THE BIG FIVE

Michael Hastings, Denmark, and Steve Sabin, USA, Brüel & Kjær Vibro, describe five technology trends in the machine condition monitoring system development arena that together provide an optimal fertilizer plant condition monitoring solution.

Machine condition monitoring has firmly established itself as an important part of a predictive-based maintenance strategy for fertilizer plants over the years. Fans, pumps and compressors, which include both

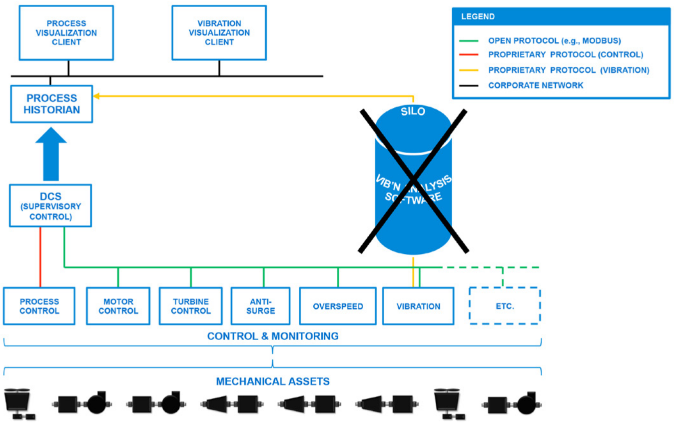

Figure 1. Use of the process historian eliminates the need for a separate vibration data server.

critical and balance-of-plant machines, are currently being monitored in many plants worldwide. The steam reforming ammonia plant, for example, includes a couple of these critical machines – the centrifugal compressor for high pressure synthesis gas compression and the refrigeration compressor for condensing the vaporised ammonia stream in the cooling cycle, both of which are typically driven by steam turbines. Both compressor trains are a critical part of single stream production. If one machine stops, production stops.

A condition monitoring system is designed to detect the potential failure modes of these compressors (and other machines) and provide diagnostic tools to help plan maintenance ahead of time, focused on the detected faults. There are a number of potential failure modes associated with these compressors that could lead to a catastrophic failure if not corrected in time, such as bearing and seal rubs, excessive bearing clearance, surge, liquid ingestion, shaft cracks and seal leaks. Other faults, such as impeller/diffuser fouling and erosion, can lead to costly inefficiency. The critical question is: how well is your monitoring system detecting and diagnosing these faults? Are there other requirements that have to be met to make your condition monitoring system effective?

Condition monitoring needs for today

Although there are few who dispute the merits of implementing a condition monitoring solution, there is still a general lack of understanding on how to achieve the full economic benefits of it. The monitoring requirements have changed over the years, especially with regards to today's stringent plant production and product quality requirements. There is also less supervision of the machines. Many legacy monitoring systems can no longer fulfil the increasing need for optimising machine uptime, reliability and efficiency, while at the same time reducing lifecycle costs of machine operation and maintenance. Protective machine monitoring systems provide very little condition monitoring capability, if at all.

Plant owners with a legacy condition monitoring solution should consider the following questions:

- Is there a lot of manpower, cost and expertise needed to operate and maintain the various systems used in the condition monitoring solution, including IT requirements?
- Is there insufficient data provided by the systems? Is it unreliable, cyber-vulnerable, or is there data loss?
- Are there too many alarms and are the services costly to interpret or convert the data into actionable information?
- Is there insufficient information reaching the right people at the right time for making important operation and maintenance decisions?
- Lastly, is the current condition monitoring solution, if used at all, not sufficiently minimising the lifecycle costs of the machines by reducing downtime and maintenance costs?

If 'yes' can be said in response to any of the questions, the plant owner may need to re-assess their monitoring solution.

Fortunately, condition monitoring technology has also evolved over the years in cadence with the increasing monitoring requirements. It is important to stress that the development of a condition monitoring solution is not the outcome of a single project, but the result of substantial experience gained over a period of time and adapting it to evolving market demands. This translates partly into new technology and partly into service concepts being continuously introduced for detecting and diagnosing additional potential failure of machine modes with greater lead-time, and under a wider range of operating conditions. New developments in the system and accompanying services now take into account the individual plant requirements of end-users, such as their level of monitoring expertise, machine reliability, maintenance and spare requirements and production requirements – all of which can vary greatly from one end-user to the next.

Current trends for successfully implementing a condition monitoring solution include the following:

- Data management: process historian.
- Data security: cyber-security.
- Data integrity: local data storage in the rack.
- Monitoring integration: holistic monitoring approach.
- Monitoring intelligence: machine learning, automatic diagnostics.

Trend 1 – data management: process historian

Much more data is being produced now by condition monitoring systems than ever before and more of this 'big data' is being made available to users and other systems. Process data in many continuous process industries, such as in fertilizer plants, is increasingly being managed by a process historian, which stores, analyses and displays data with alarm notification for machines across the entire plant. Historically, vibration monitoring systems were independent of these systems because they required specialised infrastructure to handle the high resolution vibration data and its fast sampling time. This is no longer the case for process historians such as the OSIsoft PI

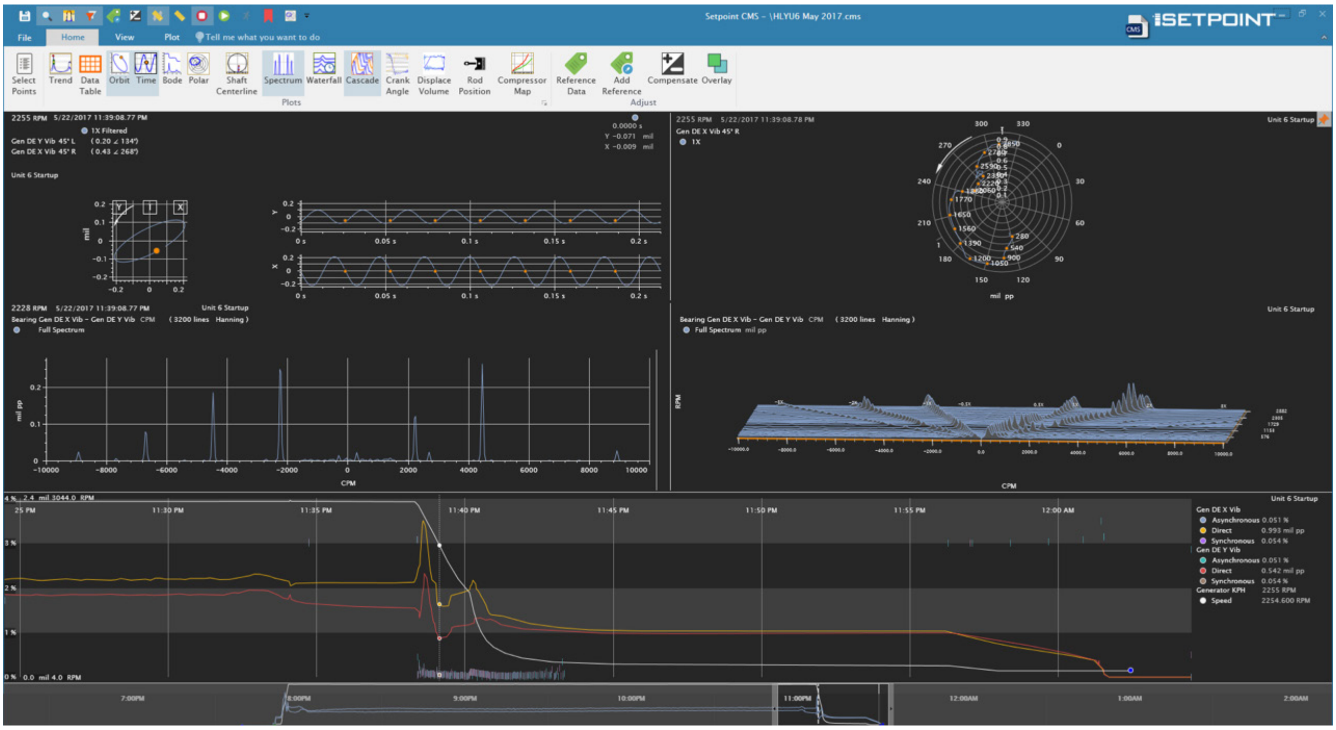

Figure 2. Specialised vibration plots from a power generation train. All data shown on the screen resides in the process historian.

system, with whom Brüel & Kjær Vibro is a partner. Detailed vibration time waveform signals are now easily stored and accessed in the PI system via specialised hardware. This milestone results in a wide range of benefits that come from integrating the condition monitoring system together with the process historian.

Chief among these, the traditional monitoring system OT/IT infrastructure complexity can be greatly reduced as shown in Figure 1. There is no need for monitoring system servers, proprietary interfaces and IT maintenance, because these are absorbed by the process historian, where all monitored data is now stored. This eliminates the need for a separate, special database just for vibration data and the process historian user interface is used for visualising all vibration data including current values, alarm statuses and high resolution trends – essentially, everything except waveforms. Waveforms and specialised condition monitoring plots and functionality are provided via special third-party visualisation tools that augment the historian's native visualisation capabilities, without requiring a separate database or infrastructure. These plots can be, for example, time waveform vibration signals, orbits, shaft centerline plots, waterfall and cascade spectrum plots, PV plots and compressor maps (see Figure 2). Additionally, other third-party products and services can be included, such as statistical data analysis, automatic decision support and thermodynamic performance monitoring of rotating equipment. In summary, if the plant already has a process historian installed, only the condition monitoring data acquisition unit needs to be installed, enabling the intelligent data capture and streaming capabilities into the process historian.

Another substantial benefit of a condition monitoring system interfaced with a process historian, when vibration data is combined in the process historian database with other process parameters, is that it is easier to correlate data, even if it is originating from other systems. This improves the speed and reliability in making a diagnosis. Moreover, more relevant people can then have access to the data, thus improving the speed and reliability of making management decisions on the operation and maintenance of the assets.

Trend 2 – data security: cyber security

Globalisation and high interconnectivity between institutions, systems and people certainly brings our world closer together, but not without some associated risk. For this reason, cyber security, the act of protecting monitored data, computerised information and control systems from criminal and unauthorised access and natural disasters, plays an increasingly important role in IT development. As more smart, interconnected devices and systems are implemented, the need for better safety standards increases.

A condition monitoring system, especially a plant-wide system, is vulnerable to these threats and therefore must rigorously comply with the relevant cyber security requirements, as should other systems, such as the process control system and plant historian. Most process historians are already highly cyber-secure, given their mission-critical role in most plants and the large number of users that access the data – both locally and remotely. By using the process historian itself for condition monitoring, cyber security is simply extended to another type of data stream rather than requiring an entirely different infrastructure to be evaluated and approved.

Trend 3 – data integrity: local data storage in the rack

Data integrity is crucial for a condition monitoring solution. Notwithstanding all of the enthusiasm surrounding the industrial internet of things (IIoT), data can still get lost. When the network or database server is down for a traditional condition monitoring system, no data can be stored or analysed. Also, for a new installation, if the protective system is brought online before a network is available, then there is no condition monitoring data available at all: a network was mandatory in the past. What can be done to mitigate these issues?

Low cost solid-state drive (SSD) technology has become readily available within the last few years for industrial use. Monitored data can now be stored on the SSD in the data acquisition unit simultaneously while it is being streamed to the database. If the network is down, no data is lost because it is also saved on the SSD. When the network is up again, this stored data is automatically sent to the process historian to fill in the gaps – often referred to as 'self-healing' or 'backfilling' technology. Even while the network is down, data can be manually retrieved and used, and then later retroactively stored in the process historian. In fact, even if the network is properly functioning, monitored data can still be uploaded to an analyst at any time without a remote connection to the database. This speeds up the time to perform diagnostics if a decision on starting up a machine has to be made very quickly.

Loss of a network, however, is not the only situation that so-called 'flight recorder' technology is designed to address. It is also finding application with customers that have no network at all and no plans to install one. In the past, this meant 'no condition monitoring'. Today, it simply means data is retrieved manually at the data acquisition unit rather than remotely via a network. The flight recorder, in effect, becomes an embedded historian.

For this flight recorder functionality to be practical, there must be enough storage space locally for all the incoming data. If the network is down for a short period of time and only a couple of machines are being monitored, a few gigabytes of storage is sufficient. If, however, there are many machines being monitored by a single data acquisition unit and the network is down for days, weeks, or months, this will be inadequate and result in lost data. Brute force techniques that simply store all vibration waveform data would require 300 MB per hour for each vibration channel. Considering that many machines have 20 or more monitoring channels, a single such machine would consume 1 TB per week. Clearly, for an SSD to be viable, a data compression or data reduction technique is needed.

To address this situation, Brüel & Kjær Vibro pioneered (and patented) technology that looks at 'data interestingness' and stores data only when it is interesting. 'Interesting' data is defined as data that exhibits sufficient variation from previously stored data. A measure of this interestingness – called the 'i-factor' – is continuously computed for each and every waveform. Only those waveforms exceeding a threshold value for the i-factor need be stored. In this manner, if no changes in the waveform's i-factor occur, the raw time signal is discarded since it is considered to be identical to the last value. Using this technique, it is possible to save many months of data without losing any data of interest. Tests on a 50-channel system monitoring typical turbomachinery trains show that the technology consumes only approximately 32 GB per month, small enough to fit comfortably on a removable SD card. Embedded SSDs can be purchased in much larger sizes, currently nearly half a terabyte, which holds well over a year of data.

This flight recorder approach is finding home outside the vibration monitoring industry as well, as numerous industrial instruments – not just vibration monitoring systems – are now adopting such capabilities. The term 'edge store' devices is often used, where weeks, months, or years of data is stored at the 'edge' of the sensor network, insulating it from network disruptions, bandwidth issues, and constraints that in the past meant data could be (and was) lost when the server itself, or its networks, were impaired. Thus, the terms 'edge device', 'edge store' and 'flight recorder' are increasingly being heard in the industrial instrumentation sector.

Trend 4 – monitoring integration: holistic monitoring approach

Condition monitoring systems are taking a more holistic approach to monitoring assets, which means several monitoring techniques are employed, not just vibration. Thermodynamic performance is one example, for detecting a drop in efficiency due to fouling and erosion. Process data is another example. Use of all available data – not just vibration – gives a better overview on the condition of the machine train. It also provides correlation capability for faster, more reliable diagnostics.

Trend 5 – monitoring intelligence: machine learning, automatic diagnostics

The condition monitoring strategy of many machines, such as the ammonia plant compressors, is largely based on trending of alarm-based 'descriptors'. When changes in these descriptor trends occur, a vibration analyst is consulted to do a deeper analysis, using the specialised plots and tools. Nowadays, however, diagnostic specialists are few and far between and it can be costly if they look at every single alarm. Intelligent system monitoring and alarm management is needed to reduce their workload. One example of this is automatic machine diagnostics, where the system spots changes and can even diagnose simple faults, so he or she can focus on the more difficult diagnostic tasks. Another example is simply to highlight the changes to the analyst.

Statistical analysis of data is another form of system intelligence. Using machine learning for example, opens up many beneficial possibilities, such as improving fault detection measurements and making prognostic models for remaining life calculations.

Conclusion

The value of a condition monitoring system is not just for detecting and diagnosing the most machine faults and providing the longest lead-time to maintenance. This value also has to offset other costs to the system such as for equipment, time, services and expertise that are required for implementing, operating, maintaining and upgrading a condition monitoring solution. The five market trends described in this article demonstrate a way to counter the additional costs, improve condition monitoring capability and increase the value it delivers. WF