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Editorial

Design, Analysis and Optimization of Electrical Machines and Drives for Electric Vehicles

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1. Introduction

Electrical machines are the key components in the ongoing energy transition and electrification and will be an integral part of people's lives in a future low-carbon society. Existing statistical data and estimations show that electric motors consume over 45% of the world's electricity, and the number of motors will double by 2040. It is, therefore, implausible to achieve sustainable development goals without bringing improvements to the electrical machines sector. Improving electrical machine designs, especially for electric vehicle (EV) applications, to achieve optimized performance can contribute significantly toward a sustainable, greener world.

This Special Issue, entitled "Design, Analysis, and Optimization of Electrical Machines and Drives for Electric Vehicles", was proposed to showcase the latest developments from researchers working in the field of electrical machines and drives for EV applications. The topics of interest included the following:

- Design, analysis, and applications of electrical machines;
- Optimization of algorithms;
- Control techniques;
- Machine fault detection and fault-tolerant control;
- Motor drive systems;
- Modeling and performance evaluation of electrical machines and drives;
- Power electronic converter topologies for motor drives.

A total of 12 papers (including 1 review paper) were published. A brief overview of these papers is provided in Section 2.

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2. Overview of Contribution

In [1], the design and performance analysis of a super-high-speed flywheel rotor for electric vehicles are presented. In this study, the authors designed electric flywheel energy and power density parameters based on CPE (Continuous Power Energy) function and vehicle dynamics. Then, according to the design index requirements, the structure, size, and material of the electric flywheel rotor were designed. In [2], the authors focused on the performance analysis, modeling, and control of permanent magnet synchronous generator (PMSG)-based wind energy conversion. In this work, the authors analyzed the controllers for a machine-side converter (MSC) and a grid-side converter (GSC) and presented a new direct torque control (DTC) scheme based on a 12-sector polygonal DTC for variable speed control of the PMSG. A comparative study that included an investigation of the performance of a BLDC drive in both steady-state and transient operations is presented in [3]. Qualitative and quantitative analyses were performed on the results obtained with each control scheme in this study. These analyses indicated the superiority of a direct power control scheme using an FCS-MPC approach over other approaches in terms of minimum torque ripple; lowest torque and speed pulsations; minimum active and reactive power ripples; and high-quality waveforms of the stator currents drawn by the motor with minimum THD. In [4], a novel and robust algorithm for an interior permanent magnet synchronous motor controller was proposed. The main contribution of this work is its simplified approach of integrating all electric motor parameters into one 3D lookup table to obtain maximum performance on each operating point of the motor in the whole range of its operation. An ant colony optimization (ACO) algorithm was proposed in [5] to adjust the PID controller gains of a DTC control to control a doubly fed induction motor (DFIM), using a combined weighting cost function, to obtain efficient torque and speed control. This study presented a new hybrid structure resulting from the intelligent ACO-DTC control implemented on MATLAB-Simulink. In [6], the authors proposed a multi-objective optimization method for tractor drive motors based on an improved non-dominated sorting genetic algorithm II (NSGA-II). The constraints were formulated according to the inherent characteristics of the motor itself and the characteristics of the tractor's working conditions. The objective function was established with the heat loss of the drive motor and the total efficiency of the drive system. A capacitor voltage offset suppression method based on reference voltage self-correction for a three-phase four-switch (TPFS) inverter-fed permanent magnet synchronous motor (PMSM) drive system to improve motor control performance was proposed in [7]. In this method, firstly, the αβ-axis reference voltage deviation caused by the capacitor voltage offset was analyzed, and the relationship between the voltage to be compensated and the offset was obtained. Then, the capacitor voltage offset was calculated according to the motor speed, rotor position, current vector amplitude, and capacitance on the capacitor bridge arm of the TPFS inverter. Finally, the reference voltage was corrected according to the voltage to be compensated and the capacitor voltage offset. This method proved to be simple and easy to implement, and there was no need to add voltage sensors or filters in the system to extract the capacitor voltage offset; thus, there was no complex parameter adjustment. The effectiveness of this method was verified via experiments using a 20 kW interior permanent magnet synchronous motor. In [8], a novel brushless synchronous machine topology that utilized stator sub-harmonic magnetomotive force (MMF) for desirable brushless operation was proposed. The sub-harmonic MMF component that was used in this topology was one-fourth of the fundamental MMF component, whereas, in previous practices, it was half. To achieve brushless operation, the machine used a unique stator winding configuration of two sets of balanced 3-phase winding wound in three layers. For the rotor, additional winding was placed to induce the sub-harmonic component to achieve brushless excitation. A new dynamic coupling drive system of three axis-double working modes based on the Simpson planetary gear train was proposed in [9]. In this study, an optimization design method based on an improved simulated annealing (I-SA) algorithm for new system parameter matching and working mode switching strategy determination was discussed. In [10], a new scheme for a brushless wound rotor synchronous machine (WRSM) by generating an additional, two-pole component of magneto-motive force (MMF) with a series-connected additional three-phase winding and armature three-phase winding was proposed. Unlike previous brushless excitation schemes, which use an inverter to inject harmonic currents in the stator windings, the proposed scheme uses a series-connected additional winding on the stator with an armature winding in a two-pole configuration. Consequently, as current flows in the armature winding, it creates a fundamental rotating air gap flux to interact with the field flux. At the same time, additional rotating flux is created from the additional three-phase winding, which cannot synchronize with the field winding. This additional flux can cause the induction of a voltage in a winding with the same number of poles. For this purpose, a harmonic winding was installed in the rotor, along with the field winding connected through a diode bridge rectifier, to feed direct current (DC) to the field winding for rotor excitation without an input current from the brush–slip–ring assembly. The 2D finite element analysis (FEA) was performed to validate the brushless operation of the proposed machine system. In [11], the back electromotive force (EMF) waveforms of a flux-switching permanent magnet (FSPM) machine and a variable flux memory permanent magnet (VFMPM) machine with the same main dimension were researched. The simulation results showed that the maximum amplitude of the phase back EMF waveform of the FSPM machine was 245% larger than that of the VFMPM machine, and this was verified by the experimental results (243%). Secondly, the phase back EMF harmonics of the FSPM machine and the VFMPM machine were compared, including the enhanced flux condition and weakened flux condition of the VFMPM machine. Finally, the mutual demagnetization effect, which led to the difference in amplitudes of the maximum back EMF waveform between the FSPM machine and the VFMPM machine was analyzed. The comparison and analysis of the back EMF waveform can provide qualitative advice for future research on the application of the FSPM machine and VFMPM machine, such as application selection, optimization control method, and so on. In [12], additive manufacturing (AM) for electromobility is comprehensively reviewed. In this review, the intersections of AM and electromobility are illuminated, showing which solutions and visions are already available for different vehicle types on the market and which solutions are being scientifically researched. Furthermore, potential and existing deficits of AM in the field of electromobility are discussed. Lastly, new and innovative solutions are presented and classified according to their advantages and disadvantages.

3. Conclusions

This Special Issue covers different aspects of the design, analysis, and optimization of electrical machines. We believe that this Special Issue will open new avenues of research methodologies and innovativeness for researchers working in the field of electrical machines and drives.

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