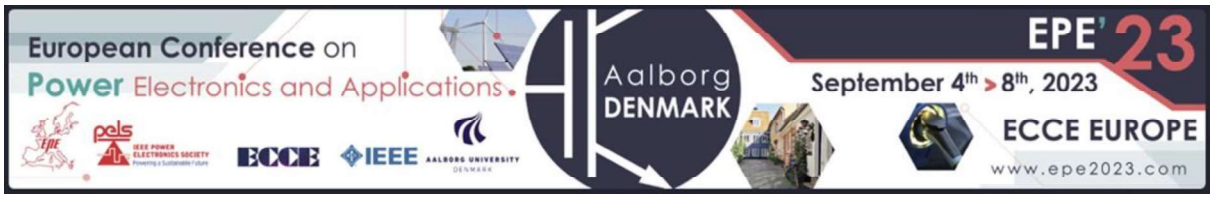

EPE'23 ECCE Europe – Call for Tutorials

Multi-objective and highly precise optimization of high performance SiC and GaN multilevel power converters with severe constraints

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

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Tutorial Objectives:

The objective of this tutorial is to give an overview on how to precisely and quickly optimize high performance converters using disruptive power semiconductor technology (SiC and GaN transistors) associated to multilevel topologies in order to achieve very high efficiency and power density. Besides the general overview about SiC and GaN technology, we focus on the precise characterization of SiC and GaN in order to evaluate their impacts in a power converter. Multilevel topologies and their impact on the system will be explained in details. Furthermore, precise (but fast) models for designing cooling system, input and output common and differential mode filters will be detailed, as well as the impact of PWM methods to increase even more the converter performance.

Target Audience:

Thus, the intention is to have an audience which has a basic-to-intermediate level of knowledge on power electronics, aiming to understand how SiC and GaN make a big difference when designing power converters for high efficiency and high power density applications.

Topical Outline:

1 -Introduction:
estimated time, 20 minutes

- General aspects of power converter optimization
- Relation between Efficiency, Power Density, Reliability and Cost in a power converter design
- Main components and their relationship with power converter performance
- Wide Bandgap (WBG) components and advanced converter topologies

2 - SiC and GaN Overview: *estimated time, 20 minutes*

- WBG physics and manufacturers (from prototype to mass production)
- WBG transistors (MOSFET, JFET, BJT…)

- Vertical or lateral structure and associated packaging
- Advantages and disadvantages

3 - SiC and GaN loss calculation: *estimated time, 40 minutes*

- Transistor characteristics
- Comparison between Si and SiC three-phase inverters for aircraft applications
- Switching characteristics of MOSFET components (deep explanation)
- Precise switching loss calculation
- Calculation and comparison with experimental results in a 15kVA/540V three-phase inverter for aircraft applications using SiC MOSFET

4 - Characterization of SiC and GaN for high precision loss calculation: *estimated time, 50 minutes*

- Characterization of switching losses
- Disadvantages of classical method (double pulse test)
- Presentation of adapted switching energy measurement method
- Example of results using this new method.
- Importance of precise switching energy in converter design

5 - Multilevel topologies: *estimated time, 50 minutes*

- Overview on multilevel topologies
- Series and parallel multilevel topologies. Advantages and disadvantages
- High performance high voltage and high current converter improvement by using series and parallel multilevel topologies
- Trade-off between losses and weight in a power drive system for aircraft applications using multilevel topologies and WBG components

6 - Filter Design: *estimated time, 90 minutes*

EMI, DC Network Stability and Power Quality

- Conducted Emissions issues
- Impact of switching speed and overvoltage in conducted common-mode EMI
- Common-mode (CM) current estimation and filter design
- Differences between coupled and uncoupled input and output models
- Influence of motor CM impedance in the system efficiency x power density
- Impact of CM filter distribution in a multilevel converter
- Network Stability and Power Quality issues
- Differential-mode (DM) current estimation and filter design
- Impact of conducted emissions limits on DM input filter design

Overvoltage and THDi issues

- Overvoltage issues on electric motor
- Impact of switching speed in overvoltage of motors connected to power converters
- Overvoltage model (simple open circuit, influence of motor impedance and single-phase x three-phase models).
- THDi issues on electric motor
- DM output filter topologies
- Impact of Overvoltage and THDi levels in the system efficiency x power density

7 - Heat sink optimization: *estimated time, 30 minutes*

- Analytical versus simulated models of heat sink
- Fast and precise analytical model and validation by experimental tests
- Optimization components position on heat sink
- Use of heat sink optimization for fast power converter optimization

8 - PWM Methods: *estimated time, 40 minutes*

- Analytical versus simulated models of heat sink

- Influence of PWM methods on converter losses and verification by experimental
- Influence PWM methods on converter reliability
- General methodology to create optimal PWM methods
- Optimal PWM methods to improve power density and efficiency of multilevel converters

9 - Conclusions

estimated time, 20 minutes

- How to further optimize the system by working on the packaging of SiC and GaN: SiC power module optimization and GaN packaging optimization by PCB embedded solutions
- Use of MultiDisciplinary Optimization (MDO) and advanced tools to improve system design
- Perpesctives on multilevel topologies, WBG semiconductors (Diamond!) and power converter optimization

Provisional Schedule of the Tutorial:

09:30 - 11:00 : Introduction / Themes 2 and 3
11:00 - 11:30 : Coffee break
11:30 - 13:00 : Themes 4 and 5
13:00 - 14:30 : Lunch break
14:30 - 16:00 : Theme 6
16:00 - 16:30 : Coffee break
16:30 - 18:00 : Themes 7 and 8 / Conclusions

About the Lecturers:

Bernardo Cougo received the B.S. degree in electrical engineering from the UFMG/Brazil, and stiudied at University of Texas at Austin/USA. He obtained his M.Sc. degree in electrical engineering from UFMG, and his Ph.D. degree from the Institut National Polytechnique (INPT), Toulouse, France, in 2010. He worked as a post-doctorate fellow at the PES Laboratory, at ETH-Zurich, in Switzerland and also at LAAS and LAPLACE laboratories in Toulouse, France. His is currently working as a Power Electronics Expert at the French Institute of Technology IRT Saint-Exupery. He has taught in different universities in Brazil and France, and he is currently a lecturer at ENSEEIHT/INP on subjects related to power electronics integration and Wide Bandgap semiconductors. He advises several Ph.D. students and Post-doctorate fellows on research projects related to SiC and GaN module and converter design, mainly for aircraft applications. He has more than 60 publications since 2008 about power electronics integration, multilevel converters and WBG semiconductor characterization and applications.

Hans Hoffmann Sathler received the bachelor's degree in Electrical Engineering from CEFET-MG, Brazil in 2015, the Master's Degree in Power Electronics at UFMG, Brazil in 2017, with research internship at IRT Saint Exupery in France. He obtained his Ph.D. degree from Paris Saclay University, Paris, in 2021. During his Ph.D. he was a visiting scholar at the Center for Power Electronics (CPES), Blacksburg, USA. He is currently working as Research Engineer on EMI Filter Design and Power Electronics at Schaffner EMV AG in Switzerland.