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Editorial: Modular power converters for renewable energy integration

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Editorial on the Research Topic
Modular power converters for renewable energy integration

Introduction

Modular design approach has drawn great attention lately in power electronics as the design of a single building block streamlines the capacity extension and assembly as well as improves efficiency and flexibility. Employment of wideband gap (WBG) devices in converters enables size reduction and efficiency improvement. Modular converters are featured in a wide range of applications, such as energy storage systems, electric vehicles (EVs) and renewable integration to power grids. However, complex integration among modular blocks in different applications instigates diverse problems, such as increased current harmonics, reduced efficiency, limited transmission capability and amplified ripples and oscillations. Such challenges can be addressed by optimizing the modular unit's architecture, device/topology design, or control.

This special issue is organized to introduce the latest research to fully exploit the modular converters' benefits by addressing the ongoing challenges. Total five papers are accepted in this special issue, including one state-of-the-art review and four original research articles. Accepted papers can be arranged into three sections based on a broader context and application. First section presents the survey of performance improvement methods for WBG devices. Second section outlines the articles on current harmonics and ripple mitigation techniques in modular converters. Third section is dedicated to the papers on the modular design of EV wireless chargers. The aims and contributions of the accepted articles are summarized in each section.

Survey of performance improvement methods for WBG devices

WBG devices are gaining popularity as they enable not only converter's size reduction but also enhance system efficiency. However, these advantages cannot be obtained simply by

superseding the silicon power devices with their WBG counterpart due to their high speed, oscillations and reliability issue. In addition, high-power WBG packages are expensive compared with Si ones. Paralleling of discrete packages (e.g., TO-247) is one of the solutions to achieve a cost-effective design, yet it suffers from unequal current sharing challenges among parallel devices. Tahir et al. presented the root causes of voltage oscillations and uneven current sharing issues along with reported state-of-the-art solutions and their comparison. The authors contributed by outlining the latest stray inductance extraction methods and providing key design guidelines, which may assist designers in achieving improved performance and cost-effective converter design.

Current harmonics and ripple mitigation in modular converters

When many modular units are deployed to attain high-power, the intricate interaction among the units may cause current harmonics, which deteriorates the life of passive components. Tahir et al. presented a profound resonance analysis for a back-to-back modular converter using a unit partition method, which can dictate the capacitor current harmonics suppression solutions. Their key contributions lie in introducing a resonance analysis method and a solution to depressing capacitor RMS current.

Likewise, to handle current ripples and the limited power capacity of resonant converters, an interleaving approach is used where multiple phases are interleaved in a modular fashion. WBG-based LLC converters are renowned for high efficiency, and interleaving is famous for ripple curtailment; however, it is challenging to achieve both advantages at the same time. To achieve both targets simultaneously, Wang et al. proposed an optimal control method to regulate the load distribution based on operating conditions. The proposed control method can achieve reduced ripple and high efficiency at high and medium loads. Yet, further research can be conducted to achieve similar results under light loading conditions.

Design and optimization of modular wireless charging units

Fast wireless charging is a research hotspot, and modularization is used to achieve the required high power. Nevertheless, many challenges exist in high-power wireless charging systems, such as unequal current sharing among parallel submodules, low efficiency, misalignment of primary and secondary coils, limited power transmission capability and uneven electromagnetic field distribution.

Aiming at uneven current sharing and misalignment issues, He et al. presented a design optimization for wireless charging. The authors featured a 30 kW charging system containing five identical 6.6 kW modules where one master module dictates the remaining four salve modules. The designed controller and collaborative working of all modules enabled improvement in current sharing and misalignment tolerance. The designed controller was validated with a 300 mm misalignment example.

The issues of uneven field distribution and limited power transfer ability are researched by Liu et al. They introduced an architecture with multiple transmitters and multiple receivers (MTMR). In MTMR, retrofitted capacitors decoupled the transmitting coils, their parameters were optimized using particle swarm optimization, and phase-shifting control realized current synchronizing. The proposed MTMR design showed equitable efficiency improvement over the conventional counterpart.

Conclusion

This special issue strived to collect recent research work and cutting-edge solutions for different challenges in modular power converters. The accepted survey article in this special issue can assist designers in using WBG devices better to maximize the system-level benefits. The remaining research articles aimed to resolve issues such as current ripple, low efficiency, complex resonance, and uneven current and electromagnetic field distribution when individual modular units are combined. The solutions and findings reported in this issue might facilitate engineers to optimize the modular converter design and may stimulate young researchers to develop innovative solutions.

Author contributions

SH: Structure, writing, reviewing, supervision and editing. MT: Draft preparation, structure, reviewing, investigation.

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