ICEM 2024, Torino, September 1-4 2024

Tutorial Proposal

TUTORIAL TITLE:

From Geometric Model to System Simulation: Physical Modeling and Control of Electric Motors with Simulink and Simscape

ABSTRACT

In the first part of this tutorial, we will explore several approaches for characterizing an electric motor using an acausal modeling approach, with a special remark on various forms of integration with different kinds of external software typically used for electric motor design.
In the second part of the tutorial, a detailed design and analysis flowchart will be presented, starting from the geometric motor model, through FEA simulations and related post-processing, to the FEA-based motor model to be included in the system model in Simscape. For the case study, a MATLAB-based design and analysis framework will be adopted giving open access to the motor, too.
The last part will refer to all the possible analysis in the Simulink environment, as control design and fault scenarios analysis, exploiting the accurate motor model obtained.
Publicly available examples featuring noteworthy applications will be presented, examining their associated objectives, obstacles, and solutions. One or two case studies, targeting traction and/or industrial applications will be tackled during the tutorial and made available for the audience.

List of contents:

- Part 1: Electric Motor Modeling (45')
  - Import of FEM data from Electric Motor design tools, e.g. Ansys Maxwell, JMAG-RT
  - Parameterization from commercial devices
  - Parameterization from measured data
  - Representation from Symbolic equations
  - Introduction to FMU exchange
- Part 2: SyR-e environment for eMotor Design and Analysis (40')
  - Introduction to SyR-e
  - Geometric modeling in SyR-e: parametrized or custom geometry
  - FEA analysis and motor modeling
  - Interface with system model
  - Case studies
- Part 3: Beyond the Electric Motor (45')
  - Control Design:
    - Through control tools

- Integrating external code
- Thermal Management Applications: Electrical Drive/Full-Electric Vehicle
- Analysis of a Faulty Scenario for an Electrical Motor
- Automatic Code generation

- Q&A (15'-20')

TUTORIAL PRESENTERS

- Feng He, MathWorks, fenghe@mathworks.com
- Simone Ferrari, Politecnico di Torino, simone.ferrari@polito.it

BIO OF THE PRESENTER

Feng He is an Application Engineer at MathWorks. He holds a M. Sc in Automation Engineering and Control of Complex Systems from Università degli Studi di Catania.
Before joining MathWorks, he worked in the automotive industry: five years at General Motors as Application Software and Algorithm Development Engineer implementing the next generation thermal control for internal combustion engines; two years at Plastic Omnium (Austria) deploying a Model Based Design toolchain for the Fuel Cell control, simulation, and target HW integration.

Simone Ferrari (Member, IEEE) receive the Ph.D. degree "cum laude" in 2020 from Politecnico di Torino, where he is currently a Research Fellow. From July to December 2018, he was a Visiting Scholar at North Carolina State University, Raleigh, NC, USA. He is one of the authors of SyR-e, an open-source design tool for synchronous reluctance and permanent magnet machines. From 2021 he is also one of the responsible of the eDrive testing infrastructure TEST-eDRIVE managed from Energy Department and the Power Electronics Innovation Center of Politecnico di Torino. His research interests include electrical machine design and testing, and multi-physical evaluation of electrical machines, with a focus on synchronous reluctance and permanent magnet machines.

EXAMPLE REFERENCES

1. S. Ferrari, G. Dilevrano, P. Ragazzo, P. Pescetto and G. Pellegrino, "Fast Determination of Transient Short-Circuit Current of PM Synchronous Machines via Magnetostatic Flux Maps," in *IEEE Transactions on Industry Applications*, vol. 59, no. 4

2. S. Ferrari, P. Ragazzo, G. Dilevrano and G. Pellegrino, "Flux and Loss Map Based Evaluation of the Efficiency Map of Synchronous Machines," in *IEEE Transactions on Industry Applications*, vol. 59, no. 2
3. P. Ragazzo, G. Dilevrano, S. Ferrari and G. Pellegrino, "Comparative Turn-off Safe Modes of Ferrite- and NdFeB- Interior PMSMs," *2023 IEEE Energy Conversion Congress and Exposition (ECCE)*, Nashville, TN, USA, 2023
4. S. Ferrari, G. Dilevrano, P. Ragazzo and G. Pellegrino, "The dq-theta Flux Map Model of Synchronous Machines," *2021 IEEE Energy Conversion Congress and Exposition (ECCE)*, Vancouver, BC, Canada, 2021
5. G. Dilevrano, P. Ragazzo, S. Ferrari, G. Pellegrino and T. Burress, "Magnetic, Thermal and Structural Scaling of Synchronous Machines," *2022 IEEE Energy Conversion Congress and Exposition (ECCE)*, Detroit, MI, USA, 2022
6. A. Varatharajan, D. Brunelli, S. Ferrari, P. Pescetto and G. Pellegrino, "syreDrive: Automated Sensorless Control Code Generation for Synchronous Reluctance Motor Drives," *2021 IEEE Workshop on Electrical Machines Design, Control and Diagnosis (WEMDCD)*, Modena, Italy, 2021
7. S. Ferrari and G. Pellegrino, "FEAfix: FEA Refinement of Design Equations for Synchronous Reluctance Machines," *in IEEE Transactions on Industry Applications*, vol. 56, no. 1