ECCE 2021 Tutorial AM5

Tutorial Title

OPTIMISED ELECTRICAL MACHINE DESIGNS FOR E-MOBILITY APPLICATIONS

Abstract

Transport electrification is seen as one of main solutions to reduce global CO2 emissions and increased demand of mechanical energy can be provided by electrical energy. The best energy conversion systems are undoubtedly the combination: electrical machines + power electronics + batteries.
The increasing demand of full electric vehicles arises specific challenges in terms of design for manufacturing, low weight, material costs and material supply chain. There is a strong interest to reduce the volume and cost of active materials in propulsion motor technologies beyond their current state-of-art, with a strong focus on industrial feasibility for mass production. Potential solutions include increased motor speeds and higher pole numbers and/or the adoption of rare earth free typologies such as reluctance (switched and synchronous) and induction machines. As there can be significantly different usage and performance requirements across e-mobility applications adopting a common standard of motor design is unlikely to yield the optimum in terms of overall system efficiency and electric vehicle range. These considerations will be discussed and compared.
Advances in fast switching power semiconductor devices and digital control have enabled high frequency operation of electrical machine drives, with fundamental operating frequencies exceeding 1 kHz being proposed. High frequency operation allows for greater mechanical speeds and designs with a larger number of magnetic poles, leading to a more compact electrical machine package for a given output requirement. However, high frequency operation results in a higher volumetric loss in he active components of the electrical machine; primarily as a result of induced circulating eddy currents in the stator laminations, winding conductors and the rotor. The non-uniform heating and reduction in efficiency associated with these AC loss effects represent a major hurdle to the successful development of compact high frequency electrical machine drives. The benefits and challenges associated with high frequency operation of electrical machines for aerospace and automotive applications will be reviewed and the techniques and design choices available to the designer to reduce high frequency loss effects and extract heat will be surveyed.
Cutting-edge sensitivity analysis and multi-objective optimisation techniques will be applied in the design of an electric motor for a PHEV traction application. Each candidate solution will be evaluated in terms of electromagnetic, thermal and mechanical behaviour across the full operating envelope. The optimisation will generate a pareto front which allows efficiency over a drive cycle to be traded off against motor cost. This approach utilises a high performance or cloud computing infrastructure to deliver a truly revolutionary design workflow.

The tutorial will be focussed around various design approaches and aspects for a range of automotive and aerospace applications. The tutorial is structured as follows:
- Elimination/reduction of rare earth magnets in E-mobility
- Holistic design against an operational duty cycle in Electrical Vehicles
- High frequency operation of E-Motors in E-mobility
- Innovative multi-physics designs of E-Motors using multi-objective optimisation.

The tutorial is mainly addressed to Engineers and Technical Professionals who have an interest in Electric Machines for automotive application.

Instructors Biographies

Dr Mircea Popescu (M'98 – SM'04 – F'14) is Chief Technology Officer for Motor Design, Ltd., UK and has more than thirty years of engineering experience. Earlier in his career, he was with Helsinki University of Technology (now Aalto University) in Finland and with the SPEED Lab at University of Glasgow, UK. He published more than 150 papers and his publications have received three IEEE best paper awards. His consultancy contributions for industry are incorporated in many state-of-the-art products. Current major projects include ReFreeDrive, rare-earth free e-drives featuring low cost manufacturing, under EGVI Horizon 2020 program. An IEEE Fellow, Mircea was 2014-2015 Chair of the IEEE IAS Electrical Machines Committee and 2013-2016 Prominent Lecturer IEEE IAS Region 8.

Prof. Philip H. Mellor, (M'12) received the B.Eng. and Ph.D. degrees in electrical engineering from The University of Liverpool, Liverpool, U.K., in 1978 and 1981, respectively. He is currently a Professor with the Department of Electrical and Electronic Engineering, University of Bristol, Bristol, U.K. Prior to this, he held academic posts with The University of Liverpool, from 1986 to 1990, and The University of Sheffield, Sheffield, U.K., from 1990 to 2000. His research interests include high-efficiency electric drives and actuation and generation systems for application in more electric aircraft and hybrid electric vehicles.

Dr. Nick Simpson, (M'14) received the B.Eng. and Ph.D. degrees in electrical engineering from the University of Bristol, Bristol, U.K., in 2009 and 2014, respectively. He is currently a Lecturer with the Department of Electrical Engineering, University of Bristol. His research interests include the modeling, manufacture, and characterization of electrical machines, and wound passive components, primarily for more electric aircraft and electric vehicle applications.

Dr. Melanie Michon is Head of Engineering for Motor Design, Ltd., UK. Melanie has gained a PhD degree in Electrical Engineering from the University of Sheffield. She has 20 years of combined academic and industrial experience enabling her to provide thought leadership and to drive innovation with a clear focus on IP development and commercialisation. She joined MDL in April 2019 in the position of Head of Engineering, where she heads the engineering team and is responsible for delivering grant funded and large engineering projects, as well as technical pre-sales support. Her previous posts include Head of Electrification at Romax Technology, where she has successfully established a Centre of Excellence for Electrification, delivering electrical machine design and novel electro-mechanical analysis solutions.

Dr. James Goss, received an MEng degree in Systems Engineering from the University of Warwick in 2009 and in 2014 received an Engineering Doctorate from the University of Bristol in the design of brushless permanent magnet machines for automotive traction. He is the CEO of Motor Design Ltd where he mainly works on automotive R&D projects and software development with large industrial partners.

Dr. Jonathan Godbehere has been with Motor Design Limited since January 2019. Previously, he was a post-doctoral researcher at the University of Bristol, where he also received his masters and PhD degrees in 2012 and 2017 respectively. Within MDL, Jonathan is a senior E-machine specialist, with over 9 years of experience in multi-physics design and optimisation of electric machines, across numerous technology sectors. Currently, he is the technical lead for an automotive APC-UK research project, where MDL is the E-machine work package lead.