

Contents

Preface — v

Part I: Advanced Process Control — 1

1 Complex and nonconventional control systems — 3

1.1 Cascade control systems — 3

1.1.1 Processes in series — 3

1.1.2 Processes in parallel — 10

1.2 Feedforward control systems — 15

1.3 Ratio control systems — 24

1.4 Inferential control systems — 27

1.5 Selective control systems — 28

References — 30

2 Model predictive control — 32

2.1 Introduction — 32

2.2 MPC history — 32

2.3 Basics of MPC control strategy — 34

2.4 Types of MPC process models — 42

2.4.1 Impulse and step response models — 43

2.4.2 State-space models — 49

2.4.3 Time series models — 49

2.5 Predictions for MPC — 50

2.6 Optimization for MPC — 60

2.7 MPC tuning — 64

2.8 MPC stability — 66

2.9 Nonlinear MPC — 68

References — 71

3 Fuzzy control — 75

3.1 Introduction — 75

3.2 Fuzzy sets — 75

3.3 Typical membership functions of the fuzzy sets — 77

3.4 Operations with fuzzy sets — 81

3.5 Fuzzy logic — 83

References — 91

4 Optimal control systems — 92

4.1 Steady-state optimal control — 92

4.2 Dynamic optimal control of batch processes — 102

4.3 Dynamic optimal control of continuous processes — 111

References — 118

5 Multivariable control — 119

5.1 Introduction — 119

5.2 Multiloop control — 120

5.2.1 Interaction among control loops — 120

5.2.2 Pairing the control loops — 126

5.2.3 Tuning the multiloop controllers — 128

5.2.4 Decoupling interaction for multiloop control — 129

5.3 Multivariable centralized control — 133

References — 134

6 Plantwide control — 136

6.1 Introduction — 136

6.2 Premises of plantwide control — 137

6.3 Designing the plantwide control strategy — 139

References — 143

7 Linear discrete systems and Z transform — 145

7.1 Introduction — 145

7.2 Discrete systems described by input-output relationship — 147

7.2.1 Sampling the continuous signals — 147

7.2.2 Reconstruction of the continuous signals
from their discrete values — 153

7.2.3 Analytical description of the discrete systems — 156

7.2.4 Z transform — 160

7.2.5 Z transform of several simple functions — 162

7.2.6 Inverse of the Z transform — 163

7.2.7 Z transfer function — 166

7.2.8 Z transfer function of the sampled system — 168

7.2.9 Z transfer function of the interconnected systems — 169

7.3 Discrete PID controller — 171

7.4 Other forms of the discrete controllers — 173

References — 175

Part II: Applied Process Engineering Control — 177

8	Reaction unit control — 179
8.1	Introduction — 179
8.2	Basic concepts of ideal continuous and batch units — 179
8.3	Temperature control — 182
8.3.1	Into thermal instability — 182
8.3.2	Out of thermal instability — 184
8.3.3	Temperature control in practice – continuous units — 188
8.3.4	Temperature control in practice – batch units — 195
8.4	Pressure control — 200
8.5	Liquid level control — 202
8.6	pH control — 202
8.6.1	pH and titration curves — 202
8.6.2	pH regulator characteristics — 206
8.6.3	Aspects of pH control in practice — 208
8.7	End-point detection and product-quality control — 210
8.7.1	Some analyzer types — 210
8.7.2	End-point detection reliability issues — 211
8.8	Control structure design for reaction units — 212
8.8.1	Principles of control structure design — 212
8.8.2	Control structure design for homogeneous ideal units — 218
8.8.3	Control structure design for some heterogeneous units — 222
	References — 230

9	Control of distillation processes — 233
9.1	Economic constraints of distillation — 233
9.2	The recovery factor — 234
9.3	Lowering energy demand of distillation units — 237
9.4	General control of continuous distillation columns — 239
9.4.1	Mass and energy balance imposed control issues — 239
9.4.2	Control solutions — 249
9.5	Control issues of continuous distillation column dynamics — 254
9.6	Control issues of batch distillation columns — 259
	References — 260

10	Control of absorption processes — 262
	References — 269

11 Control of extraction processes — 270

References — 278

12 Control of evaporation processes — 279

References — 286

13 Control of drying processes — 287

13.1 Batch drying control — 289

13.1.1 Conventional batch drying control — 289

13.1.2 Advanced batch drying control — 292

13.2 Continuous adiabatic drying — 299

References — 302

14 Control of crystallization processes — 303

14.1 The process of crystallization — 303

14.2 Crystal size distribution control — 308

14.2.1 Model-free crystal size distribution control — 309

14.2.2 Model-based crystal size distribution control — 313

References — 316

15 Problems and exercises — 318

15.1 Advanced process control — 318

15.2 Applied process engineering control — 322

Index — 325