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EDITORIAL

SPECIAL SECTION

Recent advances in electromechanical energy conversion systems

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1. INTRODUCTION

The field of energy conversion systems is undergoing rapid developments, driven by global factors such as the energy crisis, environmental concerns, and the demand for improving living standards. As the need for efficient, sustainable, and reliable energy systems continues to grow, innovations in materials science, electrical engineering, and control systems play a crucial role in powering the future.

Research on electrical machines – and related topics such as control and drive systems – features prominently in publications, including those of IEEE and IET, as well as in major conferences, such as the International Conference on Electrical Machines (ICEM), which held its last edition in Politecnico di Torino in early September 2024. In response to these trends, and in an attempt to stimulate the development of research focused on key challenges of modern technology, the Bulletin of The Polish Academy of Sciences Technical Sciences is pleased to present this Special Section collecting publications from researchers active in the areas defined by the following topics:

- Theory, modeling, and simulation;
- New designs of electric machines;
- Design and optimization;
- Materials and manufacturing;
- Measurements, diagnostics, and monitoring;
- Special machines - piezoelectric and others;
- Mechatronic systems;
- Transformers, electromagnets, and induction chokes;
- Thermal and vibroacoustic phenomena;
- Electric machines in drive systems;
- Electric machines and transformers in electric power generation systems;
- Electromobility, hydrogen technologies, energy storage;
- Teaching electric machines.

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As a matter of fact, all these issues are regularly discussed at the International Symposium on Electric Machines (SME), the 56th edition of which took place at Gdańsk University of Technology, 25th-27th June 2024. Consequently, the guest editors of this Special Section issued a call for papers to the participants of the Symposium, although all researchers active in the fields relevant to the specified themes were welcome to submit manuscripts. From the many submitted contributions and after the reviewing process, eleven papers, covering important and current problems of electromechanical energy conversion systems and related fields, were selected.

2. ELECTRICAL MACHINES

The first five papers included in the Special Section relate directly to the analysis, performance improvement, and/or experimental studies of electrical machines. In "EMF signature analysis in a marine-type brushless synchronous generator for online fault detection" by Filip Kutt, Michał Michna, and Grzegorz Kostro, the authors investigate the application of the current signature analysis type approach for the online diagnosis of such a generator. They have developed a fault detection algorithm that allows the generator to be safely operated in remote marine-type conditions where low maintenance costs are a crucial aspect of the system operation.

In "Experimental studies on reducing permanent magnet losses through segmentation in a fractional slot PMSM motor with high power density", Jan Mikoś, Tomasz Wolnik, Tomasz Jarek, and Vítezslav Styskala present numerical simulations and experimental tests on reducing eddy current losses in permanent magnets by segmentation in a high-power fractional slot PMSM motor. It is acknowledged that the segmentation of magnets allows for a significant reduction in power losses. However, in the case of introducing circumferential segmentation the technological complexity is recognized as disproportionate to the benefits obtained.

The paper "Analysis of the impact of the method of manufacturing the rotor on the parameters of an AC IPM machine" by

Mariusz Korkosz, Adrian Młot, Elzbieta Sztajmec, and Karol Ryłło addresses the technological problems related to the production of a rotor with internal permanent magnets. This article proves that the combination of the method of minimizing the phenomenon of anisotropy of the magnetic sheets and the use of a pseudo-skew of the rotor offers benefits by reducing the pulsation of the electromagnetic torque. Moreover, the cogging torque is limited to a value allowing free manual rotation of the rotor.

The next manuscript deals with a multipole design of a switched reluctance motor (SRM). In "Study on properties of multipole switched reluctance motor designed for multichannel operation – single channel operation analysis", Mariusz Korkosz, Jan Prokop, Piotr Bogusz, and Piotr Zasowski develop a mathematical model of a three-phase MC SRM allowing them to predict static electromagnetic torque characteristics and self- and mutual inductance characteristics. The authors present selected laboratory test results, suggesting that the choice of channel configuration should be based on the acceptable level of machine vibration during emergency operation.

In the paper "Three-axis forces and torque sensor", Paweł Młotek, Piotr Mynarek, and Marcin Kowol describe research on a prototype of a multi-axis force and torque sensor dedicated to the support system of a telescopic camera crane arm. The article presents an innovative use of an optical displacement sensor to measure the forces and torques exerted by the operator of a camera jib on its handle.

3. RELATED TOPICS

3.1. Control of electrical drives

Control of electrical drives is also an area of continuous research, although the focus is usually on unique applications. Examples may be found in a few papers published in this Special Section. First, Daniel Wachowiak in "A flying start method for sensorless induction machine-based electric drives" deals with the problem of the re-start of the control system after power shutdown in the electrical drive system. The key issue here is that the system is expected to start again with the non-zero speed of the machine. The proposed method suggests an intermediate control strategy, which remains active before the main control algorithm can run correctly.

Algorithms for five-phase machines are also relevant to the key topics in this Special Section. Multi-phase machines attract interest as they offer lower torque ripples, better distribution of the power among phases in the machine and inverter, and what is most important, they show much higher fault tolerance. The manuscript "Slip compensation technique in five-phase induction motors drive system" by Krzysztof Blecharz, Roland Ryndzionek, Paul Gondran, and Imad Merzou is focused on a simpler case of the scalar V/f = const control. The authors propose to inject a third harmonic component into the five-phase system and find this method to be effective, especially in simulation and experiments. A much more advanced control algorithm is proposed and investigated in "Sensorless control with the multi-scalar transformation of five-phase IPMSM" by Deepak Vyas, Sahal Joy, Marcin Morawiec, Grzegorz Kostro, and Nirav Joshi. The unique feature is that nonlinear feedback is utilized to linearize the selected x-nonlinear variables and then obtain the final control signals for the five-phase inverter. Again, the authors validated the method via simulations and experiments demonstrating excellent dynamic performance while requiring less computation power.

3.2. E-mobility

Electromechanical systems are essential components of electromobility. However, other parts of the systems are also investigated by the authors contributing to this Special Section. The paper "Energy efficiency of supercapacitors in hybrid energy storage systems" by Mirosław Lewandowski, Marek Orzyłowski, and Tadeusz Maciołek deals with issues of a key component of the energy storage system, namely the supercapacitors. These components are highly appreciated due to their ability to deliver significant peak currents; however, energy density is much lower than in electrochemical batteries. Thus, this work focused on a precise determination of energy stored in the supercapacitors can be considered as an important contribution.

In the paper "Processing and analysis of trolleybus traction data using LINQ technology" by Jacek Skibicki, Andrzej Wilk, Mikołaj Bartłomiejczyk, Leszek Jarzebowicz, Dariusz Karkosiński, Łukasz Hupka, Jan Hupka, Paweł Kaczmarek, and Natalia Karkosińska-Brzozowska, the authors perform a study of the data collected from a trolleybus using a Language-Integrated Query technique. This work provides a number of interesting observations from real-life cases of trolleybuses, the publication of which may lead to better management of the on-board batteries using advanced digital techniques.

3.3. Power electronics for electrical machines

Finally, the Special Section contains compelling work on electronic power converters for the electrical machines. In "Multilevel voltage source inverter with coupled reactors using coarsely quantized pulse amplitude modulation", Krzysztof Szwarc, Artur Cichowski, Paweł Szczepankowski, Janusz Nieznański, and Ryszard Strzelecki present research on unique converter operation without the use of pulse width modulation techniques. Thanks to the applied coupled inductors, the output voltage shows an extremely low number of high-order harmonics and can be utilized to supply high-speed machines.

4. CONCLUSIONS

The concept of this Special Section was born during the last, LVI Symposium on Electrical Machines (SME 2024) organized by the team from Gdańsk University of Technology. The leading topics of the Special Section were proposed by Guest Editors based on the conference profile and accepted by the Editorial Board. We believe that the selected papers show a high scientific level and strong practical applicability, and will be interesting for our readers, perhaps motivating them to participate in the next symposium.

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Jacek Rąbkowski is a full professor in power electronics with the Faculty of Electrical Engineering, Warsaw University of Technology, Poland. Between 2010 and 2013, he was KTH Royal Institute of Technology, Stockholm, Sweden as a guest researcher/visiting professor. Moreover, in 2015–2016, he was also involved in a research project at Taltech in Estonia. His research interest includes all issues related to new power semiconductor devices based on SiC and GaN, with particular attention to gate and base drivers, including series connection issues. A key area of interest also contains medium voltage applications and power converters for renewable energy and energy storage. Recently, he has also been working on power converters and systems for fast-charging electric vehicles. He is the author or co-author of over 230 conference and journal publications. In 2015–2024 he was an Associate Editor for IEEE Transactions on Power Electronics. He is also a topic editor in the Bulletin of the Polish Academy of Sciences: Technical Sciences.