Babak Nahid-Mobarakeh (Fellow IEEE) received the Ph.D. degree in electrical engineering from the Institut National Polytechnique de Lorraine, Nancy, France, in 2001. From 2001 to 2006, he was with the Centre de Robotique, Electrotechnique et Automatique, University of Picardie, Amiens, France. In September 2006, he joined the Ecole Nationale Superieure d'Electricite et de Mecanique, University of Lorraine, Nancy, where he was a Professor until December 2019. Since January 2020, he has been a Professor at McMaster University, ECE Dept., Hamilton, ON, Canada. Dr. Nahid-Mobarakeh has authored or co-authored over 300 international peer reviewed journal and conference papers as well as several book chapters. He also holds 6 published patents. He is the recipient of several IEEE awards. He was the General Chair of the 2020 IEEE Transportation Electrification Conference and Expo. Between 2012 and 2019, he served as an officer and then chair of the Industrial Automation and Control Committee (IACC), IEEE Industry Applications Society (IAS). He was also the IACC Committee Administrator and a Technical Committee Paper Review Chair for IEEE Transactions on Industry Applications. Currently, he is the Vice Chair of the IEEE Power Electronics Society Technical Committee on Electrified Transportation Systems. He is also a member of the Power Electronics and Motion Control (PEMC) Council. Dr. Nahid-Mobarakeh's main research interests include robust control of power converters and motor drives, fault detection and fault-tolerant control of electric systems, and design, control, and stabilization of microgrids.

Topic 1: Permanent-Magnet Motor Drives for Electrified Transportation

The electrification of transportation systems has been underway for over two decades. New trends are moving towards more environmentally friendly electric motors that reduce their carbon footprint in the manufacturing, operating and recycling process. To achieve this, a range of technologies from permanent-magnet synchronous motors (PMSM) to switched reluctance motors (SRM) and permanent-magnet assisted synchronous reluctance motors (PMa-SynRM) have been developed and used in electrified transportation systems. Various power electronic controls have been reported for driving these motors. Among them, many research present two- and multilevel voltage source inverters (VSI), Z-source inverters, and current source inverters (CSI) for different missions in electrified transportation systems and comparisons have been made based on metrics such as power density, specific power, efficiency, reliability, carbon footprint and cost.

In this lecture, after a quick overview of the concepts and presentation of some existing motor drive solutions in electrified transportation systems, the speaker will describe the state of the art of both surface-mounted and interior PM motors control techniques and their design, performance and robustness supported by simulation and experimental results. Then, future challenges and trends in electric motor control will be discussed.

Required preliminary knowledge and skills:

- General knowledge in electrical engineering
- Basic knowledge in power electronics and drives
- Basics of control theory

Topic 2: Control of Switched-Reluctance Motors

Among the available electric drive technologies, the Switched-Reluctance Machine (SRM) drives are generally the cheapest and most eco-friendly, thanks to their low carbon footprint during operation as well as manufacturing and recycling processes. Indeed, the SRM drive is not only the most cost-effective but also the greenest propulsion technology available today. SRMs are also known for their inherent and impressive fault-tolerant nature. However, the nonlinear character of SRM is also responsible for a high level of noise and vibrations which limits the scope of their applications in noise sensitive environments. In the last two decades, researchers have focused on the control of SRM drives, including its fault-tolerant control, as well as torque ripple and acoustic noise reduction. Focus was on torque sharing function (TSF) method which has been intensively studied by scholars to distribute the total torque over phases to generate a corresponding flux-linkage reference. Different distribution functions, such as the exponential function, the linear, the sinusoidal, and the cubic functions have been proposed. This allows converting distributed torque reference to current reference instead of flux-linkage reference. These analytical TSF methods are easy to implement and show good torque control performance at the low-speed range. However, the trackability of the derived reference currents is still a severe issue at the high-speed range.

In the proposed lecture, the speaker first presents the concept and structure of SRM and the way the torque is generated. Then, the concept of torque sharing function is introduced and different techniques from literature are presented and discussed. Afterward, conventional current controllers for SRM are studied and their performance is evaluated as a benchmark. Finally, the speaker presents new trends in current controlling of SRM including model predictive control, differential flatness-based control, and model-free predictive control. Lastly, future challenges and trends in electric motor control will be discussed.

Required preliminary knowledge and skills:

- General knowledge in electrical engineering
- Basic knowledge in power electronics and drives
- Fundamentals of electric machines

Topic 3: Stability and Stabilization of Microgrids

On-board energy management in small, optimized grids is an important issue in the next generation of electrified transportation systems. On one hand, design engineers are looking to minimize the size and the weight of power systems and the passive components. Inductors and capacitors are a part of the first elements that should be reduced. On the other hand, it is known that unstable oscillations on the grid may appear under overload conditions when small capacitances are used.

This lecture focuses first on the stability analysis of interconnected power converters in a microgrid. Linear and nonlinear stability analysis tools will be presented and applied to a DC microgrid developed for an aeronautic application. This practical example allows attendees to derive the relationship between the stability (small- and large-signal) and the passive components of the system. Then, the stabilization of microgrids will be developed using passive and active stabilizers. Several passive stabilizers will be designed first, then active stabilizers. Discussions on how each stabilizer improves the stability margins of the system will conclude the lecture.

Required preliminary knowledge and skills:

- General knowledge in electrical engineering
- Basic knowledge in power electronics and drives
- Modern control theory: state-space modeling
- Linear algebra