Sensorless Control of Induction Motor Based on Differential Flatness Theory and Reduced MRAS Observer

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ABSTRACT

In this paper, the authors propose a hybrid sensorless control method of IM. This method consists of using the differential flatness theory and reduced MRAS observer. The control design proceeds by showing that each input of the motor model stands for a differentially flat system, where the flat output is chosen to be the associated state variable. Next, for each regulation loop a virtual control input is computed that can invert the loop's dynamics and can eliminate the system's tracking error. The reduced MRAS observer is used to estimate the rotor speed and flux. Simulation and experimental results are presented to illustrate the effectiveness of the proposed approach for sensorless control of the induction motor.

KEYWORDS

Differential Flatness Theory, Induction Motor, Reduced MRAS Observer, Sensorless Vector Control

1. INTRODUCTION

The sensorless control of induction machine is a very broad area of research, and for that, a very large number of researches who have contributed to this. However, many problems related to parametric variations and the mechanical speed sensor still persist. Vector control and especially sensorless control can lose its performance because of these problems, because generally this kind of control depends on the stator and rotor time constant (Armando, Boglietti, Musumeci, & Rubino, 2021) (Savaragu & Narri), in this context, several strategies have been proposed in the literature to realize the sensorless control of this machine. A large part of the proposed methods is based on observers depending on the model of the asynchronous machine (Vasu, Thalluru, & Kumar, 2021), (Adamczyk & Orlowska-Kowalska, 2021; Al-Rouh, 2004; Comanescu, 2016; De Wit, Ortega, & Mareels, 1996; Manceur, 2012; Morand, 2005; Beddiaf Yassine, Fatiha, & Chrifi-Alaoui; Zbede, Gadoue, & Atkinson, 2016). Other research is on the contribution of artificial intelligence to improve sensorless control of the machine(Abdollahi, 2021) (Chang, Espinosa-Perez, Mendes, & Ortega, 2000; De Doncker & Novotny, 1994; Hussein, Ammar, & Hassan, 2017; Ismail, 2012; Lorenz, Lipo, & Novotny, 1994). In paper (Enany, Wahba, & Hassan, 2014) the author proposes a new technique to model the stator winding, for using to validate a remote and sensorless stator winding temperature estimation technique. (Salima, Loubna, & Riad, 2018) present a global stability and robust nonlinear controller applied to induction motor. (Mustafa, Nikolakopoulos, & Gustafsson, 2014) present a fault classification algorithm based on a robust linear discrimination scheme, this technique is applied to detect of two kinds of Induction

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Dfig Control Using Differential Flatness Theory And

Gerasimos Rigatos

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Nonlinear Control and Filtering Using Differential Flatness Approaches Gerasimos G. Rigatos,2015-06-05 This monograph presents recent advances in differential flatness theory and analyzes its use for nonlinear control and estimation It shows how differential flatness theory can provide solutions to complicated control problems such as those appearing in highly nonlinear multivariable systems and distributed parameter systems Furthermore it shows that differential flatness theory makes it possible to perform filtering and state estimation for a wide class of nonlinear dynamical systems and provides several descriptive test cases The book focuses on the design of nonlinear adaptive controllers and nonlinear filters using exact linearization based on differential flatness theory The adaptive controllers obtained can be applied to a wide class of nonlinear systems with unknown dynamics and assure reliable functioning of the control loop under uncertainty and varying operating conditions The filters obtained outperform other nonlinear filters in terms of accuracy of estimation and computation speed The book presents a series of application examples to confirm the efficiency of the proposed nonlinear filtering and adaptive control schemes for various electromechanical systems These include industrial robots mobile robots and autonomous vehicles electric power generation electric motors and actuators power electronics internal combustion engines distributed parameter systems and communication systems Differential Flatness Approaches to Nonlinear Control and Filtering will be a useful reference for academic researchers studying advanced problems in nonlinear control and nonlinear dynamics and for engineers working on control applications in electromechanical systems State-Space Approaches for Modelling and Control in Financial Engineering Gerasimos G. Rigatos,2017-04-04 The book conclusively solves problems associated with the control and estimation of nonlinear and chaotic dynamics in financial systems when these are described in the form of nonlinear ordinary differential equations It then addresses problems associated with the control and estimation of financial systems governed by partial differential equations e g the Black Scholes partial differential equation PDE and its variants Lastly it an offers optimal solution to the problem of statistical validation of computational models and tools used to support financial engineers in decision making The application of state space models in financial engineering means that the heuristics and empirical methods currently in use in decision making procedures for finance can be eliminated It also allows methods of fault free performance and optimality in the management of assets and capitals and methods assuring stability in the functioning of financial systems to be established Covering the following key areas of financial engineering i control and stabilization of financial systems dynamics ii state estimation and forecasting and iii statistical validation of decision making tools the book can be used for teaching undergraduate or postgraduate courses in financial engineering It is also a useful resource for the engineering and computer science community **Advanced Methodologies and Technologies in Business Operations and Management** Khosrow-Pour, D.B.A., Mehdi,2018-09-14 Businesses consistently work on new projects products and workflows to remain competitive and successful in the modern

business environment To remain zealous businesses must employ the most effective methods and tools in human resources project management and overall business plan execution as competitors work to succeed as well Advanced Methodologies and Technologies in Business Operations and Management provides emerging research on business tools such as employee engagement payout policies and financial investing to promote operational success While highlighting the challenges facing modern organizations readers will learn how corporate social responsibility and utilizing artificial intelligence improve a company s culture and management This book is an ideal resource for executives and managers researchers accountants and financial investors seeking current research on business operations and management Intelligent Renewable Energy Systems Gerasimos Rigatos,2016-08-06 Focused on renewable energy systems and the development of information and communication technologies ICTs for their integration in smart grids this book presents recent advances and methods that help to ensure that power generation from renewable sources remains stable that power losses are minimized and that the reliable functioning of these power generation units is maintained The book highlights key topics and technologies for renewable energy systems including the intelligent control of power generators power electronics that connect renewable power generation units to the grid and fault diagnosis for power generators and power electronics In particular the following topics are addressed Modeling and control of power generators PMSGs DFIGs Modeling and control of power electronics converters inverters Modeling and fault diagnosis of the transmission and distribution Grid and Modelling and control of distributed power generation units interconnected synchronous generators or photovoltaic units Because of the above coverage members of the wider engineering community will find that the nonlinear control and estimation methods presented provide essential insights into the functioning of renewable energy power systems while the academic community will find the book a valuable textbook for undergraduate or graduate courses on renewable energy systems

Encyclopedia of Information Science and Technology, Fourth Edition Khosrow-Pour, D.B.A., Mehdi,2017-06-20 In recent years our world has experienced a profound shift and progression in available computing and knowledge sharing innovations These emerging advancements have developed at a rapid pace disseminating into and affecting numerous aspects of contemporary society This has created a pivotal need for an innovative compendium encompassing the latest trends concepts and issues surrounding this relevant discipline area During the past 15 years the Encyclopedia of Information Science and Technology has become recognized as one of the landmark sources of the latest knowledge and discoveries in this discipline The Encyclopedia of Information Science and Technology Fourth Edition is a 10 volume set which includes 705 original and previously unpublished research articles covering a full range of perspectives applications and techniques contributed by thousands of experts and researchers from around the globe This authoritative encyclopedia is an all encompassing well established reference source that is ideally designed to disseminate the most forward thinking and diverse research findings With critical perspectives on the impact of information science management and new technologies

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Advances in Applied Nonlinear Optimal Control Gerasimos Rigatos,Electra Karapanou,2020-11-19 This volume discusses advances in applied nonlinear optimal control comprising both theoretical analysis of the developed control methods and case studies about their use in robotics mechatronics electric power generation power electronics micro electronics biological systems biomedical systems financial systems and industrial production processes The advantages of the nonlinear optimal control approaches which are developed here are that by applying approximate linearization of the controlled systems state space description one can avoid the elaborated state variables transformations diffeomorphisms which are required by global linearization based control methods The book also applies the control input directly to the power unit of the controlled systems and not on an equivalent linearized description thus avoiding the inverse transformations met in global linearization based control methods and the potential appearance of singularity problems The method adopted here also retains the known advantages of optimal control that is the best trade off between accurate tracking of reference setpoints and moderate variations of the control inputs The book s findings on nonlinear optimal control are a substantial contribution to the areas of nonlinear control and complex dynamical systems and will find use in several research and engineering disciplines and in practical applications **Control of Higher–Dimensional PDEs** Thomas Meurer,2012-08-13 This monograph presents new model based design methods for trajectory planning feedback stabilization state estimation and tracking control of distributed parameter systems governed by partial differential equations PDEs Flatness and backstepping techniques and their generalization to PDEs with higher dimensional spatial domain lie at the core of this treatise This includes the development of systematic late lumping design procedures and the deduction of semi numerical approaches using suitable approximation methods Theoretical developments are combined with both simulation examples and experimental results to bridge the gap between mathematical theory and control engineering practicein the rapidly evolving PDE control area The text is divided into five parts featuring a literature survey of paradigms and control design methods for PDE systems the first principle mathematical modeling of applications arising in heat and mass transfer interconnected multi agent systems and piezo actuated smart elastic structures the generalization of flatness based trajectory planning and feedforward control to parabolic and biharmonic PDE systems defined on general higher dimensional domains an extension of the backstepping approach to the feedback control and observer design for parabolic PDEs with parallelepiped domain and spatially and time varying parameters the development of design techniques to realize exponentially stabilizing tracking control the evaluation in simulations and experiments Control of Higher Dimensional PDEs Flatness and Backstepping Designs is an advanced research monograph for graduate students in applied mathematics

controltheory and related fields The book may serve as a reference to recent developments for researchers and control engineers interested in the analysis and control of systems governed by PDEs **Differential Flatness Based Design, Planning and Control for Classes of Under-actuated Systems** Vivek Sangwan,2010 Under actuated systems arise in numerous situations In certain applications such as walking robots it is unavoidable as there are phases in walking cycle where the leg tips along the heel or the toes Under actuation can be a better design choice for robots in space and industrial applications due to cost and dead weight considerations Another instance where under actuation finds application is in restoring operation in spite of actuator failure Control of nonlinear under actuated systems is an area of ongoing research In general for an under actuated system not all state trajectories are dynamically feasible and it is hard to characterize feasible trajectories analytically Even if a feasible trajectory is found designing a controller for an under actuated system is also a difficult task Differential flatness if applicable provides a systematic unified approach to i plan dynamically feasible trajectories and ii design a controller that can track those trajectories However a nonlinear under actuated system may not be differentially flat This work presents an approach to design under actuated systems to be differentially flat enabling a systematic trajectory planning and control The design methodology has two parts i a recursive inertia distribution scheme that places the center of mass COM of links at specific locations and ii an actuator and torque spring placement scheme This approach for Design Planning and Control is applied to two classes of under actuated systems i Planar Open Chain Manipulators and ii Bipedal Walking Robots Feasible trajectories are constructed using SQP based numerical optimization The optimization algorithm allows to find trajectories that satisfy motion constraints such as limit on torques for serial chain manipulator ground clearance of the swinging leg for walking robot etc A linear full state feedback controller is designed in the flat output domain to track desired trajectories Results from trajectory planning and dynamic simulations of flatness based tracking are presented for both systems Based on the design methodology experimental prototypes of i a three degree of freedom DOF under actuated manipulator and ii a four link bipedal robot have been fabricated The flatness based control methodology is experimentally demonstrated using the 3 DOF robotic arm Effect of two kinds of non idealities on the flatness based controller is studied i parametric uncertainties and ii unmodeled viscous friction at unactuated joints For parametric uncertainties it is shown that under certain conditions a robust controller can be designed For viscous friction it is shown that i for the original set of flat outputs a stable internal dynamics is induced and ii the system remains differentially flat with an alternate set of outputs Results from tracking simulations for both conditions are presented This work essentially integrates the Planning and Control of Under Actuated Mechanical Systems with their Design It has been demonstrated by simulations and experiments that certain classes of under actuated systems can be designed to be differentially flat enabling a systematic trajectory planning and control It is also shown that certain types of non idealities can be compensated with a robust control strategy or a modification in the flat outputs With additional design features such as locks at unactuated joints

these designs can potentially provide a cheaper alternative for fully actuated robots in applications where point to point motion is desired This work suggests that it can be beneficial to design a system not just from the perspective of the actual task at hand but also from the perspective of Planning and Control **Differentially Flat Systems** Hebertt Sira-Ramírez,Sunil K. Agrawal,2018-10-03 Illustrating the power simplicity and generality of the concept of flatness this reference explains how to identify utilize and apply flatness in system planning and design The book includes a large assortment of exercises and models that range from elementary to complex classes of systems Leading students and professionals through a vast array of designs simulations and analytical studies on the traditional uses of flatness Differentially Flat Systems contains an extensive amount of examples that showcase the value of flatness in system design demonstrate how flatness can be assessed in the context of perturbed systems and apply static and dynamic feedback controller design techniques **Real-time Modeling and Optimal Real and Reactive Power Management of DFIG Using Adaptive Control/** Rabindra Maharjan,University of North Carolina at Charlotte. Department of Electrical and Computer Engineering,2013 the advancement in computing technology real time simulation in small precise time step is possible Simulation with real physical device is possible with these simulators The controller testing can be done with real devices with these simulators The thesis details about the real time simulation to test the controller and its implementation in hardware in loop simulation with the proposed adaptive control method for sensorless operation and reactive power control of DFIG **Development of Vector Control System of DFIG Using Graphically Programmed DSP** Tomasz Drabek,Tomasz Lerch,Szymon Słonka,2016

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