

power systems

C. Rehtanz

Autonomous Systems and Intelligent Agents in Power System Control and Operation



Springer

Contents

1 Autonomous Control System Architecture	1
1.1 Fundamental Aspects of Autonomous Systems	1
1.2 Functional Architecture of Autonomous Components.....	3
1.2.1 Execution Layer	5
1.2.2 Coordination Layer.....	6
1.2.3 Management and Organization Layer	8
1.2.4 Information Base	9
1.3 Structures of Autonomous Systems	10
1.4 Autonomous Systems in Electrical Power Systems.....	12
1.4.1 Operational Architecture	12
1.4.2 Characteristics of Autonomous Systems	14
References.....	15
2 Implementation of Autonomous Systems	17
2.1 Requirements for the Implementation Architecture.....	17
2.2 Communication Technology.....	19
2.2.1 Topology	20
2.2.2 Protocols.....	21
2.3 Standard Data Models.....	24
2.3.1 Substation	25
2.3.2 Network Control Center	25
2.3.3 Electrical Utility Enterprise.....	26
2.3.4 Summary	27
2.4 Information-Base of Autonomous Systems	28
2.5 IT Security Considerations	29
2.6 Conclusions.....	32
References.....	33
3 Computational Intelligence and Agent Technologies for Autonomous Systems	35
3.1 Intelligence in Autonomous Systems and Agents.....	35
3.2 Kinds of Knowledge and Cognitive Modeling	36
3.3 Methods of Computational Intelligence.....	37
3.3.1 Basic Methods	37
3.3.2 Extended and Alternative Methods	41
3.4 Agent Technologies	43
3.4.1 Communication	43

3.4.2 Coordination.....	44
References	46
4 Multi-Agent Negotiation Models for Power System Applications	49
4.1 Introduction	49
4.2 Negotiation Theory and Agents: A Review.....	52
4.2.1 Basics of Negotiation Theory.....	52
4.2.2 Computer-Based Negotiation Systems	56
4.3 A Multi-Agent Negotiation System	58
4.3.1 MAS Implementation	59
4.3.2 Negotiation Protocol.....	60
4.3.3 Embedding Agents with Social Rationality	64
4.4 Illustrations	67
4.4.1 Security-Related Decision-Making	67
4.4.2 Maintenance Scheduling	68
4.5 Conclusions	72
References	72
5 A Multi-Agent Approach to Power System Disturbance Diagnosis.....	75
5.1 Introduction	75
5.2 Protection Engineering Decision Support.....	76
5.2.1 The Post-fault Analysis Process of Protection Engineers.....	76
5.2.2 Technical Requirements for the Decision Support Functions	78
5.3 Designing the PEDA Multi-Agent System	78
5.3.1 Requirements Capture and Knowledge Capture	79
5.3.2 Task Decomposition.....	80
5.3.3 Ontology Design	82
5.3.4 Agent Modeling	84
5.3.5 Agent Interactions Modeling	86
5.3.6 Agent Behavior	87
5.4 Core Functionality of the Agents within PEDA	88
5.4.1 Incident and Event Identification (IEI) Agent.....	88
5.4.2 Fault Record Retrieval (FRR)	90
5.4.3 Fault Record Interpretation (FRI).....	92
5.4.4 Protection Validation and Diagnosis (PVD)	93
5.5 Case Study of PEDA Operation.....	94
5.5.1 PEDA Initialisation	96
5.5.2 Disturbance Diagnosis Process	97
5.6 Conclusions	99
References	99
6 A Multi-agent Approach to Power System Restoration.....	101
6.1 Power System Restoration Methods	101
6.2 Power System Restoration Model.....	103
6.3 Multi-agent Power System Restoration Architecture	103
6.3.1 Bus Agents	104

6.3.2 Facilitator Agent.....	105
6.3.3 Negotiation Process between Bus Agents	105
6.4 Simulation Results	108
6.4.1 Simulation Conditions	108
6.4.2 Simulation Results.....	108
6.5 Conclusions.....	112
References.....	113
7 Agent Technology Applied to the Protection of Power Systems.....	115
7.1 Introduction.....	115
7.2 Agent Technology in Power System Protection	116
7.2.1 Definition	116
7.2.2 Agent Architecture	117
7.3 The Structure of a Utility Communication Network.....	118
7.4 Developments of EPOCHS	119
7.4.1 Overview	119
7.4.2 Related Work.....	120
7.4.3 EPOCHS Simulation Description.....	121
7.5 Simulation Architecture.....	122
7.5.1 The Run-Time Infrastructure.....	123
7.5.2 Electrical Component Subsystem.....	124
7.5.3 The Network Communication Component.....	124
7.5.4 The AgentHQ Subsystem	126
7.5.5 Implementation and Optimization.....	128
7.5.6 Simulation Scripts	128
7.5.7 Summary	129
7.6 Backup Protection Systems for Transmission Networks	129
7.6.1 Overview	129
7.6.2 The Architecture of the Agent Relay.....	130
7.6.3 The Strategy Employed by the Agent-Based Backup Protection System	131
7.6.4 Simulation results	133
7.6.5 Summary	136
7.7 An Agent Based Current Differential Relay for Transmission Lines	136
7.7.1 Overview	136
7.7.2 Related Work.....	137
7.7.3 The Differential Protection Agent Architecture	137
7.7.4 Simulation Results Using EPOCHS	139
7.7.5 Summary	141
7.8 Special Protection Systems	142
7.8.1 Overview	142
7.8.2 Algorithms for Frequency Stability Control.....	143
7.8.3 The System Studied and Agent-Based SPS Scheme	146
7.8.4 Simulation Results.....	148
7.8.5 Summary	149

7.9 Conclusions	152
References	153
8 Dynamic Output Compensation between Selected Channels in Power Systems.....	155
8.1 Introduction	155
8.2 Framework.....	157
8.3 SPS Agents	158
8.3.1 Principles.....	158
8.3.2 Example	162
8.4 Damping Agents	162
8.4.1 Linear System Model as a Connection of Agents	165
8.4.2 Model Building	167
8.4.3 Controller Building	167
8.4.4 Example	170
8.5 Coordination Agents.....	174
8.5 Conclusions	177
References	178
9 Development of a Coordinating Autonomous FACTS Control System....	179
9.1 Introduction	179
9.2 Flexible AC Transmission Systems – FACTS.....	181
9.2.1 Features	181
9.2.2 Structure.....	182
9.2.3 Modeling and Control	182
9.3 Need of Coordination	184
9.4 Theory of Autonomous Control Systems	187
9.5 Synthesis of the Autonomous Control System for FACTS	189
9.5.1 Bay Control Level.....	189
9.5.2 Substation and Network Control Level.....	192
9.5.3 Preventive Coordination.....	195
9.6 Verification	197
9.6.1 Failure of a Transmission Line.....	198
9.6.2 Increase of the Load	200
9.7 Conclusions	201
References	202
10 Multi-Agent Coordination for Secondary Voltage Control.....	205
10.1 Introduction	205
10.2 Multi-Agent Voltage Management – Feasibility Study	207
10.2.1 Necessity of the Secondary Voltage Control in Power System Contingencies.....	207
10.2.2 Multi-Agent Collaboration to Eliminate Voltage Violations	211
10.3 Multi-Agent Voltage Management – Collaboration Protocol.....	216
10.3.1 Collaboration Protocol	216
10.3.2. Test Results by Simulation.....	221

References.....	226
11 Agent Based Power System Visualization	229
11.1 Actual Problems in Power System Visualization.....	229
11.2 Decision Supporting Human-Machine Interface	230
11.2.1 Causality as the Natural Principle for Visualization.....	231
11.2.2 Hierarchically Structured Information Provision	232
11.2.3 Global System View and Problem Specific Detail View	234
11.3 Implementation as Intelligent Agents	236
11.4 Verification	238
11.4.1 User-Machine Interaction	239
11.4.2 Implementation as Multi-Agent System.....	242
11.5 Conclusions.....	245
References.....	245
12 New Applications of Multi-Agent System Technologies to Power Systems.....	247
12.1 Multi-Agent System Technologies	247
12.2 Strategic Power Infrastructure Defense System.....	249
12.2.1 SPID System Framework	249
12.2.2 Definitions and Roles of SPID System Agents	250
12.3 Controlled Islanding Agent of SPID System	252
12.3.1 Controlled Islanding of Power Systems	252
12.3.2 Context of SPID System Agents Interactions.....	253
12.3.3 Controlled Islanding Agent	254
12.3.4 Controlled Islanding Criteria.....	256
12.3.5 A Controlled Islanding Algorithm.....	256
12.4 An Application to MicroGrid Control and Operation.....	259
12.4.1 What is MicroGrid?.....	259
12.4.2 MicroGrid Design.....	260
12.4.3 MicroGrid Agent (MGA)	262
12.4.4 MicroGrid Control.....	265
12.4.5 MicroGrid Operation Issue	269
12.4.6 An Example for Oscillation Restriction	270
12.5 Conclusions.....	275
References.....	276
13 Operation of Quality Control Center Based on Multi-Agent Technology	279
13.1 Introduction.....	279
13.2 Multi-Agent and FRIENDS	280
13.3 Agent Models.....	281
13.3.1 Model of Quality Control Center.....	281
13.3.2 Model of Distribution Substation	282
13.3.3 Information Measured	282

13.3.4 Communication between Agents.....	283
13.4 Emergency Operation of Distribution Systems	283
13.4.1 Operational Policies	283
13.4.2 Proposed Algorithm	284
13.4.3 Simulation Results.....	287
13.5 Voltage Regulation of Distribution Systems in FRIENDS.....	290
13.5.1 Autonomous Voltage and Reactive Power Control in FRIENDS ..	291
13.5.2 Reconfiguration of QCC Network Topology in FRIENDS	295
13.5.3 Evaluation of the Performance of the Voltage Regulation	298
13.6 Conclusion	300
References	301
Index.....	303