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Applied Control of Electrical Drives

Real Time Embedded and Sensorless Control using VisSim™ and PLECS™

Springer

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In memory of Prof. ir. J.A. Schot

1927–2015

Foreword

Control of adjustable speed drives has developed at a rapid pace ever since the introduction of digital signal processors (DSPs), first by Texas Instruments, in the early eighties. Digital control of inverter fed machines, such as induction, synchronous machines or switched reluctance machines, made possible the implementation of dynamic torque control algorithms developed in the late seventies. Combining DSPs with programmable logic devices to control and protect the power electronic PWM voltage source inverters enabled torque control with high precision and wide bandwidth. Today, as more computational power can be integrated at low cost, more sophisticated algorithms can be implemented to make drives more robust, smarter, and easier to integrate in various applications. For example, modern drives are equipped with algorithms that automatically tune field oriented (torque) control parameters of rotating field machines. Sensor-fusion for eliminating expensive position encoders is yet another development that finds its way into state-of-the-art drive systems. No doubt, when looking at modern, high-performance drives today, any novice to the field may feel overwhelmed by the complexity of the controllers developed over the past 35 years. With this book, the authors aim to provide tools for practicing engineers and researchers alike, helping them to become familiar with the control of modern electrical drive systems, in particular drives based on induction (IM) and synchronous permanent magnet (PM) machines. In contrast to many works and publications on this matter, the authors present a systematic learning-by-doing approach. Using well-known software simulation tools, such as PLECS and TI's MotorWare laboratory software, the laboratory sessions of the book invite the reader to learn, step-by-step, field oriented control for rotating field (IM and PM) machines, open and closed loop torque control and position sensorless torque control. Using VisSim, an object oriented embedded control software package, the control algorithms can be readily validated experimentally in a (low voltage) drive system that has been developed specifically for this purpose.

The book is structured in well-defined modules, taking the reader through a sequence of laboratory sessions with increasing complexity. The learning targets of each module are clearly described, so that any drive designer can step in at his or her level of experience. As such, this work can be recommended as a reference book,

even to experienced drive designers. In addition, case studies illustrate how the transition of the control algorithms can be made to other (industrial) drive platforms.

The authors have been able to develop a unique learning platform to help readers quickly gain experience on how modern drive control algorithms function and how they can be developed. The book bundles state-of-the-art algorithms and software design tools that make development of inverter fed machines, not only a lot more productive, but also a fun experience, which I can recommend to anyone interested in the exciting field of electrical drive systems.

Aachen, Germany
January 2015

Prof. Dr. ir. Dr. h.c. Rik W. De Doncker

Preface

Our previous books, 'Fundamentals of Electrical Drives' [14] and 'Advanced Electrical Drives' [4], provide the reader with an in-depth understanding of the theoretical aspects of a drive, complemented by a series of simulations. The novelty of this book is that it takes a 'hands-on' electrical drive approach, designed to take the reader through a series of specific laboratory examples. These start with a basic AC drive and progress to sensored field-oriented control, and ultimately to sensorless control, using Texas Instruments InstaSPIN [9] technology for induction (three and single phase) and permanent magnet machines.

For this purpose, a low cost, low power dual drive hardware platform LAUNCHXL-F28069M, developed by Texas Instruments, is introduced together with an induction/PM machine combination. An embedded control approach using VisSim is used throughout this laboratory series, which allows the reader to concentrate on understanding drive operation. The comprehensive set of InstaSPIN based sensorless control laboratories for induction and PM machines included in this book is designed to familiarize the reader with this technology. Furthermore, case study examples are discussed that demonstrate the use of InstaSPIN in industrial applications. An alternative software development approach using VisSim and PLECS is also discussed where use is made of a 'processor in the loop' approach, which allows sensorless InstaSPIN drive development using either a model of the machine/converter or the actual drive. In this context, use is made of the Texas Instruments Code Composer software environment.

This book should appeal to industry and/or university based readers who have a need to understand electrical drives starting at a basic level with minimum theoretical content and/or develop their own AC drive application using sensored or sensorless technology. To accommodate this approach, the book has been configured in such a manner that the reader can step into the chapter of interest, without having to 'back flip' through the book.

In terms of content, this work starts with a basic overview of electrical drive principles, designed to provide the reader with key information on the critical parameters, which govern speed and current control. This is followed by a brief introduction on space vector modulation and fixed point scaling, given that many

applications still use ‘fixed point’ processors. The next three chapters deal with VisSim based ‘hands-on’ laboratory sessions on sensored drive control, sensorless PM and IM drive control using InstaSPIN. The final two chapters consider case studies where attention is given to industrial sensorless drive examples using VisSim and PLECS ‘processor in the loop’ technology. These last two chapters have been purposely added to assist the reader with making the transition from the material presented in this book to his/her own drive application. In terms of overall content, the reader is reminded of the fact that approximately 70% of the material presented in this book is associated with hardware/software. A disproportionately large amount of time, prior to publication, was used to remove hardware and software errors (bugs), but the reader is reminded to use the Springer ‘extra materials’ website link [11] for obtaining the latest files of the experiments that accompany this book.

It is our sincere hope and desire that this book will make electrical drives more accessible and understandable to those who have formerly been reluctant to engage with this technology.

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Acknowledgments

The process of writing this book has proved to be extremely challenging given the widespread use of experimental/practical examples. Furthermore, a decision was made to use the latest Texas Instruments drive hardware so that the reader would have the benefit of low cost companion hardware for this book. In addition, the development of software tools by VisSim and PLEXIM needed to be undertaken so that the reader can fully and seamlessly evaluate InstaSPIN based sensorless drive technology. Furthermore, the introduction of a 'case study' chapter where the reader can peruse the use of commercial drive platforms has led to some very intensive cooperation with the companies concerned. In all of the activities above, a significant number of individuals and companies have been involved, all of whom have been instrumental in getting this book to fruition. We would like to particularly thank the following persons (in alphabetical order) for their contributions: Beat Arnet, Robert Beekmans, Swaroop Bhushan, Chris Clearman, Wolfgang Hammer, Paul van der Hulst, Geert Kwintenberg, Dave Magee, Adam Reynolds, Eric Thomas, Gang Tian, Orhan Toker, Dave Wilson, Feitse van der Zou, Zhen Yu, and Jorge Zambada.

Last but not least, Prof. Pulle would like to acknowledge the feedback from the many attendees of my worldwide workshops that are associated with this book. No doubt that those who have attended will recognize the material presented and their feedback has been instrumental in getting this book where it is now.

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