

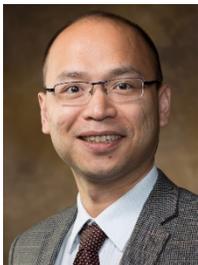
## Tutorial Title:

Hybrid Semiconductor Switches based Power Modules, Converters, and Systems

## Abstract:

Power semiconductor devices play a backbone role in the development of power electronics. Over the past decade, semiconductor devices have experienced rapid development, especially promoted by the emerging wide-bandgap device technologies. However, regardless of conventional Silicon (Si) devices or the new Gallium Nitride (GaN) and Silicon Carbide (SiC) devices, every type of semiconductor devices has its own pros and cons. To fully leverage their different characteristics, various hybrid power devices and modules have been proposed and developed in the past years, ranging from the device level to converter level, or even power electronics system level. As a matter of fact, many of the concepts of hybrid semiconductor switches have been successfully applied in industries, such as the monolithic integration of Si IGBTs and SiC anti-parallel diodes (i.e., co-pack), the Cascode JFET, and the “Si+SiC” hybrid three-level active neutral-point-clamped commercial modules. Numerous performance benefits have been achieved with such hybrid devices, modules, and converters, including efficiency and reliability improvement, EMI mitigation, cost reduction, etc.

In this tutorial, we will start with a review of the development history of various hybrid semiconductor devices and the related successful commercial examples, followed by the new opportunities and challenges with the emerging wide bandgap devices. Afterwards, we will present “Si+SiC” hybrid switching devices at the power module level, review the operating principle, gate drivers, packaging, and performance evaluation. Furthermore, we will present various “Si+SiC” hybrid power converters, specifically including the hardware development, controls, and experimental verifications. Application examples include electric aircraft propulsions and interruptible power supplies for data center applications will be discussed. Finally, we will conclude the tutorial with a summary and Q&A session.



**Dr. Fang Luo** is a new Empire Innovation Associate Professor in the ECE department at Stony Brook University (SBU). His research interests include high power-density converter design, high-density EMI filter design and integration, and power module packaging/integration for wide band-gap devices. Prior to SBU, Dr. Luo was with the Electrical Engineering Department at the University of Arkansas. From 2014 to 2017, Dr. Luo was a research assistant professor at The Ohio State University. Dr. Luo got his Bachelor and PhD degree from Huazhong University of Science and Technology in 2003 and 2010, respectively, and jointly with Virginia Tech. He was a visiting PhD student from 2007 to 2010, and then Postdoctoral researcher from 2010 to 2014, both at Virginia Tech. Dr. Luo is a senior member of IEEE, member of AIAA and ASME. He holds two US patents and has authored/co-authored more than 20 journal papers, one book, and more than 50 peer-reviewed conference papers. He is Associate Editor of IEEE Transactions on Power Electronics and International Transactions on Electrical Energy Systems. He is a recipient of NSF CAREER Award.



**Dr. Jiangbiao He**, is an assistant professor and Endowed L. Stanley Pigman Faculty Fellow in Electrical Engineering at the University of Kentucky. Before he joined academia, he has been working in multiple industrial R&D centers, most recently as a Lead Engineer with GE Global Research, NY. Dr. He obtained his Ph.D. degree in electrical engineering from Marquette University, USA. His research area has been focusing on advanced electric motor drives and power electronics with broad industry

applications, and has authored more than 100 refereed papers and 10 U.S. patents in this area. He was a recipient of 2019 Outstanding Young Member Achievement Award recognized by IEEE Industry Applications Society. He has served as Editor or Associated Editor for multiple IEEE journals, and has served as organizing committee member for numerous international conferences, including ECCEs, IEMDCs, ITECs, and others.