EPE Tutorial

TITLE

The GOOGLE Little Box Challenge - Ultra-Compact GaN- or SiC-Based Single-Phase DC/AC Power Conversion: *Component Technologies / System Concepts / Performance Barriers / Future Technologies*

NAME AND AFFILIATION OF THE AUTHORS

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SCOPE AND BENEFITS

The GOOGLE Little Box Challenge was aiming to build the worldwide smallest air-cooled 2kVA DC/AC converter and accordingly created a huge interest in the power electronics community and resulted in a massive performance improvement compared to state-of-the-art technology systems. This seminar explains the approach selected by the authors along with a detailed discussion and comparative evaluation of the concepts presented by other finalists. All important design considerations for realizing an ultra compact PV inverter such as the selection of the main power circuit topology, the buffering of the power pulsation with twice the output frequency, the EMI filter topology and the modulation and control of the converter stages are detailed in this seminar. Furthermore, GaN and SiC power semiconductor technology are evaluated and the realization of high-frequency inductors with multi-airgap magnetic cores and low high-frequency loss winding arrangements are explained. In this context also the increase of the core losses by mechanical stress resulting from the cutting process is discussed. The seminar would like to convey the main results and findings of the GOOGLE Little Box Challenge and is tailored to serve the interests of a broad audience with academic or industrial background.

CONTENTS

Afternoon Tutorial on Monday, 11 September 2017

14:00 -.14:30 GOOGLE Little Box Challenge

- Technical Specifications / Targets
- Comparison to Industrial Requirements of Single-Phase PFC Rectifiers / PV Inverters

14: 30 – 15:30 Circuit Topologies and Modulation / Control Concepts

- Full-Bridge Converter / Buck Converter and Unfolder / Autotransformer-Based Topologies
- Two-Level or Multi-Level Topologies
- Series and Parallel, DC or AC Side Power Pulsation Buffers
- EMI Filtering – Filtering against DC Rail or Conventional Filtering Splitted into DM and CM Stages
- PWM vs. Triangular Current Mode (TCM) ZVS or OFM (Optimal Combination

of PWM and TCM)
- Interleaving incl. 4D-Interleaving Strategies

15:30 – 16:00 Coffee Break

16:00 – 17:00 Active / Passive Component Technologies
- GaN vs. SiC Power Semiconductors, Switching and Conduction Losses
- Gate Drive and Accurate Calorimetric ZVS Loss Measurements
- Selection of Switching Frequency
- High Frequency Inductors / Multi-Airgap Inductors
- Increase of Core Losses due to Mechanical Stress Resulting from Cutting Process
- Winding Arrangements with Low High Frequency Losses

17:00 – 17:30 Mechanical Concepts / Experimental Results (0.5 h)
- Mechanical Construction and Heat Management of the System Realized by the Authors
- Key Waveforms of Experimental Analysis
- Details of Selected Finalists Systems
- Comparative Evaluation of Efficiency / Power Density Figures Achieved by the Finalists

17:30 – 18:00 Performance Barriers / Future Technology Requirements (0.5 h)
- Multi-Objective Optimization for Determining Absolute Performance Limits
- Performance Limit in Case of "Ideal" Switches
- Packaging / Component Technologies Required for Further Performance Improvement
- Future Prospects of Power Electronics

WHO SHOULD ATTEND

We would like to encourage researchers and engineers from both industry and academia who are interested in the design and realization of ultra-high power density converter systems to attend the tutorial session. Since all important steps of the implementation of a highly optimized power electronic converter system are covered, also graduate students are highly encouraged to attend.

Technical Level

The tutorial is tailored to serve the interests of a broad audience with academic or industrial background and will provide a broad overview of all technical concepts and challenges required for realizing high power density single-phase DC/AC or AC/DC converter systems. Although involved technical discussions are omitted in the interest of time, it is assumed that the attendee has a sound understanding of the basics of power electronics and control systems.

ABOUT THE INSTRUCTORS

Johann W. Kolar (F´10) received his Ph.D. degree (summa cum laude) from the Vienna University of Technology, Austria. He is currently a Full Professor and the Head of the Power Electronic Systems Laboratory at the Swiss Federal Institute of Technology (ETH) Zurich. He has proposed numerous novel PWM converter topologies, and modulation and control concepts and has supervised over 60 Ph.D. students. He has published over 750 scientific papers in international journals and conference proceedings, 3 book chapters, and has filed more than 140 patents. He has presented over 20 educational seminars at leading international conferences, has served as IEEE PELS Distinguished Lecturer from 2012 through 2016, and has received 25 IEEE Transactions and Conference Prize Paper Awards, the 2014 IEEE Power Electronics Society R. David Middlebrook Achievement Award, the 2016 IEEE William E. Newell Power Electronics Award, the 2016 IEEE PEMC Council Award, and the ETH Zurich Golden Owl Award for excellence in teaching. He has initiated and/or is the founder of 4 ETH Spin-off companies. The focus of his current research is on ultra-compact and ultra-efficient SiC and GaN converter systems, wireless power transfer, Solid-State Transformers, Power Supplies on Chip, as well as ultra-high speed and ultra-light weight drives, bearingless motors, and energy harvesting.

Dominik Bortis (M'09) received the M.Sc. degree in electrical engineering and the Ph.D. degree from the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland, in 2005 and 2008, respectively. In May 2005, he joined the Power Electronic Systems Laboratory (PES), ETH Zurich, as a Ph.D. student. From 2008 to 2011, he has been a Postdoctoral Fellow and from 2011 to 2016 a Research Associate with PES, co-supervising Ph.D. students and leading industry research projects. Since January 2016 Dr. Bortis is heading the newly established research group Advanced Mechatronic Systems at PES.

Dominik Neumayr (S´10) started his academic education at the University of Applied Sciences (FH) for Automation Engineering in Wels/Austria and received the Dipl.-Ing. (FH) degree in 2008. Starting as an industry internship, Dominik worked at the Center for Advanced Power Systems (CAPS) in Tallahassee/Florida between 2008 and 2011. In order to strengthen his knowledge in power electronics and control engineering, he continued his academic education at the Swiss Federal Institute of Technology in Zurich (ETH Zurich) and received the B.Sc. and M.Sc. degrees in electrical engineering and information technology in 2013 and 2015, respectively. Since spring 2015 he is a PhD student at the Power Electronic Systems (PES) Laboratory, ETH Zurich. His current research focuses on high power density converter systems.