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Technical note

Determination of the combined vibrational and acoustic emission signature of a wind turbine gearbox and generator shaft in service as a pre-requisite for effective condition monitoring

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ABSTRACT

A review of current progress in Condition Monitoring (CM) of wind turbine gearboxes and generators is presented, as an input to the design of a new continuous CM system with automated warnings based on a combination of vibrational and Acoustic Emission (AE) analysis. For wind turbines, existing reportage on vibrational monitoring is restricted to a few case histories whilst data on AE is even scarcer. In contrast, this paper presents combined vibration and AE monitoring performed over a continuous period of 5 days on a wind turbine. The vibrational and AE signatures for a healthy wind turbine gearbox and generator were obtained as a function of wind speed and turbine power, for the full normal range of these operational variables. i.e. 5–25 m/s and 0–300 kW respectively. The signatures have been determined as a vital pre-requisite for the identification of abnormal signatures attributable to shaft and gearbox defects. Worst-case standard deviations have been calculated for the sensor data. These standard deviations determine the minimum defect signal that could be detected within the defined time interval without false alarms in an automated warning system.

1. Introduction

2.3% of the world's electric power supply is provided by wind farms. Rapid increases in the construction of wind power farms are taking place worldwide, in the highest proposed growth scenario it is estimated that by 2020 wind power could supply 2.600 TWh, about 11.5–12.3% of global electricity supply, rising to 21.8% by 2030 [1–3]. It is expected that with this new technology structural problems will arise in wind turbine operation that will require vigilance in maintenance activities, especially with the introduction of increasingly large turbines. There is naturally much current interest in the CM of wind turbines and the CM approaches [4–7].

A useful perspective on the importance of effective wind turbine CM is provided from a concise life cycle wind energy costing in a report by the National Wind Coordinating Committee (NWCC) [8,9]. Amortisation of the capital cost over 20–30 years results in a cost per annum of 70% and of the total annual costs with operation and maintenance (O&M) accounting for 30%. The O&M costs divide into unscheduled maintenance costs caused by unexpected component failure (16%), scheduled maintenance (4.1%) major scheduled overhaul (0.92%) and other operating costs (8.9%). The maintenance costs thus account for 21% of the total power annum costs and the unscheduled maintenance accounts account for 75% of these costs. This result should be interpreted as a life cycle average and there will be lower than average unscheduled costs in some years and higher in others. It is estimated that the replacement of components in planned repairs during scheduled maintenance downtime costs only 43% of the cost of repairs on failure [10].

The approach taken in this work is to combine Accelerometers and AE sensors data, a method that has never been reported before for wind turbine [11–13]. Jointly these sensors can detect the entire spectrum of vibrational frequencies that are likely to be generated in the operation of a wind turbine gearbox and the generator slip ring.

2. Monitoring of wind turbine gearboxes: case histories

For the numerous components in a wind turbine Fig. 1 shows the malfunction rate as a percentage of the total number of malfunctions [14–16] and the corresponding downtime as a percentage of the total downtime [13]. This data shows that whilst the turbine gearbox, generator and main shaft/bearing and gearbox account for only 10% of the malfunctions they result in 53% of the total downtime.

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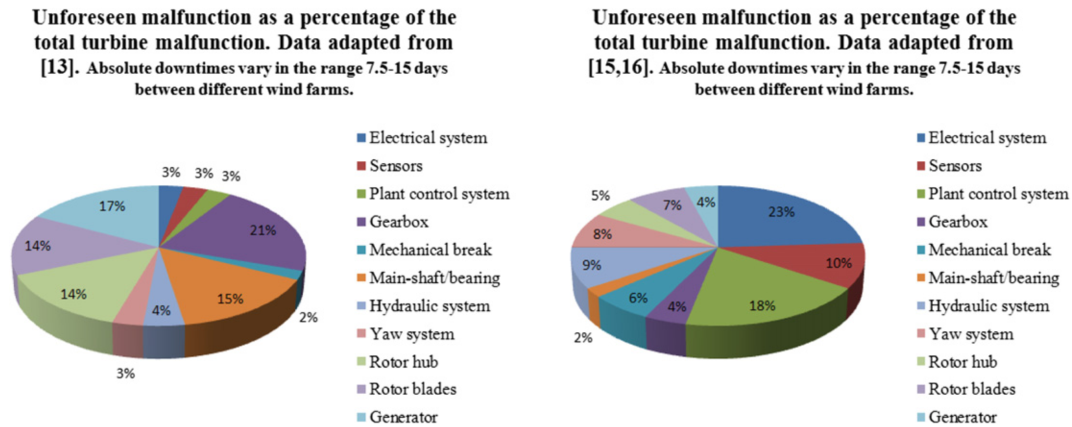

Fig. 1. Wind turbines malfunction incidents and downtime.

3. Data acquisition

The CM system developed in this work is required to be capable of distinguishing different deterioration modes and of providing data from which estimation of the time to failure can be evaluated. The 300 kW wind turbine dedicated to the testing was provided by Sinclair Knight Merz (SKM) for the BearInspect project [7]. As reported by SKM the rotational speed range of shafts in the 300 kW windmaster (Fig. 1) provided for the test is up to 1500 rpm.

3.1. Accelerometer and AE sensors

The location of the sensors and the data acquisition equipment on the wind turbine are shown in Fig. 2, Fig. 3a and b. Accelerometer No 1 and AE sensor No 1 located on the gearbox casing whilst accelerometer No 2 and AE sensor No 2 are located on the generator casing near the high-speed shaft, which transmits mechanical power into electrical power. The accelerometers (Sensonics Model P293-48H002) had output sensitivities of 100 Mv/g over 0.4 Hz −11 kHz to better than 3 dB, and the AE Sensors (Vallen Model VS900-RIC) had sensitivities exceeding 100 μV/μbar over the range 100 kHz–950 kHz, with a peak 22 dB higher at 350 kHz.

3.2. Wind speed and power measurements

The principal operation is based on the timeline shown in Fig. 4. A wind speed/power measuring Logger is given a trigger to start collecting data. Therefore, the wind speed data was initially separated and according to the modulated wave signal, the wind speed was determined. The current wind speed was compared against a table representing the bins and the number of data per bins collected from a minimum of 5 m/s to a maximum of 29.9 m/s.

4. Overview of the current data acquisition

4.1. The power versus wind speed

The operation of the CM process has resulted in 813 files (32Gbytes). The files were acquired during an overall measurement period of 5 days. The 813 files were distributed into 61 5 kW wide

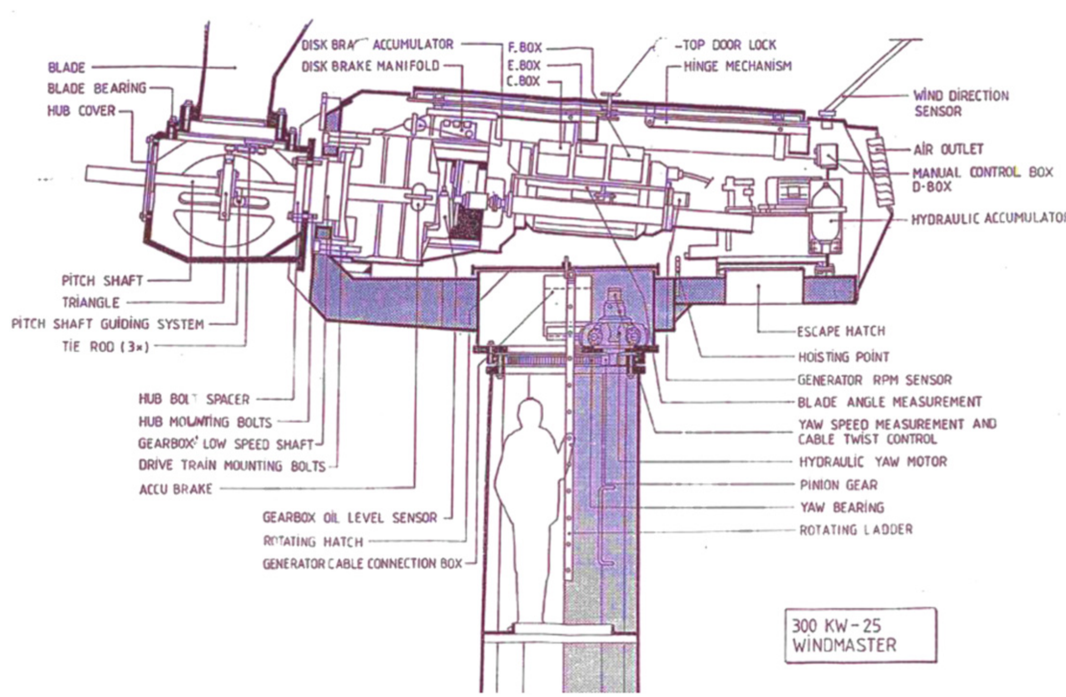

Fig. 2. Sketch of the entire wind turbine.