Challenges and Perspectives of Medium Voltage SiC MOSFETs (>6kV) in Power Electronic Converters

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Tutorial Objectives:

Reliable and sustainable green energy is one of the most important actions to combat climate change. In the research group at Aalborg University, we are funded and supported by three world-leading wind industry companies to conduct research on the use of advanced Silicon Carbide (SiC) power semiconductors (>6kV) for two-level medium-voltage power converters. According to our ongoing research project, we already see promising features of utilizing in future high-power (MW-level) energy conversion applications with increased 1-2% system-level efficiency, which can save hundreds of gigawatts of electricity for the world in the future.

During the tutorial presentations, the outcomes of our research will be shared. We will highlight the remaining challenges and our perspectives on using the advanced medium-voltage SiC technology. We will share insights from the demonstrated system where we have studied power module packaging, layout related energy dissipation, gate drivers, cooling, and magnetics, where capacitive couplings have been shown as the bottlenecks for the demonstrated medium-voltage system.

The summarized objectives of this tutorial are as follows:

- To share the motivation and perspectives for medium-voltage power converter systems enabled by the SiC MOSFETs.
- To provide the attendees with novel and state-of-the-art research knowledge on the applications of medium-voltage SiC MOSFETs.
- To share insights on system and component level challenges in utilizing the medium-voltage SiC MOSFETs.

Acknowledgment: Innovation Fund Denmark grant for the project: MVolt 'Medium voltage power electronics for wind systems'. Three industrial partners support the project, including Vestas A/S, Siemens Gamesa, and KK wind solutions.

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 challenges on material for better dielectric and thermal characteristics may inspire new and experienced researchers within the Power Electronics community with novel and innovative ideas for progressing the medium-voltage SiC power semiconductor technology further. The vision of the advanced technology and future high-power electric energy system can also motivate relevant IEEE researchers and industry members to expand the technology to more applications, e.g., power-to-X applications, ultra-fast EV charger stations, solid-state transformers, and more.

Topical Outline:

Background & Introduction to power electronics in future energy systems (25 min. + 5 min. Q&A)

- Background and state-of-the-art power electronics technology.
- Comparison between conventional and novel power electronics semiconductor components (eg. medium-voltage SiC MOSFETs), advantages, and design challenges.
- Introduction of the gains and pains of power electronics in future energy systems.

Overview and Agenda: (5 min.)

- A brief overview of the content of the next 4 topics will be given.

Medium-voltage or low-voltage? Insights from industrial applications (20 min. + 5 min. Q&A)

- Motivation and hypothesis for using 10 kV SiC MOSFETs.
- Insights from industrial applications.
- Introduction of the unique characteristics of medium-voltage SiC power semiconductors.
- Presentation of the demonstrated power electronics converter system enabled by 10 kV SiC MOSFETs.

Packaging techniques, challenges, and opportunities for 10 kV SiC MOSFETs (30 min. + 5 min. Q&A)

- Challenges of power modules made with SiC MOSFETs compared with conventional technology.
- Design paradigm and constraints in terms of challenges and opportunities for 10 kV SiC MOSFETs.
- Opportunities that can come when moving away from conventional design strategies.

Challenges in utilizing 10kV SiC MOSFET in power converter systems (30 min. + 5 min. Q&A)

- Challenges with regards to utilizing 10kV SiC devices in the practical power conversion applications.
- Overview of parasitic capacitive couplings, from component to system level.
- Layout capacitances impact on switching performance.
- Measurement circuits and strategies for medium-voltage SiC MOSFETs applications.

A power cycling test setup for medium voltage converters (25 min. + 5 min. Q&A)

- Introduction of a power cycling test platform for evaluating the medium voltage power electronic converter.

- Approaches for power loss estimation will be presented.
- Recent experimental findings will be shared.

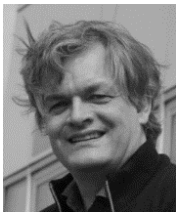
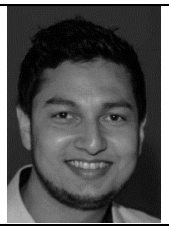
Conclusions and wrap-up (10 min. + 10 min. Q&A)

- Future perspectives and needed research topics will be shared.
- Wrap-up and conclusions on topics.

Provisional Schedule of the Tutorial:

08:45 - 10:20: Introduction & Overview / Theme 1 / Theme 2
10:20 - 10:45 : Coffee break
10:45 - 12:00 : Theme 3 / Theme 4 / Conclusions

About the Lecturers:

	**Stig Munk-Nielsen** is currently Professor at the Energy Department, Aalborg University, Denmark. He received the M.Sc. and Ph.D. degrees from Aalborg University, Denmark, in 1991 and 1997, respectively. His research interests include LV and MV Si, SiC and GaN converters, packaging and power converter circuits. Since 2013 he secured funding for a die packaging team and laboratory facilities for 10 kV SiC devices. In the last ten years, he has been involved in or has managed 10 research projects. He has published 229 international power electronic papers and has an H-index of 38.
	**Bjørn Rannestad** currently senior specialist in Power Converters, Global Technology & Innovation at KK Wind Solutions, Denmark. He has 14 years of experience in the development and research for wind turbine power electronic converters. He started his career in the industry in 1999, at Grundfos, Denmark. In 2019, he finished the industrial Ph.D. program at Aalborg University, with a focus on megawatt power electronics converters for wind turbines. He has published more than 10 patent applications and 30 academic papers on various power electronic topics.
	**Michael Møller Bech** is currently an Associate Professor at the Energy Department, Aalborg University, Denmark. In 2000 he earned the Ph.D. degree in Power Electronics and Drives from Aalborg University. He has 27 years of experience with research and development and he works a part-time consultant to Danish companies. His interests include power electronic converters, motor drives and their control, system design optimization and experimental work in these fields.
	**Jannick Kjær Jørgensen** is currently a researcher at at the Energy Department, Aalborg University, Denmark. Since 2018 he has worked on design and manufacture of 10 kV SiC-based power modules. He has recently founded the company Aalborg Power Group - helping customers accelerate their adoption of modern power electronics by design and prototype manufacturing. His great passion is the ongoing Great Electrification of society and how SiC can help accelerate this megatrend.
	**Benjamin Futtrup Kjærsgaard** is currently Research Assistant at the Energy Departmen, Aalborg University, Denmark. His research interests inlude SiC MOSFET switching dynamics and understanding the impact of capacitive couplings from an intra-component systems level perspective. Through his master's degree and activities as Research Assistant he has gained practical experience with 10kV SiC MOSFETs and power modules and the challenges associated with this novel technology.