Preface

Contemporary energy systems are changing fast and exhibit increasingly complex features. This is mainly due to the fact that conversion and supply of energy is not the only mission of energy systems nowadays. Besides providing energy, energy systems are also expected to secure their resources so that they can be operated in a long-term future, to minimize their impacts on our ecology and environmental system during construction and operation, to provide economically affordable energy to maximize their benefits to a larger population, and to contribute to the mitigation of carbon emissions for the globe's climate. New technologies have been continuously emerged toward addressing some of the above-mentioned targets. With the implementation of these technologies, renewable energy has been increasingly exploited and used, energy efficiency of conventional power generation has been continuously improved, and energy end-consumers have become more energy efficient and environmentally benign.

Albeit these achievements, large gaps are still observed between the current energy supply and demand sides. Dependence on conventional fossil fuels is still strong in most parts of the world. Alternative fossil fuel energy, shale oil and gas for instance, still needs further improvement during extraction and conversion processes. Renewable energy systems, especially wind and solar, still face the problem of intermittency, which is the major challenge against larger-scale applications of them. Novel energy consumption technologies, taking electric vehicle as an example, require huge investment in infrastructure and may exaggerate further the intermittency not only from the supply side but the demand side as well. All these existing problems of modern energy systems indicate clearly that the existing means of designing and operating the energy systems are far from perfect, and there is still a large potential for improvements.

Energy systems engineering provides a methodological scientific framework to arrive at realistic integrated solutions to complex energy systems problems, by adopting a holistic systems-based approach. This book demonstrates the potential of an energy systems engineering-based approach to systematically quantify different options at different levels of complexity (i.e., technology, plant, energy supply chain network) through state-of-the-art modeling, simulation, control, and optimization-based frameworks. The successful implementation of these approaches in a number of real-life case studies highlights further the significance of this integrated system-wide approach. The aim of this book is to mirror the importance of fundamental and applied research in energy systems engineering applications, developing mechanisms for the transfer of the new methodology to industry.

This manuscript presents an in-depth account of recent novel methodologies, frameworks, and tools for the simulation, modeling, and optimization of integrated energy systems. This book contains 28 chapters of high-quality contributions from international leading researchers in the field of process and energy systems engineering. This book is mainly intended for academics, researchers, and industrial practitioners in energy systems engineering, who are involved in model-based energy systems activities, across engineering and applied science disciplines, as well as for educational purposes both in academia and industry.

According to the application domain and nature, the research works in this book are categorized into four parts, namely (I) shale gas, refineries, and polygeneration systems, (II) power and transport systems, (III) planning and operations of energy systems, and (IV) low-carbon energy systems. Each part comprises seven chapters. A brief description of the chapters of this book follows.

Part I focuses on the optimal design and operation of energy systems in shale gas, refining, and chemical/power industry. In Chap. 1, El-Halwagi and coworkers present a multi-period mathematical programming approach to address scheduling issues of shale gas production where needed infrastructure is not fully developed. In the subsequent chapter, You and coworkers provide a comprehensive review of the most recent approaches in four major challenging research areas within the shale gas industry, namely design and planning of shale gas supply chain, water management, sustainability, and shale gas processing. In Chap. 3, Reklaitis and coworkers illustrate how energy systems engineering methods can be applied to real-life problems via shale gas supply chains and interconnected power systems as two case studies. In Chap. 4, a computational fluid dynamics model of hydrogen production via steam methane reforming, for faster online operation optimization purposes, is presented by Christofides and coworkers. Dua and coworkers in Chap. 5 present data-based model reduction techniques for computationally complex process models and applications in oil refineries. In Chap. 6, Wang introduces coal polygeneration combining circulating fluidized bed and pyrolysis, from conceptual design, engineering application, to thermodynamic and economic analyses. In Chap. 7, Yi and coworkers present a carbon dioxide circulating design for coal polygeneration energy systems, along with a performance comparison with other types of polygeneration energy systems.

Part II concentrates on energy systems issues related to power and transport systems. In Chap. 8, Chen and coworkers present an approach for evaluating the contribution of energy storage as a means of supporting the renewables integration in power systems. In Chap. 9, Baldea discusses the possibility and opportunities to use chemical processes as energy storage utilities in the context of increasing demand for demand-side response. In the subsequent chapter, Liu and coworkers analyze the future gap between supply and demand of transport fuel in China up to 2050, with the aid of a superstructure-based nationwide refining sector planning model. In Chap. 11, Pan presents a decomposition approach for China's regional energy consumption by sector and analyzes energy flows across the country. In Chap. 12, Ou and coworkers present comprehensive life-cycle assessment of alternative transport fuel pathways, together with a comparison with previous studies. In Chap. 13, Pan and coworkers use a Long-range Energy Alternatives Planning System (LEAP) to present energy consumption projections in the city of Shanghai, China. Voutetakis and coworkers in Chap. 14 provide a comprehensive review of the application of model predictive control on fuel cell systems, covering all stages from conceptual design to implementation.

PART III mainly focuses on the planning and operation of various scales and types of energy systems. In Chap. 15, Georgiadis and coworkers present a mixed-integer linear programming approach to power systems planning problems with constraints from an hourly level to a long-term capacity expansion level. In Chap. 16, Pistikopoulos and coworkers propose a mixed-integer dynamic programming approach for the integrated design and control of combined heat and power systems. In Chap. 17, Papageorgiou and coworkers propose a mathematical programming approach for the energy consumption-end management at smart homes. In Chap. 18, Grossmann and coworkers discuss energy demand-side management issues though a cryogenic air separation plant as a case study. In Chap. 19, Kopanos and coworkers provide optimization-based approaches for the integrated operational and maintenance planning of compressors networks, which are a part of industrial air separation plants. In Chap. 20, Harjunkoski and coworkers illustrate how advanced scheduling algorithms can be used in energy-intensive industries to cope with supply-side fluctuations. In Chap. 21, Feng and coworkers show how optimization-based approaches can be applied to address heat integration issues at intraplant and interplant levels.

Part IV focuses on low-carbon energy systems. In Chap. 22, Gani and coworkers illustrate how to use superstructure-based approaches for the process synthesis of biofuels. In Chap. 23, Manenti and coworkers propose generalized disjunctive programming and mixed-integer nonlinear programming methods for downstream production problems in biorefineries. In Chap. 24, Puigjaner and coworkers illustrate the application of optimization methods on biomass supply chain problems via three case studies of rather different scales. In Chap. 25, Maravelias and coworkers address biomass procurement problems via a composite-curve-based method. In Chap. 26, Gao and coworkers propose a conceptual design of a hydrogen storage-based energy system which can better accommodate intermittent power. In Chap. 27, Wang and coworkers provide a comprehensive overview of monitoring and diagnosis issues in wind turbines. In Chap. 28, Guillén-Gosálbez and coworkers provide a multi-objective optimization approach for the design of buildings considering both economic and environmental issues.

This book covers the most recently developed state-of-the-art computer-aided methodologies, algorithms, and tools for energy systems planning, design, operation, and control from unit, process, plant levels to supply chain and system-wide levels, and illustrates their applications using real-life case studies. Notwithstanding, the research works presented here may not be able to cover all the underlying fields because the relatively newly born field of energy systems engineering is highly fast developing. Through this book, a much wider audience can be introduced to energy systems engineering and the fast development momentum of this field can be maintained.

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