Guest Editorial Special Issue on New Trends in Energy Internet: Artificial Intelligence-Based Control, Network Security, and Management

I. Introduction

ENERGY Internet is recognized as a new and advanced paradigm of smart grids, where energy collection devices, distributed energy storage devices, and various types of energy nodes are interconnected by applying advanced power electronics technology, information technology, and intelligent management technology. This emerging Energy Internet brings remarkable improvement for the society from various aspects with its advantages in high efficiency, strong flexibility, great scalability, and improved reliability. However, it in turn generates new challenges in architecture design, control operation, and energy management. As a result, how to deal with these challenges in Energy Internet still needs further investigation by applying advanced techniques, such as multiagent systems, artificial intelligence-based control, big data cloud computing and management, and so on.

II. This Special Issue

The aim of this special issue is to bring together the latest research achievements in advanced control design, security mechanisms against various attacks and energy management for Energy Internet, and to offer a forum for researchers to exchange their achievements in Energy Internet. After a rigorous and careful peer-review process, the editorial team has selected 18 high-quality papers from the submissions for this special issue, where each paper has been reviewed by at least three reviewers. It is expected that the special issue can stimulate more interests of researchers in control and management of Energy Internet so as to produce more theoretical and practical outcomes in this significant and timely subject. The special issue starts with a survey paper "A Survey on Security Communication and Control for Smart Grids Under Malicious Cyber Attacks" by Peng *et al.*, which provides a comprehensive security understanding of smart grid frameworks, attacks scenarios detection and protection methods, and estimation and control strategies from both communication and control viewpoints. In this editorial, all the remaining papers have been classified into three groups as below.

A. Distributed Control for Microgrids/Power Systems

For a networked power system, a distributed control structure is capable of bringing some remarkable advantages of reliability, scalability, and efficiency. The first group includes four papers investigating distributed control issues of microgrids and power systems, especially in the presence of communication constraints. In the paper "Hierarchical Distributed Model Predictive Control of Standalone Wind/Solar/Battery Power System" by Kong *et al.*, an effective hierarchical distributed MPC method is proposed for the standalone wind/solar/battery hybrid power system, where the upper layer utilizes an iterative distributed MPC to realize the coordination of power dispatch while the lower layer is used to achieve both the economic and tracking property. Considering the effect of time delays, a distributed event-triggered secondary voltage control method is proposed in the paper "Distributed Event-Triggered Secondary Voltage Control for Microgrids With Time Delay" by Xie and Lin, to achieve voltage regulation in a microgrid with less communication resources. In the paper "Voltage Distributed Cooperative Control Considering Communication Security in Photovoltaic Power System" by Zhang *et al.*, a distributed consensus-based secondary voltage regulation scheme considering the switching communication topologies and communication delays is proposed, in which the evaluation indexes of voltage deviation and voltage difference can be satisfied. In the paper "Distributed State-of-Charge Balance Control With Event-Triggered Signal Transmissions for Multiple Energy Storage Systems in Smart Grid" by Xing *et al.*, a distributed SoC balance control scheme with an event-triggered signal transmission mechanism is presented to not only fulfil the overall power requirement but also meet the constraints of the same relative SoC variation rate for multiple distributed BESSs in a smart grid.

B. Optimal Energy Management in Energy Internet

Energy management is a fundamental topic in Energy Internet, aiming to manage energy resources efficiently and fairly to support different loads. The second group consists of five papers that address the energy management issues in Energy Internet. In the paper "Energy Crowdsourcing and Peer-to-Peer Energy Trading in Blockchain-Enabled Smart Grids" by Wang *et al.*, an optimization model and a blockchain-based architecture are proposed to manage the operation

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of crowdsourced energy systems, which can support seamless peer-to-peer energy trading between individual prosumers and/or the utility. A distributed neurodynamics-based algorithm is developed in the paper "Distributed Neurodynamic Optimization for Energy Internet Management" by Le *et al.* to realize the Energy Internet management. A case study on a five-energy-hub power–heat–gas multienergy system is conducted to verify the effectiveness of the proposed algorithm. Taking the effects of communication delays into account, the paper "Distributed Optimal Economic Dispatch for Microgrids Considering Communication Delays" by Huang *et al.* presents a delay-free-based distributed algorithm that can optimally assign the whole energy demand among local generation units while minimizing the agminated operation cost. To address the stochastic availability of energy like solar photovoltaic and wind turbine system, a mixed wavelet neural network method is utilized in the paper "Distributed Energy Management Strategy for Reaching Cost-Driven Optimal Operation Integrated with Wind Forecasting in Multi-Microgrids System" by Xing *et al.*, for short-term wind speed forecasting. Then, a distributed neurodynamic algorithm is presented to solve the nonsmooth optimization of energy management of a multimicrogrids system. In order to promote sustainable "prosumer" management in a smart grid, a feasible strategy is presented in the paper "Detecting Prosumer-Community Groups in Smart Grids From the Multi-Agent Perspective" by Cao *et al.* to detect prosumer-community groups based on individual prosumer's density. Then, by formulating prosumer-community groups detection as a multiobjective optimization problem, a partially visible multiagent system method is proposed, where the viewing angles of both prosumers and prosumer-community groups are mutually restricted.

C. Secure Control, Estimation, and Operation in Energy Internet

Basically, one of the most important issues in Energy Internet is how to ensure reliability and security of systems, especially subject to cyberattacks and system faults. To address this issue, a secure control and operation scheme is necessarily required. Here, the third group involves eight papers which are concerned about the security problems of Energy Internet from both cyber and physical perspectives. First, an event-triggered load frequency control method for multiarea power systems is proposed in the paper "Event-Triggered H_∞ Load Frequency Control for Multiarea Power Systems Under Hybrid Cyber Attacks" by Liu *et al.*, where the effects of hybrid cyberattacks incorporating DoS attacks and stochastic deception attacks are taken into account. To achieve fusion state estimation of power systems under denial-of-service attacks, a switched system approach is employed in the paper "Fusion State Estimation for Power Systems Under DoS Attacks: A Switched System Approach" by Chen *et al.,* which can explicitly reveal a trade-off between estimation accuracy, convergence speed, and computation times. The paper "Distributed Resilient Filtering for Power Systems Subject to Denial-of-Service Attacks" by Chen *et al.* constructs a new distributed filter to practically reflect the impact from both cyber-attacks and gain perturbations. With the help of matrix inequalities, a distributed resilient filtering algorithm dependent on the solution of two Riccati-like difference equations is proposed, and satisfies the requirements of scalability and distributed implementation. To overcome the impact of data deception and denial-of-service attacks on state estimation of smart grids, an ADMM-based distributed state estimation method is presented in the paper "ADMM-Based Distributed State Estimation of Smart Grid Under Data Deception and Denial of Service Attacks" by Du *et al.*, establishing the relationships between the convergence and algorithm parameters as well as the occurring probability of attacks. In the paper "False-Data Injection Attack in Electricity Generation System Subject to Actuator Saturation: Analysis and Design" by Yu *et al.*, the behavior and stealthiness of adversary are analyzed and stealthy attack strategies are designed under consideration of actuator saturation and false data injection attacks. A new collaborative intrusion detection approach using blockchain is proposed in the paper "A Collaborative Intrusion Detection Approach Using Blockchain for Multimicrogrid Systems" by Hu *et al.* to protect multimicrogrid systems from serious failures or physical damages caused by various cyberattacks. Besides the cyberattacks, physical faults also may cause performance degradation of power systems. Since hotspots may result in common abnormalities in photovoltaic energy systems, the paper "Data-Driven Detection of Hot Spots in Photovoltaic Energy Systems" by Chen *et al.* develops a space-to-space projection method is developed to achieve data-driven detection of hot spots in photovoltaic energy systems. In the paper "Fault Diagnosis for Energy Internet Using Correlation Processing-Based Convolutional Neural Networks" by Yang *et al.*, a novel and generic fault diagnosis method, the Spearman rank correlation-based convolutional neural networks, is introduced for complicated system. It is shown that this method can comprehensively extract different faults features while identifying the faults more quickly and precisely than other conventional approaches.

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