applied sciences

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Editorial

Special Issue on Advances in Integrated Energy Systems Design, Control and Optimization

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Received: 7 July 2017; Accepted: 14 July 2017; Published: 16 July 2017

1. Introduction

In the face of climate change and resource scarcity, energy supply systems are on the verge of a major transformation, which mainly includes the introduction of new components and their integration into the existing infrastructures, new network configurations and reliable topologies, optimal design and novel operation schemes, and new incentives and business models. This revolution is affecting the current paradigm and demanding that energy systems be integrated into multi-carrier energy hubs [1]. It is greatly increasing the interactions between today's energy systems at various scales (ranging from the multinational, national, community scales down to the building level) and future intelligent energy systems, which are able to incorporate an increasing amount of often fluctuating, renewable energy sources (RESs). It also increases the need for the integration of energy storage options into the energy mix, not only to reduce the need for increased peak generation capacity, but also to enhance grid reliability and support higher penetration of RESs [2]. Moreover, this transformation is accommodating active participation of end-users as responsive prosumers at different scales, which in turn helps to reduce energy costs to all consumers, increase reliability of service and mitigate carbon footprints. However, this plan of action necessitates regulatory frameworks, strategic incentives and business models for efficient deployment.

2. Energy Systems Design, Control and Optimization

To cover the above-mentioned promising and dynamic areas of research and development, this Special Issue was launched to allow the gathering of contributions in design, control and optimization of integrated energy systems. In total, 23 papers were submitted to this Special Issue, nine of which were selected for publication which denotes an acceptance rate of 39%. The accepted articles in this Special Issue cover a variety of topics, ranging from operation and control of small-scale electrical networks to the complex design and planning of energy systems.

In the first paper, a novel control scheme is proposed by Z. Zhu, J. Sun, and G. Qi for a frequency-controlled power grid not only to improve the frequency regulation of the power grid as well as the input-to-state stability, but also to minimize the communication cost within the study system [3]. The second paper, authored by J.-W. Choi and M.-K. Kim, studies the voltage stability of a renewable-based power system (mainly driven by wind turbines) using Monte Carlo simulations (MCS) and probabilistic security-constrained optimal power flow techniques [4]. In this paper, it is also demonstrated that as the wind energy penetration into a grid environment increases, the system voltage stability is more affected by the wind turbines due to the stochastic wind behavior. As a complement to the previous study, M. Vahedipour-Dahraie, H. Rashidizaheh-Kermani, H. Najafi, A. Anvari-Moghaddam, and J. Guerrero show how optimal scheduling and dispatch of electric vehicles (EVs) could enhance the system performance in terms of stability, considering high penetration of renewables in a typical network [5]. This could also be a good solution to the frequency instability (or weak stability) problem in islanded microgrids where there is low inertia for frequency compensation. The fourth paper in this Special Issue studies the important role of end-use consumers in optimal energy systems scheduling [6]. The work, done by M. Vahedipour-Dahraie, H. Najafi, A. Anvari-Moghaddam, and J. Guerrero, demonstrates the positive effect of various time-based rate (TBR) demand response (DR) programs on stochastic day-ahead energy and reserve scheduling. This is deemed to be a new trend in energy systems optimization where consumers change their consumption behavior in response to the changes in energy market prices or market incentives. Focusing on energy-related production and consumption units management, the fifth paper authored by J. Wang, K. Fang, J. Dai, Y. Yang, and Y. Zhou reflects on co-optimal distributed generation and load management considering task continuity constraints [7]. Moreover, this paper shows how energy management solutions can effectively be integrated into industrial applications to accurately perceive and access users' needs in an economic way. The focus of the next paper is to optimally size and allocate energy storage systems (ESSs) in an integrated energy system in a cost-effective and emission-aware fashion [8]. In this work, H. Lan, H. Yin, S. Wen, Y.-Y. Hong, D. Yu, and L. Zhang perform different case studies to clearly demonstrate that optimal battery sitting and sizing could ensure secure and economic integration of wind turbines into a power system to minimize the total operation cost and improve voltage profiles. As a real-world example, K. Pambour, B. Cakir Erdener, R. Bolado-Lavin, and G. Dijkema propose a practical simulation framework for analyzing security of supply in integrated gas and electric power systems [9]. This work, which is developed within the framework of the European Program for Critical Infrastructure Protection (EPCIP) of the European Commission, clearly paves the way for close collaboration and coordination between gas and power transmission system operators (TSOs) from an integrated energy system perspective.

Resource management in energy systems under faulty conditions is another research challenge that needs to be addressed suitably. In this Special Issue, B. Goo, S. Jung, and J. Hur tackle this timely topic by proposing a fast restoration procedure for power systems affected by blackouts [10]. They initially outline an optimal selection mechanism for black start units using generator characteristic data and advanced algorithms considering minimum restoration time as an objective. Afterwards, they verify the effectiveness and applicability of the proposed method by an empirical system in the eastern regions of South Korea. Last but not least, U. Tamrakar, D. Shrestha, M. Maharjan, B. Bhattarai, T. Hansen, and R. Tonkoski review the recent literature on the control of modern power systems (which are on the verge of transition from synchronous machine-based systems towards inverter-dominated systems) and describe the current state-of-the-art in such virtual inertia systems under high renewable energy penetration [11]. They also suggest potential research directions and challenges in this subject area.

3. Energy Systems of the Future

The trend in energy systems integration for sustainable development has been increasing over the past few years and becoming the point of interest for many researchers and scientists worldwide. As more and more conventional and centralized energy sources that used to ensure system stability are removed from the generation mix or shut down, distributed generation (DG) units together with energy storage options may form micro energy grids (MEG) and provide a solution. Such MEGs have a variety of micro-sources (both in the form of conventional and renewable sources) that are closely networked with one another and could play the role of virtual control units over larger areas. These integrated energy systems also have the potential to meet the high demands both economically and reliably.

In the future, we will have to integrate energy-related devices and interfaces (such as inverter-interfaced distributed energy sources) more intensely into energy systems not only to ensure secure optimal operation and control in normal mode, but also to maintain stability when a fault occurs. The next-generation virtual control units are also standardized and more affordable because they are less specific in their demands.

Acknowledgments: We would like to take this opportunity to thank all the authors for their great contributions in this Special Issue and the esteemed reviewers for their time spent on reviewing manuscripts and their valuable comments helping us to improve the articles. We wish also to place on record our appreciation to the dedicated editorial team of *Applied Sciences*, and special thanks to Natalie Sun, Senior Assistant Editor and Michelle Zhou, Assistant Managing Editor for their tremendous support and dedication.

Conflicts of Interest: The authors declare no conflict of interest.

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