SCADA Data Provides Reasons for Failures in Wind Turbines

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A flexible and accurate tool that uses large amounts of SCADA data to obtain actionable information about impending component failures in wind turbines is being developed.

Major failures in wind turbines are often expensive to repair and cause loss of revenue due to long downtimes. With a downward spiral in electricity prices wind turbine owners and operators have started to focus more on methods to predict failures in order to reduce long downtimes and reactive maintenance.

Analysis of measurements, like vibration, has been successfully applied for early fault detection in mechanical components like a gearbox. However, these techniques are limited mostly to the rotating mechanical components in the wind turbine. The wind turbine Supervisory Control and Data Acquisition System (SCADA) records a large number of measurements which represent the current operating conditions in wind turbines. An intelligent analysis of these measurements can allow a fault in wind turbine components to be detected well in advance, so that expensive failures can be avoided by planning appropriate maintenance. However, to extract actionable information from the SCADA data is not a straight forward task. Wind turbines operate in highly variable operating conditions making it difficult to set a baseline behaviour pattern, which in turn makes it difficult to detect the points in time when the wind turbine deviates from its normal operation.

> *Mathematical modelling tool – ANN – accurately predicts failures in wind turbines.*

The renewable energy intelligence platform, Breeze, is developing a flexible and accurate tool to use the large amount of SCADA data to obtain actionable information about impending component failures in wind turbines. Development is in the early experimental phases. To predict failures a mathematical modelling tool called Artificial Neural Networks (ANN) is being used. ANN is a powerful method for modelling non-linear real world physical relationships. The ANN models have been proven to work with high accuracy in the Chalmers University of Technology doctorate program and are now being implemented into Breeze. This article strives to answer five questions:

- How does ANN modelling work?
- How good are ANN models?
- What is Breeze doing to improve the ANN method?
- Why should owners and operators of wind turbines be interested?
- Where does Breeze take ANN from here?

How does ANN modelling work?

ANN is based on how a human brain functions in terms of interaction with its immediate surrounding. For example – vision is one of the functions of the brain, wherein an image, input from the retina of the eye, is processed which lets us perceive, understand and interact with the object being visualised. All this processing takes a matter of milliseconds.

The brain comprises millions of neurons connected in a particular manner, the interaction of which in a specific sequence produce the desired results. These connections are established early in life through a learning procedure, commonly referred to as 'experience'.

The ANN models intend to mimic the structure of the brain in order to model real world non-linear systems. The main similarities between the brain and the ANN is the knowledge acquisition through experience or the learning process and the retention of knowledge with the inter-neuron connections called synaptic weights. Hence, ANN models are trained on data that represent a healthy condition in the wind turbines and the experience of these models is used to detect deviations from the healthy state.

How good are the ANN models?

ANN modelling has its fair share of issues which have been the reason for its limited application as a condition monitoring tool in the wind industry. Prior to implementing ANN into Breeze intensive studies have been performed, as a part of a four year PhD project, which focused on finding the critical issues that arise due to use of ANN models. Various methods were developed to overcome these issues and increase confidence in the output from ANN models.

What are we doing to improve the ANN method?

In order to provide accurate results the ANN models need high quality data from a healthy period of the wind turbine operation. Typical SCADA data is highly inconsistent due to communication interruptions, incorrectly recorded data and missing data due to maintenance activities. With the wind farm installed in Breeze the ANN model is ensured to have consistent data as input. On top of consistent data a robust filtering approach has been developed to make sure the ANN models are not trained on data that does not represent the healthy condition correctly.

In addition to the general filtering that removes data representing non-optimal operation, an advanced multi-dimensional data clustering approach is used to detect those data points, which seem to represent normal operation to the naked eye but should in fact not be characterised as normal operation. Furthermore, a third filter is used to ensure that continuous data is present while training the ANN model. *Figure 1* shows the output from the data filters, which represents the filtered data points.

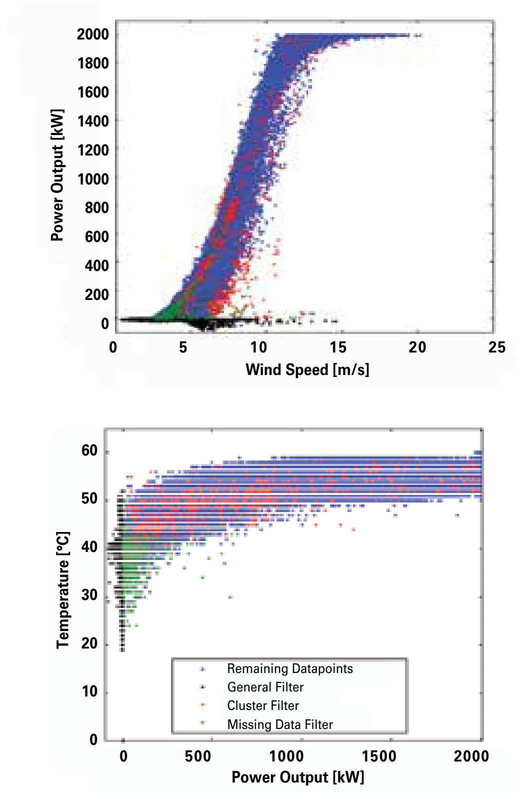

Figure 1: Output from data filters showing discarded data.

With consistent and filter data the next step is to select the correct input measurements for ANN modelling. Inputs are selected so that the model gives accurate results so that it is able to detect abnormal operation in the wind turbine. In order to ensure that the model detects failures at an early stage, the ANN model should have a good generalisation property. This aspect is often not given enough importance during the ANN modelling stage.

A large number of input parameters might improve the accuracy of the model output but might not be able to detect a failure. *Figure 2* shows the result of an incorrect choice of inputs. The ANN model provides accurate results as it is able to estimate the temperature of the gearbox bearing with very small error. However, the model also predicts the high temperature, which is abnormal operation for the said gearbox in the wind turbine. During the doctorate program various combinations of inputs were tested and the best configuration was chosen to provide accurate results and successful early fault detection.

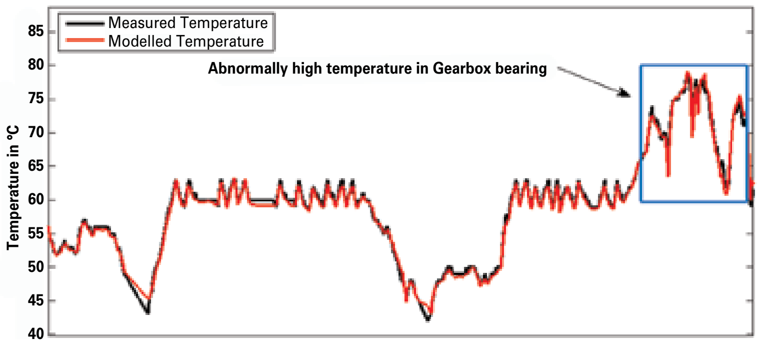

Figure 2: Overestimation from the ANN model due to incorrect input parameters.

Predictions using ANN models is an approach based solely on analysis of data and hence, there is no physics present in these models. This approach is called black box modelling, because the user provides input and gets an output based on statistical models in the black box that are often difficult to conceptualise. The Breeze approach to ANN takes cognisance of the computational capacity available in the Breeze platform infrastructure and the concepts of statistics to ensure that the anomaly detection from the ANN models is accurate and at an early stage. A unique approach using statistical measures is used to detect failures, where 99% accuracy is ensured in the estimation.

In addition to this the ANN is trained on a large number of models with the same data and take an average over all the models for an output. This eliminates the possibility of having an incorrect output from the ANN models due to randomness in the training process.

Why should you be interested?

The ANN based condition monitoring method has been tested, validated and improved over the past few years and with numerous real world case studies. It has been found to be effective and is able to detect faults as early as three months in advance. With the implementation into Breeze, the focus is on improving the methods further and providing accurate and actionable information about future failures in various components neatly packaged into the Breeze product available to any wind turbine owner.

Figure 3 shows the output from the ANN using SCADA data for a wind turbine with failure in the gearbox. The method is able to detect the fault two months in advance, whereas the vibration based condition monitoring system did not point to any failure.

This information is very valuable to owners and operators who seek to be prepared for a major maintenance in the wind turbine. In addition to this, information prior to the failure allows the opportunity to optimise the maintenance activity thereby reducing the maintenance cost.

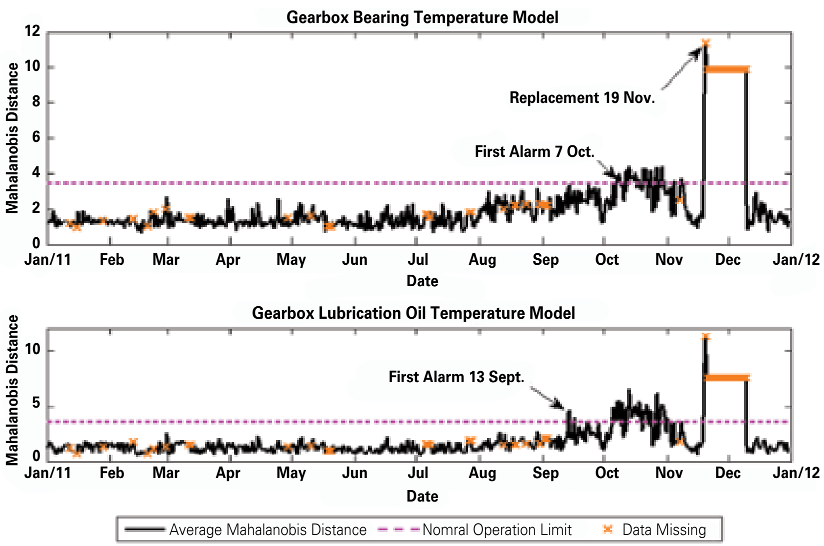

Figure 3: Output from a case study for condition monitoring using ANN models.

Where does Breeze take ANN from here?

The condition monitoring method using ANN has been tested and verified with 10-min average SCADA data in an academic environment applying the models to one wind turbine at a time. With the implementation into Breeze the ANN will be deployed to many thousand wind turbines and available for wind turbine owners and operators all over the world with the objective of increasing profitability for wind turbine owners.

Pramod Bangalore has a PhD in Electric Power Engineering (2016) from Chalmers University of Technology, Gothenburg, Sweden. His research had a focus on application of machine learning algorithms for condition monitoring of electrical and mechanical components. His experience includes working as a consultant in both oil and gas industry, and the renewable energy sector. In addition to his expertise in various machine learning algorithms, Pramod also specialises in statistical modelling methods, applied mathematical optimisation techniques and risk and reliability analysis. Currently, he is working as an Applications Expert at Greenbyte AB, in Gothenburg, Sweden.
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