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IT in the Plant

Predictive maintenance technologies come together

By **Robert Swanekamp**, PE, Editor-in-Chief

Mature condition-monitoring technologies--such as vibration monitoring and lube-oil analysis--continue to improve, and new technologies are emerging. Increasingly, they are linked together by powerful software systems that manage the mountain of data

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Power producers have been applying predictive maintenance (PdM) and condition-monitoring tools for many years. The sophisticated technologies have proved themselves by reducing machinery failures, increasing plant availability, and eliminating unnecessary preventive maintenance.

Even so, most maintenance managers agree, PdM programs rarely live up to their full potential. In part, that's because the "core" PdM technologies--the hardware and software tools that monitor equipment condition--are continually being enhanced by suppliers. Users often feel they are "behind the curve" on the new tools and not fully using their expanded features. This is true for the more mature, or "primary," PdM technologies--vibration monitoring, lube-oil analysis, and infrared thermography--as well as for the newer, "secondary" PdM technologies--such as motor-current monitoring, ultrasonic testing, and laser-based tube-leak detection.

Power producers are managing this problem with ongoing training for in-house specialists, and by outsourcing a part or all of their program to PdM specialists.

Another reason PdM programs may fall short of their full potential is common to any information technology (IT). The problem: information overload. The amount of data in a comprehensive PdM program that must be gathered, organized, archived, and analyzed is staggering. Like a tsunami, it starts small, then builds until it overwhelms the unprepared.

To help manage this problem, power producers are turning to enterprise software, via a corporate client server or the Web.

Perhaps the main reason that PdM technologies rarely live up to their full potential, both PdM suppliers and veteran users seem to agree, is not the tools themselves. Rather, it is how their results are used to mobilize action. As its name implies, PdM "predicts" a problem. Whether management chooses to act on that prediction is another issue entirely--especially in this era of industry uncertainty and short-term financial horizons. A manager who shuts down the plant to fix a predicted bearing failure may be criticized by corporate executives for an "overly conservative" outage and subsequent loss of production. Condition monitoring is not an exact science, maintenance veterans point out. There are a lot of judgment calls to be made--and second-guessed.

Mature technologies advance

Three primary technologies--vibration monitoring, lube-oil analysis, and infrared thermography--form the foundation of most PdM programs. Although they've been around for decades, these technologies continue to grow in features, capability, and applicability.

Consider the case of low-NO_x burners. In recent years, scores of powerplants have retrofit the burners to cut air emissions, but several operating problems have surfaced. Among them: abnormal vibrations in various boiler components and high noise levels. The problems have appeared in forced-draft, induced-draft, and primary-air fans, duct work between the fans and boiler, windbox, or burner housings, furnaces, superheaters, reheaters, and economizers.

To determine the source of the problems, power producers are turning to vibration-monitoring technology, and conducting detailed tests throughout the boiler load range. A typical project was discussed by Mark Tarbet, senior engineer with Mechanical & Materials Engineering, Austin, Tex, in a paper presented at the Enteract 2000 Conference, hosted by Entek IRD International, Milford, Ohio. In this test, both standard and low-frequency accelerometers were used, where standard accelerometers are rated 2-7000 Hz, and low-frequency accelerometers have a range of 0.5 to 2000 Hz. Vibration data were collected from 14 locations, including the burner, boiler, forced-draft fan, and inlet duct system.

After eliminating numerous potential sources, the vibration tests focused on high-amplitude, 21-Hz vibration levels in the inlet duct, when the boiler load was below 42,000 lb/hr. Vibration peaks at harmonics of the forced-draft fan's stall frequency--42 Hz, 63 Hz, 84 Hz, etc--indicated that the fan was operating in a stall condition near 70% of its running speed. The fan was therefore modified with a variable-frequency drive on the motor, and the problem was eliminated.

Steam turbines have been monitored with on-line vibration systems for years. One of the latest advances in the field is intended to not only monitor turbine vibration, but to correct it in real-time without shutting down the unit.

In August, BalaDyne Corp, Ann Arbor, Mich, was awarded the first installment of an Electric Power Research Institute (EPRI, Palo Alto, Calif) contract to develop this "active-balancing" technology for nuclear-station steam turbines. The contract calls for a vibration-correction device to be developed that can be installed as two pieces over the turbine shaft, without having to disassemble the shaft bearings. The device would feature counter-weighted assemblies mounted along balance planes on the shaft. A smart controller would sense vibration, determine the best counterweight position, and electromagnetically move the weights into position to minimize vibration. According to

BalaDyne's Stephen W Dyer, research manager, the technology will reduce the number of unscheduled shutdowns required for manual balancing, as well as the number of equipment startups which limit service life. BalaDyne already offers active-balancing products for industrial exhaust fans, machining lathes, and smaller turbomachinery.

Oil and vibes mix

A refinement in the integration of vibration and lube-oil analyses was described by Paul Eitner and Daryl Patrick of Nevada Power Co, Las Vegas, at the 1999 EPRI Plant Maintenance Conference. Like many powerplants, the 1200-MW Clark/Sunrise/Harry Allen (CSHA) station was struggling to monitor the condition of cooling-tower gearboxes, and determine the cause of their high failure rate. Teeth were breaking on the input pinion gears, as a result of water-contamination in the lube oil. Traditional lube-oil analysis was not detecting the problem at an early stage, because the only way to extract an oil sample was for a technician to physically climb into the cell--a hazardous and time-consuming procedure.

In response, an on-line condition-monitoring system was devised to allow oil samples to be taken from outside the cooling-tower cell while the unit remained in operation. This was accomplished by installing a 0.5-in. stainless steel tube and a variable-speed, reversible-drive pump that circulates oil from a gearbox fill plug to outside the cell, and back again. Now, gearbox oil can be sampled frequently and quickly analyzed on site to determine contamination, water content, wear particles, and viscosity.

In addition to the on-line oil-analysis system, special accelerometers were installed on the cooling-tower gearboxes. The new sensors, in contrast to the existing vibration transducers, gives a PdM specialist the ability to look not only at low-frequencies of 0 to 200 Hz--which detect bearing faults--but also at higher frequencies up to 5000 Hz--which detect gear-mesh faults.

Together, the on-line oil- and enhanced vibration-monitoring technologies have provided the CSHA station with better condition monitoring and earlier detection of gearbox faults.

New technologies emerge

2. Updated ultrasonic technology from UE Systems Inc enables users to collect data through two channels: the conventional onboard data logger, and a channel for recording of actual sound samples onto tape recorders or computers with sound cards

While the primary technologies form the foundation of most powerplant PdM programs, other "secondary" PdM technologies are increasingly being applied as they are enhanced or newly developed. Example of a secondary technology being enhanced: ultrasonic testing (UT), which recognizes changes in the ultrasonic waves that have frequency levels above a 20-kHz signature. Changes in a UT signature enable technicians to identify and locate bearing deterioration, compressed-air or hydraulic-fluid leaks, vacuum leaks, steam-trap leaks, and so on.

The latest UT technology from UE Systems Inc, Elmsford, NY, enables users to collect data through two channels: the conventional, on-board data logging to record data--such as decibel levels, frequency, date, time, and text notes--and a recording channel for the recording of actual sound samples onto tape recorders or computers with sound cards (Fig 2). The new recording feature enables spectral-sound analysis, a capability not present with earlier UT systems.

Another secondary technology being enhanced is borescope inspection. A mainstream PdM technology for gas-turbine users, borescopes provide a fascinating look at the working parts of a turbine without opening the casing. The trained eye can identify such problems as coating breaches, tip rub, foreign object damage, hot corrosion, and blade cracking.

Unlike the cumbersome, rigid tube of 20 years ago, through which an inspector could "eyeball" the interior of a turbine casing, today's video borescopes put a television minicam and a xenon light source on the end of a long, flexible cable sheath. The whole device is no bigger across than a pencil.

In recent years, borescope technology has been applied to more than just gas turbines. Steam-turbine users, for example, have begun retrofitting borescope ports into their machines and adding the technology to their PdM portfolios. In September, Everest VIT, Flanders, NJ, introduced a system that is well-suited for nuclear, hydro, steam-turbine, and gas-turbine plants. According to the supplier, the Recon Digital Inspection System combines intelligent software, intuitive functions, and rugged, hand-held control for digital imaging and loose-parts retrieval in equipment and piping internals. A durable, rigid cable is available in lengths of 100 and 150 ft, and can withstand temperatures up to 120F.

Everest VIT recently was awarded a two-year contract by Nuclear Management Company LLC, Hudson, Wis, to provide remote visual inspection services and equipment to its nuclear plants on an ongoing basis. The six sites are Monticello, Prairie Island, Kewaunee, Point Beach, Duane Arnold, and Palisades.

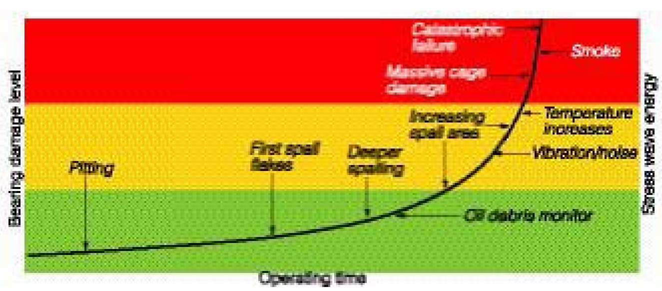
New developments

A brand-new secondary PdM technology was introduced in September by Bently Nevada Corp, Minden, Nev, aimed at the hydroelectric sector. The new stator-mounted air gap (SMAG) monitoring system measures the distance between the rotating and stationary parts of a generator--important because the hydro-generator stator is a flexible assembly up to 40 ft in diameter, so concentric integrity is critical. "With the SMAG monitoring system, operators are given advance warning of possible out-of-round situations that can lead to a stator/rotor rub, resulting in extended outage and extensive repair costs," says Bently Nevada's Jim Rasmussen, senior solutions specialist for hydro.

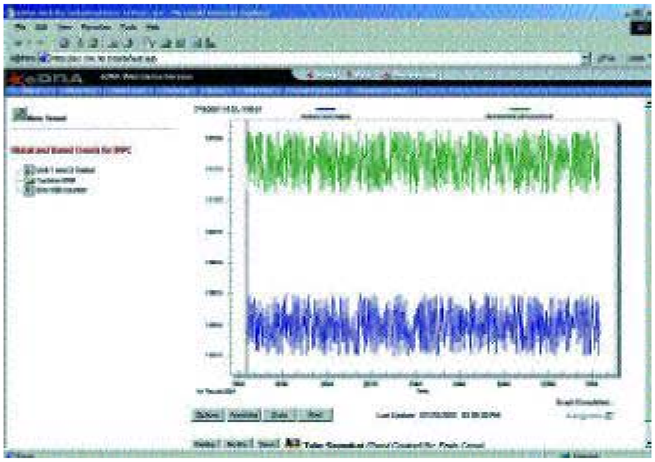
"The new wave" in condition monitoring, according to developers, is something called stress-wave analysis, developed by Swantech LLC, Fort Lauderdale, Fla, and marketed by Dresser-Rand Co, Olean, NY. Stress-wave analysis promises to detect and measure even slight shock and friction events that occur between contact surfaces in operating machinery.

Traditional condition-monitoring technology, Swantech says, often doesn't provide the advanced warning needed to prevent serious equipment damage. Also, it requires the technician to spend an excessive amount of time setting up and base-lining equipment, only to inundate the technician with false alarms. Time and money, therefore, are wasted on the tedious task of fault isolation and alarm validation.

But stress-wave analysis, according to Swantech, detects the energy created as machine parts come in contact at wear levels significantly below those required to excite vibration sensors, and before enough damage has occurred to activate metal chip detectors in lubrication systems. A sensor, externally mounted on the structure, detects stress wave energy transmitted through the machine. Analysis tools isolate and measure the energy, then quantify the degree of damage that can be expected if the trend continues (Fig 3). According to Swantech, stress wave analysis can detect localized surface damage, shaft misalignment, imbalance, lubrication problems, and seal damage, while eliminating false alarms.



3. Stress-wave analysis promises to detect the energy created as machine parts come in contact at wear levels significantly below those required to excite vibration sensors, and before enough damage has occurred to activate metal chip detectors in lube oil



4. Peach Bottom and Limerick nuclear stations are using the "eDNA" software system to capture, trend, and analyze real-time data, thereby more effectively monitoring equipment condition. The trending capabilities have identified numerous equipment problems well before alarm points were reached or serious damage occurred

The system recently was used in the test cell of a leading gas-turbine manufacturer. The test put stress-wave analysis head-to-head against conventional vibration technology in seeded fault testing for a next-generation turbine. During the initial test, the Swantech system identified a problem that was not planned as part of the seeded fault, and was not detected by the vibration sensors. During the second test, a vibration technician looked for but did not find evidence of the seeded fault. The Swantech system found the fault, and correctly correlated it to damage in a specific bearing.

More than sum of parts

A continuing challenge for power producers is to manage and tightly integrate the mountain of data delivered by core PdM technologies. Lube-oil analysis results, for example, can fill holes in the data from vibration surveys, but only if the data are integrated. To illustrate: A high-frequency vibration signature will change, which by itself could be caused by lots of different things. But then the plant runs a lube-oil analysis and finds out that the change was caused by a mechanic performing routine greasing of the bearing just prior to the vibe survey. In this case, looking at data from both tests saved a lot of time and trouble.

Integrating PdM technologies also allows plants to identify and resolve problems sooner. If you are conducting vibration analysis only, you may catch a bearing problem on a cooling-tower fan a few days before catastrophic failure. That's one level of PdM success. But by that point the bearing has already suffered metal damage.

If, instead, you are conducting both lube-oil analysis and vibration surveys, you may detect the problem months before failure, while there's still only minor damage to the bearing. Earlier detection helps the plant avoid secondary damage, such as when metal flakes from a failing bearing are transported downstream.

Condition-monitoring software

To help with the data-management and integration challenge, power producers are turning to powerful software packages, which PdM and other IT suppliers are rapidly introducing. For instance, Entek's latest generation of condition-monitoring software, called Enshare, has been designed to integrate its PdM systems with various sources of plant information--such as computer-based maintenance management systems and process historians. As Rick Wetzel, Entek's product manager, explained at the Enteract 200 Conference, these systems traditionally have been applied for fundamentally different, independent purposes, but software such as Enshare enables them to work together for maximum benefit.

Another IT supplier, Emerson Process Management, Austin, Tex, recently introduced its family of Asset Optimization solutions to help users make improvements in plant reliability. The family has grown steadily from Emerson's PlantWeb architecture--which links diagnostics and digital communications within field instruments. The new offering includes vibration analysis, oil analysis, and infrared thermography interfaces.

Emerson also offers Web-based equipment performance monitoring, called "e-fficiency services," for remote monitoring of compressors, pumps, turbines, heat exchangers, boilers, furnaces, and other process equipment. "The access to accurate, model-based equipment performance data and costs of degradation over a secure Internet link is an exciting innovation for optimizing assets," says John Berra, executive vice president for Emerson.

Ellipse is another Web-enabled, comprehensive software suite that can help power producers integrate its IT systems. Ellipse is supplied by Mincom, Denver, Colo. According to Bryan Friehauf, director of consulting operations for Mincom's Utilities practice, the supplier has helped companies ranging from Reliant Energy to Williams Energies develop reliability programs that have achieved measurable increases in reliability and increased production from their existing assets. Bryan believes that too many organizations have fallen short of their reliability goals because they have only pursued programs that are resources- and process-intensive. Most enterprises focus on the "large assets" which comprise 10-15% of the organization's assets, ignoring the remaining 85-90%, he says.

Excellence at Exelon

InStep Software LLC, Chicago, Ill, offers an enterprise software solution that is helping Exelon Corp, Chicago, integrate its many IT systems at the Peach Bottom and Limerick nuclear stations.

The offering--eDNA, for electronic distributed network architecture--captures, archives, and time-stamps massive amounts of historical and real-time data from disparate process computers, reports Craig Markle, a program manager with Exelon. "The eDNA system helps our system engineers get their hands on data quicker and more easily," he explains. "And they can now trend data for longer durations."

Prior to the 1999 implementation of eDNA at Peach Bottom and Limerick, system engineers had to log onto individual process computers, using different tools, extract the data they were interested in, and manually integrate or manipulate the data to identify trends and determine equipment condition. The process computers were severely limited in the amount of data they could archive, and their ability to perform calculations.

But, as John Kalanik, president of InStep Software, explains, eDNA is a process historian--a high-speed compression data base--that enables users to collect and store values on a 15,000-data-point system for decades (Fig 4). With eDNA, time-sensitive data are accessible, via a client server or the Web, throughout the enterprise and integrated with other systems for preventive maintenance, forecasting, and other reporting and analytical functions. For instance, flow-rate data can be captured, trended, and analyzed to indicate where a pump is operating on its performance curve.

"The eDNA suite doesn't replace PdM technologies," Kalanik emphasizes, "it works with them to better monitor equipment condition."

With the help of eDNA, Exelon engineers have identified several impending equipment problems, and taken corrective action prior to serious trouble. Markle says eDNA successfully:

• Identified vibration and temperature anomalies on a condensate-pump bearing. Plant load was temporarily reduced and the bearing replaced, avoiding potential pump damage and a unit shutdown.

• Detected a bio-fouling problem in a main condenser. With the early warning, chemists were able to correct the source of the fouling before turbine output was affected, and before mechanical cleaning was needed.

• Determined that coolers for a generator stator were becoming fouled. Engineers planned a cleaning project and completed it prior to the onset of hot weather.

• Discovered a tube leak in a feedwater heater, based on temperature trends. With eDNA, the system engineer identified the problem before the control room received a high drain-flow alarm.

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