White Paper
Power
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3 Steps to Ensuring Mechanical Asset Integrity

A Modern Approach to Rotating Equipment Condition Monitoring

EMERSON

Improving reliability is a top industry concern among utilities and it can have a significant impact on profitability. Traditional fossil units are increasingly being asked to cycle because of the renewable power available to the grid and the low cost of natural gas. These new operating realities are stressing mechanical equipment, which can lead to derates or forced outages.

Detecting critical asset failures before they occur can be difficult, particularly as most plants have fewer experts available onsite. To mitigate this issue, it is recommended that plant maintenance organizations transition from reactive or preventive programs to using a proactive strategy that employs continuous condition-based monitoring and automation where possible. Modern sensing technologies make it possible to continuously monitor the health of rotating equipment and to automatically alert plant personnel to developing problems before generation is impacted.

Reactive maintenance costs are 50% higher than planned maintenance costs.

But what about the cost? By selectively deploying this reliability approach on strategic assets, any investment changes from being a cost into a profitable business strategy that goes beyond maintenance. It is estimated that with a top reliability program, operational savings can be 5 to 10 times the amount of any maintenance savings (Figure 1).

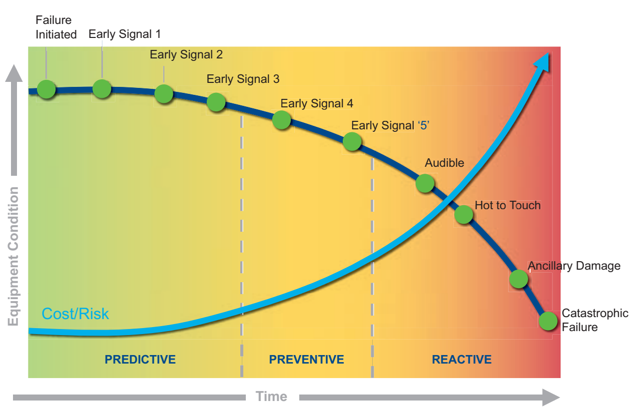

Figure 1: *Failure detection versus cost impact.*

This white paper describes the stages required for deploying condition-based monitoring in a generating plant:

1. Prioritize which assets should be monitored
2. Apply continuous condition-based monitoring
3. Analyze data and evaluate asset health

STEP 1
Prioritize Your Assets

Asset Ranking

Determining the criticality of plant assets is the foundation of any successful reliability program as it allows focus on those things that impact operations the most. The process should include all stakeholders covering the needs of the entire plant, such as maintenance, operations, purchasing, safety, environmental, and dispatch. If this is your first assessment of asset criticality, start from a system level rather than an equipment level to ensure that you are not overwhelming the stakeholders during the decision-making process. This approach also provides boundaries to the program so that it can move ahead with funding, as it helps to include all parties in the process and allows them to better understand the desired outcome.

Questions should cover each area of interest and calculations should be made to rank the effect of a system failure on the power plant. The systems with the greatest impact will be the highest priority. Once systems have been identified and ranked, the next step is to rank the individual assets using the same approach.

Plants looking to find savings on O&M should look past the typical approach of cutting investment and, counterintuitively, look to invest in a focused reliability effort.

Take the highest priority equipment and employ a failure mode effects analysis (FMEA) to help identify where and how the equipment might fail. The FMEA is a process to identify the different ways something might fail and the impacts of the different failure modes. Diagnosing and detecting all potential failure modes is beyond the scope of this white paper. Instead, this paper will focus on how to monitor the main sources of failures for typical rotating equipment.

STEP 2
Apply Continuous Condition-Based Monitoring

Outside of turbines, many plants use periodic monitoring to detect developing issues with rotating equipment. This presents a few glaring problems, the first being that facilities often find themselves running in the blind because periodic measurements only provide a snapshot in time. The second chief issue is that many companies have few—or maybe zero—vibration analysts who collect data and study it. As organizations are continually pressured with resource shortages, many no longer have time for collecting data. A solution to this is transitioning plant maintenance staffs from manual collection to continuous condition-based monitoring.

Common Asset Failure Modes

Before applying any technologies, it's important to understand the fundamentals of why rotating equipment fails. For this discussion, the focus is on vibration, which can be complex, but the clear majority of vibration issues can be isolated to one of four things: imbalance, misalignment, looseness, or mechanical wear.

- **Imbalance**
  The center of mass is not aligned with the center of rotation and causes the equipment to wobble as the heavy spot rotates about the center.
- **Misalignment**
  The center of rotation on two bearings on the same shaft, or on two shafts at a coupling, are not properly aligned.
- **Looseness**
  A mechanical element has too much clearance and is moving beyond its intended location.
- **Mechanical Wear**
  This manifests itself in different ways depending on the bearing type. On antifriction bearings, a common mechanical wear item is a defect in the inner race, outer race, or one of the rolling elements. On journal bearings, mechanical wear could be caused by a rub or a fluid instability issue—commonly called "oil whirl," or "oil whip" when it is advanced.

Protection and Prediction

Two commonly used approaches in the field of condition monitoring are prediction and protection and their differences and applications must be understood.

- **Protection**
  This typically applies to turbines in a power plant where a system is required to automatically shut down the equipment based on triggered conditions to prevent catastrophic damage and injury. Protection systems are required for plants to be able to operate. Think of protection as insurance.
- **Prediction**
  Just as the term implies, prediction uses technologies that proactively analyze the health of the equipment that is being monitored. Along with this monitoring, diagnostics to help a user solve a problem are served up. Think of prediction as an investment to improve plant reliability/availability by providing advanced warning of developing issues so that maintenance activities can be planned and scheduled.

As many as 50% of machinery malfunctions that lead to downtime are process-induced,—90% can be predicted.

Wired, Integrated, or Wireless?

Deploying predictive maintenance technologies requires proper selection of technologies for the application, and there are multiple methods that should be considered.

- **Wired, Standalone**
  A typical solution is a standalone monitoring system that is connected into a control system. These can have separate user interfaces or can provide some data to the plant's primary automation platform.
- **Wired, Integrated**
  If a plant has Emerson's Ovation™ distributed control system, an option is to use an integrated I/O card that contains all the capabilities of a standalone system. This eliminates any integration work and security compliance concerns.
- **Wireless**
  For non-turbine and other pump applications where automatic shutdown is not required, an alternative is to install a wireless transmitter.

Types of Assets Monitored

Every power plant has a protection system installed on their critical turbines, but most still collect condition monitoring data manually. Perhaps the biggest opportunity to improve unit availability is to use predictive condition monitoring on balance of plant (BOP) applications.

Typical BOP applications to consider wired or wireless technologies for include:

- Cooling tower fan gearbox and motor
- Booster water pumps
- HRSG air fans
- Service water pumps
- Lube oil pumps
- Raw water pumps
- Pulverizers
- Conveyor pump
- Condensate pump
- Polishing pump
- Lime slurry pump
- Circulating water pump
- Fuel gas compressor

STEP 3
Analyze Data and Evaluate Asset Health

Once a condition monitoring strategy is in place and data is being supplied, the analysis becomes critical. Data for data's sake should be avoided; rather the information provided should lend itself to providing actionable information in as much of an automated fashion as practicable.

Traditional Vibration

One method for monitoring is evaluating vibration data, but this often requires an expert to sift through lots of data. An approach that can help with this effort is to automate this process and dissolve the frequency spectrum into easily understandable data. This method breaks down the frequency spectrum to help diagnose what type of vibration event may be occurring, and draws the user's attention to advanced issues that need further action. Vibration experts, the maintenance team, or the reliability team can then focus on advanced analysis (Figure 2).

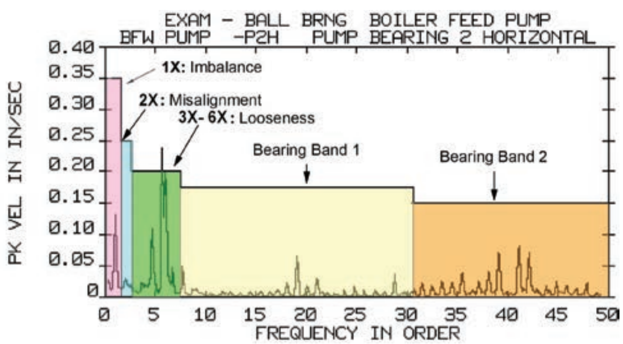

***Figure 2:** Frequency spectrum.*

PeakVue®

A preferred solution for continuous condition-based monitoring is a technology called PeakVue. PeakVue alerts users to potential problems very early in the failure curve, before traditional vibration analysis, and before other technologies like oil analysis, temperature monitoring, or sound and touch. The principle is simple and does not require vibrartion expertise to understand. It follows the rule of 10s, which is a way to depict the severity of a problem based on magnitude.

As an example, let's take a bearing on a polishing pump, operating somewhere between 900 and 4000 RPM. The rule of 10s says that if PeakVue is below 10, there is no problem with the bearing, but if it is above 10, there is something developing in the equipment. It's meant so that you don't require confirmation from any other technology; rather, PeakVue is the primary diagnostic tool. Following the rule of 10s, if PeakVue is above 20, the problem is worse and if it increases to a value above 30, failure is imminent (Figure 3).

State	~ Remaining Bearing Life	Vibration (in/sec)	PeakVue Value
0	20–100%	0.15	**0**
1	< 20%	0.15	**4**
2	< 10%	0.20	**8**
3	< 5%	0.25	**12**
4	< 1%	0.45	**25**
Failure	0%	**> 0.30**	**> 40**

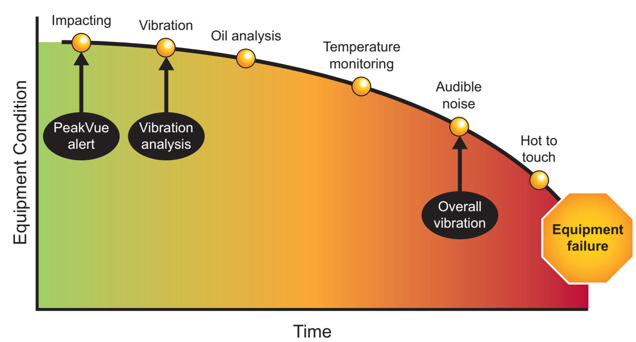

***Figure 3:** PeakVue reading and problem severity.*

Using PeakVue and the Rule of 10s doesn't imply that analysts are replaced. It means plant automation can collect data and automatically triage issues for operations. In fact, automated online monitoring will improve the productivity of the entire plant because it will alert operations with actionable information so they know when it's appropriate to contact an analyst, or maintenance personnel, or reliability expert to investigate a developing issue.

APPLICATION RESULTS

Example 1
A utility using vibration analysis was served the following data from the plant's condition monitoring system (Figure 4).

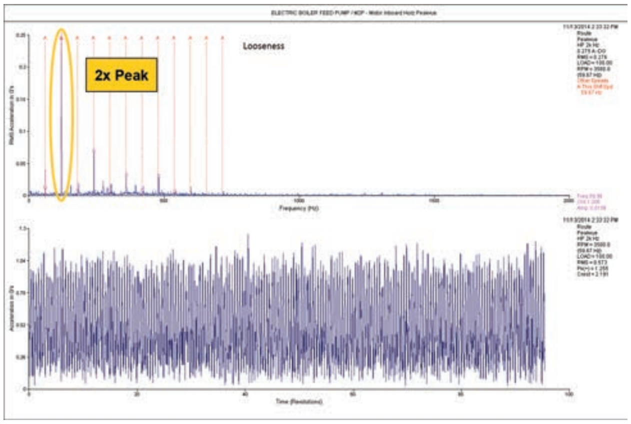

Figure 4: *Bearing misalignment.*

As shown previously, 2X speed indicates a misalignment issue and the plant scheduled shutdown of this feed pump. Upon further analysis, the inboard motor bearing showed a condition called fretting, which is wear from repeated sliding between two surfaces (Figure 5).

Figure 5: *Bearing fretting.*

Example 2
Another plant deployed continuous monitoring on a critical fan and was supplied the following data. The PeakVue readings are compared to a traditional vibration spectrum to illustrate the difference (Figure 6).

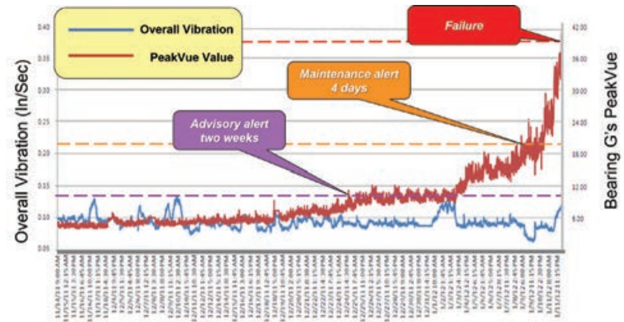

Figure 6: *PeakVue compared to traditional vibration.*

This fan was monitored using PeakVue and the rule of 10s, yet the plant did not take the unit out of service when the PeakVue value stated to do so. In retrospect, warnings were provided two weeks prior to the unit failing with bearing damage (Figure 7).

Figure 7: *Damaged bearing.*

Example 3
Tucson Electric Power's (TEP) five-member predictive maintenance team is responsible for a wide variety of equipment that varies in complexity and scale. The team needed to improve its ability to identify equipment issues early and safely, allowing adequate time to plan repairs, while minimizing costly downtime. In addition, the team focused on expanding predictive maintenance to include equipment that is difficult to access, runs intermittently, or varies by load.

TEP used both wired and wireless technologies to monitor critical rotating equipment throughout its plant. The plant relies on this technology so much that it tests high-cost/critical equipment at OEMs using it before anything ships to site.

One result from using these systems is that TEP avoided $1M in maintenance and replacement costs during 2012. In 2013, it saved over $750,000 in O&M during the first three quarters of the year

CONCLUSION

To improve plant availability and mitigate the effects of a changing workforce, power utilities need to move from manual collection to automated condition-based monitoring of rotating equipment. Plants can accomplish this by deploying wired or wireless systems that provide predictive diagnostics. More progressive utilities are moving in this direction and have lowered their O&M costs while simultaneously improving availability.

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