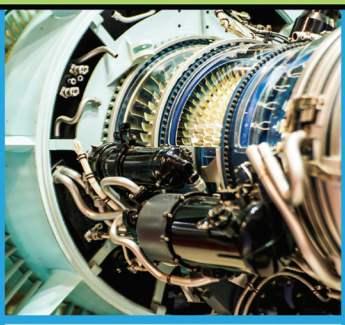
Condition Monitoring and Faults Diagnosis of Induction Motors

ELECTRICAL SIGNATURE ANALYSIS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To my wife, Rozita; sons, Syahmi and Hakim; and daughters,

Liyana, Zawani, and Nadhirah, for the patience and inspiration

Nordin Saad

To my parents, Allah Ditta and Irshad BiBi; and grandparents,

Raheem Buksh and Janin BiBi, for the prayers and endless support

Muhammad Irfan

To my beloved wife and best friend, Lidia, and my princesses

Azra, Auni, Ahna, and Ayla, my love will always be with you

Rosdiazli Ibrahim

Contents

Preface

Condition monitoring and faults diagnosis is an important means in assuring the well-being of rotating equipment, for example induction motors, normally used in manufacturing and production industries, chemical processing plants, nuclear power plants, paper mills, cooling water systems, mining industry, and oil and gas onshore and offshore facilities. Induction motors have also been used in more general situations such as with compressors, pumps, crushers, fans, lifts, air conditioners, machine tools, tractions, robotics, etc. The main purpose is to provide the "health" status of the machine and indicates type of maintenance required while achieving optimal use of parts. A failure of diagnosing the machine's status could cause significant hazard or economic loss. Normally, the condition monitoring maintenance process would be monitoring the specific parameters like vibration, overheating, and overcurrent of the equipment, for early signs of failure in order to forecast whether maintenance is needed before rigorous failure, as well as to estimate the machines' health. This could be achieved by visual inspection or through sophisticated intelligent diagnosis system. It embraces the life mechanism of the machine parts, the different data acquisition methods, and exploitation of the data to forecast the trends.

The purpose of this book is to reveal some of the recent developments, both theoretically and practically, including the condition monitoring and faults diagnostic method of induction motors based on electrical signature motor currents analysis. This book addresses the most current technique in faults diagnosis and condition monitoring of electrical machines, with special treatment to monitoring based on electrical signature analysis of motor currents, via motor current measurements, and analysis for the diagnosis of bearings and gears' faults. It covers various issues related to machinery condition monitoring, signal processing and conditioning, instrumentation and measurements, faults for induction motors failures, and new trends in condition monitoring. It pays special attention to the fault identification process using electrical signature motor currents analysis and how such systems can be implemented. The idea for proposing motor currents analysis, via the instantaneous power analysis and Park vector analysis monitoring techniques, comes from the usual practices in industries to require current and voltage transformers, both installed for the measurement of currents and voltages for control and display purposes. The instantaneous noise variations and sensor offsets are considered to be one of the common factors that yield erroneous fault tracking in an online condition monitoring and fault diagnosis system. This book aims to present a new noninvasive and nonintrusive condition monitoring system, which has the capability to detect various defects in induction motor at incipient stages, within an arbitrary noise

condition. An adaptive threshold has been designed to deal with signal noise ambiguities for decision-making on the existence of small fault signatures. The performance of the developed system was analyzed theoretically and experimentally under various loading conditions of the motor.

This book analyzes the newer method in the design of condition monitoring and fault diagnosis systems of electrical rotating machines based on electrical signature analysis, with emphasis to the following key areas: (i) access to a widely used form of condition monitoring and diagnostic techniques, a good start for some readers to prepare for many industrial careers; (ii) the case study approach provides readers examples in the condition monitoring and diagnostic systems of induction motors, using electrical signature analysis techniques, with special focus on instantaneous power analysis (IPA) and Park's vector analysis; (iii) case studies with detailed laboratory setups, while there are problems, include results of the actual experiments and tests on the motor current electrical signature analysis techniques; (iv) the book gives an option to solve condition monitoring problems via the utilization of the LabVIEW tool, a widely accepted software package in academia as well as in most industries; (v) comprehensive survey on noninvasive and invasive condition monitoring methods to provide a more diversified knowledge in the area of fault diagnosis and condition monitoring; and (vi) introduction to new fault diagnosis studies that would be the basis for the pacing technology on prescriptive maintenance, as well as the future unmanned facilities.

This book is intended for researchers, graduate students, academicians, and practicing engineers with an interest in the condition monitoring and diagnostic of induction motors. Its contents can be used for teaching courses on condition monitoring systems, and can be used by both academic tutors and students as a reference book. The noninvasive and nonintrusive condition monitoring system presented in this book can be a powerful tool and useful companion for engineers working on the practical problems of condition monitoring and the diagnostics of electrical machines, because this monitoring system, based on electrical signature analysis, has the capability to detect various defects in an induction motor at incipient stages, within arbitrary noise conditions. Since this book analyzes most of the critical issues associated with the exploitation of electrical current data, via the noninvasive electrical signature analysis, it is likely to be a useful reference for future researchers involved in the development of such systems.

With a total of six chapters, this book is structured in such a way so that its sequential flow is maintained. The readers will find the book easy to follow, since each chapter builds on the preceding chapter. Chapter 1 provides an overview of the condition monitoring, issues, and the organization of the book. Chapter 2 analyzes the literatures reviewed and provides a review of the earlier work related to sensor-based condition monitoring methods. Chapter 3 discusses the noninvasive condition monitoring and fault diagnosis methods, and provides some of the latest work on the noninvasive techniques that would be useful in many applications in the near future. Chapter 4

deals with development of an experimental rig for intelligent diagnosis of various faults related to a 0.3-hp induction motor. A generalization of the experimental condition monitoring system software and hardware modules employed is also presented in this chapter. Chapter 5 gives an extensive series of laboratory tests conducted to support the viability of the electrical signature analysis techniques. Examples of experimental results, the analysis, and discussions about the various defects of the motor and their respective current signatures are provided. Finally, Chapter 6 presents some directions for future investigations and continuation of this work.

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Dr. Nordin Saad is an associate professor of the Electrical and Electronics Engineering Department at Universiti Teknologi PETRONAS, Malaysia. He was the head of the Department of Electrical and Electronics Engineering at the university from 1998 to 2000, having joined the university in 1997. He was a cluster leader of the Industrial Automation and Control department from 2005 to 2012, and subsequently a co-cluster leader of the Power Control and Instrumentation department from 2013 to 2014. He was also the focal person for Group Technology Solution PETRONAS SKG 14 (Instrument) from 2006 to 2014. He currently teaches courses in modern control engineering, industrial automation and control systems, power electronics, and intelligent systems.

He received his BSEE from Kansas State University (USA), MSc in power electronics from Loughborough University (UK), and PhD in control engineering from the University of Sheffield (UK). He is a chartered engineer, a senior member of the IEEE (SMIEEE) and a member of the Institute of Measurement and Control (MInstMC) UK. His research interests include smart grids, renewable energy and energy systems, modern transportation systems, networked and industrial wireless communication, and smart fields. His current research work encompasses some of the issues in electrical drives control, power electronic converters for high-power transmissions and low-power applications, condition monitoring and diagnostic of machines, and instrumentation and control of facilities. He has supervised a total of six PhD and four MSc graduates. He has published around 120 academic journal articles, transactions, book chapters, and technical papers in these areas. He has received a number of best paper awards at international conferences for the research he and his teams have conducted.

Dr. Muhammad Irfan received his BSc degree in mechatronics and control engineering from the University of Engineering and Technology Lahore, Pakistan in 2009. He received his MSc and PhD degrees in electrical and electronics engineering from Universiti Teknologi PETRONAS, Malaysia, in 2013 and 2016, respectively. Currently, he is an assistant professor in the Electrical Engineering Department, College of Engineering, Najran University, Saudi Arabia. His main research areas are in intelligent control, autonomous systems, wireless control, electrical drives control, and condition monitoring and fault diagnosis of electrical machines.

Dr. Rosdiazli Ibrahim received his BSc degree in electronics and computers from Universiti Pertanian Malaysia in 1996, MSc degree in automation and control engineering from the University of Newcastle, UK, and PhD degree in electrical and electronic engineering from the University of Glasgow, UK, in 2001 and 2008, respectively. He is currently an associate professor at the Universiti Teknologi PETRONAS, Malaysia, and the dean of their graduate office. He was the head of the Department of Electrical and Electronics Engineering at the university from 2014 to 2017. He currently teaches courses in industrial automation and control systems, and intelligent systems. He is a chartered engineer, a member of the IEEE (MIEEE), and a member of the Institute of Marine Engineering, Science & Technology (MIMarEST, UK). His main research areas are in automation and process control, condition monitoring and fault diagnosis of rotating and stationary equipment, and wireless control.

List of Abbreviations

AC	alternating current
AE	acoustic emission
AI	analog input
AO	analog output
ASD	adjustable speed drive
CBM	condition-based maintenance
CM	condition monitoring
D	detection
DAQ	data acquisition
DC	direct current
DSP	digital signal processing
EPRI	Electric Power Research Institute
FEA	finite element analysis
FFT	fast Fourier transform
FL	full load
IAS	Industry Application Society
IPA	instantaneous power analysis
LSB	lower side band
MAX	measurement automation explorer
MCSA	motor current signature analysis
MD	misdetection
MSE	mean square error
NI	National Instrument
NL	no load
NN	neural network
PM	predictive maintenance
PVA	Park vector analysis
RPM	revolutions per minute
TBM	time-based maintenance
UMP	unbalanced magnetic pull
USB	upper side band
VFD	variable frequency drive
VI	virtual instrumentation