Wind Turbine Doubly-Fed Induction Generator Condition Monitoring – A Case Study

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Abstract
Operation & Maintenance (O&M) activities of wind turbines represent between 25-35% of the total expenditure of a wind farm project, where Condition Monitoring (CM) has recently been acknowledged as the key to improve them. The induction generator is one of the major contributors to failure rates and downtime of wind turbines, together with the gearbox and the drive train system, where doubly-fed induction generators (DFIG) are the dominant technology employed for variable speed wind turbines. In the present work, current signature analysis has been applied on an in-service induction generator and a diagnosis achieved.

Keywords: *Operation & Maintenance, Condition Monitoring, Doubly-Fed Induction Generator*

Introduction
More modern and larger wind turbine generators are under continuous development [1]. These exhibit more faults when compared to smaller ones [2], which becomes critical offshore [3]. Under this framework, operation and maintenance (O&M) is key to improve reliability and availability of wind turbines [4].

There are three common types of maintenance strategies: preventive, corrective and predictive [5]. New trends are moving from the first two towards predictive maintenance, where CM determines the ideal balance between preventive and corrective actions [6], improving reliability and availability while reducing costs [7].

Approach
Electrically-based condition monitoring techniques include: current, voltage, instantaneous power and flux analysis, where stator current analysis is the most common of these techniques. It is based on the principle that each fault has its own effect on the current spectra. Several signal processing methods can be applied to electrically-based techniques towards fault identification, typically classified into time-domain, frequency-domain and time-frequency [8].

In the present work, frequency-domain analysis will be applied on a real operating DFIG wind turbine via Fast Fourier Transform (FFT). This technique transforms the waveform signal from the time domain to the frequency domain. It is widely used for fault diagnosis because the variations of certain harmonic components in the frequency spectrum of a signal can be related to a specific fault type [9].

Case Study
Actual data from operating wind turbines is seldom presented. Much work has been published on modelled data, simulations and laboratory benches [10],[11] but there is a lack of field measurement campaigns for current signature analysis. In the present work, current signature analysis has been applied to an in-service DFIG wind turbine with potential gearbox faults.

The formulae used to calculate the fault frequency components related to gearbox faults and rotor unbalance through spectral analysis are presented in Table 1, including the frequency components obtained for the present case study.

Fault	Formula	Calculated frequencies		
Gearbox	$f_{gb} = f_s \pm m\left(\frac{f_s}{n(^p/_2)}\right)$	48.98 50.99	48.47 51.50	47.46 52.51
Rotor Unbalance	$f_{HRU} = f_s\|6k(1-s)+l\|$	280 310	380 410	
	$f_{FRU} = f_s\left\|\frac{k}{p}(1-s)+l\right\|$	31.65 68.33		

Table 1. Fault frequency components.

The reported wind turbine is equipped with a doubly-fed induction generator of 1,5 MW rated power, 3 pole pairs, 50 Hz supply frequency (Europe). A test case with the wind turbine at 90% of its rated nominal power operating at super-synchronous speed with 10% slip has been chosen to illustrate the study. The current spectra of the DFIG at the mentioned operating conditions is presented in Figure 1 (lower and higher frequencies respectively).

The peaks calculated as per Table 1 and found in the spectra have been marked and identified (Figure 1). Those peaks that naturally exist in the spectra and do not necessarily indicate the presence of fault are marked in black, whereas potential fault indicators are represented in red.

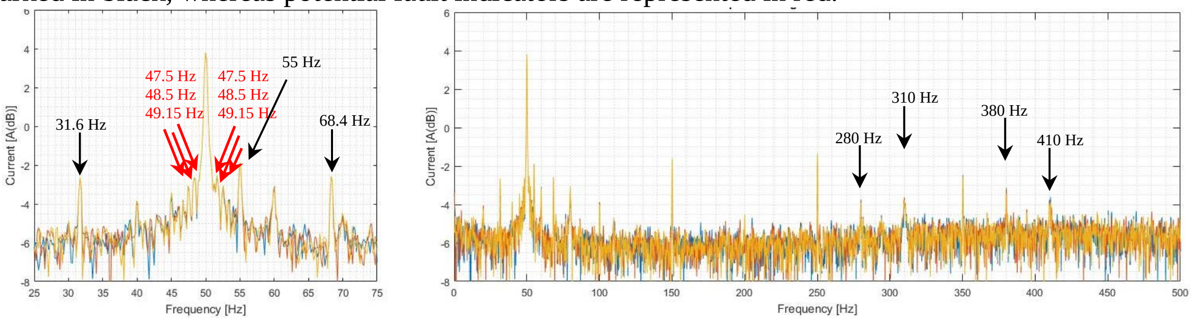

Figure 1. Current spectra – detail low frequencies (left) and high frequencies (right).

Conclusions

The motivation behind the present work is to optimise O&M activities via condition monitoring with the ultimate goal of increasing reliability and availability of wind turbines.

The basic formulae of current signature analysis and its application on DFIGs have been presented, including a case study based on real data from an operating wind turbine. Faulty components related with gearbox, as well as healthy ones, have been identified on the spectral analysis of the DFIG under study.

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