Investigation and Development of a Real-Time On-Site Condition Monitoring System for Induction Motors

by

Syaiful Bakhri

Thesis submitted for the degree of

Master of Engineering Science

School of Electrical and Electronic Engineering
Faculty of Engineering, Computer and Mathematical Science

The University of Adelaide
Australia

August 2008

THE UNIVERSITY
OF ADELAIDE
AUSTRALIA

Contents

Abstract

This thesis presents an investigation and development of a real-time on-site condition monitoring system for induction motors. Induction motors are employed in various industries as an essential machine. In order to prevent catastrophic faults during its serviceable life, **c**ondition monitoring of induction motors is commonly used in industrial applications to maintain safety and reliability of plant operation. The current practice in condition monitoring primarily involves using various forms of mobile or portable devices, usually with a single sensor input to perform tests at regular intervals. However, such devices and monitoring services can be expensive and require an experienced operator for reliable decisions. Therefore, this thesis investigates an alternative low-cost solution for continuous condition monitoring of induction machines using multiple sensors, which can be located next to a machine under test and can provide condition information using indicator lights for quick diagnosis.

The thesis provides hardware and software implementation details using an FPGA based CompactRIO platform. The CompactRIO embedded reconfigurable platform incorporates an FPGA, an analog input module, a real-time host controller and a custom-made indicator module as an on-site monitoring system. The CompactRIO custom-made indicator module utilizes bi-colour LEDs and requirements of CompactRIO MDK to display each level fault. Furthermore, a data acquisition and monitoring system was developed under LabVIEW FPGA environment and LabVIEW Real Time software. The system that has been successfully designed has had its performances and capabilities evaluated through several tests. In addition, real faults are also introduced to demonstrate the system's performance. The results show that the CompactRIO system is capable of being implemented as condition monitoring system, especially as an early warning unit. The early warning information obtained from this system can be used as valuable data for further detailed fault assessment.

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 any other person, except where due reference has been made in the text. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

Signed : _____ Date : _____

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 has encouraged improvement and development. He has also given essential support by providing a CompactRIO base unit, LabVIEW software and CompactRIO MDK.

I would like to thank to Dr. Wen L. Soong and Dr. Said Al-Sarawi for the inspiration, guidance, and suggestion that have enriched this project.

I would like to thank all the technical staff for their help and assistance during my research in power laboratory. I would also like to thank the information technology support staff, Mr Mark Innes and Mr Anthony Schueller, and school store staff Mr Danny Di Giacomo, for their help. I would like especially to acknowledge Mr. Pavel Simcik for the PCB development.

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

An AusAID Australian Development Scholarship provided me with support during my studies, for which I am grateful.

I am grateful to every member of the School of Electrical and Electronic Engineering, and staff of University of Adelaide International student centre, especially Ms Niranjala Seimon, who has helped me during my stay here.

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

Syaiful Bakhri

August 2008

List of Figures

List of Tables

List of Abbreviations and Symbols

List of Abbreviations

AC	Alternating Current
ADC	Analog to Digital Converter
AlBar	Aluminum Bars
BNC	Bayonette Neil-Concelman (connector)
CAN	Controller Access Network
CompactRIO	Compact Reconfigurable Input Output
CT	Clip on Transformer
CuDC	Copper Die Cast
CuBar	Copper Bar
DMA	Direct Memory Access
DRAM	Dynamic Random Access Memory
DSP	Digital Signal Processor
EEPROM	**E**lectrically **E**rasable **P**rogrammable **R**ead-**O**nly **M**emory
EPRI	Electric Power Research Institute
FFT	Fast Fourier Transform
FIFO	First In First Out
FIR	Finite Impulse Response
FTP	File Transfer Protocol
FPGA	Field Programmable Gate Array
GND	Ground
IEEE-IAS	Institute of Electrical and Electronic Engineering-Industry Application Society
IIR	Infinite Impulse Response
I/O	Input/Output
HTTP	Hypertext Transfer Protocol
IR	Insulation Resistance
ISA	Industry Standard Architecture
LAN	Local Area Network
LED	Light Emitting Diode

LCD	Liquid Crystal Display
LabVIEW	**Lab**oratory **V**irtual **I**nstrumentation **E**ngineering **W**orkbench
MCSA	Motor Current Stator Analysis
MDK	Module Development Kit
MISO	Master-In Slave-Out
MOSI	Master-Out Slave-Input
MSE	Mean Square Error
NI	National Instrument
OE	Output Enable
PDA	Personal Data Assistant
PI	Polarization Index
PC	Personal Computer
PCI	Peripheral Component Interconnect
PXI	**P**CI E**x**tension for **I**nstrumentation
RCK	Register Clock
SCK	Serial Clock
SI	Serial Input
SQH	Serial Output
SPI	Serial Peripheral Interface
SPI_CLK	SPI Clock
SPI_CS	SPI Chip Select
TCP/IP	Transmission Control Protocol/ Internet Protocol
RAM	Random Access Memory
RMS	Root Mean Square
VI	Virtual Instrument
VXI	**V**ME e**X**tensions for **I**nstrumentation

List of Symbols

θ	Ball contact angle
D_B	Ball diameter
D_P	Pitch diameter
f	Frequency of the source
F_{BF}	Ball fault frequency
F_{BRB}	Detectable broken rotor bar frequency
F_{CF}	Cage fault frequency
F_{ECC}	Eccentricity fault frequency
F_{ORF}	Outer race fault frequency
F_{IRF}	Inner race fault frequency
F_L	Power supply line frequency
F_P	Pole pass frequency
F_R	Rotor or shaft frequency
F_{RBPF}	Rotor bar pass frequency
F_{SF}	Stator fault frequency
$F_{SLOT+ECC}$	Slot and eccentricity fault frequency
$I_{OL,MAX}$	Maximum current to be allowed
p	Number of pole pairs
R	Number of rotor slots
R	Resistor centre value
s	Slip
tol	Tolerance of resistor
N_B	Number of balls
N_R	Rotor speed
N_S	Synchronous speed of the motor
$V_{cc,MAX}$	Maximum power supply voltage
$V_{f,LED,MIN}$	Minimum LED forward voltage at $I_{OL,MAX}$
$V_{OL,MIN}$	Minimum output low voltage from the LED driver at $I_{OL,MAX}$