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Editorial

Electric Vehicle Efficient Power and Propulsion Systems

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1. Introduction

Vehicle electrification is one of the main growing trends with an identified growth capacity of 15% until 2030. In the coming years, many internal combustion engine vehicles, hybrid vehicles and all-electric vehicles will be on the road as consumers switch to more efficient and environmentally friendly propulsion systems. To remain competitive in this electrically powered future, carmakers and researchers are investing in a wide range of propulsion technologies to increase efficiency and power capacity, developing the next generation of powertrains. The development of more efficient pure EVs, HEVs and fuel cell electric vehicles (FCEV) presents both a challenge and a definite solution to current mobility issues. A reliable EV solution should therefore harness the advantages of more efficient and powerful energy storage systems from multiple sources through their effective management and new and improved power converters, including the new generation of switching devices, and explore advanced configurations for electric motors, reducing the use of rare-earth materials.

This Special Issue entitled "Electric Vehicle Efficient Power and Propulsion Systems" was established to encourage researchers working in this field to share the latest developments on electric vehicle efficient power and propulsion systems for road, rail and air vehicles, both manned and unmanned. Therefore, this Special Issue aims to provide recent developments in any field of electric vehicle efficiency powertrains, covering a wide range of scientific topics, including, but not limited to, the following:

- Energy storage systems;
- Power Electronics;
- Electric machines;
- Energy management systems.

The Guest Editors are Prof. João Pedro F. Trovão and Minh C. Ta (University of Sherbrooke, Sherbrooke, QC, Canada). Each paper was reviewed by three independent reviewers from countries differing from each author's country of origin. In order to ensure the highest quality, only 11 submissions were accepted for inclusion in this Special Issue of *Energies*.

2. Special Issue Content

In total, 11 papers relating to electric vehicle efficiency powertrains have been accepted and published in this Special Issue. This subject encompasses a wide range of topics, as illustrated by the diversity of the accepted papers: four papers were selected on energy management algorithms and topologies, four on wheel-drives control development, transmission, and validation, two on Lithium-ion batteries and one on SiC-inverter efficiency. All four of these topics are addressed in this Special Issue.

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In the first sub-topic "Energy storage Systems" we received two papers. First, Barreras, J.V. et al. [1] present novel research on the distributed multi-objective control algorithm, which is based on a multi-agent consensus algorithm. The authors implemented and validated the control in simulations, considering an electro-thermal lithium-ion battery model and an electric vehicle model parameterized with experimental data. The results show that the proposed multi-functional balancing can enhance the performance of batteries with substantial cell-to-cell differences under the most demanding operating conditions. The second paper in this sub-topic focuses on state-of-charge (SOC) as a fundamental indicator of lithium-ion batteries, which has an important role in the battery's optimized operation. Ouyang, Q. et al. [2] propose an adaptive square-root unscented Kalman filter (SRUKF) to estimate the battery's SOC. The effectiveness of the estimation technique is demonstrated by their extensive experimental results, which show higher precision compared with other commonly used Kalman filter-based methods.

For the second subtopic "Power Electronics", one contribution was received focusing on wide-bandgap (WBG) power semiconductors. Recent research on WBG power semiconductor devices such as silicon carbide (SiC) and gallium nitride (GaN) have attracted significant attention, since the increase in inverter switching frequency contributes to the decrease in switching power loss. In paper [3], Ryu, J.-H. et al. investigate a method for switching the frequency determination of a SiC-inverter to improve the efficiency of the railway propulsion system. The hybrid switching method combined with the synchronous PWM and asynchronous PWM was considered in the analysis of the SiC inverter that feeds a PMSM. The efficiency curve of the propulsion system as a function of the switching frequency demonstrated the potential to serve as a guideline for switching frequency selection.

For the third subtopic "Electric machines", three papers focus on electric machines for traction/motion control, and one paper on the co-design technique of a continuously variable transmission (CVT) for EVs. Vo-Duy, T. et al. present an experimental platform for the evaluation of on-board real-time motion controllers for EVs [4], providing a good example of the hardware-in-the-loop (HiL) system, on which the most important vehicle dynamics, including longitudinal, lateral, yaw, kinematic, and position models, have been built and validated in various testing scenarios. The proposed HiL system can be employed for research on various topics of EV control. Paper [5] demonstrates an alternative point of view, using multi-agent-system theory. Nguyen, B.-M. et al. propose three different ways of modeling in-wheel-motor (IWMs) vehicles: a nonlinear model with a hierarchical structure for passivity-based motion control, a linearized model with a rank-1 interconnection matrix for stability analysis, and a time-varying state-space model for optimal control, using a linear quadratic regulator (LQR). The effectiveness of the three models and their design approaches are discussed in several examples with a Matlab/Carsim co-simulator. Additionally, paper [6] addresses the multi-motor configuration and control of EVs. De Pinto, S. et al. provide a comparison between 2-wheel-drive (2WD) and 4WD configurations for the same EV from the viewpoint of drivability and energy consumption. An optimization routine is used to calculate the energy-efficient gear state and/or torque distribution for each considered configuration. The results highlight that the single-speed 4WD layout can reduce the energy consumption during driving cycles by approximately 9% compared to the conventional 2WD layout with single-speed transmission. Finally, Wei, C. et al. consider the co-design of a continuously variable transmission (CVT) for EVs. In paper [7], a novel convex programming (CP)-based co-design method is proposed to minimize the total-cost-of-ownership (TCO). The strength of the co-design is highlighted in comparison with a sequential design, and insights into the design of a low-power EV that is energy-efficient and cost-effective for urban driving are provided. A highly integrated EM-CVT system, which is efficient, low-cost, and lightweight, can be expected for future EV applications.

The effective utilization of energy storage systems is still a critical issue in electrified vehicles. The subtopic of "Energy management systems" attracted four papers in this Special Issue [8–11]. First, Maddumage, W. et al. propose a design methodology for a rule-based supervisory controller of a pre-transmission parallel hybrid three-wheeler based on the optimal control strategy, i.e., dynamic programming (DP). The developed rule-based strategy shows performance within 10% of the DP results on WLTC and UDC-NEDC drive cycles and has the advantage of being near-optimal, easy-to-implement and computationally less demanding. Nguyễn, B.-H. et al. propose a novel real-time optimization-based torque distribution strategy for a parallel hybrid truck in [9]. The strategy aims to minimize the engine fuel consumption while ensuring battery charge-sustaining by using linear quadratic regulation in a closed-loop control scheme. By reformulating the problem, the obtained strategy does not require the information of the engine efficiency map like the previous studies in the literature. The proposed method has been evaluated via simulation in comparison with dynamic programming as a benchmark, and experimentally validated by using a power hardware-in-the-loop simulator. Additionally, Ghobadpour, A. et al. present the design of an energy management strategy (EMS) for an industrial hybrid self-guided vehicle (SGV), considering the size of a fuel cell (FC) stack and the degradation of a battery pack [10]. In the paper, a realistic energy model of the SGV was first proposed and validated, based on experiments. The performance of the developed FC/battery SGV powertrain was then validated under three EMS modes. Each mode was studied by considering four different FC sizes and three battery degradation levels. The results showed several important remarks, such that a small FC as a range extender is recommended to reduce system costs. Battery SOC must be kept at a high level during SGV operation to support the FC during SGV acceleration. Finally, EVs to replace fossil-fueled vehicles in logistics applications are studied in [11] by Wang, L. et al. The authors propose a system to manage energy and to schedule the vehicle route, which comprises two parts: (i) a case-based reasoning subsystem to forecast the energy consumption and travel time for each route section, and (ii) a genetic algorithm to optimize vehicle routing with an energy consumption situation as a new constraint. A dynamic adjustment algorithm is also adopted to achieve a rapid response to accidents in which the vehicles might be involved. Simulation study, validations on Solomon benchmarks, and result analysis have been performed to show that the proposed vehicle management system is more economical than the traditional method.

3. Closing Remarks and Future Challenges

The articles presented in this Special Issue cover important aspects of electric vehicle efficiency powertrains. With the wide range of topics covered in the selected papers, the contributions to this Special Issue can stimulate the EV community to undertake further research concerning more efficient EVs. Therefore, we believe that the presented papers will have practical importance for forthcoming developments in the automotive industries. The contributions included in this Special Issue offer new data, information, and findings to continue the R&D effort in the field, with the aim of stimulating the research community to further contribute to the development of the field.

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