MANAGING DRIVETRAIN HEALTH: KNOWLEDGE IS POWER, TIME IS MONEY

Stretching your O&M budget can be achieved by properly and systematically processing the data derived from condition monitoring equipment.

By Larry Jacobs

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AS THE U.S. WIND INDUSTRY transitions to a larger install base of turbines that are either out of warranty or soon to be, the focus of every owner/operator turns to optimizing their operations and maintenance and more specifically, managing the health of the drivetrain and its components. The cost of failures as it relates to drivetrain components can quickly erode an O&M budget—especially if these failures were not anticipated or if they occur within a timeframe that was not expected. Drivetrain health management is the key to understanding the existing condition of drivetrain components as it provides effective failure mode prediction (not just fault detection) and it allows for well-timed planning of maintenance activities.

The English philosopher Sir Francis Bacon has been credited with the phrase, "knowledge is power". This is never more appropriate when it comes to drivetrain health management and failure mode prediction. This knowledge comes from two sources—the knowledge that a health management system provides to the end user and even more importantly, the knowledge, expertise, and experience that went into developing such a system. There is a ton of data that can be generated by health management systems such as condition monitoring, lubrication sampling, oil particle counters,

SCADA, etc., but the true value of these systems lies with the processing and analysis of this data. Romax InSight software combines all these various health management tools into one system (Table 1) and InSight services provides the engineering know-how to implement processes, re-engineer components or develop retrofit modifications to reduce failures. Grease sampling is a common monitoring technique for large bearings, and Romax InSight iDS software provides tools to trend grease ferrography and elemental composition results; yet as shown in Figure 1, without implementation of proper sampling procedures the monitoring can be erroneous. This result is included in

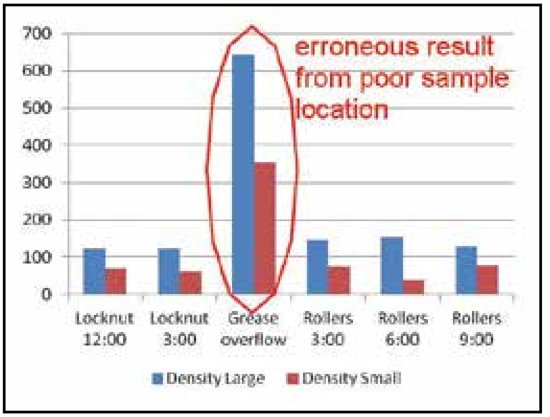


Figure 1: Particle counts for main bearing grease samples: Samples are compared for six locations (taken the same day). Sampling from the grease overflow trap (common practice) provides erroneous results.

FEATURES OF INSIGHT IDS SOFTWARE
Vibration Monitoring
Temperature Monitoring
Lubrication Sample Monitoring
Particle Counter Monitoring
Component Inspection Database
Failure Database
Reliability Analysis
CMMS Integration
Monitoring Hardware Independence

Table 1: Features of InSight iDS software.

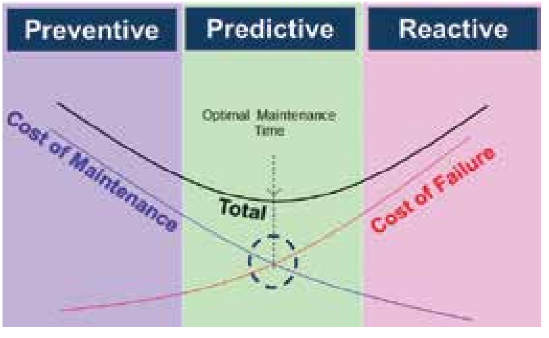


Figure 2: Optimal maintenance time.

procedures developed for technicians to illustrate why to sample a certain way.

The "Maintenance Scheduling" sidebar (p. 39) shows the progression of main bearing failure where the specialized analysis implemented within the InSight software provides at least six months prediction on failure. Having this knowledge well in advance of the pending failure is equally important to managing drivetrain health. Figure 2 looks at the optimal time to perform maintenance as it relates

	Technique	Advantage	Disadvantage	Cost
1	Temperature analysis	Inexpensive	Temperature in load zone higher than measurement point. Often warning is very short.	$
2	Grease analysis	Can offer early detection	Adds 30-60 minutes to maintenance	$$
3	Portable vibration	Cost effective in the short term. Can combine with gearbox and generator sweep	Trending requires multiple turbine visits. Over the long term fixed installation is better.	$$$
4	Visual inspection	Conclusive if conducted properly	4+ hours of machine downtime. Covers are heavy, safety issue. Grease disposal.	$$$$

Figure 3: Drivetrain health management options in lieu of permanent vibration monitoring installations.

to three maintenance models. The preventive model results in high cost of maintenance with low cost of failure. Reactive maintenance results in a low cost of maintenance with high cost of failure. The intersection of these two modes is predictive maintenance and is determined to be the optimal maintenance time. However, it should be noted that this optimal time is not necessarily a one-size-fits-all model. Having the information of a failure mode (knowledge is power) well in advance of the pending fault (time is money) puts the owner/operator in the driver's seat for scheduling the maintenance activity and allows for well-informed decisions. It provides flexibility on when to order parts, resource availability, and when to deploy a crane (if needed); and these may not always align with the "optimal" maintenance time.

So, when we say "optimizing O&M" what do we really mean? It means optimizing production—ensuring turbines are available when the wind is blowing and ensuring turbines are operating at peak performance. It also means minimizing operational costs through balancing cost of maintenance with cost of failure (as shown in Figure 2). When we take these into consideration with the understanding that time is money, then the objectives for any maintenance related activity is to schedule during low wind seasons (ideally), and when labor and equipment is available, and at most reasonable cost.

FAILURE CAUSE ANALYSIS

A Romax engineer disassembles planetary stage of a gearbox during failure root cause analysis.

An important step to developing solutions for costly machinery problems at wind farms is conducting a step-by-step root cause analysis of failures. With a thorough understanding of the failure modes and the early indicators of failure, solutions can then be developed to either mitigate the failure or reduce the severity and frequency.

Typical activities include:

- Uptower inspections – investigating the failure issue in-situ
- Factory teardown – step by step disassembly, inspection and photographing of each and every part in the failed component. Review of all the evidence by experts
- Metallurgical analysis – examining steel hardness, microstructure compositions, failure mechanisms and material quality
- Engineering simulation – assessing functional behaviour and loads and stresses versus allowable limits
- Design review – review by experienced engineers in areas such a lubrication, assembly, tolerancing and design for manufacturing

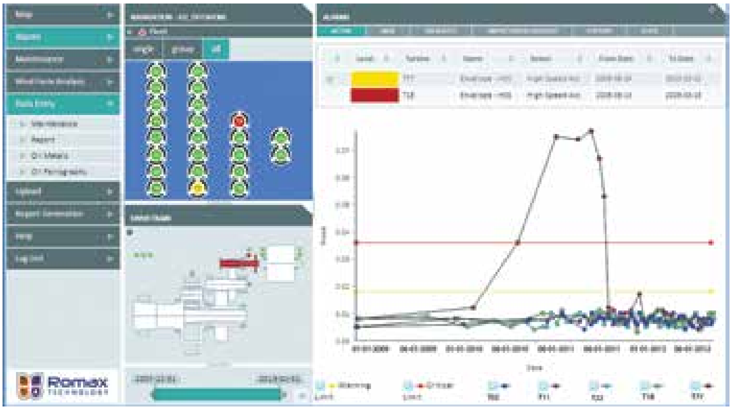


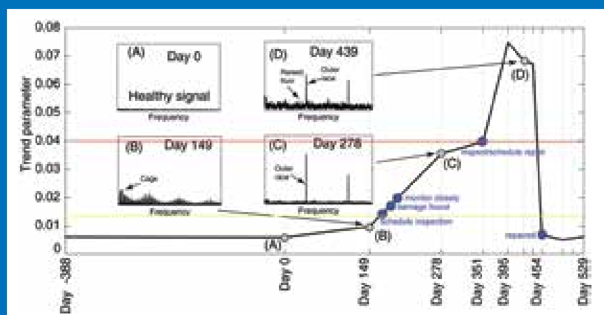
Figure 4: Screenshot of InSight iDS health monitoring ool.

Field experience is important in developing effective and reliable analysis tools (See "Failure Cause Analysis," p. 38). Root cause analysis and field inspections of drivetrain failures provide important feedback in validating analysis techniques. We all want to find the needle in a haystack so practical experience is just as valuable. With drivetrain health management there are many factors to consider when determining the best solutions—size of the wind farm, size and age of the turbines, installed condition monitoring hardware, and component failure rates. These are all considerations in determining what's best. Ideally, a well-established continuous monitoring program is in place and a historical database is being established. But in cases where CMS hardware is not yet installed what are my options? As an example, Figure 3 outlines some tools and techniques to consider when establishing a drivetrain health management program for main bearing failures.

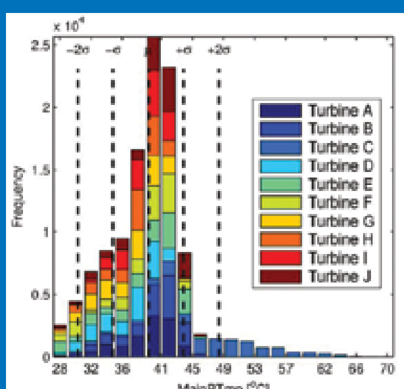
When it comes to reducing risk with knowledge and time, and turbine O&M cost savings, the long-term benefits of a health management program are clearly measureable—prevent catastrophic events, convert downtower repair/replacement into an uptower repair, effectively manage spare parts inventory, curtail operations for prolonged production, mitigate insurance risks, and amortize equipment costs.

MAINTENANCE SCHEDULING

Vibration based condition monitoring aids with scheduled maintenance planning. Given that for most wind farms, unscheduled maintenance makes up a significant portion of operation costs, better planning enables cost savings to justify the cost of installing vibration based condition monitoring. This is especially the case for failures where the repair requires removal of the aero-rotor and a crane to be deployed. There may be many days of downtime if the crane cannot be mobilized immediately. Lead time on large components such as main bearings and gearboxes can also bring delay and add to the costs of the failure. Main bearing failures are a common issue where vibration based condition monitoring is an effective tool for maintenance planning. The macropitting damage can be detected months in advance, compared with temperature analysis, which can detect damage only days, or at most a few weeks, before a machine shutdown is required. In this representative example, the damage is detected almost one year before the turbine faulted from over-temperature. Vibration analysis reveals the damage component, in this case, the outer race. The statistical temperature analysis shows Turbine C is operating at a significantly higher temperature, but the temperature rise is only evident at the final stages of damage.



Temperature monitoring shows main bearing on Turbine C running hotter than fleet. Failure indication was two weeks prior to turbine shutdown.



Vibration condition monitoring typically provides more than six months' notice for planning main bearing replacement.