

Table of Contents

Preface	1
Chapter 1. General Aspects of the Control, Regulation and Security of the Energy Network in Alternating Current	5
Noël JANSSENS and Jacques TRECAT	
1.1. Introduction	5
1.1.1. History	5
1.1.2. Network architecture	6
1.2. Power flow calculation and state estimation	7
1.2.1. Introduction	7
1.2.2. Modeling the components of the network	7
1.2.3. Power flow calculation	9
1.2.4. State estimation	11
1.3. Planning and operation criteria	13
1.3.1. Introduction	13
1.3.2. Power generation units	14
1.3.3. Transmission network	15
1.3.4. Electrical power distribution system	17
1.4. Frequency and power adjustments	18
1.4.1. Objectives and classification of the adjustments	18
1.4.2. Primary regulation	20
1.4.3. Secondary regulation	22
1.4.4. Tertiary regulation	23
1.4.5. Generating unit schedule	24
1.4.6. Load management	25
1.5. Voltage regulation	25
1.5.1. Case of short lines	26

1.5.2. Case of the line with capacity	28
1.5.3. Traditional methods of reactive energy compensation and voltage regulation	31
1.6. Bibliography	35
Chapter 2. Evolution of European Electric Power Systems in the Face of New Constraints: Impact of Decentralized Generation	37
Michel CRAPPE	
2.1. Introduction: a new paradigm	37
2.2. Structure of modern electric transmission and distribution networks . .	38
2.2.1. Modern transmission networks	38
2.2.2. Electrical distribution networks	42
2.3. Recent development in the European networks and new constraints . .	43
2.3.1. Deregulation of the electricity market in accordance with European directives	44
2.3.2. Reducing greenhouse gas emissions in the generation of electrical energy	45
2.3.3. Generation of electricity using renewable energy sources	46
2.3.4. Energy dependency of the European Union	46
2.4. The specific characteristics of electrical energy	47
2.4.1. Storage and production/consumption balance	48
2.4.2. Laws of physics on flow of energy	49
2.4.3. Strategic role of electrical energy	51
2.4.4. Voltage regulation in the electrical transmission and distribution networks	51
2.4.5. Ancillary services.	52
2.5. Decentralized power generation.	52
2.5.1. Definition	52
2.5.2. Decentralized power generation techniques in Europe, potential and costs	54
2.5.3. Decentralized power generation and CO ₂ emissions, indirect emissions from so-called “zero emission” power plants.	72
2.5.4. Decentralized production and ancillary services.	74
2.6. Specific problems in integrating decentralized production in the networks	78
2.6.1. Connection conditions	78
2.6.2. Influence on the design of the HV/MV stations	79
2.6.3. Influence on the protection of the distribution networks	80
2.6.4. Stability problems	82
2.6.5. Influence on the voltage plan	83
2.6.6. Impacts on transmission networks	85

2.6.7. Harmonic disturbances.	86
2.7. New requirements in research and development	86
2.7.1. Technical domain	87
2.7.2. Economics	91
2.8. Conclusion: a challenge and an opportunity for development for the electrical sector	92
2.9. Bibliography	92
Chapter 3. Planning Methods for Generation and Transmission of Electrical Energy	95
Jean-Marie DELINCÉ	
3.1. Introduction.	95
3.1.1. Generation functions	96
3.1.2. Functions of a transmission network	96
3.2. Planning in integrated systems and in a regulated market	97
3.2.1. Generation planning	98
3.2.2. Transmission network planning	103
3.3. Generation planning in a deregulated market	111
3.4. Establishing a development plan of the transmission network	114
3.4.1. Reasons for investment	114
3.4.2. Constraints and uncertainties	115
3.4.3. Planning criteria.	118
3.4.4. Elaboration of the development plan	121
3.5. Final observations	125
3.6. Bibliography	125
Chapter 4. Power Quality	127
Alain ROBERT	
4.1. Introduction.	127
4.1.1. Disturbances and power quality	127
4.1.2. Quality of electricity supply and electromagnetic compatibility (EMC).	128
4.2. Degradation of the voltage quality – disturbance phenomena	130
4.2.1. Frequency variations	130
4.2.2. Slow component of voltage variations	131
4.2.3. Voltage fluctuations – flicker	131
4.2.4. Voltage dips	131
4.2.5. Transients	132
4.2.6. Harmonics and interharmonics	134
4.2.7. Unbalance	135

4.2.8. Overall view of the disturbance phenomena	135
4.3. Basic concepts of standardization	136
4.4. Quality indices	139
4.4.1. Voltage continuity	139
4.4.2. Voltage quality	143
4.5. Evaluation of quality	146
4.5.1. Voltage continuity	146
4.5.2. Voltage quality	147
4.6. Connection of the disturbance facilities	148
4.6.1. Definition of the emission level of a disturbance facility	148
4.6.2. Concept of short circuit power	149
4.6.3. Determining the emission limits of a disturbance facility	151
4.6.4. Verification of the emission limits after commissioning	153
4.7. Controlling power quality	154
4.7.1. Voltage continuity	154
4.7.2. Voltage quality	156
4.8. Quality in a competitive market – role of the regulators	156
4.9. Bibliography	158
Chapter 5. Applications of Synchronized Phasor Measurements to Large Interconnected Electric Power Systems	161
Nouredine HADJSAID, Didier GEORGES and Aaron F. SNYDER	
5.1. Introduction	161
5.2. Synchronized measurements	162
5.3. Applications of synchronized measurements	164
5.3.1. State estimation	164
5.3.2. Network supervision	165
5.3.3. Power system protection	166
5.3.4. Power system control	166
5.4. Application of synchronized measurements to damp power oscillations	167
5.4.1. Power oscillations	167
5.4.2. Theory of PSS controllers	171
5.4.3. Controller tuning by residue compensation	172
5.4.4. Results	176
5.5. Conclusion	179
5.6. Bibliography	179
5.7. Appendices	182

Chapter 6. Voltage Instability	185
Thierry VAN CUTSEM	
6.1. Introduction	185
6.2. Voltage instability phenomena	187
6.2.1. Maximum deliverable power for a load	187
6.2.2. PV and QV curves	188
6.2.3. Long-term voltage instability illustrated through a simple example	189
6.2.4. Load restoration	194
6.2.5. Classification of instabilities	196
6.3. Countermeasures for voltage instability	199
6.3.1. Compensation	199
6.3.2. Automatic devices and regulators	199
6.3.3. Operation planning	201
6.3.4. Real time	201
6.3.5. System protection schemes	201
6.4. Analysis methods of voltage stability and security	204
6.4.1. Contingency analysis	204
6.4.2. Determination of loadability limits	208
6.4.3. Determination of secure operation limits	210
6.4.4. Preventive control	213
6.5. Conclusion	214
6.6. Bibliography	215
Chapter 7. Transient Stability: Assessment and Control	219
Daniel RUIZ-VEGA and Mania PAVELLA	
7.1. Introduction	219
7.2. Transient stability	220
7.2.1. Problem statement	220
7.2.2. Operating procedures	221
7.2.3. Deregulation of the electricity sector	223
7.3. Transient stability assessment methods: brief history	224
7.3.1. Conventional time domain approach: strengths and weaknesses	224
7.3.2. Direct approaches: a brief history	226
7.3.3. Note on automatic learning approaches	228
7.4. The SIME method	229
7.4.1. Origins	229
7.4.2. Formulation	230
7.4.3. Preventive SIME vs emergency SIME	235
7.5. Different descriptions of transient stability phenomena	236
7.6. The preventive SIME method	240

7.6.1. Stability limits	241
7.6.2. FILTRA: generic software for contingency filtering	243
7.6.3. Stabilization of contingencies (“control”)	245
7.6.4. Transient stability assessment and control: integrated software and example of application	247
7.6.5. Current status of the preventive SIME	252
7.7. Emergency SIME method	252
7.7.1. Aims	252
7.7.2. Origins	253
7.7.3. Estimation of time taken by the different tasks	256
7.7.4. Illustration	256
7.7.5. Note on corrective control in open loop.	258
7.7.6. Conclusion	259
7.8. Bibliography	260
Chapter 8. Security of Large Electric Power Systems – Defense Plans – Numerical Simulation of Electromechanical Transients	263
Marc STUBBE and Jacques DEUSE	
8.1. Introduction.	263
8.2. Degradation mechanisms of network operation	264
8.2.1. The system.	264
8.2.2. Continuity of supply	267
8.2.3. Degradation mechanisms	270
8.2.4. Unfavorable factors causing spread of the incident	275
8.3. Defense action and the notion of a defense plan	277
8.3.1. Frequency instability	277
8.3.2. Voltage instability	280
8.3.3. Loss of synchronism	281
8.3.4. Cascade tripping	281
8.3.5. Notion of defense plan.	282
8.4. The extended electromechanical model	282
8.4.1. Definition, validity domain	282
8.4.2. Numerical simulation	284
8.4.3. Mathematic properties	285
8.4.4. Algorithmic properties.	285
8.5. Examples of defense action study.	292
8.5.1. Methodological considerations	292
8.5.2. Load shedding due to voltage criteria [DEU 97]	293
8.5.3. Islanding plan in case of loss of synchronism	304
8.5.4. Industrial networks	306
8.6. Future prospects	310

8.6.1. Evolution of simulation tools	313
8.6.2. Real-time curative action	313
8.6.3. Load actions	314
8.6.4. Decentralized production	315
8.7. Bibliography	315
Chapter 9. System Control by Power Electronics or Flexible Alternating Current Transmission Systems	317
Michel CRAPPE and Stéphanie DUPUIS	
9.1. Introduction: direct current links and FACTS	317
9.2. General concepts of power transfer control	319
9.2.1. Introduction	319
9.2.2. Power transmission through reactance	320
9.2.3. Modification of reactance in link X	322
9.2.4. Modification of voltage and the segmentation method	324
9.2.5. Modification of the transmission angle	325
9.2.6. Comparison of three methods in a simple case	325
9.3. Control of power transits in the networks	326
9.3.1. Circulation of power in a meshed network: power loop concept	326
9.3.2. Modification of transits on parallel lines of a corridor	329
9.4. Classification of control systems according to the connection mode in the network	330
9.4.1. Series type controller	330
9.4.2. Parallel or shunt type controller	331
9.4.3. Compensators of series-series and series-shunt types	332
9.5. Improvement of alternator transient stability	333
9.5.1. Introduction to transient stability	333
9.5.2. Simplified study of transient stability by area criterion	334
9.5.3. Study of an application case	337
9.5.4. Improvement of transient stability by ideal shunt compensation	339
9.5.5. SVC type shunt compensator	341
9.5.6. Shunt compensation with SVG (static var generator) compensator	343
9.5.7. Series type compensation by modification of link reactance	344
9.5.8. Series type compensation by modification of the transmission angle	345
9.6. Damping of oscillations	346
9.7. Maintaining the voltage plan	346
9.8. Classification and existing applications of FACTS	347
9.8.1. Classic systems with thyristors	347
9.8.2. Systems with fully controllable elements	353
9.8.3. Glossary	359

9.9. Control and protection of FACTS	360
9.10. Modeling and numerical simulation.	362
9.10.1. UPFC modeled by two voltage sources	362
9.10.2. UPFC modeled by a series voltage source and a shunt current source	363
9.10.3. UPFC modeled by two current sources	364
9.10.4. UPFC modeled by two power injections	365
9.10.5. Internal models of the UPFC	366
9.11. Future prospects	367
9.12. Bibliography	368
List of authors	371
Index	373