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Tutorial Title

Direct Current (DC) Distribution Systems: Modeling, Control, Protection, and Real-World Implementation

Instructor Team

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Abstract

The increasing penetration of inverter-based resources (IBRs) has driven the paradigm shift of modern power systems in the areas of grid architecture, dynamic inverter and system modeling, and stability and resiliency oriented advanced control schemes, among others. As a critical grid section bridging upstream transmission networks and downstream end users, distribution systems play a vital role in grid modernization and serve as the major venue for IBR grid integration. Traditionally, distribution systems are mainly implemented based on AC electricity. Note that the concept of DC systems and DC grids (e.g., DC nano-grids, DC micro-grids, and medium-voltage DC distribution systems) has drawn increasing attention in both academia and industry. The revolutionary transition from AC to DC power grids calls for tremendous development and integration efforts to maximize the potential of DC-coupled systems in terms of energy conversion efficiency enhancement, system cost reduction, and hosting capacity enhancement, among other functions and benefits. Compared to legacy AC distribution systems, the integration of DC sub-grids, or even the implementation of purely DC distribution networks, brings promising and remarkable benefits and potential encompassing the following aspects: 1) flexible interconnection and power flow control with relatively easier synchronization strategies, 2) simplified grid integration scheme of IBRs with DC-coupled power electronic infrastructures, 3) enhanced power transfer capacity via DC distribution feeders nested in conventional AC distribution systems. In this tutorial, a diversified and multi-disciplinary instructor team has been assembled to consolidate the expertise from both academia and industry. Various aspects of DC distribution systems will be detailed, including dynamic modeling of individual IBRs and IBR clusters in DC distribution systems, advanced control diagrams for converter operation and system-level coordination, DC distribution system protection schemes and DC circuit breakers, and real-world case studies of DC-coupled systems. It is also noteworthy that for real-world case studies, a live grid-interactive DC house will be showcased with online measurements and real-time control signals, which will demonstrate the actual implementation of DC grid technologies and also provide interactive opportunities for the audience to understand the technical details.

Instructor Team Biographies

Xiaonan Lu received his B.E. and Ph.D. degrees in electrical engineering from Tsinghua University, Beijing, China, in 2008 and 2013, respectively. From September 2010 to August 2011, he was a guest Ph.D. student at the Department of Energy Technology, Aalborg University, Denmark. From October

2013 to December 2014, he was a Postdoc Research Associate at the Department of Electrical Engineering and Computer Science, University of Tennessee, Knoxville. From January 2015 to July 2018, he was with the Energy Systems Division, Argonne National Laboratory, first as a Postdoc Appointee and then as an Energy Systems Scientist. From July 2018 to July 2022, he was with Temple University as an Assistant Professor. In August 2022, he joined Purdue University as an Associate Professor. His research interests include modeling, control and design of power electronic inverters, hybrid AC and DC microgrids, medium-voltage DC distribution systems, and large-scale power electronics intensive power systems. Dr. Lu is the Associate Editor of IEEE Transactions on Industrial Electronics (2018-present), the Associate Editor of IEEE Transactions on Industry Applications (2016-present), and the Editor of IEEE Transactions on Smart Grid (2016-2023). He serves as the Chair of the Conference Development Committee (CDC) at the IEEE-IAS Industrial Power Conversion Systems Department (IPCSD) and the Vice Chair of the IEEE-PELS Technical Committee on Modeling and Control of Power Electronics. He is also the recipient of the 2020 Young Engineer of the Year Award in the IEEE Philadelphia Section.

Hanchao Liu is a senior electric power system engineer at GE Vernova's Advanced Research Center. His research interests include modeling and control of power electronics converters, HVDC and MVDC systems, and grid integration of renewable energy. He is leading multiple research projects sponsored by the Department of Energy and GE business sectors. He specializes in modeling, control and stability analysis of power electronics dominated power grids, especially for hybrid AC and DC systems in different grid sections, such as transmission system interconnection via HVDC networks, MVDC distribution systems, and hybrid AC and DC microgrids. He also substantially contributed to the development of impedance-based stability analysis approach for large-scale AC and DC systems, which is applied to various real-world applications. Hanchao Liu received his B.S. degree from Shandong University, Jinan, China, and his Ph.D. degree from the Rensselaer Polytechnic Institute, Troy, NY, USA.