How big data can lead to lower wind power costs

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Advances in remote diagnostics for wind turbines are helping to extend service intervals and to identify potential issues before any harm is done, thus avoiding down time and contributing to lowering the costs associated with wind energy. Merete Hoe, head of diagnostics center, Siemens Wind Service, Brande, Denmark

Imagine you own a Formula 1 racing team with ambitions of winning the next big race. It requires an innovative racing car and an exceptionally good driver. The competition is about seconds and if you are too slow to replace a tyre you can lose the race. A crew is standing by ready to repair any damage or correct any problems. Before, during and after the race another crew is working to proactively find improvement possibilities and perform deep dive analytics to predict and prepare for future fault avoidance and service of the car to keep it top notch.

When working with wind turbines another layer of complication is added. The crew must, wherever possible, aim to fix the turbine remotely and proactive diagnostic models must be available that enable an early remote fix with no stoppage of the turbine. Then diagnostic advice must be prepared and made available for use on the next scheduled service visit.

On top of that you must make sure all diagnostics-based work orders are available in due time for effective service visit planning, ensuring that all spare parts are ready and that the recommended time frame for the diagnostic advice is met.

The offshore segment adds yet another dimension of difficulty on top of all these demands. When a turbine is far from shore it can be costly to send out a service team and the booking of service vessels must be aligned with forecast weather conditions. This is why remote control and remote diagnostics are crucial to harvesting the full benefits of wind turbines at sea.

Building on big data

The remote diagnostics activities of Siemens Wind Service are based at its headquarters in Brande, where a new centre is being built. Remote diagnostics gives operators the benefits of access to specialists with many years of experience in the wind industry and a large pool of data from yesterday and today, combined with projections into the future. The data platform has been built up from many years of operation, with more than 300 million diagnostic calculation results currently

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being performed every week. Twenty four million turbine parameters are monitored on the fleet and investigated constantly to provide dynamic optimisation of turbine set up.

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In Siemens Wind Service we have had diagnostic models running on turbines since 1998 when it was decided to add diagnostic sensors into all of our larger turbines, motivated by the belief that collection and analysis of vibration data were keys to performing remote diagnostics for the successful planning of service work. We were early in the field, but the case for adopting this strategy has been supported by a number of independent industry reports and the decision to stick with and continue to develop remote diagnostics capabilities has delivered significant benefits. The decision to install diagnostic sensors, as from 1998, not only applied to offshore turbines but also included onshore turbines, which was unique in the wind turbine industry at that time. This decision has led to the assembling of a large and growing knowledge base with which to inform diagnostic decisions.

Thanks to the early investment in diagnostic data platforms and development of associated in-house competencies Siemens Wind Service has considerable in-depth expertise in wind turbine vibration diagnostics, and intends to continue to further develop diagnostics tools using both established and emerging techniques to improve ROI for wind farm investors and operators.

We send out work orders to operators on the basis of remote diagnostic models, and currently achieve an average "hit rate" of about 98% (ie, 98% of the diagnostic proactive work orders prove correct in terms of what is found during execution of the service visit). It is always a question of balance: do you send out a service team on the basis of a diagnostic system with a hit rate of 85%, or do you wait until the hit rate is 100%? We want to be as sure as is reasonably feasible and we want to create value for the operator by keeping the turbines running as long as possible.

The diagnostic models are tuned dynamically and use the newest knowledge and feedback from the turbines and service crew. In addition automated data analytics are used to develop and validate improved diagnostic models and there is a flow of feedback to the turbine designers to enable them to continuously improve the machines, listening to the "voice of the turbine."

When we detect a finding based on our analytics we notify the operator of the finding but also add specific recommendations on what can be done and an analysis of the potential consequences in the short and long term if nothing is done.

This enables our customers to act on the findings and make decisions that fit into the needs of their businesses. It is not just a turbine temperature reading, for example, but a diagnosis on which action can then be based.

Diagnostic offerings from Siemens Wind

We work in three diagnostic areas, which we call reactive, proactive and interactive.

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These can be explained in terms of a soccer team, with a goalkeeper plus defensive, midfield and offensive players.

The goalkeeper and defensive players provide the reactive diagnostic services. When an alarm occurs and perhaps forces the turbine to stop, this is noticed and registered in the knowledge and notification database, and dealt with by the goalkeeper, defence and midfield. A game could go on forever being reactive. But the true game begins when the midfield and offensive players find an opportunity to score. Proactive diagnostic services represent co-operation between midfield and offensive players as a result of many years of diagnostic model development,

building on technology, data gathered, skills and knowledge. Attack plans are formulated to ensure that the alarms from the turbines are detected in time and the midfield takes care of the ball before there is any threat of a goal. The interactive diagnostic services are somewhat akin to the activities of medical personnel who respond to requests and aim to help players stay in the game for the duration.

Today, remote diagnostics are offered by Siemens as either part of a service contract or as a standalone package for post warranty services.

The latest transparency initiative is a new customer portal called Siemens Wind Dialogue, which allows the operator to see the detailed status of all his sites. It is possible for the customer and Siemens to see pretty much everything, including, for example, agreements, delivery status, technical news and very deep dive notifications on turbine performance.

Vibration diagnostics was re-certified in accordance with the Germanischer Lloyd condition monitoring system guidelines in 2013, which means that all early warnings and alarms are handled in accordance with these strict guidelines, with the certification valid until October 2018.

The reaction time in dealing with a stopped turbine is 10 minutes, while the percentage of turbine events that can be fixed remotely is approximately 85%.

As an example, a turbine can be stopped because of temperature conditions that fall outside the allowed operational levels. The turbine can be returned to operation again remotely when the conditions are acceptable. Another example is where deep analytics show that a turbine can reduce its output gradually instead of shutting down all at once, resulting in a lessening of grid power fluctuations.

For our diagnostic experts in all three diagnostic areas the basic activities can be described as: making sense of big data, with tens of thousands of data samples per second coming in from an approximately 30 GW fleet of wind turbines; developing and using tools for data analytics; developing proactive diagnostic models; deriving findings from the diagnostics; and developing a plan of action with a timeline.

We develop and implement both preventive and predictive diagnostics. Certain components in a wind turbine need to be replaced at some point during its lifetime. We want to limit the number of service visits even though within an availability contract we have an allowed service window where we can carry out a number of service visits. We try to avoid unplanned visits and where possible execute tasks remotely, enabling higher production and lowering costs.

Using diagnostic models

Normally a power plant or other piece of machinery can be monitored by installing a number of sensors for temperature, pressure, vibration, etc, with fixed thresholds or limits. This method has also been used for wind turbines for several decades, with service providers responding in a reactive way to faults and failures.

However, wind turbines today are often installed at locations with limited accessibility, sometimes requiring transport in a challenging environment when turbines are located in areas with a poorly developed infrastructure. Sometimes wind turbines can only be reached by boat or in winter by snow scooter, for example. The need for a more proactive approach to service has therefore increased over the last decade or so and we employ new technologies to facilitate this transformation from reactive service to proactive service.

Diagnostic models enable advice to be issued well before the turbine generates a warning or an alarm, allowing timely advance planning of appropriate service activities

A wind turbine is very seldom in a steady state of operation, so a different approach is needed. A wind turbine can never be in a protected environment with a steady ambient temperature, predictable operating conditions and no

turbulence. Wind turbines must be able to operate effectively 24/7 in wind speeds typically up to 25 m/s, with a wide range of ambient temperatures, from extreme heat to extreme cold. It is simply not enough to have a fixed limit for each sensor.

The diagnostic models we employ for wind turbines are based on intelligent learning from terabytes of data samples collected from the entire fleet. Close to 8000 turbines with an average of five years operation amounts to around 40 000 years of operation and experience, reflecting all kinds of environmental exposure. By using the latest technology and methods, including neural networks, for example, a mathematical model is created.

This model then allows diagnostic specialists to verify the operational state of a system or component.

Consider a very simplified example, a hydraulic system within a wind turbine with a fixed temperature limit of 70°C for the hydraulic oil. If the limit is exceeded the wind turbine is normally stopped and needs to be visited by a service technician. The use of diagnostic models can avoid this. Based on the usage of the hydraulic system, such as in pitch adjustment activities, etc, and performance of cooling systems, the diagnostic model can calculate and predict the expected temperature, and well before the temperature limit is breached can detect anomalous behaviour. The service planners are advised of this, allowing them to schedule a technician to correct the anomaly during the next visit to the turbine, so that turbine failure and resulting downtime is avoided, shifting the emphasis from reactive service to proactive service, or unplanned service activities into planned service activities.

We currently operate more than 100 diagnostic models, covering nearly every system within a wind turbine. Each week more than 2500 anomaly detections are presented to experts, and, acting as the final verification filter, these experts issue more than 100 early warnings to service administrators, resulting in the clearing of hundreds of faults each month - faults that eventually could result in wind turbine failure.

"We currently operate more than 100 diagnostic models, covering nearly every system within a wind turbine"

Our knowledge base includes 1 300 000 diagnostic anomaly detections and we create over 5200 diagnostic-based work orders per year, increasing at around 30% per year due to increased diagnostic expertise and a growing fleet.

Large numbers of diagnostic models are always under development and we mature the models over months to make them as precise as possible and to limit the number of models in operation. With suitable development effort one model can generate diagnostic advice of several different types.

Our diagnostic efforts also produce valuable inputs to the development of new turbine and turbine component designs aimed at improving performance and reliability.

New diagnostics centre for wind turbines

Siemens recently broke ground on a new centre for its remote diagnostics activities, in Brande, Denmark. When it opens in late 2014, the centre will be one of the most advanced wind turbine diagnostic centres in the world, hosting advanced diagnostic operations and monitoring services for more than 7500 installed Siemens wind turbines worldwide.

Author notes

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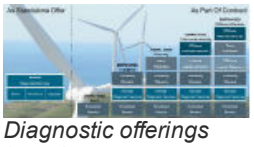
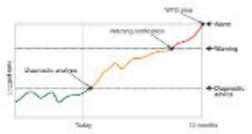
When turbines are far from shore access is difficult, which is why remote diagnostics are crucial to harvesting the full benefits of offshore wind

Evolution of diagnostic approaches

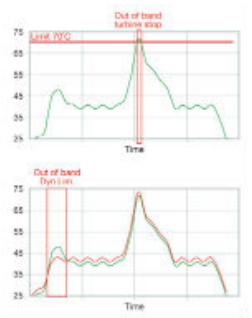
Characteristics of the three types of diagnostics



Diagnostic offerings from Siemens Wind Service



Logged data from a turbine vs time. Diagnostic models enable advice to be issued well before the turbine generates a warning or an alarm, allowing timely advance planning of appropriate service activities



Simplified example of a diagnostic model, in this case relating to

hydraulic oil temperature.

Siemens broke ground on a new diagnostics centre for wind turbines in January 2014 at the company's wind service headquarters in Brande, Denmark.

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