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Tutorial Title

Cryogenic Power Electronics Design for Electrified Aircraft Propulsion

Instructor Team

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Abstract

Cryogenic power electronics offer numerous game-changing benefits, including 1) improved performance of power semiconductor devices, such as silicon (Si)- and gallium nitride (GaN)-based, offering decreased specific on-state resistance and increased switching speed; 2) faster switching frequency operation at cryogenic temperature, greatly reducing the need for passive (e.g. EMI filtering); thereby reducing filter weight; 3) less cooling requirement at extremely low ambient temperatures, and 4) light and/or efficient busbar designs due to the low resistivity of conductors at cryogenic temperature.

This seminar will provide several key perspectives for the cryogenic power electronics design from the component up to the converter level. First, the characteristics of critical components, including power semiconductors and magnetics, at cryogenic temperature are introduced. Second, special considerations, trade, and design studies of cryogenic power stage and filter are discussed. Then, two examples of a 40 kW Si-based and a 1 MW SiC-based cryogenically cooled inverter system for electric aircraft propulsion are illustrated, with cooling design, safety considerations, and the protection scheme highlighted. Upon completion, seminar attendees will have a firm grasp on the cryogenic power electronics design and be provided with a range of possible options in order to better utilize the cryogenic cooling system in power converters.

Instructor Biography

Fei (Fred) Wang

Fei (Fred) Wang received the B.S. degree from Xi'an Jiaotong University, Xi'an, China, and the M.S. and Ph.D. degrees from the University of Southern California, Los Angeles, in 1982, 1985, and 1990, respectively, all in electrical engineering.

Dr. Wang was a Research Scientist in the Electric Power Lab, University of Southern California, from 1990 to 1992. He joined the GE Power Systems Engineering Department, Schenectady, NY, in 1992. From 1994 to 2000, he was a Senior Product Development Engineer with GE Industrial Systems, Salem, VA. From 2000 to 2001, he was the Manager of Electronic & Photonic Systems Technology Lab, GE Research, Schenectady, NY, and Shanghai, China. In 2001, he joined CPES at Virginia Tech, Blacksburg, VA as a Research Associate Professor and became an Associate Professor in 2004. From 2003 to 2009, he also served as the CPES Technical Director. Since 2009, he has been with The University of Tennessee, Knoxville (UTK), TN as a Professor and the Condra Chair of Excellence in Power Electronics. He also has a joint appointment with Oak Ridge National Lab. He is a founding member and the Technical Director of the NSF/DOE ERC CURENT led by UTK. His current research mainly focuses on wide bandgap device-based power electronics, and power electronics applications in electrified transportation, renewable energy systems, and power grids. Dr. Wang is a fellow of IEEE and a fellow of the U.S. National Academy of Inventors.

Zheyu Zhang

Zheyu Zhang received the B.S. and M.S. degrees from Huazhong University of Science and Technology, Wuhan, China, and the Ph.D. degree from The University of Tennessee, Knoxville (UTK), TN, in 2008, 2011, and 2015, respectively, all in electrical engineering.

Dr. Zhang is the Warren H. Owen – Duke Energy Assistant Professor at Clemson University. He was a Research Assistant Professor at UTK from 2015 to 2018. Afterward, he joined GE Research as the Lead Power Electronics Engineer at Niskayuna, NY, USA from 2018 to 2019. He has published over 100 papers, filed over 10 patent applications, and authored one book and one book chapter. Among them, one book chapter and seven publications are related to cryogenic power electronics. His research interests include wide bandgap-based power electronics, cryogenic power electronics, and high-performance power conversion systems for electric propulsion, electrified transportation, renewables, energy storage, and grid applications. Dr. Zhang is an Associate Editor for the *IEEE Transactions on Power Electronics* and the *IEEE Transactions on Industry Applications*. Dr. Zhang has presented seven tutorials at IEEE conferences, including two tutorials at ECCE and three professional education seminars at APEC where two of them are co-presented by Dr. Wang with more than 200 attendees, respectively.

Ruirui Chen

Ruirui Chen received the B.S. degree from Huazhong University of Science and Technology, Wuhan, China, and the M.S. degree from Zhejiang University, Hangzhou, China, and the Ph.D. degree from the University of Tennessee, Knoxville, TN, USA, in 2010, 2013, and 2020, respectively, all in electrical engineering.

Dr. Chen was an electrical engineer at FSP-Powerland Technology Inc., China from 2013 to 2015. Since 2020, he is a Research Assistant Professor in the Department of Electrical Engineering and Computer Science at the University of Tennessee, Knoxville. His research interests include wide bandgap device applications, medium voltage power electronics, cryogenic power electronics, multilevel converters, EMI filters, and high efficiency high density power conversion systems for electrified transportation and grid applications.

Shimul Dam

Shimul Dam received the B.E. degree in electrical engineering from the Department of Electrical Engineering, Jadavpur University, Kolkata, India, in 2013, the M.E. and the Ph.D. degree in electrical engineering from the Department of Electrical Engineering, Indian Institute of Science, Bangalore, India, in 2015 and 2020 respectively. At present, he is working as a research associate in CURENT, University of Tennessee, Knoxville, US. His research interests include cryogenic power electronics, aviation power electronics, EMI filter design, and energy storage systems.