Guest Editorial
Special Issue on Structured DC Microgrids

WITH the development of dc coupled devices, such as photovoltaic generations, batteries, supercapacitors, LEDs, computers, and electronics equipment, low-voltage dc distribution networks, structured dc microgrids are emerging as a natural platform to integrate renewable energy sources. However, there are a number of technical challenges: lack of standardized equipment, inadequate stability, and versatile control design. In the past, the interest of power electronics community was moving from a single power electronics converter to multiple distributed systems that encompass a number of converters connected in either series/parallel, forming a number of dc busses with different voltage levels. Recently, with the advance of new dc power technologies, several ongoing standards, alliances, and initiatives are bringing the possibility of developing future homes, offices, buildings, campuses, datacenters, ships, satellites, aircrafts, and other electrical power systems to operate totally or dominantly in dc. Research is being carried out in both the system and component levels of modeling, control, and stability of structured dc microgrids. New high-efficiency topologies and protections are also key nontrivial issues when developing practical dc microgrids.

This Special Issue brings together recent advancements in dc microgrids, which are broadly classified into three themes: power electronics converters, energy storage systems, and the control of dc microgrids. Eleven papers are accepted for publication in this Special Issue: four papers related to control of dc microgrids; four papers related to power electronics converters for dc microgrids; and three papers on energy storage for dc microgrids. A brief discussion of each paper is presented in the following.

I. Control of DC Microgrids

Controlling dc microgrids is an important topic considering the different elements of the microgrid and the whole system, which also encompasses linear and nonlinear modeling and control theory. This section includes four papers devoted to the control of dc microgrids described as follows.

1) "Review on Control of DC Microgrids and Multiple Microgrid Clusters" by Meng *et al.* It presents an extensive review on control schemes and architectures for DC microgrids. It includes hierarchical control, coordinated control, plug-and-play operations, stability and active damping aspects as well as nonlinear control. Islanding detection, protection and microgrid clusters control are also introduced.
2) "Towards Online Optimal Power Flow of a Networked DC Microgrid System" by Trinklein *et al.* proposes an advanced controller to achieve optimal power flow in large scale dc microgrid systems with high number of nodes. The approach is suitable for multimicrogrid systems.
3) "Stability of the Small-Scale Interconnected DC Grids via Output-Feedback Control" by Kazemlou *et al.* proposes a decentralized nonlinear model and control to stabilize interconnected dc microgrids including renewable energy resources and both resistive and constant power loads (CPLs). Simulation results are provided to show the feasibility of the proposed approach.
4) "Performance Evaluation of Type-3 PLLs Under Wide Variation in Input Voltage and Frequency" by Aravind *et al.* presents a detailed analysis of Type-3 PLL under wide variation in input voltage and frequency. By using this approach, the grid-connected converter interfaced to the dc microgrid can ensure stable operation. Experimental results are provided.

II. Power Electronics Converters for DC Microgrids

Power electronics converters, including topologies, modeling, and control, constitute the building blocks of dc microgrids. This section includes four papers dealing with those topics.

1) "Low-Frequency Resonance Suppression of a Dual-Active Bridge DC/DC Converter Enabled DC Microgrid" by Ye *et al.* presents the small signal stability of a DAB converter-enabled dc microgrid. Thus by using an impedance shaping technique, the dc microgrid stability has been improved. Finally, hardware-in-the-loop results are used to validate the proposed approach.
2) "Bidirectional Soft-Switching Series-Resonant Converter With Simple PWM Control and Load-Independent Voltage-Gain Characteristics for Energy Storage System in DC Microgrids" by Wu *et al.* proposes a fixed frequency-operated bidirectional series-resonant converter for energy storage systems in dc microgrids. A prototype is built and tested to evaluate the feasibility of the proposed converter.
3) "Fast SFG Modeling of Integrated Converters" by Yao *et al.* extends the application of the SFG modeling technique to integrated converters containing multiple switched inductive elements. By using the proposed methodology, the dynamic modeling of a switching

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power converter becomes a fast and easy task. The obtained small signal dynamic models were verified by simulation and by comparison with previous theoretical and experimental results.

4) "Extended Switched-Boost DC–DC Converters Adopting Switched-Capacitor/Switched-Inductor Cells for High Step-Up Conversion" by Zhu *et al.* proposes a family of switched-boost dc–dc converters for the high step-up voltage conversion applications, such as renewable energy power generation, uninterruptible power supply, and automobile high-intensity discharge headlamps. Simulations and experimental results are presented to verify the effectiveness of the proposed converter.

III. Energy Storage Systems for DC Microgrids

Energy storage systems, such as batteries, are fundamental elements in dc microgrids. This section presents three papers on the analysis and control of battery converters in the dc microgrid context.

1) "Second Ripple Current Suppression by Two Bandpass Filters and Current Sharing Method for Energy Storage Converters in DC Microgrid" by Yang *et al.* proposes a second ripple suppression method by introducing two bandpass filters into the output voltage and inductance current feedback. Furthermore, an adaptive droop control method by introducing the fine tuning virtual resistances is adopted to reduce the output voltage deviation.
2) "Optimal Distributed Nonlinear Battery Control" by Akyurek *et al.* proposes an optimal nonlinear battery control algorithm that can handle multiple batteries connected to a microgrid in a distributed and cost-optimal fashion. It presents three distributed solutions: 1) circular negotiation ring, providing convergence rates independent of number of batteries; 2) mean circular negotiation ring, converging very quickly for a low number of batteries; and 3) bisection method with a convergence rate independent of battery capacities.
3) "Bifurcation-Based Stability Analysis of Photovoltaic-Battery Hybrid Power System" by Huang *et al.* identifies and analyzes the bifurcation process when a microgrid based on PV/battery enters in unstable operation states. Furthermore, according to the nonlinear dynamics of the interconnected system with closed-loop control, a large signal stability criterion is derived with mixed potential theory. The validity of proposed criteria are verified by simulation and experimental results.

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