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Tutorial

Wireless Charging of Electric Vehicles: Design for Battery Interoperability and Reliable Dynamic Charging

Duration: 120 minutes

Abstract. Wireless power transfer (WPT) technologies have been gaining interest as convenient charging solutions for future electric vehicles (EVs). As vehicle platforms, battery architectures, and charging infrastructures grow increasingly diverse, interoperability has emerged as a central challenge in wireless charging system design. This tutorial lecture provides a comprehensive overview of static and dynamic wireless charging for EVs, emphasizing design methodologies that enable interoperable operation across different vehicles and charging scenarios. The lecture begins by introducing the fundamental design choices for EV wireless charging systems, including coil and magnetic-coupler topologies, selection of compensation networks, and power-converter stages. These elements critically affect efficiency, power capability, tolerance to misalignment, and system robustness. The role of industrial standards is then examined, with particular attention to how standardization constraints shape both electromagnetic and power electronic design decisions. Static wireless charging is addressed as the most mature application. The tutorial focuses on the interface between the wireless power transfer stage and the EV battery, presenting a voltage/current doubler converter architecture as an effective solution for achieving battery interoperability across a wide voltage range while maintaining high efficiency and relatively low hardware complexity. Building on these foundations, the tutorial extends to dynamic wireless charging, in which power is transferred while the vehicle is in motion. This section addresses additional challenges related to segmented transmitter structures. The content will focus on power fluctuations and foreign object detection issues and will introduce the operating principles and the latest advances. By integrating fundamentals, standards, and advanced applications, this tutorial equips attendees with a coherent understanding of interoperable wireless charging technologies for current and future electric vehicle systems.

Content Outline

Duration	Topics covered
5 min	Introduction
15 min	***Fundamentals of EV wireless charging:*** This section provides an overview of industrial standards, coil and magnetic-coupler topologies, selection of compensation networks, and power-converter stages.
15 min	***Static EV wireless charging:*** This section describes typical EV wireless charging architectures and designs for static wireless charging.
15 min	***Voltage/current doubler converter for battery interoperability:*** This section showcases a voltage/current doubler converter architecture as an effective solution for achieving EV battery interoperability across a wide voltage range while maintaining high efficiency and relatively low hardware complexity
5 min	Break
15 min	***Dynamic wireless charging:*** This section provides an overview of recent advances in dynamic wireless charging, with an emphasis on key challenges, including power fluctuations, material costs, and foreign object detection.
15 min	***Magnetic coupler configuration for reduced power fluctuation:*** This section introduces the operating principles of multi-phase-transmitter wireless charging systems. A new dual-phase system will be presented to highlight its superiority in power fluctuation and cost.
15 min	***Integrated detection method of EV and metallic foreign objects:*** This section generally reviews foreign object detection methods for wireless charging. For dynamic systems employing segmented coils, EV position detection is crucial for ensuring high-efficiency, low-emission operation. An integrated detection method tailored for dynamic systems will be detailed.
5 min	Conclusions
15 min	Q&A Session

Short bio of the instructors

Francesca Grazian (Member, IEEE) received her B.Sc. degree in Electrical Engineering from the University of Bologna, Italy, in 2016, followed by her M.Sc. and Ph.D. degrees in Electrical Engineering from the Delft University of Technology, The Netherlands, in 2018 and 2023, respectively. Her Ph.D. research focused on power electronics for wireless charging of electric vehicles. From 2023 to 2024, she gained experience in the railway industry as a Lead Electrical Engineer at Laser Precision Solutions in Amsterdam, the Netherlands. Since May 2024, Francesca Grazian has been an Assistant Professor at the TU/e Power Electronics Lab (PELe), the Netherlands. Her research focuses on innovative wireless power transfer systems, industrial electrification, and the environmental impact of power electronics. Email: f.grazian@tue.nl

Wenli Shi (Member, IEEE) received the Ph.D. degree in electrical engineering from Delft University of Technology (TU Delft) in 2023. In March 2023, he started working as a postdoctoral researcher at the DC System, Energy Conversion and Storage (DCE&S) group of TU Delft. Since May 2024, he has been an assistant professor at the DCE&S group. He serves as an associate editor in IEEE Transactions on Transportation Electrification and the vice-chair of the IEEE Benelux Section Transportation Electrification Council. His research interests include high-power wireless charging, electric aircraft, DC power distribution and protection, and battery modeling. Email: W.Shi-3@tudelft.nl