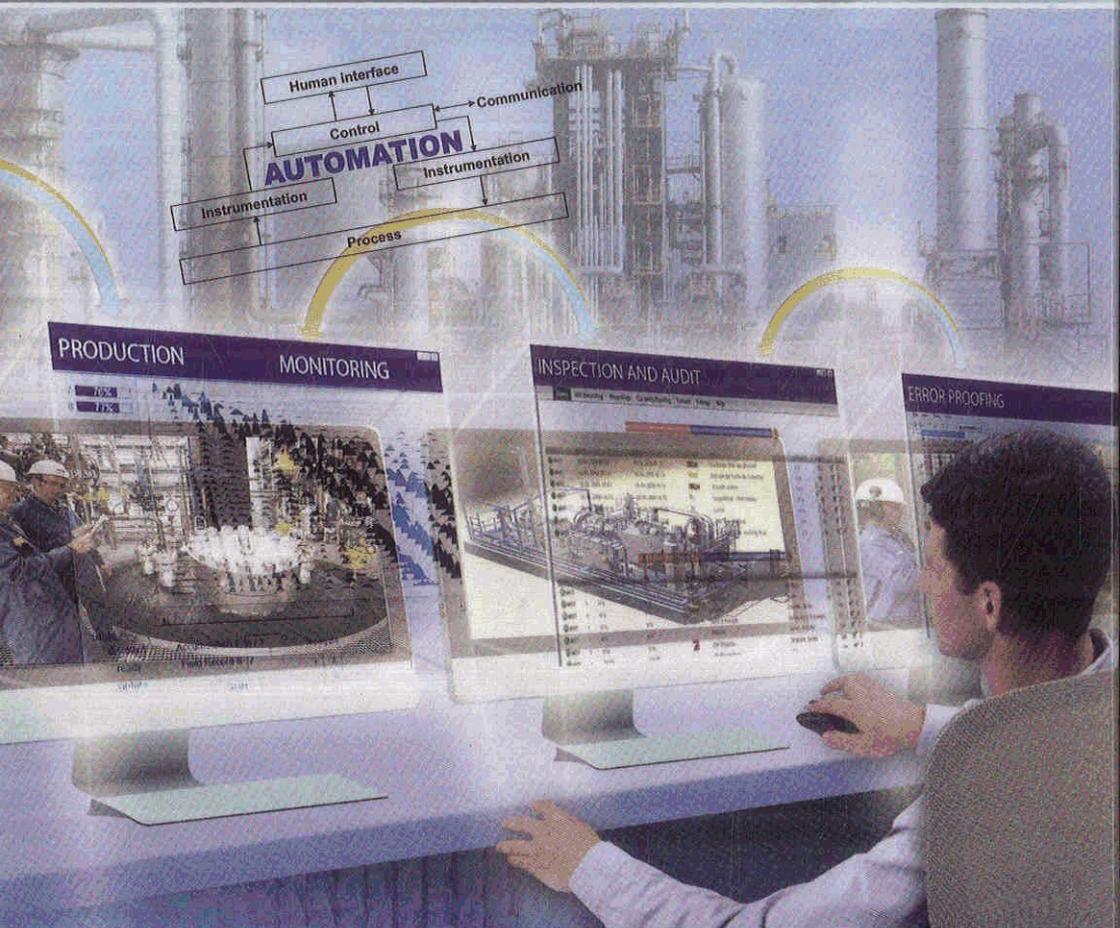


ELSEVIER INSIGHTS



OVERVIEW OF INDUSTRIAL PROCESS AUTOMATION

KLS SHARMA

Contents

Foreword	xvii
About the Author	xix
Preface	xxi
Acknowledgments	xxv
1 Why Automation?	1
1.1 Introduction	1
1.2 Physical Process	1
1.2.1 Natural Processes	2
1.2.2 Self-Regulated Processes	2
1.2.3 Man-made or Industrial Processes	2
1.2.3.1 Water Tap	2
1.2.3.2 Electric Bulb	3
1.2.4 Undesired Behavior	3
1.3 Types of Industrial Processes	3
1.3.1 Localized Processes	3
1.3.2 Distributed Processes	3
1.4 Industry Classification	4
1.4.1 Utility Industry	5
1.4.2 Process Industry	6
1.5 Process Automation System	6
1.5.1 Unattended Processes	7
1.5.2 Manually Attended Processes	8
1.5.3 Automated Processes	9
1.6 Needs Met by Automation	9
1.7 Benefits of Automation	10
1.8 Automation Steps	11
1.8.1 Step 1: Information Acquisition	11
1.8.2 Step 2: Information Analysis and Decision Making	11
1.8.3 Step 3: Control Execution	11
1.9 Process Signals	12
1.9.1 Classifications	12
1.9.2 Input and Output Signals	12
1.9.2.1 Input Signals	12
1.9.2.2 Output Signals	13
1.10 Summary	14

2	Automation System Structure	15
2.1	Introduction	15
2.2	Subsystems	15
	2.2.1 Instrumentation Subsystem	15
	2.2.2 Human Interface Subsystem	16
	2.2.3 Control Subsystem	16
2.3	Instrumentation Subsystem	17
	2.3.1 Measurement of Information	17
	2.3.2 Transfer of Control Command	19
2.4	Human Interface Subsystem	20
	2.4.1 Manual Display and Monitoring	21
	2.4.2 Manual Control	21
2.5	Control Subsystem	21
	2.5.1 Information Acquisition	22
	2.5.2 Information Analysis and Decision Making	22
	2.5.3 Control Execution	22
2.6	Summary	23
3	Instrumentation Subsystem	25
3.1	Introduction	25
3.2	Structure	25
	3.2.1 Continuous/Analog Instrumentation Devices	25
	3.2.1.1 Information Acquisition	25
	3.2.1.2 Control Execution	27
	3.2.2 Discrete/Digital Instrumentation Devices	28
	3.2.2.1 Information Acquisition	28
	3.2.2.2 Control Execution	30
	3.2.3 Fluctuating/Pulse Signals	31
3.3	Special Instrumentation Devices	31
	3.3.1 Switching Instrumentation Devices	32
	3.3.2 Integrating Instrumentation Devices	33
3.4	Interfacing Standards	34
	3.4.1 Analog Input and Output Devices	34
	3.4.2 Digital Input and Output Devices	34
	3.4.3 Switching and Integrating Devices	35
3.5	Information Reliability	35
	3.5.1 Analog Inputs	36
	3.5.2 Digital Inputs	36
3.6	Isolation and Protection	36
	3.6.1 Isolation	37
	3.6.2 Protection	37
	3.6.3 Solutions	37
3.7	Summary	39

4	Control Subsystem	41
4.1	Introduction	41
4.2	Structure	41
4.3	Interfacing	42
4.3.1	General	42
4.3.2	Instrumentation Subsystem	43
4.3.3	Human Interface Subsystem	44
4.4	Summary	45
5	Human Interface Subsystem	47
5.1	Introduction	47
5.2	Operator Panel	47
5.2.1	Active Display Elements	47
5.2.2	Active Control Elements	48
5.2.3	Panel	49
5.3	Construction	49
5.3.1	Basic Approach	50
5.3.2	Mimic Approach	50
5.4	Interfacing with Control Subsystem	51
5.5	Types of Mimic Panels	51
5.6	Summary	52
6	Automation Strategies	53
6.1	Introduction	53
6.2	Basic Strategies	53
6.2.1	Open Loop Control	54
6.2.2	Closed Loop Control	54
6.3	Discrete Control	55
6.3.1	Discrete Control—Open Loop	55
6.3.2	Discrete Control—Sequential Control with Interlocks	56
6.4	Continuous Control	56
6.4.1	Continuous Control—Open Loop	57
6.4.2	Continuous Control—Closed Loop	57
6.5	Hybrid Control	58
6.5.1	Hybrid Control—Two-Step	58
6.5.2	Hybrid Control—Two-Step with Dead-Band	60
6.6	Summary	62
7	Programmable Control Subsystem	63
7.1	Introduction	63
7.2	Discrete Control	65
7.2.1	Sequential Control with Interlocks	65

7.3	Continuous Control	69
7.3.1	Closed Loop Control	69
7.3.2	Multi-Input/Multi-Output Control	70
7.4	Hybrid Control	73
7.4.1	Two-Step Control with Dead-Band	73
7.5	Controller with Additional Features	74
7.5.1	Communicability	76
7.5.2	Self-Supervision or Watchdog	79
7.6	Upward Compatibility	79
7.7	Summary	80
8	Hardware Structure of Controller	81
8.1	Introduction	81
8.2	Major Modules of Controller	82
8.2.1	Rack	82
8.2.2	Bus	82
8.2.3	Functional Modules	84
8.2.4	System Cable	84
8.3	Data Exchange on Bus	85
8.4	Functional Subsystems	86
8.4.1	Power Supply Subsystem	86
8.4.1.1	Power Supply Module	86
8.4.2	Processor Subsystem	86
8.4.2.1	Processor Module	87
8.4.2.2	Memory Module	87
8.4.2.3	Watchdog Module	87
8.4.3	Input/Output Subsystem	91
8.4.3.1	Digital Input Module	91
8.4.3.2	Digital Output Module	91
8.4.3.3	Analog Input Module	91
8.4.3.4	Analog Output Module	92
8.4.3.5	Pulse Input Module	92
8.4.3.6	Pulse Output Module	92
8.4.3.7	Capacity in I/O Modules	94
8.4.4	Communication Subsystem	96
8.4.4.1	Communication Module	96
8.4.4.2	Communication Cables	97
8.4.5	Integrated Processor Module	97
8.5	Controller Capacity Expansion	99
8.5.1	Bus Extension (Parallel) Module	99
8.5.2	Bus Extension (Serial) Module	100
8.6	Integrated Controller	101
8.7	Summary	102

9	Software Structure of Controller	103
9.1	Introduction	103
9.2	Types of Software Systems	103
9.2.1	Non-Real-Time System	104
9.2.2	Real-Time System	104
9.3	Software Structure of Controller	105
9.3.1	Hardware Platform	106
9.3.2	Real-Time Operating System	106
9.3.3	Utility Software	106
9.3.4	Application Software	106
9.4	Scheduling of Tasks	107
9.4.1	Sequential Scheduling	107
9.4.2	Sequential Scheduling with Time-Slice	107
9.4.3	Real-Time Scheduling	108
9.4.3.1	Program Interrupt	108
9.4.3.2	Task Execution	108
9.5	Scheduling of Tasks in Automation Systems	109
9.5.1	Process Data Acquisition	109
9.5.2	Process Data Monitoring	110
9.5.3	Process Control	110
9.6	Memory Organization	110
9.7	Summary	111
10	Programming of Controller	113
10.1	Introduction	113
10.2	Higher-level Programming	113
10.2.1	Ladder Diagram	114
10.2.2	Function Block Diagram	117
10.3	Programming Examples	120
10.3.1	Sequential Control with Interlocks	120
10.3.2	Loop Control	127
10.3.3	Two-Step Control with Dead-Band	129
10.4	Summary	133
11	Advanced Human Interface	135
11.1	Introduction	135
11.2	Intelligent Operator Panels	136
11.3	Operator stations	138
11.3.1	Display Screen Layout	140
11.3.2	Interaction with the Process	141
11.3.2.1	Direct Interaction	141
11.3.2.2	Navigated Interaction	141
11.3.2.3	Other Features	145

11.3.3	Comparison with Operator Panel	146
11.3.3.1	Advantages and Disadvantages of Operator Stations	146
11.3.4	Enhanced Operator Stations	146
11.3.4.1	Multiple Monitors	147
11.3.4.2	Large Screen Displays	147
11.3.4.3	Displays with Embedded Video	148
11.3.4.4	Combined Mimic Panel and Operator Station	148
11.3.5	Variants of Operator Stations	149
11.4	Logging stations	149
11.4.1	Data Logging	149
11.5	Control Desk	150
11.6	Summary	151
12	Types of Automation Systems	153
12.1	Introduction	153
12.2	Localized Process	153
12.2.1	Centralized Control System	154
12.2.2	Decentralized/Distributed Control System	155
12.3	Distributed Process	156
12.3.1	Remote Control System	157
12.3.2	Network Control System	157
12.3.3	Front-End Processor	157
12.3.3.1	Controller-Based FEP	159
12.3.3.2	Computer-Based FEP	160
12.4	Supervisory Control and Data Acquisition	161
12.4.1	Background	161
12.4.2	Case Study	161
12.4.3	Similarities with DCS and NCS	163
12.4.3.1	SCADA in DCS	163
12.4.3.2	SCADA in NCS	163
12.5	Summary	164
13	Special-Purpose Controllers	165
13.1	Introduction	165
13.2	Controller for Localized Processes	165
13.2.1	Programmable Logic Controller	165
13.2.2	Loop Controller	168
13.2.3	Programmable Controller	169
13.3	Controller for Distributed Processes	170
13.3.1	Remote Terminal Unit	171
13.4	Other Players	174
13.4.1	PC-Based Controller	174
13.4.2	Programmable Automation Controller	174
13.5	Summary	176

14	System Availability	177
14.1	Introduction	177
14.2	Standby Schemes	177
14.2.1	No Standby	177
14.2.2	Cold Standby	178
14.2.3	Hot Standby	178
14.3	Distributed Control System	179
14.3.1	Availability Analysis in DCS	179
14.3.1.1	Level 1: Instrumentation Subsystems	179
14.3.1.2	Level 2: Controllers	180
14.3.1.3	Level 3: Local Communication Subsystem	181
14.3.1.4	Level 4: Operator Station	181
14.3.2	Availability Enhancement in DCS	182
14.3.2.1	Processor in Controller	182
14.3.2.2	Ethernet I/F in Controller	182
14.3.2.3	LAN	183
14.4	Network Control System	183
14.4.1	Availability Analysis in NCS	184
14.4.1.1	Level 1: Instrumentation Subsystem	185
14.4.1.2	Level 2: RTUs	185
14.4.1.3	Level 3: Remote Communication Subsystem	186
14.4.1.4	Level 4: FEP Subsystem	186
14.4.1.5	Level 5: Local Communication Subsystem	186
14.4.1.6	Level 6: Operator Station	186
14.4.2	Availability Enhancement in NCS	186
14.4.2.1	Serial I/F and Processor in RTU	186
14.4.2.2	WAN	186
14.4.2.3	Serial I/F, Processor, and Ethernet I/F in FEP	187
14.4.2.4	LAN	187
14.5	I/O Redundancy	188
14.6	Summary	188
15	Common Configurations	189
15.1	Introduction	189
15.2	Distributed Control System	189
15.2.1	Operator Stations	189
15.2.2	Supervisory Stations	189
15.2.3	Application Stations	190
15.3	Network Control System	191
15.4	Summary	192
16	Advanced Input/Output System	193
16.1	Introduction	193
16.2	Centralized I/O	193
16.2.1	Intelligent CIO	194

16.2.2	Advantages and Disadvantages	195
16.3	Remote I/O	196
16.3.1	Advantages and Disadvantages	198
16.4	Fieldbus I/O	199
16.4.1	Advantages and Disadvantages	200
16.4.2	Fieldbus I/F Module	202
16.4.3	Intelligent Serial I/F	204
16.4.4	Protocol Standards	204
16.5	Summary	205
17	Concluding Remarks	207
17.1	Introduction	207
17.2	Major Functionalities	207
17.2.1	Data Acquisition	207
17.2.2	Data Supervision or Monitoring	207
17.2.3	Process Survey	207
17.2.4	Process Control	208
17.2.5	Process Studies	208
17.2.6	Human Interaction	208
17.2.7	Data Logging and History Generation	208
17.2.8	Data Exchange	208
17.3	Data Availability	208
17.4	Today's Automation Systems	209
17.5	Modern Control Center	210
17.6	Application Areas of Automation Systems	210
17.6.1	Discrete Process Automation	211
17.6.2	Continuous Process Automation	211
17.6.3	Batch Process Automation	211
17.7	Summary	212
Appendix A	Hardwired Control Subsystem	213
A.1	Introduction	213
A.2	Discrete Control	213
A.2.1	Relay Technology	213
A.2.1.1	Control Strategy Implementation	217
A.2.1.2	Open Loop Control—Discrete	220
A.2.1.3	Sequential Control with Interlocks—Discrete	221
A.2.1.4	Advantages and Disadvantages	223
A.2.2	Solid State Technology	223
A.2.2.1	Control Strategy Implementation	224
A.2.2.2	Open Loop Control—Discrete	224
A.2.2.3	Sequential Control with Interlocks—Discrete	225
A.2.2.4	Advantages and Disadvantages	227
A.3	Continuous Control	228
A.3.1	Solid State Technology	228
A.3.1.1	Control Strategy Implementation	229

A.3.1.2	Open Loop Control—Continuous	229
A.3.1.3	Closed Loop Control—Continuous	230
A.4	Hybrid Control	231
A.4.1	Solid State Technology	231
A.4.1.1	Control Strategy Implementation	231
A.4.1.2	Two-Step Control	231
A.4.1.3	Two-Step Control with Dead-Band	232
A.5	FPGA- and FPAA-Based Controllers	234
Appendix B Processor		235
B.1	Introduction	235
B.2	Hardware structure	235
B.2.1	Bus	235
B.2.2	Address Space and Distribution	236
B.2.3	Interfacing of Modules with Bus	237
B.2.3.1	Power Supply Module	237
B.2.3.2	Processor Module	237
B.2.3.3	Memory Module	238
B.2.3.4	Functional Module	239
B.2.3.5	Bus Extension (Parallel) Module	240
B.2.3.6	Bus Extension (Serial) Module	240
B.2.3.7	Operations on the Bus	241
B.2.3.8	Memory Module	241
B.2.3.9	I/O Module	241
B.2.3.10	Communication Module	241
B.2.3.11	Watchdog Module	243
Appendix C Hardware-Software Interfacing		245
C.1	Introduction	245
C.2	Architectural Aspects	245
C.2.1	Address Distribution	245
C.2.2	Processor Registers	245
C.2.3	Data Range in Memory/Registers	246
C.2.4	Instruction Formats	247
C.2.4.1	Data Movement Operations	247
C.2.4.2	Logical Operations	247
C.2.4.3	Arithmetic Operations	248
C.2.4.4	Control Operations	248
C.2.5	Program Interfacing with Functional Modules	249
C.2.5.1	Status Register	249
C.2.5.2	Data Registers	250
C.2.6	Interfacing of Functional Modules with Software	250
C.2.6.1	Digital Input	250
C.2.6.2	Digital Output	251
C.2.6.3	Analog Input	251
C.2.6.4	Analog Output	251

C.2.6.5	Pulse Input	252
C.2.6.6	Pulse Output	252
C.2.6.7	Communication	253
C.2.6.8	Watchdog	254
Appendix D	Instruction Set of Processor	255
D.1	Introduction	255
D.2	Data Movement Operations	255
D.3	Logical Operations	255
D.4	Arithmetic Operations	256
D.5	Control Operations	256
Appendix E	Basics of Programming	257
E.1	Introduction	257
E.2	Lower-Level Programming	257
E.2.1	Machine Level	257
E.2.2	Assembly Level	257
E.3	Programming Examples	258
E.3.1	Programming with Digital I/O	259
E.3.2	Programming with Analog I/O	261
E.3.3	Programming with Pulse I/O	263
E.3.4	Programming with Communication	264
E.3.5	Programming with Interrupt	266
E.3.6	Assembling of Program	268
E.3.7	Higher-Level Programming	271
Appendix F	Advanced Control Strategies	273
F.1	Introduction	273
F.2	Closed Loop Control	273
F.2.1	Controller Response to Control Input	273
F.2.2	Proportional Control	275
F.2.3	Proportional and Integral Control	275
F.2.4	Proportional, Integral, and Derivative Control	276
F.2.5	Summary of Control Schemes	278
F.3	Feed-Forward Control	278
F.4	Cascade Control	279
F.5	Ratio Control	280
F.6	Multi-Step Control	281
Appendix G	Power Supply System	285
G.1	Introduction	285
G.2	Float-cum-Boost Charger with Battery Backup	285
G.3	Uninterrupted Power Supply System	286
G.4	Battery Bank	288
G.5	Power Distribution	288
Appendix H	Further Reading	291