

Contents

1	Motivation: Why This Book	1
	References	5
2	Industry 4.0, China 2025, IoT (Internet of Things), AI	7
2.1	History of Automation	8
2.1.1	Industry 4.0	11
2.1.2	Made in China 2025 or China 2025 for Short	14
2.1.3	Internet of Things (IoT) or the Everything Network (Allesnetz)	17
2.2	Industry 4.0, Artificial Intelligence (AI), Artificial Neural Networks (ANN)	19
2.2.1	Pattern Recognition, Artificial Neural Networks and Polynomial Classifiers	22
2.2.2	Speech Recognition as a Selected Example of Applications in AI	29
2.3	Predictive Maintenance	30
2.3.1	Predictive Systems in Industry	32
2.3.2	Example of Predictive Maintenance for Coating Thickness Gauges	35
2.4	Programming Languages, Fortran, C, C++, STEP7	36
2.4.1	Programming Language Fortran	37
2.4.2	Programming Language C	38
2.4.3	Programming Language C++	39
2.4.4	STEP 7 Programming Language	40
2.4.5	Summary of Programming Languages	41
2.5	Industry 4.0, Man and Machine	42
	References	43

3	Automation and Quality Control in Industry 4.0	47
3.1	Complexity Pyramid of Automation	48
3.1.1	Automation: Offline, Online, Inline.	50
3.1.2	Electromagnetic Compatibility (EMC)	55
3.1.3	CE Marking	56
3.1.4	CE Marking and Radio Approval.	59
3.1.5	Protection Classes IP	59
3.1.6	Explosive Environments ATEX, FM, IECEx.	63
3.1.7	Functional Safety or SIL: Safety Integrity Level	68
	References.	70
4	Automation Pyramid and Solutions Business	75
4.1	Solution Business in Automation and ‘Consultative Value Selling’	76
4.1.1	Contract	78
4.1.2	Service Contract.	80
4.1.3	Layer Thickness Measurement as an Example of Solution Selling or ‘Consultative Value Selling’ in Automation	81
4.2	Automation Pyramid from 1985: Industry 4.0, ‘Made in China 2025’, IoT	87
4.3	Enterprise Level or ERP Level (Enterprise Resource Planning).	91
4.3.1	SAP: An ERP Building Block of Industry 4.0.	93
4.3.2	Personal Experience with ERP Systems	96
4.3.3	How SAP Works and Which Mistakes Are Often Made: Example	99
4.3.4	Summary ERP (SAP).	105
4.4	MES Operating Level (Manufacturing Execution System)	106
4.4.1	Functionality of the MES and Differentiation from the ERP System	107
4.4.2	Standardization and Association Activities for MES Systems	111
4.4.3	Summary MES.	112
4.5	Process Control Level, Control Room or SCADA Level	113
4.5.1	History of SCADA.	113
4.5.2	Technology.	114
4.5.3	Summary SCADA System.	117
4.6	PLC Level	117
4.6.1	History of the PLC: Programmable Logic Controller	117
4.6.2	PLC Technology.	118
4.7	Field Level Sensors/Actuators.	122
4.7.1	Development of Sensors in Analytical Measurement Technology with Regard to Automation	122
4.7.2	Smart Manufacturing, Factory 4.0 in Analytical Instrumentation in 2000	138
	References.	140

5 Fieldbuses, Communication Protocols, User Interfaces, Hardware ASICs 149

5.1 Distribution of Fieldbuses, Namur Study, Requirements for Fieldbuses ... 151

5.2 Standardization of the Bus Systems 153

5.2.1 IEEE 802 (Institute of Electrical and Electronics Engineers) ... 159

5.2.2 Typical Network Topologies of Bus Systems 161

5.3 History of Fieldbuses and Bus Systems: Ethernet, HART, PROFIBUS, FF and Fieldbus Organizations. 161

5.3.1 Advantages and Disadvantages of Field Buses 167

5.3.2 Bodies and Standardization of Fieldbus and Bus Systems 167

5.4 PROFIBUS, the Umbrella Organization, PROFIBUS and PROFINET International (PI) 169

5.4.1 The Different PROFIBUS Communication Protocols and Operating Software 170

5.4.2 Summary of Fieldbus History 171

5.5 FDT/DTM™ and PACTware for Control Room..... 174

5.5.1 Functionality of the FDT/DTM™ Concept..... 176

5.5.2 FDT/DTM™ Summary 180

5.6 The OSI Model (Open System Interconnection Model)..... 181

5.6.1 Summary OSI Model..... 186

5.7 Ethernet..... 187

5.7.1 Ethernet History..... 187

5.7.2 OSI Model and Ethernet..... 189

5.7.3 Ethernet Protocol (Data Frame)..... 190

5.7.4 CSMA/CD (Carrier Sense Multiple Access/Collision Detection) Algorithm 194

5.7.5 Ethernet Connections and Networking, ASICs 195

5.7.6 Ethernet Future: Power over Ethernet (PoE) and Tbit/s Ethernet..... 207

5.8 Ethernet TCP/IP Protocol 209

5.9 EtherNet/IP: An Ethernet Fieldbus 211

5.9.1 EtherNet/IP History 211

5.9.2 OSI Model and EtherNet/IP, ControlNet and DeviceNet..... 211

5.9.3 Technology of EtherNet/IP and TCP/UDP 212

5.10 EtherCAT: An Ethernet Fieldbus..... 214

5.10.1 History EtherCAT..... 214

5.10.2 OSI Model and EtherCAT 216

5.10.3 EtherCAT Frame 216

5.10.4 Technology of the EtherCAT..... 218

5.10.5 ASIC EtherCAT from Beckhoff..... 219

5.10.6 Summary EtherCAT..... 221

5.11 PROFINET: An Ethernet Fieldbus 222

5.11.1 PROFINET History 222

- 5.11.2 OSI Model and PROFINET 223
 - 5.11.3 PROFINET Technology 225
 - 5.11.4 Summary PROFINET 227
- 5.12 CC-Link: An Ethernet Fieldbus 228
 - 5.12.1 CC-Link History 228
 - 5.12.2 OSI Model and CC- Link 229
 - 5.12.3 The CC-Link Frame 229
 - 5.12.4 CC-Link Technology 232
 - 5.12.5 Example of a CC-Link Safety Application 232
- 5.13 PROFIBUS 233
 - 5.13.1 PROFIBUS History 233
 - 5.13.2 OSI Model and PROFIBUS 235
 - 5.13.3 The PROFIBUS Protocols 238
 - 5.13.4 PROFIBUS Technology 239
 - 5.13.5 ASIC PROFIBUS DP 240
 - 5.13.6 Summary PROFIBUS 242
- 5.14 HART (Highway Addressable Remote Transducer) 243
 - 5.14.1 History HART 243
 - 5.14.2 OSI Model and HART 245
 - 5.14.3 The HART Protocol 246
 - 5.14.4 Technology of the HART 247
 - 5.14.5 HART Device Description DDL (Device Description Language) 252
 - 5.14.6 ASIC HART Modem 253
 - 5.14.7 Summary HART 255
- 5.15 WirelessHART 256
 - 5.15.1 WirelessHART History 256
 - 5.15.2 Technology of the WirelessHART 257
 - 5.15.3 Summary and Example of a Network Topology with WirelessHART and HART-IP 262
- 5.16 WLAN/Wi-Fi 263
 - 5.16.1 WLAN/Wi-Fi History 264
 - 5.16.2 OSI Model and WLAN/Wi-Fi 266
 - 5.16.3 WLAN/Wi-Fi Frame 267
 - 5.16.4 WLAN/Wi-Fi Technology 268
 - 5.16.5 ASIC for WLAN/Wi-Fi 270
 - 5.16.6 Summary WLAN/Wi-Fi 271
- 5.17 Bluetooth 1.0 to Bluetooth 5 272
 - 5.17.1 Bluetooth History 272
 - 5.17.2 Bluetooth Layer Model 273

5.17.3	Bluetooth Data Packet	274
5.17.4	Bluetooth Technology	274
5.17.5	ASIC Bluetooth	275
5.17.6	Bluetooth Summary	276
5.18	Modbus	276
5.18.1	History Modbus	276
5.18.2	OSI Model and Modbus	277
5.18.3	Modbus Protocol	278
5.18.4	Summary Modbus and Personal Experiences	279
5.19	CAN Bus	281
5.19.1	CAN Bus History	281
5.19.2	OSI Model and CAN Bus	282
5.19.3	CAN Bus Frame	282
5.19.4	CAN Bus Technology and Interference Immunity	285
5.19.5	CANopen, DeviceNet	286
5.19.6	Summary CAN Bus	287
5.20	IO-Link	287
5.20.1	History of IO-Link	287
5.20.2	IO-Link Technology and Specifications	288
5.20.3	Summary IO-Link	292
5.21	OPC UA (OPC Unified Architecture)	294
5.21.1	History OPC UA	294
5.21.2	OSI Model and OPC UA	296
5.21.3	Networking Topology of OPC UA	297
5.21.4	Cloud Computing	298
5.21.5	Example of an OPC UA Structure in the Solar Industry	300
5.21.6	Summary OPC UA	303
	References	305
6	History of Smaller Companies Regarding Industry 4.0, China 2025, IoT	331
6.1	SMEs and Automation	331
6.2	Modernization of Older Device Generations with Regard to the Automation Interface	336
	References	339
7	Automation of the Automotive Industry in Fast Motion: Robotics	341
7.1	History of the Automotive Industry	341
7.2	Robots	343
7.2.1	Tactile Measurement Technology and Robots	346
7.3	Problem of Plastic Car Bodies for Material Analysis: Solution with Terahertz	347
	References	352

8	Chronology of Automation Technology Since 1970	355
8.1	AI, Neural Networks, Programming Languages: From Robotics to the Automation Pyramid, Fieldbuses and Committees to IoT (IIoT), Industry 4.0 As Well As ‘Made in China’	362
8.2	Summary of Current Events	377
	References.	383
	Index	389