



Advances in Electric Power and Energy

Static State Estimation



Edited by
Mohamed E. El-Hawary


IEEE PRESS

IEEE
PRESS
SERIES
ON

POWER
ENGINEERING

Mohamed E. El-Hawary, *Series Editor*

WILEY

ADVANCES IN ELECTRIC POWER AND ENERGY

Static State Estimation

EDITED BY

MOHAMED E. EL-HAWARY

Dalhousie University



สำนักหอสมุดมหาวิทยาลัยเชียงใหม่
CHIANG MAI UNIVERSITY LIBRARY




IEEE PRESS
WILEY

CONTENTS

ABOUT THE EDITOR xi

ABOUT THE CONTRIBUTORS xiii

CHAPTER 1 GENERAL CONSIDERATIONS 1

- 1.1 Prelude 1
- 1.2 Defining SSE 2
- 1.3 The Need for State Estimation 3
- 1.4 Static State Estimation in Practice 4
- 1.5 Applications That Use SE Solution 10
- 1.6 Overview of Chapters 13

CHAPTER 2 STATE ESTIMATION IN POWER SYSTEMS BASED ON A MATHEMATICAL PROGRAMMING APPROACH 23

- 2.1 Introduction 23
- 2.2 Formulation 24
- 2.3 Classical State Estimation Procedure 26
- 2.4 Mathematical Programming Solution 31
- 2.5 Alternative State Estimators 32

PART 1 SYSTEM FAILURE MITIGATION 59

CHAPTER 3 SYSTEM STRESS AND CASCADING BLACKOUTS 61

- 3.1 Introduction 61
- 3.2 Cascading Blackouts and Previous Work 62
- 3.3 Problem Statement and Approach 66
- 3.4 DFAXes, Vulnerability, and Criticality Metrics 70
- 3.5 Validity of Metrics 78
- 3.6 Studies with Metrics 82
- 3.7 Summary 93
- 3.8 Application of Stress Metrics 94
- 3.9 Conclusions 94

CHAPTER 4 *MODEL-BASED ANOMALY DETECTION FOR POWER
SYSTEM STATE ESTIMATION*

99

- 4.1 Introduction 99
- 4.2 Cyberattacks on State Estimation 100
- 4.3 ATTACK-RESILIENT State Estimation 103
- 4.4 Model-Based Anomaly Detection 106
- 4.5 Conclusions 117

CHAPTER 5 *PROTECTION, CONTROL, AND OPERATION
OF MICROGRIDS*

123

- 5.1 Prelude 123
- 5.2 Introduction 126
- 5.3 State of the Art in Microgrid Protection and Control 128
- 5.4 Emerging Technologies 146
- 5.5 Test Case for DDSE 154
- 5.6 Test Results 159
- 5.7 Test Case for Adaptive Setting-Less Protection 161
- 5.8 Conclusions 167

PART 2 ROBUST STATE ESTIMATION

171

CHAPTER 6 *PSSE REDUX: CONVEX RELAXATION, DECENTRALIZED,
ROBUST, AND DYNAMIC SOLVERS*

173

- 6.1 Introduction 173
- 6.2 Power Grid Modeling 174
- 6.3 Problem Statement 176
- 6.4 Distributed Solvers 186
- 6.5 Robust Estimators and Cyberattacks 193
- 6.6 Power System State Tracking 198
- 6.7 Discussion 202

CHAPTER 7 *ROBUST WIDE-AREA FAULT VISIBILITY AND STRUCTURAL
OBSERVABILITY IN POWER SYSTEMS WITH SYNCHRONIZED
MEASUREMENT UNITS*

209

- 7.1 Introduction 209
- 7.2 Robust Fault Visibility Using Strategically Deployed Synchronized
Measurements 210
- 7.3 Optimal PMU Deployment for System-Wide Structural
Observability 221
- 7.4 Conclusions 229

CHAPTER 8 *A ROBUST HYBRID POWER SYSTEM STATE ESTIMATOR
WITH UNKNOWN MEASUREMENT NOISE* 231

- 8.1 Introduction 231
- 8.2 Problem Statement 233
- 8.3 Proposed Framework for Robust Hybrid State Estimation 234
- 8.4 Numerical Results 245
- 8.5 Conclusions 249

CHAPTER 9 *LEAST-TRIMMED-ABSOLUTE-VALUE STATE ESTIMATOR* 255

- 9.1 Bad Data Detection and Robust Estimators 256
- 9.2 Results and Discussion 266
- 9.3 Conclusions 287

PART 3 STATE ESTIMATION FOR DISTRIBUTION SYSTEMS 295

CHAPTER 10 *PROBABILISTIC STATE ESTIMATION IN
DISTRIBUTION NETWORKS* 297

- 10.1 Introduction 297
- 10.2 State Estimation in Distribution Networks 298
- 10.3 Improving Observability in Distribution Networks 309
- 10.4 Conclusion 324

CHAPTER 11 *ADVANCED DISTRIBUTION SYSTEM STATE ESTIMATION
IN MULTI-AREA ARCHITECTURES* 329

- 11.1 Issues and Challenges of Distribution System State Estimation 329
- 11.2 Distribution System Multi-Area State Estimation (DS-MASE) Approach 342
- 11.3 Application of the DS-MASE Approach 357
- 11.4 Validity and Applicability of DS-MASE Approach 369

PART 4 PARALLEL/DISTRIBUTED PROCESSING 375

CHAPTER 12 *HIERARCHICAL MULTI-AREA STATE ESTIMATION* 377

- 12.1 Introduction 377
- 12.2 Preliminaries 381
- 12.3 Modeling and Problem Formulation 385
- 12.4 A Brief Survey of Solution Techniques 387
- 12.5 Hierarchical State Estimator Via Sensitivity Function Exchanges 393
- 12.6 Add-On Functions in Multi-area State Estimation 399
- 12.7 Properties 401
- 12.8 Simulations 405
- 12.9 Conclusions 409

CHAPTER 13	<i>PARALLEL DOMAIN-DECOMPOSITION-BASED DISTRIBUTED STATE ESTIMATION FOR LARGE-SCALE POWER SYSTEMS</i>	413
------------	---	-----

13.1	Introduction	413
13.2	Fundamental Theory and Formulation	416
13.3	Experimental Results	436
13.4	Conclusion	449

CHAPTER 14	<i>DISHONEST GAUSS-NEWTON METHOD-BASED POWER SYSTEM STATE ESTIMATION ON A GPU</i>	455
------------	---	-----

14.1	Introduction	455
14.2	Background	456
14.3	Performance of Dishonest Gauss-Newton Method	461
14.4	GPU Implementation	463
14.5	Simulation Results	467
14.6	Discussions on Scalability	468
14.7	Distributed Method of Parallelization	470
14.8	Conclusions	473

INDEX	475
-------	-----