COVER STORY

OPTIMUM MAINTENANCE

A GREAT VARIETY OF COMPUTER-BASED TOOLS HELP OPERATORS PLAN THEIR STRATEGIES TO EXTEND OUTAGE INTERVALS AND KEEP MACHINES HEALTHY

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Somewhere near the intersection of OEM recommendations, industry best practices and the time-honored operating experience of seasoned plant personnel lies the ideal formula for maintaining critical and semi-critical turbomachinery equipment and auxiliaries. While site-specific maintenance protocols and priorities vary, most owners and operators can agree on this: The use of increasingly versatile and flexible software-based tools (which combine data gathering, trend analysis and anomaly detection to provide detailed decision support) is making it easier than ever for maintenance personnel to plan, prioritize and execute maintenance activities in a cost-effective way (Figure 1).

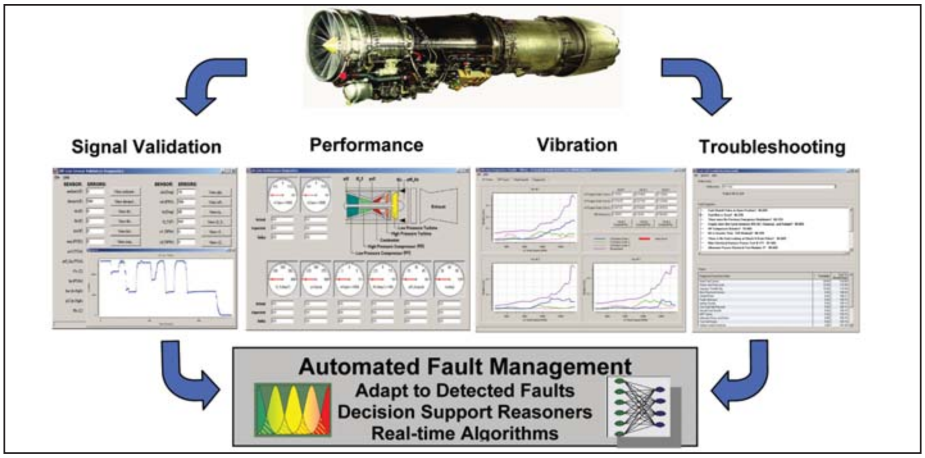

Figure 1: Versatile and flexible software tools combine data gathering, trend analysis and anomaly detection to provide detailed decision support

More and more, the personnel responsible for these plants are warming up to the idea that advanced modeling and diagnostic tools — while they require some expense and training up front — make sense, says Jerry Gorski, Director of O&M for Fossil Service at Siemens Energy (Orlando, FL). "People are starting to really experience the value of these advanced systems, especially when the condition-monitoring systems are integrated with the facility's control system to enable more automatic use and sharing of related information," adds Scott Johnson, Integrated Condition Monitoring Marketing Manager for Rockwell Automation (Mayfield Heights, OH).

From the collection of data to interpreting it and helping operators make intelligent maintenance decisions, the computer is playing an ever-increasing role in today's power plants, oil and gas and process facilities. In some cases, these systems and software are also linked to Computerized Maintenance Management Systems (CMMS) that perform work order and inventory mangement. "We have become an information-hungry society, and when it comes to plant maintenance, it is no different," adds Johnson.

Maintenance spectrum

"The criticality of the machine, the types of failures that could occur, their likelihood and consequences must all be considered when developing appropriate maintenance approaches," Jeff Schnitzer, General Manager of GE Energy's Bently Nevada Asset Condition Monitoring Division (Minden, NV). With the use of advanced instrumentation and continuously evolving modeling algorithms, today's Condition Based Monitoring (CBM) systems give operators the real-time insight they need to bridge the great divide between reliance on purely planned maintenance vs. purely reactive maintenance.

These systems are able to gather data related to a range of useful machinery parameters (discussed below) and identify and analyze telltale trends in both the values themselves and their rate of change over time. The systems interpret the results (to provide a current snapshot of equipment health) and extrapolate them (to predict events that are likely to occur in the foreseeable future) to help operators to refine their maintenance protocols.

"This helps plant operators to carry out maintenance-related activities when they are likely to have the smallest possible operational and financial impact (in light of seasonal demand or peak market conditions, for instance) and incur downtime of the smallest possible duration," says Gorski of Siemens.

Today, most CBM systems are able to accept data from a mix of data-collection sources — portable dataloggers that collect data at regular intervals or on-demand, permanent, hard-wired monitoring devices that transmit data either continuously or periodically, as needed, and wireless transducers. And most are also vendor-neutral, with an open architecture that allows them to interface seamlessly with sensors and monitoring devices from any number of providers, says Bill Nickerson, Director of Product Development for Impact-RLW Systems (State College, PA), a subsidiary of Impact Technologies, LLC (Rochester, NY).

As a result, it is now possible for operators to adopt a single condition-monitoring software platform and user interface. "This platform accepts and integrates inputs from continuous online protection systems (to meet API 670 critical-shutdown requirements), portable data-collection instruments, process control systems, wireless sensors and hard-wired scanning-type systems (where many sensors share a common sensor bus and sensors are polled periodically to send their signal back to the host computer)," says Stephan Kwan, Product Line Manager, for GE Energy's Bently Nevada Asset Condition Monitoring line (Minden, NV). "And although such a software platform is not the same thing as a CMMS, it integrates nicely with a CMMS to send messages that trigger a work order to inspect a machine or replace a particular component," he adds (see box next page).

And, thanks to advanced signal-processing technology, and high-speed, high-resolution data acquisition platforms, today's CBM systems eliminate some of the low-bandwidth limitations that characterized earlier monitoring systems, says Scott Valentine, Manager of Maintenance and Logistics Systems for Impact Technologies.

COMPUTERIZED MAINTENANCE MANAGEMENT

A growing number of operators are linking the diagnostic and prognostic capabilities of their Condition Based Monitoring (CBM) systems with the business-management capabilities that are provided by the facility's overarching Computerized Maintenance Management Systems (CMMS). When such systems work together, the resulting information transparency leads to greater performance and financial efficiencies.

The CMMS performs three key important functions: Work-order, inventory and purchase order management. Work order management automates and documents the planning and execution of the thousands of maintenance-related tasks that are routinely carried out in the facility (coordinating such details as required skills, labor, parts and tools, detailed instructions and checklists, recommended frequency of execution, required downtime and so on). "When operators comb through the OEM operating manuals and then apply their own site-specific intelligence, the system can be set up to generate customized reminders, alerts (i.e., to instruct operators to carry out a visual inspection, grease a bearing, visit the machine with a data logger or even schedule major maintenance) and work orders that are tailored to each plant component or system," says Jerry Gorski, Director of O&M for Fossil Service for Siemens Energy (Orlando, FL). "These are driven by whatever the most relevant factor happens to be for the specific component — calendar time, machine run time, the number of starts-stops, or some other critical, machine-specific process variable."

People come and go over time, maintenance plans change and unexpected events happen but the CMMS maintains a historical record of all the work that has been done and keeps track of what is planned to be done for the foreseeable future. "Work order management is an incredibly powerful tool for ensuring effective operational continuity over time," adds Gorski.

When it comes to inventory management, the CMMS not only keeps track of what's in stock at any given time and where it resides but centralizes data related to vendor specifications, warranty information, service contracts, required lead time, unit price and reorder information. And, says Gorski: "These systems make it very easy for users to study usage patterns in order to make more-informed ordering decisions, and to anticipate the required lead time and optimal re-order point more accurately."

Finally, the CMMS delivers additional efficiencies by standardizing the processes and authorizations required to generate, authorize and execute, and archive purchase orders for equipment and services.

Reading the tea leaves

By gathering a continuous stream of field data from literally thousands of data sources and looking for trends and patterns, the artificial-intelligence modeling capabilities of today's CBM systems can comb through vast amounts of data, making sense of it, and bring critical changes to the attention of operators, says Gorski of Siemens. The sheer number and complexity of systems in power plants and industrial facilities, coupled with the demands of daily startups and ongoing pressure to minimize full-time staffing, can make analyzing large amounts of data a daunting task. "At the end of the day, people at the site can only look at so much data," he adds.

Model-based performance monitoring software uses a "new and clean" model of the compressor or turbine to compare the operating data to what it would be if the machinery were in top condition. "As machinery performance deteriorates due to wear or fouling, the model is updated to match the current operation. Over time, the different models can be used to show how the performance has changed and to predict where it will wind up over time," explains Jim Jacoby, Director, Turbomachinery Controls Portfolio, Invensys Process Systems (IPS; Plano, TX).

The systems are trained to recognize the characteristic data signatures associated with such common turbine failure modes as shaft misalignment, bearing fault frequencies or overspeed, and such common compressor issues as motor frequency issues and misalignment, says Greg Hood, Product Manager for Rockwell Automation (Cleveland, OH). When certain threshold values or conditions are met, the system triggers a work-order signal to the facility's CMMS or sends an alert to an operator.

Fortunately, the underlying software algorithms in today's systems are not only able to analyze characteristic data trends but to identify subtle variations or deviations much earlier in the progression of the fault — providing earlier indications of such turbine trouble as increased blade tip clearances, packing leakage, flame instabilities, increased thermal stress in the hot-gas or other sections, progressive corrosion or erosion and so on.

"As raw signals are compared against estimated parameters, the software provides an amplified signal-to-noise ratio for detecting performance deviations and subtle changes in system behavior," explains Jeffrey Steele, Manager of Software and Services for Impact Technologies. "This effectively cancels out the normal operational variation to highlight the unwanted or unexpected variation."

"We are not talking about the obvious conditions that are easily detected by plant instrumentation, during operator rounds or via normal maintenance," adds Gorski of Siemens. "We are instead talking about the ability to flag the onset of subtle changes — very slight drifts or trends in measured values that could potentially indicate an approaching problem — that the plant personnel could not reasonably be expected to detect themselves."

Think of it as the machine's ability to whisper its secrets long before the first drop of leaking oil has hit the floor or progressive degradation has forced automatic protection systems to interrupt operation. "Plant engineers can then direct their attention to those assets and go in for a deeper dive to determine what is going on," says Gorski.

"In addition to alerts indicating the earliest onset of changes, these systems also provide specific information — indicating, for instance, a cracked gear tooth in a gearbox — to drive the most appropriate maintenance response," says Don Marshall, Director of Marketing, Machinery Health Management, for the Asset Optimization Group of Emerson Process Management (Knoxville, TN).

Interfacing with humans

Today's Human Machine Interfaces (HMI) give operators very specific prompts, such as 'Look at bearing number…' — Information that helps them make better-informed decisions more quickly. The HMI systems bring the most pertinent realtime details about operating details and asset health right to the operators on the plant floor — with state-of-the-art graphical representations that make the progression of data trends readily apparent.

Getting the data across the entire enterprise as quickly as possible, and turning it into useful, actionable information down to the operator level. Easy access to visual references and information about estimated time-to-failure information can significantly reduce repair costs and total lifetime costs of plant and machinery. "We like to think of

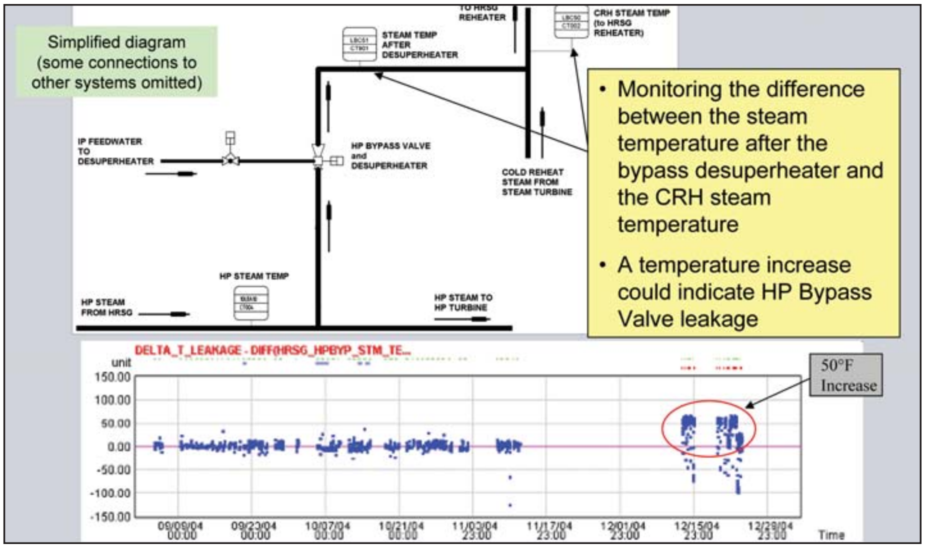

Figure 2: A Siemens 'smart' monitoring system for a HP bypass valve. The system discovered that the valve was leaking while shut by checking the temperature differential

it as 'condition monitoring for the masses,' because today's operators are saying 'Do not just give us the information — tell us what the information is saying," adds Johnson of Rockwell Automation.

Plantwide integration

The use of software-based condition-monitoring is not necessarily new, but the capabilities of these systems continues to evolve. These days, a push for greater plantwide integration to link CBM systems with plant-wide process control and automation systems helps provide operators with even greater insight into asset health and the factors that can affect it.

Changes in operating parameters elsewhere in the facility are often detrimental to turbomachinery performance. "It is one thing to look at what is going on within the turbomachine, but it is another to look at all the other variables that could take that turbomachine down," says Emerson's Marshall.

In earlier condition-monitoring systems, the piece that was really been missing had been that link to the process automation system. "When machinery condition monitoring is carried out in a vacuum, operators can miss critical pieces of information that would help in ongoing maintenance planning," adds Marshall.

Field data and operating data go hand-in-hand. "You need to integrate them all to gain an accurate picture of what is really going on," adds Johnson of Rockwell Automation.

The ability to evaluate condition-monitoring data in conjunction with overarching operating data also helps users to carry out more-effective root-cause analysis after events have occurred. "The centralized capture and analysis of data and documentation related to maintenance-related events and turnaround activities helps facilities to capture site-specific best practices, institutional knowledge and benchmarking information in one place, which is especially useful in this era of high employee turnover," notes Hood of Rockwell Automation.

The ability to 'see' the movement of the shaft centerline relative to the casing, using non-contacting, eddy current proximity probes, allows experts to accurately diagnose bearing, seal and balancing problems on high-speed rotating machinery. While vibration analysis has long been the workhorse of early condition-monitoring efforts, vibration analysis alone will not provide a complete picture of machinery health. Fortunately, today's CBM systems are able to accept a much more diverse range of machine data — and vendors encourage users to be as expansive as possible when gathering condition-monitoring data from the plant floor.

For instance, for optimal condition monitoring of turbomachinery assets, operators should add oil analysis (i.e., analyzing the condition and impurity levels of not just lube oil, but fuel oil and the oil used in transformers and hydraulic systems, as well), motor-current testing, pressure, temperature and level testing, and thermographic analysis (i.e., the use of non-contact infrared imaging to identify areas of temperature rise or heat loss) to the mix.

There are no isolated, absolute measurements that will alone indicate a complete picture of machine health. For example, when vibration levels change, a machinery engineer will need to know why. "This cannot be done by looking at vibration alone," says Kwan of GE Energy. "Rather, natural questions arise: Has machine load changed in some way? Have bearing temperatures changed? What about ambient temperatures and humidity? Gas compositon in a compressor? Machine speed? Differential pressure across an inlet filter?"

Similarly, as good as vibration-based tools are for diagnosing bearing, seal and rotor problems, they are typically only able to detect problems resulting from machine deterioration that has already happened. "Today, the ability to measure changes in friction — a common precursor to the types of rotor or bearing problems that lead to rotor displacement — can help technicians to identify and respond to certain problems (such as the presence of condensate in lube oil) much earlier, before shutdown is required," says Jacoby of IPS.

Justifying profitability

Vendors point out that even the ability to trim maintenance costs on each asset by a mere 10% by using modern, automated maintenance-management and decision-support techniques can really add up and impact plant profitability. "It is easy to justify certain condition-based measurements on a machine that represents millions of dollars per day in downtime, or one that creates other serious repercussions when it fails," says Steve Sabin, Editor of *Orbit* magazine, a technical journal covering applications and case histories related to GE Energy's Bently Nevada product line.

"Smart sensors and advanced condition-monitoring software can dramatically change the maintenance planning and scheduling for a facility by giving the maintainer and the operator realtime visibility into the operations of the assets, and an opportunity to look into the future and avoid many failures," says Nickerson of Impact-RLW Systems. "This will lower maintenance costs, improve reliability, virtually eliminate unplanned downtime and increase profitability."

For instance, in a Siemens monitoring system for a High Pressure steam bypass valve, it was found that the valve began to leak high-temperature steam when it should have been closed completely (Figure 2). The monitoring system identified a change in the pattern of this temperature differential and indicated a leaking valve long before any maintenance or operations would have identified it.

The smart system looks for only the times this valve is intended to be closed completely so it can ignore the high differentials while the valve is intended to be open. This leak was wasting energy. TI