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Vestas V90-3MW Wind Turbine Rotating Machinery Health Assessment using an Advanced Condition Monitoring System

Antonio Romero[1,2], Ángela Angulo[1], Slim Soua[1], Tat-Hean Gan[1, 2]

TWI Ltd[1], Cambridge, Cambridgeshire, CB21 6AL, United Kingdom
Brunel University[2], Kingston Lane, Uxbridge, Middlesex, UB8 3PH, United Kingdom

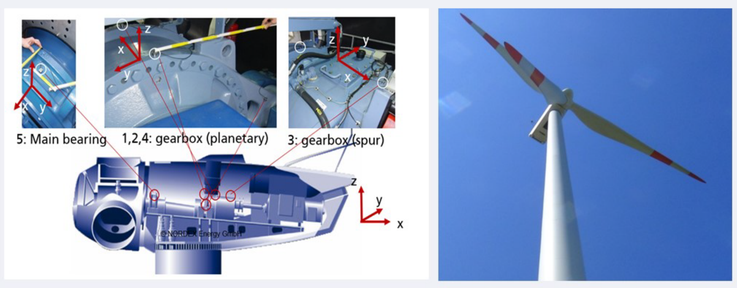
Introduction

Current wind turbine condition monitoring process can be time-consuming and costly. These systems fail to achieve the reliability and operational efficiency required by the industry. Existing reports on the monitoring of wind turbine data are restricted to a few historical cases. In order to overcome this issue, the development of a baseline data analysis method is proposed in this poster. For that, three techniques were integrated: Acoustic Emission (AE), Operational Modal Analysis (OMA) and Motor Current Signature Analysis (MCSA).

An Advanced Condition Monitoring System has been developed as part of the CMSWind FP7 Project, partly funded by the European Commission (Grant Agreement no. 286854), for the assessment of wind turbine rotating parts. CMSWind System enables prompt detection of changes in the machinery status. The validation of the CMSWind System was carried out during field trials at Bandirma Wind Energy Power Plant on a Vestas V90-3MW Wind Turbine.

Approach

The integrated Condition Monitoring System, which utilizes three new and novel techniques specifically designed for wind turbines and their components, will improve wind turbine machinery reliability. Motor Current Signature Analysis (MCSA), Operational Modal Analysis (OMA) and Acoustic Emission (AE) techniques were used for the development of a baseline that indicates the behaviour under normal operation of three different components: the generator, the drive train (including the gearbox) and high speed shaft respectively. Different signal processing methods were used to extract the wind turbine features depending on the monitoring technique. The features extracted during this initial period have been used to create a baseline (or signature) that defines the behaviour of the generator, gearbox and high speed shaft of the wind turbine under normal operation. A range of maximum and minimum values for these features have been calculated based on trends (average±standard deviation). Following on, each new set of data acquired is compared to the original baseline created during the initial stage. This gives the CMSWind System the capability of identifying deviations from a normal operation situation based on the Euclidean Distance dissimilarity.



CMSWind System applied on the Vestas V90 – 3MW drivetrain

Installation on Wind Turbine

The trials were performed at the Bandirma (Turkey) Wind Energy Power Plant where Borusan have wind turbines (Vestas V90 – 3MW). The installation was carried out in collaboration with Borusan and Vestas. The analysis of the data gathered during a period of three months is presented. The baseline was developed with the data collected during the first month. The data acquired during the following months is then compared to the mentioned baseline for a complete health assessment of the wind turbine drive train.

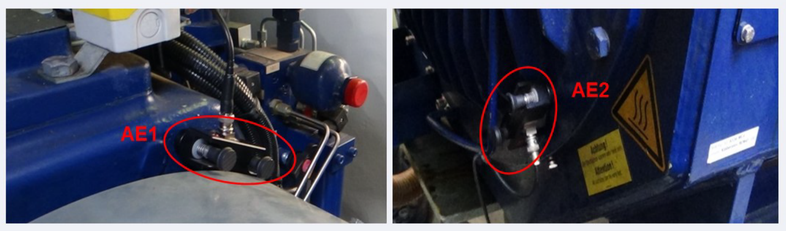
Installation of CMSWind System on the Nacelle

The data gathered by the system is sent via Ethernet cable to a laptop where the data is stored. A USB 3G Dongle is used to give remote access to the CMSWind System. 'Go To My PC' software gives access to the remote computer. This software is a powerful tool for flexible work which allows the user to perform daily checks on whether or not the software is running and that the data is being acquired correctly. It also enables the user to transfer files between the laptop in Turkey and the one where the post processing is going to be carried out.

Acoustic Emission

AE refers to the generation of transient elastic waves produced by a sudden redistribution of stress in a material. When a structure is subjected to an external stimulus (change in pressure, load, or temperature), localised sources trigger the release of energy, in the form of stress waves, which propagate to the surface and are recorded by sensors[1]. Studying AE does not require supplying energy to the object under examination; AE simply listens for the energy released by the object. The level of AE activity during multiple load cycles will form the signature development for the high speed shaft during the training process. Such activity (determined by feature extraction as well as in the previous methods) will be monitored at the later stage to determine the appearance of faults.

Two Acoustic Emission sensors were used to assess the condition of the wind turbine High Speed Shaft (HSS). The sensors were attached as closely as possible to the bearings. Acoustic Emission sensor 1 was attached using grease and a magnetic holder to the gearbox case close to the output bearing. Acoustic Emission 2 was attached following the same procedure, close to the main bearing located at the generator input. Signals coming from each sensor are gathered by two different cards. Signals gathered by AE1 are picked up by the card 00x20 whereas the ones coming from AE2 are picked up by the card 00x13.

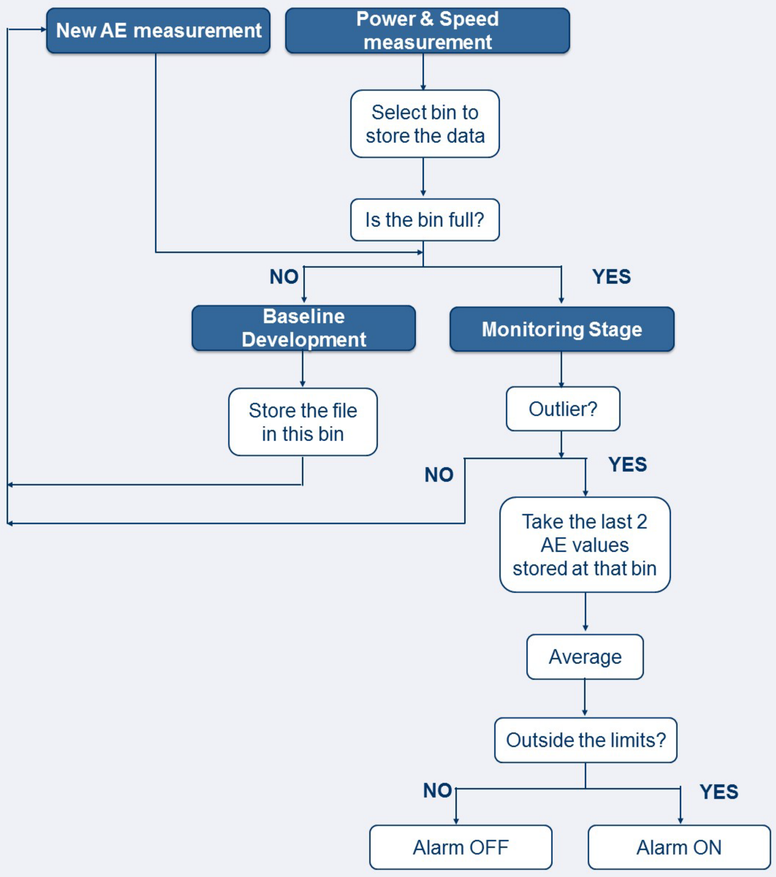


AE Sensors attached to the Vestas V90 High Speed Shaft

AE Automatic Alerts

The Acoustic Emission files generated will have a target value. When cracks appear this value increases and bursts show up in the waveform. The purpose of statistical signal processing with the CMSWind data is to produce a signal when the process mean has moved away from the target. A second purpose is to produce a signal when item to item variability has increased. In either case appropriate action must be taken by a machine operator or an engineer. Statistics can only give the signal; the action relies on other skills.

Setting the alarms based on statistics enables all alarm levels on a complex machine, such a wind turbine with many transducers, to be calculated in seconds instead of taking many hours to view the data and set the levels manually. Thus, the monitoring process can be carried out more economically. Automation of the alarm setting process can greatly improve the efficiency of the monitoring process.

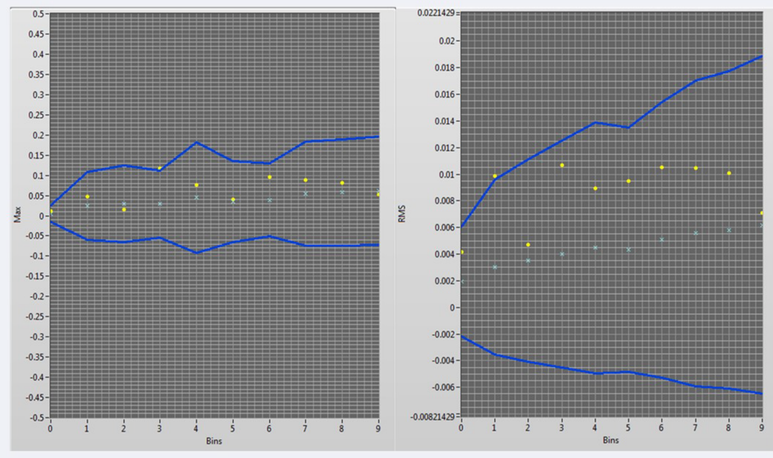


AE Automatic Alert strategy

AE Results

The following environmental and operating parameters of the wind turbine were available for data analysis: temperature, humidity, rain, wind speed, wind vane, generator rpm, electric power, pitch value and nacelle position.

Wind turbine data were continuously acquired and synchronized with the vibrational data by time stamps. A mean value of the wind turbine was calculated and environmental data for each corresponding measurement interval of AE data. These mean values represent the operational and environmental condition for the binning of the CMSWind AE-data. The most interesting features for analysing AE parameters are RMS and Peak Value.



Monitoring of the RMS and Peak Value

Control chart outer limits were established according to the strategy described in the automatic alert flow chart. Applying that methodology to control charts suggests that fewer than 5% of all points should be beyond the upper and lower limit controls. If the system is 'in control', virtually no data points should be outside the limits. Machinery faults have not been notified by the operator to date.

The plots obtained at the monitoring stage also display the current status of the machinery for each power output range. This information is plotted with the yellow points whereas the baseline limits and the mean values establish at the initial stage are plotted in blue and light blue respectively.

Conclusions

Since monitoring data for wind turbines is scarce, an approach consisting on the development of a baseline is presented. The following points can be concluded for the application:

- The AE module of the CMSWind System was validated in the present study using real data gathered from an operating 3MW WT in Turkey (Bandirma Wind Energy Power Plant).
- The software output can be regarded as the baseline feature of the measured AE signals. Any significant deviation of practically measured AE and vibration signal features from the baseline can be explained as due to abnormality inside turbine components and/or system.
- The RMS and Peak Value of the AE measurements were used for the establishment of the baseline model.
- The analysis of the real data collected from the wind turbine was processed for three different numbers of files per bin.
- The baseline generation process is sensitive to changes in the number of files used. The higher the number of files, the more accurate the limits are, reducing the number of false alarms.

Acknowledgement

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References

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