Tutorial on

Variable Flux Synchronous Machines: Design Compromises and State-of-the-Art Machine Topologies

Tutorial Presenters

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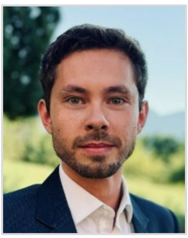
Biographies of the Presenters

Gerd Bramerdorfer (Senior Member, IEEE) received the Ph.D. and habilitation degree in Electrical Engineering from Johannes Kepler University Linz (JKU), Linz, Austria, in 2014 and 2021, respectively.
Currently, he is a Full Professor with the Faculty of Engineering and Natural Sciences and Head of the Institute of Electric Machines and Power Electronics, JKU, and a Key Researcher for Linz Center of Mechatronics, Linz, Austria. His research interests include the design, modeling, and robust optimization of high-performance electric machines and drives including multi-physics and eco-social aspects, and condition monitoring for machines and drives.
Prof. Bramerdorfer is an Associate Editor for IEEE Transactions on Industry Applications and a past Associate Editor for IEEE Transactions on Industrial Electronics and IEEE Transactions on Energy Conversion. According to the 2025 rankings by Elsevier, SciTech Strategies Inc., and Stanford, he is listed among the top 0.45% of researchers worldwide (over 125k researchers, self-citations excluded).



Gabriel Weissitsch received his Master's degree in Mechatronics from Johannes Kepler University (JKU) Linz, where he completed a thesis on the design of a variable air gap axial flux machine for an electric race car. He is currently a PhD candidate at the Institute of Electric Machines and Power Electronics of JKU, where he focuses on synchronous machines employing mechanical flux adjustment methods.

David Klink (Member, IEEE) received the B.Eng. (Hons.) degree in mechatronics engineering and science (physics) from Monash University, Melbourne, VIC, Australia, in 2020. He has worked with Electric Vehicle Technologies in Australia, Germany, and the U.K. As a Ph.D. candidate, he explored generalisation of synchronous machines, with a focus on variable flux permanent magnet machines and drive cycle analysis.

Abstract

Research on Variable Flux Machines (VFMs) is becoming increasingly prevalent due to their ability to dynamically adjust excitation levels. Preserving the benefits of permanent magnet machines at low speeds while increasing the efficiency and operating envelope at high speeds is the underlying goal of these machine topologies.

The first part of this tutorial will introduce the fundamental equations and characteristics of synchronous machines. Generalized design aspects for understanding the operating limits of traditional permanent magnet synchronous machines are presented. The trade-off of increasing permanent magnet flux or saliency ratio from a machine design perspective is highlighted for a fixed-flux system. This will create a system-level understanding of why variable-flux machines are necessary for future electrification efforts.

The second part of the tutorial will deep-dive into different machine topologies to achieve a flux variation in permanent magnet machines. These include hybrid excitation machines equipped with field windings on the stator or rotor, memory motors utilizing low-coercivity magnets with variable magnetization states, and mechanically adjustable machines that incorporate movable elements within the stator or rotor. State-of-the-art machines will be presented, and their respective advantages and disadvantages highlighted.

By the end of the tutorial, attendees will have a cohesive understanding of the compromises in static flux machines, and the value-add potential of variable flux mechanisms and when and how flux variation adds system-level value. The presented content will enhance participants' understanding of variable flux machines mechanisms, enabling them to apply state-of-the-art knowledge to the next generation of electric machines.

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