Multi-parameter Condition Monitoring

Adding a Pervasive Sensing infrastructure focused on equipment condition, not on process control, allows reliability and maintenance teams and other departments in the plant to save time and benefit from improved plant maintainability. By *Jonas Berge*.

In the past, frequent and lengthy turnarounds were the accepted norm. Now, however, plants are expected to run longer between scheduled shutdowns, and those turnarounds are expected to be shorter. There is no room for unscheduled downtime, and maintenance costs must be contained. This outage and downtime challenge is felt by plants in all industries and will only get more challenging in the future with shortages of skilled personnel. Most plants were not designed with reliability programs in mind, there is minimal operation & maintenance input into the design, and then the plant just gets handed over. As a result plants rely mainly on time-based preventive maintenance with very few predictive maintenance procedures.

In the past automation was costly because it required hardwired 4-20mA and on-off signal cables and system I/O cards, which caused a conflict between operational desires for more automation and project budgets. But today automation is inexpensive, thanks to industrial information and communications technologies (IICT) such as bus, wireless, and cloud computing. And now it is possible to improve availability, by adding a Pervasive Sensing infrastructure focused on equipment condition, not on process control. This second layer of automation, including analysis software, to turn data into actionable information allows reliability and maintenance teams and other departments in the plant to save time and benefit from improved plant maintainability. This can be used to radically transform the way maintenance, repair and overhaul (MRO) is done.

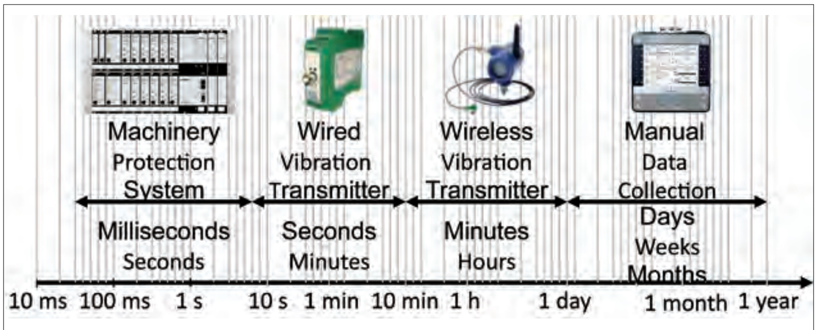

Figure 1: Frequent data collection to catch developing issues early requires automation.

Downtime challenges

Failures that cause downtime or slowdowns are difficult to predict. Affected equipment include:

- Pumps
- Blowers
- Cooling towers
- Heat exchanger
- Air cooled heat exchangers (ACHE)
- Pipe & vessel corrosion
- Valves

Maintenance contracts

Many plants have maintenance contracts for periodic manual data collection, vibration analysis of rotating equipment, inspection of pumps and mechanical seal flush systems etc. However, such service contracts may no longer be enough, as the period of inspection may be a month or even longer. Analyzing the collected data can cause further delays. Early "weak signals" of developing issues may go unnoticed. Smart plants instead have a data-driven approach to reliability and maintenance scheduling. Existing plants can be modernized to become smart plants.

Manual data collection rounds

Most plants have machinery protection system on steam turbines, gas turbines, large compressors, and their largest pumps, but hundreds of motors, pumps, cooling tower fans, blowers, air cooled heat exchangers fans, and smaller compressors etc. do not have any condition monitoring due to the high cost of full-fledged online machinery protection systems. Some equipment has vibration switches that trip the machine when vibration is excessive, but the problem should not be allowed to go that far since it results in process downtime or a slowdown, and often requires more expensive repairs. For the second-tier, yet essential equipment, plants rely on periodic spot checks with manual data collection using portable vibration testers, perhaps with intentions of weekly rounds but due to increasing demands on resources the actual rounds may be monthly or even longer. This is a labor intensive method of data collection and the data is not always analyzed or saved in an electronic database. A certified vibration analyst with expert know-how analyzes and interprets the vibration data to discern failures in advance, but there is not enough data for root-cause analysis, or to visualize degrading conditions, because of the infrequency of data points and the lack of process condition data in vibration analysis software. On top of this, there may not be enough category III and IV certified vibration analysts available on site to review all the data in a timely manner. This leaves the plant vulnerable between testing. In one month, or even in a few days, a problem can surface and escalate to a shutdown or failure before the next scheduled inspection. Moreover, some areas of the plant are hazardous so manual data collection should be minimized.

Complement with wireless vibration transmitters

The wireless vibration transmitter is another way to monitor vibration on non-critical rotating equipment, serving as an intermediate tool to complement online machinery protection systems and portable vibration testers. Using a mix of these three tools can help optimize the plant's reliability program. Wireless vibration transmitters provide automatic data collection and software does the monitoring, saving time and improving productivity, but will not completely replace manual data collection with portable vibration testers.

A set of wireless vibration transmitter costs much less than a machinery protection system and can be used when full-fledged machinery protection system is not required; it is also much easier to deploy because no power cables, signal wires, cabinets, or floor space required. Attaching a vibration sensor only requires epoxy or a rare earth magnet, or for permanent installations the sensors can be bolted to the machine without process penetration.

Many vibration points are often unreachable because fans are mounted inside protective enclosures to ensure personnel are not injured or killed, or they require climbing and working at heights to obtain manual measurements. Wireless vibration transmitters are being adopted quickly for those applications where it is not possible to collect vibration data manually due to the dangers of rotating equipment — especially fan blades in cooling towers, air cooled heat exchangers, and blowers etc. The vibration sensors are mounted inside the enclosures and wired to the wireless transmitter outside the enclosure.

More frequent data automatically monitored by software improves the data analysis to capture developing issues in the early stages rather than later, when damage or outright failure and shutdown have already occurred. More frequent and recent data makes the diagnostics more predictive, makes root-cause analysis easier, and also makes it possible to visualize degrading conditions by severity trend in software. A wireless vibration transmitter can provide an update once per hour instead of once per week or month, capturing the early warning signs when they first appear. This solution is ideal for motors, pumps, cooling tower fans, blowers, air cooled heat exchangers fans, and smaller compressors. Maintenance costs can be reduced by moving from reactive repairs to predictive maintenance for any currently unmonitored equipment by addressing the problem prior to failure, as shown in Figure 1.

Faster data collection doesn't mean an overwhelming amount of data for vibration analysts to review. Wireless vibration transmitters are used to monitor large numbers of equipment automatically to get an overview of which equipment is in good condition, which ones have failed, and which ones are starting to develop vibration issues and likely need closer attention. This way the analyst does not have to spend precious time on equipment that is healthy and can focus instead on root-cause analysis and reporting for the equipment experiencing problems like coupling wear, poor lubrication, or bearing defects.

Rather than wait for machines with a high vibration switch to stop the machine with the commensurate process upset or shutdown, hourly updates from a wireless transmitter with alarm detection in software provide the reliability team with a warning to take appropriate action before the vibration switch stops the machine.

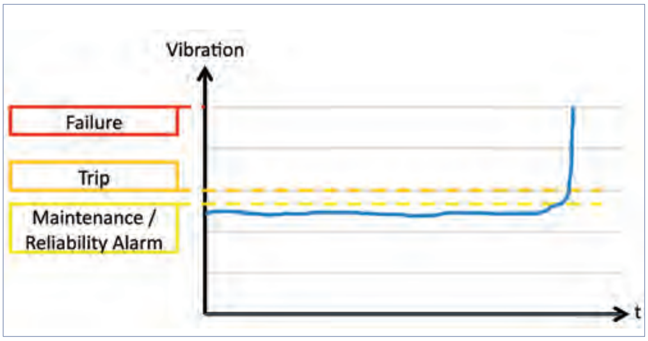

Figure 2: The reliability and maintenance team gets a warning before trip.

While alarming on vibration is helpful, it can often be challenging because a significant increase in total vibration is often seen only in the late stages when failure is imminent, which leaves little time to respond. PeakVue technology alarming on peak value acceleration provides an earlier warning of onset of a problem, and is automatic, reducing the burden on the vibration analyst, as shown in Figure 3.

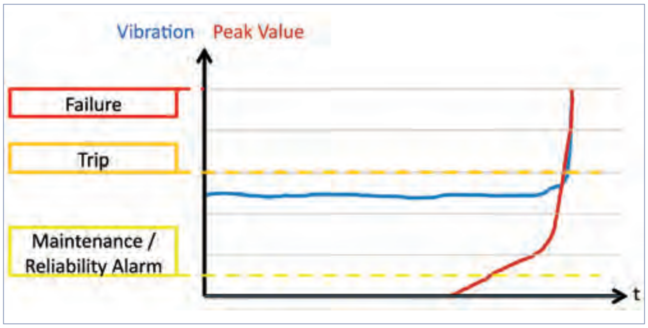

Figure 3: Alarming on peak value acceleration gives an even earlier warning of onset bearing defect.

When troubleshooting machinery problems, the reliability engineer can now review the software event log and vibration trend to see what has happened to the equipment over the days and hours leading up to the failure. The vibration spectrum and waveforms are also available from the wireless vibration transmitter at a click of a button.

All machines vibrate more or less depending on the type of machine, the mounting base, etc. Some modern multi-parameter condition monitoring software has automatic baseline for the alarms to avoid nuisance alarms. For instance, two identical pumps will have different baselines determined by how the coupling is aligned between pump and motor. Moreover, vibration is a function of flow, speed, or fan pitch. The alarm level can therefore be correlated with operating conditions in the condition monitoring software such as for variable speed pumps. Multi-parameter condition monitoring software uses statistical methods to alert only on meaningful increases in vibration. Sensors alone are often not enough; analytics software may also be required.

Multi-parameter condition monitoring for plant maintainability

Operational desires for a smart plant includes built-in maintainability. Traditional reliability engineering focuses very much on vibration, but vibration monitoring alone is not enough because it doesn't detect other problems with equipment. For example, pump problems also include loss of seal flush fluid. Multi-parameter condition monitoring is about observing measurable properties for signs of internal fouling or faults. Additional sensors for equipment pressures, temperature, flow, auxiliary seal flush fluid levels, position, pH and conductivity provide data on operating process and ambient conditions that help in root-cause analysis. This allows other problems like fouling, scaling, and leaks etc. to be detected. Combining highly instrumented assets with analytic software makes an early warning system that can be easily understood and does not require category III or IV vibration analyst to interpret. Some modern condition monitoring software uses dedicated analytics algorithms for each type of equipment such as pump, fan/blower, compressor, cooling tower, heat exchanger, and air cooled heat exchanger.

Air Cooled Heat Exchanger (ACHE)

Typically, Air Cooled Heat Exchanger (ACHE) fans are not monitored online. An ACHE will experience wear and tear on bearings, belts, gearboxes, couplings, or weakened mechanical support that can eventually lead to failure. Or there may be issues with the louvers. This reduces cooling and in turn may result in production loss, flaring, and vapor release, over and above the repair costs. Some fans may unintentionally be running at a resonant speed which can accelerate mechanical failure. Fouling on the inside of the tubes caused by precipitates like salts, or outside of the tubes due to the accumulation of dust or other airborne debris are other issues that reduce the heat transfer capability of the exchanger.

Infrequent manual inspection

Best practice in the past was to periodically collect data manually for analysis. However, this method still leaves the ACHE vulnerable between testing. Moreover, technicians cannot enter the fan section to measure vibration while in operation. As a result the ACHE may run to failure.

ACHE condition monitoring

Modernizing ACHEs with wireless transmitters and built-for-purpose analytics software with ACHE condition monitoring algorithms makes it possible to automate the condition monitoring and give plants the ability to track vibration for each motor-gearbox-fan assembly, and to visualize in trend charts how rapidly it gets more severe over time. If vibration or peak value exceeds the pre-limit, an alarm is triggered in the condition monitoring software prompting attention. Some of the required measurements may be available from the DCS, but the missing measurements such as temperatures of bearings or coils may need to be added, using WirelessHART transmitters. Fortunately, these are easy to implement and a low risk to deploy.

The additional transmitters and software turns an ordinary ACHE into a smart ACHE by providing condition indication, as shown in Fig. 4. Note that this information does not need to go to the operators, but instead to the reliability and maintenance personnel responsible for keeping the ACHE running. ACHE diagnostics include:

- High motor/fan vibration
- High motor/fan bearing temperature
- Resonance
- Bearing fault
- Exchanger fouling
- Reduced cooling
- Louver mechanical defects
- Fan pitch actuator defect

The ACHE diagnostics detects fouling enabling cleaning to be scheduled, and it detects the onset of bearing failure, allowing overhaul to be scheduled based on severity. It flags louver or fan pitch issues, driving plans for repairs. It makes it possible to avoid operation near resonance frequency, to prevent damage.

Pumps

Some very critical pumps may already have condition monitoring, but due to the high cost of online machinery protection systems, most "essential" pumps do not. Restricted discharge flow or plugged strainer results in cavitation that leads to pump failure and mechanical

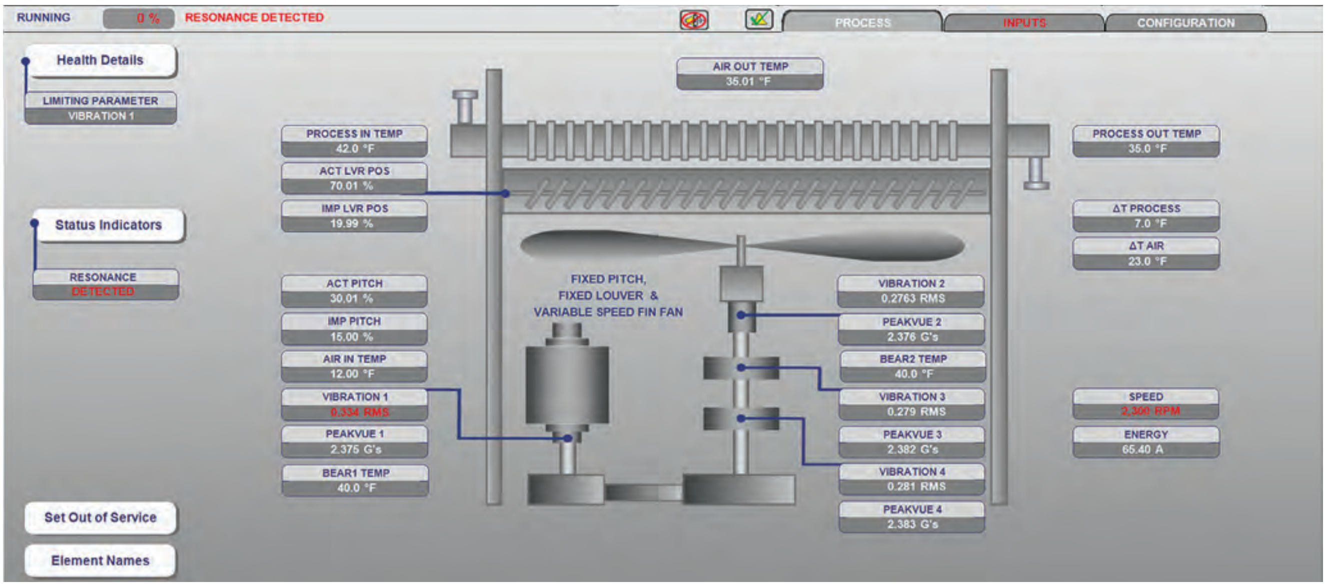

Figure 4: ACHE display – resonance alarm.

seal failure due to vibration. A pump will also experience wear and tear on bearings, which also leads to vibration and failure of pump and seal. This in turn may result in production loss, process leaks and fires, over and above the repair costs.

Infrequent manual inspection

Best practice in the past was to manually check seal fluid level and collect vibration data for analysis on a periodic basis. However, this method still leaves the pump vulnerable between inspections.

Pump condition monitoring

As with ACHE, modernizing with wireless transmitters on pumps in conjunction with built-for-purpose analytics software with fixed and variable speed pump condition monitoring algorithms automates the condition monitoring and gives plants the ability to track vibration and peak value for each motor and pump, with visualization of how rapidly the condition is deteriorating. If vibration or peak value exceeds the pre-limit, an alarm is triggered in the condition monitoring software prompting attention. Some of the required measurements may already exist, available from the plant historian or DCS, while wireless transmitters can add missing measurements such as suction and discharge pressure, seal reservoir pressure and fluid level, or bearing temperature.

Figure 5 shows how the additional transmitters and software turns an ordinary pump into a smart pump by providing condition indication. As before, this information does not need to go to the process operators, but to reliability and maintenance personnel responsible for keeping the pump running. Pump diagnostics include:

- High vibration
- Bearing fault
- Low head
- Low discharge pressure
- Seal pressure
- Strainer cleaning required
- Seal flush system faults
- Liquid hydrocarbon leak

The pump diagnostics detects issues like restricted discharge flow such that it can be attended to, or suction such that cleaning of strainers can be scheduled. They also detect the onset of bearing failure, allowing overhaul to be scheduled based on severity, or switchover to a backup pump. A low seal fluid alarm can trigger a work order before the seal leaks.

Pump seal piping plan modernization

The fourth edition of API Standard 682 for mechanical seals has moved piping plan instrumentation from switches to transmitters to provide the seal system alarms. In addition to providing a more reliable method of alarming, transmitters also offer insight that cannot be revealed with switches. This enables more sophisticated algorithms to monitor pump health. Wireless transmitters make it easy to upgrade seal flush systems from switches to transmitters as there is no need to rewire, reconfigure, or expand the system I/O cards. The new transmitters can simply use wireless instead.

Shared infrastructure

The reliability engineers and maintenance manager do not need to use the DCS workstations used by the operators. The plant-wide wireless instrument network and software is a second system shared by multiple departments that need information not provided by the DCS. The reliability and maintenance department, energy team, HS&E department, and operations often share the investment in the plant-wide WirelessHART network.

Wireless transmitters and WirelessHART gateways used for monitoring can integrate with any control system. It is not necessary to upgrade the existing systems to take advantage of this solution.

Modernization to a data-driven smart plant

Wireless transmitters in conjunction with built-for-purpose analytic software make it possible to detect issues with plant equipment that may lead to failure and downtime. These equipment include, for instance, heat exchangers, air cooled heat exchangers, pumps, fan/blowers, compressors, and cooling towers etc.

Not designing a new plant or modernizing an existing for maintainability and availability sets the stage for a reactive maintenance culture. Therefore, make sure maintenance & reliability readiness budgets are incorporated into the project prior to kickoff. Contact a reliability expert to audit your existing plant or new plant design to identify which reliability & maintenance productivity solutions are recommended and to get an estimate of the cost, potential savings, and ROI for your plant.

CEA

Jonas Berge is Director, Applied Technology, at Emerson Process Management.

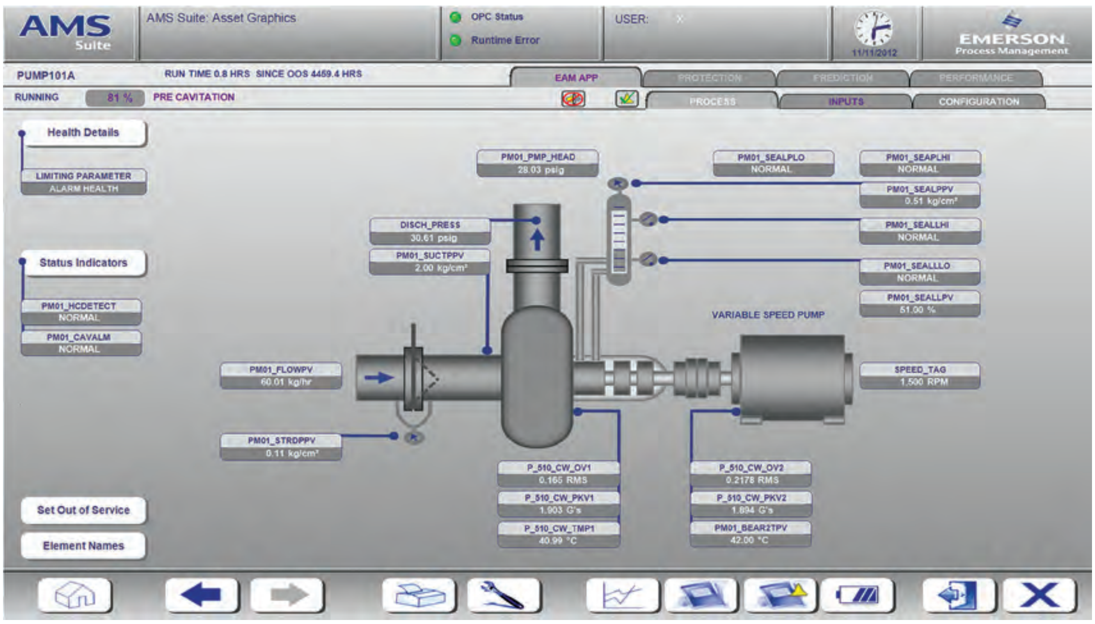

Figure 5: Pump display – pressure instability alarm.