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Tutorial on

Insulation Friendly Drives for Permanent Magnet Synchronous Machines

Tutorial Presenters

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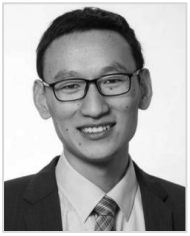
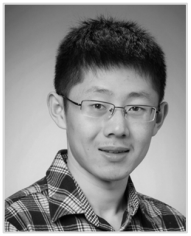
Biographies of the Presenters



Jianning Dong received the B.Sc. and Ph.D. degrees in electrical engineering from Southeast University, Nanjing, China, in 2010 and 2015, respectively. In 2016, he worked at the McMaster Automotive Resource Centre, McMaster University, Hamilton, ON, Canada, as a Post-Doctoral Researcher. Since October 2016, he has been an Assistant Professor, and then from 2025 an Associate Professor with the DC Systems, Energy Conversion and Storage (DCE&S) Group, Delft University of Technology, Delft, The Netherlands. His research interests include electromechanical energy conversion and contactless power transfer, through which he applies knowledge to applications such as transportation electrification and renewable energy generation/utilization.



Fei Peng received the B.S. and M.S. degrees in electrical engineering from Southeast University, Nanjing, China, in 2010 and 2012, respectively, and the Ph.D. degree in electrical and computer engineering from McMaster University, Hamilton, Ontario, Canada, in 2016. After that, he worked as a Postdoctoral Fellow with the McMaster Institute for Automotive Research and Technology (MacAUTO), McMaster University. Since 2016, he has been an Assistant Professor, and then from 2022 an Associate Professor with the School of Electrical Engineering, Southeast University. His research interests include optimal design and control of power converters, modeling and digital control of motor drives.

Yu Yao (Member, IEEE) received the B.S. and Ph.D. degrees in electrical engineering from Southeast University, Nanjing, China, in

2016 and 2022, respectively. Since 2022, he has been an Assistant Professor, and then from 2025 an Associate Professor with the School of Electrical Engineering, Southeast University. His main research interests include the design of the power inverter, the current regulator design, the position sensorless drive for the high-speed PMSM and the drive system with LCL output filter.

Abstract

Permanent magnet synchronous machine (PMSM) drives are characterized by their exceptional power density, high efficiency, and a wide speed range. These advantages are further amplified by the adoption of wide-bandgap power semiconductor devices (SiC and GaN), making them dominant in demanding fields such as transportation electrification and industrial automation. Pursuing higher power densities often leads to designs employing high pole counts or high rotational speeds, which in turn demands high switching frequencies. However, the fast switching transients of wide-bandgap devices, combined with the high repetition rates from high switching frequencies and limited heat dissipation area caused by high power density, impose significant electrical and thermal stresses on motor insulation, thereby compromising the lifetime and reliability of the overall drive system. This tutorial examines the impact of wide-bandgap-device-based drives on motor insulation and its implications for PMSM drive design, supported by both analytical and experimental evidence. An overview of existing mitigation measures to suppress the insulation stress will be provided, followed by detailed investigations into three specific solutions: the LCL-filter-equipped PMSM drive, the LCL filter with a capacitively coupled active damper, and the current source inverter-based PMSM drive. Particular attention will be paid to critical design choices, controller design and implementation, and experimental validation. The tutorial will be concluded with an summary of the work presented and an outlook on future PMSM drive trends.

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- Impact of wide-bandgap-device-based motor drives on motor insulation
- Overview of mitigation measures to suppress dielectric stress on motor insulation
- PMSM drives with output filters and its control
- Capacitively coupled active damper for LCL-filter equipped PMSM drives
- Current source inverter based PMSM drive and its control