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EDITORIAL

Guest Editorial: Microgrids as Part of Cellular Energy Systems

A microgrid is a small energy system involving local electricity generation and local distribution system containing energy storages, loads, and monitoring and protection devices. In addition to electricity, a microgrid may include thermal energy applications for heating and cooling. A microgrid can operate independent in islanded mode, it can be interconnected in the larger energy system, or it can alter between these two modes depending on the total system state.

Cellular electric energy systems are power systems composed of interconnected, supervised, and controlled cells. These cells can be thought of as microgrids interconnected to an overlaying grid. Such kinds of grid-connected microgrids are in normal operation not intended to autonomously supply an isolated area. Instead, they exchange power with the main grid and other cells and participate in the operation of the overall system by the provision of ancillary services (e.g., flexibility provision, active and reactive power control, frequency and voltage control, congestion management, restoration services, grid forming services, etc.). By the coordinated operation of the cells which compose a cellular electric energy system, an efficient, secure, and stable overall system operation can be achieved.

This Special Issue aims to explore methods, technologies, and solutions for the integration of grid-connected microgrids in the efficient, secure, and stable operation of future cellular electric energy systems. In total, there were seven articles covering the following topics:

1 | TOPIC 1, PLANNING AND OPERATION OF MICROGRIDS AS PART OF CELLULAR ENERGY SYSTEMS

"A linearized transmission expansion planning model under N-1 criterion for enhancing grid-scale system flexibility via compressed air energy storage integration" by Mazaheri et al. investigates transmission expansion planning under N-1 criterion for enhancing the grid-scale system flexibility via compressed air energy storage integration. The concept of flexibility is defined as the power systems´ ability to effectively respond to changes in power systems' supply–demand balance. The flexibility margins required for secure operation of power systems are being challenged by uncertainties, mostly driven by intermittent outputs of renewable energy sources (RES). To mitigate these challenges, energy storage systems (ESS) are an important and emerging option. However, to effectively harness the capacity of these ESS, often distributed in the power system, efficient planning tools are required. This paper presents a novel mixed integer linear planning model for the transmission expansion planning, to account for the role of compressed air energy storages in enhancing power system flexibility, while a mechanism is suggested for the N-1 reliability criterion.

"Optimal planning of inverter-based renewable energy sources toward autonomous microgrids accommodating electric vehicle charging stations" by Ali et al. deals with optimal planning of inverter-based RES sources toward autonomous microgrids accommodating electric vehicle (EV) charging stations. RES such as photovoltaic (PV) and wind power (WP) are considered. Best sites and sizes of PV and WP are determined using an optimization technique. The paper considers generation and load profiles, network constraints and DSTATCOM capability of RES units. A bi-level metaheuristic solution is established to solve this complex planning task. The feasibility of suggested solution is evaluated through a series of simulations and case studies.

2 | TOPIC 2, MODELLING AND SIMULATION OF MICROGRIDS WITHIN CELLULAR ENERGY SYSTEMS

"A network-decomposition-based multi-rate parallel transient simulation technique for active distribution networks" by Wang et al. examines network-decomposition-based multi-rate parallel transient simulation of active distribution networks. In large active distribution networks, emerging technologies in demand side, that is, generation resources, storages and active loads, lead to diversified dynamic processes and challenge the dynamic modelling of these systems. A network-decomposition-based multi-rate parallel transient simulation technique is proposed here to solve this problem. Advantages of the method are accentuated by balancing computational complexities of CPU cores and device core-oriented adaptive step sizes of simulation with various dynamic characteristics. A parallel simulation method of coordinated step sizes is proposed to accelerate the transient simulation.

3 | TOPIC 3, ANCILLARY SERVICES IN CELLULAR ENERGY SYSTEMS INCORPORATING MICROGRIDS

"Imbalance-based primary frequency control for converter-fed microgrid" by Suh et al. investigates imbalance-based primary frequency control for converter-fed microgrid. Frequency droop is a simple and effective frequency control method, but it is not appropriate as a primary frequency control for microgrids with energy storages and voltage source inverters. This paper proposes a new converter-fed microgrid frequency control method based on the estimated active power imbalance. This is estimated via frequency deviation, frequency drop speed and modified swing equation. Simulations show that the proposed method is significantly faster than frequency droop control methods and improves the quality of frequency control.

In "Provision of ancillary services in a grid-connected photovoltaic distributed energy resource" by Rocha et al., the provision of ancillary services in grid-connected photovoltaic distributed energy resources (DER) is investigated. The insertion of DER can be positive, providing ancillary services, for example, harmonic mitigation, or negative, causing overvoltage, depending on the proper control and characteristics of the grid. The paper proposes a pq-based control strategy for distributed generation, which in the studied case is composed of PVs providing ancillary services. The power control is based on the power balance between the grid and the converter. Besides supplying active and reactive power, the proposed strategy can provide ancillary services by controlling the grid currents from a pq-transformation.

4 | TOPIC 4, MONITORING, PROTECTION AND CONTROL OF MICROGRIDS IN CELLULAR ENERGY SYSTEMS

"Multilayer event-based distributed control system for DC microgrids with non-uniform delays and directional communication" by Alavi et al. deals with multilayer event-based distributed control system for DC microgrids with non-uniform delays and directional communication. The secondary control layer of microgrids is modelled as a multi-agent distributed system, coordinated based on consensus protocols. To minimize the convergence time in consensus protocol, the paper proposes a multilayer event-based consensus framework, which is resilient to communication delays and supports plug-and-play addition or removal of distributed generators in DC microgrids of cellular energy systems. A novel bi-layer optimization algorithm minimizes the convergence time by selecting an optimal communication topology graph and then adjusts the controller parameters. The proposed solution was tested in hardware—in-the-loop testbed to validate its performance.

"Aggregate dynamic modelling and optimal control in cellular electric energy systems" by Hinners et al. investigates aggregate dynamic modelling and optimal control in cellular electric energy systems. The paper deals with the problem of the large number of controlled distributed resources, which makes the individual modelling and control of these resources of the grid computationally challenging. Hence, some method for aggregating these resources both for modelling and control would be appealing so that they can be presented collectively. The paper presents a method combining the control goals based on geometric flexibility regions, constrained optimization, and transfer function considerations to enforce approximated first-order transfer function behaviours at the buses. Time-domain simulations are used for validation and demonstration of the method.

5 | SUMMARY/CONCLUSION

Integrating microgrids as parts of cellular energy systems is a vast and challenging problem, dealing with several areas of power system engineering. The selected papers provide a good overview of the most important aspects of cellular energy systems: planning and operation of microgrids as part of cellular energy systems; monitoring, protection and control of microgrids in cellular energy systems; modelling and simulation of microgrids within cellular energy systems; and ancillary services in cellular energy systems incorporating microgrids.

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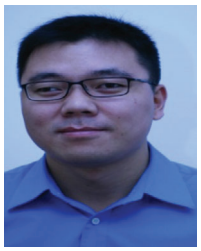

Qiuwei Wu (M'08-SM'15) obtained the PhD degree in Power System Engineering from Nanyang Technological University, Singapore, in 2009. He was a senior R&D engineer with Vestas Technology R&D Singapore Pte Ltd from March 2008 to October 2009. He has been working at the Department of Electrical Engineering, Technical University of Denmark (DTU), since November 2009 (Post-Doc, November 2009–October 2010; Assistant Professor, November 2010–August 2013; Associate Professor since September 2013). He was a visiting scholar at the Department of Industrial Engineering & Operations Research (IEOR), University of California, Berkeley, from February 2012 to May 2012 funded by the Danish Agency for Science, Technology and Innovation (DASTI), Denmark. He was a visiting professor named by Y. Xue, an academician of the Chinese Academy of Engineering, at Shandong University, China, from November 2015 to October 2017. He was a visiting scholar at the School of Engineering and Applied Sciences, Harvard University from November 2017–October 2018 funded by the Otto Mønsted Fond. His research interests are operation and control of power systems with high penetration of renewables, including wind power modelling and control, active distribution networks, and operation of integrated energy systems.

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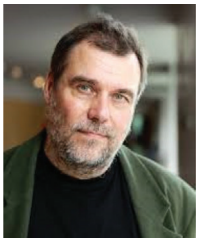

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