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*Editorial*

# Power Electronics Technologies and Applicationsfor EV Battery Charging Systems

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## 1. Introduction

Mainly throughout the last two decades, the technologies associated with electric vehicles (EVs) have achieved a pertinent interest, both in terms of scientific and industrial perspectives. In this context, it is highly anticipated that EVs will be fundamental in the transportation sector in the near future, offering a set of advantages, not only for the end-user but also in the perspective of the power grid interface (e.g., offering the possibility of operation modes for ancillary services). Moreover, it is expected that the widespread use of EVs will contribute to reducing air pollution, particularly in cities, and to reducing greenhouse gas emissions. This is specifically important if the electricity to charge the EVs is produced by renewable energy sources and even more relevant when considering the production near the consumption, optimizing the power transfer among systems (e.g., directly charging the EVs from renewables, without using the power grid as intermediary for the power transfer).

In addition, EVs are more efficient and require less maintenance compared to conventional vehicles with internal combustion engines, which are also important advantages in a global perspective of increasing efficiency and sustainability. Nevertheless, the success of the deployment of EVs around the world will be heavily dependent on their impact on electrical power systems and all the technologies associated (e.g., including optimized EV chargers, battery management systems, and battery technologies). To this end, the research and development of advanced power electronics technologies for EV battery charging systems is of paramount importance, aiming to make EVs a significant asset to the operation of future smart grids.

The main goal of this Special Issue was to focus on research and development in emerging power electronics technologies and applications for EV battery charging systems, where the topics of interest for publication included, but were not limited to, the following topics: (i) New topologies and control systems for unidirectional or bidirectional power converters applied to EV Battery Charging Systems (for Electric Vehicles in general, including heavy and light vehicles); (ii) EV Battery Charging Systems for slow charging and/or fast charging in single-phase AC, three-phase AC, and DC; (iii) Unified power electronics converters for Electric Vehicles with functions of the Electric Motor Drive and the Battery Charging Systems; (iv) Innovative operation modes for EV Battery Charging Systems framed with Smart Grids and Smart Homes: G2V (Grid-to-Vehicle), V2G (Vehicle-to-Grid), V2H (Vehicle-to-Home), V4G (Vehicle-for-Grid), V2V (Vehicle-to-Vehicle), etc.; (v) New topologies and/or control strategies for EV Battery Charging Systems with added power quality functionalities (e.g., compensation of current harmonics, reactive power, and current imbalance); (vi) Wireless Power Transfer (WPT) technologies for EV Battery Charging Systems; (vii) Optimization of the operation of EV Battery Charging Systems in the function of the Energy Storage System and operation modes (slow/fast and charging/discharging); (viii) Microgrid operations with EV Battery Charging Systems,



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Renewable Energy Generation, Energy Storage Systems, Controlled Loads, etc.; (ix) Optimized operation of groups of EV Battery Charging Systems in electrical installations; and (x) Operation management of EV Battery Charging Systems for supporting future Smart Grids in terms of Distributed Generation and Demand Response (aimed at “Peak Shaving” or “Load Levelling” concepts).

Considering the addressed topics and the quality of the submitted contributions to this Special Issue, it is possible to confirm an interdisciplinary approach about topics of EV battery charging systems, which is widespread among scientists and scholars. The final papers published cover a broad range of thematic areas, including topics such as: analytic hierarchy processes; battery balancing; battery management systems; boost converter; charge scheduling; decision making; distribution networks; electric vehicles; genetic algorithms; grid-to-vehicle; interleaved PFC converters; Laplace circuit models; lithium-ion batteries; modular battery management systems; onboard chargers (OBC); parasitic elements; particle swarm optimization; phase-shift full bridge converters; smart battery packs; temperature protection; totem-pole bridgeless; transactive energy; unified power converters; field-oriented controls; model predictive controls; vehicle-to-grid; and wide power range electric vehicles.

Section 2 presents a short review of the papers published in this Special Issue, highlighting the main contributions and achievements of each paper, while Section 3 presents their main conclusions.

## 2. Contributions for this Special Issue: A Short Review

A dispersed strategy about scheduling the EV charging with transactive energy controlling is presented in [1], aiming to manage technical issues of the operation in distribution power grids, as well as to examine the economic gains of EV charging. In this paper a distributed algorithm is offered for solving the EV charging problem with transactive energy management, including the perspectives at an individual EV level, at the node level, and at the distribution network level. The clearing electricity price is attained by a negotiation method among the distribution system operator and the EV aggregator. The EV charging scheduling was validated on an IEEE 33-bus distribution power grid.

A modular battery management system for an electric motorcycle is proposed in [2], where, other than the precise measurement of the battery voltage, current, and temperature, the proposed system can also communicate the measured data to a mixed-signal processor, with the purpose of offering full battery monitoring. Additionally, it also offers the possibility of battery balancing and protection, both during the charging and discharging processes. The obtained results validate all these functionalities, namely, those related to monitoring and protection.

A unified system for EV, including the motor drive system and the battery charging system, is proposed in [3]. This unified system is proposed due to the similarities between the power converters of both systems, since they are not used simultaneously. Therefore, by using a single unified system, the cost, volume, and weight of the power electronics are reduced, thus also making possible a reduction in the final price of the EV. Additionally, as demonstrated, the proposed unified system permits bidirectional power flow, operation in grid-to-vehicle (G2V) mode, and vehicle-to-grid (V2G) mode, both during slow or fast battery charging. Computer simulations and experimental results are presented to prove the advantages of the proposed unified system, including all the functionalities.

A modified power factor correction with an on/off control and with a 3D printed circuit board design is proposed in [4], targeting the application of a high-efficiency, high-power density EV onboard charger. By considering the adopted strategy, the proposed PFC control can diminish the load-independent power loss. Therefore, it is possible to have onboard charging with high efficiency across a wide output power range. The validation was carried-out with a developed 3.3 kW prototype based on an interleaved totem-pole bridgeless boost power factor correction converter and a full-bridge, showing a full power efficiency of 98.2% and a 52 W/in$^3$ power density.

A framework for the smart EV charging process is proposed in [5] towards addressing a framework that offers flexibility in the definition of the decision-making objectives, including the user-defined criteria. The presented framework consists of a heuristic algorithm that enables EV charging scheduling and an analytic hierarchy process to assist the EV drivers for choosing the most suitable charging station, according to their needs of transportation, as well as their personal preferences. The communications are established based on the open platform communications-unified architecture standard. A genetic algorithm and a particle swarm optimization were evaluated, proving the advantages of the particle swarm optimization for this scenario.

A phase-shift full-bridge converter is studied in [6], considering the continuous conduction mode during one switching cycle for both the leading and lagging legs of the primary bridge. The key goal consists of evaluating how the converter functionality is affected due to the stray capacitance of the transformer and the capacitances of the diodes in the bridge rectifier. The validation was performed with computer simulations and experimental results, where Laplace equivalent circuit models and equations are shown for every important time interval.

The concept of a smart battery pack is proposed in [7], which is based on wireless feedback from individual battery cells and has as its main purpose the application in EVs. By adopting the proposed strategy, combining the battery management system and the battery pack, it is possible to increases the usable capacity of the battery, as well as to prolong the life cycle. The proposed hardware structure permits balancing the batteries during both the charging and discharging processes and enables the fault-tolerant operation. With the proposed strategy, it is possible to reduce the need for cabling and, therefore, simplifying the assembly. The validation was carried out through simulations and experimental results.

A review about battery equalizer circuits, specifically used in EV applications, is offered in [8]. This review has particular importance, since the bottleneck for EVs is the high-voltage battery pack, and nowadays, a key challenge in industrial electronics is related to cell equalization. The paper presents numerous simulations considering the main battery equalizer circuits, where the achieved results were utilized to achieve a quantitative assessment among such circuits. Additionally, issues, challenges, and key parameters linked to battery equalizer circuits are also highlighted and relevant suggestions for future investigations are provided.

## 3. Conclusions

The importance of the scope of this Special Issue, "Power Electronics Technologies and Applications for EV Battery Charging Systems", was demonstrated along this document, where, particularly, it was contextualized with other relevant and emerging paradigms toward smart grids. Additionally, the topics covered by this Special Issue were presented with more details. A brief perspective of the guest editors of this Special Issue was also presented, showing the relevance of the main topics, which is reflected both in the quantity and quality of the submitted and final accepted contributions. More in detail, a short description about the contributions for this Special Issue was also presented.

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