Recent Advancements on High-Power DC/DC Converters for DC Transmission and Distribution

Name(s) and Affiliation(s) of the Lecturer(s):

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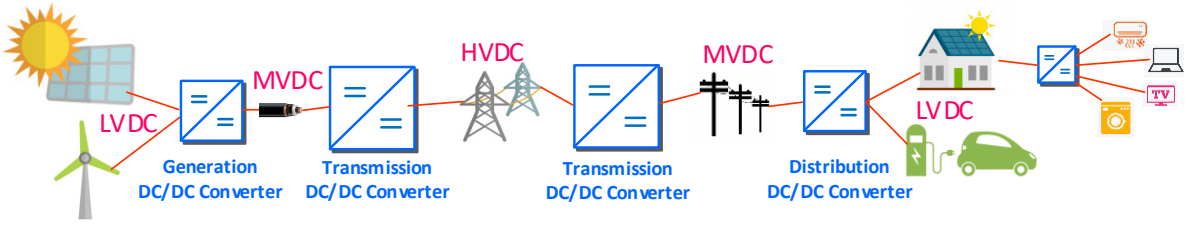
Tutorial Objectives:

In this paragraph, please describe the tutorial objectives of the tutorial that you propose. Please make sure the objectives are clearly described.

With the increased penetration of renewable energy sources and ubiquitous power electronics apparatus, DC power is making a comeback. In the generation aspect, the PV, wind, and energy storage are inherently DC sources. For transmission, the HVDC has become the feasible solution for transmitting a large amount of power over long distance or submarine/underground cables. For distribution, the MVDC is more capable of accommodating a higher penetration of renewable energy and friendly to EV charging stations. Therefore, DC grid is of increasing interests in both academics and industries.



Nevertheless, as an analogy of line-frequency transformers in AC systems, DC grids also require such a device to exchange power between networks with different voltage levels. As a DC circuit does not satisfy the law of Electromagnetic Induction, it is not possible to use magnetic transformers to convert DC voltage directly without engagement of power electronics technology. Although the DC/DC power-electronic converters have been widely studied and applied at low-power applications and a myriad of topologies have been proposed, most of these topologies are not readily scaled up to tens/hundreds of kilovolts and megawatt power ranges, due to the limitations of loss, cost, dv/dt, and ratings of the semiconductors. To overcome these limitations, several novel high-power DC/DC converter topologies have been proposed and demonstrated during the last few years. This tutorial

will give a systematic review of the latest development in this field. The tutorial will start with an introduction of the applications for high-power DC/DC converters, which is followed by a review of the basics and some widely used converter solutions in this field. Then the first theme is discussion of DC/DC converters for interconnecting LVDC and MVDC systems, including a ±10kV/±375V 1.5MW solid-state transformer, bipolar/multi-port LVDC distribution, and PV/wind DC collection. The second theme is DC/DC converters for MVDC and HVDC interconnection, which presents a novel converter solution combining the techniques of IGCT-based two-level converter and the MMC, and the converter is further improved for application of all DC offshore wind farms. Furthermore, the third theme will focus on the DC/DC conversion which interconnects HVDC systems with different voltage levels. Particularly, the capacitive energy transfer (CET) principle based DC/DC converters are discussed, which includes a series of new topologies, showing very attractive features of low cost, high efficiency, small footprint, and DC fault-blocking capability. Finally, a summary and outlook are provided. In this tutorial, all these converters and corresponding operation techniques will be explained with simulation and experimental results.

Target Audience:

In this paragraph, please describe the target audience of the tutorial that you propose. Please make sure the target audience is clearly described.

The target audience of this tutorial is anyone who is active or interested in high-power DC/DC power conversion, DC distribution, DC solid-state transformer, DC renewable energy collection, and HVDC grid. This tutorial will also be beneficial for the experienced researchers who want to have a systematic look at this research field or explore relevant projects/products.

Topical Outline:

Introduction: (Estimated time: 10 minutes)

- Review of DC/DC conversion techniques
- Application scenarios of high-power DC/DC converters
- Challenges faced by high-power DC/DC converters

Basics for High-Power DC/DC conversion: (Estimated time: 20 minutes)

- Dual-active bridge DC/DC converter
- Series resonant DC/DC converter
- Input parallel output series DC/DC converters
- Front-to-front MMC DC/DC converter
- MMC DC auto transformer

DC/DC Converters Interconnecting LVDC & MVDC Systems, Theme 1 (Estimated time: 55 minutes)

- DC solid-state transformers with a ±10kV/±375V demonstration
- DC/DC converters for bipolar MVDC and LVDC distribution
- DC/DC converters with multiple LVDC ports

- DC/DC converters for PV/wind DC collection
- Simulation or prototype verifications

Coffee Break：20 mins

DC/DC Converters Interconnecting MVDC & HVDC Systems, Theme 2 (Estimated time: 40 minutes)

- Two-level IGCT converters & MMC hybrid DC/DC Converter
- MVDC/HVDC unidirectional DC/DC converter for all-DC offshore wind farms
- Simulation or prototype verifications

DC/DC Converters Interconnecting HVDC Systems, Theme 3 (Estimated time: 55 minutes)

- The principle of capacitive energy transfer (CET) for DC/DC conversion
- CET HV DC/DC converter with integrated DC fault-blocking capability
- CET HV DC/DC converter with low-cost mechanical disconnectors
- CET HV DC/DC converter with a high step-up voltage ratio
- CET HV DC/DC converters as power flow controller in meshed HVDC grid
- Simulation or prototype verifications

Conclusions (Estimated time: 10 minutes)

- Summary
- Future Trends

Provisional Schedule of the Tutorial:

Schedule:

09:30 - 10:55 : Introduction / Basics / Theme 1
10:55 - 11:15 : Coffee break
11:15 - 13:00 : Theme2 / Theme 3 / Conclusions

About the Lecturers:

Binbin Li received his PhD degree in Electrical Engineering from Harbin Institute of Technology (HIT), China, and is currently Professor in School of Electrical Engineering and Automation, HIT. He has been selected in the Young Elite Scientists Sponsorship Program by China Association for Science and Technology. Currently, he is associate editor of IEEE Transactions on Power Electronics, IEEE Open Journal of the Industrial Electronics Society and member of Editorial Board for Journal of Power System Protection and Control. He holds more than 20 patents and has collaborated with the industries developing several mega-watt power converters, such as 1.5MW ±10kV/±375V DC solid-state transformers, 3kV/1MW modular multilevel converter, and published more than 40 journal papers in the field of modular high-power converters. He has given a number of tutorials in the conferences such as PEAC2018, IECON2019, IECON2020, and ECCE-Asia 2020.

Yingzong Jiao received his Ph.D. degree in Electrical Engineering from Zhejiang University (ZJU), China, and is currently a postdoc at the School of Electrical Engineering and Automation, Harbin Institute of Technology (HIT). He published more than 10 papers in the field of power electronics and power systems integrated with renewable generations. He received the best paper in the conference of HVDC 2020.

Shenghui Cui Shenghui Cui (Member, IEEE) received the B.S. degree from Tsinghua University, Beijing, China, in 2012, the M.S. degree from Seoul National University, Seoul, South Korea, in 2014, and the Dr.-Ing. degree with the highest distinction (summa cum laude) from RWTH Aachen University, Aachen, Germany, in 2019, all in electrical engineering.

Since September 2021, Dr. Cui is with Department of Electrical and Computer Engineering, Seoul National University, Seoul, South Korea as an assistant professor. From March 2015 to May 2021, he has been with the Institute for Power Generation and Storage Systems, E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany, where he worked as research associate and later on senior scientist. His research interests include interaction of power systems and power converters, power converters in ac/dc utility applications, and applications of wide-band gap power devices.

Dr. Cui was the recipient of the STAWAG Best Dissertation Prize from Faculty of Electrical Engineering and Information Technology, RWTH Aachen University in 2019, the Second Place Prize Paper Award of the IEEE Transactions on Power Electronics in 2018, the Second Prize Paper Award of IEEE IPEC (ECCE Asia) in 2018, and the Outstanding Presentation Award of the IEEE Applied Power Electronics Conference in 2014.