Induction Motor Parameters Estimation and Faults Diagnosis using Optimisation Algorithms

by

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Contents

Abstract

Induction motors are the most widespread rotating electric machines in industry due to their efficient and cost-effective performance. Induction motors are used to mainly operate at the constant speed since the rotor speed depends on the supply frequency. The development of power electronic devices and converter technologies has revolutionized the adjustable-speed induction motor drives. For most high-performance control methods, the effective motor control requires precise knowledge of the motor's parameters, which are usually obtained from manufacturers. However, the manufacturers describe these parameters under starting or full-loading condition only, instead of the normal operating conditions. It is well known that motor parameters are influenced by not only the load level but also environmental factors, such as temperature, humidity and lubricant viscosity.

The first part of the thesis describes the application of the sparse grid optimisation method in solving the induction motor parameter estimation problem. Kernel of the method is the efficient search in minimising the cost function on the grid created by using the Hyperbolic Cross Points (HCPs). The cost function quantifies the difference between simulation results and measurement results. Within model reference adaptive system (MRAS) framework, a global optimisation algorithm, HCP algorithm (HCPA), runs the motor model and finds the best parameters to minimise the value of the cost function. Since the proposed method requires only voltage and current signals, it is compatible with sensorless control methods, which have the benefits of increasing system reliability and reducing cost. The presented experimental validation shows that the relative errors of the estimated parameter values are less than 10% under various load levels. The estimated parameters can be further refined by applying local search method using global search result as a start point.

On the other hand, an induction motor failure results in severe damage not only to the motor itself but also to motor related equipment devices in an industrial plant. Consequently, motor condition monitoring and fault diagnosis are of great necessity to detect motor faults at the early stage in order to reduce unscheduled downtime, repair costs, and increase life span of machines. Emergence of a fault will cause a gradual drift

of fault-related characteristic model parameters. Therefore, a generic method to detect motor faults developed in this research is based on monitoring these parameters.

In the second part of this thesis, the proposed parameter estimation technique based on the sparse grid optimisation is utilised to detect stator short circuit faults by monitoring two characteristic parameters: fault level and fault location. Experimental results show that the proposed diagnosis method is capable of detecting stator short circuit fault levels and location under different load conditions. Compared to the genetic algorithm, the HCPA shows improved robustness in the case of unbalanced voltage supply. This non-invasive diagnosis method only needs a short length of voltage and current signals recorded at switch board without disrupting the machine's normal operation.

The third part of this thesis demonstrates a multi-motor condition monitoring scheme which can substantially reduce implementation cost for some industrial plants. The proposed multi-motor condition monitoring scheme builds on top of the technology implemented in modern Intelligent Electronic Devices (IEDs) for motor protection and control. The backbone of this scheme is the broadly accepted Ethernet technology and the IEC 61850 communication standard. Due to the widespread use of IEC 61850 in various industries, cost of the technology is significantly reduced while reliability has been improved. Based on the proposed systems, various applications can be developed to achieve remote condition monitoring of induction motors.

Statement of Originality

This work contains no material that 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 another person, except where due reference has been made in the text.

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Conventions

Typesetting

This thesis is typeset using the LaTeX2e software. WinEdt build 5.5 was used as an effective interface to LaTeX.

Referencing

Referencing and citation style in this thesis are based on the Institute of Electrical and Electronics Engineers (IEEE) Transaction style.

Units

The units used in this thesis are based on the International System of Units (SI units).

Prefixes

In this thesis, the commonly used numerical prefixes to the SI units are ”p” (pico, 10^{-12}), ”n” (nano, 10^{-9}), ”μ” (micro, 10^{-6}), ”m”,(milli,10^{-3}), ”k”(kilo, 10^{3}), ”M”(mega, 10^{6}), ”G”(giga, 10^{9}), and ”T”(tera, 10^{12}).

Spelling

The Australian English spelling is adopted in this thesis.

Abbreviations

ACSI	Abstract communication service interface
AI	Artificial intelligence
BRB	Broken rotor bar
DDE	Dynamic data exchange
DER	Distributed energy resource
DTC	Direct torque control
EKF	Extended Kalman Filter
ER	Event report
ESPRIT	Estimation of signal parameters via rotational invariance techniques
FFT	Fast Fourier transform
FOC	Field-Oriented Control
GA	Genetic Algorithm
GOOSE	Generic object oriented substation events
HCP	Hyperbolic Cross Point
HCPA	Hyperbolic Cross Point Algorithm
HMI	Human machine interface
IED	Intelligent Electronic Device
I/O	Input/output
LAN	Local area network
LHS	Latin hypercube sampling
LL	Load level

LM	Levenberg-Marquardt
MCC	Motor control centre
MMS	Manufacturing messaging specification
MRAS	Model reference adaptive system
MUSIC	Multiple signal classification
NI	National Instruments
NM	Nelder-Mead
OLE	Object linking and embedding
OPC	OLE for process control
PDE	Partial differential equation
PSA	Pattern search algorithm
RPM	Revolutions per minute
RRTS	Remote relay testing system
SCADA	Supervisory control and data acquisition
SCL	Substation configuration language
SCSM	Specific communication service mapping
SER	Sequence of events recording
SNR	Signal to noise ratio
SR	Squared residual
VUF	Voltage unbalance factor

Author Publications

Journal

[1] F. Duan and R. Živanović, "Condition monitoring of an induction motor stator windings via global optimization based on the Hyperbolic Cross Points," *IEEE Trans. Ind. Electron.*, vol.PP, no.99, pp. 1–9, 2014.

Conference

[1] F. Duan and R. Živanović, "Induction motor stator faults diagnosis by using parameter estimation algorithms," in *9th IEEE International Symposium on Diagnostics for Electrical Machines, Power Electronics & Drives*, Valencia, Spain, Aug. 2013, pp. 274-280.

[2] F. Duan and R. Živanović, "Automated multi-motor condition monitoring based on IEC 61850," in *5th Annual International Energy Conversion Congress and Exhibition Asia DownUnder 2013*, Melbourne, Australia, Jun. 2013, pp. 699-703.

[3] F. Duan and R. Živanović, "Diagnosis of induction machine stator faults by parameter estimation techniques based on direct search on sparse grid," in *The 9th IET International Conference on Advances in Power System Control, Operation and Management*, Hong Kong, China, Nov. 2012, pp. 1-6.

[4] F. Duan and R. Živanović, "A model for induction motor with stator faults," in *AUPEC12 - 22th Australasian Universities Power Engineering Conference*, Bali, Indonesia, Sep. 2012, pp. 1-4.

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