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Tutorial Title

General Airgap Field Modulation Theory for Electrical Machines and Its Applications in Automotive and Aerospace Industries

Instructor Team

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Abstract

Electrical machines are devices that convert mechanical energy into electrical energy or vice versa. They were invented in the 1800s and have a history of nearly 200 years. Other inventions of similar ages, such as the Watt steam engine, telegraph, incandescent light bulb, etc., have been outdated by emerging technologies. By contrast, the electrical machine shows great tenacity and vitality, becoming a living fossil of the Industrial Revolution.

Demand for high-performance electrical machines is increasing day by day with the rapid development of our social economy. Application areas of electrical machines have extended from conventional industrial drive to aerospace, transportation, numerical control machine tools, robots, and other high-tech fields, ranging from deep below the surface of the earth to deep space, from the furthest depths of the ocean to the surfaces of land and sea.

This tutorial will provide a comprehensive overview of airgap magnetic field modulation phenomena widely observed in electrical machines, and the general airgap field modulation theory that has been developed systematically to understand and research them. It will be shown by several examples that the developed theory not only serves to unify analysis of disparate electrical machines, from conventional DC machines, induction machines, and synchronous machines to unconventional flux-switching permanent magnet (PM) machines, vernier machines, brushless doubly-fed machines, etc., but also paves the way towards the creation of new electrical machine topologies.

Starting from overviews of key concepts in electrical machine engineering and in-depth specialized analysis of the novel theory itself, this short course works through applications of the developed theory before proceeding to both qualitative analysis of the theory's operating principles and quantitative analysis of its parameters. The stator-PM variable reluctance resolver for compact and high-speed motor applications and the dual-rotor power-split machine for hybrid electric vehicles invented by the principle of magnetic field modulation are included as two representative examples.

By the end of this tutorial, attendees will:

- Learn about the historical development of electrical machines and their theories, and the ubiquity of magnetic field modulation phenomena;
- Understand the general airgap field modulation theory framework for design, analysis, and innovation of electrical machines;
- Be able to apply the general airgap magnetic field modulation theory in qualitative analysis and quantitative calculation of machine performance and inventing emerging machine topologies to meet various application needs.

Instructor Biography

Ming Cheng (Fellow, IEEE, IET) received his B.Sc. and M.Sc. degrees from Southeast University, Nanjing, China, in 1982 and 1987, respectively, and his Ph.D. degree from the University of Hong Kong, Hong Kong, in 2001, all in electrical engineering. Since 1987, he has been with Southeast University, where he is currently an Endowed Chair Professor at the School of Electrical Engineering and the Director of the Research Center for Wind Power Generation. He was a Distinguished Lecturer of the IEEE IAS for 2015/2016. He has served as editor-in-chief, editor and editorial board member of various international journals, as well as chair and organizing committee member of many international conferences. His teaching and research interests include electrical machines, motor drives for EV, renewable energy generation, and servo motor & control. In these areas, he has published over 500 refereed technical papers and 7 books and holds over 150 invention patents. He has received many awards, including Second Prize in the State Technological Invention Awards; First Prize in China's Ministry of Education's Natural Science Awards; the IET Achievement Award; and the Environmental Excellence in Transportation Award for Education, Training, and Public Awareness by SAE International.

Peng Han (Senior Member, IEEE) received B.Sc. and Ph.D. degrees in electrical engineering from the School of Electrical Engineering, Southeast University, Nanjing, China, in 2012 and 2017, respectively. From November 2014 to November 2015, he was a Guest Ph.D. student at the Department of Energy Technology, Aalborg University, Aalborg, Denmark, where he focused on brushless doubly fed machines' application in wind energy conversion and high-power drives. He is currently with Ansys, Inc., USA, as a Senior Application Engineer. Before joining Ansys, he was a Postdoctoral Researcher with the Center for High Performance Power Electronics (CHPPE), Department of Electrical and Computer Engineering, The Ohio State University, and later the SPARK Laboratory, Department of Electrical and Computer Engineering, University of Kentucky. His current research interests include electrical machines, machine drives, power electronics, and renewable energy. He is 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 one short course at ITEC 2022 and delivered multiple training sessions for Ansys.

Le Sun (member, IEEE) received the Ph.D. degree in electrical engineering from the School of Electrical Engineering, Southeast University, Nanjing, China, in 2016. From 2016 to 2018, he was working as a Postdoctoral Researcher with McMaster Automotive Resource Centre, McMaster University, Hamilton, ON, Canada. Since 2019, he has been with the Nanjing University of Science and Technology, Nanjing, China, where he is currently an Associate Professor with the Department of Electrical Engineering, and a Joint Research Fellow with the School of Mechanical Engineering. His research interest includes design and control of PM machines for servo systems, and electric vehicles.

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