Editorial for the Special Issue on Applications of Wide Bandgap Devices

THE emergence of wide bandgap (WBG) semiconductor devices such as silicon carbide (SiC) and gallium nitride (GaN) devices promises to revolutionize next-generation power electronics converters. Featuring high breakdown electric field, low specific on-resistance, fast switching speed, and high junction temperature capability, these devices are beneficial for the efficiency, power density, reliability, and/or cost of power electronics converters. WBG devices have been employed in some commercial and industrial products with more applications expected in near future. However, extremely fast switching and other superior characteristics of WBG device, and high switching frequency/high voltage/high junction temperature operation, present new design challenges in gate drive and protection, packaging and layout, EMI suppression, and converter control, etc. Addressing these design and application issues is critical to the adoption, commercialization, and success of WBG based power electronics. This special issue intends to report the latest progress in these important areas.

The Special Issue on Applications of Wide Bandgap Devices collected four papers on diverse topics, ranging from device performance degradation study, device gate drive and protection, to power module design, and eventually to sensing and control of converters in practical applications. The first paper is entitled "Performance Degradation of GaN HEMTs Under Accelerated Power Cycling Tests" written by Chi Xu and his colleagues at the University of Texas at Dallas, USA. This paper presents a comprehensive analysis of degradation performance in cascode and E-mode p-GaN gate devices under cyclic electrical and thermal stresses. The parametric variations show that the on-state resistance in both GaN device types gradually changes, which provides promising results as a degradation precursor. Furthermore, for the p-GaN gate device, the threshold voltage increases and transconductance decreases as the device ages, which offers an alternative degradation precursor. Failure analyses were also conducted on both devices. The cascode GaN devices show both short and open circuit failure modes, and a weak point in the drain-side bond wires is detected. For the p-GaN gate device, the electrical parameter shifts indicate a possible gate degradation after the device is aged.

The second paper on the "Highly Compact Isolated Gate Driver With Ultrafast Overcurrent Protection for 10 kV SiC MOSFETs" was contributed by Daniel Rothmund and his colleagues at the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland. A highly compact isolated gate driver with a 20 kV isolation voltage is implemented and tested in order to simplify the use of 10 kV high-voltage SiC devices for a future intelligent medium voltage SiC module. The gate driver utilizes an encapsulated isolation transformer for its isolated power supply. This transformer with its primary winding and the secondary winding wound on separate ferrite core halves and separated by silicone insulation material, shows a volume of only 3.1 cm^3 and a coupling capacitance of only 2.6 pF, and has been successfully tested at 20 kV dc. Furthermore, an ultrafast overcurrent protection (OCP) circuit is implemented to protect the expensive SiC module from destruction due to overcurrent. The OCP circuit reacts within 22 ns to a fault and measurements prove that it can successfully clear a hard switching fault (HSF) and even a flashover fault (FOF), where one of the two switches of a bridge-leg configuration is subject to a flashover, in less than 200 ns for a dc-link voltage of 7 kV.

The third paper contributed by Lei Li and his colleagues from the Chinese Academy of Sciences, China is "A 1200 V/200 A Half-bridge Power Module Based on Si IGBT/SiC MOSFET Hybrid Switch". In this paper, a compact hybrid switch (HyS) half-bridge power module, rated at 1200 V/200 A, was fabricated in house and fully tested for the first time. An electrothermal model of the HyS was set up to determine the optimal gate sequence for the HyS. To minimize the HyS power loss, the turn-on and turn-off timing sequences for the Si IGBTs and the SiC MOSFETs were discussed. And a novel index was proposed to select the optimal prior turn-off period. Compared with the pure Si IGBTs, the HyS module can operate at a higher switching frequency with a reduced power loss. A 5 kW air-cooling voltage source inverter and a 30 kW water-cooling voltage source inverter were developed and tested for verification.

The last paper is "Impacts of High Frequency, High di/dt, dv/dt Environment on Sensing Quality of GaN Based Converters and Their Mitigation" from Bo Liu and his colleagues from the University of Tennessee, Knoxville, USA. This paper has reported a common phenomenon from a GaN based battery charger design, i.e., the high switching frequency, and high di/dt and dv/dt noise inside GaN converters may induce a dc drift or low frequency distortion on sensing signals. It provided a systematic study on different sensing distortions and their mechanisms. The identified mechanisms of different errors are strongly impacted by di/dt, dv/dt and switching frequency, all related to undesired high frequency behaviors of different amplifiers. Practical noise minimization techniques from noise source, propagation-path, and receptor are developed and experimentally verified. These techniques can improve the sensing quality and minimize the influences on feedback control.

We would like to express our sincere thanks to the guest associate editors for their efforts spent selecting these high-quality papers for this Special Issue and the expert reviewers who have provided invaluable comments and inputs to assess and enrich the quality of the submitted manuscripts.

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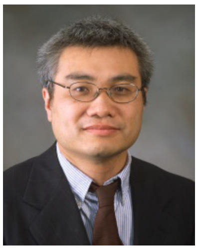

Fei (Fred) Wang received the B.S. degree from Xi'an Jiaotong University, Xi'an, China, and the M.S. and Ph.D. degrees from the University of Southern California, Los Angeles, in 1982, 1985, and 1990, respectively, all in electrical engineering.

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, as an Application Engineer in 1992. From 1994 to 2000, he was a Senior Product Development Engineer with GE Industrial Systems, Salem, VA. During 2000 to 2001, he was the Manager of Electronic & Photonic Systems Technology Lab, GE Global Research Center, Schenectady, NY and Shanghai, China. In 2001, he joined the Center for Power Electronics Systems (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 and Oak Ridge National Lab, Knoxville, TN as a Professor and the Condra Chair of Excellence in Power Electronics. He is a founding member and the Technical Director of the multi-university NSF/DOE Engineering Research Center for Ultra-wide-area Resilient Electric Energy Transmission Networks (CURENT) led by the University of Tennessee. His main research interests include WBG power electronics, and power electronics applications for utility grid and transportation. Dr. Wang is a fellow of IEEE and a fellow of U.S. National Academy of Inventors.

Bo Liu received the B.S. and M.S. degrees from Xi'an Jiaotong University, Xi'an, China, and Ph.D. degree from the University of Tennessee, Knoxville, TN, USA, in 2009, 2012, and 2018, respectively, all in electrical engineering.

Dr. Liu recently joins United Technologies Research Center, East Hartford, CT, as a Senior Design Engineer. He has authored or coauthored 40 journal and conference papers and a book chapter on GaN in AC/DC power converters. His research interests include wide bandgap device based high-frequency high-density converters for aircraft application, conducted EMI, power quality control, high power transmission system, power grid emulation, and grid-tied solar inverters.