Detailed Investigation of Negative Sequence Current Compensation Technique for Stator Shorted Turn Fault Detection of Induction Motors

by

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Thesis submitted for the degree of

Doctor of Philosophy

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The University of Adelaide
Australia

March 2013

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Contents

Abstract

Online condition monitoring is preferred specifically in critical induction machines for timely analysis of their health and to predict any incipient failures. Negative sequence current monitoring is one of the well-known condition monitoring applications that capable of identifying stator faults in induction motor as well as producing fast and reliable results using a simple measurement technique. However, the technique is sensitive to asymmetrical sources of negative sequence, not only due to motor faults but also due to the disturbances such as sensor calibration, inherent non-idealities (such as inherent machine asymmetries), external effects (such as load change and supply voltage unbalances).

This thesis addresses the limitations in shorted turn fault detection while considering real system disturbances and non-linearities using a dynamic motor model which is also verified by the experimental studies. The thesis provides a comprehensive investigation of various negative sequence contributors such as measurement asymmetry, inherent asymmetry, voltage unbalance, shorted turn faults, eccentricity and broken rotor bar faults under load variations, and presents practical results. To allow accurate shorted turn fault detection, this thesis also provides an effective phasor compensation technique for these disturbances. A new detailed compensation by demonstrating step-by-step disturbance extraction to obtain the real negative sequence current due to shorted turn faults are also presented. It is demonstrated that this technique allows even a single stator shorted turn faults to be detected as well as successfully eliminating the effect of inherent asymmetry and voltage unbalances under motor load variations.

Declaration

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Acknowledgement

Firstly, I wish to express sincere gratitude to my principal supervisor Associate Professor Dr. Nesimi Ertugrul for his guidance, inspiration, motivation, support and knowledge during my research. He encourages my study since the beginning, from the PhD application processes until end of my study. He also gives essential support to obtain scholarship for my PhD.

I would like to thank to Associate Professor Dr. Wen L. Soong for the inspiration, guidance, discussion and suggestion that have enriched this project. He also provide valuable support for me to deal with my family related problem.

I also wish to thank Prof Muslum Arkan for the discussion and motor model development.

I am thankful Dr. Said Al Sarawi and Dr. Brian Ng for the inspiration during my research.

I would like also to thank all the technical staff for their help and assistance during my research in power laboratory.

I would like to thank and acknowledge Ms Ann Nobel for the editorial assistance during my thesis writing.

I am grateful to every member of the School of Electrical and Electronic Engineering, and staff of University of Adelaide Graduate Centre, who has helped me during my stay here.

Thanks to my family, my beloved wife, and my children, for their love, support, patience, encouragement, and understanding during my studies. Thanks also to my relatives in Indonesia for supporting me throughout my study.

Syaiful Bakhri

March 2013

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List of Abbreviations

AI	Artificial Intelligence
BF	Butterworth filter
COT	Continual On-line training
CUR	Current Unbalance Ratio
DAQ	Data Acquisition System
DC	Direct Current
DFT	Discrete Fourier Transform
DMRM	Dynamic Mesh Reluctance Modelling
FEM	Finite Element Method
FFT	Fast Fourier Transform
HP	High-pass filter
I	Integral
LF	Low-pass filter
MCCM	Multiple Couple Circuit Model
MEC	Magnetic Equivalent Circuit
MWFA	Modified Winding Function Approach
NEMA	National Electrical Manufacturers Association
PDT	Power Spectral Decomposition Technique
PI	Proportional-Integral
RSH	Rotor Slot Harmonics
PVUR	Phase Voltage Unbalance Ratio
QGMT	Quasi-Global Minimum Training
RMS	Root Mean Square
SOFM	Self Organizing Feature Map
VUF	Voltage Unbalance Factor
WFA	Winding Function Approach

List of Symbols

0, p, n	Subscript symbols for zero, positive, and negative sequence components
a, b, c	Subscript symbols for the quantities in *abc* three-phase system
α and β	Subscript symbols for the quantities in reference frame
av	Subscript symbol for average values
δ	delay angle
g	Subscript symbol for the air gap of motor
h	Operator for symmetrical components ($e^{j\frac{2\pi}{3}}$)
ia	Subscript symbols for inherent asymmetry
in	Subscript symbols for measurement asymmetry
i and *v*	Instantaneous current and voltage
i,v	Superfix symbols for current and voltage related
I, V, Z, Y	Magnitude values for current, voltage, impedance and admittance
I, V, Z, Y	Phasor values for current, voltage, impedance and admittance
I_m	Peak amplitude of the current signal
L, X	Magnitude value for inductance and reactance
m, s, l, v	Subscript symbols denoting motor, supply, load and voltage related *p*
p	Operator for *d/dt*
N or N_r N_s	Number of stator and rotor winding turns
ϕ	Phase angle
p, q	Instantaneous active and reactive powers
P, Q	Fundamental active and reactive powers
q, d	Subscript symbols for the vector quantities in *q-d* reference frame
ref	Subscript symbol for reference quantities
sf	Subscript symbol for shorted turn fault
sh	Subscript symbol for shorted turn
s, r	Subscripts symbols for the quantities of stator and rotor
T_s	Supply period quantities
T	3 to 2 transformation matrix
T	*S*ymbol for torque quantities
μ_0	Permeability of free space

ψ and λ	Flux linkages
ω_s ω_r	Angular synchronous and rotor speed
x, y	Real and imaginary part of phasor (or complex number)
f	Supply frequency
f	Rotation frequency