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Tutorial on

Hands-on Design and Optimization of IPM Traction Motors with SyR-e

Tutorial Presenters

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Biographies of the Presenters

Simone Ferrari (Member IEEE) receives the Ph.D. degree in 2020 from Politecnico di Torino, where he is currently an Assistant Professor. From July to December 2018, he was a Visiting Scholar at NCSU, Raleigh, NC, USA. He is one of the authors of SyR-e, an open-source environment for the design, analysis and modeling of electrical machines and drives. He was part of several industrial projects focused on the design of electrical machines for both industrial and transportation applications. His research interests include electrical machine design and testing, with a focus on high-performance machines, fault-tolerant applications and reduced environmental impact solutions.

Gianmario Pellegrino (Fellow, IEEE) is currently a Professor of power converters, electrical machines, and drives with the Politecnico di Torino, Turin, Italy. He was a Visiting Fellow with Aalborg University, Aalborg, Denmark; the University of Nottingham, Nottingham, U.K.; and the University of Wisconsin–Madison, Madison, WI, USA. He has authored the open-source platform SyR-e for the design of electrical motors and drives, constantly developed and validated in the context of collaborations with the industry, and widely adopted worldwide. He has coauthored 65+ IEEE journal articles and nine patents. Dr. Pellegrino is an Associate Editor of IEEE Transactions on Industry Applications and the recipient of the 8th Grand Nagamori Award. He received nine best paper awards. He is a founding member of the Power Electronics Interdepartmental Center (PEIC) of Politecnico di Torino, a member of the Advisory Board of PCIM Europe, and the Adjunct Vice Rector for Technology Transfer of Politecnico di Torino.

Abstract

The design and simulation of electrical machines play a pivotal role in several industries such as automotive, robotics, industry applications, and appliances. The systematic design of custom electrical machines requires linking system-level specifications, magnetic, mechanical, thermal constraints, and drive behavior within a single workflow. Yet, in practice this workflow is often fragmented across multiple commercial tools, which limits reproducibility and hinders rapid design exploration.

This tutorial presents a unified, hands-on workflow for the design and optimization of interior PM synchronous motors (IPMSMs) using SyR-e, an open-source, MATLAB-based framework widely used in research and education. Participants will start from the specifications of an 18 krpm traction IPMSM and carry out a volume-constrained preliminary design, based on a FEA-calibrated, multi-physical view of the design space, graphically summarized in the (x,b) design plane. Selected machine candidates will then be characterized, including fault analysis, and refined for torque-ripple reduction by either rotor skewing or local optimization.

Further validation includes automatic generation and simulation of the electric drive model, with a focus on PM segmentation design under PWM supply. Finally, the optimized machine will be size-scaled to comply with a higher maximum-speed requirement of 25krpm, achieving active-volume reduction by means of the multi-physical design-by-scaling procedure embedded in SyR-e.

At the end of the tutorial, participants will be able to:

- Apply a structured, system-level-constrained design and analysis workflow for electrical machine design using SyR-e.
- Perform preliminary design and identify optimal trade-offs.
- Assess electromagnetic, thermal, structural, and fault-related performance metrics.
- Use the design-by-scaling technique for rapid redesign.

The tutorial includes hands-on activities supported by pre-computed models distributed in advance. Participants can replicate the presented steps using either MATLAB Online or MATLAB Desktop. For desktop users, the latest MATLAB release is recommended, together with FEMM and the latest SyR-e version, available on GitHub: https://github.com/SyR-e/syre_public.

List of contents

- syreDrive for PWM loss and PM segmentation design
- High-Speed Machine Design via design-by-scaling
- Wrap-Up and Q&A