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Electrical Machines

 Springer

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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 losses, 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.

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Contents

1	Introduction	1
1.1	Power Converters and Electrical Machines	1
1.1.1	Rotating Power Converters	2
1.1.2	Static Power Converters	2
1.1.3	The Role of Electromechanical Power Conversion	3
1.1.4	Principles of Operation	3
1.1.5	Magnetic and Current Circuits	4
1.1.6	Rotating Electrical Machines	4
1.1.7	Reversible Machines	5
1.2	Significance and Typical Applications	6
1.3	Variables and Relations of Rotational Movement	10
1.3.1	Notation and System of Units	12
1.4	Target Knowledge and Skills	14
1.4.1	Basic Characteristics of Electrical Machines	15
1.4.2	Equivalent Circuits	15
1.4.3	Mechanical Characteristic	15
1.4.4	Transient Processes in Electrical Machines	16
1.4.5	Mathematical Model	16
1.5	Adopted Approach and Analysis Steps	17
1.5.1	Prerequisites	20
1.6	Notes on Converter Fed Variable Speed Machines	20
1.7	Remarks on High Efficiency Machines	22
1.8	Remarks on Iron and Copper Usage	22
2	Electromechanical Energy Conversion	25
2.1	Lorentz Force	25
2.2	Mutual Action of Parallel Conductors	27
2.3	Electromotive Force in a Moving Conductor	28
2.4	Generator Mode	30
2.5	Reluctant Torque	31
2.6	Reluctant Force	32

2.7	Forces on Conductors in Electrical Field	33
2.8	Change of Permittivity	33
2.9	Piezoelectric Effect	37
2.10	Magnetostriction	38
3	Magnetic and Electrical Coupling Field	41
3.1	Converters Based on Electrostatic Field	41
3.1.1	Charge, Capacitance, and Energy	42
3.1.2	Source Work, Mechanical Work, and Field Energy	43
3.1.3	Force Expression	44
3.1.4	Conversion Cycle	46
3.1.5	Energy Density of Electrical and Magnetic Field	48
3.1.6	Coupling Field and Transfer of Energy	49
3.2	Converter Involving Magnetic Coupling Field	50
3.2.1	Linear Converter	50
3.2.2	Rotational Converter	53
3.2.3	Back Electromotive Force	55
4	Magnetic Circuit	59
4.1	Analysis of Magnetic Circuits	61
4.1.1	Flux Conservation Law	61
4.1.2	Generalized Form of Ampere Law	62
4.1.3	Constitutive Relation Between Magnetic Field H and Induction B	62
4.2	The Flux Vector	63
4.3	Magnetizing Characteristic of Ferromagnetic Materials	63
4.4	Magnetic Resistance of the Circuit	65
4.5	Energy in a Magnetic Circuit	68
4.6	Reference Direction of the Magnetic Circuit	69
4.7	Losses in Magnetic Circuits	71
4.7.1	Hysteresis Losses	71
4.7.2	Losses Due to Eddy Currents	72
4.7.3	Total Losses in Magnetic Circuit	74
4.7.4	The Methods of Reduction of Iron Losses	75
4.7.5	Eddy Currents in Laminated Ferromagnetics	76
5	Rotating Electrical Machines	81
5.1	Magnetic Circuit of Rotating Machines	81
5.2	Mechanical Access	82
5.3	The Windings	83
5.4	Slots in Magnetic Circuit	85
5.5	The Position and Notation of Winding Axis	88
5.6	Conversion Losses	89
5.7	Magnetic Field in Air Gap	92
5.8	Field Energy, Size, and Torque	93

- 6 Modeling Electrical Machines** 99
 - 6.1 The Need for Modeling 100
 - 6.1.1 Problems of Modeling 101
 - 6.1.2 Conclusion 103
 - 6.2 Neglected Phenomena 103
 - 6.2.1 Distributed Energy and Distributed Parameters 104
 - 6.2.2 Neglecting Parasitic Capacitances 104
 - 6.2.3 Neglecting Iron Losses 105
 - 6.2.4 Neglecting Iron Nonlinearity 105
 - 6.3 Power of Electrical Sources 105
 - 6.4 Electromotive Force 106
 - 6.5 Voltage Balance Equation 107
 - 6.6 Leakage Flux 109
 - 6.7 Energy of the Coupling Field 112
 - 6.8 Power of Electromechanical Conversion 114
 - 6.9 Torque Expression 117
 - 6.10 Mechanical Subsystem 119
 - 6.11 Losses in Mechanical Subsystem 120
 - 6.12 Kinetic Energy 121
 - 6.13 Model of Mechanical Subsystem 122
 - 6.14 Balance of Power in Electromechanical Converters 124
 - 6.15 Equations of Mathematical Model 126
- 7 Single-Fed and Double-Fed Converters** 129
 - 7.1 Analysis of Single-Fed Converter 131
 - 7.2 Variation of Self-inductance 132
 - 7.3 The Expressions for Power and Torque 133
 - 7.4 Analysis of Double-Fed Converter 135
 - 7.5 Variation of Mutual Inductance 137
 - 7.6 Torque Expression 138
 - 7.6.1 Average Torque 139
 - 7.6.2 Conditions for Generating Nonzero Torque 139
 - 7.7 Magnetic Poles 141
 - 7.8 Direct Current and Alternating Current Machines 141
 - 7.9 Torque as a Vector Product 142
 - 7.10 Position of the Flux Vector in Rotating Machines 145
 - 7.11 Rotating Field 149
 - 7.12 Types of Electrical Machines 151
 - 7.12.1 Direct Current Machines 151
 - 7.12.2 Induction Machines 151
 - 7.12.3 Synchronous Machines 152
- 8 Magnetic Field in the Air Gap** 153
 - 8.1 Stator Winding with Distributed Conductors 155
 - 8.2 Sinusoidal Current Sheet 157

8.3	Components of Stator Magnetic Field	158
8.3.1	Axial Component of the Field	159
8.3.2	Tangential Component of the Field	162
8.3.3	Radial Component of the Field	164
8.4	Review of Stator Magnetic Field	168
8.5	Representing Magnetic Field by Vector	169
8.6	Components of Rotor Magnetic Field	175
8.6.1	Axial Component of the Rotor Field	177
8.6.2	Tangential Component of the Rotor Field	177
8.6.3	Radial Component of the Rotor Field	179
8.6.4	Survey of Components of the Rotor Magnetic Field	181
8.7	Convention of Representing Magnetic Field by Vector	182
9	Energy, Flux, and Torque	185
9.1	Interaction of the Stator and Rotor Fields	185
9.2	Energy of Air Gap Magnetic Field	188
9.3	Electromagnetic Torque	191
9.3.1	The Torque Expression	193
9.4	Turn Flux and Winding Flux	194
9.4.1	Flux in One Stator Turn	196
9.4.2	Flux in One Rotor Turn	198
9.4.3	Winding Flux	200
9.4.4	Winding Flux Vector	203
9.5	Winding Axis and Flux Vector	205
9.6	Vector Product of Stator and Rotor Flux Vectors	205
9.7	Conditions for Torque Generation	208
9.8	Torque–Size Relation	211
9.9	Rotating Magnetic Field	213
9.9.1	System of Two Orthogonal Windings	213
9.9.2	System of Three Windings	218
10	Electromotive Forces	223
10.1	Transformer and Dynamic Electromotive Forces	224
10.2	Electromotive Force in One Turn	224
10.2.1	Calculating the First Derivative of the Flux in One Turn	225
10.2.2	Summing Electromotive Forces of Individual Conductors	227
10.2.3	Voltage Balance in One Turn	227
10.2.4	Electromotive Force Waveform	228
10.2.5	Root Mean Square (rms) Value of Electromotive Forces	229
10.3	Electromotive Force in a Winding	230
10.3.1	Concentrated Winding	230

10.3.2	Distributed Winding	230
10.3.3	Chord Factor	232
10.3.4	Belt Factor	237
10.3.5	Harmonics Suppression of Winding Belt	238
10.4	Electromotive Force of Compound Winding	241
10.5	Harmonics	242
10.5.1	Electromotive Force in Distributed Winding	244
10.5.2	Individual Harmonics	251
10.5.3	Peak and rms of Winding Electromotive Force	253
11	Introduction to DC Machines	259
11.1	Construction and Principle of Operation	261
11.2	Construction of the Stator	261
11.3	Separately Excited Machines	262
11.4	Current in Rotor Conductors	263
11.5	Mechanical Commutator	264
11.6	Rotor Winding	265
11.7	Commutation	270
11.8	Operation of Commutator	272
11.9	Making the Rotor Winding	274
11.10	Problems with Commutation	278
11.11	Rotor Magnetic Field	283
11.12	Current Circuits and Magnetic Circuits	284
11.13	Magnetic Circuits	285
11.14	Current Circuits	285
11.15	Direct and Quadrature Axis	288
11.15.1	Vector Representation	289
11.15.2	Resultant Fluxes	290
11.15.3	Resultant Flux of the Machine	290
11.16	Electromotive Force and Electromagnetic Torque	291
11.16.1	Electromotive Force in Armature Winding	291
11.16.2	Torque Generation	294
11.16.3	Torque and Electromotive Force Expressions	295
11.16.4	Calculation of Electromotive Force E_a	297
11.16.5	Calculation of Torque	298
12	Modeling and Supplying DC Machines	299
12.1	Voltage Balance Equation for Excitation Winding	301
12.2	Voltage Balance Equation in Armature Winding	303
12.3	Changes in Rotor Speed	304
12.4	Mathematical Model	305
12.5	DC Machine with Permanent Magnets	306
12.6	Block Diagram of the Model	306
12.7	Torque Control	308
12.8	Steady-State Equivalent Circuit	309
12.9	Mechanical Characteristic	311

12.9.1	Stable Equilibrium	313
12.10	Properties of Mechanical Characteristic	315
12.11	Speed Regulation	316
12.12	DC Generator	319
12.13	Topologies of DC Machine Power Supplies	321
12.13.1	Armature Power Supply Requirements	322
12.13.2	Four Quadrants in T- Ω and U-I Diagrams	323
12.13.3	The Four-Quadrant Power Converter	325
12.13.4	Pulse-Width Modulation	330
12.13.5	Current Ripple	335
12.13.6	Topologies of Power Converters	339
13	Characteristics of DC Machines	343
13.1	Rated Voltage	344
13.2	Mechanical Characteristic	344
13.3	Natural Characteristic	345
13.4	Rated Current	345
13.5	Thermal Model and Intermittent Operation	346
13.6	Rated Flux	351
13.7	Rated Speed	352
13.8	Field Weakening	352
13.8.1	High-Speed Operation	353
13.8.2	Torque and Power in Field Weakening	354
13.8.3	Flux Change	355
13.8.4	Electromotive Force Change	355
13.8.5	Current Change	355
13.8.6	Torque Change	356
13.8.7	Power Change	356
13.8.8	The Need for Field-Weakening Operation	356
13.9	Transient Characteristic	357
13.10	Steady-State Operating Area	357
13.11	Power Losses and Power Balance	358
13.11.1	Power of Supply	358
13.11.2	Losses in Excitation Winding	359
13.11.3	Losses Armature Winding	359
13.11.4	Power of Electromechanical Conversion	359
13.11.5	Iron Losses (P_{Fe})	359
13.11.6	Mechanical Losses (P_F)	360
13.11.7	Losses Due to Rotation ($P_{Fe} + P_F$)	361
13.11.8	Mechanical Power	361
13.12	Rated and Declared Values	362
13.13	Nameplate Data	363

- 14 Induction Machines** 365
 - 14.1 Construction and Operating Principles 365
 - 14.2 Magnetic Circuits 367
 - 14.3 Cage Rotor and Wound Rotor 370
 - 14.4 Three-Phase Stator Winding 370
 - 14.5 Rotating Magnetic Field 373
 - 14.6 Principles of Torque Generation 375
 - 14.7 Torque Expression 376
- 15 Modeling of Induction Machines** 379
 - 15.1 Modeling Steady State and Transient Phenomena 379
 - 15.2 The Structure of Mathematical Model 381
 - 15.3 Three-Phase and Two-Phase Machines 382
 - 15.4 Clarke Transform 387
 - 15.5 Two-Phase Equivalent 389
 - 15.6 Invariance 391
 - 15.6.1 Clarke Transform with $K = 1$ 395
 - 15.6.2 Clarke Transform with $K = \sqrt{2/3}$ 396
 - 15.6.3 Clarke Transform with $K = 2/3$ 396
 - 15.7 Equivalent Two-Phase Winding 397
 - 15.8 Model of Stator Windings 398
 - 15.9 Voltage Balance Equations 399
 - 15.10 Modeling Rotor Cage 400
 - 15.11 Voltage Balance Equations in Rotor Winding 403
 - 15.12 Inductance Matrix 404
 - 15.13 Leakage Flux and Mutual Flux 404
 - 15.14 Magnetic Coupling 406
 - 15.15 Matrix L 407
 - 15.16 Transforming Rotor Variables to Stator Side 408
 - 15.17 Mathematical Model 410
 - 15.18 Drawbacks 411
 - 15.19 Model in Synchronous Coordinate Frame 414
 - 15.20 Park Transform 415
 - 15.21 Transform Matrix 417
 - 15.22 Transforming Rotor Variables 418
 - 15.23 Vectors and Complex Numbers 420
 - 15.23.1 Simplified Record of the Rotational Transform 420
 - 15.24 Inductance Matrix in dq Frame 421
 - 15.25 Voltage Balance Equations in dq Frame 423
 - 15.26 Electrical Subsystem 424
- 16 Induction Machines at Steady State** 427
 - 16.1 Input Power 428
 - 16.2 Torque Expression 429

16.3	Relative Slip	430
16.4	Losses and Mechanical Power	430
16.5	Steady State Operation	431
16.6	Analogy with Transformer	435
16.7	Torque and Current Calculation	438
16.8	Steady State Torque	439
16.9	Relative Values	442
16.10	Relative Value of Dynamic Torque	446
16.11	Parameters of Equivalent Circuit	449
	16.11.1 Rotor Resistance Estimation	455
16.12	Analysis of Mechanical Characteristic	457
16.13	Operation with Slip	460
16.14	Operation with Large Slip	461
16.15	Starting Mains Supplied Induction Machine	462
16.16	Breakdown Torque and Breakdown Slip	463
16.17	Kloss Formula	465
16.18	Stable and Unstable Equilibrium	466
16.19	Region Suitable for Continuous Operation	467
16.20	Losses and Power Balance	469
16.21	Copper, Iron, and Mechanical Losses	469
16.22	Internal Mechanical Power	470
16.23	Relation Between Voltages and Fluxes	472
16.24	Balance of Power	472
17	Variable Speed Induction Machines	475
	17.1 Speed Changes in Mains-Supplied Machines	476
	17.2 Voltage Change	477
	17.3 Wound Rotor Machines	479
	17.4 Changing Pole Pairs	483
	17.4.1 Speed and Torque of Multipole Machines	486
	17.5 Characteristics of Multipole Machines	486
	17.5.1 Mains-Supplied Multipole Machines	487
	17.5.2 Multipole Machines Fed from Static Power Converters	488
	17.5.3 Shortcomings of Multipole Machines	488
	17.6 Two-Speed Stator Winding	490
	17.7 Notation	492
	17.8 Supplying from a Source of Variable Frequency	493
	17.9 Variable Frequency Supply	493
	17.10 Power Converter Topology	494
	17.11 Pulse Width Modulation	495
	17.12 Average Value of the Output Voltage	496
	17.13 Sinusoidal Output Voltages	497
	17.14 Spectrum of PWM Waveforms	498

17.15	Current Ripple	499
17.16	Frequency Control	502
17.17	Field Weakening	504
	17.17.1 Reversal of Frequency-Controlled Induction Machines	506
17.18	Steady State and Transient Operating Area	507
17.19	Steady State Operating Limits	508
	17.19.1 RI Compensation	509
	17.19.2 Critical Speed	510
17.20	Construction of Induction Machines	513
	17.20.1 Mains-Supplied Machines	513
	17.20.2 Variable Frequency Induction Machines	517
18	Synchronous Machines	521
	18.1 Principle of Operation	522
	18.2 Stator Windings	523
	18.3 Revolving Field	524
	18.4 Torque Generation	527
	18.5 Construction of Synchronous Machines	530
	18.6 Stator Magnetic Circuit	531
	18.7 Construction of the Rotor	532
	18.8 Supplying the Excitation Winding	533
	18.9 Excitation with Rotating Transformer	534
	18.10 Permanent Magnet Excitation	536
	18.11 Characteristics of Permanent Magnets	538
	18.12 Magnetic Circuits with Permanent Magnets	540
	18.13 Surface Mount and Buried Magnets	541
	18.14 Characteristics of Permanent Magnet Machines	543
19	Mathematical Model of Synchronous Machine	545
	19.1 Modeling Synchronous Machines	545
	19.2 Magnetomotive Force	547
	19.3 Two-Phase Equivalent	548
	19.4 Clarke $3\Phi/2\Phi$ Transform	550
	19.5 Inductance Matrix and Voltage Balance Equations	553
	19.6 Park Transform	554
	19.7 Inductance Matrix in dq Frame	556
	19.8 Vectors as Complex Numbers	558
	19.9 Voltage Balance Equations	559
	19.10 Electrical Subsystem of Isotropic Machines	561
	19.11 Torque in Isotropic Machines	563
	19.12 Anisotropic Rotor	565
	19.13 Reluctant Torque	566
	19.14 Reluctance Motor	567

20	Steady-State Operation	571
20.1	Voltage Balance Equations at Steady State	571
20.2	Equivalent Circuit	573
20.3	Peak and rms Values of Currents and Voltages	574
20.4	Phasor Diagram of Isotropic Machine	576
20.5	Phasor Diagram of Anisotropic Machine	581
20.6	Torque in Anisotropic Machine	582
20.7	Torque Change with Power Angle	583
20.8	Mechanical Characteristic	584
20.9	Synchronous Machine Supplied from Stiff Network	585
20.10	Operation of Synchronous Generators	586
20.10.1	Increase of Turbine Power	587
20.10.2	Increase in Line Frequency	589
20.10.3	Reactive Power and Voltage Changes	590
20.10.4	Changes in Power Angle	591
21	Transients in Synchronous Machines	595
21.1	Electrical and Mechanical Time Constants	596
21.2	Hunting of Synchronous Machines	596
21.3	Damped LC Circuit	600
21.4	Damping of Synchronous Machines	602
21.5	Damper Winding	603
21.6	Short Circuit of Synchronous Machines	605
21.6.1	DC Component	607
21.6.2	Calculation of I_{SC1}	609
21.6.3	Calculation of I_{SC2}	610
21.6.4	Calculation of I_{SC3}	613
21.7	Transient and Subtransient Phenomena	618
21.7.1	Interval 1	618
21.7.2	Interval 2	618
21.7.3	Interval 3	619
22	Variable Frequency Synchronous Machines	621
22.1	Inverter-Supplied Synchronous Machines	621
22.2	Torque Control Principles	623
22.3	Current Control Principles	626
22.4	Field Weakening	629
22.5	Transient and Steady-State Operating Area	632
	Bibliography	635
	Index	637

List of Figures

Fig. 1.1	Rotating electrical machine has cylindrical rotor, accessible via shaft. Stator has the form of a hollow cylinder, coaxial with the rotor	4
Fig. 1.2	Block diagram of a reversible electromechanical converter	6
Fig. 1.3	The role of electrical machines in the production, distribution, and consumption of electrical energy	8
Fig. 1.4	Conductive contour acted upon by two coupled forces producing a torque	11
Fig. 1.5	Electrical motor (a) is coupled to work machine (b). Letter (c) denotes excitation winding of the dc motor	12
Fig. 2.1	Force acting on a straight conductor in homogeneous magnetic field	26
Fig. 2.2	(a) Magnetic field and magnetic induction of a straight conductor. (b) Force of attraction between two parallel conductors. (c) Force of repulsion between two parallel conductors	27
Fig. 2.3	The induced electrical field and electromotive force in the straight part of the conductor moving through homogeneous external magnetic field	29
Fig. 2.4	Straight part of a conductor moves through a homogeneous external magnetic field and assumes the role of a generator which delivers electrical energy to resistor R	30
Fig. 2.5	Due to reluctant torque, a piece of ferromagnetic material tends to align with the field, thus offering a minimum magnetic resistance	31
Fig. 2.6	The electromagnetic forces tend to bring the piece of ferromagnetic material inside the coil	32
Fig. 2.7	Electrical forces act on the plates of a charged capacitor and tend to reduce distance between the plates	33

Fig. 2.8	Electrical forces tend to bring the piece of dielectric into the space between the plates. The dielectric constant of the piece is higher than that of the air	34
Fig. 2.9	Variation of pressure acting on sides of a crystal leads to variations of the voltage measured between the surfaces	37
Fig. 2.10	The magnetization varies as a function of force which tends to constrict or stretch a piece of ferromagnetic material	38
Fig. 3.1	Plate capacitor with distance between the plates much smaller compared to dimensions of the plates	42
Fig. 3.2	A capacitor having mobile upper plate	43
Fig. 3.3	One cycle of electromechanical conversion includes phase (a) when the plates of the capacitor are disconnected from the source U and phase (b) when the plates are connected to the source	47
Fig. 3.4	A linear electromechanical converter with magnetic coupling field	51
Fig. 3.5	A rotational electromechanical converter involving magnetic coupling field	53
Fig. 3.6	Variations of the flux and electromotive force in a rotating contour	55
Fig. 3.7	Definition of reference direction for electromotive and back electromotive forces	56
Fig. 4.1	Magnetic circuit made of an iron core and an air gap	60
Fig. 4.2	The reference normal n to surface S which is leaning on contour c	62
Fig. 4.3	The magnetization characteristic of iron	64
Fig. 4.4	Sample magnetic circuit with definitions of the cross-section of the core, flux of the core, flux of the winding, and representative average line of the magnetic circuit. Magnetic circuit has a large iron core with a small air gap in the right-hand side	66
Fig. 4.5	Representation of the magnetic circuit by the equivalent electrical circuit	67
Fig. 4.6	Two coupled windings on the same core	70
Fig. 4.7	Eddy currents in a homogeneous piece of an iron magnetic circuit (<i>left</i>). An example of the magnetization characteristic exhibiting hysteresis (<i>right</i>)	71
Fig. 4.8	Eddy currents cause losses in iron. The figure shows a tube containing flow of spatially distributed currents	73
Fig. 4.9	Electrical insulation is placed between layers of magnetic circuit to prevent flow of eddy currents	76
Fig. 4.10	Calculation of eddy current density within one sheet of laminated magnetic circuit	77

Fig. 5.1 Cross-section of a cylindrical electrical machine. (A) Magnetic circuit of the stator. (B) Magnetic circuit of the rotor. (C) Lines of magnetic field. (D) Conductors of the rotor current circuit are subject to actions of electromagnetic forces F_{em} 82

Fig. 5.2 Adopted reference directions for the speed, electromagnetic torque, and load 83

Fig. 5.3 Magnetic field in the air gap and windings of an electrical machine. (A) An approximate appearance of the lines of the resultant magnetic field in the air gap. (B) Magnetic circuits of the stator and rotor. (C) Coaxially positioned conductors. (D) Air gap. (E) Notation used for the windings 84

Fig. 5.4 Cylindrical magnetic circuit of a stator containing one turn composed of two conductors laid in the opposite slots 85

Fig. 5.5 Shapes of the slots in magnetic circuits of electrical machines. (a) Open slot of rectangular cross-section. (b) Slot of trapezoidal shape. (c) Semi-closed slot of circular cross-section 86

Fig. 5.6 Definitions of one turn and one section 87

Fig. 5.7 Notation of a winding and its axis 89

Fig. 5.8 Balance of power of electrical machine in motoring mode 90

Fig. 5.9 Balance of power of electrical machine in generator mode 90

Fig. 5.10 Cross-section of an electrical machine. (A) Magnetic circuits of the stator and rotor. (B) Conductors of the stator and rotor windings. (C) Air gap 92

Fig. 5.11 The magnetic field lines over the cross-section of an electrical machine 93

Fig. 5.12 Energy exchange between the source, field, and mechanical subsystem within one cycle of conversion. (a) Interval when the source is off, $\Phi = \text{const}$. (b) Interval when the source is on, $I = \text{const}$ 94

Fig. 6.1 Power flow in an electromechanical converter which is based on magnetic coupling field 100

Fig. 6.2 Model of electromechanical converter based on magnetic coupling field with N contours (windings). Contours 1 and i are connected to electric sources, while contours 2 and N are short circuited thus voltages at their terminals are zero 106

Fig. 6.3 The electromotive and counter-electromotive forces 107

Fig. 6.4 Definitions of the leakage flux and mutual flux 110

Fig. 6.5	Balance of power in mechanical subsystem of rotating electrical machine. Obtained mechanical power p_c covers the losses in mechanical subsystem and the increase of kinetic energy and provides the output mechanical power $T_{em}\Omega_m$	120
Fig. 6.6	Reference directions for electromagnetic torque and speed of rotation	123
Fig. 6.7	Block diagram of the electromechanical conversion process	125
Fig. 7.1	Properties of single-fed and double-fed machines	130
Fig. 7.2	Single-fed converter having variable magnetic resistance	131
Fig. 7.3	Modeling variations of the magnetic resistance and self-inductance of the winding	132
Fig. 7.4	Double-fed electromechanical converter with magnetic coupling field	136
Fig. 7.5	Calculation of the self-inductances and mutual inductance of a double-fed converter with magnetic coupling field	137
Fig. 7.6	Torque acting on a contour in homogenous, external magnetic field is equal to the vector product of the vector of magnetic induction \mathbf{B} and the vector of magnetic momentum of the contour. Algebraic intensity of the torque is equal to the product of the contour current I , surface $S = L \cdot D$, intensity of magnetic induction B , and $\sin(\alpha)$. Its course and direction are determined by the normal n_1 oriented in accordance with the reference direction of the current and the right-hand rule	144
Fig. 7.7	Change of angular displacement between stator and rotor flux vectors in the case when the stator and rotor windings carry DC currents	146
Fig. 7.8	Position of stator and rotor flux vectors in DC machines (a), induction machines (b), and synchronous machines (c)	147
Fig. 7.9	Two stator phase windings with mutually orthogonal axes and alternating currents with the same amplitude and frequency create rotating magnetic field, described by a revolving flux vector of constant amplitude. It is required that initial phases of the currents differ by $\pi/2$	150
Fig. 8.1	Cross section of the magnetic circuit of an electrical machine. Rotor magnetic circuit (a), conductors in the rotor slots (b), stator magnetic circuit (c), and conductors in the stator slots (d)	154
Fig. 8.2	Simplified representation of an electrical machine with cylindrical magnetic circuits made of ferromagnetic material with very large permeability. It is assumed that the conductors are positioned on the surface separating ferromagnetic material and the air gap	154

Fig. 8.3 Sinusoidal spatial distribution of conductors of the stator winding 156

Fig. 8.4 Unit vectors of cylindrical coordinate system. Unit vectors r_r , r_z and r_θ determine the course and direction of the radial, axial, and tangential components of magnetic field 158

Fig. 8.5 Cross section (a) and longitudinal cross section (b) of a narrow rectangular contour C positioned along axis z . Width a of the contour EFGH is considerably smaller than its length L . Signs \odot and \otimes in the left-hand part of the figure indicate reference direction of the contour and do not indicate direction of the magnetic field. Reference directions of the magnetic field are indicated in Fig. 8.2. 159

Fig. 8.6 Magnetic field strength in the vicinity of the boundary surface between the ferromagnetic material and air is equal to the line density of the surface currents 163

Fig. 8.7 Calculation of the tangential component of magnetic field in the air gap region next to the boundary surface between the air gap and the stator magnetic circuit 163

Fig. 8.8 Calculation of the radial component of magnetic field in the air gap 165

Fig. 8.9 Closed cylindrical surface S envelops the rotor. The lines of the magnetic field come out of the rotor (surface S) in the region called north magnetic pole of the rotor, and they reenter in the region called south magnetic pole 170

Fig. 8.10 Convention of vector representation of the magnetic field and flux 170

Fig. 8.11 Rotor current sheet is shifted with respect to the stator by θ_m . Maximum density of the rotor conductors is at position $\theta = \theta_m$ 176

Fig. 8.12 Calculation of the tangential component of the magnetic field in the air gap due to the rotor currents, next to the rotor surface 178

Fig. 8.13 Calculation of the radial component of the magnetic field caused by the rotor currents. Position θ_m corresponds to the rotor reference axis, while position θ_1 represents an arbitrary position where the radial component of the magnetic field is observed 179

Fig. 8.14 Convention of vector representation of rotor magnetic field and flux 182

Fig. 9.1 Magnetic fields of stator and rotor 186

Fig. 9.2 Mutual position of the stator and rotor fluxes 187

Fig. 9.3 Calculation of the flux in one turn. While the expression for magnetic induction B_{Fe} on the diameter S_1S_2 is not available, the expression $B(\theta)$ for magnetic induction in the air gap is known 196

Fig. 9.4	Flux in concentrated winding	200
Fig. 9.5	The surface reclining on a concentrated winding with three turns	200
Fig. 9.6	Vector addition of magnetomotive forces in single turns and magnetic axis of individual turns	204
Fig. 9.7	Spatial orientation of flux vector of one turn (a), axis of the winding (b), and flux vector of the winding	205
Fig. 9.8	Spatial orientation of the stator flux vector. Spatial orientation of the rotor flux vector. The electromagnetic torque as the vector product of the two flux vectors	206
Fig. 9.9	A system with two orthogonal windings	214
Fig. 9.10	Positions of the vectors of magnetomotive forces in individual phases, position of their magnetic axes, and unit vectors of the orthogonal coordinate system	219
Fig. 9.11	Field lines and vectors of the rotating magnetic field	220
Fig. 10.1	Rotor field is created by action of permanent magnets built in the magnetic circuit of the rotor	225
Fig. 10.2	Distribution of conductors of a winding having fractional-pitch turns and belt distribution in $m = 3$ slots	231
Fig. 10.3	Electromotive forces of conductors of a turn. (a) Full-pitched turn. (b) Fractional-pitch turn	233
Fig. 10.4	Electromotive forces in a fractional-pitch turn	234
Fig. 10.5	Electromotive force of a fractional-pitch turn. The amplitude of the electromotive force induced in one conductor is denoted by E_1 . The amplitude of the electromotive force induced in one turn is determined by the length of the phasor DC	236
Fig. 10.6	Three series-connected turns have their conductors placed in belts. Each of belts has three adjacent slots (<i>left</i>). Phasor diagram showing the electromotive forces induced in the turns 1, 2, and 3 (<i>right</i>)	238
Fig. 10.7	Phasor diagram of electromotive forces in individual turns for the winding belt comprising $m = 3$ adjacent slots	239
Fig. 10.8	Cross section of an electrical machine comprising one stator winding with sinusoidal distribution of conductors and permanent magnets in the rotor with non-sinusoidal spatial distribution of the magnetic inductance	245
Fig. 10.9	Calculation of the flux in turn A–B (<i>left</i>). Selection of the surface S (<i>right</i>)	247
Fig. 10.10	Semicylinder S extends along the air gap starting from conductor A and ending at conductor B	248

Fig. 11.1 Position of the stator flux vector in a DC machine comprising stator winding with DC current (a) and in DC machine with permanent magnets (b) 262

Fig. 11.2 Position of rotor conductors and directions of electrical currents. (a) Rotor at position $\theta_m = 0$. Rotor conductor 1 in the zone of the north pole of the stator and conductor 2 below the south pole of the stator. (b) Rotor shifted to position $\theta_m = \pi$. Conductors 1 and 2 have exchanged their places 263

Fig. 11.3 Mechanical collector. *A, B*, brushes; *S1, S2*, collector segments 266

Fig. 11.4 Position of the rotor current sheet with respect to magnetic poles of the stator 267

Fig. 11.5 Appearance of the rotor of a DC machine. (a) Appearance of the collector. (b) Appearance of the magnetic and current circuits of a DC machine observed from collector side 267

Fig. 11.6 Connections of rotor conductors to the collector segments in the case when 4 rotor slots contain a total of 8 conductors 268

Fig. 11.7 Direction of currents in 8 rotor conductors distributed in 4 slots 268

Fig. 11.8 Wiring diagram of the rotor current circuit 269

Fig. 11.9 Short circuit of rotor turns during commutation 270

Fig. 11.10 Rotor position and electrical connections after the rotor has moved by $\pi/4 + \pi/4$ with respect to position shown in Fig. 11.8 271

Fig. 11.11 Position of short-circuited rotor turns during commutation. The turns P1–P2 and P5–P6 are brought into short circuit by the brushes *A* and *B*, respectively 271

Fig. 11.12 Commutator as a DC/AC converter. (a) Distribution of currents in rotor conductors. (b) Variation of electromotive force and current in a rotor conductor. *Shaded* intervals correspond to commutation 273

Fig. 11.13 Unfolded presentation of the rotor 274

Fig. 11.14 Rotor of a DC machine observed from the front side 275

Fig. 11.15 Unfolded presentation of rotor conductors and collector segments. The brushes *A* and *B* touch the segments *L1* and *L3* 275

Fig. 11.16 Directions of currents in rotor conductors at position where brush *A* touches the segment *L2* 277

Fig. 11.17 Front side view of the winding whose unfolded scheme is given in Fig. 11.15 279

Fig. 11.18 Short-circuited segments *L1* and *L2* during commutation 280

Fig. 11.19	Armature reaction and the resultant flux	281
Fig. 11.20	Construction of a DC machine	284
Fig. 11.21	Vector representation of the stator and rotor fluxes. (a) Position of the flux vectors of individual windings. (b) Resultant fluxes of the stator and rotor. (c) Resultant flux of the machine	289
Fig. 11.22	Calculation of electromotive force E_a	292
Fig. 11.23	(a) Addition of electromotive forces of individual conductors. (b) Representation of armature winding by a voltage generator with internal resistance	293
Fig. 11.24	(a) Forces acting upon conductors represented in an unfolded scheme. (b) Forces acting upon conductors. Armature winding is supplied from a current generator	295
Fig. 11.25	Dimensions of the main magnetic poles	296
Fig. 12.1	Connections of a DC machine to the power source and to mechanical load	300
Fig. 12.2	Voltage balance in the excitation winding (<i>left</i>) and in the armature winding (<i>right</i>)	302
Fig. 12.3	Model of a DC machine presented as a block diagram	307
Fig. 12.4	Steady-state equivalent circuits for excitation and armature winding	310
Fig. 12.5	Supplying armature winding from a constant voltage source	311
Fig. 12.6	Steady state at the intersection of the machine mechanical characteristics and the load mechanical characteristics	313
Fig. 12.7	No load speed and initial torque	315
Fig. 12.8	The impact of armature voltage on mechanical characteristic	318
Fig. 12.9	Voltage–current characteristic of a DC generator	320
Fig. 12.10	Variations of the position, speed, and torque within one cycle	320
Fig. 12.11	Four quadrants of the T – Ω and U – I diagrams	324
Fig. 12.12	Topology of the converter intended for supplying the armature winding	325
Fig. 12.13	Notation for semiconductor power switches. IGBT transistor switch (a), MOSFET transistor switch (b), and BJT (bipolar) transistor switch (c)	328
Fig. 12.14	Pulse-width modulation	332
Fig. 12.15	Change of the armature current during one switching period	333
Fig. 12.16	Change of armature voltage, armature current, and source current for a DC machine supplied from PWM-controlled switching bridge	335
Fig. 12.17	Topology of switching power converter with transistors	341

Fig. 12.18	Topology of converters with thyristors: Single phase supplied (<i>left</i>) and three phase supplied (<i>right</i>)	342
Fig. 13.1	Simplified thermal model of an electrical machine	347
Fig. 13.2	Temperature change with constant power of losses	348
Fig. 13.3	Temperature change with intermittent load	349
Fig. 13.4	Permissible current, torque, and power in continuous service in constant flux mode (<i>I</i>) and field-weakening mode (<i>II</i>)	354
Fig. 13.5	(a) Transient characteristic. (b) Steady-state operating area	358
Fig. 13.6	Power balance	359
Fig. 14.1	Appearance of a squirrel cage induction motor	366
Fig. 14.2	(a) Stator magnetic circuit of an induction machine. (b) Rotor magnetic circuit of an induction machine	367
Fig. 14.3	Cross section of an induction machine. (a) Rotor magnetic circuit. (b) Rotor conductors. (c) Stator magnetic circuit. (d) Stator conductors	368
Fig. 14.4	Cage winding	368
Fig. 14.5	(a) Cage rotor. (b) Wound rotor with slip rings	370
Fig. 14.6	Magnetomotive forces of individual phases	372
Fig. 14.7	(a) Each phase winding has conductors distributed along machine perimeter. (b) A winding is designated by coil sign whose axis lies along direction of the winding flux	373
Fig. 14.8	Resultant magnetomotive force of three-phase winding. (a) Position of the vector of magnetomotive force at instant $t = 0$. (b) Position of the vector of magnetomotive force at instant $t = \pi/3/\omega_e$	374
Fig. 14.9	Vector representation of revolving field. (\mathbf{F}_s)-vector of the stator magnetomotive force. ($\mathbf{\Phi}_s$)-vector of the flux in one turn of the stator. ($\mathbf{\Phi}_m$)-vector of mutual flux encircling both the stator and the rotor turns	374
Fig. 14.10	An approximate estimate of the force acting on rotor conductors	375
Fig. 15.1	Positions of the phase windings in orthogonal $\alpha\beta$ coordinate system	384
Fig. 15.2	Replacing three-phase winding by two-phase equivalent	384
Fig. 15.3	Two-phase equivalent of a three-phase winding	388
Fig. 15.4	Two-phase equivalent	399
Fig. 15.5	Modeling the rotor cage	401
Fig. 15.6	Three-phase rotor cage and its two-phase equivalent	402
Fig. 15.7	Mutual flux and leakage flux	405
Fig. 15.8	Position of d - q coordinate frame and corresponding steady-state currents in virtual phases d and q	416
Fig. 15.9	Projections of \mathbf{F}_s/N_s on stationary and rotating frame	417

Fig. 15.10	Rotor coordinate system and dq system	419
Fig. 15.11	Stator and rotor windings in dq coordinate frame	422
Fig. 16.1	Components of the air-gap power	431
Fig. 16.2	Steady state equivalent circuit	434
Fig. 16.3	Voltage balance in stator winding	436
Fig. 16.4	Voltage balance in rotor winding	436
Fig. 16.5	Rotor circuit after division of impedances by s	437
Fig. 16.6	Steady state equivalent circuit	437
Fig. 16.7	Equivalent leakage inductance	454
Fig. 16.8	Equivalent circuit of induction machine	458
Fig. 16.9	Mechanical characteristic	459
Fig. 16.10	Mechanical characteristic small slip region	461
Fig. 16.11	Mechanical characteristic in high-slip region	462
Fig. 16.12	Breakdown torque and breakdown slip on mechanical characteristic	464
Fig. 16.13	Regions of the stable and unstable equilibrium	466
Fig. 16.14	Electromagnetic torque and stator current in the steady state	468
Fig. 16.15	Air-gap power split into rotor losses and internal mechanical power	471
Fig. 16.16	Equivalent circuit and relation between voltages and fluxes	471
Fig. 16.17	Balance of power of an induction machine	473
Fig. 17.1	Effects of voltage changes on mechanical characteristic	478
Fig. 17.2	Influence of rotor resistance on mechanical characteristic	480
Fig. 17.3	Wound rotor with slip rings and external resistor. (a) Three-phase rotor winding. (b) Slip rings. (c) Stator. (d) Rotor. (e) External resistor	481
Fig. 17.4	Static power converter in the rotor circuit recuperates the slip power. (a) The converter is connected to the rotor winding via slip rings and brushes. (b) Diode rectifier converts AC rotor currents into DC currents. (c) Thyristor converter converts DC currents into line frequency AC currents. (d) Slip power recovered to the mains	482
Fig. 17.5	Two-pole and four-pole magnetic fields. (a) Windings. (b) Magnetic axes. (c) Magnetic poles	484
Fig. 17.6	Three-phase four-pole stator winding	484
Fig. 17.7	A two-speed stator winding. By changing connections of the halves of the phase windings, two-pole (<i>left</i>) or four-pole (<i>right</i>) structures are realized	491
Fig. 17.8	Rotation of magnetomotive force vector in 2-pole and 4-pole configuration	491
Fig. 17.9	Desired shape of the phase voltage	494
Fig. 17.10	(a) Three-phase PWM inverter with power transistors. (b) Typical waveform of line-to-line voltages	495

Fig. 17.11 Pulse width modulation: upper switch is on during interval t_{ON} 496

Fig. 17.12 Stator current with current ripple 501

Fig. 17.13 Family of mechanical characteristics obtained with variable frequency supply 503

Fig. 17.14 Magnetizing curve 504

Fig. 17.15 The envelope of mechanical characteristics obtained with variable frequency 506

Fig. 17.16 Steady state operating limits in the first quadrant 507

Fig. 17.17 Steady state operating limits for the voltage, current, stator frequency, torque, flux, and power. The region $\Omega_m < \Omega_n$ is with constant flux and torque, while the field weakening region $\Omega_m < \Omega_n$ is with constant power 508

Fig. 17.18 *RI* compensation – the voltage increase at very small speeds 510

Fig. 17.19 Transient and steady state operating limits 512

Fig. 17.20 (a) Semi-closed slot. (b) Open slot 514

Fig. 17.21 Double cage of mains-supplied induction machines. (a) Brass cage is positioned closer to the air gap. (b) Copper or aluminum cage is deeper in the magnetic circuit 515

Fig. 17.22 A deep rotor slot and distribution of rotor currents 517

Fig. 18.1 Three-phase stator winding of synchronous machine 525

Fig. 18.2 Spatial orientation of the stator magnetomotive force 525

Fig. 18.3 Vectors of the stator magnetomotive force and flux 527

Fig. 18.4 Position of rotor flux vector and stator magnetomotive force 528

Fig. 18.5 Stator magnetic circuit is made by stacking iron sheets 528

Fig. 18.6 (a) Rotor with permanent magnets. (b) Rotor with excitation winding. (c) Rotor with excitation winding and salient poles. (d) Common symbol for denoting the rotor in figures and diagrams 532

Fig. 18.7 Passing the excitation current by the system with slip rings and brushes. (a) Shaft. (b) Magnetic circuit of the rotor. (c) Excitation winding. (d) Slip rings. (e) Brushes 533

Fig. 18.8 Contactless excitation system with rotating transformer. (a) Diode rectifier on the rotor side. (b) Secondary winding. (c) Primary winding. (d) Terminals of the primary fed from the stator side. (P) Stator part of the magnetic circuit. (S) Rotor part of the magnetic circuit 535

Fig. 18.9 (a) Rotor with interior magnets. (b) Surface-mounted magnets 536

Fig. 18.10 Magnetizing characteristic of permanent magnet 538

Fig. 18.11	Ferromagnetic material viewed as a set of magnetic dipoles	539
Fig. 18.12	Magnetic circuit comprising a permanent magnet and an air gap	540
Fig. 18.13	Surface-mounted permanent magnets. (A) Air gap. (B) Permanent magnet	542
Fig. 18.14	Permanent magnets buried into the rotor magnetic circuit	542
Fig. 19.1	Revolving vector of the stator magnetomotive force	547
Fig. 19.2	Two-phase representation of the stator winding	549
Fig. 19.3	Synchronous machine with the two-phase stator winding and the excitation winding on the rotor	553
Fig. 19.4	Transformation of stator variables to a synchronously rotating coordinate system. The angle θ_{dq} is equal to the rotor angle θ_m	556
Fig. 19.5	Transformation of stator variables to a synchronously rotating coordinate system. The angle θ_{dq} is equal to the rotor angle θ_m	558
Fig. 19.6	Model of a synchronous machine in the dq coordinate system	562
Fig. 19.7	(a) Anisotropic rotor with excitation winding and with different magnetic resistances along d - and q -axes. (b) Anisotropic rotor with permanent magnets	565
Fig. 19.8	Rotor of a reluctant synchronous machine	567
Fig. 19.9	(a) Constant torque hyperbola in the $i_d - i_q$ diagram. (b) Positions of the rotor, dq coordinate system, and complex plane	569
Fig. 20.1	Steady-state equivalent circuit	574
Fig. 20.2	Phasor diagram of an isotropic machine in motoring mode	577
Fig. 20.3	Equivalent circuit suitable for synchronous generators. Reference direction of stator current is altered, $\underline{I}_G = -\underline{I}_S$	578
Fig. 20.4	Phasor diagram of an isotropic machine in generating mode	578
Fig. 20.5	Phasor diagram of an anisotropic machine ($\omega_m = \omega_e$)	582
Fig. 20.6	Torque change in anisotropic machine in terms of power angle δ	584
Fig. 20.7	Mechanical characteristic	585
Fig. 20.8	Torque change in isotropic machine in terms of power angle	592
Fig. 21.1	Torque response of synchronous machine following the load step	599
Fig. 21.2	Damped oscillations of an LC circuit	600
Fig. 21.3	Response with conjugate complex zeros of characteristic polynomial	602
Fig. 21.4	Response with real zeros of the characteristic polynomial	602

Fig. 21.5 Damper winding built into heads of the rotor poles. Conductive rotor bars are short-circuited at both sides by conductive plates 604

Fig. 21.6 Simplified equivalent scheme of short-circuited synchronous machine with no damper winding and with the excitation winding supplied from voltage source 611

Fig. 21.7 Calculation of transient time constant 612

Fig. 21.8 Simplified equivalent scheme of short-circuited machine with damper winding and voltage-supplied excitation winding 614

Fig. 21.9 Calculating the subtransient time constant 617

Fig. 22.1 Power converter topology intended to supply synchronous permanent magnet motor and the associated current controller 625

Fig. 22.2 Variation of defluxing current i_d in the field-weakening region 630

Fig. 22.3 The transient and steady-state operating limits of synchronous motors with permanent magnet excitation 632