

CONTENTS

Preface

v

1. CONTROL DEVICES FOR INDUSTRIAL MOTOR

1

- 1.1 Introduction 1
- 1.2 Semiconductor Devices 1
 - 1.2.1 Diode 1
 - 1.2.2 Zener Diode 3
 - 1.2.3 Power Transistor 4
 - 1.2.4 Thyristor 5
 - 1.2.5 Silicon-Controlled Rectifier (SCR) 6
 - 1.2.6 Triac 8
 - 1.2.7 Diac 9
 - 1.2.8 Gate-turn-off Switch 10
 - 1.2.9 Unijunction Transistor (UJT) 11
- 1.3 Thyatron 12
- 1.4 Ignitron 15
- 1.5 Amplidyne 16
- 1.6 Saturable Reactor (Magnetic Amplifier) 18
- 1.7 Pilot Devices 20
 - 1.7.1 Push Button 20
 - 1.7.2 Limit Switches 21
 - 1.7.3 Float Switches 21
 - 1.7.4 Pressure Switches 21
 - 1.7.5 Thermostats 22
 - 1.7.6 Plugging Switches 22
 - 1.7.7 Master Controller 23
 - 1.7.8 Transfer Switches 23
 - 1.7.9 Contactors 23
 - 1.7.10 Speed Governors 26

2. ELECTRIC DRIVE

28

- 2.1 Introduction 28
- 2.2 Factors Governing Selection of Motors 28
- 2.3 Nature of Electric Supply 29
- 2.4 Nature of the Drive 31
 - 2.4.1 Group Drive 31
 - 2.4.2 Individual Drive 32
- 2.5 Starting Characteristics 32
 - 2.5.1 Starting Torque of DC Motors 32
 - 2.5.2 Three-phase Induction Motors 33
 - 2.5.3 Methods of Starting 3-phase Induction Motors 35
 - 2.5.4 Limitation of Size 38
 - 2.5.5 Single-phase Induction Motors 38
 - 2.5.6 Synchronous Motors 39
 - 2.5.7 AC Commutator Motors 40
- 2.6 Running Characteristics 40
 - 2.6.1 DC Motor 40
 - 2.6.2 The Three-phase Induction Motor 40
 - 2.6.3 The Schrage Motor 40
 - 2.6.4 The Three-phase Series Motor 41
 - 2.6.5 The Synchronous and Synchronous Induction Motor 41

- 2.6.6 The Single-phase Series Motor 41
- 2.6.7 The Single-phase Induction Motor 41
- 2.7 Speed Control 41
 - 2.7.1 Speed Control of DC Motors 41
 - 2.7.2a Field Control in Shunt Motors 42
 - 2.7.2b Field Control in Series Motor 42
 - 2.7.3 Control of Speed by Change of Series Resistance in the Armature Circuit 44
- 2.8 Electronic Control of DC Motors 48
 - 2.8.1 Speed Relations of DC Motors 48
 - 2.8.2 Thyristor Control of DC Motors 49
 - 2.8.3 DC Motor Supplied by Three-phase Thyristor Rectifiers 51
 - 2.8.4 Field Excitation of DC Motor and Generator from Rectifiers 52
- 2.9 Speed Control of Induction Motors 55
 - 2.9.1 Frequency Method of Speed Control 56
 - 2.9.2 Pole Changing Method of Speed Control 57
- 2.10 Electric Braking 59
 - 2.10.1 Advantages and Disadvantages of Electric Braking Over Mechanical Braking 59
- 2.11 Type of Insulation Employed 63
- 2.12 Heating of Motor or Temperature Rise 64
 - 2.12.1 Equation for Heating of Motor 65
 - 2.12.2 Heating Time Constant 66
- 2.13 Cooling Time Constant 68
- 2.14 Duty Cycles 68
- 2.15 Rating of Machines 71
 - 2.15.1 Effect of Altitude on Rated Output 72
- 2.16 Choice of Rating of Motors 73
- 2.17 Methods of Ventilation and Cooling of Machines 75
- 2.18 Load Equalization 77
- 2.19 Use of Flywheels 77
- 2.20 Mechanical Features of Electric Motor 81
- 2.21 Types of Enclosures 81
- 2.22 Bearings 82
- 2.23 Type of Mountings 82
- 2.24 Transmission of Drive 84
- 2.25 Noise 84
- 2.26 Cost Consideration 85
- 2.27 Motors for Particular Service 85
- 2.6.8 The Repulsion Motor 41
- 2.7.4 Control of Motor Speed by Shunting the Armature by a Resistance 44
- 2.7.5 Booster Control 46
- 2.7.6 Ward-Leonard Method of Speed Control 46
- 2.7.7 Metadyne Control 48
- 2.8.5 Chopper Control of DC Motors 53
- 2.8.6 Closed Loop System for Automatic Speed Control of DC Motor 54
- 2.8.7 Automatic Control 55
- 2.9.3 By Applying Variable Voltage to Stator 57
- 2.9.4 By Varying the Rotor Copper Losses 58
- 2.9.5 Speed Control by Slip Coupling 58
- 2.10.2 Types of Electric Braking 59
- 2.12.3 Equation for Cooling of Motor or Temperature Fall 66
- 2.15.2 Overload Capacity of Induction Motor 73

3. ILLUMINATION**109**

- 3.1 Introduction 109
- 3.2 Nature of Light 109
- 3.3 Definitions 111
 - 3.3.1 Plane Angle and Solid Angle 111
 - 3.3.2 Light Energy 112
 - 3.3.3 Luminous Flux 112
 - 3.3.4 Luminous Intensity 113
 - 3.3.5 Candela 113
 - 3.3.6 Illumination 113
 - 3.3.7 Luminance (Brightness) 114
 - 3.3.8 Mean Horizontal Candle Power (MHCP) 115
 - 3.3.9 Mean Spherical Candle Power (MSCP) 115
 - 3.3.10 Mean Hemispherical Candle Power (MHSCP) 115
 - 3.3.11 Reduction Factor 115
 - 3.3.12 Lamp Efficiency 115
 - 3.3.13 Specific Consumption 115
 - 3.3.14 Space Height Ratio 115
 - 3.3.15 Utilization Factor (UF) 115
 - 3.3.16 Maintenance Factor (MF) 116
 - 3.3.17 Depreciation Factor 116
 - 3.3.18 Waste Light Factor 116
 - 3.3.19 Absorption Factor 116
 - 3.3.20 Luminous Efficiency 116
 - 3.3.21 Beam Factor 117
 - 3.3.22 Reflection Factor 117
 - 3.3.23 Coefficient of Utilisation 117
- 3.4 Polar Curve 118
- 3.5 Rousseau Diagram 118
- 3.6 Laws of Illumination 119
- 3.7 Sources of Light 122
 - 3.7.1 Arc Lamps 122
 - 3.7.2 Incandescent Lamps 124
 - 3.7.3 Gaseous Discharge Lamps 128
 - 3.7.4 Fluorescent Tubes 135
 - 3.7.5 Compact Fluorescent Lamp 142
 - 3.7.6 LED 142
- 3.8 Requirements of Good Lighting 143
- 3.9 Diffusing and Reflecting Surfaces: Globes and Reflectors 144
- 3.10 Types of Light Fittings or Luminaries 146
- 3.11 Methods of Lighting Calculation 148
- 3.12 Factory Lighting 148
- 3.13 Street Lighting 149
- 3.14 Flood Lighting 150
- 3.15 Photometry 152
- 3.16 Integrating Sphere 156

4. ELECTRIC HEATING**163**

- 4.1 Introduction 163
- 4.2 Advantages of Electrical Heating 163
- 4.3 Heating Methods 164
- 4.4 Resistance Heating 164
- 4.5 Direct Resistance Heating 165
- 4.6 Indirect Resistance Heating 165
 - 4.6.1 Types of Furnaces 166
 - 4.6.2 Requirement of a Good Heating Material 168
 - 4.6.3 Materials of Heating Elements 169
 - 4.6.4 Causes of Failure of Heating Elements 169
 - 4.6.5 Temperature Control of Resistance Furnaces 170
 - 4.6.6 Design of Heating Element 172
- 4.7 Radiating Heating 173
- 4.8 Electric Arc Furnace 174
 - 4.8.1 Direct Arc Furnace 174

- 4.9 Indirect Arc Furnace 183
- 4.10 Electron Bombardment Heating 184
- 4.11 High Frequency Heating 186
- 4.12 Induction Heating 186
 - 4.12.1 Direct Core-type Furnace 188
 - 4.12.2 Vertical Core-type Furnace 189
 - 4.12.3 Indirect Core-type Furnace 190
 - 4.12.4 Coreless Furnace 190
 - 4.12.5 Sources of High Frequency for Induction Heating 191
- 4.13 Dielectric Heating 193
 - 4.13.1 Advantages of Dielectric Heating 195
 - 4.13.2 Uses of Dielectric Heating 195
- 4.14 Choice of Frequency 196

5. ELECTRIC WELDING

201

- 5.1 Introduction 201
- 5.2 Classification 201
- 5.3 Electric Arc Welding 202
- 5.4 How Weld Metal is Deposited? 203
- 5.5 Four Positions of Arc Welding 204
- 5.6 Bare Metal Arc Welding 205
- 5.7 Coated Electrodes 205
- 5.8 Types of Joints and Applicable Welds 206
- 5.9 Requirements of Good Weld 207
- 5.10 Atomic Hydrogen Welding 208
- 5.11 Submerged Arc Welding 210
- 5.12 Inert Gas Metal Arc Welding 212
 - 5.12.1 Tungsten Inert-Gas (TIG) Process 212
 - 5.12.2 Metal Inert-Gas (MIG) Process 213
 - 5.12.3 MAG Welding 214
- 5.13 Carbon Arc Welding 215
- 5.14 Electric Supply for Arc Welding 216
- 5.15 Machines for Arc Welding 217
 - 5.15.1 DC Welding Machines with Motor Generator Set 218
 - 5.15.2 AC Rectified Welding Unit 219
 - 5.15.3 AC Welding Machines 219
- 5.16 Resistance Welding 221
- 5.17 Spot Welding 221
- 5.18 Seam Welding 223
- 5.19 Projection Welding 224
- 5.20 Butt Welding 224
 - 5.20.1 Flash Butt Welding 224
 - 5.20.2 Upset Butt Welding 226
 - 5.20.3 Percussion Welding 226
- 5.21 Electron Beam Welding 227
- 5.22 Electro Slag Welding 229
- 5.23 Electro Gas Welding 230
- 5.24 Plasma Arc Welding 230
- 5.25 Laser Welding 232
- 5.26 Ultrasonic Welding 233
- 5.27 Power Supply for Resistance Welding 234
- 5.28 Machines for Resistance Welding 234
- 5.29 Electronic Welding Control 236
 - 5.29.1 Ignitron Contactor 236
 - 5.29.2 Heat Control Unit 237
 - 5.29.3 AC Timer Circuit 238

5.30 Energy Storage Welding 239

5.30.1 Capacitor Discharge Circuit 239

5.30.2 Magnetic Storage Welding
Circuit 240**6. ELECTRIC TRACTION****242**

6.1 Introduction 242

6.2 Traction Systems 242

6.3 Steam Engine Drive 242

6.4 Diesel-electric Drive 243

6.5 Internal Combustion Engine Drive 243

6.6 Electric Drive 244

6.7 Battery Drive 245

6.8 Hybrid Drive 245

6.9 Flywheel Drive 245

6.10 Tramways 246

6.11 Trolley Bus 246

6.12 Systems of Railway Electrification 247

6.12.1 Direct Current System 248

6.12.2 Single-phase Low Frequency AC
System 2486.12.3 Three-phase Low Frequency
System 249

6.12.4 Composite System 249

6.13 Advantages of 25 kV, 50 Hz AC System 250

6.14 Comparison between DC and AC Systems of Railway Electrification from the Point of View
of Main Line and Suburban Line Railway Service 252

6.15 Traction Mechanics 253

6.15.1 Units used in Traction
Mechanics 253

6.15.2 Types of Services 253

6.15.3 Speed Time Curve 253

6.15.4 Simplified Speed–Time
Curve 2546.15.5 Average Speed and Schedule
Speed 258

6.16 Train Movement 258

6.17 Tractive Effort 258

6.18 Tractive Effort-speed Characteristic 262

6.19 Power of the Traction Motor 263

6.20 Specific Energy Consumption 265

6.20.1 Factors Affecting Specific Energy
Consumption 266

6.21 Mechanics of Train Movement 267

6.22 Coefficient of Adhesion 267

6.22.1 Factors Affecting Slip 269

6.23 Electric Traction Systems—Power Supply 273

6.23.1 Transmission Lines to
Substations 273

6.23.2 Substations 274

6.23.3 Feeding and Distribution System
on AC Traction 2756.23.4 Feeding and Distribution System
for DC Tramways 2766.23.5 Electrolysis by Currents through
Earth 276

6.23.6 Negative Boosters 276

6.24 Block Diagram of AC Electric Locomotive 277

6.25 Overhead Equipment (OHE) 278

6.26 Current Collection System 280

6.26.1 Conductor Rail System 280

6.26.2 Current Collection Gear for
OHE 281

6.27 Traction Motor Connections 282

6.28 Smoothing Reactors 283

- 6.29 Desirable Characteristics of Traction Motors 284
- 6.30 Traction Motors 285
 - 6.30.1 Suitability of Series Motor for Traction Duty 285
 - 6.30.2 Series Motor Using Undulating DC 286
 - 6.30.3 Suitability of Shunt Motor for Traction Duty 287
 - 6.30.4 Single-phase Series Motors 288
 - 6.30.5 Three-phase Induction Motor 288
 - 6.30.6 Linear Motor 288
- 6.31 Traction Motor Control 292
 - 6.31.1 Control of DC Traction Motors 292
 - 6.31.2 Series Parallel Control 293
- 6.32 Advantage of Series Parallel Starting 296
- 6.33 Metaldyne Control 296
- 6.34 Multiple Unit Control 299
- 6.35 Wheel Arrangement 301
- 6.36 Bogie Arrangements 302
 - 6.36.1 Monomotor Bogie 303
- 6.37 Transmission of Drive 304
- 6.38 Braking 307
 - 6.38.1 Requirements of a Braking System 307
- 6.39 Types of Braking 308
 - 6.39.1 Mechanical Braking 308
 - 6.39.2 Air Brake System 308
 - 6.39.3 Vacuum Brake System 308
- 6.40 Hydraulic Brake 310
- 6.41 Eddy Current Brakes 310
- 6.42 Magnetic Brakes 310
- 6.43 Types of Electric Braking 311
- 6.44 Mechanical Regenerative Braking 311
- 6.45 Electrical Regenerative Braking 312
 - 6.45.1 How Electrical Regenerative Braking is Applied 312
 - 6.45.2 Conditions Necessary to Achieve Electric Regenerative Braking (ERB) 313
 - 6.45.3 Suitability of DC Shunt, Series and Induction Motors for ERB 314

7. ELECTROLYTIC PROCESSES

327

- 7.1 Introduction 327
- 7.2 Electrolysis-Basic Principle 327
- 7.3 Laws of Electrolysis 328
- 7.4 Terms Connected with Electrolytic Processes 330
- 7.5 Applications of Electrolysis 331
- 7.6 Electrodeposition 332
 - 7.6.1 Electroplating 333
 - 7.6.2 Electrodeposition of Rubber 335
 - 7.6.3 Electrometallisation 335
 - 7.6.4 Electroforming 335
 - 7.6.5 Electroforming 335
 - 7.6.6 Electrotyping 336
- 7.7 Manufacture of Chemicals 336
- 7.8 Anodizing 336
- 7.9 Electropolishing 337
- 7.10 Electrocleaning or Pickling 337
- 7.11 Electroparting or Stripping 338

- 7.12 Electroextraction 338
- 7.13 Electrorefining 339
- 7.14 Power Supply for Electrolytic Processes 339

8. REFRIGERATION AND AIR CONDITIONING

342

- 8.1 Introduction 342
- 8.2 Basic Terminology 342
- 8.3 Applications of Refrigeration 343
- 8.4 Refrigeration Systems 343
 - 8.4.1 Vapour Compression Refrigeration System 343
 - 8.4.2 Absorption Refrigeration System 344
 - 8.4.3 Thermoelectric Refrigeration System 345
- 8.5 Coefficient of Performance 346
- 8.6 Unit of Refrigeration 346
- 8.7 Refrigerants 346
- 8.8 Domestic Refrigerator 347
 - 8.8.1 Troubleshooting of Refrigerator 349
- 8.9 Water Cooler 350
 - 8.9.1 Instantaneous Type Water Coolers 351
 - 8.9.2 Storage Type Water Cooler 353
- 8.10 Desert Cooler 354
- 8.11 Air Conditioning 355
- 8.12 Types of Air Conditioning 355
 - 8.12.1 Unitary Type 356
 - 8.12.2 Central Type 356
 - 8.12.3 Unitary Central Type 356
- 8.13 Window Air Conditioner 356

Bibliography 361

Index 363