
Contents

1	Communication systems for distribution automation	1
1.1	Introduction	1
1.2	Importance of communication technology in distribution automation	2
1.3	Communication system model	3
1.4	Continuous-wave modulation techniques	7
1.4.1	Amplitude modulation	7
1.4.2	Angle modulation	11
1.5	Digital modulation techniques	15
1.5.1	Amplitude shift keying	15
1.5.2	Binary phase-shift keying	16
1.5.3	Binary frequency-shift keying	18
1.5.4	Continuous-phase frequency-shift keying	20
1.6	Multiplexing	23
1.6.1	Frequency division multiplexing	23
1.6.2	Orthogonal frequency division multiplexing	25
1.6.3	Time division multiplexing	26
1.6.4	Code division multiple access	26
1.7	Transmission media	27
1.7.1	Twisted pair cable	27
1.7.2	Coaxial cable	28
1.7.3	Power line communication	29
1.7.4	Fiber-optic cable	29
1.7.5	Wireless channel	32
1.8	Data communication systems	32
1.8.1	Telephone system	33
1.8.2	Mobile phone network	35
1.8.3	Trunked radio system	39
1.8.4	Cable TV network	39
1.8.5	Satellite communication system	40
1.8.6	Wireless sensor network	41
1.8.7	Wireless data networks	42
1.8.8	Wireless mesh network	43
1.8.9	Wireless automated meter reading system	44
1.8.10	Advanced metering infrastructure	44
1.9	Conclusion	45
	References	45

2	Load flow analysis	49
2.1	Load flow analysis of balanced radial distribution system	49
2.1.1	Detailed algorithm	50
2.1.2	Illustrative example	51
2.2	Load flow analysis of unbalanced radial distribution system	54
2.2.1	Detailed algorithm for unbalanced system	54
2.2.2	Illustrative example for unbalanced system	56
2.3	Load flow analysis of balanced weakly meshed distribution system	60
2.3.1	Detailed algorithm	65
2.3.2	Examples	65
2.4	Conclusion	66
	Acknowledgement	67
	References	67
3	Short-circuit analysis	69
3.1	Introduction	69
3.2	Short-circuit analysis of unbalanced radial distribution system	70
3.2.1	Single line to ground fault	71
3.2.2	Double line to ground fault	73
3.2.3	Triple line to ground fault	74
3.2.4	Line to line fault	76
3.3	Short-circuit analysis of unbalanced weakly meshed distribution system	78
3.3.1	Single line to ground fault	78
3.3.2	Double line to ground fault	79
3.3.3	Triple line to ground fault	81
3.3.4	Line to line fault	82
3.4	Example of short-circuit analysis of unbalanced radial distribution system	84
3.4.1	Results for 6-bus radial distribution system	85
3.4.2	Results for 6-bus meshed distribution system	88
3.4.3	Results for 36-bus radial distribution system	98
3.5	Conclusion	98
	Acknowledgements	98
	References	99
4	Choice of solver for distribution system state estimation	101
	Abstract	101
	Keywords	101
	List of symbols	101
4.1	Introduction	102
4.2	Statistical measures	103
4.2.1	Bias	103
4.2.2	Consistency	104
4.2.3	Quality	105

4.3	SE techniques	105
4.3.1	Measurement model	106
4.3.2	WLS estimation	106
4.3.3	WLAV estimator	107
4.3.4	Schweppe Huber generalized M estimator	107
4.4	Case study	108
4.4.1	State variables	109
4.4.2	Measurements	109
4.4.3	Measurement variance	109
4.4.4	Simulation results	109
4.4.5	Comments on error distribution and choice of solver	118
4.5	Conclusion	123
	Acknowledgements	123
4.6	Appendix	123
4.6.1	Computation of α for various estimators	123
	References	125
5	Feeder reconfiguration for loss reduction	127
5.1	Introduction	127
5.2	Definitions of different indices and objective function	127
5.3	Explanation of the reconfiguration technique	129
5.4	Algorithm	132
5.5	Example 5.1	133
5.6	Reconfiguration using fuzzy multiobjective approach	137
5.7	Membership functions of different objectives	138
5.7.1	Membership function for real power loss reduction (μL_i)	138
5.7.2	Membership function for maximum node voltage deviation (μV_i)	140
5.7.3	Optimization in fuzzy environment	142
5.7.4	Heuristic rules to minimize the number of tie switch operations and algorithm	143
5.8	Example 5.2	145
	References	146
	Appendix 1	148
	Appendix 2	150
6	Service restoration in distribution system	153
6.1	Basic aspect of service restoration	153
6.2	Conclusion	164
	References	164
7	Feeder reconfiguration for load balancing	167
7.1	Introduction	167
7.2	Structure of the automated low-voltage distributed system	168

7.3	Problem formulation	170
7.4	Solution	174
7.4.1	Heuristic method	174
7.4.2	Newton–Raphson-based solution method	177
7.4.3	Fuzzy logic-based load balancing	179
7.4.4	Neural network-based method	182
7.4.5	Adding decaying self-feedback continuous Hopfield neural network method	185
7.5	Application to load-balancing problem	186
7.5.1	Problem analysis and energy function construction	186
7.5.2	Energy function construction for the ADSCHNN	187
7.5.3	Particle swarm optimization	189
7.6	Practical feasibility and economic considerations	191
7.7	Conclusions	192
	References	192
8	Volt/VAR control in distribution systems	195
8.1	Voltage standards	195
8.2	Volt/VAR control methods	196
8.3	Volt/VAR regulation by local controllers	204
8.4	Centralized VVC	205
8.5	Centralized VVC modes of operation	210
8.6	Rule-based voltage control and VAR dispatch	212
8.7	Power flow–based VVC	214
8.8	Advanced metering infrastructure as voltage monitoring tool	217
8.9	Voltage control and demand response	217
8.10	VVC performance	219
8.11	Impact of distributed energy resources	222
8.12	About the Authors	224
	References	224
9	Fault location	227
9.1	Introduction	227
9.2	Overall idea of the fault location system	228
9.3	Fault location method that requires fault type	230
9.4	Fault location method without requiring fault type	234
9.5	Fault location method for multiple simultaneous faults	238
9.5.1	Fault location method without requiring fault type	238
9.5.2	Fault location method based on the information of fault type	240
9.6	Sample calculations and discussions on the presented fault location algorithms	244
9.6.1	Sample calculations	244
9.6.2	Discussions on the presented fault location algorithms	246

9.7	Fault location observability analysis	248
9.8	Conclusions	248
	References	248
10	Fault detection and classification in distribution network	251
10.1	Introduction	251
10.2	Fault type classification and fault data sources in distribution network	252
10.2.1	Information source of fault classification	252
10.2.2	Scope of fault processing	254
10.3	Methods of fault classification	255
10.3.1	Abstract	255
10.3.2	Methods of fault processing	256
10.4	Fault classification in distribution network based on ANFIS	257
10.4.1	Classification rules based on ANFIS	257
10.4.2	ANFIS classifiers	259
10.4.3	Test simulation and conclusion	260
10.5	Fault classification using DS evidence fusion	265
10.5.1	DS evidence fusion	265
10.5.2	Fault classification scheme	266
10.5.3	Simulation test and conclusion	272
10.6	Faulty feeder selection in distribution network based on S transform	274
10.6.1	Introduction to S transform	274
10.6.2	Faulty feeder selection method based on S transform	276
10.6.3	Simulation test and conclusion	281
	References	283
11	Economic analysis/cost–benefit analysis	287
11.1	Introduction	287
11.2	The DA project review	288
11.3	The DA system economic analysis	290
11.3.1	FA functions	291
11.3.2	Distribution analysis functions	295
11.3.3	Customer management functions	295
11.4	Further extension for FA	299
11.5	Conclusions and discussions	305
	References	307
12	Distribution automation at Enexis – a case study	309
12.1	Introduction	309
12.2	DA concept	311
12.2.1	Risk analysis	311
12.2.2	Strategy development	311
12.2.3	DA concept	312

12.3	Pilot project	312
12.3.1	Availability of components	313
12.3.2	Other issues	313
12.3.3	Preparation of large-scale roll-out	314
12.4	Technical design	314
12.4.1	MV/LV substations	314
12.4.2	MV/MV substations	315
12.4.3	SCADA/distribution management system	315
12.5	Implementation	315
12.5.1	Acceptance by workforce	318
12.5.2	Impact on daily work	318
12.5.3	Changing company processes	318
12.5.4	Required knowledge and education	320
12.6	Results	320
12.6.1	Realisation	320
12.6.2	CML savings	320
12.6.3	Other advantages	324
12.6.4	Lessons learnt and future developments	324
	References	325

Index	327
--------------	------------