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**ELECTRIC  
MACHINERY  
FUNDAMENTALS**

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# **ELECTRIC MACHINERY FUNDAMENTALS**

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**FOURTH EDITION**

**Stephen J. Chapman**

*BAE SYSTEMS Australia*



**Higher Education**

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THIS WORK IS DEDICATED WITH LOVE TO  
MY MOTHER, LOUISE G. CHAPMAN,  
ON THE OCCASION  
OF HER EIGHTY-FIFTH BIRTHDAY.



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## ABOUT THE AUTHOR

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**Stephen J. Chapman** received a B.S. in Electrical Engineering from Louisiana State University (1975) and an M.S.E. in Electrical Engineering from the University of Central Florida (1979), and pursued further graduate studies at Rice University.

From 1975 to 1980, he served as an officer in the U.S. Navy, assigned to teach electrical engineering at the U.S. Naval Nuclear Power School in Orlando, Florida. From 1980 to 1982, he was affiliated with the University of Houston, where he ran the power systems program in the College of Technology.

From 1982 to 1988 and from 1991 to 1995, he served as a member of the technical staff of the Massachusetts Institute of Technology's Lincoln Laboratory, both at the main facility in Lexington, Massachusetts, and at the field site on Kwajalein Atoll in the Republic of the Marshall Islands. While there, he did research in radar signal processing systems. He ultimately became the leader of four large operational range instrumentation radars at the Kwajalein field site (TRADEX, ALTAIR, ALCOR, and MMW).

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Mr. Chapman is a senior member of the Institute of Electrical and Electronic Engineers (and several of its component societies). He is also a member of the Association for Computing Machinery and the Institution of Engineers (Australia).





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# BRIEF CONTENTS

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<b>Chapter 1</b>	<b>Introduction to Machinery Principles</b>	<b>1</b>
<b>Chapter 2</b>	<b>Transformers</b>	<b>65</b>
<b>Chapter 3</b>	<b>Introduction to Power Electronics</b>	<b>152</b>
<b>Chapter 4</b>	<b>AC Machinery Fundamentals</b>	<b>230</b>
<b>Chapter 5</b>	<b>Synchronous Generators</b>	<b>267</b>
<b>Chapter 6</b>	<b>Synchronous Motors</b>	<b>346</b>
<b>Chapter 7</b>	<b>Induction Motors</b>	<b>380</b>
<b>Chapter 8</b>	<b>DC Machinery Fundamentals</b>	<b>473</b>
<b>Chapter 9</b>	<b>DC Motors and Generators</b>	<b>533</b>
<b>Chapter 10</b>	<b>Single-Phase and Special-Purpose Motors</b>	<b>633</b>
<b>Appendix A</b>	<b>Three-Phase Circuits</b>	<b>681</b>
<b>Appendix B</b>	<b>Coil Pitch and Distributed Windings</b>	<b>707</b>
<b>Appendix C</b>	<b>Salient-Pole Theory of Synchronous Machines</b>	<b>727</b>
<b>Appendix D</b>	<b>Tables of Constants and Conversion Factors</b>	<b>737</b>



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# TABLE OF CONTENTS

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<b>Chapter 1</b>	<b>Introduction to Machinery Principles</b>	<b>1</b>
1.1	Electrical Machines, Transformers, and Daily Life	1
1.2	A Note on Units and Notation	2
	<i>Notation</i>	
1.3	Rotational Motion, Newton's Law, and Power Relationships	3
	<i>Angular Position <math>\theta</math> / Angular Velocity <math>\omega</math> / Angular Acceleration <math>\alpha</math> / Torque <math>\tau</math> / Newton's Law of Rotation / Work <math>W</math> Power <math>P</math></i>	
1.4	The Magnetic Field	8
	<i>Production of a Magnetic Field / Magnetic Circuits / Magnetic Behavior of Ferromagnetic Materials / Energy Losses in a Ferromagnetic Core</i>	
1.5	Faraday's Law—Induced Voltage from a Time-Changing Magnetic Field	28
1.6	Production of Induced Force on a Wire	32
1.7	Induced Voltage on a Conductor Moving in a Magnetic Field	34
1.8	The Linear DC Machine—A Simple Example	36
	<i>Starting the Linear DC Machine / The Linear DC Machine as a Motor / The Linear DC Machine as a Generator / Starting Problems with the Linear Machine</i>	
1.9	Real, Reactive, and Apparent Power in AC Circuits	47
	<i>Alternative Forms of the Power Equations / Complex Power / The Relationships between Impedance Angle, Current Angle, and Power / The Power Triangle</i>	
1.10	Summary	53
	Questions	54
	Problems	55
	References	64

<b>Chapter 2</b>	<b>Transformers</b>	<b>65</b>
2.1	Why Transformers Are Important to Modern Life	66
2.2	Types and Construction of Transformers	66
2.3	The Ideal Transformer	68
	<i>Power in an Ideal Transformer / Impedance Transformation through a Transformer / Analysis of Circuits Containing Ideal Transformers</i>	
2.4	Theory of Operation of Real Single-Phase Transformers	76
	<i>The Voltage Ratio across a Transformer / The Magnetization Current in a Real Transformer / The Current Ratio on a Transformer and the Dot Convention</i>	
2.5	The Equivalent Circuit of a Transformer	86
	<i>The Exact Equivalent Circuit of a Real Transformer / Approximate Equivalent Circuits of a Transformer / Determining the Values of Components in the Transformer Model</i>	
2.6	The Per-Unit System of Measurements	94
2.7	Transformer Voltage Regulation and Efficiency	100
	<i>The Transformer Phasor Diagram / Transformer Efficiency</i>	
2.8	Transformer Taps and Voltage Regulation	108
2.9	The Autotransformer	109
	<i>Voltage and Current Relationships in an Autotransformer / The Apparent Power Rating Advantage of Autotransformers / The Internal Impedance of an Autotransformer</i>	
2.10	Three-Phase Transformers	116
	<i>Three-Phase Transformer Connections / The Per-Unit System for Three-Phase Transformers</i>	
2.11	Three-Phase Transformation Using Two Transformers	126
	<i>The Open-<math>\Delta</math> (or V-V) Connection / The Open-Wye-Open-Delta Connection / The Scott-T Connection / The Three-Phase T Connection</i>	
2.12	Transformer Ratings and Related Problems	134
	<i>The Voltage and Frequency Ratings of a Transformer / The Apparent Power Rating of a Transformer / The Problem of Current Inrush / The Transformer Nameplate</i>	
2.13	Instrument Transformers	140
2.14	Summary	142
	Questions	143
	Problems	144
	References	151

<b>Chapter 3</b>	<b>Introduction to Power Electronics</b>	<b>152</b>
3.1	Power Electronic Components	152
	<i>The Diode / The Two-Wire Thyristor or PNP Diode / The Three-Wire Thyristor of SCR / The Gate Turnoff Thyristor / The DIAC / The TRIAC / The Power Transistor / The Insulated-Gate Bipolar Transistor / Power and Speed Comparison of Power Electronic Components</i>	
3.2	Basic Rectifier Circuits	163
	<i>The Half-Wave Rectifier / The Full-Wave Rectifier / The Three-Phase Half-Wave Rectifier / The Three-Phase Full-Wave Rectifier / Filtering Rectifier Output</i>	
3.3	Pulse Circuits	171
	<i>A Relaxation Oscillator Using a PNP Diode / Pulse Synchronization</i>	
3.4	Voltage Variation by AC Phase Control	177
	<i>AC Phase Control for a DC Load Driven from an AC Source / AC Phase Angle Control for an AC Load / The Effect of Inductive Loads on Phase Angle Control</i>	
3.5	DC-to-DC Power Control—Choppers	186
	<i>Forced Commutation in Chopper Circuits / Series-Capacitor Commutation Circuits / Parallel-Capacitor Commutation Circuits</i>	
3.6	Inverters	193
	<i>The Rectifier / External Commutation Inverters / Self-Commutation Inverters / A Single-Phase Current Source Inverter / A Three-Phase Current Source Inverter / A Three-Phase Voltage Source Inverter / Pulse-Width Modulation Inverters</i>	
3.7	Cycloconverters	209
	<i>Basic Concepts / Noncirculating Current Cycloconverters / Circulating Current Cycloconverters</i>	
3.8	Harmonic Problems	218
3.9	Summary	221
	Questions	223
	Problems	223
	References	229
<b>Chapter 4</b>	<b>AC Machinery Fundamentals</b>	<b>230</b>
4.1	A Simple Loop in a Uniform Magnetic Field	230
	<i>The Voltage Induced in a Simple Rotating Loop / The Torque Induced in a Current-Carrying Loop</i>	

4.2	The Rotating Magnetic Field	238
	<i>Proof of the Rotating Magnetic Field Concept / The Relationship between Electrical Frequency and the Speed of Magnetic Field Rotation / Reversing the Direction of Magnetic Field Rotation</i>	
4.3	Magnetomotive Force and Flux Distribution on AC Machines	246
4.4	Induced Voltage in AC Machines	250
	<i>The Induced Voltage in a Coil on a Two-Pole Stator / The Induced Voltage in a Three-Phase Set of Coils / The RMS Voltage in a Three-Phase Stator</i>	
4.5	Induced Torque in an AC Machine	255
4.6	Winding Insulation in an AC Machine	258
4.7	AC Machine Power Flows and Losses	261
	<i>The Losses in AC Machines / The Power-Flow Diagram</i>	
4.8	Voltage Regulation and Speed Regulation	262
4.9	Summary	264
	Questions	265
	Problems	265
	References	266
<b>Chapter 5</b>	<b>Synchronous Generators</b>	<b>267</b>
5.1	Synchronous Generator Construction	267
5.2	The Speed of Rotation of a Synchronous Generator	272
5.3	The Internal Generated Voltage of a Synchronous Generator	273
5.4	The Equivalent Circuit of a Synchronous Generator	274
5.5	The Phasor Diagram of a Synchronous Generator	279
5.6	Power and Torque in Synchronous Generators	280
5.7	Measuring Synchronous Generator Model Parameters	283
	<i>The Short-Circuit Ratio</i>	
5.8	The Synchronous Generator Operating Alone	288
	<i>The Effect of Load Changes on Synchronous Generator Operating Alone / Example Problems</i>	
5.9	Parallel Operation of AC Generators	299
	<i>The Conditions Required for Paralleling / The General Procedure for Paralleling Generators / Frequency–Power and Voltage–Reactive Power Characteristics of a Synchronous Generator / Operation of Generators in Parallel with Large Power Systems / Operation of Generators in Parallel with Other Generators of the Same Size</i>	
5.10	Synchronous Generator Transients	319
	<i>Transient Stability of Synchronous Generators / Short-Circuit Transients in Synchronous Generators</i>	

5.11	Synchronous Generator Ratings	326
	<i>The Voltage, Speed, and Frequency Ratings / Apparent Power and Power-Factor Ratings / Synchronous Generator Capability Curves / Short-Time Operation and Service Factor</i>	
5.12	Summary	336
	Questions	337
	Problems	338
	References	345
<b>Chapter 6</b>	<b>Synchronous Motors</b>	<b>346</b>
6.1	Basic Principles of Motor Operation	346
	<i>The Equivalent Circuit of a Synchronous Motor / The Synchronous Motor from a Magnetic Field Perspective</i>	
6.2	Steady-State Synchronous Motor Operation	350
	<i>The Synchronous Motor Torque–Speed Characteristic Curve / The Effect of Load Changes on a Synchronous Motor / The Effect of Field Changes on a Synchronous Motor / The Synchronous Motor and Power-Factor Correction / The Synchronous Capacitor or Synchronous Condenser</i>	
6.3	Starting Synchronous Motors	364
	<i>Motor Starting by Reduced Electrical Frequency / Motor Starting with an External Prime Mover / Motor Starting by Using Amortisseur Windings / The Effect of Amortisseur Windings on Motor Stability</i>	
6.4	Synchronous Generators and Synchronous Motors	371
6.5	Synchronous Motor Ratings	372
6.6	Summary	373
	Questions	374
	Problems	374
	References	379
<b>Chapter 7</b>	<b>Induction Motors</b>	<b>380</b>
7.1	Induction Motor Construction	380
7.2	Basic Induction Motor Concepts	384
	<i>The Development of Induced Torque in an Induction Motor / The Concept of Rotor Slip / The Electrical Frequency on the Rotor</i>	
7.3	The Equivalent Circuit of an Induction Motor	388
	<i>The Transformer Model of an Induction Motor / The Rotor Circuit Model / The Final Equivalent Circuit</i>	

7.4	Power and Torque in Induction Motors	394
	<i>Losses and the Power-Flow Diagram / Power and Torque in an Induction Motor / Separating the Rotor Copper Losses and the Power Converted in an Induction Motor's Equivalent Circuit</i>	
7.5	Induction Motor Torque–Speed Characteristics	401
	<i>Induced Torque from a Physical Standpoint / The Derivation of the Induction Motor Induced-Torque Equation / Comments on the Induction Motor Torque–Speed Curve / Maximum (Pullout) Torque in an Induction Motor</i>	
7.6	Variations in Induction Motor Torque–Speed Characteristics	416
	<i>Control of Motor Characteristics by Cage Rotor Design / Deep-Bar and Double-Cage Rotor Designs / Induction Motor Design Classes</i>	
7.7	Trends in Induction Motor Design	426
7.8	Starting Induction Motors	430
	<i>Induction Motor Starting Circuits</i>	
7.9	Speed Control of Induction Motors	434
	<i>Induction Motor Speed Control by Pole Changing / Speed Control by Changing the Line Frequency / Speed Control by Changing the Line Voltage / Speed Control by Changing the Rotor Resistance</i>	
7.10	Solid-State Induction Motor Drives	444
	<i>Frequency (Speed) Adjustment / A Choice of Voltage and Frequency Patterns / Independently Adjustable Acceleration and Deceleration Ramps / Motor Protection</i>	
7.11	Determining Circuit Model Parameters	452
	<i>The No-Load Test / The DC Test for Stator Resistance / The Locked-Rotor Test</i>	
7.12	The Induction Generator	460
	<i>The Induction Generator Operating Alone / Induction Generator Applications</i>	
7.13	Induction Motor Ratings	464
7.14	Summary	466
	Questions	467
	Problems	468
	References	472
<b>Chapter 8</b>	<b>DC Machinery Fundamentals</b>	<b>473</b>
8.1	A Simple Rotating Loop between Curved Pole Faces	473



	<i>The Voltage Induced in a Rotating Loop / Getting DC Voltage out of the Rotating Loop / The Induced Torque in the Rotating Loop</i>	
8.2	Commutation in a Simple Four-Loop DC Machine	485
8.3	Commutation and Armature Construction in Real DC Machines	490
	<i>The Rotor Coils / Connections to the Commutator Segments / The Lap Winding / The Wave Winding / The Frog-Leg Winding</i>	
8.4	Problems with Commutation in Real Machines	502
	<i>Armature Reaction / <math>L \, di/dt</math> Voltages / Solutions to the Problems with Commutation</i>	
8.5	The Internal Generated Voltage and Induced Torque Equations of Real DC Machines	514
8.6	The Construction of DC Machines	518
	<i>Pole and Frame Construction / Rotor or Armature Construction / Commutator and Brushes / Winding Insulation</i>	
8.7	Power Flow and Losses in DC Machines	524
	<i>The Losses in DC Machines / The Power-Flow Diagram</i>	
8.8	Summary	527
	Questions	527
	Problems	527
	References	530
<b>Chapter 9</b>	<b>DC Motors and Generators</b>	<b>533</b>
9.1	Introduction to DC Motors	533
9.2	The Equivalent Circuit of a DC Motor	535
9.3	The Magnetization Curve of a DC Machine	536
9.4	Separately Excited and Shunt DC Motors	538
	<i>The Terminal Characteristic of a Shunt DC Motor / Nonlinear Analysis of a Shunt DC Motor / Speed Control of Shunt DC Motors / The Effect of an Open Field Circuit</i>	
9.5	The Permanent-Magnet DC Motor	559
9.6	The Series DC Motor	562
	<i>Induced Torque in a Series DC Motor / The Terminal Characteristic of a Series DC Motor / Speed Control of Series DC Motors</i>	
9.7	The Compounded DC Motor	568
	<i>The Torque–Speed Characteristic of a Cumulatively Compounded DC Motor / The Torque–Speed</i>	

	<i>Characteristic of a Differentially Compounded DC Motor / The Nonlinear Analysis of Compounded DC Motors / Speed Control in the Cumulatively Compounded DC Motor</i>	
9.8	DC Motor Starters <i>DC Motor Problems on Starting / DC Motor Starting Circuits</i>	573
9.9	The Ward-Leonard System and Solid-State Speed Controllers <i>Protection Circuit Section / Start/Stop Circuit Section / High-Power Electronics Section / Low-Power Electronics Section</i>	582
9.10	DC Motor Efficiency Calculations	592
9.11	Introduction to DC Generators	594
9.12	The Separately Excited Generator <i>The Terminal Characteristic of a Separately Excited DC Generator / Control of Terminal Voltage / Nonlinear Analysis of a Separately Excited DC Generator</i>	596
9.13	The Shunt DC Generator <i>Voltage Buildup in a Shunt Generator / The Terminal Characteristic of a Shunt DC Generator / Voltage Control for a Shunt DC Generator / The Analysis of Shunt DC Generators</i>	602
9.14	The Series DC Generator <i>The Terminal Characteristic of a Series Generator</i>	608
9.15	The Cumulatively Compounded DC Generator <i>The Terminal Characteristic of a Cumulatively Compounded DC Generator / Voltage Control of Cumulatively Compounded DC Generators / Analysis of Cumulatively Compounded DC Generators</i>	611
9.16	The Differentially Compounded DC Generator <i>The Terminal Characteristic of a Differentially Compounded DC Generator / Voltage Control of Differentially Compounded DC Generators / Graphical Analysis of a Differentially Compounded DC Generator</i>	615
9.17	Summary Questions Problems References	619 620 621 631
<b>Chapter 10</b>	<b>Single-Phase and Special-Purpose Motors</b>	<b>633</b>
10.1	The Universal Motor <i>Applications of Universal Motors / Speed Control of Universal Motors</i>	634

10.2	Introduction to Single-Phase Induction Motors	637
	<i>The Double-Revolving-Field Theory of Single-Phase Induction Motors / The Cross-Field Theory of Single-Phase Induction Motors</i>	
10.3	Starting Single-Phase Induction Motors	646
	<i>Split-Phase Windings / Capacitor-Start Motors / Permanent Split-Capacitor and Capacitor-Start, Capacitor-Run Motors / Shaded-Pole Motors / Comparison of Single-Phase Induction Motors</i>	
10.4	Speed Control of Single-Phase Induction Motors	656
10.5	The Circuit Model of a Single-Phase Induction Motor	658
	<i>Circuit Analysis with the Single-Phase Induction Motor Equivalent Circuit</i>	
10.6	Other Types of Motors	665
	<i>Reluctance Motors / Hysteresis Motors / Stepper Motors / Brushless DC Motors</i>	
10.7	Summary	677
	Questions	678
	Problems	679
	References	680
<b>Appendix A</b>	<b>Three-Phase Circuits</b>	<b>681</b>
A.1	Generation of Three-Phase Voltages and Currents	681
A.2	Voltages and Currents in a Three-Phase Circuit	685
	<i>Voltages and Currents in the Wye (Y) Connection / Voltages and Currents in the Delta (<math>\Delta</math>) Connection</i>	
A.3	Power Relationships in Three-Phase Circuits	690
	<i>Three-Phase Power Equations Involving Phase Quantities / Three-Phase Power Equations Involving Line Quantities</i>	
A.4	Analysis of Balanced Three-Phase Systems	693
A.5	One-Line Diagrams	700
A.6	Using the Power Triangle	700
	Questions	703
	Problems	704
	References	706
<b>Appendix B</b>	<b>Coil Pitch and Distributed Windings</b>	<b>707</b>
B.1	The Effect of Coil Pitch on AC Machines	707
	<i>The Pitch of a Coil / The Induced Voltage of a Fractional-Pitch Coil / Harmonic Problems and Fractional-Pitch Windings</i>	

B.2	Distributed Windings in AC Machines	716
	<i>The Breadth or Distribution Factor / The Generated Voltage Including Distribution Effects / Tooth or Slot Harmonics</i>	
B.3	Summary	724
	Questions	725
	Problems	725
	References	726
<b>Appendix C</b>	<b>Salient-Pole Theory of Synchronous Machines</b>	727
C.1	Development of the Equivalent Circuit of a Salient-Pole Synchronous Generator	728
C.2	Torque and Power Equations of Salient-Pole Machine	734
	Problems	735
<b>Appendix D</b>	<b>Tables of Constants and Conversion Factors</b>	737

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## PREFACE

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In the years since the first edition of *Electric Machinery Fundamentals* was published, there has been rapid advance in the development of larger and more sophisticated solid-state motor drive packages. The first edition of this book stated that dc motors were the method of choice for demanding variable-speed applications. That statement is no longer true today. Now, the system of choice for speed control applications is most often an ac induction motor with a solid-state motor drive. DC motors have been largely relegated to special-purpose applications where a dc power source is readily available, such as in automotive electrical systems.

The third edition of the book was extensively restructured to reflect these changes. The material on ac motors and generators is now covered in Chapters 4 through 7, before the material on dc machines. In addition, the dc machinery coverage was reduced compared to earlier editions. The fourth edition continues with this same basic structure.

Chapter 1 provides an introduction to basic machinery concepts, and concludes by applying those concepts to a linear dc machine, which is the simplest possible example of a machine. Chapter 2 covers transformers, and Chapter 3 is an introduction to solid-state power electronic circuits. The material in Chapter 3 is optional, but it supports ac and dc motor control discussions in Chapters 7, 9, and 10.

After Chapter 3, an instructor may choose to teach either dc or ac machinery first. Chapters 4 through 9 cover ac machinery, and Chapters 8 and 9 cover dc machinery. These chapter sequences have been made completely independent of each other, so that instructors can cover the material in the order that best suits their needs. For example, a one-semester course with a primary concentration in ac machinery might consist of parts of Chapters 1 to 7, with any remaining time devoted to dc machinery. A one-semester course with a primary concentration in dc machinery might consist of parts of Chapters 1, 3, 8, and 9, with any remaining time devoted to ac machinery. Chapter 10 is devoted to single-phase and special-purpose motors, such as universal motors, stepper motors, brushless dc motors, and shaded-pole motors.

The homework problems and the ends of chapters have been revised and corrected, and more than 70 percent of the problems are either new or modified since the last edition.

In recent years, there have been major changes in the methods used to teach machinery to electrical engineering and electrical technology students. Excellent analytical tools such as MATLAB have become widely available in university engineering curricula. These tools make very complex calculations simple to perform, and allow students to explore the behavior of problems interactively. This edition of *Electric Machinery Fundamentals* makes selected use of MATLAB to enhance a student's learning experience where appropriate. For example, students use MATLAB in Chapter 7 to calculate the torque–speed characteristics of induction motors and to explore the properties of double-cage induction motors.

This text does not teach MATLAB; it assumes that the student is familiar with it through previous work. Also, the book does *not* depend on a student having MATLAB. MATLAB provides an enhancement to the learning experience if it is available, but if it is not, the examples involving MATLAB can simply be skipped, and the remainder of the text still makes sense.

Supplemental materials supporting the book are available from the book's website, at [www.mhhe.com/engcs/electrical/chapman](http://www.mhhe.com/engcs/electrical/chapman). The materials available at that address include MATLAB source code, pointers to sites of interest to machinery students, a list of errata in the text, some supplemental topics that are not covered in the main text, and supplemental MATLAB tools.

This book would never have been possible without the help of dozens of people over the past 18 years. I am not able to acknowledge them all here, but I would especially like to thank Charles P. LeMone, Teruo Nakawaga, and Tadeo Mose of Toshiba International Corporation for their invaluable help with the solid-state machinery control material in Chapter 3. I would also like to thank Jeffrey Kostecki, Jim Wright, and others at Marathon Electric Company for supplying measured data from some of the real generators that the company builds. Their material has enhanced this revision.

Finally, I would like to thank my wife Rosa and our children Avi, David, Rachel, Aaron, Sarah, Naomi, Shira, and Devorah for their forbearance during the revision process. I couldn't imagine a better incentive to write!

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