Electric Energy Storage Systems: Flexibility Options for Smart Grids
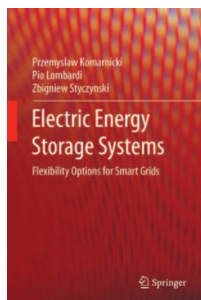
By Przemyslaw Komarnicki, Pio Lombardi, and Zbigniew Styczynski, Springer, 2017, hardback, 211 pages, 142 illustrations, 34 illustrations in color, ISBN: 978-3-662-53274-4

In recent years, electrical energy storage (EES) became the most important technology in isolated power systems (IPS), electrical power quality, distributed energy resources, and sustainable mobility. *Electric Energy Storage Systems* explains the modeling, planning, and implementation methodologies of EES systems.

The book's first chapter presents an overview of the technical and regulatory boundaries on the evolution of electric power systems to future smart grids, including concepts such as power to gas and power to heat. Distribution networks need storage due to volatile, low duty-cycle renewable energy sources (RES), such as solar and wind, to increase green energy penetration, while maintaining power quality and energy resilience.

Chapter 2 deals with EES modeling in power systems, presenting generic EES models and algorithms to compute optimal storage, storage unification, integration of EES in distribution network planning, and multicriteria optimization of storage in IPS. The approach follows the cyberphysical layers and concepts [1] and presents case studies.

Chapter 3 presents development trends in power systems in various scenarios from European countries to north and south Americas, from Japan to China, and Russia and Australia. Chapter 4 discusses the need for EES, presenting practical examples. Chapter 5 describes EES technologies, its properties and operation constraints, namely, compressed air energy storage, pump hydro energy storage, superconducting magnetic energy storage, supercapacitor energy storage, flywheel energy storage, battery energy storage (BES), and hydrogen energy storage systems.

Chapter 6 explores mobile energy storage systems (electric vehicle to grid), electric vehicles (EVs) as distributed EES, and transportation systems. Chapters 7 and 8 detail the economics of EES and the contribution of EES to smart grid reliability, respectively.

The aforementioned chapters include the following subsections:

Chapter 1: Future Power Systems
1) "Introduction"
2) "Towards a Smart Grid (Renewable Generation in the Future, European Smart-Grid Vision, Energy Policy in Europe and Smart Grids, Power System Operation and Need for More Flexible Smart Grids)"
3) "Regulatory Boundaries for Smart Grid and Electric Energy Storage."

ELECTRIC ENERGY STORAGE SYSTEMS EXPLAINS THE MODELING, PLANNING, AND IMPLEMENTATION METHODOLOGIES OF EES SYSTEMS.

Chapter 2: Electric Energy Storage System (EES)
1) "Requirements for an EES System (EES Use and Extension of Storage Usability in Smart Grids)"
2) "Generic Model of EES (Generic Model of EES, Physical Surface of the EES Model: Mathematical Generic Model)"
3) "EES in the Transmission and Distribution System (Factors for Value of Storage in Transmission Networks, EES in the Distribution Systems, Example of Modeling and Implementation of the Models in the Planning and Simulation in Distribution, Standardized Models of BES Using the Surface and Interface Structure)"
4) "Storage Systems in Isolated Power Systems (Case-Based Optimization of Electric Energy Storage Size in an Isolated Power System, Multi-Criteria Optimization of IPS, Case Studies)."

Chapter 3: International Development Trends in Power Systems
1) "State of the Art"
2) "Smart Grid Concept for the Future Grid"
3) "European Scenario"
4) "Renewable Energy Development in the Iberian Peninsula"
5) "The Danish Scenario"
6) "North American Scenario"
7) "South American Scenario"
8) "Japanese Scenario"
9) "Russian Scenario"
10) "Chinese Scenario"
11) "Australian Scenario."

Chapter 4: Need for Storage: Practical Examples

1) "Methodology of Investigation"
2) "Example: Network-Upgrade Deferral"
3) "Technical Aspects: Examples from Japan"
4) "Storage for Full RES Integration."

Chapter 5: Storage Technologies and Systems
1) "Overview"
2) "Energy Storage Performance Indicators"
3) "Electric-Energy Storage System Classification"
4) "Pumped-Hydroelectric Storage"
5) "Flywheel-Energy Storage"
6) "Battery-Energy Storage Systems"
7) "Superconducting Magnetic Energy Storage"
8) "Power-to-Gas"
9) "Compressed-Air Energy Storage."

Chapter 6: Mobile Energy Storage Systems. Vehicle-for-Grid Options
1) "Electric Vehicles"
2) "EV Standards and Technologies for Power and Transportation Systems"
3) "Electric-Vehicle Networks as Energy Storage Systems in the Power and Transportation System."

Chapter 7: Economics of Electric Energy Storage Systems
1) "Electric-Energy Storage System Applications and Services"
2) "Electric-Energy Storage Economics (Cost Analysis, Investment, and Operation Costs Analysis of EES)."

Chapter 8: Reliability in Smart Grids with Energy Storage Systems
1) "Reliability in Power-Energy Systems"
2) "Grid-Reliability Calculations"
3) "Storage-System Reliability (Case Study: Calculation of Storage-System Reliability)."

Each chapter lists meaningful references and final questions. A table of contents, preface, and acknowledgments are also included.

Authors Dr. Zbigniew Styczynski [IEEE, Conference Internationale des Grands Reseaux Electriques (CIGRE), Energietechnische Gesellschaft (ETG)], past chair of electrical networks and renewable energy sources; Otto von Guericke University, Magdeburg, Germany; Dr. Pio Lombardi (ETG, CIGRE), Fraunhofer Institute for Factory Operation and Automation, Magdeburg, Germany; and Dr. Przemyslaw Komarnicki (IEEE, International Electrotechnical Commission, deputy business unit manager process and plant technology at the Fraunhofer Institute IFF, Magdeburg, Germany) hold 20 years of experience in research and application of EES in national and international projects.

Electric Energy Storage Systems is a timely book, highlighting methods of energy storage implementation in generation, transmission, and distribution, heading to 100% green energy power systems with enhanced flexibility and reliability. The book is a valuable tool for academics, power engineers, researchers, practicing engineers, and advanced students.

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Reference

[1] S. Suryanarayanan, R. Roche, and T. M. Hansen, Eds., *Cyber-Physical-Social Systems and Constructs in Electric Power Engineering.* Stevenage, United Kingdom: Inst. Eng. Tech., 2016.

Model Predictive Control of High Power Converters and Industrial Drives
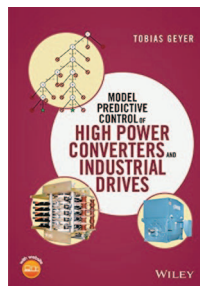
By Tobias Geyer, John Wiley, 2017, hardback, 576 pages, ISBN: 978-1-119-01090-6.

Conventionally, power electronic converters and drives have been controlled by linear single-input, single-output control loops. Particularly for high-power converters with multiple coupled dynamics and tight operating constraints, model predictive control (MPC) is expected to evolve into the control method of choice. MPC allows one to increase the power capability of a converter, lower the current distortions, reduce the converter hardware, achieve very fast transient responses, and ensure the reliable operation within safe operating area constraints.

> **CONVENTIONALLY, POWER ELECTRONIC CONVERTERS AND DRIVES HAVE BEEN CONTROLLED BY LINEAR SINGLE-INPUT, SINGLE-OUTPUT CONTROL LOOPS.**

Chapters 1–6 offer a detailed review of three-phase power electronics, electrical machines, carrier-based pulsewidth modulation, optimized pulse patterns, state-of-the-art art converter control methods, and the principle of MPC. Chapters 7–14 include an in-depth treatment of MPC methods that fully exploit the performance potential of high-power converters. These control methods combine the fast control responses of deadbeat control with the optimal steady-state performance of optimized pulse patterns by resolving the antagonism between the two.

The content consists of 15 chapters organized in five parts as follows:

Part I: Introduction
1) "Introduction"
2) "Industrial Power Electronics"
3) "Classic Control and Modulation Schemes."

Part II: Direct Model Predictive Control with Reference Tracking
4) "Predictive Control with Short Horizons"
5) "Predictive Control with Long Horizons"
6) "Performance Evaluation of Predictive Control with Long Horizons."

Part III: Direct Model Predictive Control with Bounds
7) "Model Predictive Direct Torque Control"
8) "Performance Evaluation of Model Predictive Direct Torque Control"
9) "Analysis and Feasibility of Model Predictive Direct Torque Control"
10) "Computationally Efficient Model Predictive Direct Torque Control"
11) "Derivatives of Model Predictive Direct Torque Control."

Part IV: Model Predictive Control Based on Pulse Width Modulation
12) "Model Predictive Pulse Pattern Control"
13) "Performance Evaluation of Model Predictive Pulse Pattern Control"