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Editorial

Energy Efficiency Improvement of Electric Machines without Rare-Earth Magnets

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Electric motors are one of the largest consumers of electricity and are responsible for 40–45% of the world's energy consumption. In some applications, this proportion is even higher. For example, in industry, electric motors are responsible for about 70% of electricity consumption. Therefore, reducing the energy consumption of electric motors is critical both in terms of saving limited fossil fuels and in terms of reducing the load on national electricity networks. In addition, reducing energy consumption is important in terms of mitigating the impact of human activities on the environment. It is known that the magnetic flux generated by a coil with current is proportional to the product of the area of the pole covered by the coil and the cross-section of the winding wire, that is, the linear dimensions of the coil to the fourth power. The flux created by a permanent magnet is proportional to its volume, that is, its linear dimensions to the third degree. For this reason, electrical machines with high-coercivity rare-earth permanent magnets are potentially the most compact and energy efficient. At the same time, the cost of rare earth magnets is high, they are supplied by only a few suppliers, the raw material extraction process for their manufacture is harmful to the environment and there are problems with disposal. This gives good motivation for developing electric machines without rare earth magnets [1–10].

This Special Issue aimed to gather new research publications on various topics related to improving the energy efficiency of electric machines without using rare-earth magnets. Ten articles have been published that cover various topics. In [1], it is shown that synchronous motors without permanent magnets can be an energy-efficient alternative to permanent magnet motors, as well as to conventional induction motors in widespread applications such as fixed-speed electrically driven pump units. The energy-efficiency indicators of a direct-on-line synchronous reluctance motor with a power rating of 4 kW are compared with a motor with rare-earth permanent magnets on the rotor, as well as with an IE3 energy efficiency class induction motor. For this analysis, the performance curves of the motors are interpolated based on experimental data. To consider the influence of the power factor of the motors with direct power supply from the grid, losses in the supply cable of the pumping station were also taken into account. It is shown that despite the increased losses in the supply cable due to a reduced power factor, the synchronous reluctance motor provides a significant energy-saving effect compared to the induction motor due to much higher motor efficiency. The permanent magnet motor provides slightly greater energy savings; however, unlike the synchronous reluctance motor, it has a long payback period due to its high cost associated with the use of expensive rare earth magnets. The study in [2] is devoted to increasing the energy efficiency of a solar water pump with an electric drive by optimizing the parameters of its PI controllers. The solar pump is a self-powering system that does not require power from the utility network. The considered electric drive uses an induction motor that does not have expensive permanent magnets.

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The control system uses DC link voltage and motor speed PI controllers. It is shown that, when tuning the PI controllers, the coyote optimization algorithm is more efficient in terms of computational costs and the final result than the widely used Ziegler–Nichols and trial error tuning algorithms. Paper [3] theoretically discusses the design of an axial flux induction motor without permanent magnets, the magnetic core of which is made of Soft Magnetic Composites (SMC), which simplifies its production. It is shown that such a motor can correspond to the IE3 energy efficiency class. It is also highlighted that rotor skew can provide low torque ripple for such a motor. In [4], the choice of the best flux reversal machine (FRM) configuration for a small wind generator with inexpensive ferrite magnets is discussed. A three-phase FRM design with six stator winding poles and eight rotor teeth with significantly reduced cogging torque and torque ripple is selected for this application based on comparative finite element analysis (FEA). In [5], manual optimization of the parameters of the rotor geometry of a synchronous reluctance motor without magnets with a direct start from the grid is carried out. As a result, a significant increase in efficiency and power factor is achieved. The results of testing the motor at the rated load are provided, verifying the theoretical results obtained. In [6], two winding layouts of a three-phase switched reluctance motor (SRM) with twelve stator teeth and eight rotor teeth are compared in terms of power loss and efficiency. It is shown that the winding with a short pitch provides a lower copper of loss than the winding with a full pitch. Comprehensive comparative experiments were carried out to verify the results obtained using FEA. In [7], various aspects of the development and manufacture of an electric motorcycle electric drive based on an SRM are discussed. The choice of SRM configuration for this application is discussed. It is shown that a three-phase SRM with six stator teeth and four rotor teeth shows the best performance for this application. The dynamic simulation of SRM as part of the drive of the electric vehicle is carried out. A method for determining the position of the rotor and its experimental implementation are discussed. The test results of the SRM under consideration on the test bench and as part of an electric motorcycle are also provided. In [8], a novel design of a linear flux switching motor (FSM) is proposed employing inexpensive ferrite magnets with a modular passive stator for railway transport. Optimization of the FSM parameters using a genetic algorithm was carried out. The results of the electromagnetic and thermal analysis are presented. The proposed design of the linear FSM has a high specific thrust and high efficiency and a wide range of velocity control. In [9], a novel FSM design without permanent magnets with an external rotor is proposed. The outer rotor is passive and has no windings. Due to the selected shape of the stator teeth, the proposed FSM has a reduced leakage flux, high power factor and low torque ripple. The FSM design is optimized using a genetic algorithm. The results of electromagnetic and thermal finite element analysis are presented. A theoretical comparison of the performance of the optimized FSM with several conventional wound rotor synchronous machines and FSM configurations is provided, which shows the superiority of the proposed solution in terms of efficiency and specific torque. In [10], for electric vehicles, a novel design of an SRM with twelve stator teeth and eight rotor teeth without permanent magnets is proposed. Unlike conventional SRMs, the proposed motor uses a hybrid winding excitation algorithm that provides increased specific torque. The results of FEA are confirmed by comprehensive experimental verification carried out at various speeds and torques of the motor. It is shown that the specific torque and efficiency of the proposed hybrid SRM are significantly higher than that of the conventional one.

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