
EPE'25 – Call for Tutorials

# DC Transformers for DC Distribution and Transmission

## 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 increasing integration of renewable energy sources and the widespread use of power electronics, DC power systems are gaining renewed interest. In generation, sources like photovoltaic (PV), wind, and energy storage are inherently DC-based. For transmission, High Voltage Direct Current (HVDC) technology has become a viable solution for transmitting large amounts of power over long distances or through submarine and underground cables. In distribution, Medium Voltage Direct Current (MVDC) systems are more capable of accommodating higher penetrations of renewable energy and are well-suited for electric vehicle (EV) charging stations and data centers. Consequently, DC systems are drawing significant interest from both academia and industry.

However, just as line-frequency transformers are essential in AC systems, DC systems also require devices to exchange power between networks at different voltage levels. Since DC circuits do not adhere to the law of electromagnetic induction, magnetic transformers cannot be used to directly convert DC voltage without the involvement of power electronics. Although DC/DC power-electronic converters have been extensively studied and applied in low-power applications, scaling these topologies to tens or hundreds of kilovolts and megawatt power levels presents significant challenges, including issues related to voltage stress, losses, costs, dv/dt, and volume of the passive filters.

This tutorial systematically reviews the latest advancements in high-power DC transformer technologies. The tutorial begins with an introduction to the applications of high-power DC transformers, followed by a review of the basic concepts and widely used DC converter solutions. It then focuses on three main themes:

1) DC Transformers for DC Distribution and Collection: This section will provide a comparative review of state-of-the-art dual-active bridge (DAB) and series resonant converters (SRC) based modular solutions. It will also cover their advanced control and design considerations in DC distribution, renewable DC collection, and dc energy storage, with practical industry applications highlighted to demonstrate the versatility and implementation of these converters.
2) DC Transformers for HVDC Interconnection: Solutions for efficiently managing HVDC voltage levels and integrating HVDC circuit breakers within the DC transformers will be explored. The capacitive energy transfer principle for HVDC conversion will be introduced.

3) DC Transformers for Interconnecting MVDC & HVDC Systems: This section will present a novel converter solution that combines thyristor technology with cascaded submodule topologies. The converter's enhancements for applications in all-DC offshore wind farms will also be discussed.

The tutorial will conclude with a summary and outlook on future developments in this field. Attendees will gain insights into various converter topologies, their operational principles, and related demonstration projects, supported by both simulation and experimental examples.

## 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 are active or interested in high-power DC/DC power conversion, DC distribution, DC solid-state transformer, DC renewable energy collection, DC energy storage, and multi-terminal/meshed HVDC system. 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)**

- Application scenarios of high-power DC Transformers
- Projects and Demonstrations of high-power DC Transformers
- Challenges faced by high-power DC Transformers

**Basics for High-Power DC/DC conversion: (Estimated time: 40 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 derived DC/DC converter

**DC Transformers for DC Distribution and Collection: (Estimated time: 40 minutes)**

- DC/DC converters for DC distribution and its demonstration
- DC/DC converters for PV/wind DC collection and its demonstration
- DC/DC converters for battery energy storage

**Coffee Break： 30 mins**

**DC Transformers for HVDC Interconnection: (Estimated time: 40 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 high-current capacility

**DC Transformers for Interconnecting MVDC & HVDC Systems: (Estimated time: 40 minutes)**

- DC/DC converter for all-DC offshore wind farms


- Non-isolated MVDC/HVDC DC/DC conversion
- Isolated MVDC/HVDC DC/DC conversion
- Multi-port MVDC/HVDC DC/DC conversion

**Conclusions: (Estimated time: 10 minutes)**

- Summary
- Future Trends

## Provisional Schedule of the Tutorial:

Schedule:

09:30 - 11:00 : Introduction / DC Transformer Basics / DC distribution
11:00 - 11:30 : Coffee break
11:30 - 13:00 : HVDC interconnection / MVDC&HVDC Interconnection / 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. Currently, he is AE 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 developed several mega-watt power converter products, ±10kV DC solid-state transformers, 2.4MW 10kV/240V data center power supply, and published more than 50 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, ECCE-Asia 2020, and EPE 2023.

**Yingzong Jiao** received his Ph.D. degree in Electrical Engineering from Zhejiang University (ZJU), China, and is currently assistant professor at the School of Electrical Engineering and Automation, Harbin Institute of Technology (HIT). He is PI of 5 research projects related with the DC renewable collection and DC/DC power conversion. He has published more than 10 journal papers in the field of power electronics and power systems integrated with renewable generations. He received the best paper award in the conference of HVDC 2020, given tutorials in conferences of PEDG2023 and EPE2023.

**Ning Wang** (Student Member, IEEE) received the B.S. degree from Dalian Maritime University, China, in 2021, the M.S. degree from Harbin Institute of Technology (HIT), China, in 2023. He is currently working toward the Ph.D. degree in power electronics. His current research interests include high-power DC transformers, MVdc collection/distribution system and design of medium frequency transformer.