MAINTENANCE

Operations • Service & Repair • Inspection • Safety • Equipment • Condition Monitoring • Lubrication

CONDITION MONITORING: VIBRATION ANALYSIS SHOULD NOT BE INTIMIDATING

By Jeff Walkup

Vibration analysis is the most widespread monitoring technique used in wind turbines, and on a typical basis, it is the first and primary technology that operators tend to refer to. It is applied to rotating components — in particular, the main bearing, gearbox, drivetrain, and generator — where the direct and indirect costs of failure can be critical to O&M budgets. Signals from vibration sensors are monitored in real time using software-based techniques, such as Fast-Fourier Transforms, and can be compared against a signal recorded during known healthy running operations, which, in many circles, is referred to as a machine fingerprint. Complex algorithms are then established over a predetermined time with the goal in capturing said faults and other anomalies before substantial damages can develop or occur. It is here when the other technologies — such as the oil and grease analysis, filter examinations, and detailed inspections (including the use of borescopes) — confirm which

Event Report TCM® Monitoring

Main Bearing (MnFr): Outer race fault (BPFO)

Health Indicator	Description	Report Date	Author
80	(040) Component severly affected.	12/07/2015	

Recommended Action

Description	Action	Time for reaction
Clear and severe outer race fault on the main bearing. Trend shows further increase. Exchange of component expected.	Visual inspection of bearing and grease	< 14 days

:FTT_62_Tr - Main bearing

Wind farm	Very Windy	Turbine type	StrongWind 2.5
Location	Turbine ET01	Turbine serial	

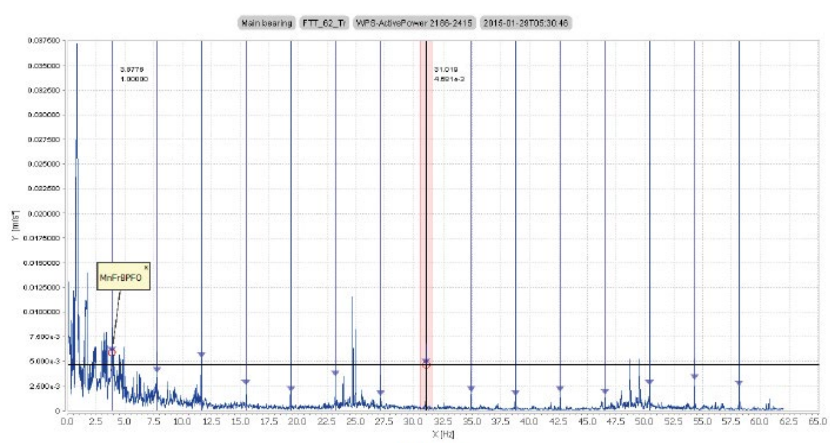

Figure 1

BPFO with distinctive harmonics.

ALSO IN THIS SECTION

vibration has been detected and can be employed. Analysis can help to identify defects in these components, allowing maintenance timings to be anticipated, especially when used in conjunction with historical data on past failures.

These windows for repairs can therefore be scheduled long before the risk of catastrophic failure and are often fitted into periods of low wind conditions when generation losses can be kept to a minimum. Wise and savvy reliability engineers and managers are constantly aware of the staggering amounts of data captured and recorded ultimately at their disposal in an ever-increasing arsenal of tools designed to assist in proactively addressing these failure modes before a catastrophic event occurs. With the number of turbines approaching end-of-service warranty, a great deal of opportunity awaits companies that are able to approach O&Ms with the ability to offer these tools to them that were most likely utilized by the OEM and their dedicated service providers only days and months before. In my experience, I have witnessed a gap in monitoring responsibility and the lack of a detailed plan for monitoring transference many times. Having said this, many reputable organizations exist in the world of condition monitoring (CM). End users are able to employ a plethora of tools, using a variety of companies and vendors, as well as in-house resources.

Many would agree there are a hundred ways to approach condition monitoring (CM) with the sky being the limit in the ways to track and report incidents discovered. To illustrate, I have added a few examples with all identifying information removed that showcases the value-added information that can be in the palm of your hands. The following questions remain: Are you using it, is it available, do you understand it, and are you willing to pay for it?

Event Report

FTT_62_Tr - Main bearing

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Location	Turbine	**Turbine serial**	

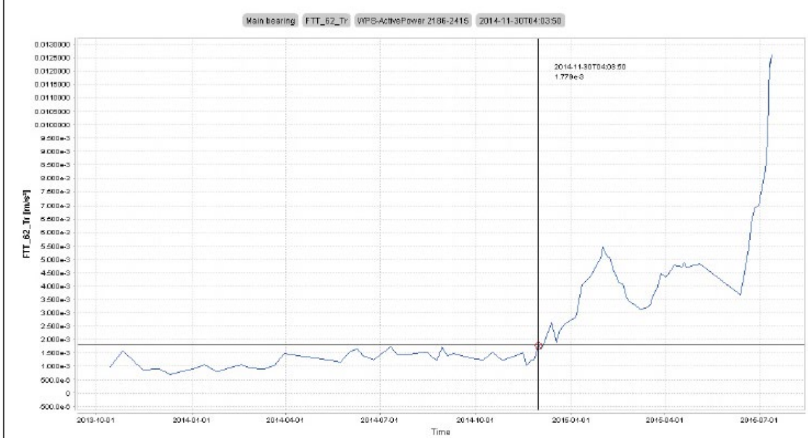
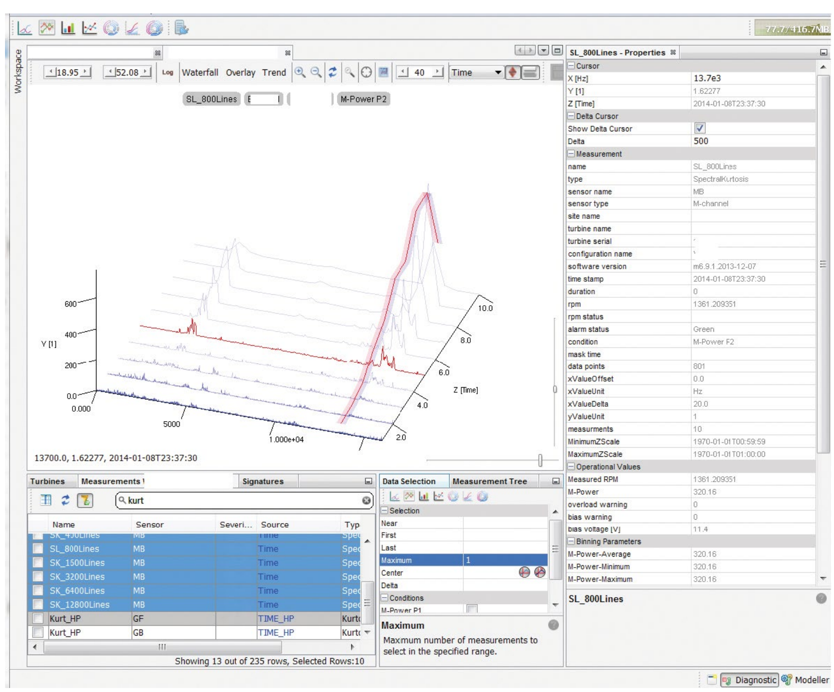
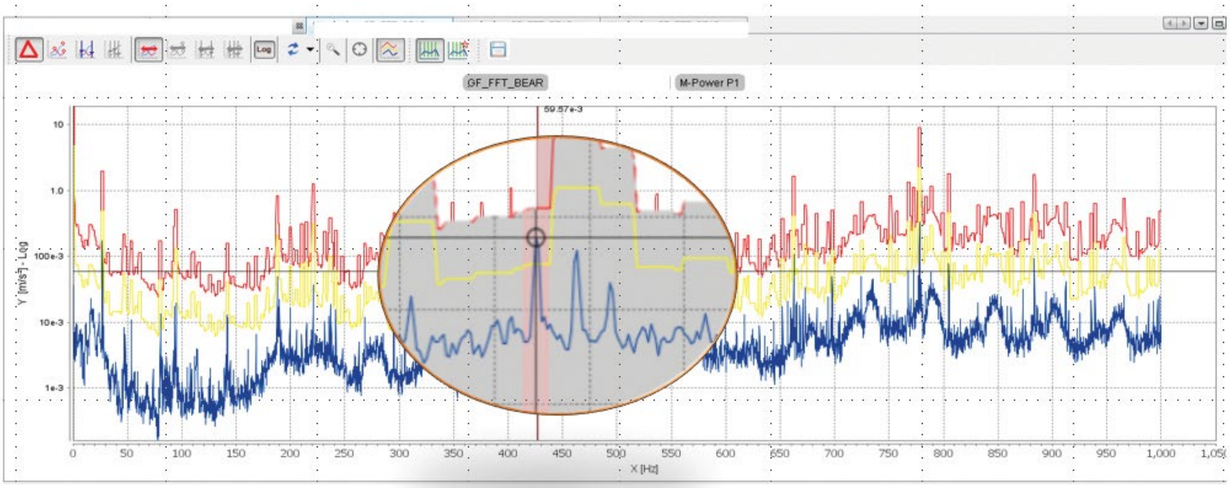


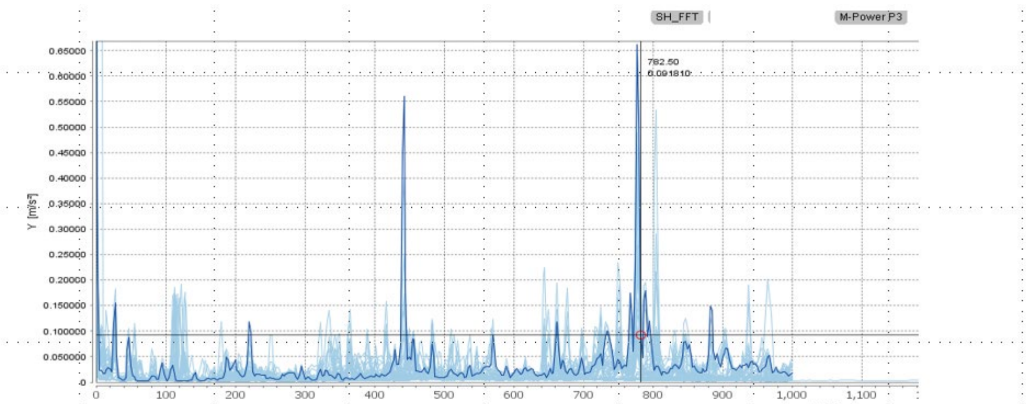
Figure 2

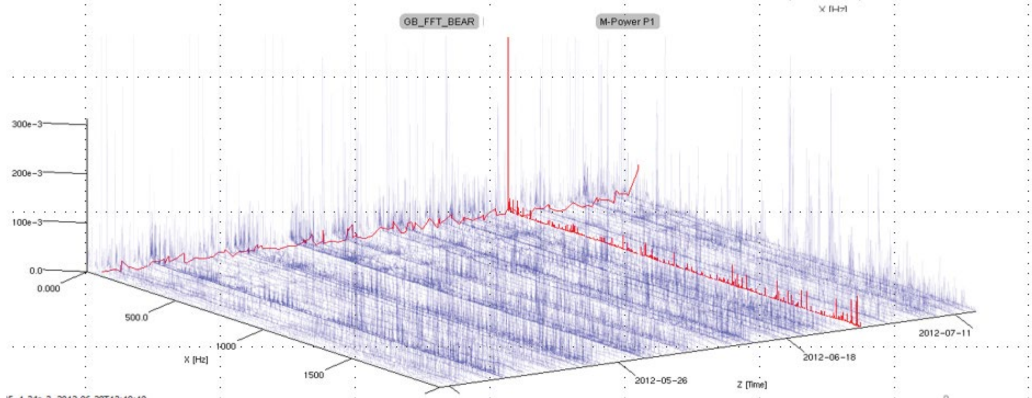
Trend increased since 30/11/2014

Property List of Measurement			
Condition	WPS-ActivePower 2186-2415	**ConfigurationName**	
Data Points	85	**First Time Stamp**	2013-10-14T12:55:07
Last Time Stamp	2015-07-12T09:50:00	**Measured RPM**	1441.826294
Trend Bound Lower	30.515625	**Trend Bound Upper**	31.523125
WPS-ActivePower	2315		









CM is based on advanced signal analysis on various signals such as vibration, strain, and process signals in combination with automation rules and algorithms for generating references and alarms. The system has a high degree of built-in automation presenting the conditions and alarms in a condensed form to the operator. An expert has the possibility to dig into measurements and alarms by using an advanced data mining tool. Configuration of the system is based on a template philosophy, so it is possible to configure a large number of wind turbines in one operation. Alarm limits are automatically generated by the system based on expert rules. In addition, the overall system has a system daemon, watching and ensuring that all parts are up and running, which is important in the reduction of human intervention.

Many years ago, I realized the value of vibration analysis and the information it can represent. Taking the time to educate ourselves in vibration analysis and applying that method on the job opens up a world of potential.

THE STATE OF WIND FARM UNDERPERFORMANCE SYNDROME

By Bruce H. Bailey

It is fair to expect that the energy output of an operating wind farm should be close to what it was designed to produce. If the wind conditions for a particular site are well-measured and the selected turbine is a well-known model, then logic would conclude that the energy prediction process is fairly straightforward. But is this an oversimplification? Industry experience has shown that it is, since the majority of operating wind farms don't meet their predicted P50 energy values in an average year.

The "underperformance syndrome" has been well-known within wind energy circles for years (recognizing that it could also be called the "overprediction syndrome"). The reasons for the phenomenon are now reasonably understood, but this wasn't the case 10 years ago. At that time, wind farms were falling short in production on average by roughly 10 percent relative to pre-construction estimates made several years earlier. Significant progress in both wind farm diagnostics and modeling techniques has reduced the observed energy shortfall by more than half for most modern projects. So, while the gap has narrowed, why hasn't it disappeared altogether?

ORIGINS OF PRODUCTION SHORTFALLS

First, let's look at the forces behind the original shortfalls and how they've been addressed. In the late 1990s and early 2000s, the wind industry was primarily focused on development and did not have the sophisticated wind farm operations management systems that are in place today. Still in the emergent phase, the industry hadn't yet built the critical mass of operational history needed to signal a widespread underperformance problem.

There was a communications problem, too. The development and operations sides of many wind energy companies effectively operated as separate businesses with differing motivations. A company team responsible for getting projects developed had little interaction with the team responsible for construction and operations, so there was little opportunity for constructive feedback. Even third-party contractors involved in making pre-construction estimates of future energy production were kept in the dark about how the wind farms they had a hand in designing were actually performing. Performance and maintenance data was closely held and not shared outside the company.

TODAY'S WIND INDUSTRY

The industry has since matured. There is a much larger base of operational experience now available, and communications on performance issues are more open. Once wind plant performance data became more widely shared, it was quickly learned that the main contributors to the underperformance syndrome were higher-than-expected losses related to wind farm availability and sub-optimum turbine performance. Lesser factors included larger-than-modeled wake losses and unrepresentative wind resource data.

In the early days, a wind plant's availability was often predicted to be around 97 percent or equal to the contractual or warranted value established between the developer and the turbine supplier. This assumption overlooked non-contractual availability factors, such as the impacts of high-wind events or delays in getting spare parts. Occasional grid outages were also ignored. And, due to teething issues, first-year availability was typically lower than in later years. Current estimates for availability losses — as verified by wind farm data — are far more encompassing and average around 6 percent for a typical wind farm.

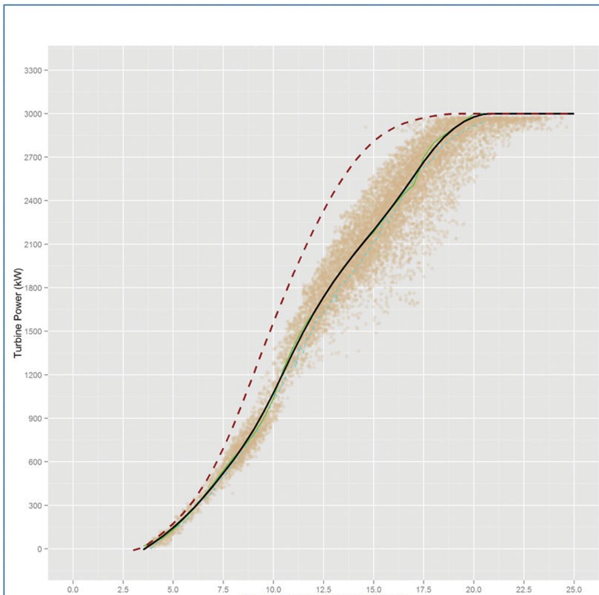


Figure 1: Power curve of a turbine with a pitch alignment problem compared to that of a well-operating turbine (dashed line)

Although a wind farm is "available" and operating, it does not necessarily mean it is operating at peak efficiency. In fact, sub-optimum performance is a common source of underperformance that is about twice as large as was first assumed in the past. Contributing factors include blade pitch or yaw misalignments, anemometer calibration drift, and other control setting errors. The turbine's actual power curve is another loss source because it often does not match up with the official or advertised density-adjusted power curve, as seen in Figure 1. High-wind events that trigger a wind turbine to shut down and undergo a restart cycle when winds lighten (known as the wind hysteresis effect) are another source of lost energy. All told, typical performance-related losses among wind farms are around 4 percent.

OTHER UNDERPERFORMANCE FACTORS

Another performance factor found for some projects has been the change in the as-built wind farm design compared to the planned design the energy analysis was based upon. It is not unusual for some last-minute design changes to occur in response to unforeseen permitting or construction constraints. Any change in the turbine layout or hub height will impact energy production to some degree.

Many underperforming wind farms had deficient wind measurement campaigns. In some cases, too few meteorological masts were deployed for the project's large footprint or complex terrain, and mast placement may have favored the highest terrain rather than a cross-section of elevations. This can lead to a biased, optimistic outcome when modeling the wind resource at every turbine location. Today, software tools such as Openwind are available to guide mast placement for the most representative results. Measurement campaigns that don't observe wind conditions at hub height (or higher) risk missing unexpected changes in wind shear and wind veer that could negatively impact turbine performance.

Unconsidered factors can play a role in the underperformance syndrome as well. Grid and environmental curtailments, as well as the impacts of newly built wind farms on nearby existing ones, can be sources of production losses that were often not accounted for in past pre-construction energy estimates. This was intentional in some cases, and it was hard to quantify in others. Nonetheless, these items can be significant performance factors, resulting in energy shortfalls of up to several percent relative to original predictions.

Project location is often a factor in underperformance, too, particularly in mountain gaps or valleys with shallow thermal wind flows, such as California's Tehachapi Pass. In these environments, wakes can last longer and wind shear can relax with height — both of which can penalize performance. Northern climates prone to icing, such as ridgetops in New England and Quebec, can be problematic, too. Icing can cause turbines to suffer outages or reduced production for extended periods during the windiest time of the year. Since ice deposition and its persistence on objects are not directly measured during a wind resource measurement campaign (and not during turbine operations, either), predictions of icing-related production losses can be hard to make. At some wind farms, ice-related production losses have been found to be two to three times greater than original estimates.

PORTFOLIOS VERSUS PROJECTS

Insights gleaned from the investigation of hundreds of wind farms have greatly reduced the magnitude of the under-

performance syndrome. Across a large portfolio of projects, the mean performance bias is likely to be small — on the order of -2 percent or less when using the latest assessment techniques. Individual projects, however, may still see larger deviations for any number of reasons. This should be no surprise given that portfolio members are built at different times by different installers using different turbine models that are connected to different grid systems in different weather regimes using different O&M providers. Some risks are unavoidable if good practices during the development, construction, and operations phases are inconsistently followed. Inferior resource assessment campaigns or errors in blade pitch and wind vane alignment during construction will have their consequences, too. The caliber of the wind farm's O&M program is another important factor.

There is a tendency to downplay or ignore risks that cannot be easily quantified. Pre-construction energy uncertainty estimates are largely an exercise in quantitative risk assessment, which works well with well-behaved sources of losses and uncertainty such as measurement errors. It works less well with poorly understood or less easily predicted risks such as installation errors and grid curtailment. Qualitative assessments can be valuable and should be included in preconstruction energy studies where appropriate. Anticipating potential problems at an early stage gives the most chance of dealing with them effectively.

CONCLUSION

What can be done to address underperformance before it happens? First, it is important that stakeholders involved in project development, financing, construction, and operations recognize that they each have a role to play and share responsibility in a project's outcome. Breaking down walls that prevent communications between stakeholders will create opportunities for change. Second, better project risk assessment and management practices are needed. Risk assessment defines the nature of risks, their probabilities, and their consequences, and risk management encompasses the actions taken to accept, assume, and manage risk. Third, independent engineers can be an integrating force across project stakeholders and phases to provide overarching industry guidance. They possess the specialized technical and analytical skills to diagnose problems and recommend cost-effective solutions. Lastly, maximizing project availability should not come at the expense of energy production. Although it is harder to maximize production, the underperformance problem won't be fully resolved until priorities get straightened out.