Stuart Raynor, Emerson Process Management, UK, explains how continuously monitoring the health of critical rotating equipment will help reduce downtime and increase profitability and operator safety.

Keeping compressor stations ONLINE

Gas transportation is traditionally a low profit margin business and these margins have increasingly come under pressure as operating costs continue to rise. This is due to a combination of increasing labour costs and the cost of implementing changes to meet new legislation, set against a background of fixed transport costs and tariffs. Gas transportation pipelines rely on compressor stations to move natural gas from one location to another and their reliable and efficient operation is essential to minimise downtime while maintaining environmental and quality standards.

Figure 1. Emerson's CSI 6500 Machinery Health Monitor provides a continuous flow of data, so a changing condition can be immediately recognised.

Compressor stations used throughout the pipeline network are based on centrifugal compressors driven by a gas turbine, or a reciprocating compressor driven by a piston gas engine (similar to an automobile engine). It is normal to provide the fuel for this process using gas from the pipeline itself. In some locations, where there is a highly reliable source of electrical power, the machines can be driven by electric motors.

In an environment that relies on critical mechanical equipment, often unmanned and in remote locations, any failure usually results in the machine going offline. A prolonged process interruption can be the difference between profit and loss. With this much at stake, having appropriate protection, prediction and performance monitoring systems in place is essential.

The critical rotating machines including both turbines and compressors used in gas compressor stations seldom fail without providing clues well in advance. Machinery health warning signs come in the form of vibration changes, process parameter changes and performance changes to name a few.

The availability of online machinery monitoring technologies means that operators can monitor mechanical assets and analyse temperature, vibration, efficiency and deviation data for changing conditions that could result in a shutdown. Advanced technologies, including online and wireless vibration monitoring and ASME calculation based equipment performance, can all be integrated with the compressor station control system to nurture the health of machinery that is essential to maintaining uninterrupted operation. By using a form of machinery protection that allows these warning signs to be anticipated and recognised, a complete protection strategy can be formulated. Shutdown protection would be relegated to the last line of defence (as required by regulatory standards) and costly outages could be eliminated.

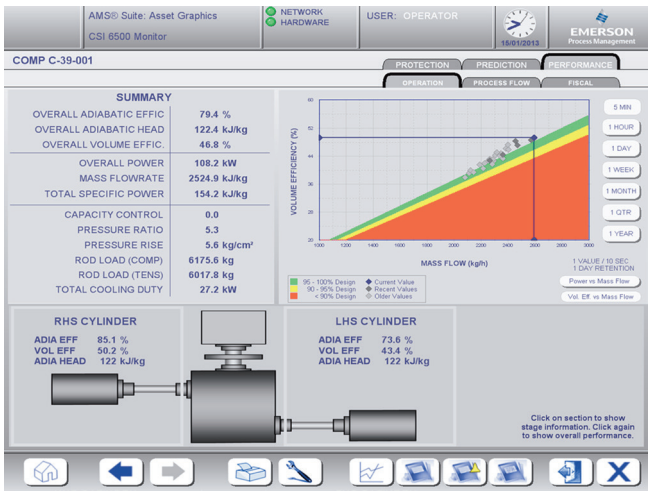

Figure 2. Performance monitoring compares the actual real time performance of equipment with design specifications.

More than ever, it is important to utilise reliable information about the operating condition of critically important process equipment, not just a 'trip' signal that comes only after significant internal damage may already have occurred. It is no longer prudent to rely heavily on a simple vibration protection system for these critical machines.

Machinery shutdown protection is only part of a complete online monitoring strategy to guard against events that can happen suddenly with little or no apparent warning. It is very important to have the right monitoring equipment, trained personnel, and a good analytical software package to pick up and identify those signs of failure long before a key compressor, turbine, gearbox, coupling, or even instrumentation fails unexpectedly. Timely maintenance is preferred over potential catastrophic failure and the costly repairs that will follow.

Monitoring equipment

Studies indicate that more than 50% of industry maintenance man-hours are spent fixing equipment after a failure has occurred, whereas less than 18% of the time is spent determining when equipment might fail and acting accordingly. The numbers will improve only when maintenance departments establish proactive monitoring of machine health as a key mission, and go beyond shutdown protection that just meets minimal statutory requirements.

The four components of a complete online monitoring solution for critical assets such as compressor stations are:

- Shutdown protection monitoring (high vibration, axial position, overspeed).
- Prediction monitoring.
- Performance monitoring.
- Integration of all the above with the compressor station control system.

Shutdown protection monitoring

These systems typically function to prevent severe damage to the compressor or turbine, and more importantly injury or environmental hazard, in the event of a totally unpredictable event – for example, a turbine blade suddenly breaking away due a metallurgical imperfection.

In this case, the 'trip' signal must be near instantaneous, like the inflation of an automobile air bag, to minimise damage. Protection systems are still mandatory for safety because unpredictable events can and do happen. Technology can still bring advantages to this well established area of machinery health operation where implementing prediction monitoring with a protection system can allow 'black box' analysis after an unplanned emergency trip.

The machinery health monitor can automatically capture high resolution information from all bearings simultaneously across an entire machine train so that a

user can retrospectively analyse the event as it unfolded and determine the cause of the trip. In this way, similar shutdowns may be prevented in the future.

Prediction monitoring

Newer technologies are enabling users to determine what was once thought unpredictable. In reality, most chronic events can be predicted. As long as personnel have access to detailed diagnostic information, they can identify potential faults and gauge their severity months in advance. This allows maintenance planners to determine the optimum time to make repairs, proactively order the right parts, and minimise their inventory operations.

Prediction monitoring of compressors and turbines is intended to provide the information needed for accurate planning. Information is frequently obtained by acquiring machinery vibration data and analysing signatures and levels, either periodically or continuously. For example, using technologies such as Emerson's PeakVue™ for rolling element bearings and gearboxes, real-time transient events can be viewed and replayed for further analysis, with animated machine and structure views for advanced diagnosis of the most difficult reoccurring machinery problems. Analysis of the results generally leads to a decision as to how long the compressor station can continue to operate productively before maintenance will be necessary.

While the periodic monitoring of production equipment using a hand-held data collector has been a staple of maintenance departments for decades, equipment that is critical to keeping a production process in operation should be monitored continuously. Indeed, some critical situations can be averted only if real-time data on equipment condition is available.

Online monitoring of compressor stations using Emerson's CSI 6500 Machinery Health Monitor, for example, (Figure 1) provides a continuous flow of data, so a changing condition can be immediately recognised. When properly interpreted, these signals pinpoint the location, nature, and even the severity of developing problems. Personnel can use such data to predict with greater accuracy when a machine will need maintenance to prevent damage and avoid lost production. Predictive maintenance of rotating assets also uses information gathered through oil analysis, infrared imaging, and ultrasonic detection. If the data indicates trouble ahead, a judgment can be made as to when a failure might be expected. With critical equipment, immediate repairs may be necessary – that is when a reliable early warning system will pay for itself. On the other hand, it may also be possible to delay repairs until a scheduled unit turnaround.

Ultimately, technology helps plant/unit maintenance managers make business decisions about what to do, when, and how to do it. Gathering and analysing of machinery information is far less expensive than reacting after something breaks.

Performance monitoring

Performance monitoring is based on comparing the actual real-time performance of equipment, such as a reciprocating compressor, with design specifications (Figure 2). As equipment performance deteriorates, energy usage increases and throughput decreases. Plant personnel may not even be aware that the performance of a piece of equipment is below normal or that it is consuming excessive energy. Furthermore reductions in machinery thermal performance can be a precursor to mechanical health issues, and equally reduced machinery condition will inevitably affect the performance of that unit.

Actual efficiency loss versus design for the given operating conditions can be determined by comparing a machine's actual thermodynamic performance with a dynamic expected baseline constructed from OEM information and/or day-zero benchmarks. Additionally, thermal monitoring allows a user additional diagnostic granularity to not only know a turbo compressor is underperforming, but to identify the components contributing to that deterioration and allow actions (control and/or maintenance) to be planned accordingly. Specialists are thus able to identify the 'bad actors' and formulate actionable recommendations.

For example, blade fouling on a gas turbine inlet can degrade performance and simultaneously increase vibration. Online water washes can improve performance and minimise downtime needed for an offline wash, but this has to be done at the correct frequency, and with the certain knowledge that this operation continues to be effective at mitigating performance loss. Too frequently, and the cost benefit of the wash operation is eroded, while too infrequently may allow fouling to build to a level only remediated by an offline wash. Each online water wash can be observed from a performance perspective to ensure it is helping to increase efficiency – and from a vibration perspective to ensure the compressor mechanical integrity is maintained. The wash schedule can be adjusted pro-actively to ensure optimal operation is maintained through seasonal variations, changes in load, etc.

Without real-time performance feedback, degrading operation may go unrecognised by production personnel for a long time. The rigorous mathematical routines embedded in this technology will highlight and quantify operating degradation quickly and help identify root causes, therefore ensuring equipment operates optimally in day-to-day service.

Summary

Visibility to machinery condition and performance health before the protection system engages is considered the critical missing component of today's machinery protection solutions. Operations and maintenance personnel are no longer looking for just a protection capability when replacing an outdated protection system. They are requiring a complete and holistic protection, prediction, and performance monitoring capability integrated with process automation.