

Speed Estimation of Sensorless Induction Motor through Vector Control Using MRAS and Direct Synthesis Test

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ABSTRACT

The objective of this project is to develop a vector controlled induction motor drive operating without a speed or position sensor but having a dynamic performance comparable to a sensed vector drive. This thesis presents the control of an induction motor through sensorless vector control using MRAS and also with direct synthesis test. The theoretical basis of each algorithm is explained in detail and its performance is tested with simulations implemented in MATLAB/SIMULINK. Vector control of induction motor is based upon the field-oriented co-ordinates aligned in the direction of the rotor m.m.f. However, there is no direct means of measuring the rotor flux linkage position ρ and therefore an observer is needed to estimate ρ for the implementation of sensorless vector control. First the Dynamic model of induction machine was developed in the arbitrary reference frame. Second, with the help of synchronous reference frame model the indirect field oriented vector control was developed. Third, Model Reference Adaptive System is studied as a state estimator. Rotor flux estimation scheme is applied to MRAS to estimate rotor speed. . By using the Direct Synthesis test, we can estimate the speed directly without feedback and control algorithm. This test can reduce the total cost.

KEYWORDS: Induction motor, Sensorless vector control, MRAS, Direct Synthesis test, MATLAB/SIMULINK.

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1. INTRODUCTION

In this thesis, the speed sensorless estimation concept via implementation of Model Reference Adaptive System (MRAS) schemes was studied[1]. It is a well-known fact that the performance of MRAS based speed estimators is beyond par from other speed estimators with regards to its stability approach and design complexity. Although this

thesis is all about MRAS based speed estimators, but it is also the aim of this project to investigate several speed sensorless estimation strategies for IMs. Explanations on the type of control strategies also were briefly discussed. As far as simulation works is concerned, the MRAS based speed sensorless estimation schemes chosen in this thesis have been implemented in the Field oriented

Sensorless Speed Estimation Of An Induction Motor In A

**Sio-long Ao, Haeng Kon Kim, Mahyar A.
Amouzegar**



Sensorless Speed Estimation Of An Induction Motor In A:

Sensorless Speed Estimation of an Induction Motor Kien Fatt Wong, 2006 *Sensorless Speed Estimation of an Induction Motor* Erik Ringøen, 1998 **Sensorless Speed Estimation of an AC Induction Motor by Using an Artificial Neural Network Approach** Abdulelah Ali Alkhoraif, 2015

Sensorless speed detection of an induction motor is an attractive area for researchers to enhance the reliability of the system and to reduce the cost of the components. This paper presents a simple method of estimating a rotational speed by utilizing an artificial neural network (ANN) that would be fed by a set of stator current frequencies that contain some saliency harmonics. This approach allows operators to detect the speed in induction motors such an approach also provides reliability, low cost and simplicity. First the proposed method is based on converting the stator current signals to the frequency domain and then applying a tracking algorithm to the stator current spectrum in order to detect frequency peaks. Secondly the ANN has to be trained by the detected peaks; the training data must be from very precise data to provide an accurate rotor speed. Moreover the desired output of the training is the speed which is measured by a tachometer simultaneously with the stator current signal. The databases were collected at many different speeds from two different types of AC induction motors: wound rotor and squirrel cage. They were trained and tested so when the difference between the desired speed value and the ANN output value reached the wanted accuracy the system does not need to use the tachometer anymore. Eventually the experimental results show that in an optimal ANN design the speed of the wound rotor induction motor was estimated accurately where the testing average error was 1 RPM. The proposed method has not succeeded to predict the rotor speed of the squirrel cage induction motor precisely where the smallest testing average error that was achieved was 5 RPM.

Sensorless Speed Estimation of an Induction Motor Robiah Ahmad, Universiti Teknologi Malaysia. Fakulti Kejuruteraan Mekanikal, 2007 Flux and Speed Estimation Techniques for Sensorless Control of Induction Motors Mihai Comanescu, 2005

Abstract: The focus of this research is the development of novel techniques for estimation and control of sensorless induction motor drives. In a sensorless drive the speed must be estimated from the system measurements. Depending on the objective of the control (speed or torque control) the speed estimate must be used in one or more areas of the control scheme. This idea and the main techniques for speed estimation are explored. The dissertation investigates the issues related to low speed flux estimation when a Voltage Model observer is used. Pure integration cannot be implemented due to offsets in the measured signals and integrators must be replaced by low pass filters. At low speed the flux estimates are incorrect in both magnitude and angle; consequently the rotor position obtained by the DFO method is incorrect. An improved Voltage Model observer that corrects the errors is developed based on a Programmable Low Pass Filter and a vector rotator. The method requires estimation of the stator frequency and this is done by a Phase Locked Loop synchronized with the voltage vector. The traditional rotor flux MRAS method can be used for speed estimation; however under non ideal integration the dynamics of the speed estimate exhibits right hand side plane zeros.

Additionally system tuning is difficult and may yield under damped responses Two novel Sliding Mode MRAS observers are designed and implemented and their features are used for speed estimation The dq rotational frame currents of an induction machine are not decoupled Decoupling can be achieved by canceling the cross coupled terms in the equations of the synchronous frame currents This approach is both inconvenient and inaccurate A novel approach for decoupling is presented an Integral Sliding Mode controller complements a traditional controller that acts on a simulated plant The use of the Integral SM controller guarantees that the currents in the real plant will track those of the simulated model The additional controller compensates for the cross terms and for variations of the machine parameters The method is also valuable for allowing fast and efficient tuning of the current controllers

High Performance Control of AC Drives with Matlab / Simulink Models Haitham Abu-Rub, Atif Iqbal, Jaroslaw Guzinski, 2012-04-13 A comprehensive guide to understanding AC machines with exhaustive simulation models to practice design and control Nearly seventy percent of the electricity generated worldwide is used by electrical motors Worldwide huge research efforts are being made to develop commercially viable three and multi phase motor drive systems that are economically and technically feasible Focusing on the most popular AC machines used in industry induction machine and permanent magnet synchronous machine this book illustrates advanced control techniques and topologies in practice and recently deployed Examples are drawn from important techniques including Vector Control Direct Torque Control Nonlinear Control Predictive Control multi phase drives and multilevel inverters Key features include systematic coverage of the advanced concepts of AC motor drives with and without output filter discussion on the modelling analysis and control of three and multi phase AC machine drives including the recently developed multi phase phase drive system and double fed induction machine description of model predictive control applied to power converters and AC drives illustrated together with their simulation models end of chapter questions with answers and PowerPoint slides available on the companion website www.wiley.com/go/aburub_control This book integrates a diverse range of topics into one useful volume including most the latest developments It provides an effective guideline for students and professionals on many vital electric drives aspects It is an advanced textbook for final year undergraduate and graduate students and researchers in power electronics electric drives and motor control It is also a handy tool for specialists and practicing engineers wanting to develop and verify their own algorithms and techniques

SPEED ESTIMATION TECHNIQUES FOR SENSORLESS VECTOR CONTROLLED INDUCTION MOTOR DRIVE. ,2005 This work focuses on speed estimation techniques for sensorless closed loop speed control of an induction machine based on direct field oriented control technique Details of theories behind the algorithms are stated and their performances are verified by the help of simulations and experiments The field oriented control as the vector control technique is mainly implemented in two ways indirect field oriented control and direct field oriented control The field to be oriented may be rotor stator or airgap flux linkage In the indirect field oriented control no flux estimation exists The angular slip velocity estimation based on the measured or

estimated rotor speed is required to compute the synchronous speed of the motor. In the direct field oriented control, the synchronous speed is computed with the aid of a flux estimator. Field Oriented Control is based on projections which transform a three phase time and speed dependent system into a two co ordinate time invariant system. These projections lead to a structure similar to that of a DC machine control. The flux observer used has an adaptive structure which makes use of both the voltage model and the current model of the machine. The rotor speed is estimated via Kalman filter technique which has a recursive state estimation feature. The flux angle estimated by flux observer is processed taking the angular slip velocity into account for speed estimation. For closed loop speed control of system torque flux and speed producing control loops are tuned by the help of PI regulators. The performance of the closed loop speed control is investigated by simulations and experiments. TMS320F2812 DSP controller card and the Embedded Target for the TI C2000 DSP tool of Matlab are utilized for the real time experiments. *High Performance Control of AC Drives with Matlab/Simulink* Haitham

Abu-Rub, Atif Iqbal, Jaroslaw Guzinski, 2021-04-06 *High Performance Control of AC Drives with Matlab Simulink* Explore this indispensable update to a popular graduate text on electric drive techniques and the latest converters used in industry. The Second Edition of *High Performance Control of AC Drives with Matlab Simulink* delivers an updated and thorough overview of topics central to the understanding of AC motor drive systems. The book includes new material on medium voltage drives covering state of the art technologies and challenges in the industrial drive system as well as their components and control. Current source inverter based drives, PWM techniques for multilevel inverters and low switching frequency modulation for voltage source inverters. This book covers three phase and multiphase more than three phase motor drives including their control and practical problems faced in the field e.g. adding LC filters in the output of a feeding converter are considered. The new edition contains links to Matlab Simulink models and PowerPoint slides ideal for teaching and understanding the material contained within the book. Readers will also benefit from the inclusion of a thorough introduction to high performance drives including the challenges and requirements for electric drives and medium voltage industrial applications. An exploration of mathematical and simulation models of AC machines including DC motors and squirrel cage induction motors. A treatment of pulse width modulation of power electronic DC/AC converter including the classification of PWM schemes for voltage source and current source inverters. Examinations of harmonic injection PWM and field oriented control of AC machines. Voltage source and current source inverter fed drives and their control. Modelling and control of multiphase motor drive system. Supported with a companion website hosting online resources. Perfect for senior undergraduate, MSc and PhD students in power electronics and electric drives. *High Performance Control of AC Drives with Matlab Simulink* will also earn a place in the libraries of researchers working in the field of AC motor drives and power electronics engineers in industry. *Intelligent Algorithms for Analysis and Control of Dynamical Systems* Rajesh Kumar, V. P. Singh, Akhilesh Mathur, 2020-10-31 This book explores various intelligent algorithms including evolutionary algorithms, swarm intelligence

based algorithms for analysis and control of dynamical systems Both single input single output SISO and multi input multi output MIMO systems are explored for analysis and control purposes The applications of intelligent algorithm vary from approximation to optimal control design The applications of intelligent algorithms not only improve understanding of a dynamical system but also enhance the control efficacy The intelligent algorithms are now readily applied to all fields of control including linear control nonlinear control digital control optimal control etc The book also discusses the main benefits attained due to the application of algorithms to analyze and control Smart Intelligent Computing and Applications Suresh Chandra Satapathy,Vikrant Bhateja,Swagatam Das,2018-11-04 The proceedings covers advanced and multi disciplinary research on design of smart computing and informatics The theme of the book broadly focuses on various innovation paradigms in system knowledge intelligence and sustainability that may be applied to provide realistic solution to varied problems in society environment and industries The volume publishes quality work pertaining to the scope of the conference which is extended towards deployment of emerging computational and knowledge transfer approaches optimizing solutions in varied disciplines of science technology and healthcare *Induction Motor Control Design* Riccardo Marino,Patrizio Tomei,Cristiano M. Verrelli,2010-08-20 This book provides the most important steps and concerns in the design of estimation and control algorithms for induction motors A single notation and modern nonlinear control terminology is used to make the book accessible although a more theoretical control viewpoint is also given Focusing on the induction motor with the concepts of stability and nonlinear control theory given in appendices this book covers speed sensorless control design of adaptive observers and parameter estimators a discussion of nonlinear adaptive controls containing parameter estimation algorithms and comparative simulations of different control algorithms The book sets out basic assumptions structural properties modelling state feedback control and estimation algorithms then moves to more complex output feedback control algorithms based on stator current measurements and modelling for speed sensorless control The induction motor exhibits many typical and unavoidable nonlinear features **AC Electric Motors Control** Fouad Giri,2013-03-25 The complexity of AC motor control lies in the multivariable and nonlinear nature of AC machine dynamics Recent advancements in control theory now make it possible to deal with long standing problems in AC motors control This text expertly draws on these developments to apply a wide range of model based control design methods to a variety of AC motors Contributions from over thirty top researchers explain how modern control design methods can be used to achieve tight speed regulation optimal energetic efficiency and operation reliability and safety by considering online state variable estimation in the absence of mechanical sensors power factor correction machine flux optimization fault detection and isolation and fault tolerant control Describing the complete control approach both controller and observer designs are demonstrated using advanced nonlinear methods stability and performance are analysed using powerful techniques including implementation considerations using digital computing means Other key features Covers the main types of AC motors including triphase multiphase and doubly

fed induction motors wound rotor permanent magnet and interior PM synchronous motors Illustrates the usefulness of the advanced control methods via industrial applications including electric vehicles high speed trains steel mills and more Includes special focus on sensorless nonlinear observers adaptive and robust nonlinear controllers output feedback controllers fault detection and isolation algorithms and fault tolerant controllers This comprehensive volume provides researchers and designers and R D engineers with a single source reference on AC motor system drives in the automotive and transportation industry It will also appeal to advanced students in automatic control electrical power systems mechanical engineering and robotics as well as mechatronic process and applied control system engineers

Transactions on Engineering Technologies Sio-Iong Ao, Haeng Kon Kim, Mahyar A. Amouzegar, 2017-02-04 This proceedings volume contains selected revised and extended research articles written by researchers who participated in the World Congress on Engineering and Computer Science 2015 held in San Francisco USA 21-23 October 2015 Topics covered include engineering mathematics electrical engineering circuits communications systems computer science chemical engineering systems engineering manufacturing engineering and industrial applications The book offers the reader an overview of the state of the art in engineering technologies computer science systems engineering and applications and will serve as an excellent reference work for researchers and graduate students working in these fields

Applied Intelligent Control of Induction Motor Drives Tze Fun Chan, Keli Shi, 2011-01-19 Induction motors are the most important workhorses in industry They are mostly used as constant speed drives when fed from a voltage source of fixed frequency Advent of advanced power electronic converters and powerful digital signal processors however has made possible the development of high performance adjustable speed AC motor drives This book aims to explore new areas of induction motor control based on artificial intelligence AI techniques in order to make the controller less sensitive to parameter changes Selected AI techniques are applied for different induction motor control strategies The book presents a practical computer simulation model of the induction motor that could be used for studying various induction motor drive operations The control strategies explored include expert system based acceleration control hybrid fuzzy PI two stage control neural network based direct self control and genetic algorithm based extended Kalman filter for rotor speed estimation There are also chapters on neural network based parameter estimation genetic algorithm based optimized random PWM strategy and experimental investigations A chapter is provided as a primer for readers to get started with simulation studies on various AI techniques Presents major artificial intelligence techniques to induction motor drives Uses a practical simulation approach to get interested readers started on drive development Authored by experienced scientists with over 20 years of experience in the field Provides numerous examples and the latest research results Simulation programs available from the book's Companion Website This book will be invaluable to graduate students and research engineers who specialize in electric motor drives electric vehicles and electric ship propulsion Graduate students in intelligent control applied electric motion and energy as

well as engineers in industrial electronics automation and electrical transportation will also find this book helpful Simulation materials available for download at www.wiley.com/go/chanmotor **Induction Motors** Rui Esteves Araújo, 2012-11-14 Motivated by the need of energy efficiency improvements process optimization soft start capability and numerous other environmental benefits it may be desirable to operate induction motors for many applications at continuously adjustable speeds The induction motor drives can provide high productivity with energy efficiency in different industrial applications and are the basis for modern automation This book provides an account of this developing subject through such topics as modelling noise control techniques used for high performance applications and diagnostics Compiled from contributions by international researchers this is not a textbook but the result is an interesting exploration of this technology that provides a combination of theory implementation issues and practical examples *Advanced Control Systems for Electric Drives* Adel Merabet, 2020-12-07 This book provides extensive information about advanced control techniques in electric drives Multiple control and estimation methods are studied for position and speed tracking in different drives Artificial intelligence tools such as fuzzy logic and neural networks are used for specific applications using electric drives Induction Motors - Recent Advances, New Perspectives and Applications Adel El-Shahat, 2023-09-13 The induction motor is one of the most significant innovations in contemporary history and it officially kicked off the Second Industrial Revolution by significantly enhancing energy generation efficiency Induction motors are utilized in a wide variety of applications in the modern industrial world Motivated by the importance of recent advances new perspectives and applications of induction motors this book presents research from distinguished experts in the field It addresses recent advances in induction motors optimal solutions in field oriented control the association of converters to induction motors dynamic analysis optimized design of synergetic control fault tolerant control mathematical modeling an adaptive system scheme for a sensorless drive modeling and simulation of a system with inter turn faults sensorless speed observer for industrial drives and induction motor applications in electric vehicles This book is useful for undergraduates graduate students researchers professors and field engineers due to its combination of both theoretical coverage and real world application concepts *Proceedings of the 3rd International Conference on Electrical and Information Technologies for Rail Transportation (EITRT) 2017* Limin Jia, Yong Qin, Jianguo Suo, Jianghua Feng, Lijun Diao, Min An, 2018-03-30 The proceedings collect the latest research trends methods and experimental results in the field of electrical and information technologies for rail transportation The topics cover novel traction drive technologies of rail transportation safety technology of rail transportation system rail transportation information technology rail transportation operational management technology rail transportation cutting edge theory and technology etc The proceedings can be a valuable reference work for researchers and graduate students working in rail transportation electrical engineering and information technologies **Power Converters and AC Electrical Drives with Linear Neural Networks** Maurizio Cirrincione, Marcello Pucci, Gianpaolo Vitale, 2017-12-19 The first book of its kind Power

Converters and AC Electrical Drives with Linear Neural Networks systematically explores the application of neural networks in the field of power electronics with particular emphasis on the sensorless control of AC drives. It presents the classical theory based on space vectors in identification, discusses control of electrical drives and power converters, and examines improvements that can be attained when using linear neural networks. The book integrates power electronics and electrical drives with artificial neural networks (ANN). Organized into four parts, it first deals with voltage source inverters and their control. It then covers AC electrical drive control focusing on induction and permanent magnet synchronous motor drives. The third part examines theoretical aspects of linear neural networks, particularly the neural EXIN family. The fourth part highlights original applications in electrical drives and power quality, ranging from neural-based parameter estimation and sensorless control to distributed generation systems from renewable sources and active power filters. Simulation and experimental results are provided to validate the theories. Written by experts in the field, this state-of-the-art book requires basic knowledge of electrical machines and power electronics, as well as some familiarity with control systems, signal processing, linear algebra, and numerical analysis. Offering multiple paths through the material, the text is suitable for undergraduate and postgraduate students, theoreticians, practicing engineers, and researchers involved in applications of ANNs.

Industrial Applications of Power Electronics Eduardo M. G. Rodrigues, Edris Pouresmaeil, Radu Godina, 2020-12-01

In recent years, power electronics have been intensely contributing to the development and evolution of new structures for the processing of energy. They can be used in a wide range of applications, ranging from power systems and electrical machines to electric vehicles and robot arm drives. In conjunction with the evolution of microprocessors and advanced control theories, power electronics are playing an increasingly essential role in our society. Thus, in order to cope with the obstacles lying ahead, this book presents a collection of original studies and modeling methods which were developed and published in the field of electrical energy conditioning and control by using circuits and electronic devices, with an emphasis on power applications and industrial control. Researchers have contributed 19 selected and peer-reviewed papers covering a wide range of topics by addressing a wide variety of themes such as motor drives, AC/DC and DC/DC converters, multilevel converters, varistors, and electromagnetic compatibility, among others. The overall result is a book that represents a cohesive collection of inter multidisciplinary works regarding the industrial applications of power electronics.

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