stock on the shaft. The sensor gap was adjusted to 5 mm or less to detect changes in the shaft's magnetic profile, which acts as a pulse trigger. Keeping the key-stock on the shaft proved difficult and our installation shifted to using either the keyway or shaft key itself. On some equipment neither was long enough so the keyways were elongated or a separate

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slot was cut into the shaft. The slot had to be sufficiently long to allow for shaft movement due to motor magnetic center.

The first iteration resulted in strange droops on the revolutions-per-minute trends as the shaft moved from the deep part of the keyway to the tapered area. The second iteration centered the sensor over the deep part of the keyway so the result was a nice sharp rpm trend. The learning curve was painful as each iteration required repeated equipment clearances. All sensor brackets were custom made for each equipment type from sufficiently thick bar-stock to avoid vibration movement of the sensor.

Originally, equipment speed was to be used for performance trending, but this data also proved useful in vibration trends to determine when the equipment was running.

The Wireless System

The ProSmart platform provides the ability to view, analyze and store data in a secure environment at the ITT facility in Seneca Falls, N.Y. Station personnel and vibration specialists may access their data from any internet connection with proper username and password. The system can be set up to send text messages or emails to pre-designated personnel should an alarm condition prevail. Once connected to the ProSmart platform, the vibration analyst selects the generating asset from any number of facilities. Listed under a generating asset is the status of each piece of equipment being monitored. Shown on the status overview below with a yellow dot is a boiler feedwater pump in a pre-alarm condition. Should the vibration or temperature condition worsen the yellow dot will change to red indicating the equipment is now in alarm. The analyst can drill-down by opening up the equipment to determine exactly which sensor is in alarm. All other equipment shown with green dots are in good condition.

This dashboard arrangement focuses the vibration analyst on the problem areas and provides drill-down to the problem sensor in a few seconds. A vibration analyst can quickly focus his or her attention to the problem areas over several generating assets, which could reside in different parts of the country.

The dashboard also allows for trending, as is shown below when the vibration level trends into the yellow pre-alarm condition. It can also be seen by the droop in vibration level that the equipment was shutoff and then restarted a short time later. The scale although difficult to view in its reduced size, shows the vibration level trending up over a several day period until it reached the pre-alarm condition. It appears that the warning alarm prompted operations to shutdown the equipment until it could be determined if this was real vibration or not. It was then restarted and continued to trend into the pre-alarm area. The scale on the left side of the trend is in inches per second (ips).

Software Setup and Configuration

Setting up the software pre-alarm, alarm, alarm delay times, sampling rates and filters varied slightly from one equipment type to another and required a good deal of effort to avoid nuisance alarms. Each of the four sensors on a horizontal equipment has an x, y and z component that can have from one to 10 times running speed band alarms setup. To some extent, some data could be copied from one sensor to the other but each running speed needed to be checked for correctness. SCE's senior vibration analyst worked with ITT software engineers to come up with a consistent configuration set that characterized each equipment type. Concurrent with this effort were ITT's own software upgrades which added features and fixed bugs that presented an even greater challenge. It wasn't always clear if the problem was a configuration issue or a software problem. The debugging went on for a better part of two months.

Station operations and maintenance staff were introduced to the vibration system in several training sessions provided by both ITT as well as by SCE's vibration expert. There were introduction classes to explain overall how the hardware worked and care in removal and reinstallation of sensors during overhauls. A software class provided instruction on the basics of logging in and determining equipment status. More recent classes dealt with the analysis of the alarm and vibration training.

The SCE vibration expert and the plant engineer, Bruce Liu attended a configuration class to learn the details of configuring the ITT ProSmart software.

As described earlier, the software is undergoing upgrades to add new features including a self-healing mesh network. Currently under development is a more robust sensor, which will separate the sensor from the cable and facilitate removal and replacement of the sensor during maintenance. **pe**

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