DETECTION AND ANALYSIS OF PERFORMANCE OF THREE PHASE INDUCTION MOTOR SUBJECTED TO DIFFERENT TYPES OF FAULTS

By

Emad Fathy Yassin Mahmoud

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In

ELECTRICAL POWER AND MACHINES ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis : "Detection and Analysis of Performance of Three Phase Induction Motor Subjected to Different Types of Faults"

Key Words: Induction motor- Stator inter turn fault - Broken bar fault- Fault detection - MCSA

Summary:

The main objective of this thesis is to study the performance of a 3-phase induction motor under faulty conditions. Broken bar rotor fault, the inter turn short circuit fault in the stator winding and mixed fault of the mentioned two types of faults are considered in details. The mathematical model is presented in healthy and faulty motor.

The MCSA is used to detect and diagnosis the fault. The simulation results done are compared with experimental results done in previous work. The error is acceptable if we take into account the simplifying assumptions in the derivation of the mathematical model and also the experimental errors normally evolved in the measurements.

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Finally, I present this work to **my Father**, God's mercy upon him, I ask Allah to make this work in his balance of his good deeds.

Table of Contents

Chapter Four

Simulation Results and Performance Analysis

List of Symbols

a	Effective turns ratio in healthy conditions
a_f	Effective turns ratio in broken bars fault conditions
B_m	Friction coefficient
F_s	Supply frequency
F_{us}	Upper side band frequency
F_{ls}	Lower side band frequency
F_{sb}	Side band frequencies related to fault occurrence
F_{ec}	Frequency components related to rotor eccentricity fault
F_{bf}	Frequency components related to bearing fault
F_v	The bearing characteristic vibration frequency.
g	Radial air gap length
J	Rotor moment of Inertia
I^s	Stator current vector
I^r	Rotor current vector
i_a^s	Current of stator phase a
i_n^r	The current of rotor loop number n
i_e	The end ring current
i_q^s	Quadrature axis stator current
i_d^s	Direct axis stator current
i_q^r	Quadrature axis rotor current
i_d^r	Direct axis rotor current
i_q^{sh}	Quadrature axis shorted winding current
$i_q^{s\prime}$	Quadrature axis un-shorted winding current
K_s	Transformation coefficient from ABC frame to d-q frame
K_c	Chording factor
K_d	Distribution factor
K_{sk}	Skewing factor
K_{ws}	Stator winding factor
K_{wr}	Rotor winding factor
l	The machine active length
L_b	Inductance of rotor bar
L_e	Inductance of portion of end ring
L_{kk}	Self-inductance of rotor loop
L_{ki}	Mutual inductance between rotor loop i and loop k ($i \neq k$)
L^{ss}	Stator inductances matrix in ABC frame
L^{rr}	Rotor inductances matrix in ABC frame
L^{sr}	Stator to rotor mutual inductance matrix
L_{abc}^{rr}	Rotor inductances matrix with equivalent 3-phase rotor in ABC frame
L_{abc}^{sr}	Stator to rotor mutual inductance matrix with equivalent 3-phase rotor
L_{asas}	Self-inductance of stator phase a
L_{asbs}	Mutual-inductance between stator phase a and stator phase b
L_{asar}	Mutual-inductance between stator phase a and rotor phase a
L_m	Stator magnetizing inductance

L_{ls}	Stator leakage inductance
L_{lr}	Rotor leakage inductance
L_{shsh}	Self-inductance of stator shorted turns
L'_{asas}	Self-inductance of stator un-shorted turns
L_{assh}	Mutual-inductance between stator phase a (un-shorted windings) and shorted turns
L_{shbs}	Mutual-inductance between stator phase b and shorted windings
L_{shar}	Mutual-inductance between rotor phase a and shorted windings
L_{qdo}^{ss}	Stator inductances matrix in d-q frame
L_{qdo}^{rr}	Rotor inductances matrix in d-q frame
L_{qdo}^{sr}	Stator to rotor mutual inductance matrix in d-q frame
L_q^s	Quadrature axis stator self-inductance
L_d^s	Direct axis Stator self-inductance
L_q^r	Quadrature axis rotor self-inductance
L_d^r	Direct axis rotor self-inductance
L_q^{sh}	Quadrature axis shorted winding self-inductance
L_d^{sr}	Direct axis stator to rotor mutual inductance
L_q^{ssh}	Quadrature axis stator to shorted winding mutual inductance
L_q^{shr}	Quadrature axis rotor to shorted winding mutual inductance
n	Number of rotor bars or loops.
N_a	Number of turns of phase a
N_r	Number of turns of rotor phase
N_s	Number of turns of a stator phase (assume symmetrical stator phases)
N_{sh}	Number of turns of shorted winding
N_f	Number of broken bars
$N_a(\theta_r, \emptyset)$	Winding function of stator phase a
$N_k(\theta_r, \emptyset)$	Winding function of rotor loop k
P	Motor Number of pair poles
p	$= \frac{d}{dt}$ Differential operator
r	The average air gap radius
r_{as}	The resistance of stator phase a
r_s	The resistance of any stator phase (assume symmetrical stator phases)
r_r	The resistance of any rotor phase (assume symmetrical rotor phases)
r_{sh}	Resistance of shorted windings
r_{ext}	External resistance
R_b	Bar resistance
R_e	End ring resistance
R^s	Stator resistance matrix
R^r	Rotor resistance matrix
R_{abc}^r	Rotor resistance matrix with equivalent 3-phase rotor
s	Rotor slip
T_{em}	The machine electromagnetic torque
V^s	Stator voltage vector in ABC frame
V^r	Rotor voltage vector in ABC frame

V_{abc}^{r}	Rotor voltage vector in ABC frame with equivalent 3-phase rotor
V_{qdo}^{s}	Stator voltage vector in d-q frame
V_{qdo}^{r}	Rotor voltage vector in d-q frame
V_{q}^{s}	Quadrature axis stator voltage
V_{d}^{s}	Direct axis stator voltage
V_{q}^{r}	Quadrature axis rotor voltage
V_{d}^{r}	Direct axis rotor voltage
ω_{m}	Mechanical angular velocity (rad/sec^2)
X	Stator inter-turn fault percentage %
μ_{o}	$= 4\pi * 10^{-7}$ H/m,The permeability of the free space
γ	Skewing angle of the rotor
α_{r}	The angle between any two healthy adjacent bars.
λ_{abc}^{s}	Stator flux linkages matrix
λ_{abc}^{r}	Rotor flux linkages matrix with equivalent 3-phase rotor
λ^{r}	Rotor flux linkages matrix
λ_{q}^{s}	Quadrature axis stator flux linkage
λ_{d}^{s}	Direct axis stator flux linkage
λ_{q}^{r}	Quadrature axis rotor flux linkage
λ_{d}^{r}	Direct axis rotor flux linkage

List of Abbreviations

EMF	Electromotive force
MMF	Magnetomotive force
MCSA	Motor Current Signature Analysis
WFT	Winding Function Theory
SCIM	Squirrel cage induction machine
ANN	Artificial Neural Network
D.O.L	Direct on-line
FL	Fuzzy Logic
FFT	Fast Fourier Transform
NEMA	National Electrical Manufacturers Association
IEC	International Electrotechnical Commission
EPRM	Electric Power Research Institute
IEEE	Institute of Electrical and Electronics Engineers

List of Figures