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2025 Power Electronics and Energy Conversion (PEEC) Workshop Summary Report

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ABSTRACT

Sandia National Laboratories hosted the 2025 Power Electronics and Energy Conversion (PEEC) Workshop in Albuquerque, New Mexico on Tuesday, July 15, and Wednesday, July 16, 2025. The purpose of this annual workshop is to bring together experts in materials, heterogeneous integration, modular power electronics, and grid applications to share and discuss how power conversion devices can be used to modernize and secure the electric grid. The format includes ample time for discussion. This report provides a summary of the 2025 PEEC Workshop, highlighting six technical sessions that covered a diverse range of topics presented by experts from industry, academia, and government. Key discussions and insights from each session are outlined, along with an overview of the presenters and their contributions. The findings and discussions from the workshop aim to foster collaboration and innovation within the field.

ACKNOWLEDGEMENTS

The author would like to thank the Sandia PEEC Workshop team and session chairs for their leadership and contributions to the report, and to Aditya Kalahasti for his detailed notes and diligent assistance in drafting the report. The team would like to extend appreciation to the panelists for their insightful presentations and discussions, and to all attendees for their attendance and engagement, which contributed to the event's success.

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EXECUTIVE SUMMARY

Sandia National Laboratories hosted the 2025 Power Electronics and Energy Conversion (PEEC) Workshop in Albuquerque, New Mexico, on July 15-16, 2025. The two-day workshop gathered more than 115 experts from industry, academia, and government to discuss advancements and challenges in power electronics and energy conversion, fostering collaboration and innovation within the field. This report summarizes the discussions and insights from the workshop.

The purpose of this annual workshop is to bring together experts in materials, heterogeneous integration, modular power electronics, and grid applications to share and discuss how power conversion devices can be used to modernize and secure the electric grid. The knowledge shared during the event aims to advance the field and support the transition to more efficient, resilient, and secure energy systems. The themes for PEEC 2025 included the integration of power electronics and power systems and security and resilience.

The workshop featured six technical sessions that explored a range of topics and technologies through expert presentations and interactive panel discussions, integrating short breaks between sessions to encourage continued discussions. Throughout the workshop, participants engaged in discussions on advancements, challenges, and opportunities in the field ranging from materials and components to applications and integration. Key takeaways from these discussions and the workshop content include:

- The dynamic, evolving nature of threats to the electric grid requires a multifaceted approach to enhancing grid security, including the integration of resilient energy technologies such as solid-state transformers and the application of advanced modeling frameworks and vulnerability assessment tools to mitigate threats.
- Power electronics will be a key enabler of future data centers. Artificial intelligence (AI) is increasing the computational and power demands of data centers, requiring advancements in transient response and thermal management to maintain a sufficient, uninterrupted power supply. Direct current (DC) architectures are being explored as potential solutions to more efficiently power future data centers.
- Medium voltage (MV) power electronics innovations are needed to support grid modernization efforts, including the secure and efficient integration of inverter-based resources (IBRs) and distributed energy resources.
- Transitioning to an IBR-based grid while maintaining grid stability will require the development and application of advanced grid-forming inverter models and technologies that enable the essential services previously provided by synchronous generators.
- Advanced wide-bandgap (WBG) semiconductor materials, including gallium nitride (GaN), silicon carbide (SiC), and beta-gallium oxide (β-Ga_2O_3), present opportunities to enhance power conversion efficiency and reliability in modern power systems, while necessitating a more thorough understanding of their unique characteristics and manufacturing processes.

This report provides an overview of the workshop, summarizing discussions and insights from each session. Presentations from the workshop can be found on the workshop website (https://energy.sandia.gov/programs/electric-grid/power-electronics-and-controls/).

ACRONYMS AND TERMS

Acronym/Term	Definition
AC	alternating current
DC	direct current
DER	distributed energy resource
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EMP	electromagnetic pulse
GaN	gallium nitride
GMD	geomagnetic disturbances
IBR	inverter-based resource
kV	kilovolt
MFT	Medium frequency transformer
MV	medium voltage
PE	power electronics
Sandia	Sandia National Laboratories
SiC	silicon carbide
SST	solid-state transformer
WBG	wide bandgap

1. WORKSHOP SUMMARY

1.1. Keynote Presentation: Unit of Compute

Peter Panfil, *Vertiv*

The keynote presentation focused on the ongoing paradigm shift in the design of data centers to address the growing computational and power demands driven by artificial intelligence (AI). Data centers are transitioning from traditional facility-centric infrastructures to integrated computational units, becoming the next logical unit of compute. The evolution represents fundamental change in the design and conceptualization of data center infrastructure, shifting from a traditional building-centric approach to a compute-centric model.

The growing adoption of AI is driving a substantial increase in data center power consumption. To meet this demand and support the dynamic compute load of AI applications, data centers will need both increased power capacity and continuous power availability. Ensuring a reliable, continuous power supply is crucial, especially for AI workloads, where even brief interruptions can lead to significant operational issues. Data centers will increasingly integrate distributed energy resources (DERs) and energy storage systems to meet growing power demands. Consequently, a revolution in power electronics is underway to address these challenges and effectively support AI applications in data centers.

The keynote presentation and ensuing discussion highlighted several key points regarding the challenges and opportunities presented by this paradigm shift in data center design:

- Ensuring a reliable, continuous power supply is crucial. Robust thermal and electrical protections, including transient response capabilities, must be incorporated to prevent power interruptions. System architectures must eliminate single points of failure.
- Thermal management is a major challenge. Data centers with racks of graphics processing units (GPUs) require liquid cooling systems to prevent overheating, necessitating a consistent power supply to both the GPUs and the cooling systems.

1.2. Opening Remarks

Co-Chairs: Valerio De Angelis and Erik Webb, *Sandia National Laboratories*

Speakers:

- Michael Pesin, *Department of Energy*
- Madhu Chinthavali, *Oak Ridge National Laboratory*

Sandia National Laboratories (Sandia) welcomed participants of the 2025 Power Electronics and Energy Conversion (PEEC) Workshop with opening messages from Valerio de Angelis, Manager of the Power Electronics and Energy Conversion Department, and Erik Webb, Director of the Nuclear Fuel Cycle and Grid Modernization Center.

Michael Pesin, Deputy Assistant Secretary for the Grid Systems and Components Division in the Department of Energy's (DOE's) Office of Electricity (OE), followed with a virtual welcome, discussing the evolving grid landscape and highlighting the need for efficient, reliable, and cost-effective power electronics to support the future grid.

Madhu Chinthavali, Electrical Systems Integration Program Manager at Oak Ridge National Laboratories (ORNL) then presented an overview of the Grid Modernization Lab Consortium (GMLC) Medium Voltage Resource Integration Technologies (MERIT) initiative, a multi-lab effort focused on the development, demonstration, and evaluation of medium voltage power electronics. The initiative involves collaboration among several national laboratories, including ORNL, Sandia, National Renewable Energy Laboratory, and Pacific Northwest National Laboratory. Chinthavali highlighted the project's goal of analyzing the quantitative impact of power electronics in MV utility applications, aiming to identify and address obstacles to the large-scale deployment of transformative power conversion and control technologies.

1.3. Session 1: Grid Security and Resilience

Co-Chairs: Steve Glover and Mike Ropp, *Sandia National Laboratories*

Panelists:

- Jason Handley, *Duke Energy*
- Matt Haupt, *Former Navy*
- Joseph Blankenburg, *DOE CESER*
- Lee Rashkin, *Sandia National Laboratories*

The Grid Security and Resilience session launched PEEC 2025 into an exploration of multifaceted approaches to enhancing the security and resilience of the electric grid in the face of evolving threats. Presentations highlighted the proactive measures that are being implemented by various organizations, including Duke Energy's strategies for safeguarding power systems against cyber and physical threats, energy resilience initiatives employed by the Department of Defense (DOD), DOE's research on ground-induced currents and their mitigation, and Sandia's development of solid-state transformer technologies aimed at improving grid stability. The discussions underscored the importance of advanced technologies, multiple sources of generation, and innovative solutions to bolster the resilience of energy systems.

1.3.1. Building a Smarter Energy Future: Duke Energy's Path to a Secure & Resilient Grid

Jason Handley, *Duke Energy*

This presentation focused on Duke Energy's approach to grid security in the face of evolving threats to the electric grid, underscoring the critical role of resilience in modern grid operations and the proactive steps being taken to secure the U.S. energy future. Jason Handley provided an overview of strategies and technologies deployed to safeguard power systems against cyber and physical threats. Key measures included advanced monitoring solutions, self-healing technologies, and enhanced physical security. The discussion highlighted the importance of operational technology in improving reliability and response capabilities, as well as the need for effective vegetation management using technologies such as Light Detection and Ranging (LIDAR). Handley also discussed the importance of increasing battery energy storage and distributed forms of generation as threats to the grid evolve.

1.3.2. Grid Resiliency and the DOD

Matt Haupt, *Former Navy*

Matt Haupt discussed grid and energy resilience initiatives employed by the DOD to strengthen energy security and enable mission success. Haupt provided an overview of the approaches, which aim to mitigate energy vulnerabilities, comparing the strategies to the methods employed by utilities to mitigate threats to the electric grid. Military installations often rely on the power provided by local utilities, underscoring the importance of grid security in enabling mission success. In addition to strengthening collaboration with local utilities, DOD is working to deploy energy developments, including microgrids and small modular reactors, to enhance the energy resilience of military installations.

Joseph Blankenburg, *Department of Energy*

This presentation focused on ground-induced currents (GICs) caused by both natural processes and manmade phenomena, which can lead to reduced power quality, losses, and potential equipment damage. Blankenburg discussed ongoing research and development efforts within DOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER), particularly regarding electromagnetic pulses (EMPs) and geomagnetic disturbances (GMD). Key topics included the development of new modeling frameworks, pilot demonstrations for GIC mitigation, and the need for improved vulnerability modeling tools. He discussed the importance of understanding EMP risks, noting the lack of historical data and the challenges posed by quasi-DC currents. Future efforts will prioritize the identification and development of new mitigation strategies to enhance the resilience and reliability of transmission systems.

1.3.3. Resilient Energy Systems Development at Sandia National Laboratories

Lee Rashkin, *Sandia National Laboratories*

Lee Rashkin provided an overview of Sandia's efforts in developing solid-state transformer (SST) technology as part of the Resilient Energy Systems (RES) Mission Campaign, aimed at enhancing grid resiliency and stability. The presentation covered the advantages of SSTs, including improved power flow and additional control compared to conventional transformers. Key challenges such as high switch counts and complex switching schemes were addressed, along with solutions like AC-to-AC converter designs that offer greater power density and lower complexity. Rashkin also highlighted ongoing work to make SSTs more compatible and responsive to threats, including modeling efforts related to high-altitude electromagnetic pulses (HEMP) and GMD.

1.3.4. Panel Discussion

The Grid Security and Resilience panel discussed the key strategies to enhance grid resilience, including the benefits and limitations of undergrounding distribution lines and the challenges of islanding military installations as independent power sources. Ongoing pilot programs for addressing geomagnetic disturbances were highlighted, along with the need for financial models to quantify resilience. The panel also addressed the installation of sensors for grid monitoring, military installations' reliance on utility power and islanding limitations, and the challenges of ensuring power availability during extreme events.

1.4. Session 2: Overview of Power Electronics

Co-Chairs: Stan Atcitty and Jake Mueller, *Sandia National Laboratories*

Panelists:

- Christina DiMarino, *Virginia Tech*

- Joseph Benzaquen, *Georgia Tech*
- Christopher Recio, *Mainstream Engineering*
- Ali Ghorashi, *Quanta Technology*

The session focused on the critical advancements and challenges in power electronics, particularly in the context of MV SiC power modules and their role in the energy transition. Presentations highlighted the barriers to adoption, the importance of integrating power electronics with energy generation sources, and the need for improved standards and diagnostics. Key discussions revolved around the transition to inverter-based grids, the optimization of power electronics for military and commercial applications, and the potential of DC architectures in powering data centers. A panel discussion emphasized the necessity for standardization, collaboration, and rigorous testing to enhance reliability and performance in the industry.

1.4.1. Electrical Insulation Investigation for Medium-Voltage SiC Power Modules

Christina DiMarino, *Virginia Tech*

This presentation focused on knowledge gaps and barriers hindering the widespread adoption of MV SiC power modules. DiMarino highlighted the challenges faced in the industry, particularly the inadequacy of existing standards to assess in-situ performance and a major gap in understanding how changes in material properties affect insulation and reliability. The presentation also highlighted the need for systematic observation and comprehensive analysis to inform the underlying physics of insulation performance, aiming to extend this understanding to degradation factors that influence the longevity of power modules.

1.4.2. Power Electronics and the Energy Transition

Joseph Benzaquen, *Georgia Tech*

This presentation focused on the critical role of power electronics in the 21st-century energy transition, highlighting its importance as a key enabler for integrating technologies. With over 2,600 gigawatts (GW) of active capacity waiting to connect to the grid—more than double the current U.S. electrical generation capacity—the shift from a synchronous generator-based system to an IBR-based grid presents unique challenges. Benzaquen discussed the Georgia Tech Center for Distributed Energy's initiatives in power electronics research, development, and deployment, including work on soft-switching solid-state transformers, micro-industrial HF isolated inverters, and other grid enhancing technologies, including those developed in collaboration with Sandia. The presentation concluded with a note on the future of the grid, will be decentralized inverter-based grid and emphasizing the importance of ensuring energy access for all and limiting energy poverty.

1.4.3. Evaluation of Power Electronics for Optimal Performance and Offsite Implementation

Christopher Recio, *Mainstream Engineering*

This presentation highlighted the essential role of power electronics in military and commercial systems, emphasizing the need for thorough evaluation to ensure performance and reliability. Mainstream Engineering's approach involves transitioning from military applications to cost-optimized commercial products, including advancements in high-voltage grid-tied applications. Key topics included the importance of diagnostics and prognostics software, and critical design considerations such as worst-case inrush currents and electromagnetic interference (EMI) simulations.

1.4.4. Powering Data Centers with DC: Opportunities and Design Insights

Ali Ghorashi, *Quanta Technology*

Ali Ghorashi addressed the technical and operational challenges of powering next-generation data centers, focused on the implications for rapid AI data center development on grid capacity requirements, and the benefits of DC architectures. As data centers continue to expand in both scale and energy consumption, DC power architectures are gaining attention for their potential to improve efficiency, reliability, and integration with distributed generation and storage systems. The presentation highlighted how DC microgrids can optimize energy use, enhance resilience, and improve sustainability. Real-world examples demonstrated the effectiveness of DC systems in managing rapid grid fluctuations and reducing the transient voltage deviations at the interconnection point.

1.4.5. Panel Discussion

Panelists discussed the need for standardization in MV power electronics packaging and the complexities associated with obtaining performance data that hinder industry connectivity. The layered nature of data sheets complicates verification, making it difficult and costly for purchasers to trust manufacturers' claims. This highlights the significant value of third-party characterization to ensure reliability and performance. The panel discussed the importance of a holistic approach to integrating detailed reliability requirements into system architecture and addressing supply chain variability to improve accountability. Overall, collaboration, standardization, and rigorous testing were identified as important drivers for advancing DC microgrid technologies and ensuring safety and reliability in power electronics.

1.5. Session 3: Power Electronics Integration with Power Systems

Chair: Brian Pierre, *Sandia National Laboratories*

Panelists:

- Matthew Reno, *Sandia National Laboratories*
- Wei Du, *Pacific Northwest National Laboratory*
- Masood Parvania, *University of Utah*

This session examined the critical role of power electronics in shaping future power system operations, particularly in the context of transitioning to inverter-dominated grids. Presentations highlighted the challenges and solutions associated with grid-forming inverters, advanced modeling and simulation tools for power electronics integration, and optimization strategies for inverter-based battery energy storage systems. The ensuing panel discussion addressed the importance of standardized testing and certification for hybrid technologies.

1.5.1. Grid-Forming Inverters: Challenges and Solutions in Power System Oscillations

Matthew Reno, *Sandia National Laboratories*

This presentation focused on the implications of transitioning to an inverter-dominated grid. As power electronics increasingly shape future power system operations, the limitations of inverter-based resources (IBRs) become evident, particularly their reduced fault current contributions compared to traditional synchronous generators. This shift necessitates a reevaluation of existing protection and stability analysis methods, as conventional techniques may not adequately address the unique challenges posed by IBRs. The discussion included a comparison of various grid-forming inverter (GFM) control strategies and their trade-offs, alongside traditional transmission protection methods.

1.5.2. Advanced Models and Simulation Tools for Studying Power Electronics in Power Systems

Wei Du, *Pacific Northwest National Laboratory*
The presentation by Wei Du from Pacific Northwest National Laboratory (PNNL) focused on advanced models and simulation tools for integrating power electronics into power systems. It highlighted the development of standard GFM models in collaboration with leading manufacturers and transmission planners, which have been adopted by the Western Electricity Coordinating Council (WECC) and incorporated into commercial power system stability simulation tools. The presentation also introduced an open-source distribution simulation platform designed to model transient and dynamic behaviors in unbalanced distribution systems with high penetration of distributed energy resources, showcasing studies conducted on a real-world distribution feeder model.

1.5.3. Frequency-Constrained Real-Time Co-Optimization of Energy and Regulation Reserve with Inverter-based Battery Energy Storage Systems

Masood Parvania, *University of Utah*
The presentation focused on a two-state stochastic optimization model designed for the real-time operation of energy and frequency regulation markets, incorporating both thermal generating units and inverter-based battery energy storage (IBES) systems. The model captures the dynamic behavior of these systems, facilitating a cost-efficient allocation of up- and down-regulation reserves in real-time markets. The speaker discussed the challenges of optimizing multi-time scale grid services, particularly in the context of integrating inverter-based resources (IBRs) into grid operations. The objective is to minimize total system costs while ensuring effective frequency regulation.

1.5.4. Panel Discussion

This panel discussion covered several questions centered on the specifics of the individual models and simulations presented by the panelists. Panelists discussed various topics related to energy storage, distributed energy systems, grid-forming technologies, and wildfire mitigation strategies. The discussion highlighted the importance of optimizing storage duration, the challenges of integrating new protection schemes for distributed generation sources, and the evolving market for grid-forming services. The discussion also explored the potential of hybrid grid-forming technologies and the role of power electronics in enhancing fault clearing speed to mitigate wildfire risks. Additionally, there was a focus on the need for standardized testing and certification for hybrid technologies.

1.6. Session 4: Semiconductor Materials

Co-Chairs: Andrew Binder and Lee Gill, *Sandia National Laboratories*

Panelists:

- Peter Panfil, *Vertiv*
- Eric Persson, *Infineon Technologies*
- Akin Akturk, *CoolCAD Electronics*
- James S. Speck, *University of California, Santa Barbara*

The Semiconductor Materials session delved into the latest advancements and challenges in power electronics, focusing on critical materials such as Gallium Nitride (GaN), Silicon Carbide (SiC), and beta-gallium oxide (β-Ga2O3). Presentations highlighted the exceptional performance characteristics of these materials, their integration into modern power systems, and the need for innovation and standardization in the industry. Discussions also emphasized the importance of safety and efficiency in the development of semiconductor technologies, addressing both current applications and future directions.

1.6.1. The Challenges and Opportunities for Integration of GaN Transistors in Modern Power Systems

Eric Persson, *Infineon Technologies*

This presentation focused on the advancements and challenges associated with Gallium Nitride (GaN) power transistors, emphasizing their exceptional switching performance and potential for ultra-high efficiency in power conversion systems. It highlighted the necessity of understanding GaN's key parameters, packaging considerations, and gate-drive requirements to fully leverage the technology's benefits. Additionally, the discussion addressed the evolving landscape of GaN devices, including integration trends, the importance of active gate management, and the future of application-specific transistors.

1.6.2. Silicon Carbide Devices for Demanding Power Conversion Applications

Akin Akturk, *CoolCAD Electronics*

This presentation covered the application of silicon carbide (SiC) devices to address the need for high power and high voltage protection devices for more reliable systems. The discussion centered on the design and fabrication of niche SiC devices, which are utilized in both terrestrial and extra-terrestrial systems operating under varying temperature and power conditions. The device solutions focus on low on-resistance power devices for next-generation power electronics and high voltage, high on-resistance devices for circuit protection. The presentation included an overview of CoolCAD's silicon carbide device development, and the company's high efficiency and high power resonant bidirectional DC-DC circuit design and fabrication efforts.

1.6.3. Progress in β-Ga2O3 Materials for High Voltage Vertical Devices

James S. Speck, *University of California, Santa Barbara*

The presentation highlighted the advancements in beta-gallium oxide (β-Ga2O3), a promising ultra-WBG semiconductor that can be grown directly from the melt, distinguishing it from other materials including SiC, GaN, and diamond. The unique properties of β-Ga2O3 make it particularly suitable for high voltage applications, with blocking voltages ranging from 5 kilovolts (kV) to 10 kV and beyond. The discussion covered the ease of doping, the various epitaxial growth techniques, and the successful demonstration of high-quality Schottky and ohmic contacts. Speck highlighted the potential for β-Ga2O3 to compete with other wide and ultra-WBG semiconductors, particularly in vertical diode and transistor applications.

1.6.4. Panel Discussion

The Semiconductor Materials panel discussion explored key issues in power electronics, focusing on the potential of flip-chipping for low-voltage applications and the challenges at high voltages, such as thermal management. The discussion highlighted the implications of the growing dual profile in energy generation, advocating for hardware and software solutions to improve efficiency. The panel also addressed the lack of standardization in manufacturers' data sheets, suggesting self-testing and collaboration with national labs for better transparency. Additionally, concerns regarding fire hazards in battery storage were emphasized, underlining the importance of safety standards and the consistent use of distributed energy resources.

1.7. Session 5: Passives & Packaging

Co-Chairs: Luciano Garcia Rodriguez and Rick Floyd, *Sandia National Laboratories*

Panelists:

- Roger Brewer, *Lockheed Martin*
- Zhicheng Guo, *Arizona State University*
- Xiaoqing Song, *University of Arkansas*
- Fang Luo, *Stony Brook University*

During the fifth session, Passives & Packaging, panelists addressed the critical advancements and challenges in the packaging and passive components of power electronics, particularly concerning high-temperature and high-power applications. The presentations covered a range of topics, including the applications of high-power density WBG technology in military aircraft power systems, the current state of high-power medium frequency transformers, strategies for high-voltage power module packaging, and innovative approaches to WBG module packaging. Both the presentations and panel discussions highlighted the importance of reliability and efficiency, as well as the necessity for advanced materials and designs to meet the evolving requirements of modern energy systems.

1.7.1. Capacitors and Aircraft Power System Considerations for Higher Temperature Operation and Wide Bandgap Enablement

Roger Brewer, *Lockheed Martin*

The presentation addressed the evolving demands on electronics in modern military aircraft, particularly focusing on the challenges posed by high ambient temperatures and mechanical vibrations. It began with an overview of a generalized aircraft power system that could leverage high-power density WBG technologies, highlighting the associated thermal management challenges. The discussion then delved into the limitations of existing capacitor technologies, including ultracapacitors, film capacitors, and ceramic capacitors, which are critical for power electronics and avionics systems. Key factors such as mechanical fatigue, material limitations, and the geometric and material engineering of capacitors were explored, emphasizing the trade-offs between capacity, temperature capability, and ripple current handling. The presentation concluded with considerations for future capacitor designs to meet the demands of higher temperature applications and supporting WBG technologies.

1.7.2. High-Power Medium Frequency Transformers in Medium Voltage Power Electronics

Zhicheng Guo, *Arizona State University*

The presentation reviewed the state of the art in high-power medium frequency transformers (MFTs) within medium voltage power electronics, addressing the associated challenges and potential solutions, particularly in insulation design and testing. Key topics included the complexities of voltage stress and electric field distribution, the effects of partial discharge under high-frequency, high dv/dt waveforms, and the relevant insulation test standards for MFTs. The discussion highlighted the trade-offs involved in increasing magnetic frequency to enhance power density, while also emphasizing the need for partial discharge-free designs to ensure reliability and performance in high-power applications.

1.7.3. Advancing High Voltage Power Module Packaging: Strategies for Partial Discharge Mitigation

Xiaoqing Song, *University of Arkansas*

The presentation focused on high-voltage power conversion (greater than 10 kV) as a critical component of modern energy systems, facilitating efficient power transmission, industrial automation, and transportation electrification. Despite its importance, the adoption of high-voltage power semiconductor devices is hindered by several challenges, including low voltage and current ratings, reliability issues, limited commercial availability, and difficulties in high-voltage power module packaging. The talk explored the current state of high-voltage power module packaging, discussing the key challenges and potential strategies to enhance efficiency, reliability, and compactness in next-generation high-power applications.

1.7.4. Advanced Packaging and Optimization for High Power/High Density WBG Modules

Fang Luo, *Stony Brook University*

The presentation focused on research on high-power, high-voltage SiC and GaN module packages that utilize double-sided cooled structures. It addressed various challenges associated with these module designs, including interconnection issues, electromagnetic interference (EMI) mitigation, and fabrication processes, while proposing potential solutions. A specific highlight was the innovative 3D GaN module design that employs fuzz button technology as an alternative to traditional soldering and sintering methods.

1.7.5. Panel Discussion

The panel discussion on Passives and Packaging in power electronics explored several critical themes related to the performance and reliability of capacitor technologies under varying environmental conditions. Key points included the impact of altitude and barometric pressure on electrolytic capacitors and supercapacitors, highlighting risks such as cracking and diminished performance. The anticipated evolution of power distribution voltage in aviation, targeting levels between 500V and 600V, was discussed alongside the need for new materials and packaging solutions to address challenges at high altitudes. The session also evaluated the reliability of fuzz buttoning compared to traditional soldering, particularly in vibration-prone applications, while acknowledging the need for alternative methods in specific contexts. Lastly, the panel addressed potential updates to IEEE standards for MFTs, emphasizing the importance of parameters like partial discharge and high slew rates in future designs.

1.8. Session 6: Demonstrations

Co-Chairs: Jack Flicker and Yuliya Preger, *Sandia National Laboratories*

Panelists:

- Mack W. Knobbe, *Southern California Edison*
- Mohammed Nassar, *Tesla*
- Murat Yildirim, *Wayne State University*
- Andreas Fornwald, *StarCharge*

The sixth and final session of the 2025 PEEC Workshop showcased innovative applications and technologies in power electronics and energy management, addressing the challenges posed by rapid electrification and the need for grid stability. Presentations highlighted the integration of solid-state power electronics in utility projects, the capabilities of Tesla's Megapack grid-forming model, predictive frameworks for managing photovoltaic (PV) inverter fleets, and the application of battery energy storage systems (BESS) in mitigating grid instability. In the concluding panel discussion, panelists emphasized the need for resilient energy solutions, discussed the challenges of implementing new technologies, and highlighted the potential for expanding collaborative efforts to enhance grid stability.

1.8.1. Demonstrations & Value Propositions for Utility integrated power electronics

Mack W. Knobbe, *Southern California Edison*

The presentation addressed the rapid electrification of buildings and transportation, which is driving unprecedented load growth that exceeds the traditional capacity of utilities. This surge in demand, coupled with the evolving nature of two-way power flow, presents new challenges for grid architecture that require innovative technology and planning. Power electronics are increasingly integrated into devices on the load side and are essential for enabling supply-side solutions. Southern California Edison (SCE) is advancing MV, multi-megawatt projects to demonstrate the value of solid-state power electronics in addressing these challenges, including DC transmission and DC as a service for data centers and transportation electrification.

1.8.2. Tesla Megapack Grid-Forming

Mohammed Nassar, *Tesla*

The presentation reviewed Tesla's Megapack grid-forming model, emphasizing its active and reactive power dispatch capabilities and the role of the virtual synchronous machine in maintaining grid stability. The speaker highlighted the growing acceptance and adoption of grid-forming inverters, including Tesla's existing grid-forming data centers and the impending mandates from the Electric Reliability Council of Texas (ERCOT) based on North American Electric Reliability Corporation

(NERC) guidelines. The discussion included real-world projects, technology comparisons, and case studies, showcasing Tesla's utility-scale grid-forming capabilities and the advantages of their hybrid approach, which combines power dispatch and virtual machine functionalities for improved transient stability and reduced complexity in power dispatch control.

1.8.3. Operationalizing Industrial Sensor Data for Scalable Asset Management of PV Inverters

Murat Yildirim, *Wayne State University*

The talk introduced predictive and decision-making frameworks for sensor-driven asset management of PV inverter fleets. The predictive modeling component integrates autonomous data preprocessing, environmental deconfounding using neural networks, and ensemble-based anomaly detection to identify early signs of degradation in inverters. This innovative approach constructs a dynamic baseline from early-life data, allowing for the detection of deviations that indicate potential failure risks without relying on labeled failure data or asset-specific models. The decision-making component demonstrates how enhanced predictions of inverter health can inform optimal maintenance strategies, crew routing, and spare part provisioning. Real-world case studies utilizing industrial data showcased the framework's effectiveness in reducing downtime and improving maintenance outcomes.

1.8.4. The Importance of BESS AC Containers for Grid Forming

Andreas Fornwald, *StarCharge*

The presentation addressed the increasing frequency of blackouts and grid instability in modern electric grids, driven by intermittent power supplies and the rise of data centers. It emphasized the importance of battery-backed solutions in mitigating these risks. The speaker discussed the goal of achieving modularization through standard, modular battery packs and hardware standardization to enable advanced software solutions. They proposed a strategy that limits current while utilizing over-current capacity to preserve angle-forming capabilities during faults. The presentation also mentioned the company's new manufacturing facility in Columbus, OH, which opened in 2024 for grid battery production.

1.8.5. Panel Discussion

The final panel discussion on addressed critical considerations for implementing new technologies in the energy sector, emphasizing the importance of a favorable benefit-to-cost ratio and the role of redundant systems in mitigating technological risks. The panel highlighted the challenges posed by extreme natural hazards to grid-level storage, advocating for hardening strategies like underground battery installations to enhance resilience. Southern California Edison (SCE) discussed its current limitations in generation capacity and the complexities of expanding its transmission and distribution systems, while also acknowledging the dominance of lithium-ion batteries in grid storage due to their cost-effectiveness and reliability. The potential of Tesla's grid-forming controls to significantly reduce fluctuations was noted, alongside SCE's cautious exploration of community-level DC microgrids, which face financial justification hurdles despite their potential benefits in reducing fire risks. Overall, the session underscored the need for innovative solutions and collaborative efforts to advance energy storage and grid stability technologies.

REFERENCES

Please see the event agenda (*Appendix A*) for a list all speakers, affiliations, and presentation titles. This report provides an overview of the workshop, summarizing discussions and insights from each session. Presentations from the workshop can be found on the workshop website (https://energy.sandia.gov/programs/electric-grid/power-electronics-and-controls/).

APPENDIX A. WORKSHOP SCHEDULE & SPEAKER BIOGRAPHIES

Tuesday, July 15, 2025

Breakfast

8:00 am – 9:00 am

Opening Remarks

9:00 am – 9:45 am

9:00 – 9:10 **Welcome:** Valerio De Angelis *(Sandia National Laboratories)*

Dr. De Angelis joined Sandia in 2020 to work on battery modeling, system integration, and power systems. He is a Distinguished Member of the Technical Staff and Manager of the Power Electronics and Energy Conversion Group. He is a co-founder of batteryarchive.org, the first public repository for easy visualization and comparison of lithium-ion battery degradation data across institutions. Before joining Sandia National Laboratories, Dr. De Angelis was the Executive Director of the City University of New York (CUNY) Energy Institute. At the Institute, he expanded the scope of the battery research from the lab to large-scale energy storage systems. Several initiatives have spun off from the research, notably the Grid-Modernization Center and Urban Electric Power, of which Dr. De Angels was co-founder, interim CEO, and VP of Product. Regarding his previous career, De Angelis was the CEO and CTO of Mindflash Technologies, a leading provider of online training platforms that he founded when he was a Ph.D. student at UC Santa Barbara. Mindflash was acquired by Applied Training Systems.

9:10 – 9:20 **Welcome:** Erik Webb *(Sandia National Laboratories)*

Erik K. Webb is the Director of the Nuclear Fuel Cycle and Grid Modernization Center at Sandia National Laboratories, leading R&D programs focused on the safety and resilience of nuclear power and the electric grid, as well as radioactive waste management. Previously, Erik was the Senior Manager of Sandia's Geoscience Research & Applications Group, overseeing efforts in fossil energy and carbon management. He has held leadership roles in the Global Security Strategic Futures organization, engaging with NNSA's Defense Nonproliferation Programs and international partners. Erik has extensive experience addressing earth science challenges with U.S. government agencies and foreign organizations, including a fellowship with the Japanese Atomic Energy Agency. He holds a BS in Engineering Geology from Brigham Young University and an MS and PhD in Hydrogeology from the University of Wisconsin, and has served as adjunct faculty at the University of New Mexico.

9:20 – 9:30 **Virtual Welcome:** Department of Energy

9:30 – 9:45 **Overview of MERIT:** Madhu Chinthavali (*Oak Ridge National Laboratory)*

The Grid Modernization Lab Consortium (GMLC) Medium Voltage Resource Integration Technologies (MERIT) is a multi-lab effort focused on development, demonstration, and evaluation of medium voltage (MV) power electronics. The project team, which includes Oak Ridge National Lab, National Renewable Energy Lab, Sandia National Labs, and Pacific Northwest National Lab, is analyzing the quantitative impact potential of power electronics in MV utility applications. This comprehensive assessment cuts across device, circuit, and system domains to identify—and ultimately overcome—obstacles to at-scale deployment of transformative power conversion and control technologies.

Madhu Chinthavali, Electrical Systems Integration Program Manager, was instrumental in founding the Grid Research Innovation and Development Center, (GRID-C) at Oak Ridge National Laboratory (ORNL) and has served in a series of leadership roles during more than two decades at the Laboratory. Dr. Chinthavali grew the lab's power electronics and grid systems research expertise from a team to large group before taking the helm of the Electric Energy Systems Integration and Controls Section. Dr. Chinthavali has managed ORNL's energy portfolio at ORNL as program lead across multiple DOE offices and provided national leadership in helping DOE's Office of Electricity establish the Power Electronics Accelerator Consortium for Electrification. Dr. Chinthavali provides broad experience in developing many facets of power electronics technologies and innovative solutions for applications including vehicle charging, building energy integration, grid-tied energy storage and photovoltaic systems, and power flow control grid devices. He earned his master's and doctorate degrees in Electrical Engineering from the University of Tennessee, Knoxville while working at ORNL. Dr. Chinthavali has been recognized with multiple honors for leadership, technology innovations and collaboration projects.

Break

9:45 am – 10:15 am

Session 1: Grid Security & Resilience

10:15 am – 12:00 pm **Co-Chairs:** Steve Glover *(Sandia National Laboratories)* & Mike Ropp *(Sandia National Laboratories)*

10:15 – 10:20 **Introduction:** Session Chairs

10:20 – 10:35 **Building a Smarter Energy Future: Duke Energy's Path to a Secure & Resilient Grid:** Jason Handley *(Duke Energy)*

As threats to the electric grid continue to evolve, securing and fortifying our energy infrastructure has never been more critical. This presentation will document Duke Energy's comprehensive approach to grid security and resilience—exploring the strategies, technologies, and innovations deployed to safeguard power systems against cyber and physical threats. From integrating advanced monitoring solutions to enhancing system redundancy and response capabilities, Duke Energy's proactive measures ensure reliability and stability in an increasingly dynamic energy landscape. By sharing key insights and lessons learned, this discussion will highlight the importance of resilience in modern grid operations and the path forward for securing America's energy future.

Jason Handley, P.E., is the General Manager of the Distributed Energy Group at Duke Energy in Charlotte, NC, with over 28 years of utility experience. He leads a team focused on engineering, deploying, operating, and maintaining regulated distributed energy resources and microgrids. Jason has held leadership roles, including past Chairman of EPRI's IntelliGrid Program Advisory Committee and service on the Smart Grid Interoperability Panel and the National Institute of Standards Technology's Smart Grid Advisory Committee. He currently serves on the IEEE Industry Technical Support Leadership Council and is Co-Chair of the SEPA Microgrids Working Group. A holder of five patents and recipient of Duke Energy's James B. Duke Award, Jason earned his electrical engineering degree from Auburn University and an MBA from Wake Forest University. He has been a registered professional engineer since 2002 and obtained his electrical contractor's unlimited license in 2009.

10:35 – 10:50 **Grid Resiliency and the DoD:** Matt Haupt *(Former Navy)*

With over three decades of distinguished C-suite leadership, Matt Haupt brings an

unparalleled ability to bridge technology, execution, and policy into transformative, holistic solutions. Renowned for his strategic vision, Matt excels at building dynamic ecosystems—connecting needs with resources, addressing the root causes of complex challenges, and driving meaningful cultural change. Matt's expertise lies in seamlessly integrating data, advanced analytics, legacy and emerging technologies, and interdisciplinary collaboration to deliver exceptional value and elevate the experience for clients, consumers, and stakeholders alike. As the former Energy Director within the Public Works Directorate at Naval Facilities Engineering Systems Command (NAVFAC) Headquarters in Washington, DC, Matt was entrusted with leading energy security initiatives and deployment strategies for the entire Department of the Navy. In this pivotal role, he developed and executed innovative solutions to enhance energy resilience and operational dominance across Navy and Marine Corps installations worldwide. His leadership in forging global partnerships—spanning academia, private industry, and government—has been instrumental in sustaining superior mission support for the warfighter through both public/public and public/private collaborations. A retired U.S. Navy Civil Engineer Corps Officer with over 25 years of service, Matt's technical and operational acumen is matched by his academic credentials: a Bachelor of Science in Ocean Engineering from Florida Atlantic University, a Master of Science in Environmental Engineering from the University of South Florida, and completion of the prestigious NAVFAC Senior Leadership curriculum. Matt is a licensed Professional Engineer (PE) in Civil Engineering in multiple states and holds the Certified Energy Manager (CEM) and Certified Protection Professional (CPP) credentials. His proven track record, visionary leadership, and commitment to innovation make him a trusted partner for organizations seeking to achieve mission-critical objectives and lasting impact.

10:50 – 11:05 **Ground Induced Current Drivers and Mitigation:** Joseph Blankenburg (*Department of Energy*)

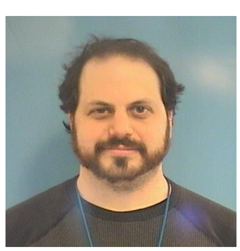
Ground Induced currents are driven by natural processes and can be caused by manmade

phenomena, causing reduced power quality, losses and potentially causing misoperations and damage. This talk will discuss the drivers of these phenomena and the potential for future investigations in power electronics and energy conversion to assist in making transmission systems more efficient, reliable and resilient.

Mr. Blankenburg is a physicist working for DOE's Office of Cybersecurity, Energy Security, and Emergency Response. He manages the program that performs new research, development and demonstrations to mitigate high energy electromagnetic pulses to energy infrastructure.

11:05 – 11:20 **Resilient Energy Systems Development at Sandia National Laboratories:** Lee Rashkin *(Sandia National Laboratories)*

Sandia National Laboratories has been working on the development of power electronics and controls to improve grid resiliency and stability for many years. Since 2020, this work has been gathered as part of a Mission Campaign in Resilient Energy Systems since 2020. This presentation will cover the development of solid state transformer (SST) technology to improve resiliency, analysis of the vulnerabilities of SST systems, and the development of packaging and materials to enable and protect SST devices.



Lee Rashkin received his Bachelor's Degree in Electrical Engineering from the University of Illinois at Urbana-Champaign in 2006. He then went on to get his Master's Degree and Ph.D. from Purdue University in 2008 and 2014 respectively. His Ph.D.

thesis, titled “Large Displacement Stability of AC Microgrids,” examined stability in power electronics controlled systems under large swings in power demand. He started at Sandia in June 2014 as a Postdoctoral Appointee before transitioning to a staff position in 2018. During his tenure at Sandia, he has worked on electric vehicle drivetrain optimization, power electronics and controls design for the Navy all-electric warships, energy storage sizing for grid applications, and many other power electronics and controls projects. His research interests include power electronics, power systems, controls, and optimization.

11:20 – 12:00 **Panel Discussion**

Lunch

12:00 pm – 1:00 pm

Session 2: Overview of Power Electronics

1:00 pm - 2:30 pm **Co-Chairs:** Stan Atcitty *(Sandia National Laboratories)* & Jake Mueller *(Sandia National Laboratories)*

1:00 – 1:05 **Introduction:** Session Chairs

1:05 – 1:20 **Electrical Insulation Investigation for Medium-Voltage SiC Power Modules:** Christina DiMarino *(Virginia Tech)*

Christina DiMarino is an assistant professor at Virginia Tech in the Center for Power Electronics Systems (CPES). She earned her M.S. and Ph.D. degrees in electrical engineering from Virginia Tech in 2014 and 2018, respectively. Her research focuses on power electronics packaging, high-density integration of wide- and ultra-wide bandgap power semiconductors, and medium-voltage power modules. Dr. DiMarino serves as a Member-at-Large for the IEEE Power Electronics Society (PELS), Chair of the PELS Technical Committee on Power Components, Integration, and Power ICs, and Associate Editor for the IEEE Transactions on Power Electronics. She is also a member of the PCIM Europe Advisory Board. Her accolades include five best paper and presentation awards at international conferences, the Outstanding New Assistant Professor Award at Virginia Tech in 2022, and the IEEE PELS Richard M. Bass Outstanding Young Power Electronics Engineer Award in 2024.

1:20 – 1:35 **Power Electronics and the Energy Transition:** Joseph Benzaquen *(Georgia Institute of Technology)*

Power electronics is at the heart of the 21st-century energy transition, serving as the key enabler and accelerator for the integration of exponential technologies, such as solar, storage, transportation, and AI. With more than twice the US electrical energy generation capacity waiting to be connected to the grid through power electronics converters in under a decade, the future inverter-based resource (IBR)-based grid will present unique challenges associated with the shift from a synchronous generator-based system to an IBR-based grid. In this presentation, we will delve into the Center for Distributed Energy’s power electronics research, development, and deployment initiatives, which focus on holistically addressing the energy transition challenges, including grid-interactive and industrial power converters, control, and grid-enhancing technologies. Lastly, we will pay special attention to energy access technologies in collaboration with Sandia National Laboratories.

Joseph Benzaquen received the B.Sc. and M.Sc. degrees in electrical engineering from Universidad Simón Bolívar, Caracas, Venezuela, in 2011 and 2015, respectively, and the Ph.D. degree in electrical engineering from Kansas State University in 2020 with the Smart Power Electronics & Control Systems (SPECS) research group. He is currently a Chief Research Engineer with the Center for Distributed Energy at the Georgia Institute of Technology, where he joined in the Fall of 2020 as a Postdoctoral Fellow; his research interests lie at the intersection of power electronics and the grid, focusing on the control of grid-interactive power converters, grid-enhancing technologies for augmentation and dynamic support, and energy access technologies.

1:35 – 1:50 **Evaluation of Power Electronics for Optimal Performance and Offsite Implementation:** Christopher Recio *(Mainstream Engineering)*

Power electronics play a pivotal role in modern military and electrical systems. The evaluation of power electronics for military and commercial applications is essential to ensure performance, reliability, and ruggedness across diverse operational environments. Advanced power electronic devices, conversion topologies, control strategies and optimization, thermal management, and packaging are considered to improve system performance. This presentation will cover the approach that Mainstream Engineering has taken from demanding military applications to cost-optimized commercial products and further development in the area high-voltage grid-tied applications.

Mr. Christopher Recio has over twenty years of experience in the design and development of power electronic converters for commercial and military applications and currently serves as Mainstream's Power Electronics Technology Leader. He received his master's degree in Electrical Engineering from the University of Illinois at Urbana-Champaign. Prior to joining Mainstream Engineering, Mr. Recio worked at General Electric where he was a lead design engineer and worked in the R&D group for power electronics. More recently, he worked on the development and commercialization of energy products for a start-up company that has reached an annual volume of 100k units, including AC motor controllers for the Oil & Gas Industry and voltage stabilizers for single, split, and three-phase commercial, industrial, and residential systems. At Mainstream Engineering, his research is focused on the use of wide-bandgap semiconductors for power electronics operating in extreme environments and where SWAP is critical. Mr. Recio holds patents in the areas of power electronics, grid stabilization, power factor correction, and reactive power support.

1:50 – 2:05 **Powering Data Centers with DC: Opportunities and Design Insights:** Amin Zamani *(Quanta Technology)*

As data centers continue to expand in both scale and energy consumption, direct current (DC) power architectures are gaining renewed attention for their potential to improve efficiency, reliability, and integration with renewable energy and storage systems. This presentation examines the evolving landscape of DC-powered data centers, focusing on key configurations such as centralized, distributed, and hybrid DC systems. It will address technical and operational challenges while exploring emerging solutions and design strategies. Real-world examples will demonstrate how DC architectures can create new opportunities for energy optimization, resilience, and sustainability in next-generation data centers.

Amin Zamani is the Senior Director of Advanced Technology Integration at Quanta Technology, with over 15 years of global experience in the utility and energy sectors. His expertise spans power system protection and control, emerging technology deployment, integration of inverter-based solutions, and advanced real-time testing. Previously, he was Director of Global Grid Modernization Services at GE Grid Solutions. Amin has led numerous utility and industrial projects involving microgrids, distribution automation, large load interconnections, and advanced protection systems. He is a Senior Member of IEEE, actively involved in the IEEE PSRC, and a licensed professional engineer in Ontario.

2:05 – 2:30 **Panel Discussion**

Break

2:30 pm – 3:00 pm

Session 3: Power Electronics Integration with Power Systems

3:00 pm - 4:30 pm **Chair:** Brian Pierre *(Sandia National Laboratories)*

3:00 – 3:05 **Introduction:** Session Chairs

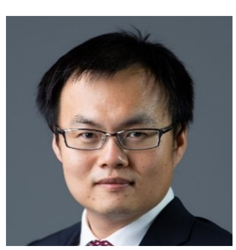
3:05 – 3:25 **Inverter-dominated Transmission Systems – Protection and Stability:** Matthew Reno *(Sandia National Laboratories)*

This presentation discusses how power electronics will impact future power system operation in an inverter-dominated grid. Due the hardware limitations of inverter-based resources (IBRs), they provide significantly smaller currents during fault events than synchronous generators in traditional power systems. These challenges demand a new approach to power system protection and stability analysis, as conventional methods may no longer be effective. This presentation discusses some of the potential tradeoffs for improving grid-forming inverter (GFM) controls compared to different protection techniques. This includes the comparison of four different fault-ride through (FRT) functions for GFM IBRs, including current limiting, virtual impedance, and virtual resistance. We compare traditional transmission protection methods including distance, differential protection, and Permissive Over-Reaching Transfer Trip (POTT) protection.

Matthew Reno is a Distinguished Member of Technical Staff in the Electric Power Systems Research Department at Sandia National Laboratories. His research focuses on distribution system modeling and analysis with Big Data and high penetrations of PV by applying cutting edge machine learning algorithms to power system problems. Matthew is also involved with the IEEE Power System Relaying Committee for developing guides and standards for protection of microgrids and systems with high penetrations of inverter-based resources. He received his Ph.D. in electrical engineering from Georgia Institute of Technology.

3:25 – 3:45 **Advanced Models and Simulation Tools for Studying Power Electronics in Power Systems:** Wei Du *(Pacific Northwest National Laboratory)*

This presentation will introduce PNNL's work on advanced models and simulation tools for integrating power electronics in power systems. It will first cover the standard library grid-forming inverter models developed in collaboration with leading inverter manufacturers and transmission planners, which have been adopted by the Western Electricity Coordinating Council (WECC) and integrated into commercial power system stability simulation tools. Simulation studies conducted by industry collaborators using these models will be presented. Additionally, the presentation will introduce an open-source distribution simulation platform for modeling transient and dynamic behaviors of unbalanced distribution systems with high penetration of distributed energy resources, highlighting studies performed on a real-world distribution feeder model.



Dr. Wei Du is the solar subsector manager and a staff research engineer at Pacific Northwest National Laboratory (PNNL), with a joint appointment as a Research Associate Professor at Washington State University (WSU), where he is responsible for PNNL's power electronics strategy and serves as the interim co-director of the PNNL-WSU Advanced Grid Institute (AGI); his research focuses on control design, modeling, and simulation of power systems with high penetration of power electronics, and he is the Principal Investigator of multiple DOE projects investigating the impacts of inverter-based resources on power system stability. Dr. Du co-leads the Modeling and Simulation Area of the Universal Interoperability for Grid-Forming Inverters (UNIFI) Consortium and is the lead developer of the US WECC standard library grid-forming inverter models, REGFM_A1 and REGFM_B1, which have been integrated into leading commercial power system stability simulation tools, and he also serves as an Associate Editor of IEEE Transactions on Smart Grid.

3:45 – 4:05 **Frequency-Constrained Real-Time Co-Optimization of Energy and Regulation Reserve with Inverter-based Battery Energy Storage Systems:** Masood Parvania *(University of Utah)*

This talk will present a two-state stochastic optimization model for real-time operation of energy and frequency regulation markets, where thermal generating units as well as inverter-based battery energy storage (IBES) systems provide the energy and regulation services. The proposed model accurately represents the dynamic behavior of thermal generation units and IBES systems, enabling the precise and cost-efficient allocation of up- and down-regulation reserves in the real-time market.

Masood Parvania is the Roger P. Webb Endowed Professor of Electrical and Computer Engineering and the Director of Utah Smart Energy Laboratory and the Utah Energy and Power Innovation Center (U-EPIC) at the University of Utah. Dr. Parvania is also the Principal Investigator and Director of the U.S.-Canada Center on Climate-Resilient Western Interconnected Grid (NSF WIRED Global Center) that is co-funded by U.S. National Science Foundation (NSF) and Natural Sciences and Engineering Research Council of Canada (NSERC), to develop solutions for safeguarding the Western Interconnection against natural disasters such as wildfire, heatwave and droughts.

4:05 – 4:30 **Panel Discussion**

Closing Remarks

4:30 pm – 5:00 pm

Evening Reception / Software Showcase

5:00 pm – 6:30 pm

- COMSOL / TCAD *(Mihai Negoita, Sandia National Laboratories)*
- LTSPICE *(Felipe Palacios II, Sandia National Laboratories)*
- PLECS *(Jake Mueller, Sandia National Laboratories)*
- PSCAD *(Miguel Jimenez Aparicio & Michael Ropp, Sandia National Laboratories)*

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