ECCE 2022 Special Session

1. Special Session Title

Power Electronics for Integration of MV Utility-Scale PV Systems

2. Abstract

The dc-bus voltage of utility-scale photovoltaic (PV) systems has reached 1,500 V to increase efficiency and reduce system complexity. Several vendors are already offering 1,500 V PV inverters. The availability of commercial high-voltage (HV) semiconductor devices based on silicon carbide (SiC), as well as cascaded multilevel converters, have spurred interest within the research community in medium-voltage (MV) topologies for the power conversion of PV systems. This special session provides an overview of topologies currently commercialized or under development for interfacing large utility-scale PV systems to the power grid including availability of HV SiC devices.

3. Session Organizers:

Organizer 1: Juan Carlos Balda, University of Arkansas and TC5 Chair, jbalda@uark.edu

Juan Carlos Balda received his B.Sc. in Electrical Engineering from the Universidad Nacional del Sur (Bahía Blanca, Argentina) in 1979. He then worked for 2.5 years at Hidronor S.A., an electric utility in the Southwestern part of Argentina. He received his Ph.D. degree in Electrical Engineering from the University of Natal (Durban, South Africa) in 1986. Upon graduation, he was employed as a researcher and a part-time lecturer at the University of Natal until July 1987. He then spent 2 years as a visiting Assistant Professor at Clemson University, South Carolina. He has been at the University of Arkansas at Fayetteville since July 1989 where he is currently a University Professor and Department Head. His main research interests are Power Electronics, Electric Power Distribution Systems, Motor Drives and Electric Power Quality. Dr. Balda is an expert in the field of power electronics and electric power distribution systems. His current research focuses on grid-connected power electronic systems with emphasis on renewable energy sources, energy storage and microgrid applications. He is a senior member of the IEEE, member of the Power Electronics and Industry Applications Societies, and the honor society Eta Kappa Nu. He is a counselor of the IEEE Power Electronics Society chapter at the University of Arkansas.

Organizer 2: Ke Ma, Shanghai Jiao Tong University and TC5 Conference Vice-Chair, kema@sjtu.edu.cn

Ke Ma received the B.Sc. and M.Sc. degrees in electrical engineering from the Zhejiang University, China in 2007 and 2010 respectively. He received the Ph.D. degree from the Aalborg University, Denmark in 2013, where he became an Assistant Professor in 2014. In 2016 he joined the faculty of Shanghai Jiao Tong University, China as a tenure-track Research Professor, and is now serving as the deputy director for Key Laboratory of Control of Power Transmission and Conversion, Ministry of Education, China.

His current research interests include the power electronics and its reliability in the application of renewable energy, HVDC, and motor drive systems. He is now serving as Associate Editor for two IEEE Transaction journals, and Vice Chair for two IEEE Technical Committees.

He was the receiver of "Excellent Young Wind Doctor Award 2014" by European Academy of Wind Energy, and several prized paper awards by IEEE.

Organizer 3: Yongheng Yang, Zhejiang University and TC5 Secretary, yang_yh@zju.edu.cn

Yongheng Yang received the B.Eng. degree from Northwestern Polytechnical University, China, in 2009 and the Ph.D. degree from Aalborg University, Denmark, in 2014. He was a postgraduate student with Southeast University, China, from 2009 to 2011. In 2013, he was a Visiting Scholar at Texas A&M University, USA. Since 2014, he has been with the Department of Energy Technology, Aalborg University, where he became a tenured Associate Professor in 2018. In January 2021, he joined Zhejiang University, China, as a ZJU100 Professor. His research is focused on the grid-integration of photovoltaic systems and control of power converters, in particular, the grid-forming technologies. Dr. Yang was the Chair of the IEEE Denmark Section (2019-2020). He is an Associate Editor for several IEEE Transactions. He was the recipient of the 2018 IET Renewable Power Generation Premium Award and was an outstanding reviewer for the IEEE Trans. Power Electron.. He recieved the 2021 Richard M. Bass Outstanding Young Power Electronics Engineer Award and the 2022 The Isao Takahashi Power Electronics Award. He is currently the Secretary of the IEEE PELS Technical Committee on Sustainable Energy Systems and a Council Member of the China Power Supply Society.

Organizer 4: Adel Nasiri, University of South Carolina and TC5 Operations Vice-Chair, nasiri@usc.edu

Adel Nasiri, Fellow IEEE, received B.S. and M.S. degrees from Sharif University of Technology, Tehran, Iran, in 1996 and 1998, respectively, and the PhD degree from Illinois Institute of Technology, Chicago, Illinois, in 2004, all in electrical engineering. He is presently a Distinguished Professor in the Electrical Engineering Department at the University of South Carolina. His research interests are smart and connected energy systems, energy storage, and microgrids. Previously, he worked at the University of Wisconsin-Milwaukee (UWM) from 2005 to 2021 and served in various roles including professor of electrical engineering, founding and Interim Executive Director, Connected Systems Institute (CSI) and Director, Center for Sustainable Electrical Energy, and the site director for the NSF center on Grid-connected Advanced Power Electronic Systems (GRAPES). He has published numerous technical journal and conference papers and co-authored two books on related topics. He also holds seven patent disclosures. Dr. Nasiri is the past chair of IEEE Industry Applications Society (IAS) Committee on renewable and sustainable energy conversion. He is also an Editor of Power Components and Systems, and Associate Editor of the International Journal of Power Electronics and was an Editor of IEEE Transactions on Smart Grid (2013-2019) and paper review chair for IAS (2018-2019). He was the general Chair of 2012 IEEE Symposium on Sensorless Electric Drives, 2014 International Conference on Renewable Energy Research and Applications (ICRERA 2014), and 2014 IEEE Power Electronics and Machines for Wind and Water Applications (PEMWA 2014).

4. Session Speakers/Panelists

Speaker 1: John Seuss, Technology Manager for DOE Solar Energy Technologies Offices (SETO)
Title: Overview of Solar Energy Technologies Office (SETO) Funding Efforts in MV Power Electronic Converters for Integrating Solar Energy to the Grid

Speaker 2: Ashish Kumar and Kraig Olejniczak, Wolfspeed, USA

Title: A Silicon Carbide-Optimized Power Module Solution for Medium Voltage PV Power Electronic Systems

Speaker 3: Jun Xu, R&D department head at Sungrow, China
Title: High Efficiency High Power Medium Voltage PV Inverter

Speaker 4: Ariya Sangwongwanich, Aalborg University, Denmark
Title: Reliability Challenges and Potential Solutions for 1,500V PV Inverters

5. Presentation Abstracts

- **John Seuss: "Overview of Solar Energy Technologies Office (SETO) Funding Efforts in MV Power Electronic Converters for Integrating Solar Energy to the Grid"**

  Abstract - The Solar Energy Technologies Office (SETO) of the U.S. Department of Energy funds research and development in several areas related to reducing the cost of solar energy and improving its ability to integrate with the electric grid. The Systems Integration group has funded several projects to explore how advanced inverter/converter technologies that interface with the grid at medium voltages could improve overall system costs and enhance grid integration capabilities, such as hybrid plant designs and providing grid services. This presentation will briefly review the portfolio of advanced grid integration power electronic work that the office has funded and discuss future research challenges.

- **Ashish Kumar and Kraigh Olejniczak: "A Silicon Carbide-Optimized Power Module Solution for Medium Voltage PV Power Electronic Systems"**

  Abstract - In this presentation, conventional and innovative transformer-less inverter circuit topologies, with energy storage, are shown to be constructed easily and effectively using Wolfspeed's new, low-inductance, silicon carbide-optimized power module. Designed for the 1.7 kV – 3.3 kV voltage nodes, the medium voltage (MV) module can be used within power electronic converters to efficiently connect utility photovoltaic systems to the distribution grid. The main motivation is to use these high-power density modules in bidirectional ultra-efficient power converters to replace large form factor, line-frequency step-down transformers.

  First, the introduction of the new 1.7 kV – 3.3 kV all-SiC power module will be introduced. The electrical, mechanical, and thermal design philosophies used and resulting performance metrics for the module will be presented. Second, when populating the module with Wolfspeed's 3.3 kV SiC MOSFETs, the static and dynamic electrothermal performance of the 3.3 kV power module using a robust body diode versus a traditional anti-parallel Schottky diode will be demonstrated. This module represents Wolfspeed's commitment to the marketplace for innovative solutions at the 1.7 kV - 3.3 kV voltage nodes. Third, it will be shown how this module can be used to design and build best-in-class grid-tied power converters to transport and store electrical energy among the PV system, energy storage system and the distribution grid.

- **Jun Xu: "High Efficiency High Power Medium Voltage PV Inverter"**

  Abstract - Typically, large utiliy-scale photovoltaic (PV) inverters are combined by central PV inverter and line frequency transform connecting to 35 kV grid. The line frequency transform has some drawbacks, such as heavy, large, excitation loss at night, and more expensive caused by the increasing price of iron and copper. The inverter system efficiency is usually lower than 98%. SST based medium voltage PV inverter could help solve some of the problem and increasing the system efficiency. Sungrow implemented the 35 kV/6 MW SST based PV inverter and the efficnecy is high than 98%, this report will give an introduction on the above mentioned system, in respect to the harware structure, converter modules and design considerations of system reliability.

- **Ariya Sangwongwanich: "Reliability Challenges and Potential Solutions for 1,500V PV Inverters"**

  Abstract - While increasing the dc-side voltage to 1500V can potentially reduce the installation cost and loss of the PV system, the increased voltage stress of the inverter may challenge its reliability. In this presentation, reliability challenges for the emerging 1500V PV inverter technology will be discussed, including the issues related cosmic ray failure, overvoltage during commutation, and uneven thermal stress distribution among the components. Then, potential

solutions to address these issues will also be discussed: topology and modulation strategy optimization, active gate driving method, and active thermal stress control solution. Through the proper design and control solution, the reliability of the PV inverter can be ensured even under the increased voltage stress. Moreover, future trend and perspective of 1500V PV inverter technology will also be provided.

6. Speaker/Panelist Biographies

John Seuss is a Technology Manager for the Solar Energy Technologies Office (SETO) of the U.S. Department of Energy. He received his bachelors and doctoral degrees in Electrical Engineering from the Georgia Institute of Technology in 2006 and 2016, and a master's from the University of Central Florida in 2010. Prior to joining SETO, he worked as an engineer for a transmission utility in substation protection and as a research and development engineer for a power systems equipment manufacturer. His research interests include the integration of PV and other inverter-based resources to the electric grid, distribution automation, and adaptive protection systems.

Ashish Kumar earned his B.Tech. in Electrical Engineering from Indian Institute of Technology, Kharagpur, India in 2008. He then worked at an offshore Oil & Gas production platform as a system electrical engineer. He completed M.Sc. (Engr.) in Electrical Engineering from Indian Institute of Science, Bangalore, India in 2014. He earned Ph.D. in Electrical Engineering from North Carolina State University, Raleigh in 2021. His doctoral research was focused on design and demonstration for medium voltage power converters enabled by modern high voltage silicon carbide power devices. He now serves Wolfspeed Inc. as an application engineer supporting the medium and high voltage power product group.

Kraig J. Olejniczak earned his B.S.E.E. degree from Valparaiso University in 1987. His M.S.E.E. and Ph.D. degrees were granted by Purdue University in 1988 and 1991, respectively. He then joined the Department of Electrical Engineering at the University of Arkansas where he led the university's High-Density Electronics Center's effort in the power electronic miniaturization and packaging thrust area. After serving on the faculty for 11 years, in August 2002, he assumed leadership of Valparaiso University's College of Engineering. After serving his alma mater for 11 years, Dr. Olejniczak resigned his tenure to join his colleagues at APEI in Fayetteville, AR. He served as co-founder, chairman of the board, and senior manager for motor drives and electric utility applications until July 2015 when APEI was acquired by Cree Inc. He now serves Wolfspeed Inc. as a Research Scientist for Medium- and High-Voltage Power Products. He is a member of Tau Beta Pi and Eta Kappa Nu. He is a senior member of IEEE and a licensed professional engineer in the State of Arkansas.

Jun Xu received the B.Sc. and Ph.D. degrees in electrical engineering from Zhejiang University, Hangzhou, China, in 2004 and 2011, respectively. He is currently in charge of Power Electronics Institute of Sungrow Power Supply Co., Ltd, focusing on innovative technologies development. From 2011 to 2015, he was working at Corporate Research & Technology of Eaton in Shanghai. His research interests include photovoltaic systems, solid-state transformer technologies, wide bandgap semiconductor applications and control of grid-connect converters.

Ariya Sangwongwanich (S'15-M'19) received the M.Sc. and Ph.D. degree in energy engineering from Aalborg University, Denmark, in 2015 and 2018, respectively. He is currently working as an Assistant Professor at the Department of Energy Technology, Aalborg University, where he is a Vice-Leader of Photovoltaic Systems research program. His research interests include control of grid-connected converters, photovoltaic systems, reliability in power electronics, and multi-level converters.

He was a Visiting Researcher with RWTH Aachen, Aachen, Germany from September to December 2017. Dr. Sangwongwanich was the recipient of the Danish Academy of Natural Sciences' Ph.D. Prize and the Spar Nord Foundation Research Award for his Ph.D. thesis in 2019.