THE UNIVERSITY OF ADELAIDE AUSTRALIA

Investigation of Single and Multiple Faults Under Varying Load Conditions Using Multiple Sensor Types to Improve Condition Monitoring of Induction Machines

PhD Thesis

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Abstract

Condition monitoring involves taking measurements on an induction motor while it is operating in order to detect faults. For this purpose normally a single sensor type, for example current is used to detect broken rotor bar using fault frequency components only under the full-load condition or a limited number of load cases. The correlations among the different types of sensors and their ability to diagnose single and multiple faults over a wide range of loads have not been the focused in previous research.

Furthermore, to detect different faults in machines using any fault frequency components, it is important to investigate the variability in its amplitude to other effects apart from fault severity and load. This area has also often been neglected in the literature on condition monitoring.

The stator current and axial flux have been widely used as suitable sensors for detecting different faults i.e. broken rotor bar and eccentricity faults in motors. Apart from detecting the broken rotor bar faults in generalized form, the use of instantaneous power signal has often been neglected in the literature condition monitoring.

This thesis aims to improve machine condition monitoring and includes accurate and reliable detection of single and multiple faults (faults in the presence of other faults) in induction machines over a wide range of loads of rated output by using current, flux and instantaneous power as the best diagnostic medium.

The research presents the following specific tasks:

A comprehensive real database from non–invasive sensor measurements, i.e. vibration measurements, axial flux, 3-phase voltage, 3-phase current and speed measurements of induction motor is obtained by using laboratory testing on a large set of identical motors with different single and multiple faults. Means for introducing these faults of varying severity have been developed for this study.

The collected data from the studied machines has been analysed using a custom-written analysis programme to detect the severity of different faults in the machines. This helps to improve the accuracy and reliability in detecting of single and multiple faults in motors using fault frequency components from current, axial flux and instantaneous power spectra.

This research emphasises the importance of instantaneous power as a medium of detecting different single and multiple faults in induction motor under varying load conditions. This enables the possibility of obtaining accurate and reliable diagnostic medium to detect different faults existing in machines, which is vital in providing a new direction for future studies into condition monitoring.

Another feature of this report is to check the variability in healthy motors due to: test repeatability, difference between nominally identical motors, and differences between the phases of the same motor. This has been achieved by conducting extensive series of laboratory tests to examine fault frequency amplitudes versus fault severity, load, and other factors such as test repeatability and machine phases.

The information about the variations in the amplitudes of the fault frequency components is used to check the accuracy and reliability of the experimental set-up, which is necessary for the practical application of the results to reliably detect the different faults in the machines reliably.

Finally, this study also considers the detection of eccentricity faults using fault frequency amplitudes as a function of average eccentricity, instead of as a function of load under different levels of loading. This has not been reported in previous studies.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in University Library, being made available for photocopy and loan subject to the provisions of the Copyright Act 1968

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Symbols and Abbreviations

$\mathbf{f_1}$	fundamental frequency
$\mathbf{f_2}$	slip frequency
$\mathbf{f_r}$	rotor frequency
$\mathbf{N_s}$	synchronous speed
$\mathbf{N_r}$	rotor speed
T	total sampling time
$\mathbf{\Delta t}$	sampling time
$\mathbf{\Delta f}$	sampling frequency
$\mathbf{L_R}$	total points of record length
s	slip of motor
V	voltage
I	current
p	number of pair of poles
$\mathbf{P_i}$	total active power in three-phase system
PF	power factor
P_{ins}	instantaneous power
k	number of integers
$\mathbf{f_{BRB}}$	broker rotor bar frequencies
$\mathbf{f_p}$	supply frequency from power signal
Ir	rated current of motor
Vr	rated voltage of motor
fecc	eccentricity fault frequency
R	number of rotor bars
CM	condition monitoring
BRB	broken rotor bar
FT	Fourier transform
STFT	short time Fourier transform
DE	driving end
NDE	non-driving end
DEH	driving end horizontal
DEV	driving end vertical