Sensor Less Speed Control Of Pmsm Using Svpwm Technique

Proceedings of the IEEE International Conference on Industrial Technology (ICIT).
Speed Control of Sensorless Brushless DC Motor
Sensorless Control of Induction Motors
Sensorless Speed and Position Control of Induction Motor Drives
Speed Control of Sensorless Rotor Field Oriented for Faulty Three-phase Induction Motor by Using Extended Kalman Filter
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Sensorless speed control of a switched reluctance motor
Method and System for Controlling Angular Speeds of Motors in Speed Sensorless Induction Motors

Proceedings of the IEEE International Conference on Industrial Technology (ICIT ).
Speed Control of Sensorless Brushless DC Motor

Speed Sensorless Control of Induction Motors

Abstract: Induction machines are widely used in industry application. Consequently more and more attention has been given to design and development of induction machine control. High performance of induction machine control is achieved by so called field orientation control (FOC). Speed sensorless technology has also been proposed for decades to overcome the disadvantages of cost and fragility of a mechanical speed sensor. However, due to the high order, multiple variables and nonlinearity of induction machine dynamics, the development of advanced induction machine control is still a challenging task. In this research, a sliding mode based flux and speed estimation technique for speed sensorless control of field oriented induction machine is first investigated. The parameter sensitivity of the control method is also analyzed. A robust sliding mode speed controller is also presented, which has the advantage of disturbance rejection and avoiding re-tuning gains comparing to traditional PI controller Then an adaptive sliding mode observer is proposed and the stability is verified by Lyapunov theory. Two sliding mode current observers are utilized to compensate the effects of parameter variation on the rotor flux estimation, which make flux estimation more accurate and insensitive to parameter variation. The convergence of the estimated flux to actual rotor flux is proved by the Lyapunov stability theory. Finally, an efficiency optimization method which does not require extra hardware and is insensitive to motor parameters is presented. The relationship between stator current
minimization and motor loss minimization in the induction motor vector control system is investigated. A fuzzy logic based search method is simulated and implemented. It is determined that the motor loss minimization can be achieved by minimizing stator current in practice. An experimental setup is presented in the appendix to verify the proposed approaches. The simulation and experimental results are presented to demonstrate the potential and practicality of the presented approaches.

**Sensorless Speed and Position Control of Induction Motor Drives**

ABSTRACT SENSORLESS DIRECT FIELD ORIENTED CONTROL OF INDUCTION MACHINE BY FLUX AND SPEED ESTIMATORS USING MODEL REFERENCE ADAPTIVE SYSTEM

This work focuses on an observer design which will estimate flux-linkage and speed for induction motors in its entire speed control range. The theoretical base of the algorithm is explained in detail and its both open-loop, and closed-loop performance is tested with experiments, measuring only stator current and voltage. Theoretically, the field-oriented control for the induction motor drive can be mainly categorized into two types.

**Speed Control of Sensorless Rotor Field Oriented for Faulty Three-phase Induction Motor by Using Extended Kalman Filter**

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 Rr' 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.

**Sensorless Zero Speed Control of Induction Motors**

**Proceedings**
Sensorless Speed Control of Induction Motors Using Sliding Mode Control Strategy

Speed-sensorless Estimation and Position Control of Induction Motors for Motion Control Applications

Position and Speed Sensorless Control of Permanent Magnet Synchronous Motors

Este trabalho propõe uma análise comparativa do desempenho de técnicas de controle e estimação de velocidade, com realização discreta no tempo, aplicadas a motores de indução trifásicos, utilizando plataforma com base em um processador digital de sinais de ponto-fixo. Algumas modificações em algoritmos existentes na literatura são propostas para melhorar o desempenho das técnicas em estudo. Inicialmente, uma revisão histórica sobre a evolução dos sistemas de acionamento para motores de corrente alternada e uma revisão bibliográfica das principais técnicas de estimação de velocidade implementadas em DSP são realizadas. Em seguida, são obtidos diferentes modelos para o motor de indução trifásico representados em referenciais semi-estacionários. A partir do modelo da máquina foram projetados dois controladores de velocidade: um controlador clássico e amplamente utilizado no meio industrial (PI), e, com o objetivo de compensar distúrbios e dinâmicas não modeladas, um controlador adaptativo robusto por modelo de referência (RMRAC) é implementado. Para o projeto de servomecanismos sensorless de alto desempenho, duas técnicas de estimação de velocidade baseadas no modelo do MI foram selecionadas. Uma delas é amplamente
difundida. no meio acadêmico e industrial, sendo fundamentada em um sistema adaptativo por modelo de referência (MRAS) e outra tem base em um algoritmo de mínimos quadrados recursivos modificado (MRLS) e é apresentada como uma alternativa de alto desempenho. No desenvolvimento deste trabalho, resultados de simulações utilizando o software Matlab®, simulações em tempo-real em plataforma DSP, e por fim, resultados experimentais são apresentados. A partir destes resultados, parte-se para avaliação para determinar quais dos controladores sensorless analisados apresentam resposta dinâmica satisfatória em uma larga faixa de velocidade, inclusive em condições de velocidade baixa e nula, e também diante de situações de variação de carga e de parâmetros.

SPEED ESTIMATION TECHNIQUES FOR SENSORLESS VECTOR CONTROLLED INDUCTION MOTOR DRIVE.

Complete with a tutorial introduction, this convenient anthology of the foremost technical papers on sensorless control of AC motor drives discusses the full range of methods and schemes for cost-effective speed sensorless operation of induction motors, position sensorless operation of PM motors, sensorless operation of synchronous motors, and switched reluctance motors.

Sensorless Control of a PM Motor from Standstill Up to Nominal Speed

This monograph shows the reader how to avoid the burdens of sensor cost, reduced internal physical space, and system complexity in the control of AC motors. Many applications fields—electric vehicles, wind- and wave-energy converters and robotics, among them—will benefit.
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Sensorless AC Electric Motor Control describes the elimination of physical sensors and their replacement with observers, i.e., software sensors. Robustness is introduced to overcome problems associated with the unavoidable imperfection of knowledge of machine parameters—resistance, inertia, and so on—encountered in real systems. The details of a large number of speed-and/or position-sensorless ideas for different types of permanent-magnet synchronous motors and induction motors are presented along with several novel observer designs for electrical machines. Control strategies are developed using high-order, sliding-mode and quasi-continuous-sliding-mode techniques and two types of observer-controller schemes based on backstepping and sliding-mode techniques are described. Experimental results validate the performance of these observer and controller configurations with test trajectories of significance in difficult sensorless-AC-machine problems. Control engineers working with AC motors in a variety of industrial environments will find the space-and-cost-saving ideas detailed in Sensorless AC Electric Motor Control of much interest. Academic researchers and graduate students from electrical, mechanical and control-engineering backgrounds will be able to see how advanced theoretical control can be applied in meaningful real systems.

Sensorless Control of the BLDC Motors from Near-zero to Full Speed

Focus of this work is closed-loop speed control of an induction machine based on direct field-oriented control (DFOC) algorithm, using estimates of speed and flux observers which utilize only stator current and voltage. Theoretical bases of the algorithms are explained in detail and their performances are investigated with simulations.
and experiments. Field Orientated Control is based on projections which transform a threephase 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. Transformations are done in synchronous frame alligned to d-axis of rotor flux. So rotor flux position must be known accurately to make these transformations. Degined flux observer, in which voltage model is assisted by current model via a closed-loop to compensate voltage model2s disadvantages, estimates the position of the rotor flux. Obtaining adequate torque control via FOC, speed loop is closed using conventional PI regulators. Speed feedback is necessary to complete control loop. Model Reference Adaptive System is studied as a speed estimator. Reactive power scheme is applied to MRAS algorithm to estimate rotor speed. In this study, the direct (rotor) flux oriented control system with flux and speed estimators is described and tested in real-time with the starter kit named TMS320F2812 eZdsp DSK and the Embedded Target for the TI C2000 DSP tool of Matlab.

Development of Adaptive Speed Observers for Induction Machine System Stabilization

Flux and Speed Estimation Techniques for Sensorless Control of Induction Motors

Sensorless Speed Control of PMSM Drives Using DSSPACE DS1103 Board

Sensorless AC Electric Motor Control
SENSORLESS DIRECT FIELD ORIENTED CONTROL OF INDUCTION MACHINE BY FLUX AND SPEED ESTIMATION USING MODEL REFERENCE ADAPTIVE SYSTEM.

This book is all about running a brushless DC motor using a sensorless technique. The target of the work was to make a very simple operating method for a brushless motor and formulate a speed control mechanism. Initially the work was started with both considering back-EMF and without considering back-EMF. Because of more complexity in the back-EMF sensing method, and as our intention was to make a simpler and cost effective operation, so finally we assembled our project the without back-EMF sensing. Even though being a simple and inexpensive machine, the performance was quite good. However adding back-EMF sensing in this machine can give it more dependability.

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Energy Efficiency in Electric Devices, Machines and Drives

Sensorless Speed Control of Permanent Magnet Synchronous Motor

This Special Issue deals with improvements in the energy efficiency of electric devices, machines, and drives, which are achieved through improvements in the design,
modelling, control, and operation of the system. Properly sized and placed coils of a welding transformer can reduce the required iron core size and improve the efficiency of the welding system operation. New structures of the single-phase field excited flux switching machine improve its performance in terms of torque, while having higher back-EMF and unbalanced electromagnetic forces. A properly designed rotor notch reduces the torque ripple and cogging torque of interior permanent magnet motors for the drive platform of electric vehicles, resulting in lower vibrations and noise. In the field of modelling, the torque estimation of a Halbach array surface permanent magnet motor with a non-overlapping winding layout was improved by introducing an analytical two-dimensional subdomain model. A general method for determining the magnetically nonlinear two-axis dynamic models of rotary and linear synchronous reluctance machines and synchronous permanent magnet machines is introduced that considers the effects of slotting, mutual interaction between the slots and permanent magnets, saturation, cross saturation, and end effects. Advanced modern control solutions, such as neural network-based model reference adaptive control, fuzzy control, senseless control, torque/speed tracking control derived from the 3D non-holonomic integrator, including drift terms, maximum torque per ampere, and maximum efficiency characteristics, are applied to improve drive performance and overall system operation.

**A New Observer for Speed Sensorless Field Oriented Control of an Induction Motor**

Angular speed of a rotor of an induction motor without an encoder for rotor position and speed sensing is controlled by first sensing stator currents and voltages of the induction motor. A dynamic gain estimator is designed by applying a state transformation to a model of the induction motor.
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motor. A states of the induction motor is estimated by applying the dynamic gain estimator to the currents and the voltages, and then the state is used to control the angular speed of the rotor of the induction motor.

Nonlinear Sensorless Indirect Adaptive Position and Speed Control of Induction Motor with Unknown Rotor Resistance

Fuzzy Logic Based Exact Sensorless Speed Control of Induction Motor at Low Range of Operations

Sensorless Control of AC Motor Drives

Adaptive Sliding Mode Observer and Loss Minimization for Sensorless Field Orientation Control of Induction Machine

Sensorless Speed Control of Permanent Magnet-assisted Synchronous Reluctance Motor (PMa-synRM)

Integrated Sliding-Mode Sensorless Driver with Pre-driver and Current Sensing Circuit for Accurate Speed Control of PMSM.

Sensorless Speed Estimation of an Induction Motor
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Motor

Speed Sensorless Vector Control of Induction Machine

Modeling and Analysis of Four Quadrant Sensorless Control of a Switched Reluctance Machine Over the Entire Speed Range

Proceedings of the 1995 IEEE IECON: Signal processing and control, Robotics vision and sensors, Emerging technologies, and Factory automation

"The excitation of the switched reluctance motor (SRM) phases needs to be carefully synchronized with rotor position to obtain an acceptable drive performance. Therefore, rotor position sensing is an integral part of the SRM drives control. Additionally, for precise torque and speed control applications, it is necessary to have rotor position information with reasonably good resolution and high degree of accuracy. Sensorless control methods are an attractive approach in which the rotor position is sensed indirectly without a discrete mechanical position sensor. In the past, several methods have been developed to replace the discrete position sensor. Some of these methods are inductance based while others are flux based. Unfortunately, all of them were confined with the estimation to a limited range of speed and for only one quadrant operation. This dissertation develops a four-quadrant sensorless controller for SRM drives functioning over low and high speeds, including zero speed, with a
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high resolution position information over the entire speed range. This four-quadrant sensorless controller combines two different methods. At zero and low speeds, a pulse injection position estimation method is used to estimate the rotor position in all four quadrants. At high speeds, a sliding mode observer (SMO) based position and speed estimation is used and combined to work with the low speed algorithm. The transition between the algorithms is smooth and transparent to the inner loop torque controller. The accuracy and resolution of the sensorless controller developed in the research has been enhanced through the use of a novel switched reluctance (SR) machine model based on the Fourier series expansion that is accurate and invertible. This model, derived from machine geometry and materials properties, is accurate enough to be used for actual machine representation, and can also be simplified for real time sensorless controller application. The model predicts both the inductance and flux linkage accurately for use in various sensorless control algorithms. The experimental tests performed showed accurate position estimation using the new Fourier model. The error analysis performed in this research demonstrated the superiority of the Fourier model over the models developed in previous research."--iii-iv.

Sensorless Speed Control of Induction Motor Using Differential Algebraic Speed Estimator

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.

Slip Estimation for Induction Motors in Speed Control Applications with Particular Reference to Sensorless Field Oriented Controlled Drives

Sensorless Speed Control of a Csi-fed Field Oriented Controlled Induction Machine

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.

**Comparison of speed sensorless control techniques applied to induction motors in a DSP platform**

**Sensorless Speed Control of Vector Controlled Reluctance Synchronous Motor Drives**

An interesting alternative for today's high efficiency variable speed drives is the Permanent Magnet-Assisted Synchronous Reluctance Motor drive, which belongs to the family of brushless synchronous AC motor drives. Generally, the reluctance torque of this motor is significant compared to the Permanent Magnet electrical torque. The advantage of increased reluctance torque is the decreased need of expensive permanent magnet (PM) material, which makes this solution thus cheaper than the respective permanent magnet motor. Also due to its synchronous operation, sensorless rotational control is possible along with higher power factor and better efficiency compared to the induction motor (IM). Therefore, this thesis first deals with the implementation of a vector control strategy for speed control of the PMa-synRM motor that can be applied to a washing machine application. The machine is supplied by a current controlled voltage source PWM inverter to control the instantaneous stator currents which are decided by the reference speed. Secondly, the thesis focuses on the sensorless speed operation of the PMa-SynRM to take advantage of the lower costs as well as increased system reliability which otherwise is not possible using the delicate speed or position sensors. The concept involves estimation of the rotor speed and/or position.
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There are several speed estimation techniques proposed by researchers and among them the observer based technique is proven and commonly used in the industry. The only requirements of the observer system are a very fast signal processor, specialized and optimized to perform complex mathematical calculations. The feasibility and effectiveness of the control techniques are verified using the experimental results, implemented using the Texas Instruments TMS320F2812 eZDSP controller board and the overall motor drive system in the laboratory.

Investigation of Sensorless Flux and Speed Estimation for Direct Torque Control of PMSM

Quasi and Fully Sensorless Speed Control of Indirect RFOC Induction Motor Drives for Low Speed Operation

Sensorless speed control of a switched reluctance motor

Method and System for Controlling Angular Speeds of Motors in Speed Sensorless Induction Motors

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