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Editorial

Data-Driven Methods for Design and Analysis of Electromagnetic Devices

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Electromagnetic devices, such as electrical drive systems for electric vehicles, have been widely employed in domestic and industrial equipment. In the context of Industry 4.0, their analysis methods are experiencing significant progress and innovation due to integrating industrial big data. Researchers have explored data-driven approaches for various electromagnetic devices and systems to facilitate this progress. These include modelling, design, optimisation, condition monitoring, and reliability and robustness evaluation. One such approach is the data-driven design optimisation method in permanent magnet motors for electric vehicles. Additionally, data-driven fault diagnosis methods have been developed for wind power generators. These new models and analysis methods will benefit the development of digital twins for electromagnetic devices.

This Special Issue aims to present a collection of scientific manuscripts covering the theoretical and practical aspects associated with data-driven methods for designing and analysing electromagnetic devices and systems. A total of ten research articles are presented.

Wu et al. [1] proposed a physics-informed generative adversarial network (PIGAN) and a permanent magnet linear synchronous motor (PMLSM)-based magnetic field dataset for fast magnetic field estimation. In the training process, physics-informed loss functions were utilised, resulting in the output governed by Maxwell's equation. Different slot-pole combinations of the PMLSM were involved in the dataset to extend the generalisation of PIGAN. The effectiveness of the physics-informed method was verified by comparing the magnetic field approximation results and the performance analysis results of the PMLSM with those of the finite element method (FEM), and the speed of PIGAN is approximately 40 times faster than that of FEM while maintaining similar accuracy.

Raia et al. [2] introduced geometric parametric models to evaluate the multi-physical performances of electrical machines and built a machine-learning model that can predict the multi-physical characteristics of electrical machines from input geometrical parameters. Three individual machine-learning models were built based on the data obtained from 2D/3D motor parametric models: a model for the torque and back electromotive force harmonic orders, a model for motor losses, and a model for natural frequencies of the mode shapes. Finally, the developed multi-attribute model was integrated into an optimisation routine to compare the computational time with the classical finite element analysis (FEA) optimisation approach.

Huang et al. [3] investigated the effect of the alternate flux bridge combining Halbach array in permanent magnet vernier machines. It is found that the new design can provide a flux path for low-order harmonics and effectively improve the torque density of the machine. Through FEA and experimental verification, the torque density of the proposed design reaches 40.11 KNm/m^3, significantly higher than its existing counterparts.

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Mendizabal et al. [4] proposed a global sensitivity analysis procedure (based on the Monte Carlo method) that identifies the most influential design parameters and determines guidelines to reduce the vibration of permanent magnet synchronous motors. The proposed sensitivity analysis method was performed for a particular electric motor design. Some general design guidelines are deduced, which can be extrapolated to similar machines.

Du et al. [5] investigated a multi-objective optimisation process for an outer rotor low-speed permanent magnet motor (LSPMM) by considering efficiency, thermal load, and copper loss. Compared with the initial scheme, the optimised scheme improves efficiency and reduces the temperature. The optimised motor design scheme was verified by experimentation on a 22 kW prototype, which can provide a reference for the multi-objective optimisation of LSPMMs by comprehensively considering the electromagnetic performance and temperature.

Du et al. [6] compared temperature characteristics considering magnetic load and current density for an outer rotor LSPMM. Four schemes were proposed, and the loss and temperature characteristics of the four schemes under rated load were also compared to obtain the comprehensive effects of magnetic load and current density on temperature. A prototype was built and tested to verify the feasibility of the conclusions. This paper can help researchers to choose a better optimisation scheme to achieve good temperature performance.

Du et al. [7] conducted a comprehensive comparative study for four types of electrical machines, i.e., induction motors, synchronous reluctance motors, ferrite-assisted synchronous reluctance motors, and interior permanent magnet motors, regarding electromagnetic performance, material cost, and temperature distribution. It has been found that the electromagnetic performance, heat dissipation, and cost requirements of the four motors are different for different applications. Therefore, this paper provides a reference for selecting motors for different applications.

Gurusamy et al. [8] designed and simulated a small-sized electromagnetic generator as a biomechanical energy harvester to produce more power by using the knee angle transition during the walking phase as the input rotary force. The proposed generator design was investigated through COMSOL Multiphysics simulation. The achieved output RMS power ranged from 3.31 to 14.95 W.

Chen et al. [9] presented an alternative non-cascade sliding mode control (SMC) strategy based on the singular perturbation approach to drive surface-mounted permanent magnet synchronous motors (SPMSMs). A composite sliding mode surface was constructed using the Lyapunov equation to ensure stability. A novel tracking-differentiator-based SMC strategy was synthesised by incorporating a nonlinear function. The experimental results of an SPMSM servo system verified the advantages of the proposed approaches.

Li et al. [10] conducted a comparative study on four 19 kW 160,000 rpm high-speed permanent magnet synchronous machines (HSPMSMs) for the air compressors of fuel cell electric vehicles. The motors were compared in terms of electromagnetic, mechanical, rotor dynamics, and thermal performance. The electromagnetic and mechanical performance of these HSPMSMs was obtained by using FEM. The temperature increase distributed on the HSPMSMs was also obtained to avoid demagnetisation of the permanent magnets.

Although submissions for this Special Issue have been closed, more in-depth research in the design optimisation of electromagnetic devices continues to address the challenges we face today, such as climate change and energy crises.

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