Tutorial: **Capacitors in Power Electronics Applications – Passive and Active Capacitive DC Links**

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1. Scope and Benefits

Capacitors are key components in typical power electronic systems in terms of cost, volume, and reliability. Power electronics applications are consuming unprecedented quantities of electrolytic capacitors, film capacitors, and ceramic capacitors, especially for capacitive DC links of voltage source converters (VSC). Innovative capacitive DC-link solutions have attracted many attentions from industry and academia in the applications of wind power, Photovatics, electric vehicles, and modular multi-level converters, etc. This tutorial aims to discuss the design and reliability of various types of capacitive DC links in VSC applications. The topology derivation, operation principle, technology benchmarking, and reliability-oriented design of active capacitive DC links assisted by semiconductor devices will be presented. A concept of two-terminal active capacitors having the same convenience level as passive capacitors will also be introduced.

By attending the tutorial, the participants expect to be able to answer the following questions:

- What are the strengths and limits of different types of capacitors for power electronics applications?
- How to size capacitive DC links to avoid over-design or lack of design margin?
- Which active capacitive DC-link solution(s) is the best for specific applications with given design constraints in terms of cost, lifetime, efficiency, and power density?
- Are active capacitive DC links more reliable than passive capacitors? Are they economic viable? How to perform a quantitative reliability analysis and a fair comparison?
- How to achieve the same convenience level for active capacitive DC links as that of passive ones in new product development or existing product maintenances?

2. Tutorial Contents and Time Schedule

September 17th, 2018, half-day

- **Introduction to capacitive DC links in power electronic systems (45 minutes)**
  - Functions of capacitive DC links
  - Strengths and limits of different capacitor technologies from application perspective
  - Sizing criteria of capacitive DC links
- **Active capacitive DC links – technology evolution (45 minutes)**
  - A generic topology derivation method
  - Key performance factors of active capacitive DC links

Coffee Break (30 minutes)

- **Technology benchmarking of active capacitive DC links (30 minutes)**
  - Description of case studies
  - Reliability oriented component sizing
  - Cost assessment and scalability analysis
- **A two-terminal active capacitor (45 minutes)**
  - Concept of two-terminal active capacitor – control scheme and self-power strategy
  - Practical implementation of a two-terminal active capacitor
  - Application case studies
- **Final Q&A and wrap up (15 minutes)**

3. Who Should Attend

- University researchers who are interested in capacitors for power electronic applications in general and active DC-link solutions assisted by semiconductor devices.
- Industry power electronic designers who would like to have better understanding in how to design proper capacitive DC links to fulfil electrical, thermal, and reliability aspects of product specifications with reduced cost.
- Capacitor manufacturers and/or suppliers who would like to know more about the capacitor challenges and opportunities in specific power electronics applications.
- The pre-requisites knowledge is basic power electronics.

4. About the Instructors

Huai Wang is currently an Associate Professor and a Research Thrust Leader with the Center of Reliable Power Electronics (CORPE), Aalborg University, Denmark. His research addresses the fundamental challenges in modelling and validation of power electronic component failure mechanisms, and application issues in system-level predictability, condition monitoring, circuit architecture, and robustness design. In CORPE, he also leads a capacitor research group including multiple PhD projects on capacitors and its applications in power electronic systems, and collaborates with various industry companies across the value chain from manufacturers to end-users of capacitors. Prof. Wang lectures two Industrial/PhD courses on Capacitors in Power Electronics Applications, and Reliability of Power Electronic Systems at Aalborg University. He has given more than 20 tutorials at leading power electronics and reliability engineering conferences (e.g., ECCE, APEC, IECON, PCIM, ESREF, etc.) and a few keynote speeches in the above research areas. He has co-edited a book on Reliability of Power Electronic Converter Systems in 2015.

Prof. Wang received his PhD degree from the City University of Hong Kong, Hong Kong, China, and B. E. degree from the Huazhong University of Science and Technology, Wuhan, China. He was a short-term visiting scientist with the Massachusetts Institute of Technology (MIT), USA, and ETH Zurich, Switzerland. He was with the ABB Corporate

Research Center, Baden, Switzerland, in 2009. Dr. Wang received the Richard M. Bass Outstanding Young Power Electronics Engineer Award from the IEEE Power Electronics Society in 2016, for the contribution to reliability of power electronic converter systems. He serves as the Award Chair of the Technical Committee of the High Performance and Emerging Technologies (TC6), IEEE Power Electronics Society, and as an Associate Editor of IET Power Electronics, IEEE Journal of Emerging and Selected Topics in Power Electronics, and IEEE Transactions on Power Electronics.

Haoran Wang received the B.S. (Hons) degrees in control science and engineering from Wuhan University of Technology, Wuhan, China, in 2012. During 2012 to 2015, he was enrolled in a master joint training program in School of Automation, Wuhan University of Technology, Wuhan, China and Department of Electrical Engineering, Tsinghua University, Beijing, China, and received the M.S. (Hons) degrees in control science and engineering in 2015. He is currently a PhD student in Center of Reliable Power Electronics (CORPE), Department of Energy Technology, Aalborg University, Denmark. Now, he is a visiting PhD student with the ETH Zurich, Switzerland, since Dec. 2017.

He received the Best Oral Presentation Award from 16th International Symposium "Topical Problems in the Field of Electrical and Power Engineering" in 2017, Best Thesis for Bachelor and Best Thesis for Master Degree in Hubei Province, China, in 2012 and 2015, respectively, and Grand Prize and First Prize Academic Science and Technology Competition Award, at 2010 and 2011.

5. Contact Details

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