The real value of condition monitoring

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Before considering the impact that condition monitoring systems (CMS) have on our industry, it is important to first establish what CMS entails and how it came to be such an established piece of hardware in the renewable energy sector.

A condition monitoring system would normally comprise of a series of sensors strategically placed on fundamental components to sense the state of this component relative to a known benchmark or healthy state. These sensors send signals to a piece of hardware or circuitry for processing and distribution. A condition monitoring system can be described as analogous to the human nervous system.

Our nerves detect when something is not normal, normally through the perception of pain and the nervous system relays this message to the brain. The brain then decides on the best approach to protecting the body from this source of pain. In this same way, our condition monitoring sensors, based on some pre-programmed parameters on acceptable, detects when something moves away from this, sends a signal to a motherboard which will make a decision on how to protect a component, normally via raising an alarm, or in an extreme case, shut down of an electrical component.

In the wind industry a condition monitoring system is widely used to provide health information on the rotating drivetrain components. The drivetrain of a wind turbine generator is an expensive but

important component of the energy generating system. In the case of a geared machine it is composed of the main bearing, main shaft, gearbox, brake, generator shaft, and generator. Direct-drive machines do not comprise of the gearbox section; however, the complexity of the arrangement remains. The multi-physical complexity of this arrangement, the expense involved in downtime and maintenance due to failure, ensures that it is both recommended and normal for turbines to have several measures in place to monitor the health of the components.

Vibration monitoring via an onboard CMS, is considered a superior method of damage detection, albeit at a higher monetary cost. Utilising spectral techniques, phenomena in data can be uncovered. Damage can be pinpointed to a component location likely to be undergoing some structural change. Classical spectral methods, for example, the Fast Fourier Transform (FFT) provide valuable algorithms to obtain frequency information directly related to the kinematics of a gear or bearing, Figure 3. The rotational nature of the drivetrain lends itself nicely to being able to mathematically determine events per cycle that allow a high level of accuracy when detecting and locating damage. Calculating these frequencies of interest and analysing how they trend and evolve over time provides an analyst with a good indicator function of component condition. Figure 2 demonstrates an increasing trend of vibration that indicates possible component damage.

Further analysis in orders and harmonic analysis for sidebands provides useful information when making decisions on the type of damage that a signal analyst could be looking at. In addition to the mathematics that are involved the decision making is also assisted with the provision of ISO codes that provide useful advisory limits when triggering alerts or alarms within horizontal axis wind turbines with a gearbox, such as ISO 10816-21, [1], VDI 3834, [2]. A downside to this type of analysis is the data rates involved are high and the systems are complicated and require highly qualified signal analysts to interpret the data.

Reliability incorporates historical failures, repair and downtime, these can be measured in terms of availability. A study presented in [3] evaluated repair and maintenance cost as 30% when looking at operational expenditure. Due to the sensitive nature of divulging information within the wind industry it can be difficult to obtain information regarding accurate failure rates and resulting downtime. There are several databases that we can look to for this information. In a recent study, a compilation of global database information, concluded that there are significant variations in failure rates and downtime depending on the data source analysed, [3].

One thing that is unanimous across the literature is that the drivetrain components are the most frequent and most expensive component to repair. In the case of a gearbox failure, the turbine downtime, gearbox repair time, cost of spare parts and tooling (including crane costs) and resourcing of technicians make this the most expensive and most time-consuming repair a turbine will experience. It is widely thought that 10% of all major component failures can be attributed to the gearbox alone, [4].

In a separate study, it was stated that as high as 30% of all main bearings will fail within the expected 20-year life expectancy, [5, 6]. With the average cost of repair being such a high figure, the industry has seen a change in attitude. From corrective maintenance that would find a solution following a problem, to a predictive approach that seeks to plan and perform repair ahead of a failure. Predictive maintenance can be timed-based at regular intervals or condition-based depending on the condition of a monitored component. Both are critical to reliability.

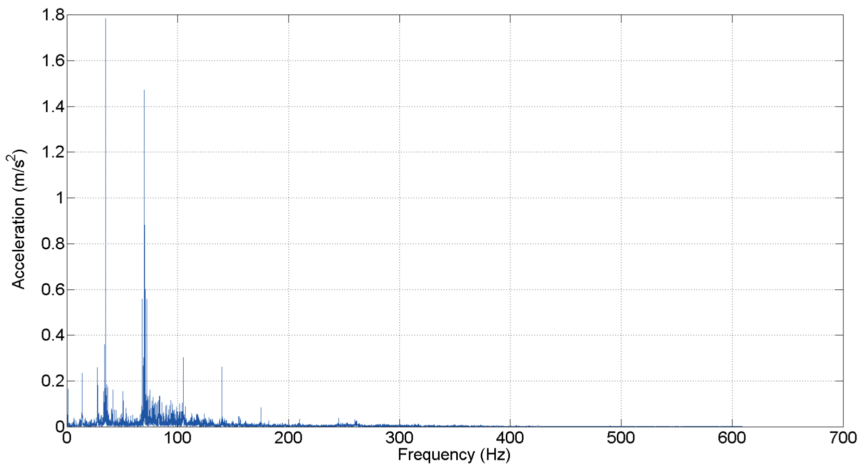

Figure 3: Classical FFT methods reveal frequencies of interest in a spectral signature

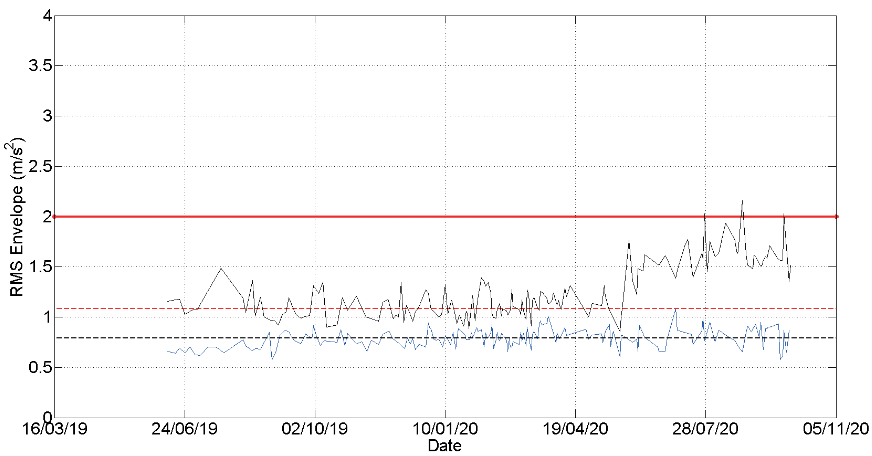

Figure 2: Trend analysis reveals when a particular frequency component begins to increase in vibration level and flag as being problematic.

Figure 4: Known frequency components can give data analysis information supporting damage to the mechanical components. The image reveals an outer race crack on a bearing

Utilising sophisticated CMS equipment greatly assists the implementation of an effective predictive maintenance approach to maintenance and repair. A predictive maintenance approach to inspections means that you can detect, categorise and quantify damage and defects on a wind turbine generator and track its progression.

Predictive maintenance allows asset operators to plan scheduled maintenance ahead of catastrophic failure and during periods of low power production. By adopting this approach to monitoring, a good reliability engineer will add value to a client by uncovering minor, stand-alone or serial defect issues affecting the efficiency of a wind turbine.

A predictive maintenance approach to inspections ensures tracking progression can assist clients in scheduled maintenance consultation ahead of catastrophic failure and in periods of low power production. This minimises downtime and reduces the

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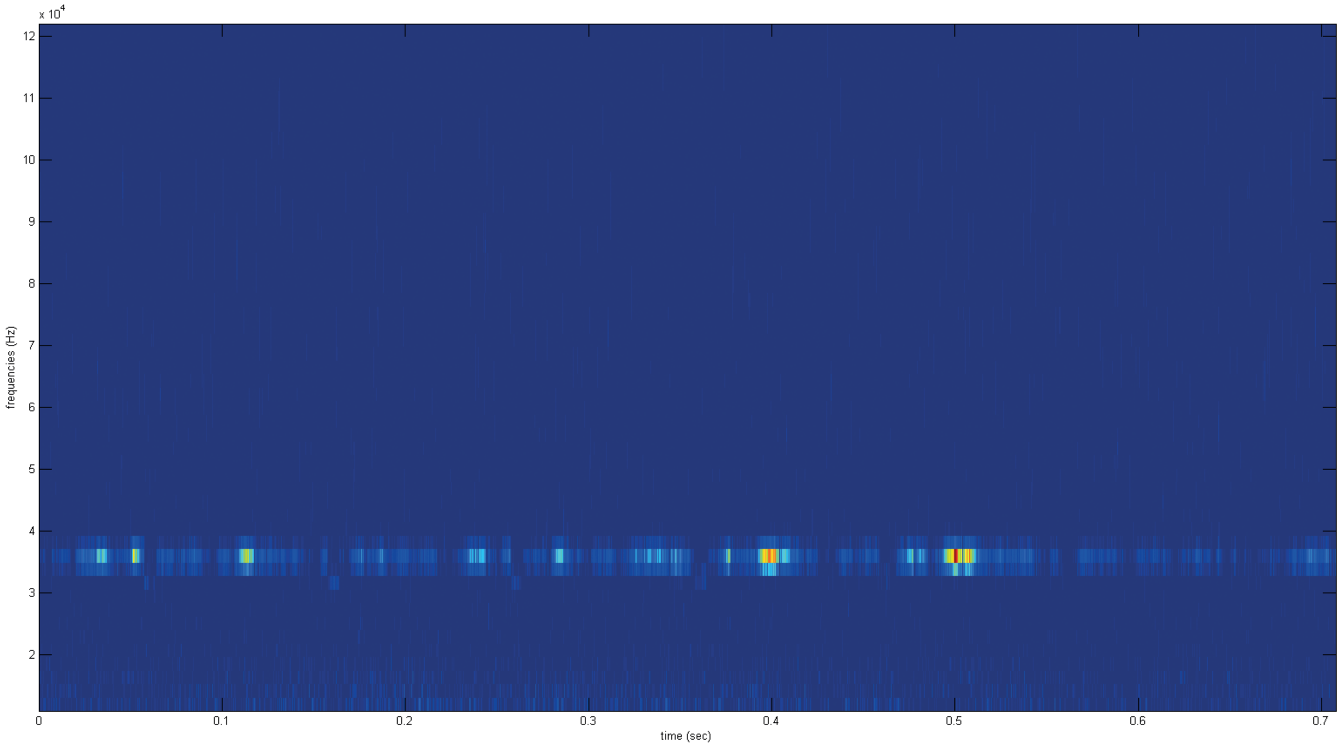

Figure 1: A wavelet transform can be used to reveal how rotational frequencies can vary over a time period

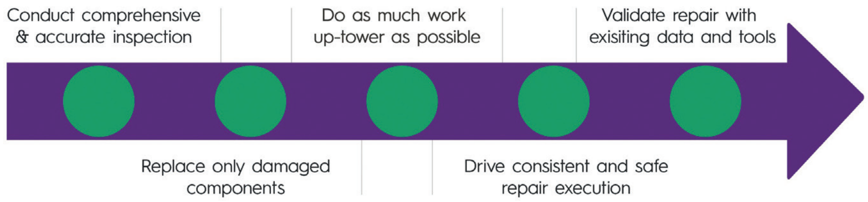

Figure 5: Flow chart demonstrating a good approach to predictive maintenance

amount of major component replacements. The flow chart in Figure 1 demonstrates a good approach to inspecting the turbine through all available data and attempting to isolate maintenance to up-tower, as much as is reasonably practical.

It is important to note that failure is a process and not a single event. The optimum window for fault detection is right after the beginning of the fault propagation and before serious wear and secondary damage occurs. For example, as a bearing fault starts to grow, more and more wear debris is shed which is carried by the lubrication system. Debris particles travelling through the gearbox, where they can find their way into other gear and bearing designations, usually cause further damage escalating the repair costs. Avoiding this secondary damage is the key to saving money for the owner and contractor.

Table 1 below provides the differential cost of up-tower versus down-tower repair.

Table 1: Estimated Crane Costs

	Up-tower	Down-tower
Estimated Crane Costs	GBP 7-14 k	GBP 170-340 k

The goal is to be able to utilise a good maintenance and inspection program coupled with excellent data analysis, and combine the results to predict damage, schedule repair accordingly in times of minimum production and availability, and avoid high maintenance costs and secondary damage. This is the ideal solution to the headache of crane costs and unplanned downtime.

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