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Editorial

The Performance of Induction Machines

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1. Introduction

Induction machines are one of the most important technical applications for both the industrial world and private use. Since they were invented (the achievements of Galileo Ferraris, Nikola Tesla, and Michal Doliwo-Dobrowolski), they have been widely used thanks to such features as reliability, durability, low price, high efficiency, and resistance to failure. Induction machines are used in different electrical drives and as generators.

The main objective of this Special Issue on "The Performance of Induction Machines" is to contribute to the development of induction machines in all areas of their applications.

2. A Short Review of the Contributions in This Special Issue

Eleven scientific papers were collected in this Special Issue [1–11]. These papers concern many aspects of the theory, design, control, optimization, supervision, and use of induction machines (IMs).

In [1], the authors present a review of IMs over the last 75 years. This paper cites many important articles describing the recent development of IM technology (e.g., [12]) and gives many valuable tips on the proper use and operation of IMs. The paper also contains many tips on the selection of appropriate materials for IM structures, windings, and insulation.

In [2], the thermal conductivity of soft magnetic materials in electric traction machines was studied and presented. Within this study, eight different soft magnetic materials were analyzed. An analytical approach was introduced to calculate the thermal conductivity of these materials. Temperature-dependent measurements of the electric resistivity were performed to obtain sufficient data for the analytical algorithm. Finally, an experimental approach was performed, and the thermal diffusivity, density, and specific heat capacity were determined. The accuracy study of all measurements shows good agreement for all materials. This is of great importance in all types of electrical machines; the selection of the appropriate soft magnetic material is a significant influencing factor on the overall efficiency of all drives.

In [3], a procedure for the accurate modeling of ring induction motors (RIMs) is proposed. This modeling was carried out based on the measured data for the torque-slip characteristic and using the equivalent circuit of the RIM. The use of the Monte Carlo method allowed for significant improvement in the modeling results in terms of both the torque-slip characteristic and extended Kloss equation of RIMs.

Different methods of IMs' optimization were summarized in [4]. The main purpose of this paper was to develop methods to reduce the computational effort in the design and optimization of IMs using the finite element method or analytical methods. For this, indirect machine models, such as the Response Surface Model, Kriging Model, or Artificial Neural Networks, have been proposed. With the help of the above algorithms, it is possible to optimally select the geometrical sizes of machines with a given structure. By means of appropriate analysis, the Response Surface Model seeks to relate a response of input variables that influence the output of the system. Kriging is able to exploit the spatial correlation of data in order to predict the shape of the objective function based only on limited information. These surrogate models replace the machine model and estimate

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the output parameters of the machine based on the input parameters. The optimization environment using the model and parameter selection procedures was applied to the design of a traction IM.

In [5], a procedure for the methodical selection of the most suitable model for design optimization is presented. The model selection based on the electromagnetic field calculation is presented. For this purpose, models of different value ranges and levels of detail were considered. The model selection approach was explained in detail and applied based on a coupled electromagnetic–thermal simulation of an exemplary IM. The results show that this model selection can be used to methodically determine the most suitable model in terms of its value range, level of detail, and computational effort for a given multiphysical problem.

The work in [6] deals with fault detection in IMs. This is a fundamental element of the electric power industry, manufacturing enterprise, and services; hence, considerable efforts have been carried out on developing reliable, low-cost procedures for fault diagnosis in IMs since the early detection of any failure may prevent the machine from suffering catastrophic damage. In this paper, a straightforward procedure was introduced for identifying and classifying faults in IMs working as motors. The proposed approach is based on the analysis of the startup transient current signal through the current signal homogeneity and fourth central moment (kurtosis) analysis. It was applied for training a feed-forward, backpropagation artificial neural network used as a classifier. From experimentally obtained results, it was demonstrated that the brought-in scheme attained high certainty in recognizing and discriminating among different IM conditions, i.e., a machine in good physical condition, a machine with one broken rotor bar, a machine with two broken rotor bars, a machine with damage on the bearing outer race, and a machine with an unbalanced mechanical load.

The next contribution [7] presents a predictive rotor field-oriented angle compensation approach for IM drives. The algorithm proposed here makes it possible to improve the traditionally used algorithms for controlling IMs, which are very sensitive to changes in the resistance and impedance of the machine circuit. Therefore, the d-axis and q-axis currents in the rotation reference frame are predicted based on the model and compared with the feedback current to correct the rotor field-oriented angle. A very similar predictive algorithm was used to control linear induction motors (LIMs) in urban transit applications, where the motors are usually required to operate at peak thrust and the main parameters responsible for the precise peak tracking (the rotor resistance and the mutual inductance) vary in a very wide range [13].

The field vector-oriented control is one of the most advanced and widely accepted methods used for the rotary machine torque control. It was first conceptualized by Blaschke [14]. Direct Torque Control is yet another vector control technique. It was introduced by Depenbrock [15] and Takahashi [16]. The control algorithms presented here, as well as other algorithms used to control IMs, are based on the above fundamental achievements, which belong to the canon of literature on IM control.

Garbiec and Jagiela [8] have presented a validated computational algorithm that enables the inclusion of the nonsinusoidal or asymmetrical voltage supply in the multi-harmonic field-circuit model of IM. The development of the strongly coupled multi-harmonic field model concept effectively accounted for the nonlinearity and asymmetry of the voltage supply in the calculation of the operating characteristics of a high-speed IM with a solid rotor in a steady-state complex-valued finite element modeling framework. The multi-harmonic field-circuit model may become an effective tool in the process of designing IMs, in particular for reducing losses due to higher harmonics of the magnetic field of various origins.

The next paper [9] presents an adaptable simulation of an IM with a downstream protection scheme. For this purpose, a special algorithm was proposed to implement both static and dynamic modeling of a three-phase IM due to possible faults and high-performance requirements. This algorithm has been tested against several conventional methods. It was observed that during the stable condition of the machinery, it prevented the occurrence of many serious faults. To simulate and examine the behavior of a three-phase IM, the Matlab-Simulink software was used. Many simulations were carried out to obtain realistic characteristics of the analyzed IM, such as torque-speed, efficiency-torque, etc.

Park, S.-U. et al. [10] have investigated the efficiency improvement of the slip frequency in LIMs. In their study, mathematical analysis was conducted for each factor that mutually affects the control of the train. On this basis, the magnitude of the normal force related to the safety of the train is limited. Operating efficiency was improved by varying the slip frequency according to the operating conditions of the train. This algorithm takes advantage of the fact that the generated normal force is a factor that destabilizes the levitation system of the train and is a potential safety problem due to train levitation failure. It also induces additional energy consumption in both the propulsion system and the levitation system, thereby reducing efficiency. The verification of the proposed method was proved through a comparative experiment for the Maglev Train running at Incheon International Airport.

The following paper [11] presents the theory and classification of LIMs. Fundamental achievements on LIMs and rotating IMs were studied here, and specific LIM problems are discussed. Many methods of LIMs' calculation, optimization, and control are identical (or very similar) to the methods applicable to rotating IMs. However, because of the differences between the LIM and the rotary machine, some unconventional analysis techniques and modeling methods have been developed. The electromagnetic calculations of the rotary motor are reasonably simple because of the motor's "infinite" character and the possibility of applying many simplifications, thus limiting the solution region and speeding up the calculations even further. This paper provides an overview of linear transportation systems—levitated, non-levitated, with synchronous motors, with induction motors, and with superconducting induction motors—and focuses on the application of a LIM as a major constituent of such systems. Thus, solutions to the following problems are presented there: the development of new analytical solutions and finite element methods for LIM evaluation [17]; self-developed LIM adaptive control methods [13]; LIM performance under voltage supply (non-symmetrical phase current values); method for the power loss evaluation in the LIM reaction rail [13,18]; the temperature rise prediction method of a traction LIM; and the discussion of the performance of the superconducting LIM (superconducting propulsion and levitation [19]). The addressed research topics have been chosen for their practical impact on the advancement of a LIM as the preferred urban transport propulsion motor [20].

The problems presented in the last two papers are based on the foundational achievements of authors such as Nasar and Boldea [21], Yamamura [22], and Tegopoulos and Kriezis [23], who laid the foundations for the development of LIMs, which are still relevant today.

3. Conclusions

The Special Issue, "The Performance of Induction Machines", highlights the variety of problems faced by designers and users of induction machines.

Some of the presented approaches, e.g., design, control, optimization, and fault detection in induction machines, may also be adapted and applied to other related applications of electrical machines. Therefore, the Guest Editor hopes that the collected papers may be inspiring for the readers, leading to the further development of new methods of designing and using modern, high-efficient electrical machines.

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