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EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL SMART GRIDS: A HUB OF INTERDISCIPLINARY RESEARCH

The smart grid is an important hub of interdisciplinary research where researchers from different areas of science and technology combine their efforts to enhance the traditional electrical power grid. Due to these efforts, the traditional electrical grid is now evolving. The envisioned smart grid will bring social, environmental, ethical, legal and economic benefits. Smart grid systems increasingly involve machine-to-machine communication as well as human-to-human, or simple information retrieval. Thus, the dimensionality of the system is massive. The smart grid is the combination of different technologies, including control system theory, communication networks, pervasive computing, embedded sensing devices, electric vehicles, smart cities, renewable energy sources, Internet of Things, wireless sensor networks, cyber physical systems, and green communication. Due to these diverse activities and significant attention from researchers, education activities in the smart grid area are also growing.

The smart grid is designed to replace the traditional electrical power grid. The envisioned smart grid typically consists of three networks: Home Area Networks (HANs), Neighborhood Area Networks (NANs), and Wide Area Networks (WANs). HANs connect the devices within the premises of the consumer and connect smart meters, Plug-in Electric Vehicles (PEVs), and distributed renewable energy sources. NANs connect multiple HANs and communicate the collected information to a network gateway. WANs serve as the communication backbone. Communication technologies play a vital role in the successful operation of smart grid. These communication technologies can be adopted based upon the specific features required by HANs, NANs, and WANs. Both wired and the wireless communication technologies can be used in the smart grid [1]. However, wireless communication technologies are suitable for many smart grid applications due to the continuous development in the wireless research domain. One drawback of wireless communication technologies is the limited availability of radio spectrum. The use of cognitive radio in smart grid communication will be helpful to break the spectrum gridlock through advanced radio design and operating in multiple settings, such as underlay, overlay, and interweave [2].

The smart grid is the combination of diverse sets of facilities and technologies. Thus, the monitoring and control of transmission lines, distribution facilities, energy generation plants, and as well as video monitoring of consumer premises can be conducted through the use of wireless sensor networks [3]–[6]. In remote sites and places where human intervention is not possible, wireless sensor and actuator networks can be useful for the successful smart grid operation [7], [8]. Since wireless sensor networks operate on the Industrial, Scientific, and Medical (ISM) band, the spectrum might get congested due to overlaid deployment of wireless sensor networks in the same premises. Thus, to deal with this spectrum congestion challenge, cognitive radio sensor networks can be used in smart grid environments [9], [10].

The objective of this Special Section in IEEE ACCESS is to showcase the most recent advances in the interdisciplinary research areas encompassing the smart grid. This Special Section brings together researchers from diverse fields and specializations, such as communications engineering, computer science, electrical and electronics engineering, educators, mathematicians and specialists in areas related to smart grids. In this Special Section, we invited researchers from academia, industry, and government to discuss challenging ideas, novel research contributions, demonstration results, and standardization efforts on the smart grid and related areas. This Special Section is a collection of eleven articles. These articles are grouped into the following four areas: (a) Reliability, security, and privacy for smart grid, (b), Demand response management, understanding customer behavior, and social networking applications for smart grid, (c) Smart cities, renewable energy, and green smart grid, and (d) Communication technologies, control and management for the smart grid.

I. RELIABILITY, SECURITY, AND PRIVACY FOR SMART GRID

The electrical power grid is a critically important infrastructure in today's world. Cyber Physical Systems and many other facilities and networks depend on the proper functioning of the electrical power grid. For instance, an anomaly in the electrical power grid may disrupt banking transactions and thus a country's economy may freeze for a while. This problem will be more severe in terms of security and privacy, when the traditional power grid will totally evolve into the smart grid. Considering this important aspect, the first three articles in this Special Section address reliability, security and privacy.

The article entitled "On reliability of smart grid neighborhood area network" by Shengjie Xu, Yi Qian, and Rose Qingyang Hu, discuss in detail a comprehensive survey on reliability in Smart Grid. More precisely, the article emphasize on reliability requirements, challenges, and case studies related to Smart Grid Neighborhood Area Network.

The Advanced Metering Infrastructure (AMI) is a component of Smart Grid that ensures communication for all smart meter related applications. One such application is automated meter reading, where the customer's electricity usage is communicated to the authorized persons for billing purpose and can also be used to forecast customers' demand for electricity. Thus, keeping privacy of this data is important. In the article entitled ''DEP2SA: A decentralized efficient privacy-preserving and selective aggregation scheme in advanced metering infrastructure'' by Mustafa A. Mustafa, Ning Zhang, Georgios Kalogridis, and Zhong Fan, authors proposed a privacy-preserving data collection scheme for advanced metering infrastructure.

Smart meters and automatic meter readings also result in generation of big data, which have to be moved to communication network supporting smart grid. In the article entitled ''Smart meters big data: Game theoretic model for fair data sharing in deregulated smart grids'' by Abdulsalam Yassine, Ali Asghar Nazari Shirehjini, and Shervin Shirmohammadi, authors proposed a solution to the problem of access control and proposed a game theory mechanism that compare between the beneficial use of data and individual's privacy in the context of decentralized smart grid.

II. DEMAND RESPONSE MANAGEMENT, UNDERSTANDING CUSTOMER BEHAVIOR, AND SOCIAL NETWORKING APPLICATIONS FOR SMART GRID

Demand Response Management (DRM) is considered as an important tool for the smart grid, as it is used to regulate and predict the electricity demand and supply profiles. DRM requires active participation from customer and one can understand customer behavior through DRM or vice versa. In DRM, customers can change their electricity consumption pattern through electricity tariff variations. Moreover, understanding customer behavior is important as it helps the engineers and researchers to design social networking based applications to facilitate the customers to use the smart grid efficiently. The next two articles deal with DRM and understanding customer behavior.

In the article entitled ''Demand response management for residential smart grid: From theory to practice'' by Wen-Tai Li, Chau Yuen, Naveed Ul Hassan, Wayes Tushar, Chao-Kai Wen, Kristin L. Wood, Kun Hu, and Xiang Liu, authors proposed a DRM scheme and constructed a residential smart grid testbed to implement the proposed scheme. This article includes a valuable experimental effort where the proposed scheme is verified through a testbed.

In the article entitled ''Understanding customer behavior in multi-tier demand response management program'' by Aqsa Naeem, Ali Shabbir, Naveed Ul Hassan, Chau Yuen, Ayaz Ahmad, and Wayes Tushar, authors aimed to provide deeper understanding of the customer behavior. In fact, authors investigated the factors that affect the customer's decision in subscribing to a particular DRM program.

III. SMART CITIES, RENEWABLE ENERGY, AND GREEN SMART GRID

The use of renewable energy sources is recommended for smart cities. Urban planning for new villages and cities is underway for the incorporation of smart grid. Information and Communication Technologies (ICT) are moving towards powering their communication infrastructure through renewable energy sources to reduce energy consumption and carbon emissions. Considering the importance, we have included three articles for this topic.

In the article entitled ''Impact of interdisciplinary research on planning, running, and managing electromobility as a smart grid extension'' by Alfredo D'Elia, Fabio Viola, Federico Montori, Marco Di Felice, Luca Bedogni, Luciano Bononi, Alberto Borghetti, Paolo Azzoni, Paolo Bellavista, Daniele Tarchi, Randolf Mock, and Tullio Salmon Cinotti, authors discuss smart grid by integrating Electromobility and the urban power distribution network. Authors discussed the results of different European projects for the development of a co-simulator tool which will be used for Electromobility planning, and recharging services in the smart grid.

In the article entitled ''Integrating cellular networks, smart grid, and renewable energy: Analysis, architectures, and challenges'' by Hussein Al Haj Hassan, Alexander Pelov, and Loutfi Nuaymi, authors proposed an architecture to power cellular networks with renewable energy sources.

In the article entitled ''Revenue optimization frameworks for multi-class PEV charging stations'' by Cuiyu Kong, Islam Safak Bayram, and Michael Devetsikiotis, authors proposed two queuing theory based optimization frameworks for Plug-in Electric Vehicles (PEVs).

IV. COMMUNICATION TECHNOLOGIES, CONTROL AND MANAGEMENT FOR THE SMART GRID

For the successful operation of the smart grid, data should be communicated efficiently and reliably between different entities. Moreover, the assets in the smart grid should also be controlled and monitored. Thus, considering the importance of this topic, we have included three articles in this section.

The article entitled ''Delay critical smart grid applications and adaptive QoS provisioning'' by Irfan Al-Anbagi, Melike Erol-Kantarci, and Hussein T. Mouftah, discuss a smart grid monitoring application utilizing wireless sensor networks. Authors proposed an adaptive Quality of Service (QoS) scheme to prioritize alarm data for high intensity traffic in IEEE 802.15.4 Wireless Sensor Networks that comply with smart grid latency requirements.

In the article entitled ''Distributed state estimation using RSC coded smart grid communication'' by Md Masud Rana, Li Li, and Steven Su, authors proposed a distributed approach to microgrid state estimation based on the concatenated coding structure.

The article entitled ''Cascading failures in smart grid: Joint effect of load propagation and interdependence'' by Zhen Huang, Cheng Wang, Tieying Zhu, and Amiya Nayak, contains the study of cascading failures in the smart grid.

As mentioned earlier, in the smart grid, both the communication/control network and the power network are dependent upon each other. A failure to any segment of the power or communication network may lead to cascading sequential failure in the entire smart grid, thus leading to cascading failures. Considering this important problem, authors classified the cascading failures and discussed them in detail.

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