TUTORIAL 1

"Multiphysics Equivalent Circuit Modeling for Electric Machinery – From Macro-scale to Micro-scale"

Sunday, May 18
8:00AM - 11:30AM
Room: Magnolia 1

SPEAKER

Matthew Gardner

University of Texas at Dallas

SPEAKER

Baoyun Ge

Georgia Institute of Technology

SPEAKER

Peng Han

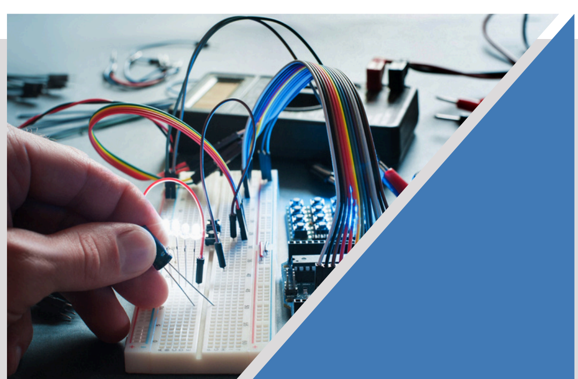
Ansys

Equivalent circuits have long been used to understand and analyze electric machines. Traditionally, these equivalent circuits, based on lumped elements capturing the main physical characteristics, have provided an intuitive way to explain electric, magnetic, and thermal phenomena. However, high-resolution analysis is necessary in high-fidelity virtual prototyping. To this end, finite element analysis (FEA) is usually the ultimate tool. In this tutorial, we illustrate a continuous spectrum from traditional macro-scale equivalent circuit modeling to micro-scale FEA using equivalent circuits.

First, a unified circuit view of multiphysics FEA for electric machines is presented. Specifically, FEA of electromagnetic, thermal, and elastic fields are viewed as constructing and solving equivalent circuits at the micro-scale (mesh) level. The RL and RC circuits familiar to electrical engineers are now transferred to physical processes beyond electrical circuits.

Secondly, we introduce recent advancements in magnetic equivalent circuit theory. A new element, magductance, can be used to account for eddy currents. The existence of magductance is indicated in the unified circuit view presented first. the electric power can then be calculated from the magnetic equivalent circuit. Examples using vector magnetic circuit theory, which employs reluctance and magductance, to design, analyze, and control various electromagnetic devices are presented.

Lastly, we discuss how to solve these equivalent circuits rapidly, which is necessary for micro-scale evaluation. We discuss using circuit-solving techniques to systematically and efficiently set up a matrix equation taking advantage of symmetric boundary conditions, how to efficiently solve the matrix equation, and how to solve nonlinear equivalent circuits.



BIOS

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Matthew C. Gardner earned his B.S. in electrical engineering from Baylor University, Waco, Texas in 2014. He earned his Ph.D. in electrical engineering from Texas A&M University, College Station, Texas in 2019. In August 2020, he joined the University of Texas at Dallas, where he is an assistant professor. His research interests include optimal design and control of electric machines and magnetic gears.

Baoyun Ge received the B.E. degree in electrical engineering from Southeast University, Nanjing, China, in 2012, and the Ph.D. degree in electrical and computer engineering from the University of Wisconsin-Madison in 2018. For his Ph.D., he focused his research on the mathematical modeling and manufacturing of electrostatic machines. Dr. Ge received the First Prize Paper Award and the Third Place Thesis Award from the IEEE Industry Application Society (IAS) in 2017 and 2019, respectively. His work was also recognized by the Electrical and Computer Engineering Department at UW-Madison with the Harold A. Peterson Distinguished Dissertation Award. He received the CAREER Award from the US National Science Foundation in 2024. Dr. Ge served as guest associate editor for the IEEE Journal of Emerging and Selected Topics in Power Electronics and as invited topic and session chairs for the IEEE Energy Conversion Congress & Expo (ECCE). His research interests mainly focus on the design automation of electric machines and power electronics, multiphysics design and modeling, and advanced control architecture for electric machines and power electronics.

Peng Han is now with Ansys, Inc. as an Application Engineering Manager focusing on low-frequency electromagnetic products. He received the B.Sc. and Ph.D. degrees in Electrical Engineering from the School of Electrical Engineering, Southeast University, China, in 2012 and 2017, respectively. From November 2014 to November 2015, he was with the Department of Energy Technology, Aalborg University, Aalborg, Demark, where he focused on electric machines for wind energy conversion and high-power drives. He was a Post doctoral Researcher with the Center for High-Performance Power Electronics (CHPPE), ECE Department, The Ohio State University, and later the SPARK Laboratory, ECE Department, University of Kentucky. His current research interests include electric machines, machine drives, power electronics, consumer electronics, renewable energy and scientific machine learning. He was an Associate Editor for IEEE Transactions on Industrial Electronics, IEEE Transactions on Industry Applications and Journal of Power Electronics. He received two best paper/poster awards from IEEE conferences and Third Prize in the IEEE IAS Student Thesis Contest in 2018. He has instructed short courses/tutorials at ITEC 2022, IEMDC 2023, ITEC 2023 and ECCE 2023. He also delivered multiple training sessions for Ansys.