PREFACE

The chief objective of *Electric Machinery* continues to be to build a strong foundation in the basic principles of electromechanics and electric machinery. Through all of its editions, the emphasis of *Electric Machinery* has been on both physical insight and analytical techniques. Mastery of the material covered will provide both the basis for understanding many real-world electric-machinery applications as well as the foundation for proceeding on to more advanced courses in electric machinery design and control.

Although much of the material from the previous editions has been retained in this edition, there have been some significant changes. These include:

- A chapter has been added which introduces the basic concepts of power electronics as applicable to motor drives.
- Topics related to machine control, which were scattered in various chapters in the previous edition, have been consolidated in a single chapter on speed and torque control. In addition, the coverage of this topic has been expanded significantly and now includes field-oriented control of both synchronous and induction machines.
- MATLAB®[1] examples, practice problems, and end-of-chapter problems have been included in the new edition.
- The analysis of single-phase induction motors has been expanded to cover the general case in which the motor is running off both its main winding and its auxiliary winding (supplied with a series capacitor).

Power electronics are a significant component of many contemporary electric-machine applications. This topic is included in Chapter 10 of this edition of *Electric Machinery* in recognition of the fact that many electric-machinery courses now include a discussion of power electronics and drive systems. However, it must be emphasized that the single chapter found here is introductory at best. One chapter cannot begin to do justice to this complex topic any more than a single chapter in a power-electronics text could adequately introduce the topic of electric machinery.

The approach taken here is to discuss the basic properties of common power electronic components such as diodes, SCRs, MOSFETs, and IGBTs and to introduce simple models for these components. The chapter then illustrates how these components can be used to achieve two primary functions of power-electronic circuits in drive applications: rectification (conversion of ac to dc) and inversion (conversion of dc to ac). Phase-controlled rectification is discussed as a technique for controlling the dc voltage produced from a fixed ac source. Phase-controlled rectification can be used

[1] MATLAB is a registered trademark of The MathWorks, Inc.

to drive dc machines as well as to provide a controllable dc input to inverters in ac drives. Similarly, techniques for producing stepped and pulse-width-modulated waveforms of variable amplitudes and frequency are discussed. These techniques are at the heart of variable-speed drive systems which are commonly found in variable-speed ac drives.

Drive-systems based upon power electronics permit a great deal of flexibility in the control of electric machines. This is especially true in the case of ac machines which used to be found almost exclusively in applications where they were supplied from the fixed-frequency, fixed-voltage power system. Thus, the introduction to power electronics in Chapter 10 is followed by a chapter on the control of electric machines.

Chapter 11 brings together material that was distributed in various chapters in the previous edition. It is now divided into three main sections: control of dc motors, control of synchronous motors, and control of induction motors. A brief fourth section discusses the control of variable-reluctance motors. Each of these main sections begins with a discussion of speed control followed by a discussion of torque control.

Many motor-drive systems are based upon the technique of field-oriented control (also known as vector control). A significant addition to this new edition is the discussion of field-oriented control which now appears in Chapter 11. This is somewhat advanced material which is not typically found in introductory presentations of electric machinery. As a result, the chapter is structured so that this material can be omitted or included at the discretion of the instructor. It first appears in the section on torque control of synchronous motors, in which the basic equations are derived and the analogy with the control of dc machines is discussed. It appears again in its most commonly used form in the section on the torque control of induction motors.

The instructor should note that a complete presentation of field-oriented control requires the use of the dq0 transformation. This transformation, which appeared for synchronous machines in Chapter 6 of the previous edition, is now found in Appendix C of this edition. In addition, the discussion in this appendix has been expanded to include a derivation of the dq0 transformation for induction machines in which both stator and rotor quantities must be transformed.

Although very little in the way of sophisticated mathematics is required of the reader of this book, the mathematics can get somewhat messy and tedious. This is especially true in the analyis of ac machines in which there is a significant amount of algebra involving complex numbers. One of the significant positive developments in the last decade or so is the widespread availability of programs such as MATLAB which greatly facilitate the solution of such problems. MATLAB is widely used in many universities and is available in a student version.[2]

In recognition of this development, this edition incorporates MATLAB in examples and practice problems as well as in end-of-chapter problems. It should be emphasized, though, that the use of MATLAB is not in any way a requirement for the adoption or use of *Electric Machinery*. Rather, it is an enhancement. The book

[2] The MATLAB Student Version is published and distributed by The MathWorks, Inc. (http://www.mathworks.com).

now includes interesting examples which would have otherwise been too mathematically tedious. Similarly, there are now end-of-chapter problems which are relatively straightforward when done with MATLAB but which would be quite impractical if done by hand. Note that each MATLAB example and practice problem has been notated with the symbol , found in the margin of the book. End-of-chapter problems which suggest or require MATLAB are similarly notatated.

It should be emphasized that, in addition to MATLAB, a number of other numerical-analysis packages, including various spread-sheet packages, are available which can be used to perform calculations and to plot in a fashion similar to that done with MATLAB. If MATLAB is not available or is not the package of preference at your institution, instructors and students are encouraged to select any package with which they are comfortable. Any package that simplifies complex calculations and which enables the student to focus on the concepts as opposed to the mathematics will do just fine.

In addition, it should be noted that even in cases where it is not specifically suggested, most of the end-of-chapter problems in the book can be worked using MATLAB or an equivalent program. Thus, students who are comfortable using such tools should be encouraged to do so to save themselves the need to grind through messy calculations by hand. This approach is a logical extension to the use of calculators to facilitate computation. When solving homework problems, the students should still, of course, be required to show on paper how they formulated their solution, since it is the formulation of the solution that is key to understanding the material. However, once a problem is properly formulated, there is typically little additional to be learned from the number crunching itself. The learning process then continues with an examination of the results, both in terms of understanding what they mean with regard to the topic being studied as well as seeing if they make physical sense.

One additional benefit is derived from the introduction of MATLAB into this edition of *Electric Machinery*. As readers of previous editions will be aware, the treatment of single-phase induction motors was never complete in that an analytical treatment of the general case of a single-phase motor running with both its main and auxiliary windings excited (with a capacitor in series with the auxiliary winding) was never considered. In fact, such a treatment of single-phase induction motors is not found in any other introductory electric-machinery textbook of which the author is aware.

The problem is quite simple: this general treatment is mathematically complex, requiring the solution of a number of simultaneous, complex algebraic equations. This, however, is just the sort of problem at which programs such as MATLAB excel. Thus, this new edition of *Electric Machinery* includes this general treatment of single-phase induction machines, complete with a worked out quantitative example and end-of-chapter problems.

It is highly likely that there is simply too much material in this edition of *Electric Machinery* for a single introductory course. However, the material in this edition has been organized so that instructors can pick and choose material appropriate to the topics which they wish to cover. As in the fifth edition, the first two chapters introduce basic concepts of magnetic circuits, magnetic materials, and transformers. The third

chapter introduces the basic concept of electromechanical energy conversion. The fourth chapter then provides an overview of and on introduction to the various machine types. Some instructors choose to omit all or most of the material in Chapter 3 from an introductory course. This can be done without a significant impact to the understanding of much of the material in the remainder of the book.

The next five chapters provide a more in-depth discussion of the various machine types: synchronous machines in Chapter 5, induction machines in Chapter 6, dc machines in Chapter 7, variable-reluctance machines in Chapter 8, and single/two-phase machines in Chapter 9. Since the chapters are pretty much independent (with the exception of the material in Chapter 9 which builds upon the polyphase-induction-motor discussion of Chapter 6), the order of these chapters can be changed and/or an instructor can choose to focus on one or two machine types and not to cover the material in all five of these chapters.

The introductory power-electronics discussion of Chapter 10 is pretty much stand-alone. Instructors who wish to introduce this material should be able to do so at their discretion; there is no need to present it in a course in the order that it is found in the book. In addition, it is not required for an understanding of the electric-machinery material presented in the book, and instructors who elect to cover this material in a separate course will not find themselves handicapped in any way by doing so.

Finally, instructors may wish to select topics from the control material of Chapter 11 rather than include it all. The material on speed control is essentially a relatively straightforward extension of the material found in earlier chapters on the individual machine types. The material on field-oriented control requires a somewhat more sophisticated understanding and builds upon the dq0 transformation found in Appendix C. It would certainly be reasonable to omit this material in an introductory course and to delay it for a more advanced course where sufficient time is available to devote to it.

McGraw-Hill has set up a website, **www.mhhe.com/umans**, to support this new edition of *Electric Machinery*. The website will include a downloadable version of the solutions manual (for instructors only) as well as PowerPoint slides of figures from the book. This being a new feature of *Electric Machinery,* we are, to a great extent, starting with a blank slate and will be exploring different options for supplementing and enhancing the text. For example, in recognition of the fact that instructors are always looking for new examples and problems, we will set up a mechanism so that instructors can submit examples and problems for publication on the website (with credit given to their authors) which then can be shared with other instructors.

We are also considering setting up a section of the website devoted to MATLAB and other numerical analysis packages. For users of MATLAB, the site might contain hints and suggestions for applying MATLAB to *Electric Machinery* as well as perhaps some Simulink®[3] examples for instructors who wish to introduce simulations into their courses. Similarly, instructors who use packages other than MATLAB might

[3] Simulink is a registered trademark of The MathWorks, Inc.

want to submit their suggestions and experiences to share with other users. In this context, the website would appear again to be an ideal resource for enhancing interaction between instructors.

Clearly, the website will be a living document which will evolve in response to input from users. I strongly urge each of you to visit it frequently and to send in suggestions, problems, and examples, and comments. I fully expect it to become a valuable resource for users of *Electric Machinery* around the world.

Professor Kingsley first asked this author to participate in the fourth edition of *Electric Machinery;* the professor was actively involved in that edition. He participated in an advisory capacity for the fifth edition. Unfortunately, Professor Kingsley passed away since the publication of the fifth edition and did not live to see the start of the work on this edition. He was a fine gentleman, a valued teacher and friend, and he is missed.

I wish to thank a number of my colleagues for their insight and helpful discussions during the production of this edition. My friend, Professor Jeffrey Lang, who also provided invaluable insight and advice in the discussion of variable-reluctance machines which first appeared in the fifth edition, was extremely helpful in formulating the presentations of power electronics and field-oriented control which appear in this edition. Similarly, Professor Gerald Wilson, who served as my graduate thesis advisor, has been a friend and colleague throughout my career and has been a constant source of valuable advice and insight.

On a more personal note, I would like to express my love for my wife Denise and our children Dalya and Ari and to thank them for putting up with the many hours of my otherwise spare time that this edition required. I promised the kids that I would read the Harry Potter books when work on this edition of *Electric Machinery* was completed and I had better get to it! In addition, I would like to recognize my life-long friend David Gardner who watched the work on this edition with interest but who did not live to see it completed. A remarkable man, he passed away due to complications from muscular dystrophy just a short while before the final draft was completed.

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