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Fault Size Estimation Using Vibration Signatures in a Wind Turbine Test-Rig

Sailendu Biswal, Jithin Donny George, G.R Sabareesh*

Department of Mechanical Engineering, BITS-Pilani Hyderabad Campus, Hyderabad,500078,India

Abstract

Fault size evaluation has become more significant in recent years to determine the fault size or the severity of fault apart from the fault detection for prediction of remaining useful life. The present investigation focuses on the fault size estimation of gear root crack in a wind turbine test rig using vibration signatures. A wind turbine test rig was developed at BITS-Pilani, Hyderabad Campus to simulate the working of a wind turbine. Time domain vibration signals are acquired using accelerometers for the healthy as well as faulty components. Discrete Wavelet Transform of vibration signature is performed and features are extracted from the statistical analysis of wavelet coefficients and the extracted features are used as inputs in an ANN (Artificial Neural Network) to effectively predict the size of gear root crack.

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Keywords: Wind Turbine, Vibration Signature, Discrete Wavelet Transform, Fault Size Estimation, ANN

1. Introduction

Wind power has come up as an emerging source of renewable energy and it's expected to amount to 25% of world's total energy by 2035.However, the operating and maintenance cost of wind turbine is estimated to be 20-35% of the total power generation cost during its lifetime. Condition Based Maintenance (CBM) has become more significant in wind turbine health monitoring due to its convincing ability to reduce Life Cycle Cost (LCC). Predictive maintenance of critical components of wind turbine such as gearbox , bearings, shaft has become matter

* Corresponding author. Tel.: +91-8185919590; fax: +91-40-66303655.
E-mail address: sabareesh@hyderabad.bits-pilani.ac.in

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of concern as unscheduled maintenance cost of these components will be significantly larger than the scheduled maintenance cost [1].The wind turbine gearbox is vulnerable towards failure due to high amount of load, low speed and both fluctuating speed and load[2].The critical components used in wind turbine gearbox is often susceptible to catastrophic failure due to development of localized faults .Gear faults such as wear ,misalignment etc. can be categorised as distributed fault whereas pitting ,chipping, crack etc. are categorized as local faults[3]. Local faults or cracks of varying sizes often occur in gears of wind turbine. Nature of fault as well as its intensity is characterized by the depth and width of these cracks. However it has become more significant to determine the fault size or the severity of fault apart from the fault detection for prediction of remaining useful life[4].

Signal processing of raw vibration data obtained from critical component has been a crucial factor in successful fault detection as well as in fault size estimation. Many research and investigations has been made for fault detection in gears as they are considered as one of the vital component in a wind turbine, automotive or other rotating machineries for power transmission. The fault detection becomes a challenging affair in a wind turbine gearbox due to presence of multi stage of gears and the fault features are covered up by background random noise and vibration [2].

The time domain analysis technique such as time synchronous averaging (TSA) technique was implemented [5-7] for gearbox fault diagnostics due to its ability to diminish the effects of vibration signal which are not synchronous to the shaft and gear mesh frequencies and at the same time can amplify required part of signal over the noise. Statistical parameters such as skewness, kurtosis, root mean square (rms) value, crest factor, shape factor, clearance factor, impulse factor etc. has been used for fault detection and fault severity prediction [3, 8].Apart from earlier mentioned statistical parameters some special statistical parameters which includes FM0,FM4,NA4,NB4,M6A etc. has become advantageous particularly for gear fault detection[3, 4, 7]. Frequency domain analysis such as cepstral analysis [9] and spectrum analysis [10] has been effectively implemented for gear fault detection. Frequency domain features such as energy ratio, energy operator, mean frequency, frequency centre, root mean square frequency, standard deviation frequency was used along with other time domain features for fault level estimation[3, 11]. Vibration signal obtained from a gear having local fault contains amplitude and phase modulation. Faulty teeth of a gear often gives rise to sidebands which results from modulation of gear meshing frequency. Sidebands occur around a central frequency and it spreads over a wide frequency range due to its short time period of impact. The central frequency is also known as carrier frequency. The sideband is the region of importance containing local fault features, thus a properly chosen narrow band spectrum analyser could be very useful for fault detection[12]. However recent fault detection techniques for wind turbine gear box fault detection gives a preference for time frequency analysis. Vibration signatures obtained from wind turbine gear box used to be nonstationary. The time frequency analysis is desirable for nonstationary signal analysis[13].The time frequency analysis techniques such as time-frequency demodulation [14],Wigner-Ville Distribution(WVD) [13], Empirical Mode Decomposition(EMD) [15],wavelet analysis[13, 16-20],Hilbert –Huang Transform[21, 22] etc. has been utilized for fault detection in gear. However, wavelet transformation is found to be a better time frequency analysis technique practised for nonstationary vibration signals from wind turbine. Fault diagnosis in wind turbine was performed based on Morlet wavelet transformation [13, 23] and multiwavelet denoising [24].

The fault diagnosis and fault size estimation of wind turbine components is a matter of great concern in order to provide an effective maintenance solution as well as it helps in reducing the overall operating and maintenance cost. The time frequency analysis of vibration signature is often accomplished by performing feature extraction [25], followed by feature classification. Artificial intelligent methods based on Artificial Neural Network (ANN)[26],Support Vector Machine(SVM) [8, 27, 28],Immune Genetic Algorithm(IGA)[29]etc. were successfully implemented for feature classification in wind turbine fault diagnosis.

This paper discusses the fault size estimation for a gear root crack in a wind turbine test rig using Discrete Wavelet Transform (DWT) and Artificial Neural Network (ANN).

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