

Condition Monitoring of Wind Turbines

Christopher J Crabtree ¹⁾, Peter J Tavner ¹⁾

¹⁾ Durham University School of Engineering and Computer Sciences, UK

ABSTRACT

Condition monitoring (CM) of wind turbines (WT) is assuming greater importance as the installed capacity of wind turbines increases. This paper briefly describes a test rig for the development of CM techniques for WTs. The test rig includes features of a WT including its variable speed and torque nature, a simple gearbox, induction generator and grid connection. 'Fault-like perturbations' are applied to the rig and signals recorded and analysed. This paper gives an example of fault detection in the three phase power signal by tracking fault frequencies using a wavelet energy tracking method.

KEYWORDS

Condition monitoring, drive train, power signal,

1 INTRODUCTION

WTs are fast becoming one of the major sources of renewable energy in the UK with over 3.7GW currently installed on UK networks [1]. The move to offshore development is primarily a result of increased wind speeds, lower turbulence levels and the resulting higher capacity factor. However, these benefits lead to harsher operating conditions and a need for improved monitoring and maintenance strategies. Tavner et al. [2] have demonstrated that failures in the drive train result in large downtimes and high costs. This research aims to further the understanding of CM of WTs through the development of a test rig and the application of signal processing techniques. CM of rotating machines is well understood for large, high speed rotating machines but has not been widely investigated for wind turbines with low speed shafts and highly dynamic variations in torque and speed. The test rig allows repeatable driving conditions to be applied to the drive train. The research investigates the possibility of using the generator three phase power signal as an available and global source of drive train information.

2 CONDITION MONITORING TEST RIG

2.1 Drive Train Layout

The test rig consists of a 30kW wound rotor induction generator being driven through a two-stage gearbox by a 54kW DC motor. The driving conditions are controlled by a LabVIEW control environment which also acts as a data acquisition system sampling at 5kHz. The test rig is shown in figure 1. The test rig is fitted with two tachometers, an accelerometer on the gearbox or generator and a torque transducer and x-y displacement sensors on the high speed shaft.

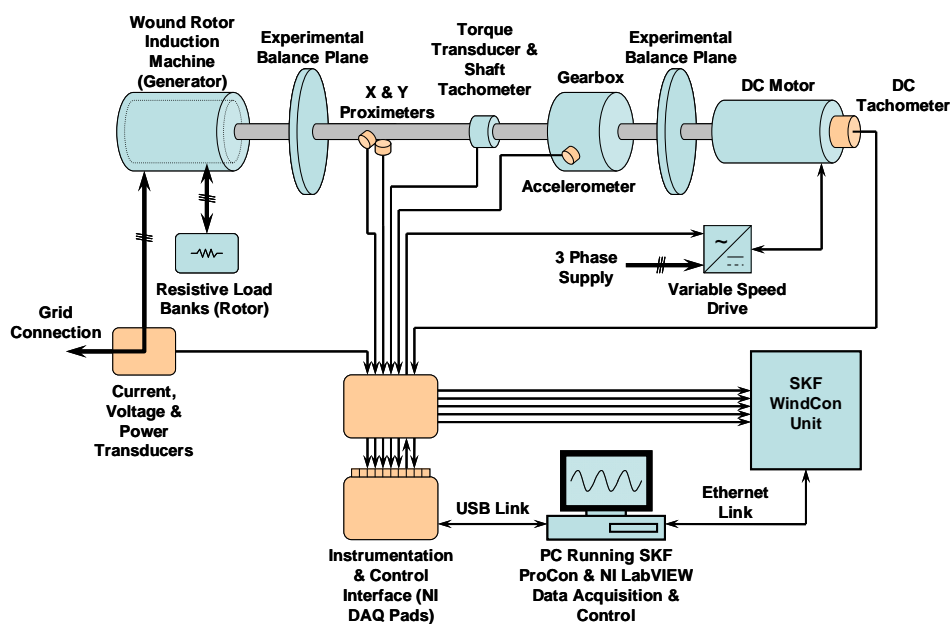


Figure 1: Durham University Condition Monitoring Test Rig

The rig is also fitted with current and voltage transducers allowing for the calculation and frequency analysis of the instantaneous three phase power signal. Resistive load banks on the rotor circuit allow electrical asymmetry to be applied to the generator and experimental balance planes are mounted on the low and high speed shafts to emulate mass unbalance.

2.2 Driving Conditions

A WT drive train is subject to highly dynamic speed and torque changes and it is important that any CM technique is capable of dealing with these. The test rig is driven using data from a detailed 2MW turbine model developed at the University of Strathclyde as part of the SuperGen Wind Energy Technologies Consortium at two mean wind speeds, 7.5m/s and 15m/s, and two levels of turbulence, 6% and 20%, representative of normal and turbulent conditions offshore. An example of the 7.5m/s, 20% turbulence driving condition is given in figure 2. It can be seen that the resulting three phase power and shaft torque signals feature highly variable amplitudes over time.

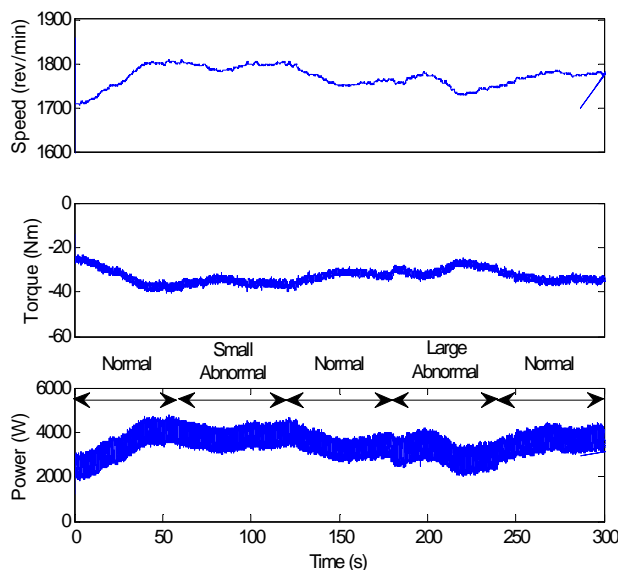


Figure 2: Example speed, torque and three phase power measurements taken from the Durham University test rig under fault testing

3 EXAMPLE RESULTS

3.1 *Electrical Asymmetry of the Generator Rotor*

To demonstrate the variable nature of monitoring signals the test rig was driven under wind driving conditions and asymmetry applied periodically as shown in figure 3 with different severities. The signals recorded from this test are shown in figure 2.

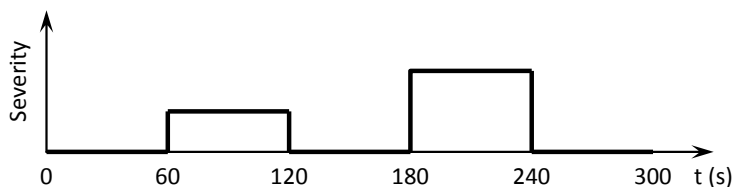


Figure 3: Electrical asymmetry applied to the generator rotor

It can be seen from figure 2 that the variable level of three phase power has masked any clear change as a result of the fault being applied and so it is necessary to track a known fault-related frequency. In this case the frequency twice slip frequency ($2sf_{se}$) was tracked as this is characteristic of an electrical asymmetry and its frequency is shown in figure 4. Using an energy tracking method based on the wavelet transform [3] developed at Durham University we can extract the energy in this frequency and this is shown in figure 5. It can be seen that the small asymmetry applied in the period 60-120s is not easily detectable however the larger asymmetry applied in the period 180-240s is clearly visible in the result.

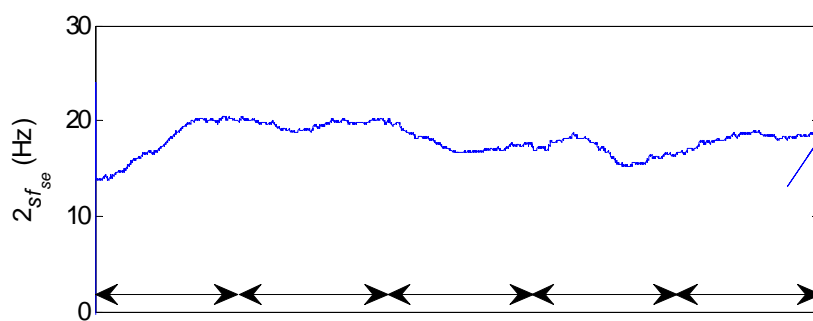


Figure 4: Value of frequency $2sf_{se}$ being tracked

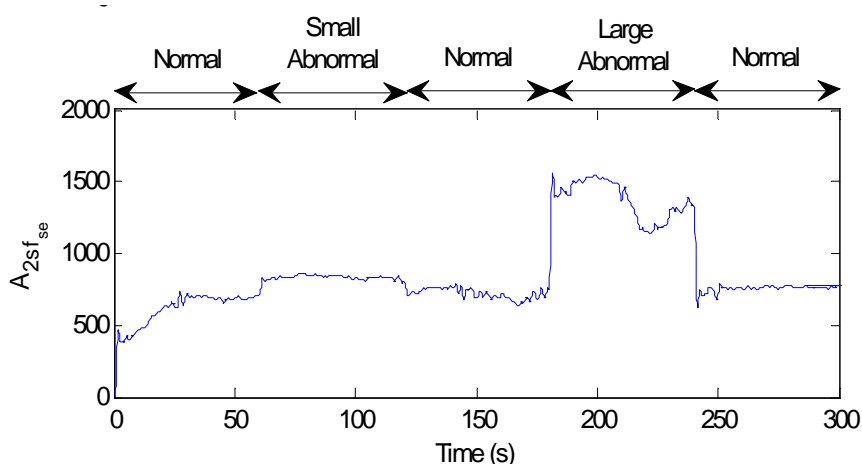


Figure 5: Energy in the frequency $2sf_{se}$ extracted using the wavelet transform

4 CONCLUSIONS

It can be seen that condition monitoring of wind turbines will play an important role in improving the reliability of the technology and that techniques will need to be developed to deal with highly dynamic signals being generated in the turbine drive train. This work has demonstrated that faults are detectable in the electrical power signal without the need for complex and expensive transducers.

Future work will aim to detect a greater range of fault conditions and to improve the quality of detection algorithms with the aid of the test rig.

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