Guest Editorial Special Section on Smart Grid and Renewable Energy Resources: Information and Communication Technologies With Industry Perspective

THE successful integration of renewable energy into the power grid is expected to reduce the dependence of the grid on the fossil fuels. The potential renewable energy resources include light, wind, vibration, heat, biofuel, biomass, and tides [1], [2]. It is envisaged that the use of renewable energy will reduce the use of traditional energy resources, such as nuclear, oil, and gas, in the future and this trend will continue in order to reduce the emission of greenhouse gases. The abundance of these renewable distributed energy resources (DERs) at the consumer side may help to develop distributed renewable energy generation at a large scale [3]. The DERs will likely be an integral part of the future electric grid, i.e., the smart grid [4]–[6]. A prominent feature of the smart grid is that it allows for two-way communication between the utility and its customers through information and communication technologies (ICTs) [7].

For this special section of the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, we received 67 article submissions. After a detailed and rigorous peer-review process, we have included 19 original and unpublished articles in this special section in the domain of ICTs with an industry perspective for smart grid systems with emphasis on the integration of renewable energy resources. Therefore, this special section focuses on recent developments in the smart grid and its integration with renewable energy resources. We organize these 19 articles into four categories, which are explained in detail below.

I. Security, Privacy, and Encryption Techniques for SG With RERs

This group contains five articles on security and privacy related aspects of renewable energy resources (RER)-based smart grid (SG) communication systems. Although incorporating distributed renewable energy resources with the SG has several advantages, it also brings security and privacy concerns for both the consumer and the utilities. At the consumer end, residential units and smart meters share critical information, such as the daily electricity demands, pricing and billing information, as well as surplus generated energy to the electricity suppliers. Thus, the SG needs to ensure security and privacy aware data communication. The article "Toward Delay-Tolerant Flexible Data Access Control for Smart Grid with Renewable Energy Resources" by Z. Guan *et al*. addresses such data security requirements. Based on key policy attribute-based encryption, the authors propose a delay-tolerant data access control scheme for SG communication. The proposed scheme not only reduces the time needed for decryption, but also generates less overhead compared with traditional schemes. Moreover, the proposed scheme is distributed in nature and does not rely on a central trusted server for encryption/decryption.

The article "Secure Three-Factor User Authentication Scheme for Renewable-Energy-Based Smart Grid Environment" by M. Wazid *et al*. proposes a user authentication scheme called TUAS-RESG. The proposed authentication scheme shows robustness against various well-known attacks by using one-way hash functions, elliptic curve cryptography, and bitwise XOR operations. The effectiveness of TUAS-RESG is demonstrated through NS-2-based simulations.

An adversary can profile the activities and habits of subscribers by using available tools of nonintrusive load monitoring techniques on the smart meters or may even modify the metered data. This gives rise to privacy concerns for the customers. To protect the customers' privacy, the article "Comparative Analysis of Load-Shaping-Based Privacy Preservation Strategies in a Smart Grid" by C. E. Kement *et al*. performs a comparative analysis of eight privacy approaches and proposes a unified stochastic mathematical programming framework for fair comparison.

At the utility end, energy storage systems are used to store and inject power into the grid. This injection of energy into the grid is supervised and conducted in a controlled manner. The article "On the Impact of Cyber Attacks on Data Integrity in Storage-Based Transient Stability Control" by A. Farraj *et al*. examines the power stability and transient stability of power systems. Power system stability corresponds to the ability of the power system to become operational (i.e., in equilibrium state) after physical disturbance, while transient stability deals with stability when there are synchronous generators in the power system. The authors propose a framework for false data

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injection (FDI) attacks by developing reactive control strategies to counter FDI attacks.

The final article in this group, "Secure Optimal Itinerary Planning for Electric Vehicles in the Smart Grid" by A. Bourass *et al*. addresses the security of electric vehicles while interacting with the SG. The authors propose an architecture for itinerary planning and charging time slot reservations at charging stations of the SG. The proposed scheme was evaluated in MATLAB- and CPLEX-based simulations to optimize paths of electric vehicles (EVs) with respect to energy consumption and waiting time.

II. Communication and Networking Protocols for SG With RERs

This group contains three articles dealing with communication networks and architectures for the SG. The article "A Graph Theory Based Energy Routing Algorithm in Energy Local Area Network" by R. Wang *et al*. proposes a graph theory-based energy-routing algorithm for energy LANs, which are devised for the energy Internet. The energy Internet is an emerging concept that differs from the traditional Internet in the sense that it aims to increase the energy transmission efficiency and to optimize the energy distribution. In the energy Internet, an energy router will be the core device for the management of power flows among different connected devices. Two routing algorithms are proposed by the authors, one selects the lowest cost routes, while the second routing algorithm is designed for heavy load conditions.

The article "A Novel Random Access Mechanism for Timely Reliable Communications for Smart Meters" by C. Karupongsiri *et al*. proposes a random access (RA) control mechanism for smart meters to gain access to a long term evolution (LTE) network. The proposed mechanism combines both the contention and noncontention based RA methods. Moreover, the proposed mechanism does not require backoff time if the first attempt to access the medium is unsuccessful. Both simulations and mathematical analysis were performed to validate the effectiveness of the proposed RA mechanism.

The article "A Flexible Distributed Infrastructure for Real-Time Cosimulations in Smart Grids" by L. Bottaccioli *et al*. proposes a multipurpose, distributed infrastructure for real-time simulations of SG scenarios. The distributed infrastructure consists of six main blocks, namely load simulator, generator simulator, physical devices, control and management algorithm, communication adapter, and real-time simulator. The proposed infrastructure is very useful for simulating, testing, and validating new protocols for the SG.

III. Electricity Pricing and Resource Management for SG With RERs

This group contains four articles. The article "Optimal Energy Management and Marginal-Cost Electricity Pricing in Microgrid Network" by M. H. K. Tushar and C. Assi proposes an optimization scheme to minimize electricity prices. Moreover, a framework is proposed for the optimal trading of energy between sellers and buyers in the microgrid network (MGN) of the smart grid. More precisely, the authors propose a minimum energy pricing model (MEPM). The authors proved that the MEPM is a polynomial time algorithm, which is suitable for real-time pricing in MGNs.

The article "Residential Demand Response for Renewable Energy Resources in Smart Grid Systems" by L. Park *et al*. investigates demand response control methodologies for the SG. In fact, the authors propose a real-time pricing policy which is based on convex optimization. The authors proposed a heuristic to solve the non-deterministic polynomial-time (NP)-hard optimization problem. The heuristic finds an optimal solution to maximize user convenience while minimizing the electricity bill and peak consumption.

The article "Enabling Localized Peer-to-Peer Electricity Trading Among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains" by J. Kang *et al*. proposes an electricity trading model for local buying and selling of electricity among plug-in hybrid electric vehicles (PHEVs). The authors propose a P2P electricity trading system with a consortium blockchain (PETCON). In the PETCON, an iterative double auction mechanism maximizes social welfare in electricity trading. One of the important features of this article is that PETCON used a real map of Texas for the evaluation.

The last article in this group, "Integrated Mutation Strategy With Modified Binary PSO Algorithm for Optimal PMUs Placement" by N. H. Abd Rahman and A. F. Zobaa addresses the phasor measurement unit (PMU) placement problem. The authors proposed a binary particle swarm optimization (BPSO) algorithm for placing the PMUs. The authors evaluated the BPSO technique on an IEEE 300-bus system and demonstrated that the proposed algorithm reduces the number of required PMUs.

IV. Power Flow and Scheduling Techniques for SG With RERs

This group contains seven articles on diverse topics in the SG. The article "A Local-Optimization Emergency Scheduling Scheme With Self-Recovery for a Smart Grid" by T. Qiu *et al*. examines topology optimization and packet scheduling schemes for the Internet of Things (IoT) based SG. The authors propose LOES, a priority-based packet scheduling scheme. The authors compared LOES with first come first serve, multilevel, and dynamic multilevel priority packet scheduling. LOES outperformed these benchmark schemes in terms of packet end-to-end delay, packet waiting time, and packet loss ratio.

The article "Ensuring Data Integrity of OFP Module and Energy Database by Detecting Changes in Power Flow Patterns in Smart Grids" by A. Anwar *et al*. proposes an anomaly detection method to identify abnormal patterns in network power flows. The authors used multivariate time series statistical forecasting techniques to understand the power flow behaviors of the system. The authors used the IEEE 34-node and 123-node test systems to validate the proposed schemes.

In the smart grid, accurate grid topology information is required for smooth operation. The article "Distributed Topology Inference for Electric Power Grids" by N. Honeth and L. Nordstrom examines how to infer the topology of the electric power grid. The proposed algorithm is designed considering the needs of IEC 61850 compliant substation automation systems. The authors used an RBTS bus 4 model for the evaluations. One of

the unique features of this article lies in its capability to infer electrical connectivity of power grids without a central entity.

The article "Impacts of Power Factor Control Schemes in Times Series Power Flow Analysis for Centralized PV Plants Using Wavelet Variability Model" by M. Emmanuel *et al*. proposes three power factor control strategies, namely fixed power factor, power factor schedule, and power factor function for PV plants in the SG system. The authors validated their approach using an IEEE-34 distribution feeder. The authors also considered two types of customers with varying load patterns. They then presented minimum and maximum feeder voltage and active and reactive power profiles.

The article "Power Flow Coloring System Over a Nanogrid With Fluctuating Power Sources and Loads" by S. Javaid *et al*. proposes a power flow coloring system. This system helps to design multiple power flow patterns between distributed and fluctuating power sources. The proposed scheme can recognize the cost-effective usage of power from different renewable energy resources. The proposed schemes also help to manage distributed and dynamically fluctuating power sources and loads.

The article "Smart Grid Solution for Charging and Discharging Services Based on Cloud Computing Scheduling" by D. A. Chekired and L. Khoukhi proposes electric vehicle charging and discharging mechanisms based on cloud computing. The authors claimed that they are the first to integrate the concept of EV charging/discharging with cloud computing. The proposed scheme is evaluated through MATLAB-based simulations.

Finally, the last article of this group, "Monitoring Traffic Optimization in a Smart Grid" by G. Habault *et al*. proposes methods that lower the impact of continuous monitoring of equipment, thus ultimately reducing the corresponding traffic. The authors also identify best practices for monitoring of equipment according to their behaviors.

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