

Online vibration monitoring integrated with process control and combined with shutdown protection, predictive maintenance and performance monitoring is a sure-fire way to keep your rotating equipment up and generating revenue.

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Protecting Critical Machinery

— the value of a complete solution



With today's advanced technology, it is both possible and essential to access decision-making information about the operating condition of critical equipment – not just a 'trip' signal after significant internal damage has occurred. Some companies are putting productivity at risk by relying on 'protection' systems for their critical turbomachinery – vital though this is, it is only part of the complete solution.

A complete strategy for protecting critical machinery covers three real-life scenarios using four monitoring components. These scenarios are:

- Unpredictable events
- Predictable events
- Controllable events

Unpredictable events happen suddenly and without warning, eg a metallurgical imperfection or slug of water from the boiler may cause a blade to snap. If this occurs, an instant decision to 'trip' must be made and integrated with process control to orchestrate the machine, area, or plant shutdown. Additionally, machine health data gathered before and during the 'trip' will aid the assessment of what happened.

Predictable events are machine malfunctions that are detected and tracked months in advance of a planned outage. Maintenance planners use this information to identify the area of the fault and fault type, to gauge its severity, order parts and plan the outage. When machine malfunctions in this category are monitored, business decisions can be made either to continue running the machine and cause possible damage, or to determine the most convenient time for scheduling the outage. In parallel, the protection system is monitoring for a sudden turn for the worse so as to avoid catastrophic failure.

Controllable events represent scenarios that give the largest return on investment for monitoring capital outlay, and provide the best opportunity to optimise process and performance. For example, on an unusually cold day, the operator ramps up the turbine and receives an oil whirl vibration alert from the predictive vibration monitoring system and simultaneously sees a low temperature alarm from the process control system on the same bearing. This is a controllable scenario, and the operator knows exactly what to do. Reducing the RPM of the turbine will immediately stop oil whirl from damaging the bearing. Solving the low oil temperature problem will keep the turbine out of the damaging oil whirl condition when the turbine is brought back online. In controllable scenarios, an operator simultaneously has both machine health and process status and is able to avoid problems that would otherwise lead to machine degradation.

And the four monitoring components are:

- Protection monitoring
- Prediction monitoring
- Performance monitoring
- Integration of the above to process control

Predictive maintenance of rotating assets is best practiced using information gathered through vibration monitoring. Sometimes this data signals big trouble down the road, allowing analysts to make a judgement as to when a failure might be expected. Based on their prediction, immediate repairs may be necessary in time to avoid the failure. It may be possible to delay repairs until a scheduled plant shutdown - or let them go altogether. Ultimately, this technology helps the plant and maintenance managers make business decisions about what to do – and when and how to do it. The result is generally a far less expensive proposition than reacting after something breaks.

Yet, according to a Deloitte & Touche study, more than 50% of industry maintenance man-hours are spent fixing equipment following a failure, whereas less than 18% of those hours are spent determining when equipment might fail and planning accordingly. These numbers will improve as more maintenance departments implement predictive maintenance programmes based on online vibration monitoring of key machines.

The 'most critical' category usually involves only about 5% of rotating assets, but this small number of machines represents an easy target for a complete online monitoring solution - with enormous financial returns on a single 'find' with a controllable outcome.

Online monitoring

Continuous, online monitoring of rotating machinery represents technology well beyond systems that provide only periodic snapshots, yet some critical situations can only be averted if a stream of data regarding the current condition of the equipment is available. Fortunately, it is now possible to continuously obtain information about the health of a whole range of gas or steam turbines, generators, compressors, fans, motors, pumps, etc, (see note). Essential equipment can be monitored automatically for changing vibration patterns and rising temperatures – sure signs of impending trouble.

Some of the earliest automated monitoring systems were dedicated to expensive steam-driven power turbines.

Continued on page 22

Continued from page 20

Data received directly from a machine is stored on a hard drive, buffered and presented in a variety of graphs that depict exactly what is occurring within that machine. Maintenance engineers and machine specialists suddenly had never-before-available information to use in analysing changes in the machine's operation.

When properly interpreted, these signals will pinpoint the location, nature and severity of developing problems. Data from automated monitoring systems enable plant personnel to predict with greater accuracy when a machine will need maintenance to prevent damage and avoid lost production. Machinery health management recognises the significance of each machine in a production environment, focusing greater attention on those machines that, if stopped, would likely shut down all, or a major section of, the plant. Online monitoring ensures that machine condition is being assessed continuously.

Performance monitoring

Another technology compares machine performance with a thermodynamic efficiency performance model. Compressors, boilers and steam or gas turbines are the most commonly modelled types of equipment, but a thermodynamic model can be applied to literally any plant machinery. Performance deteriorates mainly due to fouling or build-up on blades and other surfaces, resulting in greater energy usage and lost throughput.

Equipment performance monitoring systems use existing process measurements, pass them through the thermodynamic model and provide a true picture of how well that machine is actually performing. While plant personnel may be aware that equipment performance is below normal, they may not know the significant cost of lost heat rate and excess energy usage. Such data can help lead to the root cause of degradation.

The most important element of performance monitoring is the expertise required to build the thermodynamic model and then distil and validate the large amount of input data. By utilising the performance model to analyse this information and formulate actionable recommendations, performance specialists are able to identify lagging performance that has not been recognised by either production or maintenance personnel.

Because the model input data comes from the existing process measurements commonly found already in the plant history, the data can be analysed by either on-site systems, or remotely using off-site specialists. Analysis based on thermodynamic modelling also enables a specialist to predict when a piece of equipment needs to be taken out of service for either the recovery of lost efficiency or a comprehensive overhaul. A machine's future performance is evaluated, based on its history, in order to predict when the efficiency of that unit will drop below a certain financial or performance threshold, signalling when it should be taken out of service. In this way, performance monitoring complements predictive maintenance.

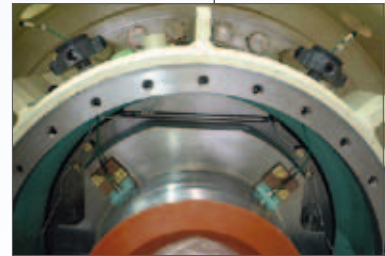
Pulling it all together

Let's look at how a complete solution like the one described in this article would work in a typical turbomachinery application. In Fig 1, the sensors mounted to bearings on a critically important machine provide a continuous flow of vibration measurements. A large turbo generator may have more than 10 bearings with two sensors at each bearing plus other unique instrumentation

– like speed sensors, differential expansion sensors and case expansion sensors. There could be as many as nine different types of measurements at various locations down a machine train.

The cables leading from these sensors are connected to online monitoring hardware that is the foundation for the complete online solution. By measuring for detailed vibration, in addition to peak vibration, the new turbomachinery protection system, which is intended as a retrofit on shutdown systems, has the ability to monitor machine parameters for signs of developing problems so that vibration never gets to the level where 'protection' ie, shutdown, is necessary. However, in the rare scenario of a rapid degradation, the machine is still protected.

Machinery health parameters are integrated with the plant's control system. For the first time, vibration monitoring becomes an extension of the central control system, which often monitors temperature, pressure, load, etc, any one of which could be symptomatic of a problem. Vibration monitoring actually monitors the position and the



motion of the shaft inside the bearings. That information is now integrated with the control room, making operators aware of what is happening deep inside a critical machine - such information is of much greater value than just the symptoms of degrading performance.

Up to 50% of machinery problems are process induced. If they are not caused by operators directly, they are the result of standard procedures used by control room personnel. When adjustments are made under these conditions without machine health feedback, trade-offs occur. Improvements are made to production, but operations personnel are blind to the stress placed on machinery health.

When the operators have real-time supervisory and vibration parameters at their disposal, they can observe the impact of process adjustments on a machine's health and learn what steps can be taken to actually improve performance. For example, during the start-up of a turbine, if case expansion or rotor eccentricity levels are not within acceptable limits, operators can make real-time adjustments to ramp rates and also make business decisions to optimise the ramp rate versus the impact on machinery health. Informed real-time decisions are best made when vibration data is integrated with the process automation system.

Conclusions

For the most critical rotating equipment in the plant environment, three scenarios must be accounted for: the unpredictable, the predictable and the controllable. The complete solution covers all three scenarios by providing protection monitoring, prediction monitoring and performance monitoring all integrated with the process control system.

Monitoring systems utilising advanced predictive technologies are giving end users newer, faster and more complete methods for analysis and automated analysis - information that can be acted upon. ✨

Figure 1

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Note

A Complete Solution Now

It is now possible to continuously obtain information about the health of a whole range of rotating equipment. Emerson's AMS® Suite: Machinery Health Manager predictive maintenance software can provide real-time updates, recording and play back. It is able to receive complex data continuously from a broad range of plant equipment, analyse it and present recognisable images to give machinery specialists a better understanding of what is going on within a machine. It also is capable of coupling this information with process control, providing the path to a complete monitoring solution.