Tutorial Title:

Advanced Magnetic Designs Enabling Electrification of High Power Industrial Systems

Organizer:

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Abstract:

This tutorial will outline the emerging technologies in co-optimization of converters by highlighting recent developments in magnetic materials for wide bandgap (WBG) power electronics and component design. The tutorial will provide design examples showing how these technologies are enabling the electrification of high power systems for industrial applications. It will also highlight the research conducted at the industry and university consortium for Advanced Magnetics for Power and Energy Development (AMPED). Leveraging extensive experience in high power/voltage power converters in multiple industry sectors - HVDC, FACTS, MV converters for high-speed motor and traction drives, MVDC and AC grid enabling SSTs (Solid State Transformers), and shipboard SSTs, the team will demonstrate and provide tools for using emerging magnetic materials and postprocessing techniques, e.g., ferrites and advanced amorphous and nanocrystalline alloys, spatially tuned properties, and heterogeneous materials.

The improvements required in efficiency, power density, specific power, and volumetric density metrics needed to enable multi-MW converters are forcing the industry to re-evaluate the present state-of-the-art SiC based power converters. With the use of new and advanced magnetic component design, the benefit of SiC converters can be fully realized. Furthermore, the concepts provided in the tutorial will also highlight the pathways towards enabling ultra wide bandgap (UWBG) devices with the research in new magnetic material development.

The opportunities for HV SiC devices for MV and high power converters and utility applications and the challenges to apply these HV SiC devices successfully will be presented in-depth with SiC device voltage ranges from 1200V to 1700V MOSFETs, and HV SiC 10 kV - 15 kV MOSFETs, JBS diodes, and 15 kV SiC IGBTs and the newly developed four quadrant 1200V, SiC BiDFET [Bi-Directional FET] switches. The potential and challenges of emerging magnetic materials and components design will be explored with demonstrated application examples of SST, MV SiC power converters for grid-tied solar applications, MV motor drives, shipboard power supply applications, and MVDC grids. The roadmap of HV power devices and magnetics will be addressed in terms of cost targets, module packaging, reliability qualification, and standards compliance of HV SiC devices.

Bio:

Dr. Paul R. Ohodnicki is an associate professor in the Department of Mechanical Engineering and Materials Science at the University of Pittsburgh. He received his Ph.D. in Materials Science and Engineering from Carnegie Mellon University in 2008, after which he joined PPG Industries R&D working on thin-film coating materials and earned the Advanced Manufacturing and Materials Innovation Award from Carnegie Science Center in 2012. Ohodnicki later continued his career at the DOE National Energy Technology Laboratory (NETL), where he eventually served as a technical portfolio lead guiding teams of materials scientists working on the development of optical and microwave sensors as well as magnetic materials and power electronics development for high frequency transformer based solar PV / energy storage inverters. He is the recipient of the 2016 Presidential Early Career Award for Scientists and Engineers, the highest honor the federal government can bestow on early-career scientists or engineers. Before joining the University of Pittsburgh as an Associate Professor, he received the 2019 R&D 100 Award owing to his work on cobalt-rich metal amorphous nanocrystalline alloys for permeability-engineering gapless inductors.

Dr. Brandon Grainger is currently an Eaton faculty fellow, an assistant professor, and associate director of the Energy GRID Institute and Electric Power Engineering program in the Department of Electrical and Computer Engineering at the University of Pittsburgh (Pitt), Swanson School of Engineering. He holds a PhD in electrical engineering with a specialization in power conversion. He also obtained his master's degree in electrical engineering and bachelor's degree in mechanical engineering (with minor in electrical engineering) all from Pitt. He was also one of the first original R.K. Mellon graduate student fellows through the Center for Energy at Pitt. Dr. Grainger's research interests are in electric power conversion, medium to high voltage power electronics (HVDC and STATCOM), general power electronic converter design (topology, controller design, magnetics), resonant converters and high power density design, power semiconductor evaluation (SiC and GaN) and reliability assessment, aerospace power conversion systems, electric vehicle motor drives, and solid state transformer design. Dr. Grainger has either worked or interned for ABB Corporate Research, ANSYS Inc., Mitsubishi Electric, Siemens Industry, and has regularly volunteered at Eaton's Power Systems Experience Center. In his career thus far, he has contributed to 80+ articles, 1 issued patent, and editor of one research textbook Dr. Grainger is a Senior Member of the IEEE.

Dr. Richard Byron Beddingfield received his BS EE and MS PE in Electric Power Systems Engineering from North Carolina State University in 2014 and 2015 respectively. He completed his PhD in High Power Medium Frequency Magnetics for Power Converter Applications in 2018. His research focus is on magnetic material drive power converter designs and novel applications of magnetic materials. He has contributed to the converter designs leveraging high temperature magnetics and strain induced anisotropy magnetic ribbon materials. He has also developed methods for high power, contactless, power transformers and arc-free interconnects as well as variable inductors for DC circuit breakers.

Dr. Subhashish Bhattacharya is a Professor, founding faculty member, and co-PI of NSF ERC FREEDM systems center and DOE initiative on WBG based Manufacturing Innovation Institute – PowerAmerica at NCSU. He has authored over 600 peer-reviewed technical articles, 2 book chapters, and has 10 issued patents to his credit. His research interests are Solid-State Transformers, MV power converters, FACTS, Utility applications of power electronics and power quality issues; high-frequency magnetics, active filters, and application of new power semiconductor devices such as SiC for converter topologies.