Full-turbine predictive maintenance: an opportunity for early adopters

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For many years, the wind industry has been working to reduce the Levelized Cost of Energy (LCoE), with the aim of increasing profits and building strong balance sheets. However, it's now becoming clear that some major economic headwinds are emerging for the sector, and the continuous downward trend of LCoE may be in jeopardy.

Rising costs have been observed across the entire value chain of the wind industry. Some issues are driven by global factors, such as higher prices of raw materials, production costs, skills shortages, and labour inflation. This has led to a major shift in forecast profits for many players, even to the point where some developers have cancelled projects entirely. We saw in July that the Swedish utility company Vattenfall stopped development of the 1.4 GW Norfolk Boreas wind farm, concluding that taking a $537 m loss was economically favourable compared to ploughing on with the project.

We've also seen that a number of financial challenges are related to the reliability of the wind turbines themselves. For a recent pertinent example, Siemens Energy announced that it is now forecasting an additional one billion Euros in costs to deal with operations and maintenance (O&M) issues over the next five years. In this case, the issues were attributed to the reliability of Wind Turbine Generator (WTG) blades and bearings, with problems affecting up to 30 % of the more than 132 gigawatts of Siemens turbines worldwide. In figure 1 we can see that all of the top three European wind turbine OEMs have reported major losses in 2022, with major reliability issues cited as a leading factor.

These cost increases are not only affecting the OEMs. Operators and owners of turbines with multi-brand fleets are all set for major increases in O&M spend over the next decade, especially as the OEMs appetites for full-risk agreements are decreasing. Wood Mackenzie predicts that the global O&M market for onshore wind will rise to nearly $25 billion per annum in 2029, with the leading costs being attributed to drivetrain, blade, and pitch bearing corrective action. We see reliability issues creeping up for other components too. From towers and foundations to generators, accumulators, and cables, it's clear that wind farm O&M is increasingly becoming a full-turbine problem.

Why full-turbine predictive maintenance (PdM) matters

Pressure is higher than ever to ensure the wind industry is running as economically as possible, and tackling reliability issues across the full turbine must be a key focus going forward. However, what options do operators and owners have available to them?

Predictive maintenance (PdM) techniques are perhaps one of the most promising solutions to tackle full turbine reliability issues and reducing production downtime. PdM has been proven across the power generation sector and promises significant O&M cost savings over reactive or interval-based maintenance strategies.

PdM relies on accurate knowledge of the condition of wind turbine components as they degrade over time, and this knowledge can be provided via an online condition monitoring system (CMS).

The knowledge of a fault developing with a long lead time before a critical failure occurs delivers major cost savings, as cheaper replacement parts, cranes and staff can be sourced well in advance. This also enables maintenance to be scheduled outside of

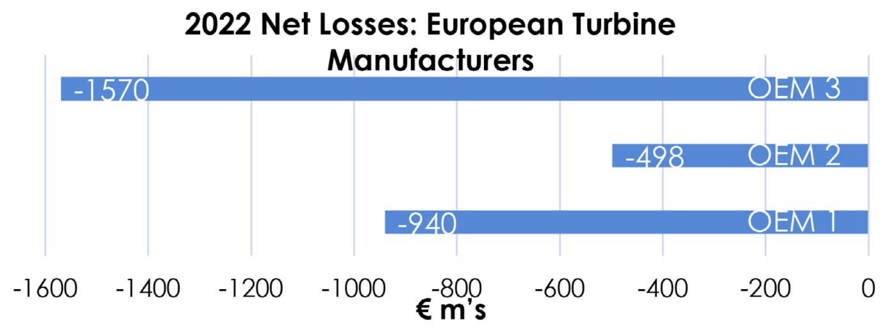


Figure 1. 2022 net losses for the top 3 EU Turbine OEMs

the windy season, reducing the risk of catastrophic failure, lowering downtime costs, and consolidating multiple turbine repairs into lower cost campaigns.

Over the last few years, PdM has delivered significant gains for the wind turbine drivetrain. Drivetrain CMS accurately determines early signs of damage in the rotating machinery components, such as gears, bearings, couplings, etc., by analysing vibration, temperature, and oil condition. This enables accurate estimates of the remaining useful component life to be made, therefore allowing optimised maintenance planning and reduced maintenance costs. This has led to very wide adoption of drivetrain CMS hardware and continuous data monitoring across the industry, with a very short payback period for this initial investment.

However, very little PdM is carried out beyond the drivetrain in the wind industry. CMS technology for other wind turbine components has not been widely accepted in the market, whilst the cost of maintaining these components continues to stack up.

Opportunity for early adopters

The Technology Adoption Lifecycle is a model often used to describe the deployment of new technology. It proposes that when a technology is introduced to a market, initially only a small number of 'innovators' and 'early adopters' reap the benefits of a new product. At a later stage, the 'early majority' and 'late majority' will accept the solution, before finally the 'laggards' will be the last to adopt it. This has been exactly the journey for drivetrain CMS in the wind industry over the last 20 years.

We are seeing this model play out again on the wind industry's pathway to full-turbine predictive maintenance. A small number of innovative solutions have emerged over the last few years to enable PdM beyond the drivetrain. Technology acceptance is still limited to a small number of early adopters, however the benefits some of these new products can bring is significant.

For example, hub-based CMS systems have begun to enter the market, with sensors that can now be deployed to monitor the condition of some components for the first time. Carrying out regular visual inspections of components in the hub can be particularly labour intensive, present significant risks from a safety perspective, and often do not yield conclusive results of the condition of the components themselves. Replacing these inspections with an online condition monitoring system yields significant cost savings, whilst enabling PdM to be carried out successfully.

Pitch bearings are a prime example where hub-based sensing products are useful. Vibration and displacement sensors can now be installed to reliably detect the early signs of damage caused by a number of failure modes. Pitch bearing faults can be detected with months of lead time before catastrophic failure, enabling highly effective predictive maintenance and delivering significant cost savings in spare parts sourcing and replacement operation planning.

Likewise, sensors can be used to monitor the health of the blade-to-bearing connection. If any changes in stiffness of this crucial connection develop, they can be continuously monitored, and corrective action can be taken well before a blade-liberation incident occurs. This issue is particularly prevalent in certain types of blades that use a root-insert style connection, as opposed to a T-Bolt type connection.

Even more recently, hub-based CMS products have been introduced that claim to detect damage in the blades themselves. Blades are the second highest contributor to unplanned turbine O&M spend, after the drivetrain, and represent a major opportunity for industry-wide cost savings. Annual drone inspections are widely accepted to monitor slowly progressing damages that present themselves on the blade's exterior surface. However, more sinister structural failures often develop internally, and progress quickly, thus reducing the effectiveness of visual inspection methods. If these types of internal damages can be monitored using online sensors, then significant reductions in blade repair costs can be achieved.

Looking beyond blades, pitch bearings, and drivetrains, we can also find a multitude of new offerings in the market addressing other reliability issues for the rest of the wind turbine.

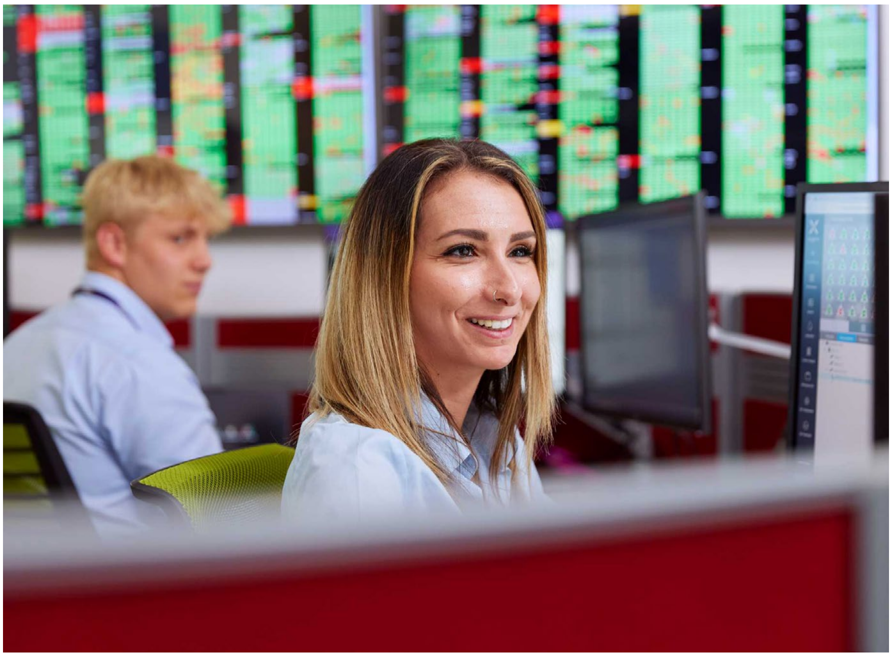
Attend any major wind conference and you will find an array of companies developing creative solutions for monitoring almost any WTG component. From towers and foundations, to loose bolts and high voltage cables, there are an ever growing number of novel monitoring solutions available to today's wind turbine owner.

Taken at face value then, this looks like the dawn of a new age of CMS products that cater for your every need. Is the bright future for full-turbine predictive maintenance really just around the corner?

The risks and rewards of early technology adoption

One thing the technology adoption curve does not account for is that sometimes the conservative caution of the 'late adopters' and 'laggards' can be justified. It is inherently risky to be an early adopter, and the reality is that some new products may not deliver on their initial promises. In the wind industry, new technology may be perceived as expensive or lacking a good fault detection track record. In a time of increasing costs, every investment decision will also be analysed very carefully.

For example, wind turbine blade CMS is a fast developing market. A wide range of sensing technologies are being trialled, such as airborne sound, acoustic emission, fibre optic strain gauges and accelerometers, with no single solution yet accepted widely by the market. Buyers need to gain confidence and see a track record, but not all trials have delivered good results and there are many reports of high up-front costs.



So what can be done? Care must be taken when reviewing new offers and carrying out appropriate due diligence. To mitigate risks, important information needs to be gathered from the technology provider, such as their quality control methods, the number of other turbines they monitor, and their true positive/negative detection rates for the CMS product. Another reliable way of assessing the credibility of a solution provider is to thoroughly review the business case and pay-back period for the product they are selling. Small scale pilots are a common way to increase confidence before committing to a larger scale roll out, but care must be taken not to allow the pilot period to drag on too long and delay wider adoption of the technology.

Full-turbine CMS is a nascent market, and there is a burden on wind turbine owners to identify which innovative CMS products can genuinely deliver the cost savings promised, and which may struggle. However, when this is successfully navigated then the reductions in O&M spend can be vast. Early adopters will likely be the winners, providing they tread carefully.

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About the author

Henry Tanner is the Product Manager for Advanced Sensing at ONYX Insight, a leading global predictive analytics solution provider, with a combination of software, hardware, consultancy and engineering services exclusively for the wind industry. ONYX brings unbiased predictive analytics underpinned by real-world engineering expertise, and monitors 14,000 wind turbines in 30 countries around the world.