Operation, Planning, and Analysis of Energy Storage Systems in Smart Energy Hubs

Behnam Mohammadi-Ivatloo • Farkhondeh Jabari
Editors

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Preface

Along with rapid population growth, the demand for and consumption of energy has also grown exponentially. Therefore, energy efficiency, greenhouse gas emissions, and environmental concerns are crucial concerns around the world. Meanwhile, different renewable energy sources, including solar, wind, hydro, geothermal, and tidal energy are broadly employed to provide a clean and sustainable source of electricity generation. Such energy can then be applied to air and water heating and cooling, transportation infrastructure and development, rural, off-grid energy services, and so on. The aim of the book is to robustly design and investigate a natural gas and electricity coupled energy hub as a super node that is meant to receive various energy carries, including renewable energy sources, and organize demand and supply side management with different energy storage technologies.

This book also focuses on operational issues when combining renewable energy, natural gas, and electricity into energy hubs, with an emphasis on energetic, economic, and environmental viewpoints. Moreover, the variable nature of renewable energy sources, together with traditional load and generation forecasting, introduces increased uncertainty in the operation and planning of combined renewable and natural gas electrical grids. Therefore, risk-constrained stochastic programming and robust optimization techniques are used to investigate the robustness and opportunistic aspects of optimal scheduling problems to make the risk-averse or risk-taker decisions, respectively.

The main purpose of Chap. 1 is to introduce the concept of smart energy hub. In this regard, an introduction to the concept of the smart grid, its definitions, features, and main challenges are presented. Some advantages, goals, and impacts of using energy storages in energy hub are discussed in Chap. 2.

Chapter 3 examines different technologies, structures, and the technical and operational constraints of compressed air energy storage. In addition, the impact of advanced adiabatic compressed air energy storages on day-ahead economic emission dispatch of coal and gas-fired generators is investigated using a mixed-integer, nonlinear program that utilized the GAMS software package and SBB tool.

In Chap. 4, optimal scheduling of a residential hub energy system based on the consumption and presence of solar thermal energy is presented. One model of a residential hub energy system includes equipment such as combined heat and power systems, a boiler, battery storage system, solar thermal storage, and smart appliances. In Chap. 5, short-term optimal scheduling of solar powered multi-chiller plants is presented. In Chap. 6, day-ahead economic dispatches of three different multi-chiller plants is addressed using a basic, open-source, nonlinear, mixed-integer program, using the GAMS software package. Compared with competitive heuristic algorithms, the use of the BONMIN solver in finding optimal loading points of centrifugal chillers reduces their electricity requirement significantly.

In Chap. 7 research related to demand side management programs in residential, commercial, agriculture, and industrial energy hubs is reviewed and discussed. In Chap. 8, the applicability of compressed air energy storage systems in handling the fluctuating energy generation of local renewable energy units in the hub energy system is examined. Chapter 9 investigates the capability of stochastic frameworks when dealing with energy resources scheduling problems in renewable energy hubs. The authors of Chap. 10 consider a renewable-based energy hub, which includes wind turbines, photovoltaic cells, energy storage, and boilers, to name a few. The volatile nature of renewable energy resources create new and unique problems when addressing the demand for energy. In this regard, stochastic short-term scheduling is optimal, considering the uncertainty in the supply of renewable energy generation. Chapter 11 presents grid assistance opportunities through charging and discharging of electric vehicles, and explores the technical and operational challenges in integrating this movable and changeable energy storage within the power system. The chapter discusses the development of charging load curves of electric vehicles based on mobility attributes and charging protocols. Chapter 12 optimizes the operation of a residential energy hub, which includes a combined heat and power unit, a boiler, a plug-in hybrid electric vehicle, photovoltaic panels, and a heat storage system. This is meant to provide adequate electricity and heat to a home. A two-stage stochastic model for a long-term distribution network model is proposed in Chap. 13. This is meant to solve the challenging issue of the uncertainty associated with renewable generation and the integration of electric vehicles based on the network's technical constraints. In Chap. 14, a joint energy storage and distribution system is proposed, taking into consideration voltage stability constraints. An introduction to the concept of optimal design of distributed energy systems is presented in Chap. 15. Chapter 16 endeavors to present a general modeling and optimization scheme for coupled power flow investigation in various energy networks.

In Chap. 17, the importance of different applicable pathways of sustainable power to gas is explained. Finally, Chap. 18 investigates the performance of hub energy systems from both economic and environmental viewpoints in the presence of hydrogen energy storage systems and demand response programs.

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