Guest Editorial Special Issue on Topology, Modeling, Control, and Reliability of Bidirectional DC/DC Converters in DC Microgrids

DC MICROGRIDS have higher efficiency, better current carrying capacity, and faster response compared to the conventional ac systems. They also provide more natural interface with many types of renewable energy resources (RERs) and energy storage systems (ESSs), as well as better compliance with consumer electronics. These facts lead to increased applications of dc microgrid-type power architectures in remote households, data/telecom centers, renewable energy systems, electric vehicle charging stations, ships, aircrafts, and so on. Bidirectional dc/dc power converters (BDCs) constitute the fundamental building blocks of dc microgrids. They can be isolated or non-isolated and operated independently or in parallel to manage the power flow between sources and the dc microgrid. They can also be stacked together to operate in the so-called solid-state transformer architecture, which manages the power flow between dc microgrid and the upstream distribution network. The reliability, stability, efficiency, and power density of the BDC become very crucial for the dc microgrids. There are thus increasing research efforts made on the topology, modeling, control, and reliability of the BDC.

To promote further research and development of this emerging technology, we proposed a Special Issue on the topology, modeling, control, and reliability of bidirectional dc/dc converters for application in dc microgrids. In response to Call for Papers, we received 58 manuscripts, and 23 papers were finally selected for publication. The manuscripts were submitted from different countries all around the world such as China, Brazil, India, Hong Kong, France, Denmark, Chile, Iran, Singapore, United States, Germany, South Africa, Spain, Australia, and Canada. The 23 papers in this Special Issue cover a variety of aspects pertinent to the selected special topic. While many papers address multiple aspects together, the papers can be broadly categorized as follows: Review Papers, Control Strategies, and Converter Topologies.

We discuss briefly each single paper in the following.

A. Review Papers

S. Rivera, R. Lizana, S. Kouro, T. Dragicevic, and B. Wu, "Bipolar DC power conversion: State-of-the-art and emerging technologies," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2980994.

This paper reviews the power architectures and control strategies of bipolar dc distribution systems.

Q. Xu, N. Vafamand, L. Chen, T. Dragičević, L. Xie, and F. Blaabjerg, "Review on advanced control technologies for bidirectional DC/DC converters in DC microgrids," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2978064.

This paper reviews the advanced control strategies for bidirectional dc/dc power converters.

B. Control Strategies

E. Kowsari, J. Zarei, R. Razavi-Far, M. Saif, T. Dragičević, and M. H. Khooban, "A novel stochastic predictive stabilizer for DC microgrids feeding CPLs," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.3008885.

This paper proposes a new type of robust controller that can stabilize a dc microgrid feeding constant power loads in presence of uncertainty.

N. Sarrafan, J. Zarei, R. Razavi-Far, M. Saif, and M. Khooban, "A novel on-board DC/DC converter controller feeding uncertain constant power loads," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2019.2963417.

In this paper, the disturbance observer-based tracking control for the dc/dc boost converter loaded by unknown time-varying constant power loads has been presented.

Y. Yang, C. Li, J. Xu, F. Blaabjerg, and T. Dragicevic, "Virtual inertia control strategy for improving damping performance of DC microgrid with negative feedback effect," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2998812.

This paper proposes a novel inertia emulation strategy in dc microgrid to improve its stability margins.

Q. Xiao *et al.*, "A novel operation scheme for modular multilevel converter with enhanced ride-through capability of submodule faults," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2967576.

This paper proposes a new type of controller that improves the performance of modular multilevel converter in the presence of submodule faults.

M. Nabatirad, R. Razzaghi, and B. Bahrani, "Decentralized voltage regulation and energy management of integrated DC microgrids into AC power systems," in IEEE JOURNAL OF

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EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.3034946.

This paper proposes a control strategy for the integration of dc microgrids into power systems, which provides a seamless transition between the islanded and grid-connected modes of the dc microgrid. In this method, the dc microgrids are capable of importing or exporting energy from or to the ac grid based on the loading conditions.

G. Haritha, S. Kumaravel, and S. Ashok, "Xilinx system generator-based rapid prototyping of solid-state transformer for on-grid renewable energy integration," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2019.2963277.

This paper proposes the highly detailed modeling and control of solid-state transformers in the FPGA platform.

M. Jafari, S. Peyghami, H. Mokhtari, and F. Blaabjerg, "Enhanced frequency droop method for decentralized power sharing control in DC microgrids," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2969144.

This paper proposes a signal injection method that facilitates accurate power sharing in a dc microgrid.

S. Pang, B. Nahid-Mobarakeh, S. Pierfederici, Y. Huangfu, G. Luo, and F. Gao, "Towards stabilization of constant power loads using IDA-PBC for cascaded LC filter DC/DC converters," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2019.2945331.

This paper proposes a new controller that stabilizes cascaded dc/dc converters in dc distribution systems.

R. Roy and S. Kapat, "Input filter-based ripple injection for mitigating limit cycling in buck converters driving CPL," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2985426.

An input voltage signal injection method is proposed to extract inductor current information and offer a virtual damping effect in the closed-loop system in a dc microgrid.

O. M. Hebala, A. A. Aboushady, K. H. Ahmed, I. Abdelsalam, and S. J. Burgess, "A new active power controller in dual active bridge DC-DC converter with a minimum-current-point-tracking technique," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.3016771.

This paper proposes a new power regulation controller for dual active bridge dc−dc converter based on a new scheme that tracks minimum RMS current to ensure minimum losses.

C. Converter Topologies

L. Zhang, H. Ding, W. Tian, and K. Lu, "Research on five-level control scheme of hybrid-bridge bidirectional DC-DC converter," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2019.2957016.

This paper proposed an improved hybrid bridge dc–dc converter topology with a five-level control, which features operation in a wide voltage range, minimum current stress, reduced reactive power, wide zero-voltage switching range along with the overall control simplicity as the power flow is controlled using a single control variable.

M. P. Hirth, R. Gules, and C. H. I. Font, "A wide conversion ratio bidirectional modified SEPIC converter with non-dissipative current snubber," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2966410.

In this paper, a new wide conversion ratio bidirectional dc–dc converter based on the modified SEPIC converter is presented. The proposed converter features extended step-up and step-down voltage conversion ratio without extreme low or high duty-cycle and reduced voltage stress in all semiconductors.

A. Tong, L. Hang, H. S. Chung, G. Li, K. Wang, and Y. He, "Using sampled-data modeling method to derive equivalent circuit and linearized control method for dual-active-bridge converter," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2019.2961138.

In this paper, a novel second-order equivalent circuit based on a sampled-data modeling approach is introduced, which could help to investigate the relationship of the dual active bridge (DAB) converter stability versus circuit parameters, controller gain, input voltage, and the load. In contrast with the conventional reduced-order model that is developed by averaging the output current, the proposed equivalent circuit provides accurate representations of both the inductor current and the output voltage at the sampling points.

X. Pan, F. Yang, L. Li, R. Zhang, and C. Wang, "An improved modulation scheme of active commutated current-fed bidirectional DC/DC converter," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2972014.

In this paper, the L-L type current-fed bidirectional dc–dc converter with a discontinuous current dual-phase shift (DCDPS) modulation method is proposed. The DCDPS modulation method can solve the current resonance problem and reduce the large circulating current at light loads typical for the conventional modulation methods and provides a lower peak and RMS values of both leakage inductor current and switches current, thus providing higher power conversion efficiency.

P. Liu and S. Duan, "A ZVS range enhancement strategy for the DAB converter by using blocking capacitors," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.3016052.

This paper explores the ZVS range enhancement strategy for the DAB converter with blocking capacitors according to specific operating conditions by introducing the hybrid modulation technique with different voltage offsets across the blocking capacitors.

S. Wang, C. Li, K. Wang, Z. Zheng, and Y. Li, "Loss imbalance and transient DC-bias mitigation in dual active bridge DC/DC converters," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2983870.

This paper proposed a fundamental and detailed analysis of dc biases as well as loss imbalances between phase arms in DAB converters. A dedicated pulsewidth modulation (PWM)

generation technique was proposed with exact gate signal timing control to eliminate the loss imbalances and the dc-biases at the same time, without any additional dc blocking capacitors or high-frequency sensors in DAB converters.

X. Tang, H. Wu, W. Hua, Z. Yu, and Y. Xing, "Three-port bidirectional series-resonant converter with first-harmonic-synchronized PWM," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2975164.

In this paper, an isolated three-port bidirectional series-resonant converter with first-harmonic synchronized pulsewidth modulation (FHS-PWM) is proposed for energy storage application. Due to the load-independent voltage conversion characteristic of FHS-PWM, the power decoupling can be achieved automatically at the circuit level. Furthermore, the power flow can be changed and regulated quickly and smoothly.

F. Xue, R. Yu, and A. Huang, "A family of ultra-high efficiency fractional DC-DC topologies for high power energy storage device," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.2966177.

In this paper, a family of non-isolated bidirectional fractional dc–dc converter is proposed for a high-power energy storage device. The proposed converter has the benefits of low cost, low system profile, and high efficiency. Only part of the total power is processed by the converter; therefore, ultra-high efficiency of over 99% can be achieved while the converter has low rated power.

A. Sharma, S. S. Nag, G. Bhuvaneswari, and M. Veerachary, "Analysis and transition techniques for a bidirectional DC-DC converter," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.3023433.

This paper proposes two new PWM schemes, namely, asynchronous PWM scheme (APS), and synchronous PWM scheme (SPS), for a nonisolated fourth-order bidirectional dc–dc converter (FOBDC), which are implemented to achieve a smooth start-up operation and mode transition to reverse the direction of power flow.

R. Hu, J. Zeng, Z. Yu, Z. Yan, and J. Liu, "Secondary side cascaded (SSC) winding-coupled bidirectional converter with wide ZVS range and high conversion gain," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2019.2960032.

In this paper, a secondary side cascaded bidirectional dc–dc converter is proposed with the winding-coupled structure for the bidirectional operations of power flow, which features high voltage gain, full range of soft switching, low current ripple in low voltage side, and extended duty cycle range.

C. Zheng, T. Dragčević, J. Zhang, R. Chen, and F. Blaabjerg, "Composite robust quasi-sliding mode control of DC-DC buck converter with constant power loads," in IEEE JOURNAL OF EMERGING AND SELECTED TOPICS IN POWER ELECTRONICS, doi: 10.1109/JESTPE.2020.3021942.

This paper proposes a composite robust discretized quasi-sliding mode control (DQSMC) scheme for stabilization of buck-converter fed dc microgrids with CPLs to address the stability issues aroused by the negative-resistance effect of constant power loads. The proposed approach features enhanced disturbance rejection, inherent chattering suppression, and guaranteed dynamics.

The editorial team hopes that this Special Issue will provide readers with new inspirations for research and will encourage them to make further progress in the dc microgrid-related topics, especially in the development of high-performance, cost-effective, and reliable power electronic systems. We believe that in the long-term, the extensive research in this challenging field will push innovation forward and accelerate the industrial uptake of the highly promising dc microgrid technology.

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