

Contents

<i>Preface to the Third Edition</i>	<i>xi</i>
<i>Preface to the First Edition</i>	<i>xiii</i>
1. Introduction	1
1.1 Introduction	1
1.2 Basic Principle, Types and Constructional Features of Electric Machines	3
1.3 Recent Trends in R&D in Electric Machines	8
2. Magnetic Circuits and Induction	11
2.1 Introduction	11
2.2 Magnetic Circuits	11
2.3 Magnetic Materials and their Properties	27
2.4 Magnetically Induced Emf and Force	30
2.5 AC Operation of Magnetic Circuits	34
2.6 Hysteresis and Eddy-current Losses	36
2.7 Permanent Magnets	39
2.8 Application of Permanent Magnet Materials	44
<i>Practice Problems</i>	<i>47</i>
3. Transformers	52
3.1 Introduction	52
3.2 Transformer Construction and Practical Considerations	53
3.3 Transformer on No-load	59
3.4 Ideal Transformer	64
3.5 Real Transformer and Equivalent Circuit	68
3.6 Transformer Losses	79
3.7 Transformer Testing	79
3.8 The Per Unit System	88
3.9 Efficiency and Voltage Regulation	91
3.10 Excitation Phenomenon in Transformers	100
3.11 Autotransformers	104
3.12 Variable Frequency Transformer	107

3.13	Three-phase Transformers	111
3.14	Parallel Operation of Transformers	126
3.15	Three-winding Transformers	132
3.16	Phase Conversion	136
3.17	Tap Changing Transformers	140
3.18	Voltage and Current Transformers	143
3.19	Audio-frequency Transformer	145
3.20	Grounding Transformer	146
	<i>Matlab Program</i>	147
	<i>Problems</i>	149
4.	Principles of Electromechanical Energy Conversion	156
4.1	Introduction	156
4.2	Energy in Magnetic System	156
4.3	Field Energy and Mechanical Force	161
4.4	Multiply-excited Magnetic Field Systems	178
4.5	Forces/Torques in Systems with Permanent Magnets	188
4.6	Energy Conversion via Electric Field	191
4.7	Dynamical Equations of Electromechanical Systems	195
	<i>Problems</i>	198
5.	Basic Concepts in Rotating Machines	202
5.1	Introduction	202
5.2	Elementary Machines	204
5.3	Generated Emf	212
5.4	Mmf of Distributed AC Windings	225
5.5	Rotating Magnetic Field	233
5.6	Torque in Round Rotor Machine	241
5.7	Operation of Basic Machine Types	246
5.8	Magnetic Leakage in Rotating Machines	259
5.9	Losses and Efficiency	263
5.10	Rating and Loss Dissipation	270
5.11	Matching Characteristics of Electric Machine and Load	276
5.12	Resume	279
	<i>Practice Problems</i>	280
6.	Armature Windings	284
6.1	Introduction	284
6.2	AC Windings	286
6.3	DC Windings	296
	<i>Matlab Program</i>	310
	<i>Practice Problems</i>	312
7.	DC Machines	314
7.1	Introduction	314
7.2	Certain Observations	316

7.3	Emf and Torque	317
7.4	Circuit Model	321
7.5	Armature Reaction	325
7.6	Compensating Winding	331
7.7	Commutation	333
7.8	Methods of Excitation	337
7.9	Magnetization Characteristic	340
7.10	Self-excitation	344
7.11	Characteristics of DC Generators	348
7.12	Characteristics of DC Motors	358
7.13	Starting of DC Motors	370
7.14	Speed Control of DC Motors	375
7.15	Braking of DC Motors	392
7.16	Efficiency and Testing	394
7.17	DC Machine Dynamics	402
7.18	Permanent Magnet DC (PMDC) Motors	406
7.19	DC Machine Applications	406
	<i>Practice Problems</i>	407
8.	Synchronous Machines	413
8.1	Introduction	413
8.2	Basic Synchronous Machine Model	414
8.3	Circuit Model of Synchronous Machine	421
8.4	Determination of the Synchronous Reactance	424
8.5	Determination of Armature Reaction Ampere-turns and Leakage Reactance of a Synchronous Machine—Potier Method	434
8.6	Nature of Armature Reaction	442
8.7	Synchronizing to Infinite Bus-bars	443
8.8	Operating Characteristics	445
8.9	Power Flow (Transfer) Equations	462
8.10	Capability Curve of Synchronous Generator	468
8.11	Salient-pole Synchronous Machine— Two-reaction Model	472
8.12	Parallel Operation of Synchronous Generators	484
8.13	Hunting in Synchronous Machines	486
8.14	Short-circuit Transient in Synchronous Machine	490
8.15	Single-phase Synchronous Generators	498
8.16	Brushless DC Motors	511
	<i>Practice Problems</i>	519
9.	Induction Machine	523
9.1	Introduction	523
9.2	Construction	523
9.3	Flux and Mmf Waves in Induction Motor— Principle of Operation	526
9.4	Development of Circuit Model (Equivalent Circuit)	531
9.5	Power Across Air-gap, Torque and Power Output	536
9.6	Tests to Determine Circuit-model Parameters	547

9.7	The Circle Diagram (Approximate)	564	
9.8	Starting	572	
9.9	Cogging and Crawling	580	
9.10	Speed Control	582	
9.11	Deep-bar/Double-cage Rotor	597	
9.12	Classes of Squirrel-cage Motors	602	
9.13	Induction Generator	603	
9.14	Induction Machine Dynamics: Acceleration Time	606	
9.15	Inverted Induction Machine	623	
9.16	High Efficiency Induction Motors	624	
	<i>Practice Problems</i>	624	
10.	Fractional Kilowatt Motors		629
10.1	Introduction	629	
10.2	Single-phase Induction Motors	629	
10.3	Single-phase Synchronous Motors	653	
10.4	Circuit Model of Single-phase Induction Motor	656	
10.5	Balanced 2-phase Motor Fed from Unbalanced Supply	667	
10.6	Stepper Motors	674	
10.7	Series Motor-Universal Motor	681	
	<i>Practice Problems</i>	687	
11.	Motor Control by Static Power Converters		689
11.1	Introduction	689	
11.2	Solid-state Devices	692	
11.3	Electrical Drives	702	
11.4	Power Converters	703	
11.5	Thyristor Motor Control	705	
11.6	DC Motor Control Through Converters	706	
11.7	DC Motor Control Through Choppers	720	
11.8	AC Motor Control	730	
11.9	Inverters	735	
11.10	Forced Commutation	746	
11.11	Vector Control of an Induction Motor	751	
	<i>Practice Problems</i>	754	
	Appendix I: AC Steady-state Circuit Analysis	757	
	Appendix II: Three-phase Systems	767	
	Appendix III: Special Topics in Transformers	779	
	Appendix IV: Cross-field Machines	782	
	Appendix V: AC Commutator Machines	785	
	Appendix VI: Linear Induction Motor (LIM)	792	
	Appendix VII: Resistance	796	
	Appendix VIII: Sample Examples Solved Using Matlab	798	
	Appendix IX: Table of Constants and Unit Conversion	813	
	References		814
	Answers to Problems		818
	Index		825