12th International Conference - IcETRAN 2025
Čačak, Serbia, June 9-12, 2025

Power Engineering Section (EEI)
INVITED PAPER:

"Advancements in Electrical Machines for E-mobility"

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Abstract: Electric transportation has rapidly evolved over the past decade, driven by advancements in electrical machines and power electronics. From electric vehicles to high-speed trains, aviation, and urban air mobility solutions, efficient and high-performance electrical machines are the core of modern sustainable transportation. The demand for higher power density, improved efficiency, and cost-effective solutions has led to the development of novel machine topologies, advanced materials, and innovative manufacturing techniques.

In the early years of development, electrical drives for transportation utilize DC motors before transitioning to induction machines due to their robustness and simplicity. However, with the advancement of power semiconductors, permanent magnet synchronous machines have gained dominance due to their superior efficiency and power density. Additionally, high-speed machines have emerged as a solution for improving power-to-weight ratios, making them particularly attractive for aerospace, railway, and next-generation EV drivetrains.

Despite their advantages, permanent magnet machines rely on rare-earth materials, which pose supply chain risks and environmental concerns. As a result, there is a growing focus on rare-earth-free solutions, including advanced reluctance machines, improved induction motor designs, and hybrid excitation synchronous machines. These alternatives aim to maintain high efficiency and performance while reducing dependence on critical raw materials.

One of the major challenges in electric transportation is achieving higher efficiency while minimizing losses and improving thermal management. Advanced cooling techniques, lightweight materials, and novel winding configurations play a crucial role in enhancing machine performance. Furthermore, the integration of machine and power electronics enables more compact system designs.

Recently, multi-phase machines, axial flux motors, and innovative winding techniques have gained attention for their ability to improve reliability and fault tolerance in e-mobility applications. Additionally, digital twin technology and AI-driven optimization are revolutionizing the design and predictive maintenance of electrical machines, ensuring longer operational lifespans and reduced maintenance expenses.

This presentation will provide an overview of the latest advancements in electrical machines for e-transportation, with a focus on primary technological themes. A comparative analysis of various motor technologies, design considerations, and emerging trends will be highlighted, with real-world applications and innovations serving as illustrative examples.

Short biography:

Jan Barta received his Master's degree in Power Electrical and Electronic Engineering from Brno University of Technology, Czechia, with several courses completed at Aalto University, Finland. In 2018, he earned his Ph.D. in Power Electrical and Electronic Engineering, focusing on the R&D of a high-speed electrical machine for a helium turbo-circulator. During his doctoral studies, he undertook research stays abroad at Lappeenranta University of Technology and SpinDrive, both in Finland.

After completing his Ph.D., he continued his career at the Brno University of Technology, where he was successful several times in writing proposals and obtaining funding for various projects related to advanced electrical machines intended for applications ranging from aerospace to fusion reactor cooling. Among the companies and research organizations with whom he collaborates on grant or contract, research projects are Honeywell, Garrett Motion, AVL Moravia, Linz Center of Mechatronics, Johannes Kepler University in Linz, et al.

Jan Barta's current research interests are in the design and modeling of electrical machines for transportation electrification, and he is a supporter of international collaboration and knowledge transfer to students. Within the framework of cooperation with foreign countries, through its contacts, he has already secured the preparation of a number of jointly supervised master theses and several internships for both doctoral and master students. Currently, Jan Barta guarantees key courses focused on electrical machines; he is the initiator and guarantor of a new bachelor's program focused on e-mobility and sustainability at Brno University of Technology.