Protection Scheme for Weather Resilient and Reconfigurable Solid-State Transformers

Mehdi Abolhassani, Resilient Power Systems

Abstract:
As dependency on renewables increases, these resources become a necessity that must continue operating during harsh and extreme weather-related events. Solid State Transformers (SST's) as backbone of future grid need to be resilient, fault tolerant and support the grid during unprecedented events. An SST establishes the interface between a MV AC three-phase grid and LV AC or DC grid. Distribution grids experience voltage oscillations due to the faults, capacitor switching or low-inertia grid forming inverters every day. Transient voltage during capacitor switching or faults can reach up two times of rated voltage. North American Electric Reliability Corporation NERC and IEEE standards require distribution grid equipment to withstand 2X rated voltage to survive during normal or weather-related conditions. In this talk, different stresses which is relevant to SST's are discussed and as well protection scheme and analysis for resilient SST's is presented.

Speaker Bio:
Dr. Mehdi Abolhassani received his PhD in electrical engineering from Texas A&M University, (Texas, USA) in 2003. Currently, he is serving as CTO at Resilient Power Systems who oversee the development and commercialization of solid state-based EV chargers. Prior to joining Resilient, Mehdi was R&D Manager of Toshiba's Drives division and led a multi-disciplinary design team of electrical, mechanical, test and validation engineers for development of Low Voltage Drive products to support $100M+ Toshiba's Low Voltage Business. He was previously Director of Gtest Transportation lab and assistant professor in the Department of Electrical and Computer Engineering at the University of Houston in Texas, USA. He has solid industrial background in designing, manufacturing, and testing of power electronic converters and PM electric drives from fractional Hp to 15 MW in various applications in automotive, traction, industrial, home appliances, and wind energy. He also has years of leadership experience in various product development from concept to production. He contributed in some chapters of DSP-Based Electromechanical Motion Control, and of Handbook of Power Electronics, 2nd Edition: Devices, Circuits and Applications. Dr. Abolhassani holds 31 granted and pending US and international patents. He is also the author of 40+ journal and conference papers. His main research interest areas include high-frequency and high-power energy conversion, multi-level inverters, electrical machine design, variable speed drives for traction and propulsion applications, and wind energy conversion systems.

Reliability testing and in-situ failure analysis of wide bandgap power electronic device

Moinuddin Ahmed, PhD, Argonne National Laboratory

Abstract:

Wide bandgap (WBG) power electronic devices have emerged as a replacement for conventional Si-based power devices due to their high voltage, high-frequency capability, and higher energy conversion efficiency. However, reliability testing of these devices is important for their wide-scale adoption. Also, in-situ failure analysis of these devices can accelerate device manufacturing by revealing the weak point of a device. This presentation will focus on Argonne Electronic Materials Characterization Group's capabilities in reliability testing and in-situ failure analysis of WBG power electronic devices under various conditions for their clean energy, grid and harsh environment application. Research results on current and past projects will be discussed.

Speaker Bio:

Moinuddin Ahmed is a member of the Emergent Materials and Processes group of Argonne National Laboratory. Dr. Ahmed is currently working as a technical lead to establishing power electronics reliability testing facility for wide- and ultrawide-bandgap materials including SiC and GaN-based power devices. His research interests also include power component development and their integration in clean energy. He has been working in the research and development area for more than ten years. He finished his Ph.D. from the University of Texas in 2014 and B.S. from Bangladesh University of Engineering & Technology. Before joining Argonne in 2017, he worked at the University of Texas as a Postdoctoral Fellow.

Reliability of GaN power devices: Current status and Future challenges

Ozgur Aktas, Sandia National Laboratories

Abstract:

The commercial availability and the ongoing adoption of various types of GaN power HEMT switches became possible with the advances in the reliability of these devices, which were in turn made possible by detailed studies for the understanding and control of the failure modes. Propelled with improvements in free-standing GaN substrate technology and advances in GaN-on-Si epitaxy, vertical GaN power device technology have demonstrated excellent performance and the reliability of these devices can now be investigated. This talk will review the current status of GaN HEMT and vertical power device reliability and discuss how the learning from the reliability of HEMT switches can be applied to the vertical devices.

Speaker Bio:

Dr. Aktas has been involved with GaN technology developments since its early days. During his graduate studies and postdoc at University of Illinois, Dr. Aktas contributed to the fundamental work on GaN epitaxy, RF HEMTs and GaN MMIC technology. Later on, Dr. Aktas led the GaN device characterization team at IRF, managed the diode test and reliability team at Avogy, and directed the device technology development on large area engineered substrates at Qromis. Dr. Aktas joined Sandia team recently with a focus on GaN reliability.

Application of SST in a 380 V bipolar DC microgrid Systems

Sijo Augustine, New Mexico State University

Abstract:

Power sharing capability and integration with the AC grid are critical to the feasibility of the DC microgrid system. This work focuses on identifying challenges of interconnection, power transfer, and energy management in 380V Bipolar solar-PV based DC microgrid systems. One solution to this problem is analyzing the feasibility of a solid-state transformer (SST) between AC and DC microgrid systems that can be utilized to accomplish the goals. Also, the SST can be considered to integrate energy storage devices at the DC bus.

Speaker Bio:

Sijo Augustine received the Ph.D. degree in electrical engineering from Indian Institute of Technology Madras, India, in 2016. He is currently working as a Post-Doctoral Research Scientist with New Mexico State University, Las Cruces, NM, USA. His research interests include power electronics, solar PV dc microgrids, and energy management.

Solid State Transformer journey – from concept to pilot demonstration in a decade

Subhashish Bhattacharya, NC State University

Abstract:

Power electronics is a key enabling technology of any modern society in which automation of processes and energy transportation systems, combined with large-area communication networks, play an ever-increasing role. In today's world, access to electricity for everyone should be a human right, not a choice. There are 1.3 billion people (1/6 of humanity) that do not have access to electricity – this is a staggering fact and should be a sobering fact or awakening to change their lives. To solve this global problem and provide all access to electricity, Dr. Bhattacharya conceived a Solid-State Transformer (SST) as a power conversion system for integrating distributed renewable energy resources into the grid, particularly with Silicon Carbide (SiC) devices to provide higher efficiency. The SST concept was visionary in 2008 and has been one of the distinguishing aspects of the FREEDM Center. Dr. Bhattacharya has now taken the SST from the concept to an actual first pilot demonstration with the US Navy in 2021, in a decade. The SST project funded by the US Navy is the first demonstration of any 10kV SiC devices based SST (or even any power conversion system) in the world [100kVA ESTEP-MUSE SST commissioned at NPS, Monterey, CA - Video Link https://drive.google.com/drive/folders/1Q0vUYPvfCgiu-_85T0mmi-C7W65T-OBt].

Speaker Bio:

Subhashish Bhattacharya is Duke Energy Distinguished Professor in ECE department at NC State University. He is a founding faculty of NSF FREEDM Center and PowerAmerica. He was with FACTS and Power Quality Division, Westinghouse R&D and Siemens Power from 1998-2005. His research interests are Solid-State Transformers with HV SiC devices.

He received B.E. from IIT-Roorkee, India, M.E. from IISc, India, and Ph.D. from University of Wisconsin-Madison, all in electrical engineering. He was with FACTS and Power Quality Division at Westinghouse R&D and Siemens Power, from 1998 to 2005. He joined NCSU in August 2005, where. A part of his PhD research on active power filters was commercialized by York Corporation. His research interests are Solid-State Transformers with SiC devices, Integration of renewable energy resources, Microgrids, high-frequency magnetics, active filters, application of new power semiconductor devices such as SiC and GaN for power converters. His research is funded by several industries, NSF, DoE/ARPA-E, Navy, NASA. He has over 650 publications, 10 patents, H-index of 64, and 18,000+ citations.

Challenges for Solid State Transformer for Industrial Applications

Dr. Vijay Bhavaraju, Eaton Research Labs

Abstract:

Solid state transformers have promising application in the emerging EV charging infrastructure design and other high-power applications. However, there is a need to resolve the specifications to meet the industrial application requirements. The application of low voltage power devices for medium voltage is promising but are the testing standards adequate for medium voltage applications? The speaker will address some these issues based on the experience.

Speaker Bio:

Vijay brings decades of industrial and academic experience including last 17 years with Eaton. He has a PhD in power electronics from Texas A&M. Before Eaton, Vijay worked with Ballard Power Systems, Ford/Ecostar and Tech Power Controls. At Eaton, Vijay worked on Flow batteries, APU for hybrids, Solar and storage inverters, advanced microgrid controls, and solid-state transformer for DCFC (ongoing). Vijay proposed and lead several gov't proposals in the areas of microgrids and power conversion. He championed the solar inverter designing it from grounds-up and supporting its commercialization. This led to grid-tied inverter business for Eaton. He successfully completed several gov't programs, such as Fort Sill (Green-field microgrid), IAPS (integrated alternative power systems), and Portland General Electric's 5MW energy storage project, which laid foundation for Eaton to actively pursue commercial opportunities in the fields of microgrids and energy storage. He led a team recently and completed a microgrid for critical infrastructure meeting the cybersecurity standards integrated with tertiary controls for resiliency. Currently he is leading projects addressing EV charging infrastructure with MV power electronics.

Distributed Smart Inverter: problem or solution?

Leo Casey, Fellow IEEE

Abstract:

At higher penetrations of renewables and as we move towards increased electrification there is very real concern about stability issues. This talk will discuss the area of inverter orchestration and build on unconditional stability ideas to advanced inverter concepts.

Speaker Bio:

Dr. Leo Casey, Fellow IEEE is the Power Systems Lead Engineer at Google X. Prior to that, he was Satcon's Chief Technology Officer and EVP of Engineering. Leo has over 40 years of experience in power electronics and power engineering, including ultimate responsibility for the design and commercialization of numerous utility scale power conversion products. These products included inverters, solid state switches, converters, and flywheels, with a focus on the management and integration of alternative, renewable and distributed resources into the grid.

He has served on NREL's solar advisory board the NIST/DOE Hi-MW Leadership Committee, the advisory board of Power America; has been an editor of the IEEE Transactions on Energy Conversion; and is active in IEEE and NEC code and standard development for Grid Electronics. He is a committee member of SCC21, the IEEE oversight board for DER standards. He is a board member of the IEEE-ISTO. He is a Fellow of the IEEE. Dr. Casey has published over 85 papers related to power conversion and Grid Power Electronics and has more than 30 issued patents. He has a Bachelor of Engineering Degree from the University of Auckland and Masters, Engineers and Doctorate degrees from the Massachusetts Institute of Technology.

Medium-Voltage SiC MOSFETs: Powering the EV Traction Inverter

James Cooper, Sonrisa Research, Inc. and Purdue University (Emeritus)

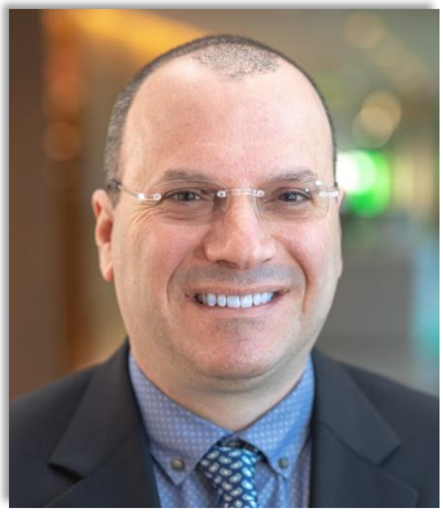
Abstract:

Silicon carbide (SiC) power MOSFETs are used in the main traction inverter of electric vehicles because they offer 5-10% increased range or 5-10% lower battery cost. Tesla uses forty-eight 650 V SiC DMOSFETs in each EV and put 45 million 650 V SiC DMOSFETs on the road in 2021. Worldwide, automotive manufacturers are projected to install 2.7 billion SiC MOSFETs per year by 2035, a $13 billion annual market. This places enormous demands on the supply chain for SiC epitaxial wafers. In this talk we will describe two revolutionary SiC MOSFET structures, each with half the on-resistance of today's commercial 650 V DMOSFETs. This will allow manufacturers to halve the number of MOSFETs per EV, relieving supply chain bottlenecks, reducing parts costs, simplifying assembly, and increasing vehicle reliability through reduced parts count.

Speaker Bio:

James A. Cooper is Jai N. Gupta Professor Emeritus of Electrical and Computer Engineering at Purdue University and President of Sonrisa Research, Inc., a 501(c)3 corporation doing government contract research. He received his Ph.D. from Purdue in 1973 and was a member of technical staff at Bell Laboratories, Murray Hill, NJ from 1973 until 1983, when he joined the Purdue faculty. His research group at Purdue is responsible for a number of advances in SiC technology including the first DMOS power transistors, the oxide-protected UMOS power transistor, the self-aligned short-channel DMOSFET, and the first n-channel IGBTs on free-standing epilayers.

Professor Cooper was elected Fellow of the IEEE in 1993. He served on the editorial boards of IEEE Transactions on Electron Devices and IEEE Proceedings, and was Technical Program Co-Chair for the International Conference on Silicon Carbide and Related Materials in September 2017. He has co-authored over 250 referred publications and the textbook Fundamentals of Silicon Carbide Technology (Wiley, 2014).



Gaining Market Access for Disruptive Technologies

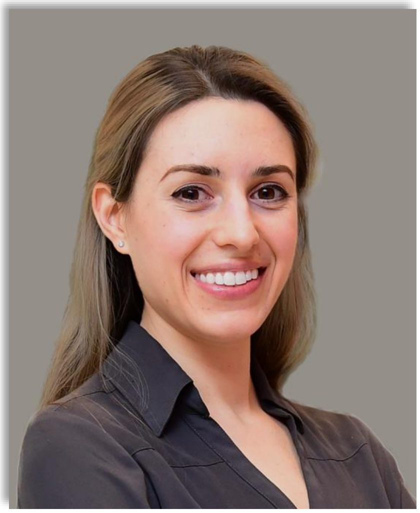
Scott Daniels, CSA Group

Abstract:
The focus of this presentation is to inform technology developers that there are often unexpected challenges in gaining access to global markets. It is critical to understand when to engage standards, testing, inspection, and certification organizations such as CSA Group when commercializing a disruptive technology. Our organization enables manufacturers to demonstrate that their products are "in compliance" with applicable safety, environmental, and operating performance standards for markets around the world.

Speaker Bio:
As Head of Energy & Power and Energy Storage at CSA Group, Scott is an emerging technology and advanced energy resources professional with over 20 years of experience in the energy and clean technology sectors. A respected leader in power generation, distributed energy resources, and energy management, Scott has expertise in technology and business strategy focusing on energy, sustainability, technology commercialization, and investment strategy.

Prior to joining CSA Group, Scott held senior roles in the energy storage sector, including Senior Director, Head of Energy Storage Centre of Excellence at Powin Energy, where Scott built a world class team and expanded Powin's ability to characterize battery cells, modules, stacks, systems and integrate new technologies by opening or adding labs, offices, infrastructure, and test equipment. Before holding this position, Scott was the Director, Technology & Business Strategy - Secure Power Division at Schneider Electric, responsible for identifying opportunities for investment in new technologies and developing proofs of concept and business cases for new product development activities. Scott also served as the lead global battery expert at Schneider Electric.

Scott holds a Master's Degree in Business Administration from Boston University – School of Management, as well as a Master and Bachelors of Science Mechanical Engineering Degrees from Northeastern University with a concentrations in Materials Science and Combustion.



Packaging of WBG and UWBG Power Semiconductors

Christina DiMarino, CPES, Virginia Tech

Abstract:

This presentation will review the challenges of packaging wide bandgap (WBG) power devices, current solutions and trends, and opportunities for further improvement to unleash the full potential of these devices. Topics that will be covered include design tools, materials, manufacturing processes, and package architectures, from low-voltage integrated packages to high-voltage, high-power modules. The opportunities and packaging challenges for future ultra-wide bandgap (UWBG) power devices will also be discussed.

Speaker Bio:

Christina DiMarino is an assistant professor at Virginia Tech in the Center for Power Electronics Systems (CPES). She earned her B.S. degree in engineering from James Madison University in 2012, and her M.S. and Ph.D. degrees in electrical engineering from Virginia Tech in 2014 and 2018, respectively. Her research interests include power electronics packaging and high-density integration using wide- and ultra-wide bandgap power semiconductors and medium/high-voltage power modules. Dr. DiMarino currently serves as a member-at-Large for the IEEE Power Electronics Society (PELS) Administrative Committee, Vice Chair for the PELS Technical Committee on Power Components, Integration, and Power ICs, Associate Editor for the IEEE Transactions on Power Electronics, and is a member of the PELS Women in Engineering steering committee.

Multiport Bidirectional Solid-State Transformer

Deepak Divan, Georgia Institute of Technology

Abstract:

Hundreds of gigawatts of PV solar, wind and storage are being deployed globally on the grid every year. In addition, new loads such as EV fast charging, are requiring high peak charging. Microgrids are being built to provide resiliency and to alleviate grid stress. Finally, as we move to high inverter penetration systems, the question of maintaining grid stability and control is becoming a pressing issue. Today, all these functions are achieved with single-purpose power converters that have to then be integrated in a highly customized manner for every installation. The multiport bidirectional solid-state transformer provides a new building block to manage a wide variety of applications. The SST implements a multiport power converter that is flexible, modular and scalable, and which can simultaneously and safely interface with PV solar, batteries, generators and loads, managing power flows between various sources/loads and ensuring stable operation under normal, transient and fault conditions, and providing grid-forming functionality as needed.

Speaker Bio:

Dr. Deepak Divan is Professor, John E Pippin Chair, GRA Eminent Scholar and Director of the Center for Distributed Energy at the Georgia Institute of Technology in Atlanta, GA. His field of research is in the areas of power electronics, power systems, smart grids and distributed control of power systems. He works closely with utilities, industry and is actively involved in research, teaching, entrepreneurship and starting new ventures.

Dr. Divan has started several companies, including Varentec in Santa Clara, CA, where he served as Founder, President and CTO from 2011-14, and as Chief Scientist for several years after. He led the company as it developed its suite of innovative distributed real-time grid control technologies. Varentec is funded by leading green-tech Venture Capital firm Khosla Ventures and renowned investor Bill Gates. He has founded or seeded several new ventures including Soft Switching Technologies, Innovolt, Varentec and Smart Wires, which together have raised >$160M in venture funding.

Dr. Divan is an elected Member of the US National Academy of Engineering, member of the National Academies Board on Energy and Environmental Systems, Committee on the Future Grid and Committee on Deep Decarbonization. He a Fellow of the IEEE, past President of the IEEE Power Electronics Society, is a recipient of the IEEE William E Newell Field Medal and is International Steering Committee Chair of the IEEE Empower a Billion Lives global competition to crowdsource scalable energy access solutions. He has 40 years of academic and industrial experience, 70 issued and pending patents, and over 400 refereed publications. He received his B. Tech from IIT Kanpur, and his MS and PhD degrees from the University of Calgary, Canada.

Transmission and distribution controllability opportunities and modeling challenges with direct current systems and solid-state transformers

Marcelo Elizondo, Pacific Northwest National Laboratory

Abstract:

Direct current (DC) systems and solid-state transformers (SST) bring flexibility and controllability opportunities to transmission and distribution (T&D) power delivery systems. These opportunities are especially valuable in the fast system transition expected in the upcoming years to achieve decarbonization goals, as DC systems and SST could help integration of renewable resources. On the other hand, modeling challenges currently exist in the utility industry due to ongoing growth of inverter-based resources (mainly generation and energy storage) because of the fundamental changes in the system dynamics. Such modeling challenges will also affect the system level studies for wide adoption of DC systems and SST. In this presentation, Dr. Marcelo Elizondo will provide examples of controllability system-level benefits of DC systems and SST at the transmission and distribution levels. He will also review current and expected modeling challenges to study scenarios with large adoptions of these technologies. Marcelo will close with open questions to encourage discussions with attendees.

Speaker Bio:

Dr. Marcelo Elizondo is a power system research engineer in the Electricity Infrastructure and Buildings division at Pacific Northwest National Laboratory (PNNL), where he joined in 2009. His research includes topics from bulk electric systems planning, stability, and resilience, to dynamics in distribution systems and microgrids. He leads a portfolio of projects for U.S. Department of Energy and U.S. Department of State on cross-border and interregional transmission, HVDC transmission, resilience, and system recovery after natural disasters, and leads internal PNNL research to develop new capabilities. Dr. Elizondo has helped developing various planning tools for transmission and distribution resilience analysis (EGRASS), dynamic cascading failure analysis (DCAT), sub-transmission reactive power planning (CReST-VCT), generation flexibility assessment (GRAF-Plan), electromechanic and phasor-dynamics for distribution resilience (added to GridLAB-D), as well as for national-scale energy resilience planning and situational awareness (NAERM).

Review of needs and impacts of fast-charging networks

Richard Fioravanti, Quanta Technology

Abstract:
This presentation will discuss the potential electrification impacts of heavy/medium duty charging on utility grids. The discussion will focus on unique motivations behind electrifying this market segments, challenges facing utilities, an approach to quantifying the impact, and finally provide an example of how tools have been used to assist utilities in accommodating the challenges.

Speaker Bio:
Executive Advisor, Director, Transportation Electrification: Mr. Fioravanti brings over 25 years of experience working with emerging energy technologies in both commercial and consulting roles. He has worked with major manufacturers, utilities, state/federal agencies, and developers to understand and deploy advanced energy systems. He currently focuses his efforts on electric transportation, EV infrastructure, and technology electrification - evaluating electricity grid impacts and linking the technologies to grid modernization, utility of the future initiatives. For electrification, he is currently leading efforts to examine load impacts for airport and seaport electrification. Mr. Fioravanti also was a founding Board Member of New York BEST (Battery and Energy Storage Technology Consortium) and served on their Board for five years. In this role, he helped create the NY-BEST Energy Storage testing lab for the organization. He has authored several papers on advanced storage technologies and has been cited frequently as a leader in his field. He received his M.B.A and a B.S. in Electrical Engineering from the University of Southern California.

Ultra-Wide-Bandgap Semiconductors

Stephen Goodnick, Arizona State University

Abstract:

Ultra-wide-bandgap (UWBG) semiconductors are materials with bandgaps 5 eV or higher that are actively being investigated for future power electronics applications beyond current widebandgap materials, i.e. SiC and GaN. Some UWBG materials of interest include diamond (5.5 eV), AlN (6.2 eV) and alloys of AlGaN, BN (6.4 eV) and Ga2O3 (4.8 eV). The large bandgaps of UWBG materials lead to much higher theoretical values of the critical field for breakdown compared to SiC and GaN, which has advantages in power electronic applications, e.g. requiring fewer devices for power converters at a given operating voltage. Many of the UWBG materials also exhibit good low and high-field transport properties, which support high frequency operation, which leads to reduced component size, particularly passive components. However, the technological maturity of UWBG materials is significantly behind that of SiC and GaN, which have been developed over the past three decades. Defect control, appropriate substrate materials and the ability to dope with shallow donor and acceptor levels are ongoing challenges for these materials to meet their potential. For solid-state power converters, which involve high frequency switching, the material and device requirements are often encapsulated in various Figures of Merit (FOM) appropriate for the application, the simplest being the Baliga FOM characterizing DC power handling in terms of the forward current and reverse breakdown voltage. In the present talk, we discuss the state of the art of UWBG materials relative to more mature technologies, and the advantages and disadvantages of these materials in terms of device performance, their FOMs, and potential applications such as solid-state transformers for future grid applications.

Speaker Bio:

Stephen M. Goodnick is currently the David and Darleen Ferry Professor of Electrical Engineering at Arizona State University. He received his Ph.D. degrees in electrical engineering from Colorado State University, Fort Collins, in 1983, respectively. He was an Alexander von Humboldt Fellow with the Technical University of Munich, Munich, Germany, and the University of Modena, Modena, Italy, in 1985 and 1986, respectively. He served as Chair and Professor of Electrical Engineering with Arizona State University, Tempe, from 1996 to 2005. He served as Associate Vice President for Research for Arizona State University from 2006-2008, and presently serves as Deputy Director of ASU Lightworks, as well as Deputy Director for the ULTRA Energy Frontier Research Center. He was also a Hans Fischer Senior Fellow with the Institute for Advanced Studies at the Technical University of Munich. Professionally, he served as President (2012-2013) of the IEEE Nanotechnology Council, and served as President of IEEE Eta Kappa Nu Electrical and Computer Engineering Honor Society Board of Governors, 2011-2012. Some of his main research contributions include analysis of surface roughness at the Si/SiO2 interface, Monte Carlo simulation of ultrafast carrier relaxation in quantum confined systems, global modeling of high frequency and energy conversion devices, full-band simulation of semiconductor devices, transport in nanostructures, and fabrication and characterization of nanoscale semiconductor devices. He has published over 450 journal articles, books, book chapters, and conference proceeding, and is a Fellow of IEEE (2004) for contributions to carrier transport fundamentals and semiconductor devices.

Wirebondless SiC Power Module Packaging

Arun V. Gowda, GE Research

Abstract:

Advanced power module packaging is required to fully realize the benefits of SiC device technology at the system level. The industry has evolved from adopting packaging technologies typically deployed for Si IGBTs to developing modules tailored for SiC. One such advancement has been the move from heavy aluminum wirebonding to copper wirebonding and to wirebondless technologies. Wirebondless packaging offer several advantages in terms of power density, electrical performance, double sided cooling capability, and reliability. In this talk, we will discuss the advancements in interconnect technology and use Power Overlay (POL), an example of wirebondless interconnection to illustrate the performance improvements. We will also discuss some new research in the exploration of packaging power devices using direct write additive technologies.

Speaker Bio:

Arun Gowda is SiC Mission Leader and Principal Engineer at GE Research, responsible for packaging development and deployment of GE's SiC technology into applications. Prior to this role, Arun led the Electronics Packaging and Miniaturization lab at GE Research, responsible for the development of advanced packaging and integration of microelectronics, sensors, and power devices. Arun has 18 years of GE experience spanning various technical contributor, project leadership, and management roles. He received his Ph.D. from Binghamton University (State University of New York) in 2004 with a specialization in electronics manufacturing.

M4 Inverter: A PV + Storage Solid State Transformer

Alex Q. Huang, University of Texas at Austin

Abstract:
Photovoltaic (PV) power generation plant with integrated battery energy storage (BES) is becoming increasingly attractive and necessary as the PV penetration increases. Traditional solution involves two paralleled inverter systems at the same site. This increases the balance of the system cost as well as the control complexity. Furthermore, high-power step-up transformers are needed to connect to the distribution grid, further increasing the capital cost, land use and installation cost. Combining PV and BES into a single inverter system without the 60Hz step-up transformer is therefore very attractive as the next generation technology for utility scale solar. This talk will discuss the design and progress of the M4 Inverter, a 13.8 kV/3MVA PV plus storage solution based on 1700V SiC technology. The M4 Inverter can directly connected to 13.8 kV distribution grid on the AC side and 1500V PV farm on the DC side. A total of 27 SiC converter modules are utilized in an M4 Inverter. Each module is based on 1700V SiC power MOSFET switch and a novel single stage isolated DC/AC conversion topology. Optimized PCB busbar design is utilized to achieve a high power-density of 1.6MW/m3 (26W/inch3) and a DC to AC port efficiency of 98%. Medium frequency transformer (MFT) design to achieve very high efficiency and isolation voltage is a grand challenge in the proposed M4 Inverter and is discussed in detail. The control architecture is discussed with a focus on voltage balancing and real and reactive power controls.

Speaker Bio:
Alex Q. Huang received his B.Sc. degree from Zhejiang University, China in 1983 and his M.Sc. degree from Chengdu Institute of Radio Engineering, China in 1986, both in electrical engineering. He received his Ph.D. from Cambridge University, UK in 1992. He was a professor at CPES Virginia Tech from 1994-2004. From 2004 to 2017, he was the Progress Energy Distinguished Professor of Electrical and Computer Engineering at NC State University where he established and led the NSF FREEDM Systems Center. Since 2017, he has become the Dula D. Cockrell Centennial Chair in Engineering at University of Texas at Austin where he directs the Semiconductor Power Electronics Center (SPEC). He has mentored and graduated more than 90 Ph.D. and master students, and has published more than 600 papers in international conferences and journals. He has also been granted more than twenty U.S. patents. He is the recipient of the NSF CAREER award, the prestigious R & D 100 Award, the MIT Technology Review's 2011 Technology of the Year Award, the 2019 IEEE IAS Gerald Kliman Innovator Award, the 2020 IEEE PELS R. David Middlebrook Achievement Award and the 2021 IEEE PES Energy Internet Pioneer Award. Dr. Huang is a fellow of IEEE and National Academy of Inventors.

Power Electronics for a Better Grid

Zhenyu (Henry) Huang, Pacific Northwest National Laboratory

Abstract:

Power electronics is becoming ubiquitous in the power system. Driven by the big push in deeper electrification and decarbonization, more than 80% of electricity will be generated, transferred, and/or consumed through power electronics interfaces. If the grid is the fabric, power electronics are the glue to connect things together at all levels of generation, transmission, distribution, and end uses. As a result, power electronics are fundamentally changing the system dynamics as they displace conventional inertia-heavy synchronous generation. Though the faster dynamics can be a challenge, it brings an opportunity for a better future grid – more responsive and flexible! In this talk, Henry will discuss the challenge and the opportunity and what needs to be done to harness this opportunity in order to enable the full functions of power electronics for power systems.

Speaker Bio:

Dr. Zhenyu (Henry) Huang is Laboratory Fellow and Deputy Sector Manager at Pacific Northwest National Laboratory (PNNL), Richland, WA and holds a joint appointment of Research Professor at Washington State University, Pullman, WA. He was a Technical Advisor at the US DOE EERE Solar Energy Technologies Office (SETO) in 2019 – 2020. At PNNL, Dr. Huang leads the power electronics and renewable integration portfolios. His research interests include high performance computing, data analytics, and optimization and control for inverter- and renewable-dominant power and energy systems. He led PNNL's Future Power Grid Initiative – a research and development effort that developed important open-source software packages for power grid modeling, simulation, and control, including GridPACKTM, HELICSTM, and VOLTTRONTM. Dr. Huang has over 200 peer-reviewed publications. He is a Fellow of IEEE and is active in several IEEE Power and Energy Society (PES) technical committees. Dr. Huang is a registered Professional Engineer in Washington State. Dr. Huang received his B. Eng. from Huazhong University of Science and Technology, Wuhan, China, and Ph.D. degree from Tsinghua University, Beijing, China.

Designing Soft Magnetic Materials

Dale Huber, Sandia National Laboratories

Abstract:

This talk will begin with a brief history of magnetic materials development and the main classes of soft magnetic materials in use today. This will include the trade offs and figures of merit for various application spaces. This will lead into a discussion of current approaches to develop new soft magnetic materials and both the difficulties and opportunities that they represent.

Speaker Bio:

Dale L. Huber is a Distinguished Member of the Technical Staff at Sandia National Laboratories in the Center for Integrated Nanotechnology (CINT), a U.S. DOE Nanoscale Science Research Center jointly operated by Sandia and Los Alamos. He holds a BA in Chemistry from the University of Pennsylvania and a PhD in 2000 in Polymer Science from the University of Connecticut. He has been at Sandia since 2000, where his research interests include novel approaches to the synthesis of nanomaterials, in particular nanoparticles, and nanocomposites with unique magnetic properties.

R&D Opportunity in Power Conversion Systems

Jackie Huynh, AES

Abstract:

This presentation discusses R&D opportunity in power conversion systems to solve the grid stability challenges as more renewable energy come online. An overview of today's challenges with tomorrow's solutions, and questions about what future technologies. Look into criteria on choosing what innovative solutions make senses.

Speaker Bio:

Jackie Huynh is part of the Technology Innovation and Product Solutions (TIPS) group at AES as Sr Energy Storage Manager with over ten years of experience in renewable energy resources. One of his main responsibilities is to evaluate new technologies that will reduce the total levelized cost of the energy system for stand-alone storage and PV +BESS. Jackie held various roles as a Sr Manager Technical & Commercial Support Manager at Powin, Sr Solution Development Engineer at Go Electric a SAFT Company, and Microgrid Solutions Architect at Schneider Electric all within the value chain of renewable energy decarbonizing the electrical grids with experiences deploying GWs of renewable energy. Jackie holds a Master's degree in Engineering Management and Bachelor of Science in Agriculture and Biological Engineering Degree from Purdue University.

Grid Tied Medium Voltage Systems: Topologies, control and Architecture

Rajendra Prasad Kandula, Oak Ridge National Laboratory

Abstract:

Medium voltage converters are typically used in direct grid connected applications such as fast EV chargers, utility battery storage, MVDC applications etc. The presentation will cover various topologies for implementing medium voltage AC/DC or DC/DC conversion with and without isolation. A brief comparison of the topologies and major implementation challenges will be provided. Finally, future research trends will be presented.

Speaker Bio:

Rajendra Prasad Kandula (Member, IEEE) received the B.E degree from NIT, Nagpur, India, in 2002, the M.E degree from IISC, Bangalore, India, in 2004, and the Ph.D. degree from Georgia Institute of Technology, Atlanta, GA, USA in 2014, all in electrical engineering. He worked for three years at Bharat Heavy Electricals Limited (BHEL) R&D, Hyderabad, as a Design Engineer in the area of industrial drives and PV applications. He worked at Varentec, Santa Clara, as a Principal Engineer, mainly working in the area of development of power flow controllers and hybrid transformers for meshed transmission systems. He worked as a Chief Engineer with the Center for Distributed Energy, Georgia Tech, Atlanta, USA, from 2015 to 2021. He is currently working as R&D Staff Scientist at Oak Ridge National Laboratory. His main research interests include applications of power electronics for utility applications such as hybrid transformers, solid state transformers, fast EV chargers, grid-forming converters, etc.

Electrification of Everything

Olga Lavrova, New Mexico State University

Abstract:
The United States has a long-term goal to decarbonize the electric grid[1]. This will require several market transformations across multiple sectors, including renewable power generation and storage options, increased electrification of end-use energy consumption and transition to demand-side management of residential and industrial loads. This overview talk will highlight and discuss electrification efforts (residential, commercial, industrial, transportation) and ubiquitous applications of power electronics within the electrification efforts.

[1] The White House. 2021. "President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability." https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/.

Speaker Bio:
Dr. Olga Lavrova is an Associate Professor in the areas of Power Systems and Renewable Energy Integration at the New Mexico State University. Her current research areas are Power electronics, Grid-interactive microgrids, Cybersecurity for power systems and microgrids, Semiconductor device physics, Solar cell and PV system design, Reliability and lifetime studies, Resiliency of infrastructure, Hardware in the Loop simulation, Power systems stability and transients. Prior to joining NMSU, Dr. Lavrova was a Principal Member of Technical Staff at Sandia National Labs in the Photovoltaics and Distributed Systems Integration Department. Prior to that, she held position of Assistant Professor at the Electrical and Computer Engineering Department at the University of New Mexico. Dr. Lavrova has performed groundbreaking work in power electronics, sensors, and materials for grid applications, and recently led experiments assessing EMP (Electro-Magnetic Pulse) effects on utility components at Sandia's state of the art EMP testing facilities. Until 2019, Dr. Lavrova lead SNL's efforts in the areas of novel Sensors for power systems, as part of the GMLC (Grid Lab Modernization Consortium). Dr. Lavrova has been a PI on multiple other DOE- and NSF-funded grants concentrating on fundamental PV materials and device operation, as well as their cost-effective, economical, and practical deployment in consumer PV applications, as well as grid integration and off-grid operation (such as in remote or isolated locations). During her career as a university professor and as the technical team lead at Sandia National Labs, she has demonstrated leadership in identifying research gaps and opportunities, building and motivating multi-disciplinary teams, and producing impactful results. Her current work includes projects in grid modernization and

cybersecurity for power systems and microgrids. During her tenure at the University of New Mexico, she collaborated with PNM on the installation and deployment of the first in New Mexico PV+Storage project (PNM Prosperity Project). Dr. Lavrova was responsible for the controls and algorithms development which are still running peak shaving and smoothing algorithms 10 years later at the Prosperity site. Later, Dr. Lavrova collaborated with EPRI on PV+Storage project development for other US and European utilities (Southern Co, Red Electrica, etc.).

Semiconductors Fundamentals for Higher Voltage, Higher Power, and Higher Efficiency and Reliability

John Muth, North Carolina State University

Abstract:

The future electric grid will require new generations of high voltage, high power devices that are smarter, more efficient, and reliable. This talk is focused on how the fundamental properties of semiconductor materials connect to their implementation into functional power electronic devices and the system level advantages they potentially offer. The importance of understanding the system level challenges and system level economic advantages and the principle of Co-Design is emphasized since it impacts the rate of technology development and adoption.

Speaker Bio:

John is a Professor of Electrical Engineering North Carolina State university and has worked with wide bandgap semiconductors since 1993 investigating fundamental optical and thermal properties of materials fabrication of photonic devices, sensors, and thin film transistors. He co-founded NSF Engineering Research Center ASSIST and led the start-up of PowerAmerica a national manufacturing institute for wide band gap power electronics. He is a retired nuclear submarine officer and Jefferson Science Fellow.

Enabling Soft Magnetics for Wide Bandgap (WBG) and Ultra-Wide Bandgap (UWBG) Power Electronics

Dr. Paul Richard Ohodnicki, Jr., University of Pittsburgh

Abstract:
Numerous trends are driving the need for advances in electrical power conversion technologies, including rapid deployment of renewables in the electric power grid and electrification of the transportation sector. Soft magnetics technologies play a critical role as an enabler for state-of-art power electronics conversion topologies and systems able to fully exploit the latest advances in wide bandgap (WBG) and ultra wide bandgap (UWBG) semiconductor-based switching devices. Current commercial soft magnetic materials and manufacturing solutions are not optimized for these new application requirements. Amorphous and nanocrystalline soft magnetic alloys have emerged as the premier solution for many WBG-based power electronics converter applications, including medium frequency transformers and inductors, as a result of increased saturation flux densities relative to ferrites and reduced eddy current losses compared to electrical steels. Historically, brittle mechanical properties of nanocrystalline alloys have limited their application in WBG power electronics conversion. In case of future UWBG power electronics, alternative soft magnetic materials systems and manufacturing pathways are required for the unprecedented combinations of power, voltage, and switching frequencies. This presentation will provide an overview of needs and examples of future engineering design pathways being pursued. Specifically, we will discuss (1) emerging nanocrystalline alloys with improved magnetic properties and enhanced ductility combined with advanced manufacturing methods for WBG power electronics and (2) new ideas in ferrite based soft magnetic materials for future UWBG power electronics. Broader needs for workforce development in advanced magnetic materials and devices for power applications will also be addressed.

Speaker Bio:
Paul R. Ohodnicki Jr. is currently an associate professor in Mechanical Engineering and Materials Science department at the University of Pittsburgh and the Engineering Science program director. He is also the founding director of the Advanced Magnetics for Power and Energy Development (AMPED) consortium, a university – industry – government collaborative partnership focused on educating next generation workforce at the intersection between new soft magnetic materials, device applications, and system level for renewable integration and vehicle electrification. In addition, he serves as the Chief Technology Officer

and co-founder of CorePower Magnetics, an early-stage startup seeking to commercialize a portfolio of intellectual property developed during his time as an employee at the US Department of Energy. Prior to his current roles, he was a materials scientist and technical portfolio lead in the Functional Materials Team of the Materials Engineering & Manufacturing Directorate of the National Energy Technology Laboratory. He graduated from the University of Pittsburgh in 2005 with a B.Phil. in engineering physics and a B.A. in economics and subsequently earned his M.S. (2006) and Ph.D. (2008) in materials science and engineering from Carnegie Mellon University. Ohodnicki has published more than 150 technical publications and holds more than 15 patents, with more than 30 additional patents under review. He also is the recipient of a number of awards and recognitions, including the Federal Employee Rookie of the Year Award (2012), Presidential Early Career Award in Science and Engineering (2016), and the Advanced Manufacturing and Materials Innovation Category Award for the Carnegie Science Center (2012, 2017, 2019). In 2017, he was a nominee for the Samuel J. Heyman service to America Medal.

Micro to nanoscale thermal characterization of wide bandgap electronics

Georges Pavlidis, University of Connecticut

Abstract:

Gallium nitride (GaN) based electronics have shown great potential for RF devices and power electronics. Its superior material properties have enabled the fabrication of high frequency and high voltage devices. Under high power operational conditions, significant localized Joule heating can have detrimental effects on the device performance. The quantification of performance parameters such as the gate junction temperature is thus necessary to accurately assess the device's quality and lifetime. This talk will present advanced methods for in-situ transient temperature measurements using gate resistance thermometry and microscale temperature mappings via transient thermoreflectance imaging (TTI). While micrometer resolution thermal characterization techniques are advantageous, the feature size of electronics is continually reducing. Characterization tools that can capture transport phenomena on the nanoscale are thus necessary. The second part of this talk will cover AFM based techniques used to map temperature distributions with nanometer resolution. This will include scanning thermal microscopy (SThM) for mapping the temperature distribution in superlattice castellated FETs and AlGaO/GO HFETs. Novel optomechanical probes with the potential to improve the signal to noise ratio by 50x and increase the time resolution to 10 ns will also be introduced.

Speaker Bio:

Dr. Georges Pavlidis joined the Department of Mechanical Engineering at the University of Connecticut as an Assistant Professor in 2022. Prior to that, he was an NRC Postdoctoral Researcher in the Nanoscale Spectroscopy Group. He earned his M.Eng in Mechanical Engineering from Imperial College London in 2013 and his Ph.D. degree in Mechanical Engineering from the Georgia Institute of Technology in 2018. Dr. Pavlidis specializes in the thermal characterization of WBG semiconductors for RF and power electronics. He has developed electrical/optical methods, with high spatial and temporal resolution, to assess the performance and reliability of III-nitrides devices. His recent publications investigate improving hBN polariton lifetimes and developing high throughput techniques for interfacial thermal conductance mapping.

Charge-Balanced Lateral Polar Junctions in GaN for Future Superjunction Power Devices

Spyridon Pavlidis, NC State University

Abstract:

There has been a surge of research and commercial interest in gallium nitride (GaN)-based devices for power conversion applications. This is motivated by the critical electric field (EC) of GaN, which offers a unipolar limit of performance that is larger than that of silicon's and silicon carbide's. To reduce or even close this gap, both vertical Si- and SiC-based superjunction (SJ) devices have been demonstrated. Vertical SJ structures in GaN, however, remain elusive due to the challenges associated with selective area doping via traditional methods, such as ion implantation and etch and regrowth. Recently, however, we demonstrated the use of supersaturation modulated growth (SMG) to grow GaN lateral polar junctions (LPJs) with 3D doping control. Using SIMS and APT, charge balance between alternating n- and p-type GaN pillars was confirmed. Here, we electrically characterize camel diodes with LPJ drift regions and compare the measured results against TCAD models. This analysis confirms barrier height and doping control, and unveils the depletion region's evolution in reverse bias, paving a path for high-efficiency GaN-based SJ devices.

Speaker Bio:

Spyridon Pavlidis is an Assistant Professor in the Department of Electrical and Computer Engineering at North Carolina State University, and the principal investigator for the Laboratory for Electronics in Advanced Devices and Systems (NCSU LEADS). He is affiliated with NCSU's PowerAmerica, FREEDM and ASSIST Research Centers. He was previously a post-doctoral researcher in the School of Materials Science and Engineering at the Georgia Institute of Technology. Dr. Pavlidis received the PhD in Electrical and Computer Engineering from Georgia Tech, and the M.Eng in Electrical and Electronics Engineering from Imperial College London. His research interests lie at the intersection of semiconductor devices, novel materials and circuits with applications for high-frequency and power electronics, as well as sensing. He is the recipient of the 2022 NSF CAREER Award, the 2022 Bennett Fellowship and the 2015 EuMW Young Engineer Prize. He is an active member of the IEEE, serving on several technical program committees, as well as on the IEEE MTT-S Technical Committee on Microwave and Millimeter-Wave Solid State Devices.

Solid-State Power Substation (SSPS) Applications

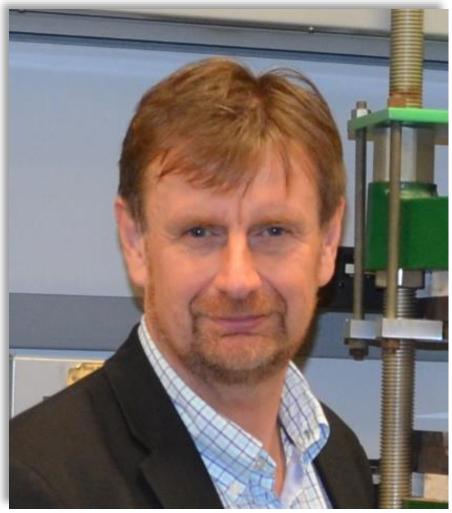
Dr. Radha Sree Krishna Moorthy, Oak Ridge National Laboratory

Abstract:

Solid state power substations (SSPSs) are a nexus of intelligent power electronic conversion stages which are controlled and protected both strategically and hierarchically. The concept envisions to maximize the grid support through coordinated and optimized operation of the downstream power conversion units. The power conversion units thus act as the fundamental entities of the SSPS architecture require intelligent and advanced features like decision making capability and online health monitoring to improve the grid metrics of reliability, resiliency, power quality and efficiency. Realization of the concept of SSPS requires a framework for the grid of the future with SSPS, nodes, hubs and their associated building blocks in the distribution system. The presentation will elaborate on the framework which includes controls, communication, intelligence, and optimization at various levels and highlight ORNL's efforts and accomplishments in realizing this concept.

Speaker Bio:

Radha Sree Krishna Moorthy is a R&D Associate Staff Member at Oak Ridge National Laboratory (ORNL) in Knoxville, Tennessee, USA. Her research at ORNL focuses predominantly on Solid State Power Substations (SSPS) for the grid of the future and their fundamental building blocks - Smart Universal Power Electronics Regulators (SUPERs) and Intelligent Power Stages (IPSs). She is actively involved in the validation of grid/system architectures in hardware in loop (HIL) platforms and in hardware. Prior to ORNL, she held a postdoctoral appointment at North Carolina State University (NCSU), Raleigh, NC. At NC state, she focused on SiC based high power inverters for vehicular applications. Her work has been published in major journals including IEEE Transactions in Industrial Electronics, IEEE Transactions on Industry Applications and Journal of Emerging and Selected Topics in Power Electronics. Her research interests include grid modernization and futuristic grid architectures, futuristic charging solutions and grid architecture validation in real-time systems.



Time Dependent Dielectric Phenomenon Under High Electric Fields

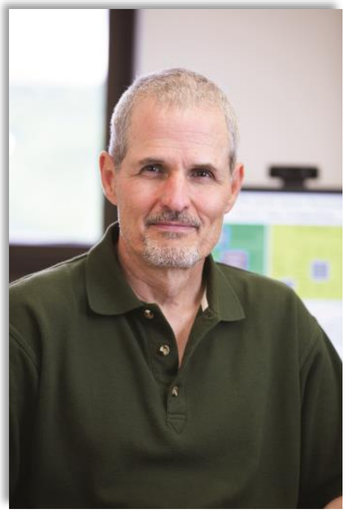
Clive Alan Randall, The Pennsylvania State University

Abstract:

This paper discusses the long time wear out mechanisms of dielectric material that limit insulation and capacitor devices. These time dependent phenomena are essential to understand, quantify, and mitigate as dielectric applications become more demanding. Here we will consider examples and mechanisms in high voltage cables and ceramic capacitors. We will discuss metrology, screening strategies, limitations in MTTF predictions, and radically new design opportunities for future dielectric materials.

Speaker Bio:

Prof. Randall received a B.Sc. with Honors in Physics in 1983 from the University of East Anglia, and a Ph.D. in Experimental Physics from the University of Essex in 1987. He has authored/co-authored over 450 technical papers, with over 30,000 citations and an h-factor of 90. He also holds 26 patents. He is a Fellow of the National Academy of Inventors, Fellow of American Ceramic Society, Fellow of IEEE , honorary Fellow of the European Ceramic Society, Academician of the World Academy of Ceramics.



Power Electronics Enabled Resilient Networked Microgrids

Dr. Rush D. Robinett III, Michigan Technical Institute

Abstract:

The present United States electrical power grid began as a collection of independent microgrids that were focused on connecting a source of power generation to a manufacturing load. Over time, these independent microgrids have been connected into a transmission/distribution network structure across the US based on fossil-fueled generators with large spinning inertia for stabilization. In addition, we are in a “Sea of Microgrids” (i.e., laptop computers, cell phones, PHEVs, EVs, etc.) within a “Sea of Information” (i.e., cellular network, cloud computing, etc.) that’s not being used to enhance the existing US electrical power grid due to regulations. Basically, it’s “Back to the Future” with better information/communication networks and excess energy storage capacity that are ripe for the pickings to enhance the electrical power grid resiliency.

Dr. Rush D. Robinett III will discuss one way to envision the transition of the present-day electrical power grid to a “Smart Grid” with two-way power and information flow based on power electronics enabled resilient network microgrids. Networked microgrids provide a means to take advantage of the “Sea of Microgrids”, “Sea of Information”, and intrinsic excess capacity required for resiliency while enabling the grid owners and operators to determine the best hierarchical (combination of distributed and centralized) grid architectures over time. The replacement of fossil-fuel burning generators with intermittent renewable energy sources and the recovery from existential threats (i.e., hurricanes, EMP, etc.) will require power electronics enabled energy storage, feedback control systems, and adaptive agent-based architectures within the networked microgrids. Hamiltonian methods including exergy, Fisher Information, and Complex Adaptive Systems (i.e., fractal and self-* systems) will be utilized to provide the framework for designing and analyzing optimal networked microgrids.

Speaker Bio:

Dr. Rush D. Robinett III is a Research Professor of Mechanical Engineering-Engineering Mechanics at Michigan Technological University. He specializes in nonlinear control and optimal system design of energy, robotics, and aerospace systems. Over the past 20 years, Dr. Robinett has been developing innovative controls and optimization techniques based on exergy concepts. In July 2018, he retired from Michigan Tech University after 5.5 years of service as the Co-Director of the Agile and Interconnected Microgrids Center, the Director of Research, and the Richard and Elizabeth Henes Chair Professor in Mechanical Engineering-Engineering Mechanics. In January 2013, he retired from Sandia National Laboratories after 25 years of service as the Senior Manager of the Grid Modernization and Military

Energy Systems Group focusing on the research and development of microgrids and networked microgrids. During his 25-year career, Dr. Robinett worked on ballistic missile defense, spacecraft systems, glide weapons, teams of robots, and renewable energy grid integration. He is an associate fellow of AIAA and has authored more than 250 technical articles including 3 books and holds 24 patents. Dr. Robinett has three degrees in Aerospace Engineering: a BS and Ph.D. from Texas A&M University and an MS from the University of Texas at Austin.

Medium Voltage power converters and their controls for enhanced grid integration of DERs

Dr. Akanksha Singh, National Renewable Energy Laboratory

Abstract:

With the increasing commercial availability of high-quality, and reliable wide bandgap devices that can operate at voltages relevant to medium-voltage distribution utility applications, it is critical to develop a technical pathway for such applications. the increasing penetration of renewable energy sources into the power grid has resulted in increased medium-voltage power converters as interfaces to these energy resources. This presentation includes discussion on grid applications that have been realized by the MV power converters. It will also include discussion on controls for advanced grid support through these devices and how they benefit the power grid.

Speaker Bio:

Akanksha Singh received the B.S. degree from Indian Institute of Engineering Science and Technology, India in 2010. She worked from 2010 to 2012 as an Electrical Engineer, Research and Development in ESAB India Limited. She received the Ph.D. degree in electrical engineering from the Kansas State University, KS, USA, in 2017. Since then, she has been working at the National Renewable Energy Laboratory (NREL) in various research roles. Her work at NREL has been focused on the design and control of wide bandgap - based power converters for grid connection, and application of power electronics for widespread integration of distributed energy to the grid. Her recent work is focused on integration of medium voltage SiC-based power converters to the distribution system. Her research interests also include design and control of power converters for motor drive applications.

ARPA-E Funding Opportunities in Power Electronics

Olga Spahn , ARPA-E

Abstract:

This talk will focus on ARPA-E perspective on power electronics needs to support advancements in grid resiliency and reliability, as well as other applications. Past and current power electronics programs at ARPA-E will be reviewed, and R&D gaps will be identified. Finally, potential future directions and program opportunities will be discussed.

Speaker Bio:

Dr. Olga Spahn currently serves as a Program Director at the Advanced Research Projects Agency-Energy (ARPA-E). Her focus at ARPA-E is on grid resiliency, power management and distribution, aviation and instrumentation for harsh environments leveraging optical and semiconductor device technologies.

Before joining ARPA-E, Dr. Spahn managed Advanced and Exploratory Systems at Sandia National Laboratories where she oversaw new system development and technology maturation activities for Nuclear Deterrence applications. Prior to that, she managed the Semiconductor Material and Device Sciences department where she focused on advancement of wide- and ultrawide- bandgap semiconductor devices and applications, which earned an R&D 100 Award. Her experience as a principal investigator spans technology development for nuclear non-proliferation, photonics and optoelectronics, optical MEMS, and laser material processing

Spahn holds her B.S. in Electrical Engineering from University of Illinois Urbana-Champaign, M.S. and Ph.D. in Electrical Engineering from University of California, Berkeley. She has published more than 90 publications, holds 3 patents, and is a co-author of several book chapters.

Medium Voltage PCB-based Bus Design and Insulation Coordination in a 10 kV SiC-based Power Electronics Building Blocks

Joshua Stewart, Virginia Tech

Abstract:

Wide bandgap semiconductors devices have enabled power electronics converters that operate at higher voltage, switching frequency, and temperature which lead to the reduction in size of passive components. To fully leverage these benefits while maximizing power density, component- and system-level insulation design is essential. In this work, 6 kV PCB-based DC bus using geometrical techniques for electric field control is presented. Improvements to the forced-air cooling system leading to a 24% increase in power density are also presented. The bus and cooling system were demonstrated to be partial discharge free at 6 kV and 30 kV respectively.

Speaker Bio:

Joshua Stewart received the B.S. and M.S. in electrical engineering from the University of New Mexico in 2015 and 2017 respectively. He is currently pursuing his PhD in electrical engineering at Virginia Tech in the Center for Power Electronics Systems (CPES). His research interest includes medium voltage power electronic converter and insulation design.

Moisture Ingress Models of Film Capacitors in PV Inverters

Ramanathan Thiagarajan, Power System Engineering Center, National Renewable Energy Laboratory

Abstract:
This presentation discusses the methodology for developing moisture ingress models for components inside a PV inverter. This method uses time series-based analyses for moisture ingress unlike a single maximum temperature, humidity, and voltage setpoint used in Hallberg-Peck equations. Experiments were performed for determination of moisture ingress time to estimate moisture ingress in and out of the capacitor device under normal and extreme temperatures and RH conditions.

Speaker Bio:
Mr. Ramanathan Thiagarajan received his bachelor's degree from Anna University in 2011 in Electrical and Electronics Engineering. After three years in the role of Development Engineering at Vellore Institute of Technology in India, he pursued his master's in electrical engineering from Arizona State University from 2015 to 2017. He is currently a Research Electrical Engineer at the National Renewable Energy Laboratory (NREL) in the Power System Engineering Center. He has been involved with multiple DOE efforts on inverter reliability including PREDICTS (Physics of Reliability: Evaluating Design Insights for Component Technologies in Solar), PVQAT (PV Quality Assurance Task Force), Power Electronics Reliability Standards, and TRACE-PV (Tool for Reliability Assessment of Critical Electronics in PV). His research interests include Grid Forming Inverters (GFM), PV inverter reliability, electrothermal multiscale models of inverters, humidity models for inverters, testing of PV inverters for advanced grid functionality, characterization of residential battery inverters coupled with PV, Controller Hardware-in-the-Loop (CHIL), and Power Hardware-in-the-loop (PHIL) testing of inverters. He was the recipient of the best poster award in the Photovoltaics Specialist Conference (PVSC) in 2019 and the NREL 2022 PV Reliability Workshop (PVRW).

Modern Magnetic Material Model for PSPICE

Coty Tran, University of New Mexico

Abstract:

As grid modernization efforts have evolved toward reliable and resilient power systems, scant attention has been paid to the role of passive components such as resistors, capacitors and inductors. The role of these passives should not be underestimated in attaining the desired quality in the grid of the future. Passive components - primarily soft magnetic components - are increasingly recognized as a vital component of efficient power systems not only for accurate sensors but as critical components in power converters, transformers as well as protective elements from electromagnetic interference such as chokes.

PSpice modeling has developed into an essential tool for the design of electronics. It is especially critical for the smart grid with its focus on high-performance and reliability while also being highly flexible. However, in practice, a recurring problem occurs because of the rigidity of the magnetic models frequently used in Pspice.

Pspice has adopted magnetic modeling equations from Jiles and Atherton that does well in portraying saturation and hysteresis effects found in ferromagnetic materials. Unfortunately, the equations that are being used do not exhibit any changes due to changes in frequency and temperature. It has been observed that ferromagnetic materials have shifts in max saturation due to temperature and there is an increase of coercive loss as frequency rises. These are important factors to determine the magnetic model's efficiency in designs.

The grid of the future will include an array of novel materials with new capabilities. For example, the development of electric vehicle chargers aims for simultaneous high power density and an efficiency exceeding 97%. This may only be achieved through the use of low loss magnetic materials and clever circuit architectures. Appropriate models must be developed to realistically represent their performance under a wide variety of operational conditions.

Speaker Bio:

Working at Sandia while pursuing degree at UNM.

Solid State Transformers – Control Architectures to Enhance System Resilience

Giri Venkataraman, Keith and Jane Nosbusch Professor, Department Electrical and Computer Engineering/Director, Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC)/University of Wisconsin-Madison

Abstract:

Transformers are ubiquitous in the power system that we know of today. All the power that is generated and consumed passes through a numerous of transformers. Some of them are equipped with tap-changing equipment for voltage regulation or phase-shifting, but most of them are not. They are also among the most reliable components because they are a mature technology and are made entirely of passive components. However, their failures, often caused by externalities, are often dramatic, and affect system resilience during extreme events.

Widespread introduction of solid-state transformers with or without dc link and/or energy storage capacity is controversial, not in the least due to cost, inertia and a cautious fear of the unknown. Substations are perhaps the most likely location in the system where the responsibility centers and operating paradigms may be favorable to their installation. The most significant feature of their adoption in substations will be the capacity to control and regulate anything beyond our wildest imaginations: frequency, voltage, phase angle, harmonics, phase balancing, fault-current control, active power, reactive power, and more to come, not just the capabilities of FACTS or D-FACTS. In such a scenario, while it would be rather tempting to create a top-down centralized control approach to operate the system, they will fall on their face under contingencies. Under extreme-weather events communications, and power for communications would be among the first to take a kit. Localized intelligence is key to ensuring resilience under such conditions. This presentation will introduce some robust self-organizing and distributed/localized control approaches that can coexist with centralized higher-level controllers.

Speaker Bio:

Giri Venkataramanan studied electrical engineering degree at the Government College of Technology, Coimbatore, India. He received the B.S. degree from the University of Madras, Chennai, India, in 1986, the M.S. degree from the California Institute of Technology, Pasadena, CA, USA, in 1987, and the Ph.D. degree from the University of Wisconsin–Madison (UW-Madison), Madison, WI, USA, in 1992. He began his academic career at Montana State University, Bozeman, MT, USA, before joining the faculty at UW-Madison in 1999. He has been actively conducting research in the areas of power converter topologies, microgrids, wind power systems, and utility-scale power electronic systems. He is currently the Director of the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC), Madison. His current research interests include power electronics with educational activism both inside and outside the classroom, developing hands-on student projects aimed at increasing learning effectiveness and addressing energy development issues. He is known on campus for his leadership in developing the Undergraduate Certificate in Engineering for Energy Sustainability, his active involvement in many small-scale wind turbine and photovoltaic installations, and his long record of inspiring student participation in a wide range of sustainability activities. Dr. Venkataramanan is the recipient of several major awards recognizing his preeminence as an engineering educator including the Gerald Holdridge Teaching Award, the 2008 Benjamin Smith Reynolds Award for Excellence in Teaching, the 2022 Harvey Spangler Award for Innovative Teaching and Learning Practices, and the UW-Madison Chancellor's Award for Distinguished Teaching.

Insulation, thermal management, and passive components: three remaining challenges for high power density converters

Jin Wang, The Ohio State University

Abstract:
With Gallium Nitride (GaN), Silicon Carbide (SiC) and other emerging wide bandgap (WBG) devices, power electronics is going through another round of evolution. Many challenges for circuit implementations of WGB devices have been fully addressed in the last decade. Insulation, thermal management, and passive components are among remaining challenges that still need more research and developments. The presentation will provide some insight on these challenges, introduce several high power density design examples, and discuss few new solutions.

Speaker Bio:
Jin Wang (IEEE Fellow) received his Ph.D. degree from the Michigan State University in 2005. He worked at Ford for two years before joined the Ohio State University (OSU) in 2007 as an Assistant Professor. He became a Full Professor at OSU in 2017. His current research interests include wide bandgap power device based high-voltage and high-power converters, renewable energy integration, and transportation electrification. Dr. Wang has over 200 journal and conference papers and 9 patents. Dr. Wang received the PELS Richard M. Bass Young Engineer Award in 2011, the National Science Foundation's CAREER Award in 2011, the Nagamori Award in 2020, and IEEE Power Electronics Emerging Technology Award for his contribution to high power density power converters and motor drives with wide bandgap devices.

The Optimal Control with Implicit Phase Coordination of a Collective of Wind Turbines

Joseph Young, OptimoJoe

Abstract:

The following presentation details an optimal control algorithm that coordinates a small collective of wind turbines. The algorithm consists of a reduced order model (ROM) of the wind turbine collective, a discretization of the resulting state equations using a collocation method, and an optimization formulation that guides the collective's behavior. In order to validate this algorithm, the presentation provides results from a scenario where two separate three turbine collectives are connected via a transmission line. The control ensures that each collective delivers a constant amount of power to the grid while simultaneously coordinating their performance to bound any excessive fluctuations in the voltage. This scenario suggests that a collective of wind turbines, combined with energy storage, can be coordinated to provide a constant amount of power with consistent voltage to the grid in spite of rapidly changing wind conditions.

Speaker Bio:

Dr. Joseph Young is the president and chief scientist of OptimoJoe. He received his Ph.D. in Computational and Applied Mathematics in 2008 from Rice University. Following graduation, Dr. Young performed postdocs at the University of Bergen and Sandia National Laboratories. In 2009, he founded the firm OptimoJoe. OptimoJoe provides innovative consulting services and customized software for industries that require expertise in computational mathematics and scientific computing. Recently, this has included optimization and control strategies for renewable energy generators and their connected microgrids.