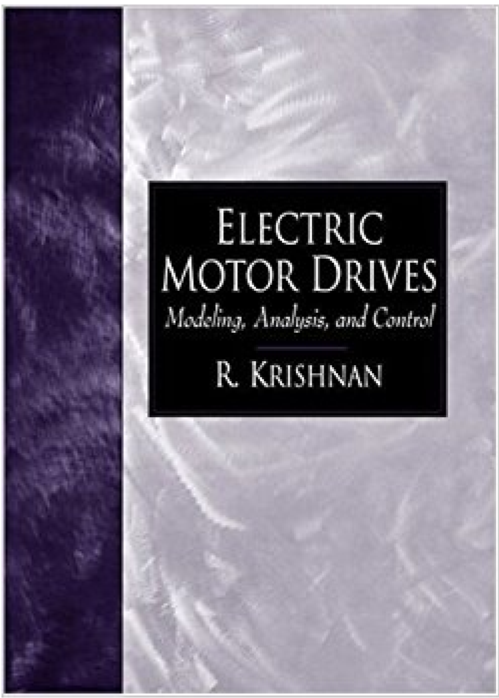
Electric Motor Drives: Modeling, Analysis, And Control



Synopsis

Electronic Control of Machines develops a systematic approach to motor drives. This book places emphasis on practice through the use of extensive modeling, simulation and analysis to help readers better understand the subject. Detailed industrial applications help readers relate theory to practice. This extensive book cover numerous topics including: system level analysis, design and integration of the motor drives; and modeling and analysis of electrical machines and drive systems. For readers with an interest in electric drives and power electronics.

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Customer Reviews

Electric Motor Drives is a comprehensive book for seniors, graduates, and practicing engineers. Designed to motivate students and professional engineers alike, the book emphasizes a systematic approach to motor drives based on physical insight and practical implementation aspects. DC and AC drives share the same pedagogical framework throughout. Present day practice as well as recent research and development are covered. FEATURES System equations are derived from first principles based on a physical understanding of the machine. It is therefore distinct from other books in that it does not rely on the reader’s memory. Each of the motor drives is illustrated with an industrial application in detail at the end of chapters to enable readers to relate theory to practice. Current and speed controller designs have been standardized throughout the book to emphasize the commonality of the drive design. Interrelationships between subsystems and the performance of the integrated system are derived and illustrated with a large number of simulation results. Readers can check the validity of their simulation software by correlating their findings with the simulation results given in the book. Basic concepts are illustrated with numerous analysis and design examples. Each chapter contains discussion questions to reinforce the reader's understanding, and to help them probe advanced topics independently with the help of references.

Preface Electronic control of machines is a course taught as an elective at senior level and as an introductory course for the graduate-level course on motor drives. Many wonderful books address individually the senior-level or graduate-level requirements, mostly from the practitioner's point of view, but some are not ideally suited for classroom teaching in American universities. This book is the result of teaching materials developed over a period of twelve years at Virginia Tech. Parts of the material have been used extensively in seminars both in the United States and abroad.   The area of electric motor drives is a dependent discipline. It is an applied and multidisciplinary subject comprising electronics, machines, control, processors/computers, software, electromagnetics, sensors, power systems, and engineering applications. It is not possible to cover all aspects relevant to motor drives in one text. Therefore, this book addresses mainly the system-level modeling analysis, design and integration of motor drives. In this regard, knowledge of electrical machines, power converters, and linear control systems is assumed at the junior level. The modeling and analysis of electrical machines and drive systems is systematically derived from first principles. The control algorithms are developed, and their implementations with simulation results are given wherever appropriate.   The book consists of nine chapters. Their contents are briefly described here.   Chapter 1 contains the introduction and discusses the motor-drive applications, the status of power devices, classes of electrical machines, power converters, controllers, and mechanical systems.   Chapter 2 is on dc machines, their principle of operation, the steady-state and dynamic modeling, block-diagram development, and measurement of motor parameters. Chapter 3 describes phase-controlled dc motor drives for variable-speed operation. The principle of do machine speed control is developed, and four-quadrant operation is introduced. The electrical requirements for four-quadrant operation are derived. Realization of these voltage/current requirements for four-quadrant operation with phase-controlled converters is studied. In that process, the operation and control of phase-controlled converters are developed. The closed-loop speed-controlled dc motor drive system is considered for analysis and controller synthesis. The synthesis of current and speed controllers is developed. The dynamic simulation procedure is derived for the motor drive system from the subsystem differential equations and functional relationships. The same procedure is adopted throughout the book. Impact of harmonies both on the utility and on the machine is analyzed. Supply-side harmonics can cause resonance in the case of interaction with the power systems, as is illustrated with an example, and machine-side harmonics cause increased resistive losses, resulting in derating of the machine. Some application considerations for the drive are given. An application of the drive is described. A more or less similar approach is taken for all other drives in this book.   Chopper-controlled dc motors are described in Chapter 4. The principle of operation of a four-quadrant chopper, realization of do input supply, regeneration, modeling of a chopper, the closed-loop speed-controlled drive and its current- and speed-controller synthesis, harmonics, and their impact on electromagnetic torque, losses, and derating are developed and presented.   The principle of operation of induction machines and their steady-state and dynamic modeling are presented in Chapter 5. The concept of space-phasor modeling is also introduced, to enable readers to follow literature mainly from Germany. A number of illustrative examples are included.   The principle of speed control of induction motors is introduced in Chapter 6. The rest of the chapter is devoted to the stator-phase control and slip-energy recovery control of induction motors. Only steady-state aspects are covered. Their dynamic analysis is left to the interested reader. Emphasis is placed on efficiency, energy savings, speed-control range, harmonics, and application for these drives.   Variable-frequency control of induction machines with both variable voltage and variable current is introduced in Chapter 7. The realization of variable voltage and variable frequency with two-stage controllable converters and single-stage pulse-width-modulated (PWM) inverters is introduced. Reducing harmonics with multiple inverters or with one PWM inverter is discussed and is illustrated with examples. Steady-state analysis using fundamental and harmonic equivalent circuits, direct steady-state evaluation, and the use of a dynamic model with boundary-matching conditions is systematically developed in this chapter. Various control strategies for variable-voltage, variable-frequency drives are explained. They are V/Hz, constant-slip-speed, and constant-air gap-flux controls. The limitations and merits of each control scheme and relevant modeling to evaluate their dynamic performance are developed. Effects of harmonics on the machine losses, with the resultant derating and torque pulsation due to six-step voltage input to the machine, are quantified. Torque pulsations are calculated by using harmonic equivalent circuits of the induction motor fed from voltage-source inverters. The concept of current source is introduced by using a PWM inverter with voltage-source and current-feedback control. A two-stage current-source inverter drive with thyristor converter front end and autosequentially commutated inverter is considered for both steady-state and dynamic performance evaluation. The design aspects of the current-source drive control are considered in adequate detail. The high-performance induction motor drive is considered from the control point of view in Chapter 8. The principle of vector control and design and its various implementations, their strengths and weaknesses, impact of parameter sensitivity, parameter-compensation methods, flux-weakening operation, and the design of a speed controller are explained with detailed algorithms and illustrated with dynamic simulation results and example problems. Tuning of the vector controller and position-sensorless operation are not dealt in detail. Interested readers will be helped by the cited references. Chapter 9 deals with permanent magnet (PM) synchronous and brushless dc motor drives. The salient differences between these two types of motors are derived. Vector control and various control strategies within the scope of vector control, such as constant-torque-angle control, unity-power-factor control, constant-mutual-flux-linkages control, and maximum-torque-per-unit-current control are derived from the dynamic and steady-state equations of the PM synchronous motor. Two types of flux-weakening operation and their implementations, speed-controller design, position-sensorless control, and parameter sensitivity and its ,compensation are developed with control algorithms. Ample dynamic simulation results are included to enhance the understanding of the PM synchronous motor drive operation. Similar coverage is carried out for the PM brushless dc motor drive. In addition, an analytical method to evaluate torque pulsation and various unipolar/half-wave inverter topologies is included for low-cost but high-reliability motor drive systems. A list of symbols has been given to enable readers who skip some sections to follow the text they are interested in. The material in this book is recommended for two semesters. In the author's experience, the subject matter that can be covered for each semester is given only to serve as a guideline. Depending on the strength of the program in each school, course instructors can flexibly choose the material from the book for their lectures. The introductory course that can be taught at senior elective or at graduate level includes the following: Chapters 1, 2, 3, and 4, Chapter 5 (covering only the steady-state operation and modeling of induction motors), Chapter 6, and Chapter 7 (excluding the dynamic performance evaluation or parts that use dynamic model of the induction motor). The advanced graduate course can consist of the following: Dynamic modeling of induction machines from Chapter 5, voltage- and current-source drive dynamic performance from Chapter 7, and Chapters 8 and 9. The author's many graduate and undergraduate students have enriched this book in the course of its development. Some of them deserve my special thanks and gratitude. They are Mr. Praveen Vijayraghavan, Dr. Shiyoung Lee, Dr. A. S. Bharadwaj, Dr. Byeong-Seok Lee and Dr. Ramin Monajemy. Without their crucial help, this endeavor would still be in the manuscript stage. The Chapter 5 development draws heavily from the work of one of my doctoral supervisors, Dr. J. F.

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