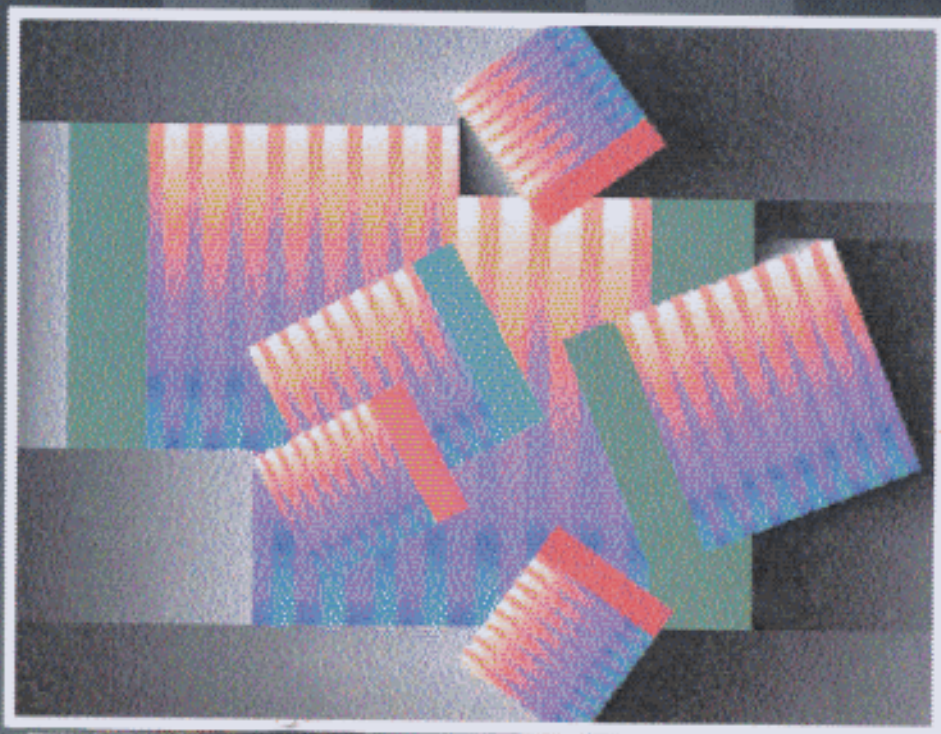


Electrical Power and Controls



Suranaree University of Technology



31051000623005

ANNA KVARENINA

WILLIAM DEWITT

CONTENTS

1. FUNDAMENTALS OF ENERGY AND THE POWER SYSTEM 1

- Introduction 1
- Objectives 1
- Gravitational Force 1
- Energy 2
- Thermodynamic Considerations 8
- Power 8
- Torque 9
- The Power System 10
- The National Power Grid 16
- Changing Times for the Electric Utilities 18
- Summary 23
- Questions 24
- Problems 24

2. SINGLE- AND THREE-PHASE POWER 26

- Introduction 26
- Objectives 26
- DC Circuits 26
- Single-Phase AC Circuits 27
- Three-Phase AC Circuits 31
- Power Factor Correction 35
- Summary 39

- Questions 39
- Problems 40

3. POWER QUALITY CONSIDERATIONS 42

- Introduction 42
- Objectives 42
- Disturbances 43
- What Are Harmonics? 51
- Why Worry About Harmonic Currents? 58
- Notching 69
- IEEE Standard 519 70
- Troubleshooting Power Quality Problems 71
- Summary 74
- Questions 75
- Problems 76

4. MAGNETIC MATERIALS AND CIRCUITS 77

- Introduction 77
- Objectives 78
- Magnetic Fields 78
- Properties of Magnetic Materials 84
- Electrical Circuit Analogy 86
- Hysteresis 88

- Magnetic Core Losses 89
 - Summary 91
 - Problems 91
- 5. TRANSFORMERS 93**
- Introduction 93
 - Objectives 93
 - Transformer Nameplate Data 93
 - Transformer Construction 94
 - Ideal Transformer Operation 99
 - Exciting Current 102
 - Transformer Equivalent Circuits 106
 - Determining Circuit Parameters 111
 - Transformer Efficiency 114
 - Transformer Frequency Response 115
 - Voltage Regulation 117
 - K-Factor-Rated Transformers 120
 - Autotransformers 121
 - Instrument Transformers 123
 - Three-Phase Transformers 125
 - Summary 131
 - Questions 133
 - Problems 134
- 6. INTRODUCTION TO MOTORS AND GENERATORS 136**
- Objectives 137
 - Five Electromagnetic Principles 137
 - A Simple AC Machine 142
 - A Practical AC Synchronous Machine 146
 - A Simple DC Machine 154
 - A Practical DC Machine 157
 - Efficiency and Losses 160
 - Heating, Cooling, and Lifetime of Machines 162
 - Summary 164
 - Questions 165
 - Problems 165
- 7. THREE-PHASE INDUCTION MOTORS 166**
- Introduction 166
 - Objectives 166
 - Construction Features 167
 - Nameplate Data 170
 - Principles of Operation 174
 - Induction Motor Equivalent Circuit 177
 - Torque-Speed Characteristic 182
 - Determination of Equivalent Circuit Parameters 185
 - Induction Motor Performance 186
 - NEMA Motor Designs 188
 - Induction Motor Efficiency 194
 - Energy-Efficient Motors 196
 - Types of Load Torques 201
 - Motor Application Information 202
 - Wiring Connections for Induction Motors 207
 - Starting Considerations for Induction Motors 208
 - Summary 210
 - Questions 211
 - Problems 211
- 8. SINGLE-PHASE MOTORS 213**
- Introduction 213
 - Objectives 213
 - Principle of Operation of a Single-Phase Motor 213
 - Types of Single-Phase Motors 216
 - Troubleshooting 223
 - Questions 223
 - Problems 223
- 9. POWER ELECTRONICS 224**
- Introduction 224
 - Objectives 224
 - Power Electronic Switching Devices 225
 - Adjustable-Speed Drives 232
 - Adjustable-Speed Induction Motor Drives 233
 - Motor Performance Under Variable-Frequency Operation 242
 - Operation of an Adjustable-Speed Drive (ASD) 246
 - Selecting a Motor for Variable-Frequency Operation 249
 - Brushless DC and Stepper Motors 250

Summary 257
 Questions 258
 Problems 258

10. THE SYNCHRONOUS MACHINE 259

Introduction 259
 Objectives 259
 Synchronous Machine Construction 260
 Principles of Operation 264
 Steady-State Equivalent Circuit for a Round-Rotor Synchronous Machine 267
 Performance and Analysis of Synchronous Generators 271
 Synchronous Motors 290
 Power Factor Improvement with a Synchronous Machine 297
 Efficiency and Losses in the Synchronous Machine 298
 Summary 300
 Questions 301
 Problems 301

11. DC MACHINES 304

Introduction 304
 Objectives 304
 Construction and Operating Principles of the DC Machine 305
 DC Generators 317
 DC Motors 329
 Losses and Efficiency 340
 Summary 344
 Questions 346
 Problems 346

12. CONTROL DEVICES AND CIRCUITS 348

Introduction 348
 Objectives 348
 Relays, Contactors, and Motor Starters 348
 Pilot Devices 356

Control Methods and Ladder Diagrams 359
 Reduced-Voltage AC Motor Starters 365
 Reversible Starters 368
 Starting DC Motors 369
 Troubleshooting 372
 Questions 372
 Problems 373

13. BUILDING ELECTRICAL SYSTEMS 374

Introduction 374
 Objectives 374
 Building Design 374
 Electrical Conductors 376
 The *National Electrical Code (NEC)* 378
 Voltage Drop 380
 Motor Circuits 381
 Motor Circuit Design 385
 Residential Electrical Systems 388
 Summary 391
 Questions 392
 Problems 392

14. PROGRAMMABLE LOGIC CONTROLLERS (PLCs) 394

Introduction 394
 Objectives 394
 PLC Overview 395
 Arithmetic Conversions 400
 PLC Components 403
 PLC Programming 412
 Communications 430
 Summary 434
 Questions 434
 Problems 435

APPENDIX A: NEC TABLES 437

APPENDIX B: LIST OF SYMBOLS 449

INDEX 455