Advances in High-Voltage Conversion-Ratio Step-Up Isolated DC-DC Converters with SiC Power Semiconductor Devices

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Scope and Benefits:

High-voltage conversion-ratio step-up isolated DC-DC converters have been widely used in industrial application such as electrostatic precipitation, medical X-ray, MVDC or HVDC grid, as well as pulsed power supply. This tutorial focuses the recent advances of high-voltage conversion-ratio step-up isolated DC-DC converters. The tutorial starts with the introduction of high frequency high-voltage conversion-ratio step-up isolated DC-DC converters including the basics, development history, the state-of-the-art technologies and future trends. The opportunities and challenges of SiC devices for the high-voltage conversion-ratio step-up isolated DC-DC converters are presented. Secondly, the HV architectures are classified and evaluated in detailed. Then the characterization and modelling of SiC MOSFET, and comprehensive design methodology are given. The generic steady-state circuit modeling methodologies and output voltage sharing technologies are introduced. Finally, the technology demonstrator and prototype experimental results of SiC MOSFET based 300kHz~500kHz 10kW DC-DC converter with 650V input voltage and 140kV output voltage are provided. The audience will be the entry level and intermediate university students and engineers in industry who are interested in high frequency DC-DC converter, SiC devices, and high-voltage conversion-ratio power supply technologies.

Contents:

Schedule is as follows:

Friday, 9 September 2022 - 2nd Tutorial Day - Afternoon

14:00 – 14:30 Introduction: 30 minutes

A. The state-of-the-art technologies of high-voltage conversion-ratio step-up isolated DC-DC converters
B. Development trends of high-voltage conversion-ratio step-up isolated DC-DC converters
C. Key enabling technologies for performance improvement of high-voltage conversion-ratio step-up isolated DC-DC converters
D. Opportunities of SiC power semiconductor for the high-voltage conversion-ratio step-up isolated DC-DC converters
E. Challenges of SiC power semiconductor for the high-voltage conversion-ratio step-up isolated DC-DC converters

14:30 – 15:00 Architectures for the high-voltage conversion-ratio step-up isolated DC-DC converters: 30 minutes

A. Derivation and classifications of HV architectures
B. Evaluation of HV architectures
C. Recommendations for the selection of the HV architectures

15:00 – 15:30 Design considerations of high frequency SiC power stage: 30 minutes

A. Switching characterization of 1200V SiC MOSFET
B. Circuit modeling of 1200V SiC MOSFET
C. High-speed gate driver solution for SiC MOSFET
D. Device parallel operation of SiC MOSFETs
E. High-speed digital control of SiC inverter

15:30 – 16:00 Coffee break

16:00 – 16:30 SiC and Silicon hybrid rectifier solutions for the voltage multiplier of high-voltage conversion-ratio step-up isolated DC-DC converters: 30minutes

A. Steady state analysis of Half-Wave Series Cockcroft-Walton voltage multiplier
B. Diode reverse recovery process of Half-Wave Series Cockcroft-Walton voltage multiplier
C. Diode reverse recovery mitigation of Half-Wave Series Cockcroft-Walton voltage multiplier with SiC and Silicon hybrid rectifier solutions
D. Prototype experimental validation results

16:30 – 16:50 Generic steady-state circuit modeling methodologies: 20 minutes

A. Modeling of the LCC resonant high-voltage conversion-ratio step-up isolated DC-DC converters with the diode rectifier
B. Modeling of the LCC resonant high-voltage conversion-ratio step-up isolated DC-DC converters with the voltage multiplier
C. Generic steady-state circuit modeling of the LCC resonant high-voltage conversion-ratio step-up isolated DC-DC converters with multiple transformers and voltage multipliers
D. Comprehensive design and optimization procedures

16:50 – 17:10 Output voltage sharing technologies for high-voltage conversion-ratio step-up isolated DC-DC converters: 20 minutes

A. Output-voltage unbalance analysis of the modular high-voltage conversion-ratio step-up isolated DC-DC converters
B. The analysis of the output-voltage sharing mechanism of the coupled-inductor based modular high-voltage conversion-ratio step-up isolated DC-DC converters

17:10 – 17:25 Technology demonstrator: 15 minutes

A. Technology demonstrator introduction
B. Experimental validation of the advantages of high-voltage conversion-ratio step-up isolated DC-DC converters with SiC power semiconductor devices
C. Experimental validation of the generic steady-state circuit modeling methodologies for the high-voltage conversion-ratio step-up isolated DC-DC converters
D. Experimental validation of output-voltage sharing performance of the coupled-inductor based modular high-voltage conversion-ratio step-up isolated DC-DC converters

17:25 – 17:30 Summary: 5 minutes

A. Summary of the recent advances in high-voltage conversion-ratio step-up isolated DC-DC converters
B. Development trends of high-voltage conversion-ratio step-up isolated DC-DC converters

Who should attend:

The targeted audience will be the entry level and intermediate university graduate students and engineers in industry who are interested in high frequency DC-DC converter, SiC devices, and high-voltage conversion-ratio power supply technologies.

Technical Level:

Beginners, Advanced engineers who are interested in electrostatic precipitation, medical X-ray generator, MVDC or HVDC grid, pulsed power supply and other high-voltage conversion-ratio power supplies.

About the Lecturers:

Saijun Mao received the B.S. and M.S. degrees from Nanjing University of Aeronautics and Astronautics, Nanjing, China, the Ph.D. degree from Delft University of Technology, Delft, the Netherlands, all in electrical engineering. From 2006 to 2017, he was a senior engineer and project leader with the GE Global Research Center, Shanghai, China. He was also with the Electrical Power Processing group in the department of Electrical Sustainable Energy at the Delft University of Technology, Delft, the Netherlands as a Ph.D. Researcher since December 2014. He is now a Research Fellow in Fudan University, China. His research interests include wide-bandgap power semiconductor devices-based power conversion

systems, high frequency high voltage generator systems, as well as harsh environment power conversion and packaging. He has published more than 50 conference and journal papers. He holds over 50 issued patents and pending patent applications. He received one IEEE Best Paper award. He received more than 15 awards, including annual technology excellence award, annual technology excellence team award and top inventor award in GE Global Research Center. Dr. Mao was the tutorial instructor in 8 premier IEEE power electronics conferences.