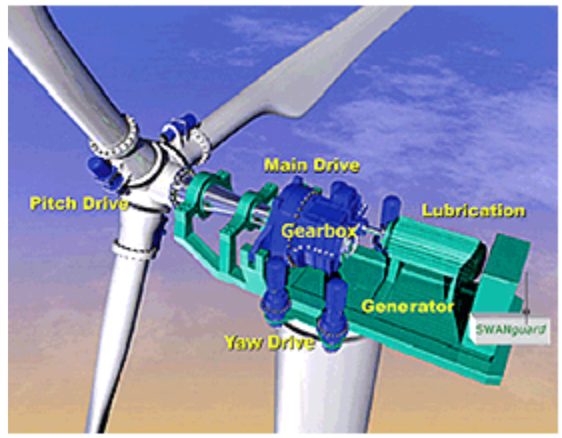
CURTISS WRIGHT Flow Control Company SCIENTECH

Monitoring Wind Turbines Drivetrains

Insuring peak performance and continuous availability



Wave Analysis (SWAN) techniques do not suffer from the inherent limitations of vibration analysis.

Wind turbines must function at optimal levels to efficiently harness and convert wind energy to electricity. To insure peak performance and maintain high turbine availability, a solid condition monitoring and maintenance program is required. In an attempt to monitor the health of drive system components, wind turbine operators have used traditional condition monitoring methods with mixed results.

There is, however, an approach that has proven to be very effective and reliable. High frequency sound-based Stress Wave Analysis (SWAN™) techniques do not suffer from the inherent limitations of vibration analysis. Stress Wave Energy (SWE)-based on sound rather than motion-is an excellent indicator of the overall health of wind turbine drive systems because it provides direct measurement and comparison of the amount of friction and impact occurring within the machine.

Regardless of when failures occur during a wind turbine's life cycle, they start as small discrepancies and progress to larger ones that result in secondary damage, unacceptable operating conditions or catastrophic failure. Traditional diagnostic techniques do not provide a clear indication of problems until late in the failure process, if at all. Stress wave energy measurements, however, provide a quantitative measure of friction and shock events during the machine's entire life cycle.

The quantitative nature and predictive accuracy of SWE, as a measure of machine condition, allows the time between overhauls to be safely extended to the time when wear out begins. The benefits of this service life extension are not only economic but operational as well. The trend of SWE measurements from normal levels through caution and danger zones provides the information necessary for advance scheduling of corrective action and true predictive maintenance.

The information presented in this document was developed through work with leading wind turbine operators and manufacturers. It is based on real equipment in the field, and it has provided both manufacturers and equipment operators with accurate and easily interpreted assessments of the operating condition of their wind turbine drive systems.

Overall Health Indication Through Operating History

Healthy drivetrains produce low stress wave energy, as compared to damaged machines, where energy levels are dramatically elevated in proportion to the level of damage. This makes it easy to not only identify the presence of an adverse operating condition, but also to instantly assess the severity of the problem. This eliminates the cumbersome and difficult task of analyzing complex vibration spectra. With SWAN technology, even minimally trained operators can quickly and reliably determine the health of wind turbine drive system components. In addition, SWAN technology provides the ability to isolate the location of the damage.

The first tool for assessing the health of a drive system component is the Stress Wave Energy Operating History chart, which trends stress wave energy over time and is plotted against a backdrop of health-indicating color zones (green/yellow/red). Sensors are placed at key points, based on structural paths to the components of interest. The amount of stress wave energy detected by each sensor can be viewed real-time and is stored for historical trending.

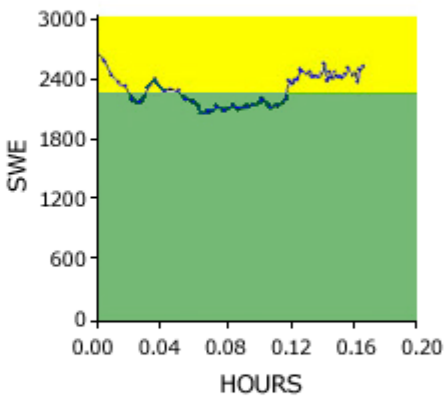


Figure 1. *SWE History ~ Damaged / erratic trend, higher SWE level, breaching yellow zone*

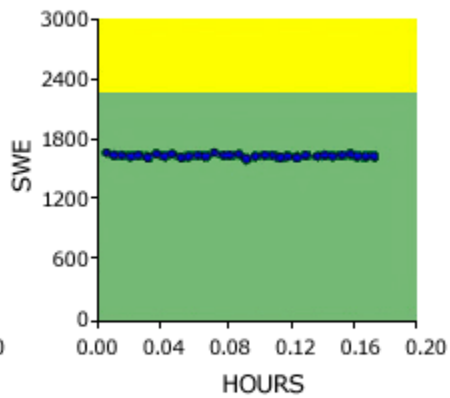


Figure 2. *SWE History ~ Healthy / steady, linear plot middle of green zone*

Figure 1 shows stress wave energy from a sensor placed on a gearbox in a turbine drive system. The stress wave energy plot depicts a linear and stable trend, indicating that the gearbox is operating at consistent, low stress levels. With this tool, it is possible to trend data on a continuous basis and set alarm thresholds so transient events do not go undetected.

Figure 2 shows a trend of the same sensor position from a different turbine of the same make and model. The drive systems in both turbines are identical. This sensor exhibits an elevated stress wave energy level coupled with an erratic trend line. At a glance, it is clear that this machine is less healthy than the other.

Stress Wave Amplitude Histogram

The Stress Wave Energy Operating History provides an intuitive method for quickly assessing machine health. If a sensor records unusually high levels of stress wave energy and/or an erratic trend, a Stress Wave Amplitude Histogram provides insight into the cause of the problem. The histogram tool provides a measure of lubrication effectiveness and is an indicator of random friction and impact events.

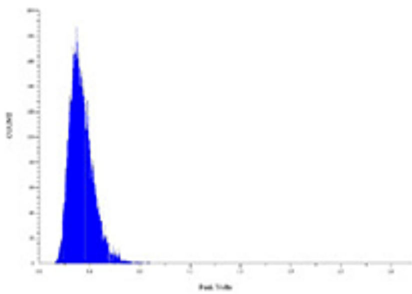


Figure 3. *SWA Histogram ~ Healthy / narrow base, low voltage readings*

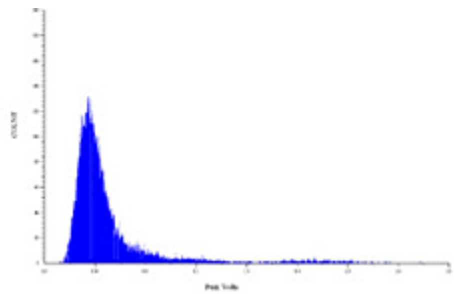


Figure 4. *SWA Histogram ~ Damaged / skewed shape with higher voltage readings, indicates random friction events*

Figure 3 shows data taken from the sensor on the healthy gearbox. All of the stress wave energy is at low voltages in a narrowly distributed bell-shaped curve. This indicates a healthy, well-lubricated mechanical system.

The Stress Wave Amplitude Histogram in Figure 4 shows a broader-based distribution with excessive tailing to the right on the x-axis, as compared with the normal, healthy gearbox. The skewed distribution is an indicator of random friction and impacting events caused by particulate or fluid contamination, skidding, sliding contact, or other factors that reduce lubrication effectiveness.

Stress Wave Spectral Analysis

A third tool, Stress Wave Spectral Analysis, is ideal for isolating damage to dynamic components, thus pinpointing the damage location. A flat spectrum and low background noise (see Figure 5) verifies that no significant impacting is occurring. Contrast this to Figure 6, where major spectral lines confirm repetitive impacting that correlates to a bearing defect frequency. In addition, the elevated background noise confirms increased friction levels as compared to Figure 5. Readily available data assists in identifying the machine components that could potentially cause a shock event at that frequency, thus identifying the damaged element. Confirmation of the detected bearing damage is shown in Figure 6.

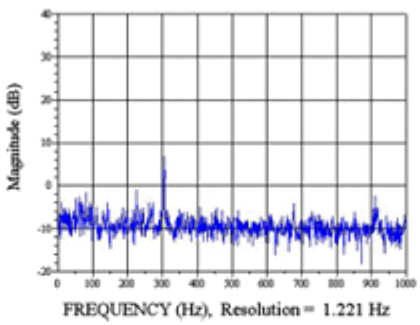


Figure 5. *Spectral Analysis ~ Healthy / low level, no significant peaks with harmonics.*

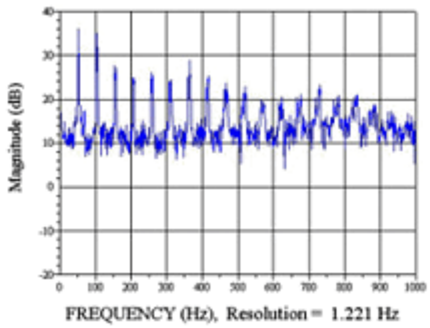
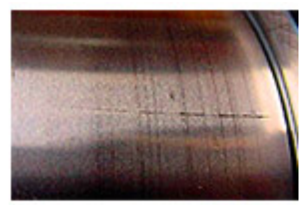


Figure 6. *Spectral Analysis ~ Damaged / elevated noise due to increased friction, fundamental peak with harmonics correlating to inner ring defect frequency of bearing.*

High Availability with Lower Operating and Maintenance Costs

SWAN technology delivers high turbine availability with lower operating and maintenance costs. The SWAN system can also be used by wind turbine OEMs to ensure the flawless operation of their products, reducing development and warranty repair costs, as well as providing value to its customers.



Earliest Problem Detection

SWAN identifies damage in the failure process earlier than any other technology. This enables manufacturers and operation and maintenance providers to:

- Eliminate unscheduled bearing and gear related maintenance activities, reducing overtime expenses and production losses
- Schedule maintenance during low or no-wind periods
- Perform condition-based repair up-tower, reducing crane time
- Eliminate secondary damage and extend component service life, reducing component inventories and consumption rates

Continuous Condition Monitoring

SWAN's easy to use analysis tools provide continuous monitoring of the health of land-based and offshore turbines, providing:

- Factory-integrated parameters in wind plant SCADA systems
- Integration with CMMS to automate maintenance-related activities
- Reduction in the number of site visits for mechanical assessments Design and Acceptance Testing

Design and Acceptance Testing

SWAN technology provides additional important benefits for wind turbine OEMs:

- Effective design and reliability testing, identifying component and manufacturing defects
- Confirms machinery performance level during commissioning
- Reduces the effect of infant mortality issues and the overall financial exposure during the warranty term

SWAN may be incorporated with a new product or provided as an add-on to an installed turbine population.

Conclusions

SWAN prevents the unexpected failure of a wind turbine drive system components. When the red zone is reached on a Stress Wave Operating History chart, the turbine should be pulled from service to prevent secondary damage or catastrophic failure.

SWAN also eliminates false alarms. At least a 500% growth in signal strength is required to reach the red zone threshold. When this occurs, without question an undesirable condition has developed in the gearbox or other turbine component. When it is pulled from service, it will show clear signs of wear or physical damage.

SWAN technology provides power generators with timely, accurate assessment of the health of mission-critical operating equipment. Unlike vibration analysis, SWAN tools can accurately detect even slight shock and friction events inside a wind turbine drive system, bringing previously inaccessible components under the control of true predictive maintenance.

SWAN tools are powerful and sophisticated in their diagnostic capabilities; however, they are simple enough even for the most junior-level operator to use. As little as one or two days training is all that is required, as opposed to the weeks and months of initial and recurring training that are required by other condition monitoring technologies. SWAN technology is available in several different product packages, depending upon a company's individual needs. The examples in this document were developed using the SWANview™ system.

SWAN technology reduces a company's operating costs and improves its return on important assets. For more information on how SWAN technology can improve your bottom line, please contact us.

For More Information Contact:
Steve Scheeren, sscheeren@curtisswright.com
Phone: 954-253-8588