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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 sensored 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.*

I. 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

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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 Induction Motor* Robiah Ahmad,Universiti Teknologi Malaysia. Fakulti Kejuruteraan Mekanikal,2007 *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 *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 d q 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 **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

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 *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 **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 **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 **Speed Sensorless Induction Motor Drives for Electrical**

Actuators: Schemes, Trends and Tradeoffs ,1997 *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 **Sensorless Speed Control of Induction Motor Using Differential Algebraic Speed Estimator** Hafidzah Ahmad,2013 *Nature-Inspired Computation and Machine Learning* Alexander Gelbukh,Félix Castro Espinoza,Sofía N. Galicia-Haro,2014-11-05 The two volume set LNAI 8856 and LNAI 8857 constitutes the proceedings of the 13th Mexican International Conference on Artificial Intelligence MICAI 2014 held in Tuxtla Mexico in November 2014 The total of 87 papers plus 1 invited talk presented in these proceedings were carefully reviewed and selected from 348 submissions The first volume deals with advances in human inspired computing and its applications It contains 44 papers structured into seven sections natural language processing natural language processing applications opinion mining sentiment analysis and social network applications computer vision image processing logic reasoning and multi agent systems and intelligent tutoring systems The second volume deals with advances in nature inspired computation and machine learning and contains also 44 papers structured into eight sections genetic and evolutionary algorithms neural networks machine learning machine learning applications to audio and text data mining fuzzy logic robotics planning and scheduling

and biomedical applications **Speed Estimation Techniques for Induction Motor Using Digital Signal Processing** Solly Aryza,2011 Speed estimation is one of the methodsof speed sensor less control for three phase induction motors With the advancement of the power electronics switching devices and digital technologies the developments of speed estimation methods have been intensively implemented from many researchers Thus this field of research has become more interested to investigate Speed sensor less control techniques can make the hardware simple and improve the reliability of the motor without the introducing the feedbacksensor and it becomes more important in the modern AC servo drive It is one of the attracting research directions in the high precision servo control field because of its robust characteristics simple realization and excellent dynamic response Several common rotor speed estimation was introduced in the thesis The model must accurately represent both the electrical and electromagnetic interactions within the machine and associated mechanical systems In this Thesis the neural networks controller for speed estimation has been developed approach to induction motor that has been implemented in digital signal processing controller DSP and gave the control signal to IGBT for run three phase inductions motor Analysis of speed estimation nonlinear characteristics is carried out and makes a comparison with traditional linear method speed sensor less method First the simulation of the proposed control system is performed by using the MATLAB software and then the real time implementation is performed by using the MATLAB and the hardware According to the mathematical model of the induction motor the simulation of model and hardware implementation of speed sensor less induction motor had been successfully implemented The design and implementation of the speed estimation system for three phase induction motor and the experimental research is presented in this Thesis Finally this Thesis shows the implementation of the speed estimation using DSP controller and the design of hardware and software for speed sensorless of induction motor The experiment is completed at different speed and experiment results show that artificial neural network controller obtained a good response when compared to conventional methods *Technological Developments in Education and Automation* Magued Iskander,Vikram Kapila,Mohammad A. Karim,2010-01-30 Technological Developments in Education and Automation includes set of rigorously reviewed world class manuscripts dealing with the increasing role of technology in daily lives including education and industrial automation Technological Developments in Education and Automation contains papers presented at the International Conference on Industrial Electronics Technology Automation and the International Conference on Engineering Education Instructional Technology Assessment and E learning which were part of the International Joint Conferences on Computer Information and Systems Sciences and Engineering

Flux, Position, and Velocity Estimation in AC Machines Using Carrier Signal Injection Michael W. Degner,1998

Proceedings of the ... Annual Conference of the IEEE Industrial Electronics Society IEEE Industrial Electronics Society. Conference,2004 **Speed-sensorless Estimation and Position Control of Induction Motors for Motion Control Applications** Murat Barut,2006 High performance sensorless position control of induction motors IMs calls for estimation

and control schemes which offer solutions to parameter uncertainties as well as to difficulties involved with accurate flux and velocity estimation at very low and zero speed In this thesis novel control and estimation methods have been developed to address these challenges The proposed estimation algorithms are designed to minimize estimation error in both transient and steady state over a wide velocity range including very low and persistent zero speed operation To this aim initially single Extended Kalman Filter EKF algorithms are designed to estimate the flux load torque and velocity as well as the rotor Rr or stator Rs resistances The temperature and frequency related variations of these parameters are well known challenges in the estimation and control of IMs and are subject to ongoing research To further improve estimation and control performance in this thesis a novel EKF approach is also developed which can achieve the simultaneous estimation of R r and Rs for the first time in the sensorless IM control literature The so called Switching and Braided EKF algorithms are tested through experiments conducted under challenging parameter variations over a wide speed range including under persistent operation at zero speed Finally in this thesis a sensorless position control method is also designed using a new sliding mode controller SMC with reduced chattering The results obtained with the proposed control and estimation schemes appear to be very compatible and many times superior to existing literature results for sensorless control of IMs in the very low and zero speed range The developed estimation and control schemes could also be used with a variety of the sensorless speed and position control applications which are challenged by a high number of parameter uncertainties 1996 IEEE Instrumentation and Measurement Technology Conference ,1996

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