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Editorial

Special Issue "Advanced DC-DC Power Converters and Switching Converters"

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1. Introduction

Nowadays, power electronics is an enabling technology in the energy conversion development scenario. Furthermore, power electronics is strictly linked with several fields of technological growth, such as consumer electronics, IT and communications, electrical networks, utilities, industrial drives, robotics, transport system, and automotive. Moreover, the widespread use of power electronics enables cost savings and minimization of losses in several technology applications required for sustainable economic growth. The topologies of DC-DC power converters and switching converters are under continuous development and deserve special attention to highlight the advantages for use increasingly oriented towards green and sustainable development.

DC-DC converter topologies are developed to achieve higher efficiency, reliable control switching strategies, and fault-tolerant configurations. Switching converter topologies are divided into isolated DC-DC converter and non-isolated DC-DC converter solutions operating in hard-switching and soft-switching conditions. Switching converters have applications in a broad range of power rate levels. The articles presented in the Special Issue titled "Advanced DC-DC Power Converters and Switching Converters" consolidate the work on the investigation of the switching converter topologies considering the technological advances offered by innovative wide-bandgap devices and performance optimization methods in control strategies. Furthermore, the use of passive components such as high-frequency isolation transformers is considered and deeper investigated.

The articles addressing switching converters follow the general trend topics of the power electronics applications and sustainable development such as:

- New switching converter topologies;
- Control and optimization of switching converter circuits;
- Innovative power devices in switching converter applications;
- Modelling of Advanced DC-DC and common switching converters;
- Switching converters in smart grid applications and energy transmission systems;
- Advanced switching converters for renewable energy conversion;
- Innovative DC-DC converters for energy storage systems;
- Switching converters in automotive and traction systems.

From an overview of the articles presented, the issues of the role of converters in the generation of renewable energy and optimization in smart electricity grids, together with the problems of recharging batteries for both microgrid energy storage systems, as well as in electric traction are predominant.

In the paper contributions, arise also the key role of new wide-band-gap semiconductor devices in the advanced circuital topologies, that allow a significant impact on improving the power converters' energy efficiency.

Therefore, the topics covered in the articles described in the following section lead toward the development of power electronic switching converters more and more efficiently, with reduced volume and acceptable costs for sustainable growth, in several areas of energy conversion, and storage, as well as of the electrical power systems.

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2. Overview of the Contributions

The various topics-addressed by the articles included in this special issue-reflect some of the current trends in place in the power electronics field. By narrowing the field to better classify the articles presented, they can be framed in the following three main application topics:

- Renewable Energy conversion;
- Microgrid system and energy storage applications;
- Automotive and sustainable transport areas.

Some papers cover two of the above main topics considered. This shows how switching converters are fundamental building bricks for the development of these technological areas belonging to the evolution of electrical energy conversion.

The next subsections describe and specify the role of every article in advancing the state of the art concerning the corresponding topic.

2.1. Renewable Energy Conversion

In the field of renewable energy solar photovoltaic (PV) systems and energy conversion technologies lead to wide research opportunities in green energy source use.

In the first paper, "Interleaved High Step-Up DC-DC Converter with Voltage-Lift and Voltage-Stack Techniques for Photovoltaic Systems" [1], the authors (Shin-Ju Chen et al.) describes an innovative topology of an interleaved high step-up DC-DC converter for applications in PV generation systems. The topology configuration is composed of three-winding coupled inductors, voltage multiplier cells, and a clamp circuit. The operation conditions in steady-state conditions are presented and critically described. The advance and drawbacks of the proposed converter solution are focused on the PV application. Furthermore, a reduced scale of an actual converter prototype (1kW of the power rate) is presented to evaluate experimentally the operation and the effectiveness of the proposed converter topology.

In the paper "Computationally Efficient Modeling of DC-DC Converters for PV Applications" by Fabio Corti et al. modeling of the PV system combined with the power converter is explored to allow a viable pre-design methodology with lowered computational effort. In the modeling approach described the one-diode model for photovoltaic (PV) devices is combined with the converter model according to the state-space formulation. Furthermore, an accurate steady-state detection methodology is developed [2]. Moreover, the modeling procedure is experimentally validated to demonstrate its accuracy and usefulness.

The third contribution described is the article titled, "Evaluation of a Three-Phase Bidirectional Isolated DC-DC Converter with Varying Transformer Configurations Using Phase-Shift Modulation and Burst-Mode Switching" by N.S. Mohd Sharifuddin et al. The paper describes a Three-Phase Bidirectional Isolated DC-DC Converter used mainly in solid-state transformers (SST). Several high-frequency transformer configurations in different power transfer conditions in continuous and intermittent switching have been investigated [3]. The topological structure of dual-active bridge (DAB) with Phase-Shift modulation, presented, can be included in all three macro-areas of the application fields. The Three-Phase Bidirectional Isolated DC-DC Converter (3P-BIDC) is an advantageous high-efficiency and volume-reduced interface between renewable source generation systems with the power grid. Furthermore, the proposed 3P-BIDC converter is usefully applicable for energy storage applications in renewable energy systems.

2.2. Microgrid System and Energy Storage Applications

Microgrids and energy storage systems are increasingly receiving considerable attention and interest due to their profitable characteristics for modern power systems with the possibility of operating both in grid-connected mode and in a stand-alone mode. In this wide and rapidly growing area of energy conversion, the development of power devices and converter topologies is increasing the quality and quantity of applications. In the first contribution on this topic, the article "A Multi-Input-Port Bidirectional DC/DC Converter for DC Microgrid Energy Storage System Applications", by Binxin Zhu et al. a bidirectional DC/DC converter with multi-input-port characteristics for the energy storage systems in DC microgrid is presented [4]. The converter topology solution is able to connect various energy storage batteries to the DC bus at the same time. The proposed converter system features the advantages of low switch voltage stress and high voltage conversion gain. In the paper contribution, a scaled two-input-port experimental prototype of low power rate (200 W) is tested to evaluate the correctness of the theoretical analysis of the described multi-port converter.

In continuity with the previous contribution, the article "From Non-Modular to Modular Concept of Bidirectional Buck/Boost Converter for Microgrid Applications" by Michal Frivaldsky et al. shows an extensive comparative study on DC/DC converters bidirectional buck/boost (bi-BB) of both modular (or multiport) and non-modular types [5]. Various aspects related to applications in microgrids are analyzed and compared. In addition, an in-depth characterization for SiC and GaN technology-based converters (modular low voltage GaN-based non-modular high voltage SiC-based dual-interleaved converter) is carried out. In the comparative study, the main factors are taken into consideration such as the efficiency, the overall volume of the system, the ripple of the output voltage, and the ripple of the input current, as well as the costs. These parameters characterize the quality and applicability of modern converters for microgrid systems.

Electronic power converters are beginning to replace many traditional electrical and electromagnetic devices such as power switches, transformers, and synchronous generators for power grid stabilization. As already described in the previous paragraph, DABs topologies with high-frequency transformers can be used in modern. SST arrangement. The SST compared with the traditional magnetic transformer operating at industrial frequency, furnished accessible DC buses, and is possible to adjust the AC ports voltages independently as reported in [3].

Furthermore, Virtual Synchronous Machines (VSM) is a developing topic to achieve a novel approach for emulating the inertia effect of traditional synchronous machines. In modern power systems, the advanced and emerging control techniques for grid-tied converters are addressed to investigate some regulation arrangements such as cascaded controllers (e.g., voltage and current) and virtual synchronous generators (VSGs). The VSG is a type of device in the broader group of VSM. In this emerging topic, in the article "State-Space Modeling Techniques of Emerging Grid-Connected Converters", by Fabio Mandrile et al. a survey of the requirements of power electronics modeling in power systems are carried out. In this deep investigation, the converter model is based on the Component Connection Method (CCM). The CCM procedure is explained in detail and is applied to achieve an accurate VSG model. The obtained model is validated experimentally to demonstrate the practical accuracy of such used approach [6].

2.3. Automotive and Sustainable Transport Areas

Electric vehicles are now a rapidly developing actual technological system in sustainable mobility. This technological evolution is an unavoidable and effective transition to green growth. Indeed, the electrification transition is permeating every transport sector such as the naval and aviation. In this section, the articles explore some topics on this wide innovative scenario. In the first paper, "SiC-MOSFET and Si-IGBT-Based dc-dc Interleaved Converters for EV Chargers: Approach for Efficiency Comparison with Minimum Switching Losses Based on Complete Parasitic Model-ing", the authors (Jelena Loncarski et al.) investigate the improvement aspect of power device technology in power converters devoted to the EV energy storage management, highlighting the impact on efficiency and dynamic characteristic. Silicon Car-bide advanced MOSFET (SiC-MOSFET) and pure Silicon (Si) IGBT performance is compared in interleaved DC-DC topology for the EV charging system. The analysis is carried out in a wide range of switching frequency and output inductances. The several benefits of SiC-MOSFET in the used converter on the wide test range considered are clearly demonstrated [7].

In the second paper, "A Tool for Evaluating the Performance of SiC-Based Bidirectional Battery Chargers for Automotive Applications", by Giuseppe Aiello et al. a procedure to simulate an electronic power converter for control design and optimization purposes in bidirectional battery chargers' application is proposed. The SiC-MOSFETs are used as switches in the power converter system [8].

The bidirectional battery chargers considered are composed of two power stages.

The first stage consists of a single-phase AC/DC power factor correction synchronous rectifier to connect the charger to the grid. The second stage is a phase shift DC/DC dual active bridge. The power converter presented is considered to manage bidirectional power flows.

The converter development based on a model-based simulation approach discussed in the paper is crucial to simplifying and making effective the different converter design phases for these strategic applications in the field of energy storage in automotive.

The third article, "Power Scalable Bi-Directional DC-DC Conversion Solutions for Future Aircraft Applications" focuses on an interesting topic concerning an innovative aspect of the use of electrification in-flight systems. The starting point for the investigation begins from the consideration that in future on-board energy distribution networks, the so-called high voltage DC power supplies (typically +/−270 V) will be introduced.

Future aircraft power distribution systems will most likely also include energy storage devices (possibly batteries) for emergency backup and engine starting. As a result, new DC-DC conversion solutions are needed, capable of interfacing the traditional low voltage (28V) DC bus with the new 270 V bus.

The authors, Antonio Lamantia et al. deal with the design and testing of bidirectional DC-DC converters to interconnect and manage the power transfer between the two bus levels, also allowing for the addition of energy storage devices. The converter design constraints depend on the need for reduced volume, high efficiency, and reliability as well as the requirement for a considerable degree of flexibility in the power transfer capabilities, and several numbers of inputs/outputs. Additionally, the paper investigates the use of advanced wide-band-gap (WBG) solid-state technology, particularly silicon carbide, for use as high-frequency switches within the bi-directional converter on the high-voltage side [9].

3. Conclusions

The collection of articles in this Special Issue provides indications on some directions of development of the current research in the field of advanced DC-DC power converters and switching converters. The electrical energy conversion for sustainable development is the fil rouge that links the nine articles. Three macro-areas are identified to collect the papers presented

- Renewable Energy conversion;
- Microgrid system and energy storage applications;
- Automotive and sustainable transport areas.

Energy conversion via switching converters plays a crucial role in the development of these necessary technological areas related to the growth of the human community.

In these progress scenarios, the articles contribute to offering a clear and competent point of view that allows the growth of new ideas to continue the tireless work of applied research, fundamental for technological development.

Finally, the analysis and results presented, while not exhaustive, move in the direction of a further step towards continuous improvement to which we are all called in our research work.

Each small research contribution acts in the growth of the quality of life for the well-being of present and especially future generations.

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