Sandia National Laboratories

# THE POWER ELECTRONICS AND ENERGY CONVERSION WORKSHOP

## August 2 - 3, 2023

Co-Sponsored By:

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# 2023 Power Electronics and Energy Conversion Workshop

STATE BAR OF NEW MEXICO | 5121 MASTHEAD ST NE ALBUQUERQUE, NM 87109 | AUGUST 2-3, 2023

**Co-Sponsors:** University of New Mexico, New Mexico State, and University of Texas at Austin

## Wednesday, August 2, 2023

### Breakfast

7:00 am – 8:00 am

### Session 0: Opening Remarks and DOE Program Managers

8:00 am – 10:15 am

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| 8:00 – 8:05 | Welcome: *Amy Halloran (Sandia National Laboratories)* |
| 8:05 – 8:10 | Welcome: *Charles Hanley (Sandia National Laboratories)* |
| 8:10 – 8:20 | Welcome: *Craig Lawton (Sandia National Laboratories)* |
| 8:20 – 8:40 | Energy Conversion – What We Need…Yesterday: *Robert (Bob) W. Cummings (Red Yucca Consulting, LLC)* |
| 8:40 – 9:00 | DOE Transformer Resilience and Advanced Components (TRAC) Program Overview: *Andre Pereira (Department of Energy – Office of Electricity)* |
| 9:00 – 9:20 | DOE Energy Storage Program Power Electronics Overview: *Dr. Imre Gyuk (Department of Energy – Office of Electricity) & Dr. Stan Atcitty (Sandia National Laboratories)* |
| 9:20 – 9:40 | ARPA-E Perspective on Power Electronics for the Future Grid: *Olga Spahn (Department of Energy – Advanced Research Projects Agency-Energy)* |
| 9:40 – 10:00 | Recent Funding Efforts in Power Electronics Hardware and Control by the Solar Energy Technologies Office: *John Seuss (Department of Energy – Solar Energy Technologies Office)* |
| 10:00 – 10:15 | Panel Discussion |

### Networking Break

10:15 am – 10:45 am

### Session 1: Electrification of Everything – Electricity Delivery and the Future Grid

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|---|---|
| 10:45 am – 12:15 pm | Co-Chairs: *Michael Ropp (Sandia National Laboratories) & Richard Fioravanti (Quanta Technology)* |
| 10:45 – 11:00 | Cost Challenges of Electrifying Everything: *Richard Fioravanti (Quanta Technology)* |
| 11:00 – 11:15 | Transportation Electrification in Dense Urban Regions: Challenges and Opportunities: *Ahmed Mohamed (City University of New York, City College)* |
| 11:15 – 11:30 | Learning to Operate Distribution Grids with Extreme Penetration of Renewables: *Di Shi (New Mexico State University)* |
| 11:30 – 11:45 | Building the New Grid Is a Marathon Not a Sprint: *Jonathan Sykes (Quanta Technology)* |
| 11:45 – 12:00 | Power Electronics for Electrify Everything: *Dr. Leo Casey (Google)* |
| 12:00 – 12:15 | Panel Discussion |

## Lunch

12:15 pm – 1:00 pm

## Session 2: Solid-State Transformers: Grid Applications and Roadblocks

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|---|---|---|
| 1:00 pm - 2:30 pm | | Co-Chairs: *Ali Bidram (University of New Mexico), Steve Glover (Sandia National Laboratories), Alex Huang (University of Texas at Austin), & Stan Atcitty (Sandia National Laboratories)* |
| | 1:00 – 1:15 | Type I Solid State Transformer with Bidirectional Switches: *Jack Flicker (Sandia National Laboratories)* |
| | 1:15 – 1:30 | Development of High Power Medium-Frequency Transformers for Solid State Transformer: *Zhicheng Guo (University of Texas at Austin)* |
| | 1:30 – 1:45 | Medium Voltage Solid State Transformer for Grid Applications; Opportunities and Challenges: *Bogdan Borowy, Ph.D. (Eaton Research Labs)* |
| | 1:45 – 2:00 | Empowering the Grid: Unleashing the Potential of Self-Healing Solid-State Transformers: *Mehdi Abolhassani (Resilient Power Systems)* |
| | 2:00 – 2:15 | Transition towards future DC grids: Challenges and Possibilities: *Ghanshyamsinh Gohil (Hitachi Energy)* |
| | 2:15 – 2:30 | Panel Discussion |

## Networking Break

2:30 pm – 3:00 pm

## Session 3: Medium Voltage Circuit Topologies and Controls

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|---|---|---|
| 3:00 pm - 4:45 pm | | Co-Chairs: *Jack Flicker (Sandia National Laboratories) & Jacob Mueller (Sandia National Laboratories)* |
| | 3:00 – 3:15 | Medium Voltage Circuit Topologies and Controls: *Ramanathan Thiagarajan (National Renewable Energy Laboratory)* |
| | 3:15 – 3:30 | A Cascaded Power Electronics Architecture for Transformerless Medium-Voltage PV Systems: *Brian Johnson (University of Texas at Austin)* |
| | 3:30 – 3:45 | Integrated Liquid Metal Based Cooling -- An Ultimate Cooling Strategy for Electronics: *Jin Wang (Ohio State University)* |
| | 3:45 – 4:00 | Solid State Transformer and DC Grids: From Concept to Pilot Demonstration in a Decade Enabled by HV SiC 10-15kV IGBTs and MOSFETs: *Subhashish Bhattacharya (North Carolina State University)* |
| | 4:00 – 4:15 | Evaluating Medium Voltage, Multilevel Topologies in Electric Grid Applications: Realization and High Voltage Academic Facilities for Testing: *Brandon Grainger, Ph.D. (University of Pittsburgh)* |
| | 4:15 – 4:30 | Power Electronics at PNNL: *Dr. Xiaoyuan Fan (Pacific Northwest National Laboratory)* |
| | 4:30 – 4:45 | Panel Discussion |

## Evening Reception & Dinner

5:00 pm - 6:30 pm

## Thursday, August 3, 2023

### Breakfast

7:00 am – 8:00 am

### Session 4: Semiconductor Materials

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|---|---|
| 8:00 am – 10:15 am | Co-Chairs: *Bob Kaplar (Sandia National Laboratories) & Andrew Binder (Sandia National Laboratories)* |
| 8:00 – 8:20 | Advances in Wide and Ultrawide Bandgap Semiconductor Materials for High Voltage, High Power Electronics: *John F. Muth (North Carolina State University)* |
| 8:20 – 8:40 | Ultra-Wide Bandgap Semiconductors and Interfaces for High Power Electronics: *Robert J. Nemanich (Arizona State University)* |
| 8:40 – 9:00 | Recent Advancements in (Al)GaN High Electron Mobility Transistor Power Electronics at Sandia: *Brianna Klein (Sandia National Laboratories)* |
| 9:00 – 9:20 | Reliability Test and In-Situ Failure Analysis of Wide Bandgap Power Electronics: *Moinuddin Ahmed (Argonne National Laboratory)* |
| 9:20 – 9:40 | An Overview of Multi-Scale Device Level Control in Power Electronics Using Electrical and Photonic Device Technologies: *Sudip K. Mazumder (University of Illinois Chicago)* |
| 9:40 – 10:00 | Observation of Lock on in Gallium Nitride Photoswitches: *Jane Lehr (University of New Mexico)* |
| 10:00 – 10:15 | Panel Discussion |

### Networking Break

10:15 am 10:45 am

### Session 5: Passives

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|---|---|
| 10:45 am – 12:15 pm | Co-Chairs: *Todd Monson (Sandia National Laboratories) & Jane Lehr (University of New Mexico)* |
| 10:45 – 11:00 | Dielectric Materials and Capacitor Reliability for Power Electronic and Pulsed Power Applications: *Michael Lanagan (Penn State University)* |
| 11:00 – 11:15 | Recent Advances in Soft Magnetics for Emerging Applications in Electric Power Conversion Technologies: *Paul Richard Ohodnicki, Jr. (University of Pittsburgh)* |
| 11:15- 11:30 | Design of High Silicon Steel for Motors and Electronics: *Gaoyuan Ouyang (Ames National Laboratory)* |
| 11:30 – 11:45 | Designing Soft Magnetic Materials: *Dale Huber (Sandia National Laboratories)* |
| 11:45 – 12:00 | Inductor Core Design for Power Electronic Ultrahigh Frequency Applications: *Vincent G. Harris (Northeastern University)* |
| 12:00 – 12:15 | Panel Discussion |

### Lunch

12:15 am - 1:00 pm

## Session 6: Packaging and Manufacturing; and Supply Chain, Power Density and Thermal Modeling

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|---|---|
| 1:00 pm - 2:30 pm | Co-Chairs: *Lee Gill (Sandia National Laboratories), Luke Yates (Sandia National Laboratories), Lee Rashkin (Sandia National Laboratories)* |
| 1:00 – 1:15 | Medium Voltage PCB-based Bus Design and Insulation Coordination for Power Electronics Building Blocks: *Joshua Stewart (Virginia Tech)* |
| 1:15 – 1:30 | Packaging and Integration Design for High-Voltage WBG Modules: *Fang Luo (Stony Brook University)* |
| 1:30 – 1:45 | 2.5D HI Packaging of Lower Voltage Power Converter Using TSV Interposer: *Helen Chung (Sandia National Laboratories)* |
| 1:45 – 2:00 | Liquid Immersion for Next Generation Utility Scale Power Electronics: *Giri Venkataremanan (University of Wisconsin-Madison)* |
| 2:00 – 2:15 | Reliability Characterization and In-Situ Health Estimation of WBG Semiconductor-Based Power Converters: *Dr. Harish Krishnamoorthy (University of Houston)* |
| 2:15 – 2:30 | Panel Discussion |

## Networking Break

2:30 pm – 3:00 pm

## Session 7: R&D Gaps and Business Opportunities

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|---|---|
| 3:00 pm - 4:30 pm | Co-Chairs: *Richard Baxter (Mustang Prairie Energy)* |
| 3:00 – 3:15 | Opportunities in the Renewable and Distributed Power Environment: *Rohan Raghunathan (Wolfspeed)* |
| 3:15 – 3:30 | Venture Capital in Industrial Technology: *Henk Both (Anzu Partners LLC)* |
| 3:30 – 3:45 | Addressing Compliance Hurdles to Gain Market Access: *Scott Daniels (CSA Group)* |
| 3:45 – 4:00 | Energy Storage Solutions for the Next 30 Years of Rapid Deployments: *C. Michael Hoff (American Battery Solutions)* |
| 4:00 – 4:15 | Critical Role of Power Electronics in Short and Long Duration Energy Storage: *Himamshu Prasad (Schneider Electric)* |
| 4:15 – 4:30 | Panel Discussion |

## Closing Remarks

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|---|---|
| 4:30 pm – 5:00 pm | *Charles Hanley (Sandia National Laboratories)* |

# Amy Halloran

*Sandia National Laboratories, Director, Nuclear Fuel Cycle and Grid Modernization*

Amy Halloran provides leadership and management direction for Sandia's research and development (R&D) programs as Director of the Nuclear Fuel Cycle and Grid Modernization Center at Sandia National Laboratories. She also serves as Program Area Director for the Nuclear Fuel Cycle and Grid Modernization Program within Sandia's Energy & Homeland Security Portfolio.

Previously, as Senior Manager of Renewable Energy Technologies, Amy led Sandia's $50M R&D program in wind energy, solar energy, water power, geothermal energy and water/energy nexus to improve the reliability, reduce the cost, and decrease the regulatory burden of renewable energy and water supplies. Amy's Sandia career started in 2011 as Manager of the Geophysics and Atmospheric Science Department, a team developing leading-edge technical solutions for the Department of Energy (DOE), the Department of Defense (DOD), and industrial customers in nuclear threat detection, climate measurement, and oil and gas extraction. She also oversaw Sandia's work on the North Slope of Alaska for DOE's Climate Program.

Prior to joining Sandia, Amy was a Vice President at CH2M Hill, managing business development for environmental work for federal customers across the United States. Hired as a CH2M Hill environmental engineer in 1989, Amy delivered multimillion-dollar projects in contaminated soil and groundwater investigation and remediation, industrial waste treatment, compliance audits, and energy efficiency. Her customers included DOD, DOE, the Environmental Protection Agency, and private industry.

Amy has a strong commitment to diversity and inclusion and received the New Mexico Technology Council's annual Women in Technology Award in 2019. She is Sandia's Campus Executive for the University of Illinois; a past President of both the New Mexico Engineering Foundation and the Society of American Military Engineers, Albuquerque Post; and a former Community Panel Chair for the United Way of Central New Mexico. Amy has a bachelor's degree in chemical engineering from Virginia Tech and a master's degree in civil and environmental engineering from the University of Illinois at Urbana-Champaign. She has been licensed as a Professional Engineer since 1994.

# Charles Hanley

*Sandia National Laboratories, Senior Manager, Grid Modernization and Energy Storage*

Mr. Hanley is Senior Manager of the Grid Modernization and Energy Storage Group at Sandia National Laboratories. His group conducts research on enhancing the resilience of our critical energy infrastructures, including grid-scale optimization, controls, and microgrids; energy storage technologies; renewable energy integration; power electronics; cyber security; and advanced analytics for complex systems. He joined Sandia in 1988 and has been working in Sandia's renewable energy and electric grid programs since 1994. From 2005 through 2014, Charlie managed Sandia's Photovoltaics and Distributed Systems Integration Program. Prior to that, he managed Sandia's international renewable energy programs, through which he oversaw the implementation of more than 400 photovoltaic and wind energy systems in Latin America. He received his B.S. in Engineering Science from Trinity University in San Antonio, Texas, and his M.S. in Electrical Engineering from Rensselaer Polytechnic Institute, in Troy, New York.

# Craig Lawton

*Sandia National Laboratories, Manager, RES Mission Campaign*

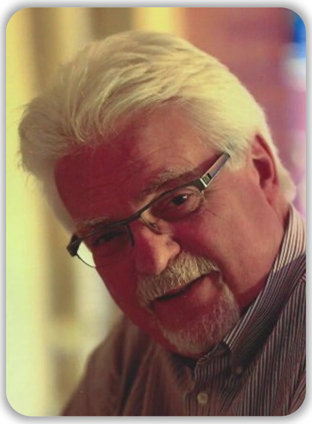
Craig is currently Sandia's Campaign Manager for the Resilient Energy Systems (RES) Mission Campaign. The RES Mission Campaign is a multi-million-dollar research investment focused on developing capabilities that will help improve the resilience of our critical energy system and related national security assets and functions. Prior to his role on the RES Mission Campaign, Craig served as Sandia's Program Manager for Defense Energy and the Manager of the Mathematical Analysis and Decision Sciences department.

Prior to his roles with Defense Energy and the Mathematical Analysis & Decision Sciences department, Craig served as the Program Manager for the Future Force Integrated Support Team (FIST) which designs, develops and applies innovative modeling and analysis approaches to large-scale, complex problems for the military services and the Department of Defense (DoD) in the area of Model Based Systems Engineering. During his tenure with FIST, Craig was the lead architect for both the Capability Portfolio Analysis Toolset (CPAT) – 2015 Edelman Prize Finalist and the Military Operations Research Society's Barchi Prize winner, as well as the Whole System Trades Analysis Tool (WSTAT) – winner of the 2015 Army Modeling and Simulation Excellence Award.

Craig has 25+ years of experience in the field of Operation Research, most of which has focused on simulation and optimization modeling for complex systems. He has a Master of Science in Operations Research & Statistics from Rensselaer Polytechnic Institute and a Bachelor of Arts in Cognitive Science from the University of Rochester.

# Robert (Bob) W. Cummings

*Red Yucca Consulting*



Robert Cummings graduated from Worcester Polytechnic Institute with a Bachelor of Science in Electrical Engineering with a concentration in power systems. He retired after 23 years with the North American Electric Reliability Company (NERC) in April of 2020 as the Senior Director of Engineering and Reliability Initiatives. During his time with the NERC, he was the principal investigator of the 2003 Northeast Blackout and the Arizona-Southern California outage of 2011. He is recognized as the "father" of power interchange transaction "tagging" and the Interchange Distribution calculator for the Eastern Interconnection, which is known as the Enhanced Curtailment Calculator in the Western Electricity Coordination Council. His work in such projects and his role in advisory boards and committees for the DOE and Center for the Ultra-Wide Area Resilient Electric Energy Transmission Networks has served for remarkable advancements in the field of power system reliability.

## Energy Conversion – What We Need…Yesterday

Often, research projects concentrate on new, unproven technologies. That leaves a gap between what is needed in today's rapidly changing energy production and consumption world. What promising energy conversion technologies are left struggling for adoption by the electric industry and the public, while visions of magic boxes with no scientific basis in reality are pursued? That is the challenge we must face if we are to make through a realistic transition to any lower carbon emissions world!

# Andre Pereira

*Department of Energy – Office of Electricity*

Andre Pereira is the Program Manager for the Transformer Resilience and Advanced Components (TRAC) program within the Office of Electricity. The TRAC program conducts cutting-edge research and development for new grid hardware technologies, including advanced transformers, Solid State Power Substations (SSPS), advanced power electronics, High Voltage Direct Current (HVDC) transmission, Grid Enhancing Technologies (GETs), and advanced materials. Prior to joining DOE, Andre worked for the U.S. Department of Labor as a Project Manager. Andre received a degree in engineering from the West Virginia University and a Master's in Engineering Management from the Arkansas State University.

## Power Electronics and the Transformer Resilience and Advanced Components (TRAC) Program

An overview of the role of power electronics in the grid, the Transformer Resilience and Advanced Components (TRAC) program, and some of the key program priorities moving forward.

# Dr. Imre Gyuk

*Department of Energy – Office of Electricity*

Dr. Imre Gyuk directs Energy Storage Research at the U.S. Department of Energy. He has a B.S from Fordham and a Ph.D. from Purdue. He has taught at the University of Wisconsin and at Kuwait University. For the past 2 decades, he has directed innovative research at the forefront of Energy Storage. His team develops a wide portfolio of storage technologies for a broad spectrum of applications. He is now partnering with states, municipalities, tribes, and utilities on numerous projects for grid resilience and decarbonization. Dr. Gyuk's Program includes research on materials, devices, and systems; it also funds work on analytics, policy, finance, and most recently, social equity and long duration storage. His work has led to 13 R&D 100 awards, two EPA Green Chemistry Challenge Award, and Lifetime Achievement Awards from ESA and NAATBatt. He is internationally recognized as a leader in the energy storage field.

# Dr. Stan Atcitty

*Sandia National Laboratories*

Dr. Stan Atcitty received his BS and MS degrees in electrical engineering from the New Mexico State University in 1993 and 1995, respectively. He received his PhD from Virginia Tech University in 2006. He is presently a Senior Scientist at Sandia National Laboratories in the Nuclear Fuel Cycle & Grid Modernization Center. He has worked at Sandia for over 28 years. His interest in research is power electronics necessary for integrating energy storage and distributed generation with the electric utility grid. He leads the power electronics and tribal energy storage subprograms as part of the DOE Office of Electricity Energy Storage Program. He also leads the National Nuclear Security Agency (NNSA) funded Minority Serving Institute Partnership Program targeting Tribal Colleges & Universities.

**Power Electronics for Energy Storage - 20 Years of Progress at Sandia**

Research on power electronic devices for energy storage applications at Sandia National Laboratories has a history of 20 years of innovation. This work has led to many accomplishments which represent world firsts and resulted in 7 R&D100 awards.

# Olga Spahn

*Department of Energy – Advanced Research Projects Agency-Energy*

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. Dr. Spahn holds her B.S. in Electrical Engineering from University of Illinois Urbana-Champaign and 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.

## ARPA-E Perspective on Power Electronics for the Future Grid

This talk will focus on the ARPA-E perspective on power electronics for the future grid and its resiliency and reliability, as well as other applications. Past and current power electronics programs at ARPA-E will be reviewed and some example activities will be discussed.

# John Seuss

*Department of Energy – Solar Energy Technologies Office*

John Seuss is a Technology Manager in the Systems Integration group in the Solar Energy Technologies Office (SETO) of the U.S. Department of Energy. In this role he manages funding opportunities for research, development, demonstration, and deployment of new technologies that will aid the integration of solar energy with the electric grid. Prior to joining SETO, he has worked in the utility industry as an engineer and researcher on various topics including renewable integration, inverter controls, distribution automation, and adaptive protection systems. He received his bachelor and doctoral degrees in Electrical Engineering from the Georgia Institute of Technology in 2006 and 2016.

## Recent Funding Efforts in Power Electronics Hardware and Control by the Solar Energy Technologies Office

This presentation will provide an overview of the Department of Energy's Solar Energy Technologies Office's (SETO) mission and recent funding programs related to power electronics hardware and controls. SETO has funded R&D at national laboratories, universities, and private industry to study new power electronic hardware topologies that may improve the reliability of solar energy generation sites and reduce lifetime levelized cost of energy. More recent funding has targeted research into the control of power electronic converters to enable grid-supporting and grid-forming features in solar and hybrid energy plants.

# Richard Fioravanti

*Quanta Technology*

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 and 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.

## Cost Challenges of Electrifying Everything

Recent studies have provided cost estimates for the infrastructure upgrades required to electrify "everything." Numbers as high as $60 billion for a state is not uncommon. Currently, these numbers exceed capital planning budgets and lead to a big question – how is this transition going to be paid for? This presentation examines the drivers of these cost and the role DER technologies such as electricity storage can play in mitigating these projected cost impacts.

# Ahmed Mohamed

*City University of New York, City College*

Ahmed A. Mohamed is an Associate Professor of Electrical Engineering (EE) at the City College of the City University of New York (CUNY). He is the EE Ph.D. Program Advisor and the director of the CUNY Smart Grid Interdependencies Laboratory (http://smartgrid.ccny.cuny.edu). Prof. Mohamed has been leading various research projects sponsored by private companies and government agencies, e.g., Con Edison, the National Science Foundation, and New York State Energy Research and Development Authority. His research interests include critical infrastructure interdependencies, smart grid resilience, microgrids, and transportation electrification. He has numerous publications in these fields as books, book chapters, and articles in journals and conference proceedings. Prof. Mohamed serves on the editorial board of several journals, including the IEEE Transactions on Transportation Electrification. He is the recipient of the NSF CAREER Award, among several other honors and awards.

## Transportation Electrification in Dense Urban Regions: Challenges and Opportunities

In this talk, some of the key grid-related challenges that are associated with the electrification of the transportation sector in dense urban regions will be discussed, with a focus on New York City. In addition, the presenter will delve into opportunities that can potentially mitigate some of those challenges and expedite electrification, specifically opportunities that arise due to synergies between various critical infrastructures (CI), such as vehicle-to-grid services and the potential coupling between the subway network and electric vehicle supply equipment. The talk aims to uncover realistic collaboration opportunities leading to a modernized grid and a holistic circular-economy design for next-generation sustainable CIs.

# Di Shi

*New Mexico State University*

Di Shi is an Associate Professor at New Mexico State University's Klipsch School of Electrical and Computer Engineering. Prior to academia, he founded a tech startup, commercialized two technologies, led the AI & System Analytics group at GEIRINA, and held research roles at NEC Labs, EPRI, and Arizona State University. An active participant in IEEE, he leads two IEEE PES task forces/working groups and boasts a rich research portfolio with over 170 papers and 26 patents, and serves as associate editors for several transactions. His team triumphed in the 2019 "Learning to Run a Power Network (L2RPN)" AI competition. He earned both Ph.D. and M.S. degrees from Arizona State University and his B.S. from Xi'an Jiaotong University.

## Learning to Operate Distribution Grids with Extreme Penetration of Renewables

As the power systems landscape is reshaped by renewables, managing distribution grid operations presents new challenges. In this talk, I will introduce an innovative, data-driven, learning-based framework for autonomous distribution grids, coupled with the corresponding software platform. This system efficiently synthesizes data from wide sensor networks for strategic energy resource allocation, a crucial element in managing grids with high penetration of renewables. I will share real-world outcomes from the successful deployments of these platforms at various dispatch centers, demonstrating the transformative potential of this approach in power system operations. Additionally, the talk will explore the prospects of a highly efficient, distributed learning-based framework. Designed to run on lightweight edge devices, this framework aims to enhance the coordination, optimization, and control of distribution grids.

# Jonathan Sykes

*Quanta Technology*

Jonathan Sykes is the Vice President of Advanced Applications at Quanta Technology. He spent most of his 41 years in the industry working for the electric power utilities of SRP and PG&E and recently transitioned from the VP Transmission and Substations at Luma Energy in Puerto Rico. Jonathan brought his extensive industry knowledge and expertise to help the people of Puerto Rico and build the grid of the future. He has always been a steward of the electrical power industry and has held leadership roles in utilities (SRP, PG&E, and Luma), regulatory entities (WECC, NERC, IEEE), and SEL, a leading provider of substation control equipment and applications. He is a Fellow of IEEE and a licensed Professional Engineer and was elected to the IEEE PES Executive Committee as the Secretary. Jonathan has always leveraged technology in collaboration to close gaps and champion success. In the 1990s, Jonathan's teams provided the first integrated protective relay/RTU/SCADA systems in Arizona USA; in the 2000s, he pioneered the first wide-area protection scheme based on IEC 61850 GOOSE messaging; and in the 2010s, Jonathan's team implemented one of the most advanced synchrophasor systems in North America. Today, Jonathan and the collective teams at Luma Energy are taking an electrical T&D system that has been neglected for years and decimated by natural disasters and implementing leading-edge concepts in asset life cycle management for mission-critical systems and developing new techniques and processes to transform the grid to a reliable, sustainable, and affordable grid of the future.

## Building the New Grid Is a Marathon Not a Sprint

For the last 40 years the electric power industry has been upgrading the grid. At first it was the solid-state technology that caused all the controls to be upgraded, then it was business concerns that caused utilities to decrease the margins on equipment, then consumers needed more electric power to keep up with more products, then microprocessors, then carbon emissions, then renewables, and finally electrification. All of this and much more is pushing the industry to look and perform much differently than your grandfather's electric grid. This is very evident and illustrated in what is going on in Puerto Rico.

# Dr. Leo Casey

*Google*

Dr. Leo Casey, IEEE Fellow, 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, and 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 and is a board member of the 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 Master's, Engineer's and Doctorate degrees from the Massachusetts Institute of Technology.

### Power Electronics for Electrify Everything

"Electrify Everything" means to move the 70% of our energy that is not electricity to electricity. Power electronics are a key to this transition which we will discuss.

# Jack Flicker

*Sandia National Laboratories*

Jack Flicker (Senior Member, IEEE) received B.S. degrees from Penn State University, State College, PA, USA, in physics and chemistry and a Ph.D. degree in materials science and engineering from Georgia Tech, Atlanta, GA, USA, in 2011. He joined Sandia National Laboratories, Albuquerque, NM, USA, as a Postdoctoral Appointee, focusing on power semiconductor reliability in photovoltaic applications. He is currently a Principal Member of the Technical Staff. His research interests include all aspects of power electronics and power conversion systems that enable improvements in power system operation, from incorporation of new materials and devices in power conversion systems to utilizing new topologies and controls at the system level, and his research touches all areas of the power electronics value chain, ranging from usage of new devices (wide- and ultra-wide bandgap semiconductors) to new topologies and controls to evaluation of system-level behavior. The nature of his work spans multiple TRL levels and incorporates everything from basic analysis to optimization and simulation to experiment and field-deployment.

## Type I Solid State Transformer with Bidirectional Switches

Solid State Transformers (SSTs) are an enabling technology for the next generation electrical grid, allowing for operational flexibility due to the ubiquitous presence of power electronics. Conventional Type IV SST architectures utilize two full-bridge stages and two half- or full-bridge stages in an AC:DC:AC topology, requiring a significant number of switches (18-20). This reduces reliability and increases complexity/cost. A more efficient direct Type I AC:AC SST topology is possible with only six switches and without any DC bus. However, this requires bidirectional switch elements (BiDFETs). This talk focuses on fabrication and demonstration of a high-power density, modular, Type I SST AC:AC prototype that utilizes Silicon Carbide (SiC) BiDFETs. Additionally, the talk will introduce efforts to design, fabricate, and demonstrate application-specific BiDFETs and soft magnetic materials with comparison to baseline commercial devices in the Type I SST prototype.

# Zhicheng Guo

*University of Texas at Austin*

Zhicheng Guo received a Ph.D. degree in power electronics and power systems from the University of Texas at Austin. Currently, he is a postdoctoral fellow at the Semiconductor Power Electronics Center, UT Austin. Zhicheng Guo will join Arizona State University as an assistant professor in January 2024.

## Development of High Power Medium-Frequency Transformers for Solid State Transformer

Medium voltage solid-state transformers have been widely studied as the next generation technology for medium voltage applications. As one of the key components, the medium frequency transformer needs to process high power and provide high insulation capability. For MV high-power MFTs design, the challenge is the tradeoff among competing objectives: 1) high efficiency, high power density; 2) superior thermal performance; and 3) reliability: partial discharge free under high dv/dt high frequency voltage stress. The presentation will introduce our latest technologies about the MFTs' optimal design.

# Bogdan Borowy, Ph.D.

*Eaton Research Labs*

Dr. Bogdan Borowy is a Senior Chief / Principal Engineer of Power Electronics with Eaton Research Labs, Menomonee Falls, Wisconsin. With over 30 years of experience in the areas of power conversion, motor drives, advanced controls of power electronics, magnetic levitation, and power systems, he led developments of multiple systems in a wide range of applications including grid-scale inverters, LIPO battery-based frequency regulation system, magnetically levitated vehicles (MagLev), Electromagnetic Launching System, and SiC MV-scale converters. Dr. Borowy authored and coauthored over 60 peer reviewed journal and conference technical papers. He holds several US patents in the area of power electronics and propulsion systems, is a Senior Member of IEEE and has been serving as member of IEEE conferences and standards committees.

### Medium Voltage Solid State Transformer for Grid Applications; Opportunities and Challenges

Accelerated increase in renewable resources penetration levels combined with growing electric vehicle (EV) markets and data storage centers pose a series of new demands on the electric grid. On the generation side, the stochastic nature of renewables' dynamic and quasi-static availability requires higher levels of controllability and a significant amount of storage in the form of hydro, hydrogen, compressed air, and batteries. The high inertia turbine driven synchronous generators that have until recently been the backbone of the grid are gradually being replaced by Inverter Based Resources (IBRs) linking variable speed (wind) or DC (photovoltaics or PVs) renewables. Batteries, being the preferred storage type are also linked to the grid via electronic converters. Additionally, growing demand for MW-scale fast and extreme fast charging systems for large EVs (trucks) poses additional demands on the grid.

These new grid pressure points necessitate more coordinated and faster dynamics integration of low-voltage and high- and medium-voltage grid networks with high power electronic converters that provide high flexibility in dynamic control and dispatching levels. Medium Voltage Stolid-State Transformer (MVSST) technology offers a solution, meeting the new demands, while exhibiting several advantageous features such as low cost, size and weight compactness, high efficiency, capability of voltage and frequency regulation, and bidirectional power flow control.

While the MVSST technology is being developed, several challenges still need to be addressed. Among those, communications, implementation, protection, and modularity are currently identified as most important. This presentation provides an overview of the MVSST technology developed at Eaton Research Labs; control schemes, communications protocols, high frequency transformer design, insulation concerns and implementation, protection, and grid conditions and faults operation are discussed.

# Mehdi Abolhassani

*Resilient Power Systems*

Dr. Mehdi Abolhassani is a highly accomplished electrical engineer and technology executive specializing in power electronics, electrical machines, and renewable energy systems. With a Ph.D. in Electrical Engineering from Texas A&M University, he has made significant contributions to the field. Dr. Abolhassani's research spans various areas, including fast electric vehicle chargers, multi-level inverters, power electronics applications in power systems, novel electrical machine design, and digital motor control. His passion lies in energy conversion systems for renewable and alternative energy resources, as well as advancing electric transportation. Currently, Dr. Abolhassani holds the position of Chief Technology Officer and Co-founder at Resilient Power Systems, an Austin-based company specializing in solid-state transformer-based DC Fast Electric Vehicle chargers. Throughout his career, Dr. Abolhassani has held key positions in both industry and academia, contributing to his rich professional experience. As the former R&D Manager of Toshiba's Drives division, he led a multidisciplinary design team in developing Low Voltage Drive products. In academia, Dr. Abolhassani served as an Assistant Professor and Director of the Gtest Lab at the University of Houston. He supervised graduate students, conducted research in electrical machines and power conversions, and delivered courses in the field. His industry experience includes positions at Main Spring Energy, TECO-Westinghouse Motor Company, Black & Decker, Wavecrest Labs, and General Motors, where he spearheaded the design and development of various power conversion products. Dr. Abolhassani is a prolific inventor, holding 35 US and international patents. He has also published numerous research papers in respected journals and conference proceedings and authored chapters in relevant books. With his extensive knowledge and experience, Dr. Mehdi Abolhassani continues to drive innovation in power electronics, renewable energy systems, and electric transportation.

## Empowering the Grid: Unleashing the Potential of Self-Healing Solid-State Transformers

In today's power electronics landscape, the demand for reliable and efficient grid systems is paramount. Solid state transformers (SSTs) have emerged as promising alternatives to traditional transformers, offering enhanced functionality and improved performance. This presentation delves into the transformative power of self-healing solid-state transformers and their profound impact on grid applications. By integrating advanced self-healing capabilities, SSTs possess the remarkable ability to autonomously repair faults, ensuring uninterrupted power flow and mitigating potential disruptions. Through a comprehensive exploration of the underlying technology and innovative design principles, this talk elucidates how self-healing SSTs enable the creation of highly reliable and resilient grid infrastructures. Real-world case studies will be presented, showcasing the practical implementation of self-healing SSTs and their profound implications for power distribution networks. Join us as we embark on an enlightening journey, revealing the immense potential and exciting prospects that self-healing solid-state transformers offer for empowering the grid of the future.

# Ghanshyamsinh Gohil

*Hitachi Energy*

Ghanshyamsinh Gohil received an M.Tech. degree in electrical engineering, with specialization in power electronics and power systems, from the Indian Institute of Technology Bombay, Mumbai, India, in 2011, and a Ph.D. degree in electrical engineering from the Department of Energy Technology, Aalborg University, Denmark, in 2016. He was a Postdoctoral Researcher with the FREEDM Systems Center, North Carolina State University, Raleigh, NC, USA, where his focus was on combined photovoltaic-energy storage systems and medium voltage power conversion. He currently works as a Lead Scientist with Hitachi Energy. Before joining Hitachi Energy, he worked as an Assistant Professor with the University of Texas at Dallas (UTD), Richardson. He was a Lead Research Engineer with Siemens Corporate Technology and Deputy Manager Technology with the Crompton Greaves Global R & D Center. His research interests include medium voltage power conversion and its applications to power systems.

### Transition Towards Future DC Grids: Challenges and Possibilities

A DC grid is an enabler to energy transition, and it will continue to evolve to meet ambitious decarbonization goals by unlocking interconnection of large remote renewable energy sources to load centers. The possible evolution scenario and R&D needs to realize the future DC grid will be presented.

# Ramanathan Thiagarajan

*National Renewable Energy Laboratory*

Ramanathan Thiagarajan is a research electrical engineer from the Power System Engineering Center at the National Renewable Energy Laboratory (NREL). He has been involved with multiple efforts on medium voltage power electronics, residential PV and storage inverter testing and characterization, grid forming inverters, and PV inverter reliability for the last six years at NREL. He holds a master's degree in electrical engineering from Arizona State University, specializing in Power Electronics. He obtained his bachelor's in electrical engineering from Anna University in 2012. Prior to his master's degree, he worked as a researcher in India for three years developing battery management systems for lithium-ion batteries.

## Medium Voltage Circuit Topologies and Controls

NREL has been involved with developing medium voltage inverter controls and characterization enabling integration of renewables to the distribution grid. This is enabled by power converters developed with Wide Band Gap (WBG) devices such as GaN and SiC technologies. The topologies enabled by WBG converters allow direct integration of renewables into the distribution grid. This presentation will include the existing and developing medium voltage converter testing capabilities and ongoing MV converter projects at NREL.

# Brian Johnson

*University of Texas at Austin*

Brian Johnson is an Assistant Professor and a Fellow of the Jack Kilby/Texas Instruments Endowed Faculty Fellowship in Computer Engineering in the Department of Electrical and Computer Engineering at The University of Texas at Austin. He obtained his M.S. and Ph.D. degrees in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign, Urbana, in 2010 and 2013, respectively. Previously, he was the Washington Research Foundation Innovation Assistant Professor within the Department of Electrical and Computer Engineering at the University of Washington in Seattle. Prior to joining the University of Washington in 2018, he was an engineer with the National Renewable Energy Laboratory. His research interests are in renewable energy systems, power electronics, and control systems. His work was recognized with a National Science Foundation (NSF) CAREER Award in 2022. He is currently co-leading the multi-institutional Universal Interoperability for Grid-Forming Inverters (UNIFI) Consortium, which is funded by the U.S. Department of Energy (DOE). UNIFI brings together leading researchers, industry stakeholders, utilities, and system operators to advance grid-forming inverter technologies. UNIFI will focus on developing the technologies and best practices for the seamless integration of renewable-based power electronics into electric grids.

## A Cascaded Power Electronics Architecture for Transformerless Medium-Voltage PV Systems

In this talk, we provide an overview of a novel circuit topology that facilitates power delivery from multiple low-voltage PV strings to a medium-voltage grid without the use of low-frequency transformers. The proposed system is comprised of several modules that each have a dc input for PV and three ac outputs that allow for series connections with other modules. Our circuit structure leverages smooth dc power delivery due to balanced three-phase waveforms to minimize passive component energy storage and streamline control. A breakthrough method is outlined that enables the use of printed-circuit-board-based high-frequency transformers that can withstand medium voltages, thus enabling low-cost mass production. Controls facilitate decentralized operation such that plug-and-play systems are obtained where many series-connected modules can be interconnected and operated with ease.

# Jin Wang

*Ohio State University*

JIn Wang, IEEE Fellow, received his Ph.D. degree from the Michigan State University in 2005. He worked at Ford for two years before joining 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, transportation electrification, and renewable energy integration. Dr. Wang has over 200 journal and conference papers and 9 patents. Dr. Wang received the IEEE PELS Richard M. Bass Young Engineer Award in 2011, the National Science Foundation's CAREER Award in 2011, the Nagamori Award in 2020, and the IEEE Power Electronics Emerging Technology Award in 2022. Dr. Wang initiated and served as the inaugural General Chair for the IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA) in 2013 and the IEEE Workshop on Power Electronics for Aerospace Applications (PEASA) in 2022.

## Integrated Liquid Metal Based Cooling -- An Ultimate Cooling Strategy for Electronics

During this talk, efforts of high-power density converter designs at the Ohio State University's Center for High Performance Power Electronics will be introduced as a background. Then the talk will focus on how integrated liquid metal-based cooling could further increase the power density of power converters. Principles and performance of integrated liquid metal-based cooling will be presented in detail based on multiple generations of designs. Remaining implementation challenges will also be discussed.

# Subhashish Bhattacharya

*North Carolina State University, FREEDM Systems Center, PowerAmerica Institute, Dept of ECE*

Subhashish Bhattacharya is currently a Duke Energy Distinguished Professor in the Department of ECE at NC State University. He received a B.E. from IIT-Roorkee, India, an M.E. from IISc, India, and a Ph.D. from University of Wisconsin-Madison, all in electrical engineering. He worked at the FACTS and Power Quality Division at Westinghouse R&D, as well as Siemens Power Transmission & Distribution from 1998 to 2005. He joined NCSU in August 2005, where he is a founding faculty member of NSF FREEDM Center, ATEC, and DoE PowerAmerica Institute. A part of his PhD research on active power filters was commercialized by York Corporation, now Johnson Controls. His research interests are solid-state transformers with HV SiC devices, integration of renewable energy resources, microgrids, high-frequency magnetics, active filters, and the 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, and others. He has over 700 publications, 12 patents, H-index of 70, and 20,800+ citations.

## Solid State Transformer and DC Grids: From Concept to Pilot Demonstration in a Decade Enabled by HV SiC 10-15kV IGBTs and MOSFETs

The Solid State Transformer Journey from Concept to Pilot Demonstration in a Decade will be presented. The MV SST for grid interconnection is enabled by advances in HV SiC power devices at 10-15kV blocking voltages. The design, control, development, and testing of SST with HV SiC 10kV MOSFETs and 15kV SiC IGBTs, with a pilot demonstration for the Navy of an MV 4160V, 100kVA SST with SiC 10kV MOSFETs, will be presented. The HV 10kV SiC MOSFET enabled SST for “Mobile Utility Support Equipment” [MUSE] based applications was focused on integrating an MV to an LV grid and enabled DC grids. The most impactful effect of using SST lies in the reduced material usage compared to conventional 60 Hz transformers, especially copper and aluminum, which have $CO_2$ production emissions of up to 25 $kgCO_2/kg$. This is important since, with an increased focus on climate change and greenhouse gas emissions, it is imperative to minimize the carbon footprint of transformers.

# Brandon Grainger, Ph.D.

*University of Pittsburgh*

Dr. Brandon Grainger is currently an Eaton faculty fellow, associate professor and Director of the Electric Power Technologies Laboratory in the Department of Electrical and Computer Engineering at the University of Pittsburgh (Pitt), Swanson School of Engineering. He is also the associate director of the Energy GRID Institute and Co-Director of Pitt AMPED. Dr. Grainger is one of the co-architects of the electric power program at Pitt that started in the fall of 2008. Grainger holds a PhD in electrical engineering (with a specialization in power conversion), master's degree in electrical engineering and bachelor's degree in mechanical engineering (with a minor in electrical engineering) all from Pitt. He was one of the first original R.K. Mellon graduate student fellows through the Center for Energy. He also obtained an executive education certificate from Carnegie Mellon's Tepper School of Business. Dr. Grainger's research interests are in electric power conversion, medium to high voltage power electronics (HVDC and STATCOM), general power electronic converter design (topology, controller design, magnetics), resonant converters and high power density design, power semiconductor evaluation (SiC and GaN), aerospace power conversion systems, EV motor drives, solid state transformer design, and optimized magnetic components. Dr. Grainger has either worked or interned for ABB Corporate Research in Raleigh, NC; ANSYS Inc. in Southpointe, PA; Mitsubishi Electric in Warrendale, PA; Siemens Industry in New Kensington, PA; and has regularly volunteered at Eaton's Power Systems Experience Center in Warrendale, PA designing electrical demonstrations. In his career thus far, he has contributed to 100+ articles in the general area of electric power conversion, all of which have been published through the IEEE, ASEE or ASNE. He also holds one patent and has edited one research textbook. Dr. Grainger is a senior member of the IEEE and IEEE Power Electronics Society (PELS). He has served as the IEEE Pittsburgh PELS Chapter Chair when the section won numerous awards under his leadership. He has also served on various IEEE technical committees and was a technical program committee chair for IEEE ECCE in 2022.

### Evaluating Medium Voltage, Multilevel Topologies in Electric Grid Applications: Realization and High Voltage Academic Facilities for Testing

It has been stated that by 2030, 80% of our electricity generation will be processed by power electronic systems. The electric power industry is seeing continued improvements in wide bandgap device technology, new circuit topologies for direct medium voltage interconnection, and trends in the utilization of DC based architectures for integrating DC based generation resources and forthcoming loads such as electric vehicles. Power electronic systems will allow this transition to occur and build intelligence into grid systems, future all-electric ship designs, aircraft, vehicles and satellite systems. Although the voltage and power levels are drastically different between all domains mentioned, there is indeed overlap that can be considered in these system designs with available options in the circuit topologies, magnetic design, wide bandgap device utilization, and control strategies for the power electronic systems that play a role in power conditioning current and voltage signals in all arenas. In this talk, we will provide an executive summary of the modular multilevel converter (MMC) and how industry has cleverly increased the power density of the converter topology for use in high voltage power transmission and medium voltage drives. Pittsburgh vendors are currently manufacturing these products. Second, multi-port power converter systems are growing in R&D exploration, with the dual active bridge (DAB) dc-to-dc converter being the basis of the design. The DAB has been significantly studied globally with adjustments made for fault tolerant performance by using mutual inductors. This talk explains the current-fed behavior that mutual inductors introduce to the load ports of a DAB based, multi-port converter and interesting features to consider when utilized for a given application. Our last discussion point will focus on medium voltage facilities that can be sought for testing discussed topologies.

# Dr. Xiaoyuan Fan

*Pacific Northwest National Laboratory*

Dr. Xiaoyuan Fan is currently a senior staff engineer and Power Electronics Team Leader at PNNL. Serving as a project manager, principal investigator/co-principal investigator and key contributor, he has been managing and supporting multiple research projects funded by the Department of Energy, Department of State, Department of Homeland Security, ARPA-E, Bonneville Power Administration, and other industrial collaborators. His research interests focus on data analytics for power system reliability, wireless communication, multi-discipline resilience analysis, and high-performance computing. He is a senior member of IEEE, and serves as a volunteer reviewer of 20+ top-level journals and conferences in power systems and signal processing. He is the recipient of the 2021 Federal Laboratory Consortium for Technology Transfer Award, and three Energy and Environment Directorate Outstanding Performance Awards. He received his PhD in electrical engineering from the University of Wyoming and MS and BS degrees in electrical engineering from Huazhong University of Sciences and Technology.

## Power Electronics at PNNL

This presentation will introduce PNNL's research activities in power electronics at the power system level. Key activities include grid-forming inverter control design, modeling, and field demonstration in bulk power systems, developing an integrated T&D simulation platform to study the system stability with 10,000+ inverters, and the positive-sequence and offline/real-time electromagnetic transient simulation for evaluating the impacts of HVDCs on bulk power systems.

# John F. Muth

*North Carolina State University*

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

## Advances in Wide and Ultrawide Bandgap Semiconductor Materials for High Voltage, High Power Electronics

Ultra-wide and wide bandgap materials have potential to transform the future grid and power conversion applications due to their high voltage, power, switching speed and temperature advantages. This talk will discuss recent developments in ultra-wide and wide bandgap materials and devices with the aim of illustrating where advances in materials and heterogeneous integration can make an impact at the system level.

# Robert J. Nemanich

*Arizona State University*

Robert Nemanich is Regents' Professor in the Department of Physics at Arizona State University. He leads the DOE EFRC on ULTRA Materials for a Resilient Smart Electricity grid. His research is focused on growth, interfaces and phenomena of diamond and ULTRA materials.

## Ultra Wide Bandgap Semiconductors and Interfaces for High Power Electronics

Ultra Wide Bandgap Semiconductors (UWBS) have been identified as crucial materials for a new generation of power electronics that would enable the future electricity grid. The UWBS materials of AlN, cubic BN and diamond exhibit high carrier mobility and high thermal conductivity, which would support high power electronics. Interfaces of different UWBS must encompass the different crystal structure (cubic vs wurtzite), the different chemical bonding (III-V vs group IV), and the interface electric field (polarization and piezoelectric effects). This presentation reviews recent progress on growth of c-BN / diamond heterostructures, noise spectroscopy to characterize electrical defects, polarization and charge transfer at interfaces, and the challenge of electrical contacts.

# Brianna Klein

*Sandia National Laboratories*

Brianna received her BS and MS from the New Mexico Institute of Mining and Technology in 2008 and 2009, respectively, and her PhD from the University of New Mexico in 2014. Her PhD work included molecular beam epitaxial growth, fabrication, and characterization of InAs/GaSb superlattice infrared detectors. Since 2016 she has been working at Sandia National Laboratories on AlGaN and GaN HEMTs for power, logic, and RF applications.

## Recent Advancements in (Al)GaN High Electron Mobility Transistor Power Electronics at Sandia

Next-generation semiconductor switches and integrated circuits require higher power density, greater customizability, and improved radiation hardness than what is commercially available today. Nitride-based Wide- and Ultrawide-Bandgap (WBG and UWBG) semiconductors, including GaN (gallium nitride) and AlGaN (aluminum gallium nitride) are well-suited to meet these performance demands. In power electronics, the higher bandgap results in a proportionally higher critical electric field, thus enabling (U)WBG-based devices to achieve larger breakdown voltage and output power than devices made from conventional semiconductors (e.g., Si, GaAs). Furthermore, a single (Al)GaN wafer can support multiple device functions (power switch, logic, etc.) thus enabling a modular, monolithically integrated circuit with greater reliability and lower part count but without the soldering connections and bulkiness of a conventional circuit board. Starting with the Ultra-Wide Bandgap Grand Challenge Laboratory Directed Research and Development (LDRD) project in 2015, numerous technical advances (Ohmic contacts, enhancement mode devices, radiation hardening, low gate leakage) have been made in (Al)GaN electronics at Sandia, with subsequent R&D investments to develop and assess power switches, RF devices, and logic. Today, Sandia has technical leadership in AlGaN rad-hard power electronics [1], AlGaN high operating temperature logic and switches (25°C to 500°C) [2], and GaN-based integrated circuitry. Technical challenges, such as increasing drain current, improving on-resistance, characterizing reliability and electrostatic discharge robustness, and packaging are ongoing efforts to further improve Sandia (Al)GaN technology. (Al)GaN R&D efforts at low technology readiness level have established a baseline knowledge of strengths and limitations, environmental response (rad[3], temperature), device architecture variables, and manufacturing techniques.

1. *Klein, B.A., et al., Enhancement-Mode 1.5-A, 700-V Breakdown $Al_{0.85}Ga_{0.15}N/Al_{0.7}Ga_{0.3}N$ High-Electron-Mobility Transistor. Journal of Radiation Effects Research and Engineering, 2021.* ***39****(1): p. 149-155.*
2. *Klein, B.A., et al., AlGaN High Electron Mobility Transistor for High-Temperature Logic. Journal of Microelectronics and Electronic Packaging, 2023.* ***20****: p. 1-8.*
3. *Martinez, M.J., et al., Radiation Response of AlGaN-Channel HEMTs. IEEE Transactions on Nuclear Science, 2019.* ***66****(1): p. 344-351.*

# Moinuddin Ahmed

*Argonne National Laboratory*

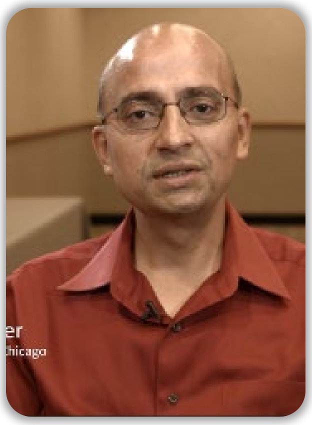
Moinuddin Ahmed is a member of the Emergent Materials and Processes group of Argonne National Laboratory. Dr. Ahmed is currently working as a technical lead to establish a power electronics reliability testing facility for wide- and ultra wide-bandgap materials including SiC and GaN-based power devices. 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 received a 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 Test and In-Situ Failure Analysis of Wide Bandgap Power Electronics

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.

# Sudip K. Mazumder

*University of Illinois Chicago*



Sudip K. Mazumder received his Ph.D. degree from Virginia Tech in 2001 and his M.S. degree from RPI in 1993. He is the Director of the Laboratory for Energy and Switching-Electronics Systems (LESES) and a Professor in the ECE Department at UIC. He has 30+ years of professional experience, has held R&D and design positions in leading industrial organizations, and has served as Technical Consultant for several industries. He also serves as the President of NextWatt LLC, a small business organization that he set up in 2008. He is a Fellow of IEEE (2016), AAAS (2020), and AAIA (2022). He has also made original contributions to the areas of control of power-electronic systems at the semiconductor device level for numerous and wide-ranging applications in commercial and defense space; high-frequency-link power electronics, including hybrid-modulation-based pulsating-dc-link inverter and differential-mode-converter topologies for applications encompassing but not limited to renewable and alternative energy, electric vehicles, solid-state transformer, energy storage, and offshore wind; discretized high-frequency and Boolean energy and data transfer; and optically controlled power semiconductor devices and power electronics.

## An Overview of Multi-Scale Device Level Control in Power Electronics Using Electrical and Photonic Device Technologies

In this presentation, the speaker will provide a radically new perspective to how next generation power electronics can be controlled by centering the focus on solid state semiconductor devices. Such device-centric multi-scale control can yield unprecedented advantages with regard to bandwidth, short- and long-term reliabilities, efficiency, and electromagnetic interference to name a few. The speaker plans to demonstrate how such device centric controls can be realized using electrical and photonic devices and mechanisms. Given the enhanced market penetration of fast and ultrafast wide-bandgap devices and emerging ultra-wide-bandgap devices that are operating or expected to operate at medium and high voltages, this presentation plans to provide an overview on how such multiscale power electronics control at device level may become a necessity to realize the device benefits.

# Jane Lehr

*University of New Mexico*

Jane Lehr (Fellow, IEEE) received the Bachelor of Engineering degree in engineering physics from Stevens Institute of Technology, Hoboken, New Jersey, USA and a Ph.D. degree in electrical engineering from New York University, New York City, New York, USA in 1996. She joined the faculty of the Electrical and Computer Engineering Department, University of New Mexico, Albuquerque, New Mexico USA in 2013. Since 2020, she is the Director of the Center for Engineered Resilience and Ecological Sustainability (CERES) at UNM. Prior to joining UNM, she was a researcher at Sandia National Laboratories from 2002 to 2013 and the Air force Research Laboratory's Directed Energy Directorate from 1997 to 2002. She has over 150 publications in journals and conferences and is the author of Foundations of Pulsed Power Technology, IEEE Wiley, 2017. Prof. Lehr is a member of the Union of Radio Science Internationale (URSI) and serves as Vice-Chair of Commission E. She is a board member of the Summa Foundation. She was President of the IEEE Nuclear and Plasma Sciences Society in 2007-2008 and is a member of its Executive Committee. Prof. Lehr co-chairs its Diversity and Inclusion Committee and is an elected member of the Plasma Science and Applications Committee. She was the recipient of the IEEE Shea Distinguished Member Award in 2015.

## Observation of Lock on in Gallium Nitride Photoswitches

One of the most promising devices studied since the late 80's is the photoconductive semiconductor switch (PCSS) which has shown outstanding switching characteristics in gallium arsenide (GaAs) but suffers from poor power handling and lifetime limitations under pulsed power conditions. Advances in the fabrication processes of wide bandgap (WBG) semiconductors along with their outstanding properties, including electrical strength and thermal conductivity, allow their consideration as an important candidate for high power switching devices.

Gallium nitride (GaN) has been considered a prime candidate for the high gain mode of operation of the PCSS. While multiple researchers have reported on linear operation of WBG-based PCSS, the non-linear, high gain mode of operation has been quite elusive over the last years. Recent experiments show clear evidence of high gain operation in lateral GaN PCSS devices with average electric fields < 30 kV/cm and pulsed laser energies of a few tens of microJoules.

# Michael Lanagan

*Penn State University*

Professor of Engineering Science and Mechanics with research interest in high energy density dielectric materials, capacitors, power electronic and pulsed power applications, and high temperature packaging materials.

## Dielectric Materials and Capacitor Reliability for Power Electronic and Pulsed Power Applications.

Capacitor miniaturization is directly related to improved energy density and power density, both of which are determined at the component and material levels for multilayer ceramic, electrolytic and polymer film classifications. The volumetric efficiency of a capacitor depends on material properties such as permittivity, dielectric loss, and the breakdown electric field. The presentation will compare energy density for ceramic and polymer materials and provide concepts for increasing energy density and dielectric breakdown strength. High temperature capacitor reliability must be improved to close this gap in terms of scientific understanding and engineering design of these components. Power density values range enormously from the material level through to the application level.

# Paul Richard Ohodnicki, Jr.

*University of Pittsburgh*

Paul R. Ohodnicki Jr. is currently RK Mellon Faculty Fellow in Energy in the Mechanical Engineering and Materials Science department at the University of Pittsburgh with a secondary appointment in Electrical and Computer Engineering. In addition, he is the Engineering Science program director and founding director of the Advanced Magnetics for Power and Energy Development (AMPED) consortium, a university – industry – government collaborative partnership focused on educating the next generation workforce at the intersection between new soft magnetic materials, device applications, and system level for renewable integration and vehicle electrification. He also serves as 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 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 200 technical publications and holds more than 30 patents, with more than 30 additional patents under review. He also is the recipient of numerous awards and recognitions, including the R&D 100 Award (2019, 2022), 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.

## Recent Advances in Soft Magnetics for Emerging Applications in Electric Power Conversion Technologies

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. 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. In addition, novel soft magnetic materials and manufacturing pathways can play a critical role in high performance electric motor technologies, which represent a major fraction of electrical energy utilization. This presentation will provide an overview of recent advances in new soft magnetic materials and manufacturing pathways for these demanding applications including: (1) novel processing of nanocrystalline alloys and a detailed investigation of high temperature stability under application relevant conditions for WBG power electronics, (2) new ideas in ferrite based soft magnetic materials for future UWBG power electronics, and (3) spatially tuned bulk crystalline alloy motor laminations for optimized electric motor applications. Broader needs for workforce development in advanced magnetic materials and devices for power applications will also be addressed and discussed in detail.

# Gaoyuan Ouyang

*Ames National Laboratory*

Dr. Ouyang is a staff scientist in the Materials Science and Engineering Division at US DOE Ames National Laboratory. Before that, he was a post-doc researcher at Iowa State University. Dr. Ouyang's research aims to provide material solutions through compositional and processing designs for energy-related and harsh environment applications. Dr. Ouyang's current research focuses on functional materials and high-temperature structural materials. His current research projects include Fe-Si based soft magnetic materials for motor and power electronics, refractory high entropy alloys for high-temperature applications, Al-Ce alloys for aerospace applications, and combinatorial synthesis and characterization of shape memory alloys. He has published 40+ refereed journal articles and owns 10+ granted or pending patents in energy-related fields.

## Design of High Silicon Steel for Motors and Electronics

Soft magnetic materials are used in electric machines, power electronics, sensors, and electromagnetic interference preventions. They play a vital role in today's energy-use sectors of the economy. The most widely used soft magnetic material, silicon steel, is known for its high saturation magnetization and low cost. High saturation magnetization is needed for high energy density. However, the increasing eddy current losses at higher switching frequencies must be properly managed to improve energy efficiency, which depends heavily on high electrical resistivity. In this talk, I will briefly overview crystalline soft magnetic materials for motors and electronics. I will then discuss our approach to adopting Fe-6.5%Si for high-frequency applications.

# Dale Huber

*Sandia National Laboratories*

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 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 nanoparticles and nanocomposites with an emphasis on tuning the magnetic properties of nanomaterials.

## Designing Soft Magnetic Materials

This talk will begin with a brief history of magnetic materials development and the main classes of soft magnetic materials in use today. The discussion will include the tradeoffs 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.

# Vincent G. Harris

*Northeastern University*

Vince has assumed a multiplicity of roles during his career including engineer, physicist, educator, entrepreneur, and S&T policy fellow. In 1990, after earning degrees in mechanical and electrical engineering and S&T management, Vince joined the Naval Research Laboratory (NRL) as a member of the research staff. He later became Head of the Complex Materials Section and Head of the Materials Physics Branch. In 2003, he joined the faculty of Northeastern University's Department of Electrical and Computer Engineering, where he is presently a University Distinguished Professor and the William Lincoln Smith Chair Professor. As a scholar, Vince has published approximately 450 peer-reviewed S&T articles, including editing the recent Wiley texts *Modern Ferrites* (Volumes I and II, 2022). Vince has been recognized with international awards for scholarship, including the American Ceramics Society's (ACerS) Edward C. Henry Award (2020); The Minerals, Metals and Materials Society's (TMS) Distinguished Scientist Award (2016); Chinese Academy of Sciences' Lee Hsun Research Award for Seminal Contributions to Materials Science (2013); and as an IEEE Distinguished Lecturer on the topic of RF applications of magnetoceramics (2011). Further, for his career achievements in S&T leadership and scholarship, he has been elevated to Fellow of the American Association for the Advancement of Science (AAAS), Institute of Electrical and Electronic Engineers (IEEE), American Physical Society (APS), Institute of Physics (UK), and the National Academy of Inventors (NAI), among other societies of distinction. Vince has also served as a Fulbright Fellow (2016) and as a Jefferson Science Fellow (Department of State, 2020-2021). Vince's other activities include Director of the Center for Microwave Magnetic Materials and Integrated Circuits ($CM^3IC$, est. 2004), and as Special Chief Editor of *Frontiers – Quantum Materials*.

## Inductor Core Design for Power Electronic Ultrahigh Frequency Applications

Power ferrite inductors are considered essential to power electronic systems in energy conversion and conditioning functions. During the past decades, high frequency and low loss ferrite inductor cores have received much attention to reduce their form factor, weight, temperature rise, and overall efficiency. While many researchers around the world have approached these challenges through optimization of core composition, microstructure, and topology, we pursue a path of systematic engineering of grain boundary (GB) regions in both chemistry, structure, and physical dimensionality. Specific goals are to suppress loss mechanisms that dominate at such frequencies, that is, eddy currents, dynamic eddy currents, and quantum tunneling mechanisms, among others. Although studies involving GB engineering predate ours, those involved employment of nonmagnetic oxide phases collocated at GBs designed to disrupt intergranular current flow. Many of those proved to be effective in the suppression of intergranular eddy currents but were also found to disrupt magnetic continuity that led to the degradation of permeability and Curie temperature and overall inductor efficiency. Our approach differs from others in that we employed magnetic insulating inclusions to GB regions that are equally effective in disrupting eddy currents but do not disrupt magnetic continuity between grains. This first demonstration provides a path forward to significantly reduce core loss while concomitantly sustaining high permeability and efficiency. Other insights will be provided regarding the efficient use of ferrite cores in high power pulse generators that the authors have recently studied.

# Joshua Stewart

*Virginia Tech*

Joshua Stewart received a 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.

## Medium Voltage PCB-based Bus Design and Insulation Coordination for Power Electronics Building Blocks

As we progress toward adopting wide bandgap (WBG) power devices rated for 10 kV and higher, the significance of insulation design at both component and system levels becomes crucial to fully capitalize on the power density benefits offered by these advanced devices. This presentation aims to explore the challenges involved in designing a 6 kV, 1 MW power electronics building block (PEBB) from the perspective of insulation coordination. We will delve into the design methods employed for high-voltage PCB-based components, such as the dc bus, as well as the cooling system. The PEBB was partial discharge (PD) free under differential mode voltage at 6 kV and common mode voltage at 30 kV, while achieving a power density of 20 $MW/m^3$.

# Fang Luo

*Stony Brook University*

Dr. Fang Luo (S'06- M'10- SM'13) is an Empire Innovation Associate professor and the director of Spellman High Voltage Power Electronics Lab at Stony Brook University. He was an Assistant Professor in the Electrical Engineering Department at the University of Arkansas ('17-'20) and a research assistant professor at the Ohio State University ('14-'17). His research interests include high power-density converter design, high-density EMI filter design and integration, and power module packaging/integration for wide band-gap devices. Dr. Luo is a senior member of IEEE. He holds two US patents and has authored/co-authored more than 50 journal papers and 100 peer-reviewed conference papers, and one book. He is an Associate Editor of IEEE Transactions on Power Electronics and International Transactions. He is a recipient of the NSF CAREER Award.

## Packaging and Integration Design for High-Voltage WBG Modules

This presentation covers the latest WBG module development from the presenter's team. Those presented include high-power, high-voltage SiC module packages and GaN module packages including double-side-cooled modules, hybrid switch packaging, and hybrid low-inductance integrated packages for 3-level TNPC topologies. The speaker will share his understanding of the challenges in these module designs, including interconnection, EMI mitigation, and fabrication processes, and provide some of the potential solutions.

# Helen Chung

*Sandia National Laboratories*

Helen got a Ph.D. in the Materials Science and Engineering dept. at Univ. of IL at Urbana-Champaign. Helen has worked on numerous research areas, including CMOS 7nm, MRAM, R-RAM device integration and display panel design and integration. Helen is in the Advanced Electronics Packaging Division at Sandia working on 2.5D/3D Heterogeneous integration using flip chip technology.

**2.5D HI Packaging of the Power Converter Using TSV (Through Silicon Via) Interposer.**

Advantages of the 2.5D HI (Heterogeneous Integration) electronics packaging of the power electronics compared to PCB packaging will be presented. Current 2.5D packaging efforts using TSV (Through Silicon Via) will be presented in terms of fabrication, microstructural analysis, reliability, and thermal simulation.

# Giri Venkataramanan

*University of Wisconsin-Madison*

Giri Venkataramanan studied electrical engineering at the Government College of Technology, Coimbatore, India. He received a B.S. degree from the University of Madras, India, the M.S. degree from Caltech, and a Ph.D. degree from the University of Wisconsin–Madison, in 1992. He began his academic career at Montana State University, Bozeman, MT, USA, before joining the faculty at UW-Madison in 1999. He is currently the Director of the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC) at UW-Madison and Keith and Jane Nosbusch Professor of Engineering. He has been actively conducting research in the areas of power converter topologies, microgrids, wind power systems, and utility-scale power electronic systems. Dr. Venkataramanan is the recipient of several major awards recognizing his preeminence as an engineering educator at the department, college and university level, including the Chancellor's Award.

## Liquid Immersion for Next Generation Utility Scale Power Electronics

Advancements in power electronics, such as wide band gap semiconductors, are pushing package size reduction and higher power density through higher switching frequency operation, but continued growth requires innovation in the areas of high voltage circuit design and thermal management. High voltage component and circuit design is dictated by creepage and clearance standards for operation in ambient air. This presentation will introduce the salient aspects of utilizing electrically insulating liquids to provide protection against electric field breakdown in submerged electronics. This will allow for new design standards and opportunity for increasing power density and smaller footprints. Immersion of the circuits in the insulating FR3 fluid will also work to improve thermal power dissipation of electronics.

# Dr. Harish Krishnamoorthy

*University of Houston*

Harish S. Krishnamoorthy (Senior Member, IEEE) received his B.Tech. degree from the EEE department, NIT Tiruchirappalli, India, and his Ph.D. degree from the ECE department, Texas A&M University, College Station, USA, in 2008 and 2015, respectively. From Jun. 2008 to Jul. 2010, he worked at GE Energy, Hyderabad, India, and received the Lean 6-Sigma Green Belt certification. From Apr. 2015 to July 2017, he was with Schlumberger, TX, USA. He has also worked at Ford and Google. Since Aug. 2017, Dr. Krishnamoorthy has been an Assistant Professor in the ECE department of the University of Houston (UH). He has over 95 conference/journal papers in refereed publications, one granted US patent and three US patent applications. He is an Associate Editor of the IEEE Transactions on Power Electronics. He received the UH Cullen College of Engineering's Research Excellence Award in 2022 and Teaching Excellence Award in 2021. He was named an 'OTC Emerging Leader' by the Offshore Technology Conference in 2022 and an Early Career Research Fellow (ECRF) by the Gulf Research Program of the US National Academies. He also recently received the NSF CAREER Award and the IEEE PELS Young Professional Exceptional Service Award in 2023.

## Reliability Characterization and In-Situ Health Estimation of WBG Semiconductor-Based Power Converters

With over 80 % of electricity expected to flow through power converters by 2030, there is a growing requirement to nearly double their operational lifetime (e.g., 50 years for solar PV / battery systems, 30 years for offshore wind, subsea oil and gas production, etc.), along with meeting size and efficiency targets in grid interface applications. The underlying problem with most existing converter installations is that it is difficult to assess their health in real-time without disrupting their operation. Hence, there is a clear need for mission profile-oriented design methods, component characteristic data, and seamless integration of in-situ health estimation techniques with power converters onboard. In this talk, the speaker will first go over a few methods and processes for performing mission profile-based accelerated thermal cycling (ATC) tests on wide bandgap semiconductor devices (especially GaN). It will be followed by a discussion on the GaN HEMT reliability data under ATC and an analytical method for estimating the component-level activation energy from the data. The talk will conclude by presenting a statistical method for predicting the system-level probability of survival and performing in-situ health estimation with the help of machine learning.

# Rohan Raghunathan

*Wolfspeed*

Rohan holds BS and MS degrees in Electrical Engineering from Arizona State University and an MBA from Cornell University. He has held various roles in his 13+ years in the semiconductor industry. At Wolfspeed, Rohan is responsible for Product Marketing/Product Definition for MV/HV Die and Power Modules. From July 2019 to September 2022 he worked at onsemi managing the fast-growing low voltage Automotive MOSFET business and helped OEM's and Tier 1's in their vehicle electrification efforts. From July 2018 to July 2019 he worked as a Management Consultant in PwC's Strategy & Operations practice advising executives of Fortune 500 technology companies. From June 2007 to May 2017 at Microchip technology he held product engineering roles covering operational amplifiers, buck converters/controllers, digital isolators, MOSFET's and temperature sensors for industrial and automotive end markets. At Microchip technology, Rohan led the first MOSFET development for Switch Mode Power Supplies.

## Opportunities in the Renewable and Distributed Power Environment

The expanding distributed power market is providing a host of opportunities for new and innovative power electronics. Areas such as renewable energy, energy storage, and industrial and motive power charging requires better power management to provide a safe operating environment while giving dproject developers and consumers better choices and uses of these new technologies.

# Henk Both

*Anzu Partners LLC*

Henk is an investor at Anzu Partners. He leads investments in early-stage industrial technology companies, with a focus on energy technologies, materials, and manufacturing processes. In the energy sector, Anzu has made investments in renewable energy generation, long-duration energy storage, infrastructure planning, critical materials, and manufacturing improvements.

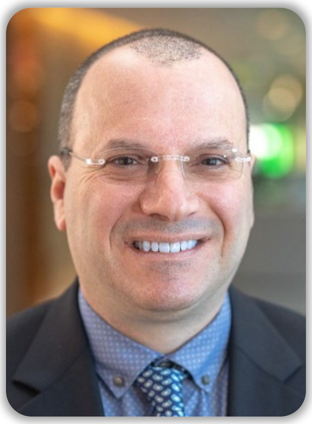
Before Anzu, Henk completed his PhD in Chemistry at Stanford University, where his research focused on ultrafast spectroscopy and photophysics. After graduating, he worked as a management consultant in the Energy practice at Boston Consulting Group, advising Fortune500 companies in hydrocarbon extraction as well as energy generation, transmission, and distribution.

## Venture Capital in Industrial Technology

Henk will provide an overview of how venture capital interacts with early-stage technology companies, including: Factors to consider when deciding if venture funding is right for you and your company; factors that venture capital firms consider when making investment decisions, including "big picture" items as well as specific diligence criteria; when to engage a VC, and stages at which various types of VCs invest; and financial VCs vs. corporate VCs.

# Scott Daniels

*CSA Group*



Head of Power & Energy Storage at CSA Group, a nationally recognized test laboratory that provides global testing, inspection, and certification services. 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 distributed energy resources, electrification, and energy management, Scott has expertise in technology and business strategy focusing on energy, sustainability, technology commercialization, and investment strategy.

## Addressing Compliance Hurdles to Gain Market Access

Power electronic systems and projects have decreasing development cycles to reduce time to market and minimize costs. This push for quick market access brings significant challenges to organizations that have limited knowledge and resources to address compliance with mandatory regulations and codes. Stakeholders that demand compliance include customers, regulators, and Authorities Having Jurisdiction (AHJs).

Compliance is necessary to gain access to markets around the world, and it is very important to bring compliance to the forefront of the development cycle. Addressing compliance early will reduce or eliminate potential delays, cost overruns and headaches that are often experienced when compliance is an afterthought. In this presentation we will cover regulatory standards and codes related to power electronic systems and their deployment.

This presentation includes standards that are applicable to Energy Storage, Electric Vehicle Supply Equipment (EVSE) including EV chargers, and eMobility.

# C. Michael Hoff

*American Battery Solutions*

C. Michael Hoff has over thirty years of experience in the power and energy storage industries, working for a utility, private sector companies and his own consultancy. At these companies he worked various roles as systems engineer, CTO, VP Research, Directors of Applications Engineering, Safety and Compliance, and Engineering, as well as independent consultant. In 2006, Michael started the systems group at A123 System and subsequently built industry pioneering teams in Safety and Compliance, Applications and Research, which established the new owners, NEC Energy Storage Solutions, as a leader among its peers and in the hearts and minds of its customers. His expertise in batteries, power conversion, and safety and controls comes from many years of applied product research and his active participation in engineering and product development. Michael has written and cowritten over a dozen patents, and many technical articles, including a book on energy storage. He holds a master's degree in Electrical Engineering from Northeastern University.

## Energy Storage Solutions for the Next 30 Years of Rapid Deployments

If the USA wants to be 100% renewable by 2050, and fusion or some other miracle energy source is still on the drawing table, it will have to install 6 TWh of energy storage to manage its renewable energy supply. That amounts to an average of 200 GWh of energy storage installations per year. Last year, 12 GWh were installed in the US. At the current project size, 200 GWh amounts to about one energy storage project per day. Contrast that to typical project timelines that are in the 3 to 6 months range. If we want to accomplish our 2050 goals, we will need to step up our deployment rate by deploying larger, lower cost, safer, easier to install building blocks. Do we have to rethink everything we have developed so far in this industry?

# Himamshu Prasad

*Schneider Electric*

Himamshu is currently leading the Energy Storage Center of Excellence within Schneider Electric. Himamshu joined Schneider Electric in 2019 and was leading the Offer Management for Home & Business Networks (HBN). Prior to that, Himamshu has over 20 years of industry experience in technology, engineering, product management, and P&L management at GE, Osram and Motorola. Himamshu co-authored 19 patents and published 11 technical papers in the field of power electronics, including 1 that won the IEEE PELS Best Price Award. Himamshu Prasad received his B.S. degree in Electrical and Electronic Engineering from Indian Institute of Technology, Madras; M.S. degree in Electrical Engineering from Virginia Tech, USA; and M.B.A. degree from Kellogg Graduate School of Management, USA.

## Critical Role of Power Electronics in Short and Long Duration Energy Storage

Energy Storage Systems (ESS) play a pivotal role in the adoption of clean and distributed variable energy resources such as wind and solar by balancing supply and demand. Energy storage systems encompass a diverse range of technologies, including chemical, electrical, electrochemical, mechanical and thermal storage systems. Power electronics is the backbone of energy storage systems, enabling efficient energy conversion, bidirectional power flow, and seamless integration with the grid to ensure a reliable and stable supply of electricity.

Typical metrics for Power Electronics include Efficiency, Size, Cost and Reliability (Lifetime/Warranty).

This presentation will cover some of the recent developments in the use of wide band gap devices such as SiC and GaN in Commercial Energy Storage offers (both short duration and long duration), and also discuss some of the challenges and opportunities that will help further drive the rapid deployment of cost-effective Energy Storage systems.

# Notes: