Advancing knowledge to optimise global wind farm performance

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The view from the turbine nacelle with lidar to detect wind data

In response to the global market requirement for more efficient and targeted O&M strategies for operational wind farms, there is an increasing need for operators to focus on turbine performance and reliability. Having recognised this as a priority to support operational teams and to advise on strategies to optimise sites, our approach has been to research, develop and implement several new methodologies that highlight short and long-term considerations for operations and asset management (O&M) planning across client portfolios, advanced performance engineering (APE).

The detailed analysis of wind regimes can pinpoint the optimum time frame for undertaking maintenance activities to ensure revenue losses are minimised; whilst turbine benchmarking assessments can identify trends specific to individual technologies and therefore highlight and inform the future management and maintenance of wind farms.

In this article, we will take a look at the role of APE and how it can aid operators in their decision making.

We begin with the drivetrain of a wind turbine which is one of the most expensive and important components of its mechanical functionality. As such, it is standard practice for a site to have measures in place to monitor the health of the drivetrain

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components. These include remote systems such as supervisory control and data acquisition (SCADA) and vibration monitoring, collectively known as a condition monitoring system (CMS).

It is vitally important to employ an independent expert in the analysis of the data produced by this system to ensure a clear understanding of the drivetrain components’ performance.

By interfacing with existing onboard vibration measurement systems and providing independent analysis of the data, detailed drivetrain performance assessments can be provided.

This analysis will identify any deviations from the normal expected performance between turbines or over time. By combining knowledge of the site behaviour with knowledge of the particular turbine make and model, and cross referencing with ISO standard information, we can make informed decisions about the health of the drivetrain and advise site teams of any likely sources of failure prior to the component status becoming critical.

Vibration data should be analysed as soon as it is made available – reviewing activities from both a time and vibration frequency perspective. Any issues that are observed as a result of data analysis can then be flagged and acted upon as soon as possible.

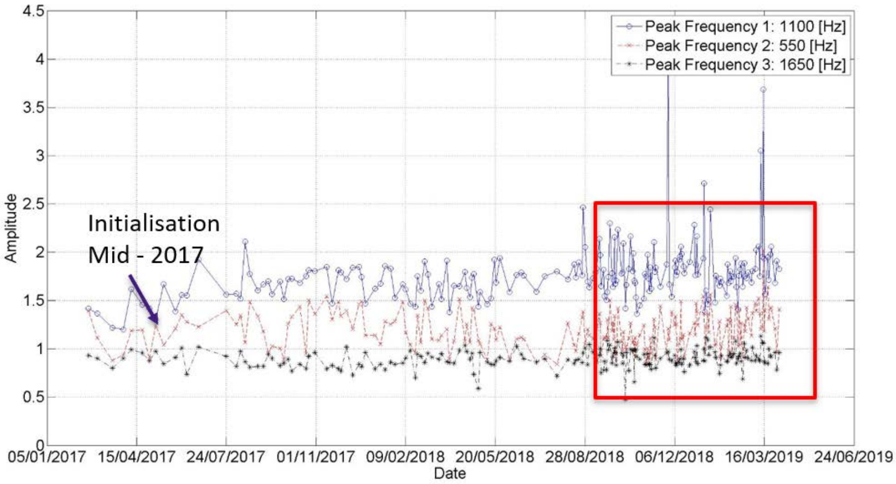
Advanced performance engineering methodology

A high-level review of the operational history should be carried out in order to determine any site-specific performance issues and derive a baseline availability level. This will be undertaken specifically in terms of the vibration levels measured by the onboard sensors. Available data should then be processed and statistically examined to return mean and standard deviation signals across the turbine wind speed range and kinematic rotational speeds of drivetrain components. These trends will then be utilised as a future reference point for vibration levels at known turbine operational conditions.

All drivetrain components are diagnosed based on known drivetrain kinematics. We make informed decisions on vibration levels and their criticality in order to advise site engineers of any potential failures and where these would potentially occur. Data collected is analysed for any excessive vibration signatures in accordance with international standards.

Vibration analysis involves analysing raw time signals measured from a machine using a variety of time and frequency dependant techniques to uncover the vibratory signatures of all rotating and motioning components. We then look for spectral trends in the signals to detect any unwarranted signals.

The analysis of all data measurements enables us to make recommendations on components that would benefit from further investigation.



A power curve through time, showing the evolution of underlying signals in lead up to a failure

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Why is this approach beneficial?

State-of-the-art advanced performance engineering provides a combined data analysis and working knowledge of turbine drivetrain technology to ensure that all data types and sources are investigated and a full decision-making methodology is used. A combination of data analysis with mechanical engineering ensures that the reporting and documentation provided is not purely mathematical but primarily focuses on the components. This ensures that the site team is provided with a clear and practical insight, and that the knowledge gained supports an enhanced predictive maintenance strategy.

The primary focus of this analysis is for early stage damage detection. This ensures all components can be assessed, and any potential damage is flagged to a site team well before damage progression and certainly some time prior to catastrophic failure. The site team benefits from early site decision making and so ensures cost saving in maintenance strategies.

Utilising a combination of data sources is an excellent method of providing certainty that an issue does exist, for example, combining any vibration trends with SCADA signals and oil sampling reports. This approach can assist sites deploying teams to a turbine and provides an enhanced information-based decision-making capability.

Methods of advanced performance engineering

There are a variety of different methods to support an advanced performance engineering approach. These include:

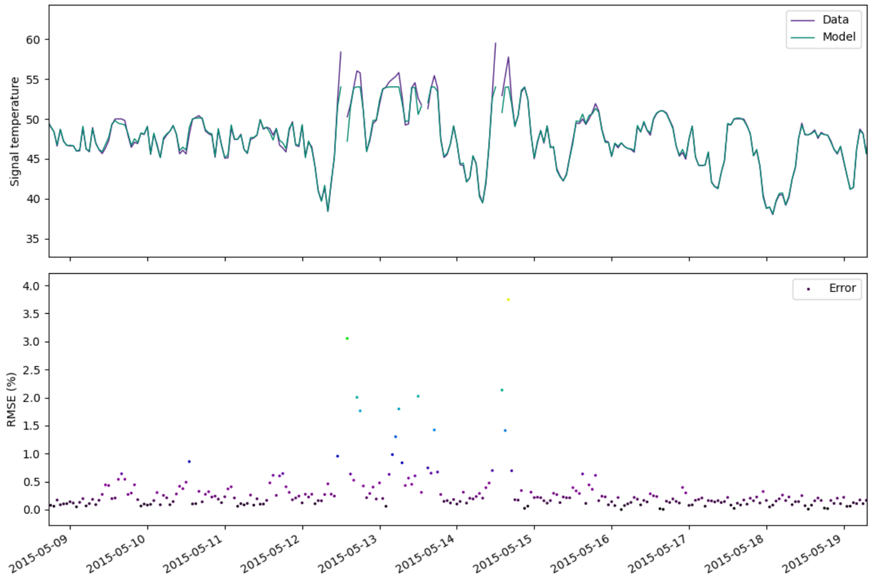
- External report review, independent interpretation and reporting
- An independent report review service is intended to assist the site team with decision making based on external reports that are provided by third-party companies. The wide-ranging number of reports that come to any site vary hugely, and reviewing all this information is time consuming and can detract key personnel from other necessary site resources.
- Using industry best practises and relevant ISO standard limits to independently review third-party documentation ensures maximum due diligence is taken.

Continual performance improvement analysis

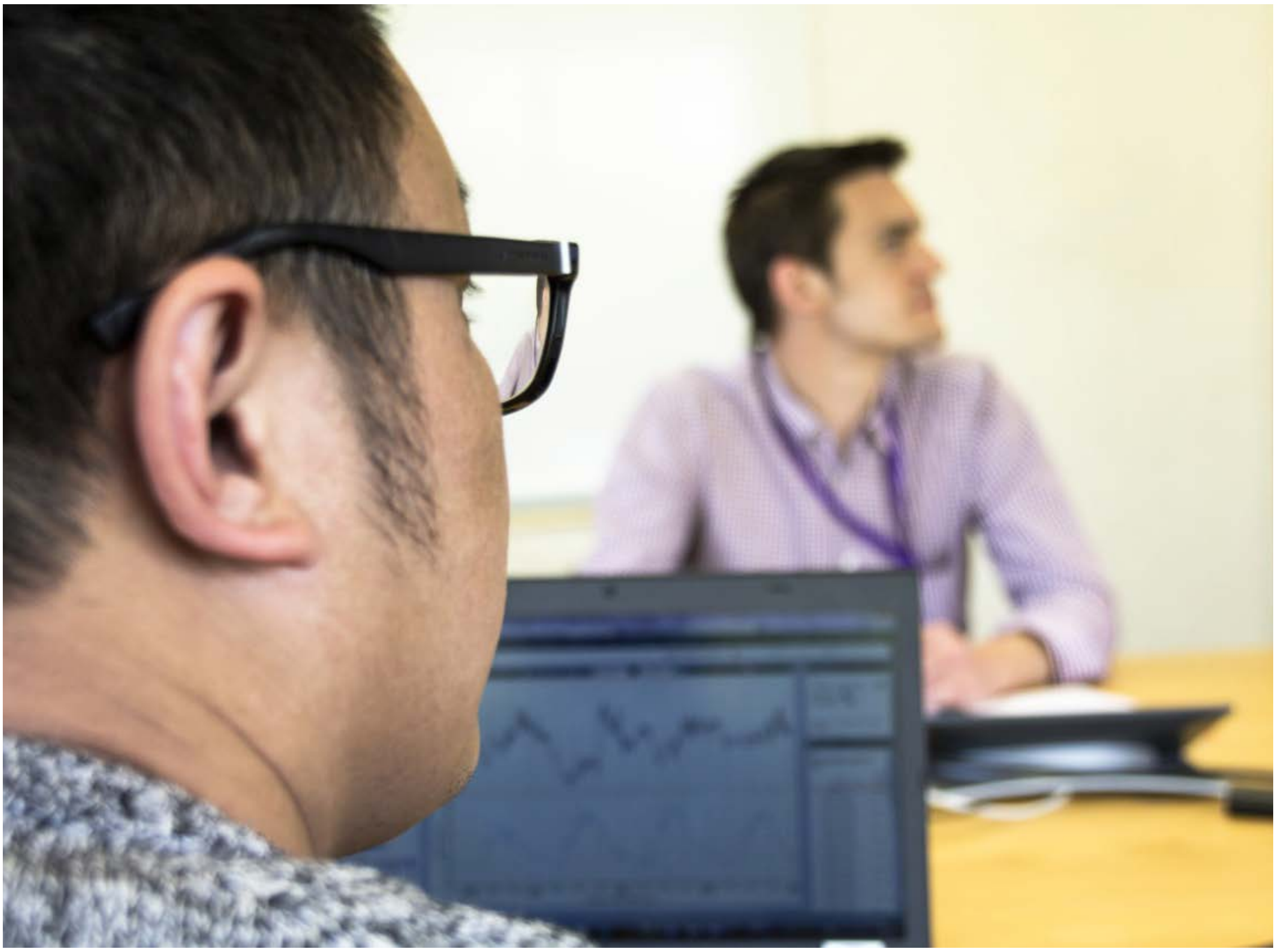
Due to the complex and transient nature of wind farm operations, there is a constant opportunity to drive improvements in performance and optimise maintenance activities. In order to achieve this, owners need to have a clear benchmark of the current performance and a process in place to accurately monitor changes. By integrating the analysis of site operational data with maintenance activities, a data driven approach to servicing and site work packages can drive continuous improvement. By adopting a structured, quantifiable approach lessons learned can be efficiently applied to additional assets in an owner's portfolio.

Predictive analytics

Predictive maintenance is the key tool for optimising wind farm performance. By combining SCADA, CMS, maintenance records and expert analysis, predictive tools can identify component level performance degradation and failure indicators. This can be applied to any wind farm in order to



A comparison between a modelled and measured signal in SCADA data, highlighting periods of abnormal behaviour which require further investigation



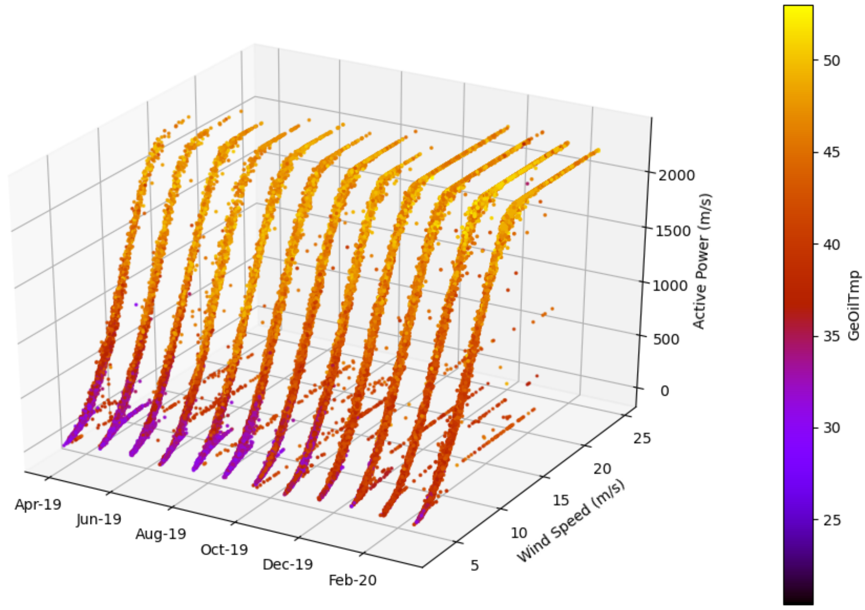
The APE team at work

proactively identify components at risk and underperforming assets.

Performance assessments

Turbines in any wind farm are subject to a broad range of wind conditions and are under frequent review and maintenance by the OEM. Turbines adjustments, routine maintenance and wear and tear can lead to changes in the turbines' behaviour, all of which can affect performance. Analysis of the SCADA data can reveal performance changes due to any of these factors. Recently, turbine OEM's are more frequently offering performance enhancements such as installation of vortex generators or other control-based upgrades.

One off or regular performance analysis services to provide detailed turbine performance assessments can identify deviations from normal expected performance between turbines or over time, or to quantify performance gains for power enhancement products.



A power curve through time, showing the evolution of underlying signals in lead up to a failure

Natural Power's servicing team working with the APE team to deliver essential repairs

Site wind flow conditions assessment

Wind farm sites in complex locations and wind flow can be subjected to manufacturer-imposed curtailments based on pre-construction turbine suitability and site conditions assessments. A heavy reliance on pre-construction site measurements and modelling approaches can lead to a higher than normal level of uncertainty in the results, with safety factors applied to ensure turbines are adequately protected.

Once site operations have commenced, the pre-construction modelling can be assessed against the actual conditions for wind speed, direction and turbine production. For example, the Ventos advanced CFD flow model can be applied to enable enhanced assessments to be made for turbulence comparisons where suitable data is available. Based on the assessment, it may be possible to request a modification to the curtailment strategy, subject to agreement from the OEM, either to reduce curtailments or provide more refined curtailment options that reduce turbine loading and enhance protection against damaging conditions.

GAP analysis

In some cases, wind farm performance is not in line with budgetary expectations, often leading to a shortfall in production. The reasons for this can be difficult to identify when turbines may not be performing to power performance expectations or budget predictions were based on uncertain pre-construction energy yield analysis and site suitability studies.

As such, it is possible to undertake a reconciliation analysis to investigate the source of any significant deviations identified between the current long-term forecast figures (based on the operational data from the turbines) and the pre-construction budget. It should be noted that as part of the reconciliation, certain factors resulting in budget deviation, for example related to wind conditions, may not be mitigated by a change in future operational strategies.

To conclude, there are a variety of advanced performance engineering strategies that can be deployed to ensure optimal wind turbine performance. This pro-active approach not only delivers well for resolving immediate issues, but protects the life-time operational output and overall profitability of our assets, and that can only be of benefit to us all.

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Natural Power is an independent consultancy and service provider employing more than 400 staff across 12 international offices supporting a global client base in the effective delivery of a wide range of renewable projects including onshore wind, solar, renewable heat, energy storage and offshore technologies.

The business is purely focussed on renewable energy projects and has extensive experience of the entire operational life cycle, from feasibility right through to servicing. Crucially, this experience feeds into the APE and analysis offerings provided by the team. Furthermore, as an independent provider, Natural Power has its own proprietary analysis software to support expert delivery, and works collaboratively with clients to provide the most effective outcome.