Power Electronics and Power Systems

For further volumes:
http://www.springer.com/series/6403

Slobodan N. Vukosavic

Electrical Machines

Springer

Slobodan N. Vukosavic
Dept. of Electrical Engineering
University of Belgrade
Belgrade, Serbia

ISBN 978-1-4614-0399-9 ISBN 978-1-4614-0400-2 (eBook)
DOI 10.1007/978-1-4614-0400-2
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2012944981

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

This textbook is intended for undergraduate students of Electrical Engineering as their first course in electrical machines. It is also recommended for students preparing a capstone project, where they need to understand, model, supply, control and specify electric machines. At the same time, it can be used as a valuable reference for other engineering disciplines involved with electrical motors and generators. It is also suggested to postgraduates and engineers aspiring to electromechanical energy conversion and having to deal with electrical drives and electrical power generation. Unlike the majority of textbooks on electrical machines, this book does not require an advanced background. An effort was made to provide text approachable to students and engineers, in engineering disciplines other than electrical.

The scope of this textbook provides basic knowledge and skills in Electrical Machines that should be acquired by prospective engineers. Basic engineering considerations are used to introduce principles of electromechanical energy conversion in an intuitive manner, easy to recall and repeat. The book prepares the reader to comprehend key electrical and mechanical properties of electrical machines, to analyze their steady state and transient characteristics, to obtain basic notions on conversion losses, efficiency and cooling of electrical machines, to evaluate a safe operating area in a steady state and during transient states, to understand power supply requirements and associated static power converters, to comprehend some basic differences between DC machines, induction machines and synchronous machines, and to foresee some typical applications of electrical motors and generators.

Developing knowledge on electrical machines and acquiring requisite skills is best suited for second year engineering students. The book is self-contained and it includes questions, answers, and solutions to problems wherever the learning process requires an overview. Each Chapter is comprised of an appropriate set of exercises, problems and design tasks, arranged for recall and use of relevant knowledge. Wherever it is needed, the book includes extended reminders and explanations of the required skill and prerequisites. The approach and method used in this textbook comes from the sixteen years of author's experience in teaching Electrical Machines at the University of Belgrade.

Readership

This book is best suited for second or third year Electrical Engineering undergraduates as their first course in electrical machines. It is also suggested to postgraduates of all Engineering disciplines that plan to major in electrical drives, renewables, and other areas that involve electromechanical conversions. The book is recommended to students that prepare capstone project that involves electrical machines and electromechanical actuators. The book may also serve as a valuable reference for engineers in other engineering disciplines that are involved with electrical motors and generators.

Prerequisites

Required background includes mathematics, physics, and engineering fundamentals taught in introductory semesters of most contemporary engineering curricula. The process of developing skills and knowledge on electrical machines is best suited for second year engineering students. Prerequisites do not include spatial derivatives and field theory. This textbook is made accessible to readers without an advanced background in electromagnetics, circuit theory, mathematics and engineering materials. Necessary background includes elementary electrostatics and magnetics, DC and AC current circuits and elementary skill with complex numbers and phasors. An effort is made to bring the text closer to students and engineers in engineering disciplines other than electrical. Wherever it is needed, the book includes extended reinstatements and explanations of the required skill and prerequisites. Required fundamentals are recalled and included in the book to the extent necessary for understanding the analysis and developments.

Objectives

- Using basic engineering considerations to introduce principles of electromechanical energy conversion and basic types and applications of electrical machines.
- Providing basic knowledge and skills in electrical machines that should be acquired by prospective engineers. Comprehending key electrical and mechanical properties of electrical machines.
- Providing and easy to use reference for engineers in general.
- Acquiring skills in analyzing steady state and transient characteristics of electrical machines, as well as acquiring basic notions on conversion losses, efficiency and heat removal in electrical machines.

- Mastering mechanical characteristics and steady state equivalent circuits for principal types of electrical machines.
- Comprehending basic differences between DC machines, induction machines and synchronous machines, studying and comparing their steady state operating area and transient operating area.
- Studying and apprehending characteristics of mains supplied and variable frequency supplied AC machines, comparing their characteristics and considering their typical applications.
- Understanding power supply requirements and studying basic topologies and characteristics of associated static power converters.
- Studying field weakening operation and analyzing characteristics of DC and AC machines in constant flux region and in the constant power region.
- Acquiring skills in calculating conversion losses, temperature increase and cooling methods. Basic information on thermal models and intermittent loading.
- Introducing and explaining the rated and nominal currents, voltages, flux linkages, torque, power and speed.

Teaching approach

- The emphasis is on the system overview - explaining external characteristics of electrical machines - their electrical and mechanical access. Design and construction aspects are of secondary importance or out of the scope of this book.
- Where needed, introductory parts of teaching units comprise repetition of the required background which is applied through solved problems.
- Mathematics is reduced to a necessary minimum. Spatial derivatives and differential form of Maxwell equations are not required.
- The goal of developing and using mathematical models of electrical machines, their equivalent circuits and mechanical characteristics persists through the book. At the same time, the focus is kept on physical insight of electromechanical conversion process. The later is required for proper understanding of conversion losses and perceiving the basic notions on specific power, specific torque, and torque-per-Ampere ratio of typical machines.
- Although machine design is out of the overall scope, some most relevant concepts and skills in estimating the machine size, torque, power, inertia and losses are introduced and explained. The book also explains some secondary losses and secondary effects, indicating the cases and conditions where the secondary phenomena cannot be neglected.

Field of application

Equivalent circuits, dynamic models and mechanical characteristics are given for DC machines, induction machines and synchronous machines. The book outlines the basic information on the machine construction, including the magnetic circuits and windings. Thorough approach to designing electric machines is left out of the book. Within the book, machine applications are divided in two groups; (i) Constant voltage, constant frequency supplied machines, and (ii) Variable voltage, variable frequency machines fed from static power converters. A number of most important details on designing electric machines for constant frequency and variable frequency operation are included. The book outlines basic static power converter topologies used in electrical drives with DC and AC machines. The book also provides basic information on loses, heating and cooling methods, on rated and nominal quantities, and on continuous and intermittent loading. For most common machines, the book provides and explains the steady state operating area and the transient operating area, the area in constant flux and field weakening range.

Acknowledgment

The author is indebted to Professors Miloš Petrović, Dragutin Salamon, Jožef Varga, and Aleksandar Stanković who read through the first edition of the book and made suggestion for improvements.

The author is grateful to his young colleagues, teaching assistants, postgraduate students, Ph.D. students and young professors who provided technical assistance, helped prepare solutions to some problems and questions, read through the chapters, commented, and suggested index terms.

Valuable technical assistance in preparing the manuscript, drawings, and tables were provided by research assistants Nikola Popov and Dragan Mihic.

The author would also like to thank Ivan Pejcic, Ljiljana Peric, Nikota Vukosavic, Darko Marcetic, Petar Matic, Branko Blanusa, Dragomir Zivanovic, Mladen Terzic, Milos Stojadinovic, Nikola Lepojevic, Aleksandar Latinovic, and Milan Lukic.

Contents

List of Figures