Tutorial Title:

Recent Advances on Modular-based Multilevel Voltage-Source Converter (VSC) for MV and HV applications: Principle, Control, and Its competitiveness with MMC

Organizer:

Dong Dong, Virginia Tech, dongd@vt.edu

Di Zhang, Naval Postgraduate School, di.zhang@nps.edu

Abstract:

The global electrification trend in power grid and transportation accelerates the demand for high-performance, high-density, and high efficiency ac-dc power conversion system in the Medium-voltage (MV) and High-voltage (HV) areas ranging from a few kV to hundreds of kV. The conventional voltage-source converter (C-VSC) cannot meet such demand due to limited range of voltage offering, poor power quality, slow dynamic-response, and last but not least, long development and test cycle.

Since the invention of Modular Multilevel Converter (MMC) technology, it quickly dominated the high-voltage direct current (HVDC) VSC market and penetrated to the MV grid-interface applications like STATCOM. The modular-in-nature solution offered by MMC fundamentally changed the way of building MV and HV converters. However, MMC still faces several challenges like large footprint, high-cost, and low-efficiency, making it face a strong competition from the C-VSC in the MV area. Therefore, combing the benefits from both MMC-VSC and C-VSC are strongly desired for next-generation modular-in-nature VSCs.

This tutorial will summarize and present an overview of the most recent research progress on various modular MV/HV VSC converter topologies, including Alternative-Arm-Converter (AAC), Asymmetric Alternate Arm Converter (AAAC), hybrid modular-multilevel converters (HMMC) and hybrid modular-multilevel rectifier (HMMR), as the next-generation solution beyond both MMC and C-VSC. The basic operational principle, topological derivation, modeling and control, and apple-apple comparison with MMC in terms of efficiency, cost, and size will be discussed. Several emerging and existent MV and HVDC application cases will be presented to showcase the detailed HMMC/HMMR use cases and their competitiveness to surpass MMC and C-VSC as the next-generation VSC solutions.

Bio:

Dong Dong received the B.S. degree from Tsinghua University, Beijing, China, in 2007, and the M.S. and Ph.D. degrees from Virginia Tech, Blacksburg, VA, USA, in 2009 and 2012, both in electrical engineering.

From 2012 to 2018, he was with GE Global Research Center (GRC), Niskayuna, NY, USA, as an Electrical Engineer. At GE, he participated in and led multiple technology programs including MV/HVDC power distribution and power delivery, SiC high-frequency high-power conversion systems, solid-state transformers, and energy storage system. He received GE gold medallion

patent award and GE technology transition awards. Since 2018, he has been with the Bradley Department of Electrical and Computer Engineering, Virginia Tech. He has published over 35 referred journal publications and more than 80 IEEE conference publications. He currently holds 29 granted US patents. His research interests include wide-band-gap power semiconductor-based high frequency power conversion, soft-switching and resonant converters, high-frequency transformers, and MV and HV power conversion system for grid, renewable, and transportation applications. Dr. Dong is currently an Associate Editor for IEEE Transactions on Power Electronics. He received two Prize Paper Awards from the IEEE TRANSACTIONS ON POWER ELECTRONICS and IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS and William Portnoy Prize Paper Award from IEEE IAS. He served as the Vice Chair of IEEE Industry Application Society Schenectady Region Chapter in 2017 and General Chair of IEEE International Conference on DC Microgrids in 2021.

Di Zhang received the B.S. and M.S. degrees from Tsinghua University, Beijing, China, in 2004 and 2006, respectively, and the Ph.D. degree from Virginia Tech, Blacksburg, VA, USA, in 2010, all in electrical engineering. He is currently an Associate Professor with Naval Postgraduate School, Monterey, CA, USA. His research interests include the modeling and design of medium to high voltage power converters, SiC-based high performance power conversion, and power conversion system for grid, renewable, and aviation.