Guest Editorial: Special Issue on Power Electronics for Distributed Energy Resources

DISTRIBUTED energy resources (DERs) are any energy resources in the electrical distribution systems, which can produce electricity, consume or store energy in a controlled manner, or be utilized to improve energy efficiency. They are typically smaller in scale than the traditional large-generation facilities. DERs include distributed generation units, energy storage facilities including electric vehicles, and controlled loads. Power electronic technologies, as the focus of this Special Issue, are critical to enabling the integration, protection, performance, and interoperability of DERs in power systems. DERs are rapidly growing in the global electricity market and are entering into power systems as an integral part of the system thanks to the increasing penetration of renewable energy and energy storage units. The technologies for DERs have advanced significantly over the past two decades and so have the DER interconnection standards. In addition to meeting the requirements for power system specifications, safety, and protection, DERs are required to support grid operation in recently developed interconnection standards by providing functions of voltage and frequency ride-throughs, voltage and frequency regulations, or inertial responses.

In addition to the increased functionality of DERs for supporting power systems, the performance of DER power converters has experienced significant improvements during the past decades, noticeably in efficiency, size, weight, cost, switching frequency, thermal management, dynamics, compatibility, security, and reliability. In particular, the advancement in wide-bandgap devices has enabled power converters to be more efficient, lighter, smaller in form factor, and operate at even higher frequencies and elevated temperatures with reduced cooling. It is expected that the continuing advancements in power electronic components, control methods, and integration technologies will further enhance the performance and functionality of the DER systems along with their increased level of penetration into electric grids.

This Special Issue is devoted to the state-of-the-art technologies of power electronics for DERs, encompassing components, circuits and systems, control, protection, and verification. After rigorous reviews of 99 manuscripts submitted by professionals worldwide, 35 papers were accepted for publication, of which 31 papers were included in this Special Issue and four papers were included as regular papers. These papers presented a glimpse of the recent developments of power electronics for DERs with applications for energy storage systems, grid-connected PV systems, solid-state transformers, and dc or ac microgrids. The topics of these papers are quite broad in the areas of converter topologies, modeling and design, converter control and modulation, system control and grid support, protection and security, and test and verification, as summarized in the following. It was noted that with the exception of review papers, all other reported new technologies were experimentally verified by the authors.

Many papers in this Special Issue are focused on the fundamental and essential matters within power converters for DERs. Eleven papers presented new power converter control and modulation methods, on the topics of double-side asymmetrical phase-shift modulation for dual-active-bridge converters [A1]; simplified finite-set model predictive control for optimal voltage vectors for cascaded H-bridge converters [A2]; modified pulse-width modulation for active neutral-point clamped switched-capacitor multilevel inverters with inrush charging current attenuation and balanced dc-link capacitor voltages [A3]; output-error-driven incremental model predictive control for buck converters [A4]; a robust control scheme for single-phase grid-tied inverters including hybrid phase-locked loop, sliding mode current control for power injection and sliding mode voltage control for dc-link voltage [A5]; a current estimation technique for integrated dual-dc boost converters [A6]; a model predictive current control method based on optimal switching sequence for four-leg two-level grid-connected converters [A7]; a selective harmonic elimination formulation based on average dc voltage for three-phase cascaded H-bridge multilevel converters [A8]; a control strategy for active, reactive and selective distortion power in single-phase grid-following inverters [A9]; a virtual oscillator based frequency-locked loop in a virtual synchronous machine [A10]; and a fictitious quadrature sequence components extraction scheme without any filters [A11].

Eleven papers reported new developments in power converter topologies, components, and designs. The topics include: SiC-based integrated building blocks for two-level dc–dc solid-state transformers [A12]; topological solutions for universal power electronic interface for dc or single-phase ac grids [A13]; a modular and universal power converter for dc-to-dc and dc-to-ac power conversion in both three-phase three-wire and four-wire connections [A14];

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review and comparison of high voltage-step-down ratio dc–dc converters based on modular multilevel converters for grid-tied energy storage systems [A15]; improved active gate drivers for paralleled SiC MOSFETs [A16]; a reduced-switch hybrid dual-active bridge converter for direct ac–ac solid-state transformers [A17]; a mission profile-tailored design procedure and control for an interconnected hybrid grid connecting converter architecture [A18]; sub-modules based on HV IGBTs and SiC MOSFETs for medium-voltage cascaded H-bridge converters in DER applications [A19]; a new cascaded H-bridge inverter with input voltage boost capacity and associated controls [A20]; a single-stage matrix-type solid-state transformer with reduced switches [A21]; and methods for modeling capacitor voltage ripples and sizing capacitors for three-phase four-wire converters [A22].

Five papers elaborated system level controls of DERs interacting with grids or supporting system operation, with topics on adaptive frequency droop control based on virtual power method for distributed energy storage units [A23]; active power compensation for microgrids [A24]; series dc-bus voltage compensation technique for voltage regulation in dc microgrids [A25]; a nonisolated dc energy router integrating energy storage, distributed generation, local loads, and dc grid [A26]; and an overview of the state-of-the-art control strategies for voltage support by PV inverters in low voltage distribution networks [A27].

Two papers were devoted to the topics of protection and security of DER converters and systems: a current limiting type of fault ride-through scheme for power converters in dc microgrids [A28] and a self-protective algorithm for inverters to detect malicious setpoints [A29].

Two papers were related to the verification of DER systems and technologies by using emulators and hardware-in-the-loop systems: an overview of testing capacity requirements of grid emulators based on recent grid standards [A30] and right-half-plane pole trajectory study for impedance-based stability monitoring using a power-hardware-in-the-loop system [A31].

The Guest Associate Editors (GAEs) of this Special Issue have made tremendous efforts in managing the review process of the submitted manuscripts, ensuring the quality, originality, and relevance for the publication of this Special Issue. We would like to take this opportunity to extend our deep gratitude to these amazing GAE colleagues worldwide:

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APPENDIX: RELATED ARTICLES

[A1] J. Tian, F. Wang, F. Zhuo, and H. Deng, “A full-power-range optimization scheme under double-side asymmetrical phase-shift modulation in DAB-based distributed energy storage system,” *IEEE J. Emerg. Sel. Topics Power Electron.*, vol. 12, no. 2, pp. 1192–1202, Apr. 2024.

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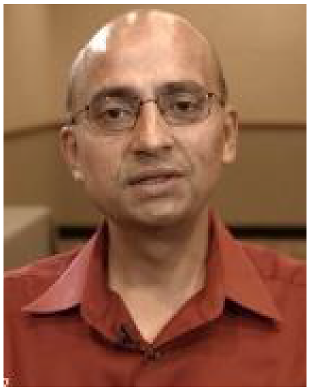

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