Table of Contents

Introduction ix
Scope of *Understanding Basic Motor Controls* ix
How to Use This Textbook ix

CHAPTER 1—INTRODUCTION TO MOTOR CONTROLS 1

UNIT 1—BASIC PRINCIPLES OF MOTOR CONTROLS 3
Unit 1—Introduction 3
1.1 Motor Control Language 4
1.2 Motor Control Basics 8
Unit 1—Conclusion 8
Unit 1—Practice Questions 9

UNIT 2—DEFINITIONS, ABBREVIATIONS, AND SYMBOLS 11
Unit 2—Introduction 11
2.1 Definitions of Control Terminology 11
2.2 Common Abbreviations Used for Electrical Terms and Devices 18
2.3 Standard Symbols 19
Unit 2—Conclusion 20
Unit 2—Practice Questions 21

UNIT 3—COMMON CONTROL EQUIPMENT, DEVICES, AND SYMBOLS 23
Unit 3—Introduction 23
3.1 Auxiliary Contacts 23
3.2 Relays 24
3.3 Drum Switch 25
3.4 Float Switch 26
3.5 Flow Switch 26
3.6 Limit Switch—Mechanical 27
3.7 Limit Switch—Proximity 28
3.8 Limit Switch—Optical 28
3.9 Pressure Switch 28
3.10 Pushbutton Switch 29
3.11 Solenoid 31
3.12 Switch Operations 31
3.13 Temperature Switch 34
3.14 Timing Relay—Pneumatic 35
3.15 Timing Relay with Instantaneous Contacts 35
3.16 Timing Relay—Solid-State 36
3.17 Timing Relay Terminology 36
3.18 Reading a Motor Control Schematic 37
Unit 3—Conclusion 39
Unit 3—Practice Questions 40

CHAPTER 2—MOTOR CONTROLS AND SCHEMATICS 43

UNIT 4—COMPONENTS OF CONTROL CIRCUIT SCHEMATICS 45
Unit 4—Introduction 45
4.1 A Simple Control Circuit 45
4.2 Control Devices with Multiple Contacts 48
Unit 4—Conclusion 49
Unit 4—Practice Questions 50

UNIT 5—MAGNETIC CONTROL 53
Unit 5—Introduction 53
5.1 Electromagnetic Control 53
5.2 Power Sources for the Coil and Control Circuit .. 54
5.3 Coil Applications 55
5.4 Remote Control—Introduction 59
5.5 Lighting Contactor 61
5.6 Feeder Disconnect Contactor with Automatic Control 64
Unit 5—Conclusion 65
Unit 5—Practice Questions 66

UNIT 6—MAGNETIC MOTOR STARTERS 69
Unit 6—Introduction 69
6.1 Magnetic Motor Starters 69
6.2 Other Overload Protection Methods 75
6.3 Auxiliary Contacts 75
6.4 Motor Starter Add-On Accessory Devices 76
Unit 6—Conclusion 76
Unit 6—Practice Questions 77

UNIT 7—BASIC CONTROL CIRCUITS 81
Unit 7—Introduction 81
7.1 2-Wire Control Circuits 81
7.2 3-Wire Control Circuits 84
7.3 3-Wire Circuit in a Wiring (Connection) Diagram 87
7.4 Multiple Start-Stop Pushbutton Stations 89
7.5 Option of Using a 2- or 3-Wire Circuit in One Diagram 92
Unit 7—Conclusion 93
Unit 7—Practice Questions 94

UNIT 8—OVERCURRENT PROTECTION FOR CONTROL CIRCUITS 99
Unit 8—Introduction 99
8.1 Protection for Control Circuits 99
8.2 Common (Tapped) versus Separate Control Circuits 99
8.3 Control Conductor Sizes 16 AWG and 18 AWG 100
8.4 Control Transformer Protection 102
8.5 Other Standard Control Circuit Overcurrent Protection Arrangements 103
Unit 8—Conclusion 104
Unit 8—Practice Questions 105

UNIT 9—INDICATOR (PILOT) LIGHTS AND ILLUMINATED PUSHBUTTONS 107
Unit 9—Introduction 107
9.1 Pilot (Indicator) Lights 107
9.2 Typical Applications for Pilot Lights in Control Circuits 108
9.3 Illuminated Pushbuttons 112
Unit 9—Conclusion 113
Unit 9—Practice Questions 114

UNIT 10—SELECTOR SWITCHES AND TRUTH TABLES 117
Unit 10—Introduction 117
10.1 Truth Tables 117
10.2 Two-Position Selector Switch 117
10.3 Three-Position Selector Switch 118
10.4 Selector Switches—Variations 120
Unit 10—Conclusion 123
Unit 10—Practice Questions 124

CHAPTER 3—REVERSING CONTROLS 127

UNIT 11—REVERSING CONTROLS FOR THREE-PHASE MOTORS 129
Unit 11—Introduction 129
11.1 Reversing Three-Phase Motors 129
11.2 Forward and Reverse Contactors 129
11.3 Interlocking Devices 130
11.4 Electrical Interlock for Magnetic Reversing Controls 131
11.5 Combined Interlock Methods for Reversing Starters 134
11.6 Wiring a Reversing Control Pushbutton Station 136
11.7 Wiring a Reversing Control with a Selector Switch 136
Unit 11—Conclusion 137
Unit 11—Practice Questions 138

UNIT 12—REVERSING CONTROLS WITH INDICATOR (PILOT) LIGHTS FOR THREE-PHASE MOTORS 141
Unit 12—Introduction 141
12.1 Adding Forward and Reverse Pilot Lights 141
12.2 Alternate Pilot Light Connection Points 142
Unit 12—Conclusion 143
Unit 12—Practice Questions 144

UNIT 13—REVERSING CONTROLS WITH LIMIT SWITCHES FOR THREE-PHASE MOTORS 147
Unit 13—Introduction 147
13.1 Reversing Controls with Limit Switches Used to Automatically Stop a Motor 147
13.2 Reversing Controls—Limit Switches for Automatic Forward and Reverse 148
13.3 Reversing Controls and Limit Switches for Garage Door Applications 150
13.4 Forward-Reverse Control With 2-Wire Circuits 153
Unit 13—Conclusion 153
Unit 13—Practice Questions 154

UNIT 14—REVERSING SINGLE-PHASE MOTORS 157
Unit 14—Introduction 157
14.1 Types of Motors 157
14.2 Reversing Control Circuit 159
14.3 Sequence of Operation 159
Unit 14—Conclusion 161
Unit 14—Practice Questions 162

CHAPTER 4—CONTROLS FOR MULTIPLE MOTORS 165

UNIT 15—SEQUENCING CONTROL 167
Unit 15—Introduction 167
15.1 Sequencing Control 167
15.2 Controls for Sequencing Multiple Motors 170
Unit 15—Conclusion 173
Unit 15—Practice Questions 174

UNIT 16—MASTER STOP FUNCTION 177
Unit 16—Introduction 177
16.1 Master or Emergency Stop Controls for Multiple Motors 177
16.2 Factory Installed Jumpers 178
16.3 Types of Pushbuttons 178
Unit 16—Conclusion 178
Unit 16—Practice Questions 179

ANNEX A—MISCELLANEOUS REQUIREMENTS 181

UNIT 17—MOTOR AND CONTROLLER DISCONNECTING MEANS IN SCHEMATICS 183
Unit 17—Introduction 183
17.1 Motor Controllers and Disconnects 183
17.2 Disconnect for Separate Control Circuit 187
Unit 17—Conclusion 187
Unit 17—Practice Questions 188

UNIT 18—MISCELLANEOUS MOTOR CONTROL CIRCUITS 191
Unit 18—Introduction 191
18.1 Combining Devices and Functions for Motor Control Circuits 191
18.2 Control Relay (CR) 191
18.3 Selector Switch Pushbutton 193
Unit 18—Conclusion 195
Unit 18—Practice Questions 196

UNIT 19—MOTOR WINDING CONNECTIONS 199
Unit 19—Introduction 199
19.1 Three-Phase Motors 199
19.2 Dual-Voltage, Nine Lead, Three-Phase Motors 200
19.3 Single-Phase, Dual-Voltage Motors 204
Unit 19—Conclusion 204
Unit 19—Practice Questions 205

UNIT 20—MISCELLANEOUS CONTROL AND SIGNALING CIRCUITS 209
Unit 20—Introduction 209
20.1 Doorbells 209
20.2 Thermostats for Air-Conditioning and Heat 211
Unit 20—Conclusion 212
Unit 20—Practice Questions 213

ANNEX B—BONUS MATERIAL: ARTICLE 430—MOTORS, MOTOR CIRCUITS, AND CONTROLLERS 215

ARTICLE 430—MOTORS, MOTOR CIRCUITS, AND CONTROLLERS 217

Part I. General 217
430.1 Scope 217
430.2 Definitions 217
430.6 Table FLC versus Motor Nameplate Current Rating 219
430.8 Marking on Controllers 220
430.9 Motor Controller Terminal Requirements 220
430.14 Location of Motors 220
430.17 The Highest Rated Motor 220

Part II. Conductor Size 220
430.22 Single Motor Conductor Size 220
430.24 Several Motors—Conductor Size 222
430.28 Motor Feeder Taps 222

Part III. Overload Protection 223
430.31 Overload 223
430.32 Overload Sizing for Continuous-Duty Motors 224
430.36 Use of Fuses for Overload Protection 224
430.37 Number of Overload Devices 224

Part IV. Branch-Circuit, Short-Circuit, and Ground-Fault Protection 224
430.51 General 224
430.52 Branch-Circuit, Short-Circuit, and Ground-Fault Protection 225
430.55 Single Overcurrent Device 226

Part V. Feeder Short-Circuit and Ground-Fault Protection 227
430.62 Feeder Protection 227

Part VI. Motor Control Circuits 228
430.72 Overcurrent Protection for Control Circuits 228
430.73 Protection of Conductors from Physical Damage 228
430.75 Disconnect for Control Circuits 229

Part VII. Motor Controllers 229
430.83 Controller Rating 229
430.84 Need Not Open All Conductors of the Circuit 230
430.87 Controller for Each Motor 230

Part IX. Disconnecting Means 230
430.102 Disconnect Requirement 230
430.103 Operation of Disconnect 231
430.104 Marking and Mounting 232
430.107 Readily Accessible 232
430.109 Disconnecting Means Rating 232
430.111 Combination Controller and Disconnect 233

Part XIV. Tables 233
Article 430—Practice Questions 234

FINAL EXAM 237

INDEX 253