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Analysis, Modeling, Control

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In memory of Prof. A. J. A. Vandenput
who has inspired the authors.

Foreword

The value of a textbook is largely determined by how well its structure supports the reader in mastering the depth and breadth of the intended subject. This textbook provides a structure that can achieve that goal for engineers seeking to master key technologies for a wide range of advanced electrical drives.

To achieve that goal it wisely places very significant, but common background material in the early chapters, where it introduces the core topologies of power converters and the key issues needed to understand and apply practical power electronic converters. It also lays a sound foundation for understanding the two fundamental approaches for current regulators: hysteresis control and model-based control. By providing a sound and detailed background on power converters and current regulators, the rest of the text is able to focus on the advanced electrical drive concepts that are unique to the major classes of machines: DC, AC synchronous machines, AC induction machines, and switched reluctance machines.

Common structures are used to great advantage. To develop a common basis for modeling and control, the machines that are predominately Lorentz force machines, i.e. the DC, AC synchronous, and AC induction (asynchronous) machines are all modeled using an ideal rotating transformer. By first applying it to the DC machine, the link to AC machines is very clear. Common modules are used to provide uniformity in the discussion between the various machine types and to be directly compatible with a simulation modeling environment. A similar structure is extensively used for the controls modules that follow the machine modules.

The text's separation of machine modeling from drive control is very helpful. Machine modeling lays a foundation such the controls can logically sequence from classical to advanced drive methodologies. The inclusion of both surface and interior permanent magnet synchronous machines is particularly relevant since those machines are beginning to dominate many applications. The significant treatment of field weakening operation is also critical. The inclusion of limits such as maximum current, maximum flux, maximum torque

per flux, and maximum torque per ampere make the range of operation of the machine drives very transparent. The universal field-oriented control structure is aptly used to unify the subsequent presentation of indirect and direct field orientation control methods.

A very clear transition is made from predominately Lorentz force-based machines to purely reluctance torque-based machines. The detailed modeling and evaluation of switched reluctance machines allows drives engineers to correctly model the inherently pulsating torque that each phase provides. The treatment of saturation and its affect on power conversion leads nicely into evaluation of drives with these properties. By including a rigorous discussion of classical hysteresis current control and multi-phase direct instantaneous torque control, the reader can appreciate the structure needed for high performance control of torque in switched reluctance drives.

Throughout the text, extensive tutorials tie modules that codify key concepts in the theory, to their implementation in a simulation environment. This makes it possible for the reader to quickly explore details and develop confidence in their mastery of major concepts for advanced electrical drives.

By following the approach of this book, I believe that advanced drive engineers will be able to develop depth and breadth that is not normally easy to achieve.

Madison, Wisconsin, U.S.A. *Robert D. Lorenz*

Preface

Mastering the synergy of electromagnetics, control, power electronics and mechanical concepts remains an intellectual challenge. Nevertheless, this barrier must be overcome by engineers and senior students who have a need or desire to comprehend the theoretical and practical aspects of modern electrical drives. In this context, the term *drive* represents a plethora of motion control systems as present in industry.

This book *Advanced Electrical Drives* builds on basic concepts outlined in the book *Fundamentals of Electrical Drives* by the same authors. Hence, it is prudent for the uninitiated reader to consider this material prior to tackling the more advanced material presented in this text. Others well versed in the basic concepts of electrical drives should be able to readily assimilate the material presented as every effort has been made to ensure that the material presented can be mastered without the need to continually switch between the books.

In our previous work, the unique concept of an *ideal rotating transformer* (IRTF), as developed by the authors, was introduced to facilitate the basic understanding of torque production in electrical machines. The application of the IRTF module to modern electrical machines as introduced in *Fundamentals of Electrical Drives* is fully explored in this volume and as such allows the user to examine a range of unique dynamic and steady-state machine models which covers brushed DC, non-salient/salient synchronous and induction machines.

In addition, this volume explains the *universal field oriented* (UFO) concept which demonstrates the concepts of modern vector control and exemplifies the seamless transition between so-called *stator flux* and *rotor flux* oriented control techniques. This powerful tool is used for the development of flux oriented machine models of rotating field machines. These models form the basis of UFO vector control techniques which are covered extensively together with traditional drive concepts. In the last sections of this book, attention is given to the dynamic modeling of *switched reluctance* (SR)