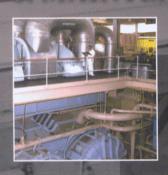
McGraw-Hill HANDBOOKS

ELECTRICAL EQUIPMENT HANDBOOK

TROUBLESHOOTING & MAINTENANCE



- Covers diagnostic testing & inspection methods for electrical equipment
- Presents fault detection techniques
- Provides information on equipment selection and applications

CONTENTS

1.1

Preface

Acknowledgments

Capacitors / 1.1

Chapter 1. Fundamentals of Electric Systems

Current and Resistance / 1.4 The Magnetic Field / 1.6 Faraday's Law of Induction / 1.9 Lenz's Law / 1.11 Inductance / 1.13 Alternating Current / 1.15 Three-Phase Systems / 1.21 References / 1.24	
hapter 2. Introduction to Machinery Principles	2.
Electric Machines and Transformers / 2.1 Common Terms and Principles / 2.1 The Magnetic Field / 2.2 Magnetic Behavior of Ferromagnetic Materials / 2.3 Faraday's Law—Induced Voltage from a Magnetic Field Changing with Time / 2.7 Core Loss Values / 2.9 Permanent Magnets / 2.9 Production of Induced Force on a Wire / 2.14 Induced Voltage on a Conductor Moving in a Magnetic Field / 2.15 References / 2.15	
hapter 3. Transformers	<i>3</i> .
Importance of Transformers / 3.1 Types and Construction of Transformers / 3.1 The Ideal Transformer / 3.2 Impedance Transformation through a Transformer / 3.4 Analysis of Circuits Containing Ideal Transformers / 3.5 Theory of Operation of Real Single-Phase Transformers / 3.9 The Voltage Ratio across a Transformer / 3.10 The Magnetizing Current in a Real Transformer / 3.12 The Dot Convention / 3.14 The Equivalent Circuit of a Transformer / 3.15 The Transformer Voltage Regulation and Efficiency / 3.18 The Autotransformer / 3.22 Three-Phase Transformers / 3.23 Transformer Ratings / 3.25 Reference / 3.28	

viii CONTENTS

Main Components of a Power Transformer / 4.2

Classification of Transformers / 4.1

Introduction / 4.1

Chapter 4. Transformer Components and Maintenance

4.1

	Types and Features of Insulation / 4.9 Forces / 4.11	
	Cause of Transformer Failures / 4.11	
	Transformer Oil / 4.13	
	Gas Relay and Collection Systems / 4.22 Relief Devices / 4.24	
	Interconnection with the Grid / 4.24	
	Reference / 4.27	
•		
C	hapter 5. AC Machine Fundamentals	5.1
	The Rotating Magnetic Field / 5.1	
	The Induced Voltage in AC Machines / 5.6	
	The Induced Torque in an AC Machine / 5.9 Winding Insulation in AC Machines / 5.10	
	AC Machine Power Flow and Losses / 5.11	
	Reference / 5.12	
C	hapter 6. Induction Motors	6.1
	Induction Motor Construction / 6.1	
	Basic Induction Motor Concepts / 6.1	
٠.	The Equivalent Circuit of an Induction Motor / 6.6	
	Losses and the Power Flow Diagram / 6.9 Induction Motor Torque-Speed Characteristics / 6.9	
	Control of Motor Characteristics by Squirrel-Cage Rotor Design / 6.14	
	Starting Induction Motors / 6.17	
	References / 6.21	
C	hapter 7. Speed Control of Induction Motors	7.1
	Speed Control by Changing the Line Frequency / 7.1	•
	Speed Control by Changing the Line Voltage / 7.3	
	Speed Control by Changing the Rotor Resistance / 7.5	
	Solid-State Induction Motor Drives / 7.5 Motor Protection / 7.5	
	The Induction Generator \checkmark 7.5	
	Induction Motor Ratings / 7.8	
	Reference / 7.11	
C	Chapter 8. Maintenance of Motors	8.1
	Characteristics of Motors / 8.1	
	Enclosures and Cooling Methods / 8.1	
	Application Data / 8.3	
	Design Characteristics / 8.4 Insulation of AC Motors / 8.5	
	indutation of the motors in our	

Predictive Maintenance / 8.6 Predictive Maintenance / 8.6 Motor Troubleshooting / 8.7 Diagnostic Testing for Motors / 8.7 Repair and Refurbishment of AC Induction Motors / 8.19 Appendix: Typical Causes of Winding Failures in Three-Phase Stators / 8.21 Reference / 8.22	
napter 9. Power Electronics, Rectifiers, and Pulse-Width odulation Inverters	<i>9</i> .
Introduction to Power Electronics / 9.1 Power Electronics Components / 9.1 Power and Speed Comparison of Power Electronic Components / 9.7 Basic Rectifier Circuits / 9.7 Filtering Rectifier Output / 9.10 Pulse Circuits / 9.12 A Relaxation Oscillator Using a PNPN Diode / 9.13 Pulse Synchronization / 9.15 Voltage Variation by AC Phase Control / 9.16 The Effect of Inductive Loads on Phase Angle Control / 9.18 Inverters / 9.19 Reference / 9.24	
hapter 10. Variable-Speed Drives	10.
Basic Principles of AC Variable-Speed Drivers (VSDs) / 10.1 Inverters / 10.1 Input Power Converter (Rectifier) / 10.3 DC Link Energy / 10.4 Output IGBT Inverter / 10.4 Input Sources for Regeneration or Dynamic Slowdown / 10.5 Regeneration / 10.7 PWM-2 Considerations / 10.8 Transients, Harmonics Power Factor, and Failures / 10.9 Thyristor Failures and Testing / 10.11 AC Drive Application Issues / 10.12 AC Power Factor / 10.13 IGBT Switching Transients / 10.13 Cabling Details for AC Drives / 10.16 Cable Details / 10.16 Motor Bearing Currents / 10.17 Summary of Application Rules for AC Drives / 10.20 Selection Criteria of VSDs / 10.21 Regeneration / 10.21 Maintenance / 10.23 Common Failure Modes / 10.23 Motor Application Guidelines / 10.24 Reference / 10.24	11
hapter 11. Synchronous Machines	11
Physical Description / 11.1 Pole Pitch: Electrical Degrees / 11.2 Air Gap and Magnetic Circuit of a Synchronous Machine / 11.2	

Reference / 15.16

Synchronous Machine Windings / 11.4	
Field Excitation / 11.5 No-Load and Short-Circuit Values / 11.6	
Torque Tests / 11.7	
Excitation of a Synchronous Machine / 11.9	
Machine Losses / 11,10	
Reference / 11.12	
Chapter 12. Synchronous Generators	12.1
Synchronous Generator Construction / 12.1	
The Speed of Rotation of a Synchronous Generator / 12.3	
The Internal Generated Voltage of a Synchronous Generator / 12.3	
The Equivalent Circuit of a Synchronous Generator / 12.6	
The Phasor Diagram of a Synchronous Generator / 12.10	
Power and Torque in Synchronous Generators / 12.11	
The Synchronous Generator Operating Alone / 12.13	
Parallel Operation of AC Generators / 12.15 Operation of Generators in Parallel with Large Power Systems / 12.21	
Synchronous Generator Ratings / 12.25	
Synchronous Generator Capability Curves / 12.26	
Short-Time Operation and Service Factor / 12.28	
Reference / 12.29	
Chantar 12 Ganaratar Campananta Assiliarias and Fredrick	
Chapter 13. Generator Components, Auxiliaries, and Excitation	13.1
The Rotor / 13.1	
Turbine-Generator Components: The Stator / 13.17	
Cooling Systems / 13.31	
Shaft Seals and Seal Oil Systems / 13.35	
Stator Winding Water Cooling Systems / 13.38	
Other Cooling Systems / 13.43	
Excitation / 13.43	
The Voltage Regulator / 13,49 The Power System Sections / 13,53	
The Power System Stabilizer / 13.53 Characteristics of Generator Exciter Power (GEP) Systems / 13.55	
Generator Operation / 13.55	
Reference / 13.58	
Chapter 14. Generator Main Connections	
Chapter 14. Generator Main Connections	14.1
Introduction / 14.1	
Isolated Phase Bus Bar Circulatory Currents / 14.1	
System Description / 14.3	
Reference / 14.3	
Chapter 15. Performance and Operation of Generators	15.1
Owner S. c. P. 25.	
Generator Systems / 15.1	
Condition Monitoring / 15.3 Operational Limitations / 15.7	
Fault Conditions / 15.7	

Chapter 16.	Generator Surveillance and Testing	16.1
Appendix A	Operational Checks (Surveillance and Monitoring) / 16.1 A: Generator Diagnostic Testing / 16.2 B: Mechanical Tests / 16.18	
Chapter 17.	Generator Inspection and Maintenance	17.1
Off-Load N	Inintenance and Monitoring / 17.1 Inintenance / 17.4 Testing / 17.7 / 17.12	
	Generator Operational Problems and ent Options	18.1
Generator I Generator I Types of Ir Generator I High-Speed	Renerator Operational Problems / 18.1 Rotor Reliability and Life Expectancy / 18.7 Rotor Refurbishment / 18.8 Issulation / 18.8 Rotor Modifications, Upgrades, and Uprates / 18.9 I Balancing / 18.9 Test / 18.11 / 18.11	
Chapter 19	. Circuit Breakers	19.1
Physics of Circuit Bre Convention Methods fo Plain Breal Magnetic I Arc Splitte Application Oil Circuit	Circuit Interruption / 19.1 Arc Phenomena / 19.1 aker Rating / 19.3 nal Circuit Breakers / 19.4 or Increasing Arc Resistance / 19.4 k Type / 19.4 Blowout Type / 19.4 r Type / 19.6 n / 19.6 Breakers / 19.6 velopments in Circuit Breakers / 19.9	,
Chapter 20	. Fuses	20.1
Features of Advantage	uses / 20.1 Current-Limiting Fuses / 20.4 s of Fuses over Circuit Breakers / 20.6 Electrical System Protection Considerations / 20.6	
Chapter 21	. Bearings and Lubrication	21.1
Statistical	learings / 21.1 Nature of Bearing Life / 21.3 and Finish / 21.3	

Sizes of Bearings / 21.3 Types of Roller Bearings / 21.5 Thrust Bearings / 21.7 Lubrication / 21.7 References / 21.13	
Chapter 22. Used-Oil Analysis	
Proper Lube Oil Sampling Technique / 22.1 Test Description and Significance / 22.1 Summary / 22.7 Reference / 22.8	
Chapter 23. Vibration Analysis	23. 1
The Application of Sine Waves to Vibration / 23.1 Multimass Systems / 23.1 Resonance / 23.3 Logarithms and Decibels / 23.4 The Use of Filtering / 23.5 Vibration Instrumentation / 23.5 Time Domain / 23.6 Frequency Domain / 23.8 Machinery Example / 23.9 Vibration Analysis / 23.9 Resonant Frequency / 23.12 Vibration Severity / 23.12 A Case History: Condensate Pump Misalignment / 23.12	
Chapter 24. Power Station Electrical Systems and Design Requirements	24 .1
Introduction / 24.1 System Requirements / 24.1 Electrical System Description / 24.3 System Performance / 24.4 Power Plant Outages and Faults / 24.15 Uninterruptible Power Supply (UPS) Systems / 24.16 DC Systems / 24.16 References / 24.19	
Chapter 25. Power Station Protective Systems	25 . 1
Introduction / 25.1 Design Criteria / 25.1 Generator Protection / 25.8 DC Tripping Systems / 25.8 Reference / 25.14	
Appendix. Frequently Asked Questions	A .1