

LB/DON/78/07

DETECTION AND DIAGNOSIS OF STATOR INTER TURN SHORT CIRCUIT FAULT OF AN INDUCTION MACHINE

A dissertation submitted to the
Department of Electrical Engineering, University of Moratuwa
In partial fulfillment of the requirement for the
Degree of Master of Science

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

by



University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
J.A.D.S.RANJAN

Supervised by : Dr. J.P. Karunadasa
Dr. P.S.N. De Silva

621.3 "07"
621.3 (043)

**Department of Electrical Engineering
University of Moratuwa, Sri Lanka**

January 2007

87853

University of Moratuwa



87853

87853

Declaration

The work submitted in this thesis is the results of my own investigations, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.



J.A.D.S Ranjan

January 2007

We/I endorse the declaration by the candidate.

Dr. J.P. Karunadasa
Supervisor

UOM Verified Signature

Dr. P.S.N. De Silva
Supervisor

CONTENTS

Declaration	i
Abstract	iv
Acknowledgement	v
List of figures	vi
List of table	viii
1. Introduction	01
1.1 Introduction to Induction Motor failure.	01
1.2 Introduction to Fault Diagnosis	07
1.3 Introduction to Inter-turn Faults	10
1.4 Method of Inter-Turn fault detection	10
2. Literature survey	12
2.1 Method of Fault Detection	12
3. Inter- Turn fault detection by Negative Sequence Analysis (NSA)	17
3.1 Modeling of the inter –turn short circuit	17
3.2 Magnetic modeling of generalized concentrated winding	18
3.3 Inter –Turn Short circuited induction machine model is as asymmetric four phase.	21
3.4 The negative sequence component extracted using power decomposition technique (PDT)	24
3.5 Conclusion	27
4. Simulation and Practical Testing of Inter-Turn Fault Detection by PDT	28
4.1. MATLAB/SIMULINK Simulation	28
4.1.1 Healthy motor model	28
4.1.2 Simulations of the Faulty Motor Model	31
4.1.3 Comparison of current I_D for 2turns and 25turns Shorted Condition	35
5. Practical Testing	37
5.1. Test Rig development	37

6. Practical and Simulation Results Analysis	41
6.1 Analysis of the Practical Test Results	41
6.2 Calculation Technique for Phase Shift between Two Phases	46
6.3 Fast Fourier Transformation (FFT) Analysis for Practical Test Results	51
6.4 Analysis of the Simulation Results	53
6.5 Phase Shift Comparison of Simulated Three Phase Current Waves	54
6.6 Conclusion of the Results	56
7. Conclusions	57
7.1. Conclusions of the thesis	57
7.2. Proposal for further research	58
Reference	59
Appendix A - MATLAB Program for the Healthy Motor S-function	61
Appendix B - MATLAB PROGRAM FOR THE FAULTY MOTOR S-FUNCTION	63
Appendix C - MAT LAB Program for PDT to calculate Negative Sequence and Positive Sequence Current Components	65

ABSTRACT

Motors are the workhorses of the industry. Safety, reliability, efficiency, and performance are some of the major concerns and needs for motor system applications. The issue of preventive and condition-based maintenance, online monitoring, system fault detection, diagnosis, and prognosis are of increasing importance. The use of motors in today's industry is extensive and the motors can be exposed to different hostile environments, misoperations, manufacturing defect etc. Different internal motor faults (eg. inter-turn short circuits, short circuit of motor leads, ground faults, bearing and rotor faults) along with external motor faults are expected to happen sooner or later.

Early fault detection, diagnosis, and prognosis allow preventive condition based maintenance to be arranged for the motor system during scheduled downtime and prevent an extended period of downtime caused by system failures.

This thesis deals with the stator faults and mainly for inter-turn short circuit fault. The faults related to the rotor and bearing also are considered in many research and developed successful fault diagnosis techniques. Literature survey revealed that Fast Fourier Transform (FFT) based current spectrum analysis can be successfully applied in rotor and bearing faults analysis.

FFT based Inter-turn short circuit analysis, Air-gap flux sensing by external coils and Partial Discharge (PD) analysis have been discussed. This research has been focused to the negative sequence current analysis, since the FFT augmentation due to inter- turn fault is marginal.

A Power Decomposition Technique (PDT) has been used to derive positive and negative sequence components of measured voltage and current. A multi-phase based motor model is developed to simulate the inter turn fault and the results are verified by practical testing. The practical current waveforms are subjected to power decomposition based sequence component analysis in MATLAB calculation platform.

The practical testing has been done for loaded machine and the machine under no load condition to prove no load machine is more suitable for applying this technique. Harmonic analysis also has been done for comparison.

Simulation model is validated using the practical test results. Either novel methods of on line monitoring or off-line inter turn fault diagnosis as routing maintenance test scheme is presented.



ACKNOWLEDGMENT

I wish to express my appreciation and sincere thanks to the Post Graduate Studies Division of the University of Moratuwa for providing me with the opportunity of following the Master's Degree Program in Electrical Engineering. Special thanks goes to Prof. H.Y.R.Perera, Head, Department of Electrical Engineering and Eng.W.D.A.S.Wijayapala, Senior Lecturer, Department of Electrical Engineering for giving me their immense assistance with the encouragement and laboratory facilities, frequently used for this project.

I must express my profound gratitude and sincere thanks to the lecturing staff, other academic personnel of the Electrical Engineering Department of the University and my supervisors Dr.J.P.Karunadasa and Dr.P.S.N De Silva whose guidance of the research. I appreciate for the motivation and encouragement for this research project by Dr. P.S.N. De Silva. It was great pleasure to conduct the work under his supervision.

I wish to extend my sincere gratitude to Mr.U.D.Jayawardana, the Chief Executive Officer and Mr.M.J.M.N.Marikkar, the Chief Operation Officer in Lanka Transformers Group of Companies including other senior officers and my colleagues who granted me for this research and their invaluable support during the most difficult times.

I must specially mention Mr.Leelasiri, Technical Officer in Electrical Machine Laboratory, University of Moratuwa. He provided me an invaluable support without any hesitation to the practical test was done several time to get most accurate data for the project. Therefore I would like to express my grateful thanks for giving his hands to success my research.

List of Figures

		Page No
Figure 1.1	Construction of an Induction Machine	01
Figure 1.2	Pie Chart of Faults Distribution of An Induction Machine	02
Figure 1.3	Insulation Failure of Induction Machine	03
Figure 3.1	Representation of shorted winding	17
Figure 3.2	Decomposition of Shorted Winding	18
Figure 3.3	Magnetic Flux Distribution along the Stator Periphery	18
Figure 4.1	Healthy Motor Simulating Model	28
Figure 4.2	Parameters of Healthy Model Input Line Voltage Blocks	29
Figure 4.3	Phasor Diagram of S-Function Input Voltages	29
Figure 4.4	Balanced Current Output at the Transient Conditions	30
Figure 4.5	Balanced Current Output at the Stable Conditions	31
Figure 4.6	Faulty Motor Simulating Model	31
Figure 4.7	Parameters of Faulty Model Input Line Voltage Blocks	32
Figure 4.8	Transient state condition of fault current for 2-turns short	33
Figure 4.9	Steady State Condition of Fault Current for 2-Turns Short	33
Figure 4.10	Steady State Condition of Fault Current for 2-Turns Short-Highlights Phase-D Current	34
Figure 4.11	Steady State Condition of Fault Current for 25-Turns Short – Highlights Phase-D Current	35
Figure 5.1	Test Rig	37
Figure 5.2	Induction Motor connected to the Load (DC Generator)	38
Figure 5.3	Tapping Selector for the turns shorted arrangement of 3-Phase Stator Winding	39
Figure 5.4	3- Φ Variac with Hall Effect Current Transducers	39
Figure 5.5	Image of the storage oscilloscope	40
Figure 6.1	Negative Sequence Current Vs No. of Shorted Turns (No Load Machine)	42

Figure 6.2	Positive Sequence Current Vs No. of Shorted Turns (No Load Machine)	42
Figure 6.3	Negative Sequence Current Vs No. of Shorted Turns with 0.96kW load	43
Figure 6.4	Negative Sequence Current Vs No. of Shorted Turns with 1.48kW load	44
Figure 6.5	Negative Sequence Current Vs No. of Shorted Turns with varied load	44
Figure 6.6	Increment of Negative Sequence Current Vs No of shorted turns	45
Figure 6.7	Zero Cross Points to find the Phase Shift-Healthy Motor	47
Figure 6.8	Zero Cross Points to find the Phase Shift- Two Turns Shorted Motor	48
Figure 6.9	Zero Cross Points to find the Phase Shift- Seven Turns Shorted Motor	49
Figure 6.10	Zero Cross Points to find the Phase Shift- Twelve Turns Shorted Motor	50
Figure 6.11	Graphical representation of Phase Shift Variation for each test Condition	51
Figure 6.12	FFT Comparison of Two Turns Short Circuit Condition and Healthy Condition	51
Figure 6.13	FFT Comparison of Seven Turns Short Circuit Condition and Healthy Condition	52
Figure 6.14	FFT Comparison of Twelve Turns Short Circuit Condition and Healthy Condition	52
Figure. 6.15	In Vs No. of Shorted Turns	53
Figure 6.16	Current Waves for Two Turns Short Circuited Motor	54
Figure 6.17	Current Waves for Seven Turns Short Circuited Motor	55
Figure 6.18	Current Waves for Twelve Turns Short Circuited Motor	55

List of Tables

		Page No
Table 6.1	I_n and I_p Values for shorted turns at No load Condition	41
Table 6.2	I_n and I_p Value for shorted turns at 0.96kW load Condition	43
Table 6.3	I_n and I_p Value for shorted turns at 1.48kw load Condition	43
Table 6.4	Increment of Negative Sequence Current for the increasing no of shorted turns with varied load	45
Table 6.5	Phase Shift Variation for each test Condition	50
Table 6.6	I_n Values for shorted turns	53