IEEE ENERGY CONVERSION CONGRESS & EXPO

2021

Virtual Conference ≋ Oct. 10–14

# Virtual Conference PROGRAM

October
10–14

Sponsored by the IEEE Power Electronics And Industry Applications Societies

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# Welcome from General Chair

On behalf of the entire ECCE 2021 Organizing Committee it is my pleasure to welcome you to the 13th Energy Conversion Congress and Expo, ECCE 2021, co-sponsored by the **IEEE Industry Applications Society (IAS)** and **IEEE Power Electronics Society (PELS)**. Joining IAS and PELS this year are STMicroelectronics as a Gold Sponsor and OPAL-RT as a Silver Sponsor. Please visit their booths in the user-friendly virtual exhibit, where you'll also find many other companies which will provide you with information on their newest products and solutions.

Since its debut in 2009, ECCE has become the key annual event to attend if you, like me, are passionate about electrical and electromechanical energy conversion technology and if you enjoy sharing your ideas with other engineers, students and researchers from industry and academia. In the spirit of worldwide inclusion, ECCE 2021 is virtual, on a user-friendly platform, and with a plethora of events focused on giving you the opportunity to learn, network and discover what's new and trending in integrated energy systems as well as individual energy conversion components.

ECCE 2021's program features four live plenary talks by experts and leaders from Tesla, MagniX, General Electric Aviation, and Intel. They will present the latest energy conversion technologies and their visions for future research and development. Adopting the same live format as the plenary session, several special sessions will provide you with opportunities to participate in panels with experts from industry and academia. The topics are very timely and important ranging from additive manufacturing for electric machines to wide bandgap devices, from power electronics to interface distributed energy resources to standard development, from energy access for all countries to cybersecurity, from power converters as grid-interface to simulations, controls and thermal design.

The tutorial program opens the conference on Sunday with several informative and engaging live sessions. Thanks to the virtual format, you can access the tutorial presentations a few days before Sunday, to get the most out of the live sessions with the tutorial presenters. The topics include grid-forming technology, wide bandgap devices, electric machine design, electric drives, solar photovoltaic and energy storage systems, design practices, electromagnetic interference, resilience, reliability and electro-thermal design.

At the core of ECCE 2021, is the regular technical program, with almost 900 technical papers and as many on-demand oral presentations, which deliver the latest advancements in energy conversion technology with focus both on components and systems. I hope you'll enjoy interacting with the authors, at your own pace, through the chats available for each technical presentation throughout the conference. Two of these sessions are dedicated to Prof. Akira Nabae and Prof. Braham Ferreira, who recently passed away and were attendees of many ECCE conferences. They left their imprint on the field of energy conversion through their research contribution and through their many students; we will never forget them.

Following the tradition of the past few years, ECCE 2021 is co-located with the 2021 IAS Annual Meeting. We share the plenary session, the award presentations and the exhibit hall, which is free for everybody. If you are a student, you have access to both technical programs.

The ECCE 2021 program was created by an extraordinary and diverse team of volunteers, women and men from the industry, government laboratories, and academia who selflessly donated their time and talent to ECCE 2021 for almost two years. The contribution from IEEE personnel, SmithBucklin and Vfairs was also instrumental in organizing this conference. Thank you for making ECCE 2021 as engaging in virtual format as it has been in-person in past years.

I invite you to enjoy the 5 live days, and to also take advantage of the additional 25 days during which the on-demand content, including exhibitor materials, technical presentations, recorded live sessions and panels, product sessions, award presentations and student demonstrations, will be available on the virtual platform.

Thank you for participating in ECCE 2021. Together, we contribute to a more sustainable world!

Giovanna Oriti

**Giovanna Oriti**
*ECCE 2021 General Chair*

# Welcome from Technical Program Committee

On behalf of the Technical Program Committee it is our great pleasure to welcome you to the IEEE Energy Conversion Congress & Exposition (ECCE 2021). We were hoping to resume the in-person meeting this year or to have a hybrid conference at the very least. Unfortunately, this turned out to be impossible, but we hope that the virtual mode meets your expectations. We created an exciting program for all virtual attendees with live events such as tutorials, special sessions, plenary sessions and the expo, and we combined it with prerecorded videos for the rest of the technical program.

The world's leading conference on energy conversion systems, ECCE, is sponsored by the IEEE Industry Applications Society (IAS) and IEEE Power Electronics Society (PELS). It offers a multidisciplinary array of topics, ranging from devices to electrical power systems. Almost 900 technical presentations are organized into thematic sessions, with offline Q&A that authors will monitor daily. The material of the conference will be available for 30 days for attendees.

The ECCE Technical Program Committee managed a larger team this year consisting of 27 track chairs and 179 topic chairs who organized and supervised the review process to identify the best papers for ECCE. We had two plenary virtual meetings in April to finalize all paper decisions, and more in July and September to decide on the final program. The conference received a total of 1576 digest submissions from 62 countries. After a rigorous peer review and scheduling process, 893 papers are scheduled for presentation. On average, each digest received over 4 reviews. Our gratitude goes to the valued track chairs, topic chairs and to the generous 1650 reviewers who made all this possible.

The tutorials co-chairs received and reviewed 50 proposals and selected 17 tutorials to offer online this year. We are also proud of offering 24 special sessions on various topics.

***We look forward to virtually welcoming you to ECCE 2021—thank you for helping us keeping the ECCE community connected!***

## ECCE 2021 Technical Program Committee

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**Michael Harke**

**Gianmario Pellegrino**

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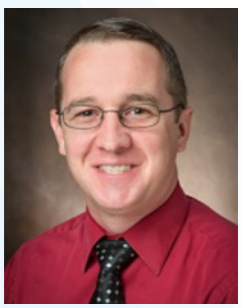

**Mark Scott**

**Luca Zarri**

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## Conflict of Interest

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# Schedule-at-a-Glance

*All session times are in Pacific Standard Time*

## Sunday, October 10, 2021
## Meet the Instructors Tutorial

| ALL IN PACIFIC STANDARD TIME | Virtual 1 | Virtual 2 | Virtual 3 | Virtual 4 |
|---|---|---|---|---|
| 9:00AM-9:45AM | **TUTORIAL 9AM1** Photovoltaic Systems – From Basics to Advanced Grid Supportive Control | **TUTORIAL 9AM2** Pulse-Width-Modulation: with Freedom to Optimize EMI | **TUTORIAL 9AM3** A MATLAB/Simulink Approach of Photovoltaic Power Systems: Designing, Modeling, Simulation, and Control | |
| 9:45AM-10:00AM | **BREAK** | | | |
| 10:00AM-10:45AM | **TUTORIAL 10AM1** Emerging Bidirectional Switches and Their Impact on Future AC Power Converters and Applications | **TUTORIAL 10AM2** Interaction Among the Grid-connected Converters through Their Synchronization Mechanism | **TUTORIAL 10AM3** Wide Bandgap Power Electronics Based Electric Machine Drives | **TUTORIAL 10AM4** Monitoring Power Module Degradation via Lifetime-Varying Parameters |
| 10:45AM-11:00AM | **BREAK** | | | |
| 11:00AM-11:45AM | **TUTORIAL 11AM1** Advances in Intelligent Solid-State DC Substations for Future Interconnected DC Grids | | **TUTORIAL 11AM3** Optimised Electrical Machine Designs for E-Mobility Applications | **TUTORIAL 11AM4** Conducted, Near-field "and Radiated EMI Emission Mitigation for Wide Bandgap Converters: Fundamentals, Modeling and Solutions |
| 11:45AM-12:00PM | **BREAK** | | | |
| 12:00PM-12:45PM | **TUTORIAL 12PM1** Applying Artificial Intelligence to Battery State Estimation | **TUTORIAL 12PM2** Resiliency-Oriented Grid-Interactive Converters: Concepts, Design, and Field Implementation | **TUTORIAL 12PM3** Cryogenic Power Electronics Design for Electrified Aircraft Propulsion | **TUTORIAL 12PM4** Hybrid Semiconductor Switches based Power Modules, Converters, and Systems |
| 12:45PM-1:00PM | **BREAK** | | | |
| 1:00PM-1:45PM | **TUTORIAL 1PM1** Design and Development of Scalable Battery Testers/Emulators and Their Applications for Future Transportation Electrification | **TUTORIAL 1PM2** Printed Circuit Boards in Power Converter Applications: Design Considerations and Failure Mechanisms | **TUTORIAL 1PM3** Defining, Modeling, and Optimizing for Energy Efficiency in 5G | |

Nearly 900 Technical Sessions available for flexible viewing to best accommodate your schedule.

*All session times are in Pacific Standard Time*

# Monday, October 11, 2021

| ALL IN PACIFIC STANDARD TIME | Virtual 1 | Virtual 2 | Virtual 3 | Virtual 4 |
|---|---|---|---|---|
| 8:30AM-10:30AM | **PLENARY SESSION**<br>**Motor Technology Selection and System Level Optimization Effects in Drive Systems**<br>Dr. Konstantinos Laskaris<br>*Principal Motor Designer, Tesla*<br>**Electric Aircraft: From Concept to Reality**<br>Roei Ganzarski<br>*CEO, magniX*<br>**Hybrid Electric Systems for the Commercial Aviation Sector**<br>Christine Andrews<br>*Hybrid Electric Systems Leader, GE Aviation*<br>**Driving Digital Transformation**<br>Dr. Irene J. Petrick<br>*Senior Director of Industrial Innovation in the Internet of Things Group, Intel* | | | |
| 10:30AM-12:00PM | **EXHIBITS**<br>Explore more than 30 booths to learn about the latest products to support your projects and make an appointment to meet with a vendor. | | | |
| 12:00PM-12:30PM | **BREAK** | | | |
| 12:30PM-2:00PM | **SS16**<br>Coming Soon: Medium- and High-Voltage Gallium Nitride Power Devices | **SS17**<br>Power Electronics-Based Technologies for Grid Stabilization: Grid-Forming Inverters, Control of Inverter-Based Resources (IBRs), and Advanced Testing of IBRs | **SS10**<br>Energy Access and Empower Billions of Lives: Technologies, Impact and Opportunities for PELS | **SS25**<br>Power Electronics Enabled Power System with High Penetration of Renewables |
| 2:00PM-3:30PM | **EXHIBITS**<br>Explore more than 30 booths to learn about the latest products to support your projects and make an appointment to meet with a vendor. | | | |

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# Tuesday, October 12, 2021

| ALL IN PACIFIC STANDARD TIME | Virtual 1 | Virtual 2 | Virtual 3 | Virtual 4 |
|---|---|---|---|---|
| 8:30AM-9:00AM | **PRODUCT SESSION – STMICROELECTRONICS**<br>Evolution of Power Delivery for Cloud Computing | | | |
| 9:00AM-9:30AM | **PRODUCT SESSION OPAL-RT**<br>HIL Demo of Solar rters | | | |
| 9:30AM-11:00AM | **EXHIBITS**<br>Explore more than 30 booths to learn about the latest products to support your projects and make an appointment to meet with a vendor. | | | |
| 11:00AM-2:00PM | **BREAK**<br>Don't forget to check out the student demonstrations! | | | |
| 2:00PM-3:30PM | **SS24**<br>Booming the Blue Economy: A New Era for Wave and Hydrokinetic Energy | **SS20**<br>PV Inverter Reliability: Industry Status, Technical Gap, and Future Needs | **SS6**<br>Energy Storage Systems: Applications, Control and Interfaces | **SS7**<br>Advanced Power Electronics Integration for Renewables |
| 3:30PM-4:00PM | **PRODUCT SESSION GeneSiC**<br>G3R™ SiC MOSFETs, Unparalleled Per ance and Robustness | | | |
| 4:00PM-4:30PM | **BREAK** | | | |
| 4:30PM-6:00PM | **EXHIBITS**<br>Explore more than 30 booths to learn about the latest products to support your projects and make an appointment to meet with a vendor. | | | |

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# Wednesday, October 13, 2021

| ALL IN PACIFIC STANDARD TIME | Virtual 1 | Virtual 2 | Virtual 3 | Virtual 4 |
|---|---|---|---|---|
| 8:30AM-10:00AM | **SS1** Cybersecurity for Power Electronics | **SS3** "ENSURE" Meets the World" the German Strategic Initiative ENSURE Presents Its Energy Outcomes | **SS4** Power Electronic Technologies for Distributed Energy Resources | **SS5** Wide-Bandgap Bidirectional Switches and the Applications They Enable |
| 10:00AM-12:00PM | **SS1** Cybersecurity for Power Electronics | **SS3** "ENSURE" Meets the World" the German Strategic Initiative ENSURE Presents Its Energy Outcomes | **SS4** Power Electronic Technologies for Distributed Energy Resources | **SS3** "ENSURE" Meets the World" the German Strategic Initiative ENSURE Presents Its Energy Outcomes |
| 12:00PM-2:00PM | **BREAK** | | | |
| 2:00PM-3:30PM | **SS11** Power Electronics Dominated Grids: Dynamic Modeling and Simulation for Reliable and Resilient Operation of Future Grids | **SS9** Advances in SiC/GaN Grid Applications to Support EV and Renewable Energy | **SS15** Future of Wide-Bandgap Devices SiC, GaN and Diamond and Their Emerging Applications in Power Electronics | **SS22** Grid Integration of Inverter-Based Distributed Energy Resources: Operation, Planning, and Guidelines |

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## Thursday, October 14, 2021

| ALL IN PACIFIC STANDARD TIME | Virtual 1 | Virtual 2 | Virtual 3 | Virtual 4 |
|---|---|---|---|---|
| 9:00AM-10:30AM | **SS2** Energy Storage for Grid of the Future: Emerging Technologies, Applications and Trends | **SS8** Thermal Design and Control for High Reliability Power Electronics, Electrical Drives, and Batteries | **SS13** Standard Development and Industry Engagement Update from IEEE Power Electronics Society | **SS23** EMI and Insulation Related Challenges and Solutions for WBG-based Power Electronic Systems |
| 10:30AM-12:00PM | **SS2** Energy Storage for Grid of the Future: Emerging Technologies, Applications and Trends | **SS12** Advanced Design and Manufacturing Techniques for Electric Machines – Simulation and Test | **SS21** P2964 IEEE Standard for Datasheet Parameters and Tests for Integrated Gate Drivers | **SS18** EMI and Insulation Related Challenges and Solutions for WBG based Power Electronic Systems |
| 12:00PM-1:30PM | **SS19** Experimental Verification versus Simulation | | **SS14** Additive Manufacturing for Electric Machines | |

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**AWARDS**
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# Plenary Session

**Monday, October 11** **8:30AM-9:00AM**

## Motor Technology Selection and System Level Optimization Effects in Drive Systems

Dr. Konstantinos Laskaris

*Principal Motor Designer, Tesla*

True optimal design constitutes an important competitive advantage in electric vehicles and requires good knowledge of physics modeling, parametric design, numerical simulations, and decision making. Battery, Motor, Inverter and Gear design space is searched during the optimization process. The efficiency and mass of the resulting powertrain affect the total cost, depending on the application. Powertrain compaction is key objective, but it comes with reduction in system efficiency and in many cases, at higher overall cost. Moreover, higher speed, more compact systems, exhibit dominant high frequency losses, introducing the need for advanced modeling to capture the phenomena. This keynote outlines key characteristics of motor, inverter and gears to achieve optimal design with particular focus on the motor technology.

Bio: Dr. Konstantinos Laskaris was born in Athens, Greece, received his diploma in Electrical and Computer Engineering from the National Technological University of Athens (NTUA), his master's degree in Signal Processing from the Imperial College London, UK, and his PhD in Electric Motor geometry optimization for variable speed drives from the NTUA, Greece. Since 2012, Dr. Laskaris has been the Chief Motor Designer at Tesla Motors, located in the Silicon Valley, California, where he leads the team of motor design engineers. Some of his most significant projects at Tesla include the drive unit system design and optimization for the Model S, Model X, Model 3, Model Y and Semi-Truck vehicles. His research interests include parametric design and loss modeling of synchronous and asynchronous machines using finite element analysis, as well as development of multi-objective optimization methods using supercomputers. Dr. Laskaris has also worked in education, as a laboratory partner in NTUA, teaching the science of electric machines and is a co-founder of the Prometheus team in NTUA, which participates in EV fuel economy contests and holds the Panhellenic fuel consumption record today.

**Monday, October 11** **9:00AM-9:30AM**


## Electric Aircraft: From Concept to Reality

Roei Ganzarski

*CEO, magniX*

There are multiple companies and programs around the world pursuing electric aviation. From pure battery electric, to Hydrogen electric, to hybrid, these programs are mostly run by new entrants into the aviation industry, with some programs also being introduced by the incumbents. We will review from a new entrants perspective, what it really means to take electric propulsion and aircraft from concept to reality including challenges, pitfalls, and successes. What practical real-world lessons should be considered when taking on such an audacious goal.

Bio: Roei is CEO of magniX, an electric aviation propulsion company. With a vision of connecting communities with low-cost, clean air transportation, magniX is disrupting aviation as we know it. Roei is also executive chairman of Eviation, the electric aircraft OEM bringing a newly designed all-electric aircraft to market. Prior to magniX, Roei was CEO of BoldIQ – a provider of dynamic real-time scheduling optimization software. Under Roei's leadership, BoldIQ grew from seed software startup to multi-million-dollar profitable SaaS company. Before BoldIQ, Roei was with the Boeing family of companies in continuously increasing roles of responsibility. His last role was Chief Customer Officer for Boeing's Flight Services division where he led worldwide customer and market facing organizations and was responsible for revenue growth and customer service. Other experiences prior to Boeing include investment banking, corporate finance, advertising, and the military. He is a graduate of Wharton's Advanced Management Program, earned an MBA from the University of Washington, and a BA in Economics from The University of Haifa. Roei lives with his family in Redmond, Washington, USA.

**Monday, October 11** **9:30AM-10:00AM**

## Hybrid Electric Systems for the Commercial Aviation Sector

Christine Andrews

*Hybrid Electric Systems Leader, GE Aviation*

GE Aviation is committed to a more sustainable future of flight. One of the enabling technologies the jet engine maker is pursuing to help the aviation industry reach its decarbonization goals is hybrid electric capability for single-aisle aircraft. Single-aisle air transport is the largest civil aviation market, where emissions-reducing technologies would have a major impact. In this presentation, GE Aviation will provide an overview of the challenges and opportunities for making hybrid electric systems a reality for this commercial aviation sector and the integration of motors and generators with gas turbine engines, electrical power distribution systems, electrical power converters, electricity storage and more.

Christine is the Hybrid Electric Systems leader for GE Aviation, responsible for the advancement of all power electronics technology development and integration with the gas turbine. Previously, Christine served as the Business Program Manager for the Aviation business at GE Research, where she evaluated future technologies and developed relevant aviation technologies from supporting next generation platforms to servicing existing fleet to improve revenues.

Christine has been at GE for 8 years, and has held various leadership positions across many disciplines within aviation engineering that have yielded many technology advancements in both the combustor and augmentor modules. She has an excellent track record of establishing and maintaining strong customer relationships by consistent execution of government programs. Prior to joining GE, Christine held various engineering positions at Gulfstream Aerospace.

**Monday, October 11** **10:00AM-10:30AM**

## Driving Digital Transformation

Dr. Irene J. Petrick

*Senior Director of Industrial Innovation in the Internet of Things Group, Intel*

Industry 4.0 harnesses digital tools to make industrial operations smarter, more efficient, and ultimately to operate autonomously. At the heart of this transformation lies data and its ability to drive proactive decisions. To accelerate the digital transformation journey you need both a long term vision and a digital architecture. It's not just applying digital tools to current operations. Instead, successful companies have had to rethink complex interactions between people, processes, organizational culture and technology. This presentation highlights lessons learned during Intel's three year study of over 500 people at over 400 companies.

Bio: Dr. Irene J. Petrick joined Intel in 2015 and is Senior Director of Industrial Innovation in the Internet of Things Group. Irene focuses on emerging technology, social, and global trends and their combined impact on the industrial space. Her work highlights the industrial internet of things, edge computing, the transition to intelligent manufacturing and the needs of the future workforce, 3D printing and distributed manufacturing and the new business models that are enabled by intelligent manufacturing. Prior to joining Intel, Irene was a professor at Penn State and has been actively engaged with companies in their innovation and technology strategies for over 25 years, including work with twelve Fortune 100 companies, the U.S. military, and a wide variety of small to medium sized enterprises. Petrick is author or co-author on more than 200 publications and presentations.

# Special Sessions

*These presentation-only sessions are focused on timely and practical topics in the field.*

**Wednesday, October 13** **8:30AM-10:00AM | 10:00AM-12:00PM**

## SS1 | Cybersecurity for Power Electronics

SESSION ORGANIZERS:

**Prof. Alan Mantooth,** *Distinguished Professor, The Twenty-First Century Research Leadership Chair in Engineering, University of Arkansas, USA*

**Prof. Frede Blaabjerg,** *Danish Professor and Villum Investigator, Aalborg University, Denmark*

**Prof. Sudip K. Mazumder,** *Professor, University of Illinois at Chicago*

The growing threat of cyber-physical attacks targeting the electric power grids is rising in number and sophistication. The Ukraine Power Grid cyberattack is an evidence of this vulnerability. Emphasis on maintaining cyber resiliency for power electronics at the grid edge is due to the devastating effects on reliability of widespread infrastructure, given the potential cascading effect. The attack may be introduced to the grid through single or multiple power electronic converters and impact the harmonious operation of the entire network which may cause catastrophic grid failure and large blackouts. The existence of numerous smart devices in power electronics dominated grids (PEDG), provides an immense attack surface for attackers to target and compromise the system. Thus, power electronics plays a vital role in edge resilience. The inevitability of cyberattacks on critical systems dictates more innovative measures to protect their operations. Power electronics is the core of many cyber assets that faces the physical ingredient of cyber-physical systems.

This special session covers several aspects of trending secure power electronic design, intrusion detections, and resilient control schemes. The concept of cyber resiliency in the realm of power electronics at the system level will be presented. The special session hosts demonstrate the importance of designing power electronics with security features in mind in the context of increasingly connected power electronics as a result of IoT, Industry 4.0, and 5G. Device-level attacks that aim to compromise the controllers, intentional noises and denial of service will be presented considering their impact and potential mitigation approaches.

Subsequently, this special session presents the significance of the power electronics at the device-level resiliency as it supports a system-level resilience framework. We will target the new trend of securing the edge following the "resilience by design" principle. We will be covering business challenges and futuristic paths to play a role in different market segments. The importance of new attack surfaces and defensive design strategies in PEDG with mixed inertia characteristics will be presented. The host propositions on multi-layer security mechanisms aided with artificial intelligence-based power electronics with the goal of minimizing the attack surface and real-time intrusion detection will be discussed. Further, traditional fault-tolerance techniques work well for automatically surviving random, non-coordinated failures, but are limited against the coordinated failures of a cyber-attack. As such, this session will also discuss an approach for combining fault-tolerance techniques with cyber-attack surface diversification to make legacy real-time control systems resilient against classes of attacks.

Additionally, this special session also presents several industry-oriented topics covering the latest developments from the DER community in the areas of stakeholder education programs, standards development, and cybersecurity research. Updates will focus on the pre-standardization activities and requirements development in the SunSpec/Sandia DER Cybersecurity Workgroup, Rule 21, and IEEE 1547.3 working group. Participants will talk about the process they have used to bring together cybersecurity and DER communities to discuss issues related to the security of grid-edge devices. Lastly, anonymized results of more than a half dozen electric vehicle charger penetration tests, along with recommendations for vendors and network providers, will be shared.

Furthermore, a technology for increasing the resiliency of High Voltage Direct Current (HVDC) systems against cyberattacks will be presented. While some cyberattacks are detected and/or mitigated by proper cyber hygiene and conventional intrusion detection systems, more complex attacks could breach these electronic perimeter defenses. To address this security gap, an inner defense security layer within the HVDC station that works in unison with the existing HVDC real-time protection and control system will be presented. The developed algorithms defend against cyberattacks that aim to disrupt electric power service by spoofing spurious power system control commands, or altering a device configuration, even if commands and data are compliant with respect to syntax, protocol, and targeted device. An overview of the deployed cybersecurity functions will be provided which are closer to the HVDC control devices, beyond the station firewall and or security gateway.

**Alan Mantooth (S'83 - M'90 - SM'97 – F'09)** received the Ph.D. degree from the Georgia Institute of Technology in 1990. In 1998, he joined the faculty of the Department of Electrical Engineering at the University of Arkansas, Fayetteville, where he currently holds the rank of Distinguished Professor. He currently serves as Senior Past-President for the IEEE Power Electronics Society. He is a Fellow of IEEE. He helped establish the National Center for Reliable Electric Power Transmission (NCREPT) at the UA in 2005. He serves as the Executive Director for NCREPT and two of its centers of excellence: the NSF Industry/University Cooperative Research Center on GRid-connected Advanced Power Electronic Systems (GRAPES) and the Cybersecurity Center on Secure, Evolvable Energy Delivery Systems (SEEDS) funded by the U.S. Department of Energy. In 2015, he also helped to establish the UA's first NSF Engineering Research Center entitled Power Optimization for Electro-Thermal Systems (POETS) that focuses on high power density systems for transportation applications.

**Frede Blaabjerg (S'86–M'88–SM'97–F'03)** was with ABB-Scandia, Randers, Denmark, from 1987 to 1988. From 1988 to 1992, he got the Ph.D. degree in Electrical Engineering at Aalborg University in 1995. He became an Assistant Professor in 1992, an Associate Professor in 1996, and a Full Professor of power electronics and drives in 1998. From 2017 he became a Villum Investigator. He is honoris causa at University Politehnica Timisoara (UPT), Romania and Tallinn Technical University (TTU) in Estonia. He has published more than 600 journal papers in the fields of power electronics and its applications. He is the co-author of four monographs and editor of ten books in power electronics and its applications.

**Sudip K. Mazumder (S'97–M'01–SM'03–F'16)** received his Ph.D. degree from Virginia Tech in 2001. He is a Professor in the Department of Electrical and Computer Engineering at the University of Illinois, Chicago. He also serves as the President of NextWatt LLC since 2008. He was an IEEE Power Electronics Society (PELS) Distinguished Lecturer and the Chair for IEEE PELS Technical Committee on sustainable energy systems. He is the Editor-in-Chief at Large of IEEE Transactions on Power Electronics. He is a Fellow of the IEEE and a Fellow of the American Association for the Advancement of Science (AAAS).

**Thursday, October 14** **9:00AM-10:30AM | 10:30AM-12:00PM**

## SS2 | Energy Storage for Grid of The Future: Emerging Technologies, Applications and Trends

SESSION ORGANIZER:

**Dr. Tu Nguyen,** *Sandia National Laboratories*

As the electric grid is rapidly transforming to be more renewable and distributed, there are significant technical issues imposed on the grid due to the highly variable renewable generation (e.g., wind and solar). Furthermore, the increasing threats of natural disasters and cyber/physical attacks have created a significant need to improve the resilience and reliability of current grid infrastructure. Grid energy storage systems (ESSs) can be a flexible grid asset that can help mitigate those issues by providing multiple services to grid operators, utilities, and end-users.

Even though the application space for grid energy storage has grown rapidly over the last few years, there are multiple challenges that need to be addressed in order to further facilitate the incorporation of ESSs in the grid. Therefore, this special session gathers the experts in this field to provide an overview and updates on emerging challenges, recent technologies, applications, and trends in the energy

storage area. The information provided in this panel will benefit not only the industry but also other key stakeholders such as policymakers, project developers, and researchers in this area.

**Tu Nguyen** is a Senior Member of the Technical Staff at Sandia National Laboratories. He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE) and an editor of IEEE Transactions on Sustainable Energy. He is also a member of the publication committee and the R&D committee of IEEE Smart Grid. He received his Ph.D. degree in Electrical Engineering from Missouri University of Science and Technology in 2014 and his B.S degree in Power Systems from Hanoi University of Science and Technology in 2007. Before joining Sandia National Laboratories in September 2016, he worked as a Postdoctoral Research Associate at the University of Washington. In 2019, Tu Nguyen received the Outstanding Young Engineer Award from IEEE - Albuquerque Section.

**Wednesday, October 13** **8:30AM-10:00AM | 10:00AM-12:00PM**

## SS3 | "ENSURE" Meets the World: the German Strategic Initiative ENSURE Presents Its Energy Cosmos

SESSION ORGANIZERS:

**Prof. Dr. Marco Liserre,** *Christian-Albrechts-Universität zu Kiel (Kiel University)*

**Maximilian Dauer,** *Siemens AG*

In 2050, the German power generation will mostly rely on renewable sources such as wind and PV and will face a variety of new electrical consumers such as electric vehicles, which requires a restructuration of the entire energy grid. In the German strategic project "New ENergy grid StructURes for the German Energiewende – ENSURE" partners from industry, academia and civil society are developing a holistic solution for the future German energy grid called "Energy cosmos ENSURE" based on new technological concepts, such as sector coupling, innovative power electronics-based assets and profound ICT-integration and automatization, which fit in the actual social-economic framework. Along the way, a digital twin of the entire system is built for co-simulation and advanced testing purposes and selected pilot plants are installed in northern Germany to demonstrate the systematic interaction of the novel assets, control and protection strategies in the "Energy cosmos ENSURE". In the first part of the special section the challenges and conceptual solutions of ENSURE will be presented including: Power Electronic Transformer, MVDC grid coupling, dynamically meshed operation of hybrid distribution grids, and Co-Simulation as advanced testing facility for large grid infrastructure projects. The second part is dedicated to international strategic projects to expand the vision of future power grids to a worldwide perspective, including topics such as Hybrid AC/DC networks in the US, new HVDC technologies in China and soft-open points and DC links in the distribution network in UK.

**Marco Liserre (S'00-M'02-SM'07-F´13)** received the MSc and PhD degree in Electrical Engineering from the Bari Polytechnic, respectively in 1998 and 2002. He has been Associate Professor at Bari Polytechnic and from 2012 Professor in reliable power electronics at Aalborg University (Denmark). From 2013 he is Full Professor and he holds the Chair of Power Electronics at Kiel University (Germany). He has published 500 technical papers (1/3 of them in international peer-reviewed journals) and a book. These works have received more than 35000 citations. Marco Liserre is listed in ISI Thomson report "The world's most influential scientific minds" from 2014. He has been awarded with an ERC Consolidator Grant for the project "The Highly Efficient And Reliable smart Transformer (HEART), a new Heart for the Electric Distribution System".

He is member of IAS, PELS, PES and IES. He has been serving all these societies in different capacities. He has received the IES 2009 Early Career Award, the IES 2011 Anthony J. Hornfeck Service Award, the 2014 Dr. Bimal Bose Energy Systems Award, the 2011 Industrial Electronics Magazine best paper award and the Third Prize paper award by the Industrial Power Converter Committee at ECCE 2012, 2012, 2017 IEEE PELS Sustainable Energy Systems Technical Achievement Award and the 2018 IEEE-IES Mittelmann Achievement Award.

**Wednesday, October 13** **8:30AM-10:00AM | 10:00AM-12:00PM**

## SS4 | Power Electronic Technologies for Distributed Energy Resources (DERs)

SESSION ORGANIZERS:

**Liuchen Chang,** *University of New Brunswick*

**Sonny Yaosuo Xue,** *Oak Ridge National Laboratory*

**Hanh-Phuc Le,** *UC San Diego*

**Sudip Mazumder,** *University of Illinois Chicago*

**Minjie Chen,** *Princeton University*

**Yongheng Yang,** *Zhejing University*

**Gab-Su Seo,** *National Renewable Energy Laboratory*

**Xiaonan Lu,** *Temple University*

**Jin Wang,** *Ohio State University*

**Prasad Enjeti,** *Texas A&M University*

**Juan Balda,** *University of Arkansas*

**Xiongfei Wang,** *Aalborg University*

**Ke Ma,** *Shanghai Jiaotong University*

**Jose Fernando Jimenez Vargas,** *Los Andes University*

This special session will present a comprehensive overview of the state-of-the-art technologies of power electronics for distributed energy resources (DERs). The topics and their contents include:

*Introduction to Distributed Energy Resources:* DER definitions and values to electric grids, market drivers (including climate change, energy transformation, regulatory policies), world DER market growth in terms of the revenue and capacity, DER grid interconnection requirements and standards, DER grid interoperability requirements and standards, and evolving DER technology trends.

*Integrated Power Components and Subsystems:* Power semiconductor devices: their roles and types including SiC and GaN, photoconductive semiconductor switches based on wideband gap devices, power semiconductor device modules and reliability, passive components, storage technologies, power management, integrated power circuits, power-systems-on-chip, and packaging.

*Power Conversion for DERs:* Overview of the power electronics technologies and converter-level roadmaps for distributed energy resources, including the roles and requirements of power electronics for DER systems, and design and implementation of future DER systems including solar photovoltaic, wind energy, charging infrastructure, and grid-scale energy storage, with focus on power electronics technologies featuring high efficiency, high power density, and advanced functions that are needed to support the future grid.

*Integration and Control of DERs:* Summary of the recent developments in integration and control of DERs, covering the state-of-the-art DER technologies for grid integration and control including power system support functions from DERs, control of individual DERs including grid-forming inverter controls, stability of power systems with inverter-based resources, microgrids and networked microgrids, and protection with a high level of converters for distribution and transmission systems.

*Security, Protection and Resilience for DERs:* Cyber security at the device level and system level, protection (including solid-state protection), reliability, safety, grid system restoration, resiliency-oriented controls, and communication protocols.

*MV and HV Technologies for DERs:* medium-voltage (MV) and high-voltage (HV) power electronic interfaces for distributed energy resources, including the following main topics: energy storage systems (ESS), PV farms and hybrid PV-ESS, wind farms, solid-state transformers, DC networks, and fast chargers for electric vehicles.

*Testing and Validation:* Overview of grid emulation technologies including the hardware-in-the-loop testing methods, along with the challenges and prospects in the end.

**Liuchen Chang** joined the University of New Brunswick in 1992 and is a Professor Emeritus at UNB. He is a long-time volunteer for IEEE of over 28 years and is the President of the IEEE Power Electronics Society (2021-2022). He is a fellow of the Canadian Academy of Engineering. He has published more than 380 refereed papers in journals and conference proceedings. Dr. Chang has focused on research, development, demonstration and deployment of renewable energy based distributed energy systems and direct load control systems.

**Yaosuo Xue** received the B.Sc. degree in electrical engineering from East China Jiaotong University in 1991 and the M.Sc. degree in electrical engineering from the University of New Brunswick, Canada, in 2004. He also completed all his Ph.D. work but dissertation at the University of New Brunswick in 2008. From 1991 to 2000, he was an electrical engineer-in-charge in the China's Ministry of Railways and led traction power systems research and design of the first China's high-speed railway. In 2005-2006, he worked in Capstone Turbine Corporation as a Lead Power Electronics and Systems Engineer. He was a research scientist and R&D manager in Siemens Corporate Research from 2009 to 2015 and established Siemens Corporate Technology North American power electronics research program. Currently, he leads the Grid Components and Controls Research Group within the USA Department of Energy's Oak Ridge National Laboratory. His research interests include multilevel converters and smart inverter controls for renewable energy and utility applications. He is an Associate Editor or Editor of IEEE TPEL, IEEE JESTPE, and IEEE OAJPE. He served as Program Co-Chair for IEEE WiPDA 2015, IEEE PEDG 2013 and Vice-Chair for IEEE ECCE 2015, 2016, and 2020.

**Hanh-Phuc** Le is Assistant Professor of ECE at UC San Diego. He received the Ph.D. degree from UC Berkeley (2013), M.S. from KAIST, Korea (2006), and B.S. from HUST, Vietnam (2004). In 2012, he co-founded and served as the CTO at Lion Semiconductor until October 2015. He held R&D positions at Oracle, Intel, Rambus, JDA Tech in Korea and the VAST in Vietnam. His research interests center around DC-DC converters, miniaturized/on-die power conversions, large conversion ratios, smart power delivery and control for a wide range of applications. He has published three book chapters, over fifty journal and conference papers with one best paper award, and is an inventor with 18 U.S. patents (10 granted and 8 pending). He has served the IEEE as Associate Editor for the IEEE JESTPE, TPC Chair/co-chair for the PwrSoC event series, and IEEE CICC. Dr. Le is an IEEE Senior Member.

**Sudip K. Mazumder** is the Director of Laboratory for Energy and Switching-Electronics Systems (LESES) and a Professor in the Department of Electrical and Computer Engineering at the University of Illinois at Chicago (UIC). He has about 30 years of professional experience and 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 and a Fellow of AAAS and the EiC-at-Large for TPEL.

**Minjie Chen** is an Assistant Professor of Electrical and Computer Engineering and the Andlinger Center for Energy and the Environment at Princeton University where he leads the Princeton Power Electronics Research Lab. His research interests include high frequency, high-performance power electronics, power magnetics, and switched-capacitor-based power converters.

**Yongheng Yang** is a ZJU Professor at Zhejiang University, China. Before this, he was an Associate Professor at Aalborg University, Denmark, where he served as the Vice Program Leader of the Photovoltaic Systems. He was the Chair of the IEEE Denmark Section. His research is focused on advanced control of power electronics converters for grid applications and renewable energy integration. He is the secretary of the IEEE PELS TC5.

**Gab-Su Seo** received the Ph.D. degree in electrical engineering from the Seoul National University, Seoul, South Korea, in 2015. He is currently a Senior Engineer at the U.S. Department of Energy's National Renewable Energy Laboratory. At NREL, he currently leads R&D projects focused on the power electronics and power systems application for electric grids with increasing levels of inverter-based renewable generation. His current research interests include power electronics for renewable energy systems and microgrids, hybrid power conversion using wide bandgap semiconductors and switched capacitors, and power systems engineering for grid modernization including grid-forming inverter control for low or zero inertia grids to improve grid resilience and stability. Dr. Seo currently serves as an IEEE Roadmap Working Group Chair, IEEE International Technology Roadmap of Power Electronics for Distributed Energy Resources (ITRD)-WG3 Integration and Control of DER. He is an Associate Editor of IEEE Open Journal of Power Electronics, Associate Editor of Springer Journal of Power Electronics, and Editorial Board Member of Energies.

**Xiaonan Lu** received his B.E. and Ph.D. degrees in electrical engineering from Tsinghua University, Beijing, China, in 2008 and 2013, respectively. From September 2010 to August 2011, he was a guest Ph.D. student at the Department of Energy Technology, Aalborg University, Denmark. From October 2013 to December 2014, he was a Postdoc Research Associate at the Department of Electrical Engineering and Computer Science, University of Tennessee, Knoxville. From January 2015 to July 2018, he was with Argonne National Laboratory, first as a Postdoc Appointee and then as an Energy Systems Scientist. In July 2018, he joined the College of Engineering at Temple University as an Assistant Professor. His research interests include modeling and control of power electronic inverters, hybrid AC and DC microgrids, real-time hardware-in-the-loop simulation, etc. Dr. Lu is the Associate Editor of IEEE Transactions on Industrial Electronics, the Associate Editor of IEEE Transactions on Industry Applications, and the Editor of IEEE Transactions on Smart Grid. He serves as the Vice Chair of the Industrial Power Converters Committee (IPCC) in the IEEE Industry Applications Society (IAS). He is also the recipient of the 2020 Young Engineer of the Year Award in the IEEE Philadelphia Section.

**Jin Wang** received his Ph.D. from Michigan State University, East Lansing, in 2005. He worked at Ford for two years before he joined the Ohio State University in 2007, where he currently serves as a Full Professor. His research interests include wide bandgap power devices and their applications, high-voltage and high-power converter/inverters, integration of renewable energy sources, and electrification of transportation. Dr. Wang has over 200 peer-reviewed publications and 9 patents. Dr. Wang received the Nagamori Award in 2020, IEEE Power Electronics Society Richard M. Bass Young Engineer Award in 2011, and the National Science Foundation's CAREER Award in 2011. Dr. Wang is an IEEE Fellow and an active volunteer to IEEE PELS technical activities.

**Prasad N. Enjeti** received his B.E. degree from Osmania University, Hyderabad, India, in 1980, the M.Tech degree from Indian Institute of Technology, Kanpur, in 1982, and Ph.D. degree from Concordia University, Montreal, Canada, in 1988, all in Electrical Engineering. He has been a member of Texas A&M University faculty since 1988 and is widely acknowledged to be a distinguished teacher, scholar and researcher. He currently holds the Texas Instruments (TI) Professorship in Analog Engineering. His primary research interests are in advancing power electronic converter designs to address complex power management issues. His recent research focus has been on innovative power electronic solutions to interface renewable energy sources to electric utility. To date he has graduated 35 PhD and 53 MS students. Fourteen of his Ph.D. students currently serve as faculty in institutions at home and across the world while others have leadership positions in industry. He along with his students have over 100 journal publications and received numerous best paper awards from the IEEE. Among the many honors he has received are the IEEE Fellow Award in 2000, Texas A&M University Association of Former Students University Level teaching award in 2001 and the R. David Middlebrook Technical Achievement Award from the IEEE Power Electronics Society in 2012.

**Juan Carlos Balda** received his B.Sc. in Electrical Engineering from the Universidad Nacional del Sur (Bahía Blanca, Argentina) in 1979, and his Ph.D. degree in Electrical Engineering from the University of Natal (Durban, South Africa) in 1986. He was first employed as a researcher and a part-time lecturer at the University of Natal until July 1987. He spent two years as a visiting Assistant Professor at Clemson University, South Carolina. He has been at the University of Arkansas at Fayetteville since July 1989 where he is currently a University Professor, Department Head, associate director for applications of the National Center for Reliable Electric Power Transmission (NCREPT) and campus director for the NSF IUCRC Grid-connected Advanced Power Electronic Systems (GRAPES). His main research interests are Power Electronics, Electric Power Distribution Systems, Motor Drives and Electric Power Quality. He is a senior member of the IEEE, a member of the Power Electronics and Power & Energy Societies, and the honor societies Eta Kappa Nu and Tau Beta Pi. He is also the chair of the IEEE PELS TC5 committee and faculty advisor to the local chapter of the IEEE Power Electronics Society.

**Xiongfei Wang** is a Professor and Leader of Research Group on Electronic Power Grid (eGrid) in the Department of Energy Technology, Aalborg University, and the Visiting Professor at KTH Royal Institute of Technology, Sweden. His research interests include analytical modeling and control of grid-interactive converters, stability and power quality of power-electronic-based power systems, harmonic analysis and mitigation.

**Ke Ma** received the B.Sc. and M.Sc. degrees in electrical engineering from the Zhejiang University, China in 2007 and 2010 respectively. He received the Ph.D. degree from the Aalborg University, Denmark in 2013, where he became an Assistant Professor in 2014. In 2016 he joined the faculty of Shanghai Jiaotong University, China as a tenure-track Research Professor, and is now serving as the deputy director for Key Laboratory of Control of Power Transmission and Conversion, Ministry of Education, China. His current research interests include the power electronics and its reliability in the application of renewable energy, HVDC, and motor drive systems. He is now serving as Associate Editor for two IEEE Transaction journals, and Vice Chair for two IEEE Tecnical Committees. He was the receiver of "Excellent Young Wind Doctor Award 2014" by European Academy of Wind Energy, and several prized paper awards by IEEE.

**José Fernando Jimenez Vargas** received the degree in electrical engineering from the Universidad de los Andes (UNIANDES, Bogotá, Colombia) in 1979; the "Diplome d´Études Approfodie" in automatic control from the National School of Aeronautics and Space (Sup'aero, Toulouse, France) in 1983 and the Ph.D. in Industrial Systems from INSA Toulouse in 2000. He is an Associate Professor at the Department of Electrical and Electronics Engineering in UNIANDES and is an associate researcher at the Laboratory of Architecture and Analysis of Systems (LAAS-CNRS) in Toulouse. His main research activities are in Discrete Event Dynamical Systems and Design Automation of Embedded Systems. He has contributed to industrial applications in microgids and distributed power generation.

**Wednesday, October 13** **8:30AM-10:00AM | 10:00AM-12:00PM**

## SS5 | Wide-Bandgap Bidirectional Switches and the Applications They Enable

SESSION ORGANIZERS:

**Dr. Thomas M. Jahns,** *University of Wisconsin – Madison*

**Dr. Victor Veliadis,** *North Carolina State University*

Monolithic bidirectional switches hold the potential to trigger a revolution in the future of power electronics technology. Unfortunately, an impressive catalog of high-performance power converter topologies designed to use bidirectional switches has never achieved marketplace success for the lack of commercially available monolithic BD (M-BD) switch devices. No silicon-based M-BD switch technology has emerged that has successfully crossed the threshold into large-scale production. New wide-bandgap power device technology using GaN and SiC has opened intriguing avenues to WBG-based M-BD switches that hold much higher promise for overcoming the barriers to commercialization. Both lateral and vertical M-BD device topologies have been proposed using GaN and SiC that have resulted in prototype devices with ratings as high as 1400V and 100A. The purpose of this special session is to showcase promising state-of-the-art WBG-based M-BD switch technology in a manner that objectively evaluates both their strengths and technical challenges. This session also highlights some of the most promising applications for this prospective new generation of M-BD switches as well as the most likely power converter topologies that will take the fullest advantage of their availability. These application areas cover a wide spectrum extending from ac solid-state circuit breakers to static power converters to motor drives.

**Thomas M. Jahns (M'79-F'93-LF'19)** received the S.B., S.M. (1974), and Ph.D. (1978) degrees in electrical engineering from MIT, Cambridge, MA, USA. In 1998, he joined the Department of Electrical and Computer Engineering, University of Wisconsin-Madison, as a Grainger Professor of Power Electronics and Electric Machines, where he is currently the Director of the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC). Prior to joining UW-Madison, he worked at GE Corporate Research and Development (now GE Global Research Center), Niskayuna, NY, for 15 years. His current research interests include high-performance permanent-magnet synchronous machines, electric propulsion drives, and integrated motor drives. Dr. Jahns received the 2005 IEEE Nikola Tesla Technical Field Award and the IAS Outstanding Achievement Award in 2011. He is a Past President of PELS and served two years as Division II Director on the IEEE Board of Directors (2001-2002). He was elected as a member of the U.S. National Academy of Engineering in 2015.

**Victor Veliadis** received the B.S. degree from the National Technical University of Athens Greece in 1990, and the M.S. and Ph.D. degrees in electrical and computer engineering from Johns Hopkins University, Baltimore, MD, USA, in 1992 and 1995, respectively. He is the Chief Executive and CTO of PowerAmerica, which is a U.S Department of Energy WBG power electronics Manufacturing Institute. He manages an annual budget in excess of $30 million that he strategically allocates to over 35 industrial and University projects to accelerate WBG manufacturing, workforce development, job creation, and clean energy. He is also an ECE Professor at NCSU and an IEEE Fellow and IEEE EDS Distinguished Lecturer. He has 27 issued U.S. patents, 6 book chapters, and over 120 peer-reviewed technical publications. Prior to starting in academia and taking an executive position at Power America in 2016, he spent 21 years in the semiconductor industry where his work included design, fabrication, and testing of 1-12 kV SiC SITs, JFETs, MOSFETs, Thyristors, and JBS and PiN diodes, as well as financial and operations management of a commercial semiconductor fab.

**Tuesday, October 12** **2:00PM-2:30PM**

## SS6 | Energy Storage Systems: Applications, Control and Interfaces

SESSION ORGANIZER:

**Juan Carlos Balda, Professor,** *University of Arkansas*

Power systems are rapidly evolving from few large generating stations into many distributed generating stations ranging from several megawatts to few kilowatts. Higher penetrations of distributed generation are leading to system operating modes not experienced in traditional power systems, for example, intermittent distributed generation and bidirectional power flows. Energy storage systems making use of power electronic interfaces complement intermittent distributed generation and may also provide services like reducing peak demands, particularly in constrained distribution systems, and frequency regulation. Additionally, energy storage is the enabling technology for green transportation, including electric vehicles. Governments are enacting regulations to accelerate the deployment of these systems. This special session will focus on energy storage systems by bringing speakers from different points of view; in particular, government, electric utilities, manufacturers, and academia.

**Juan Carlos Balda** received his B.Sc. in Electrical Engineering from the Universidad Nacional del Sur (Bahía Blanca, Argentina) in 1979, and his Ph.D. degree in Electrical Engineering from the University of Natal (Durban, South Africa) in 1986. He was first employed as a researcher and a part-time lecturer at the University of Natal until July 1987. He spent two years as a visiting Assistant Professor at Clemson University, South Carolina. He has been at the University of Arkansas at Fayetteville since July 1989 where he is currently a University Professor, Department Head, associate director for applications of the National Center for Reliable Electric Power Transmission (NCREPT) and campus director for the NSF IUCRC Grid-connected Advanced Power Electronic Systems (GRAPES). His main research interests are Power Electronics, Electric Power Distribution Systems, Motor Drives and Electric Power Quality. He is a senior member of the IEEE, member of the Power Electronics and Power & Energy Societies, and the honor societies Eta Kappa Nu and Tau Beta Pi. He is also the chair of IEEE PELS TC5 committee and faculty advisor to the local chapter of the IEEE Power Electronics Society.

**Tuesday, October 12** **2:00PM-2:30PM**

## SS7 | Advanced Power Electronics Integration for Renewables

SESSION ORGANIZERS:

**John Seuss,** *United States (US) Department of Energy (DOE)*

**Suman Debnath,** *Oak Ridge National Laboratory (ORNL)*

As hybrid resources (like photovoltaic [PV]) and energy storage systems [ESS]) are integrated into the grid and the interconnection standards are upgraded, it is important to understand newer power electronic topologies that can be utilized to reliably integrate these resources like providing advanced grid services. With the increasing maturity shown by silicon carbide (SiC) devices and their corresponding adoption in certain sectors (like industrial drives), there is a need to explore the next-generation power electronics topologies that can utilize the SiC devices to integrate hybrid resources and provide fast/efficient grid services. In this talk, several ongoing research efforts will be discussed to discuss these newer integration approaches of SiC devices and the corresponding advanced control functionalities that they can introduce.

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

**Suman Debnath** received his bachelors and masters from Indian Institute of Technology Madras (IIT Madras) in 2010, and doctoral degree from Purdue University in 2015. He has since been working with Oak Ridge National Laboratory and is a research and development (R&D) staff over there. He has published over 40 publications and has been awarded several projects worth millions. His research interests include applied mathematics for simulation, modeling, and control of power electronics in various applications (including high-voltage direct current systems, wind, PV, high-power drives, among others).

**Thursday, October 14** **9:00AM-10:30AM**

## SS8 | Thermal Design and Control for High Reliability Power Electronics, Electrical Drives, and Batteries

SESSION ORGANIZERS:

**Prof. Marco Liserre,** *University of Kiel, Kiel, Germany*

**Prof. Rik W. De Doncker,** *RWTH Aachen University, Aachen, Germany*

Temperature has a major effect on both batteries and power electronics (PE) performance and reliability. The development of the electromobility sector and the spreading of PE throughout society (e-mobility, industry, grid, consumer electronics, etc.), together with the trend towards increasing power- and energy- densities, and the rise of PE-based critical applications (more electrical aircraft, grid applications, etc.), therefore puts the spotlight on thermal management and reliability issues. Consequently, limiting peak temperatures, temperature gradients, and thermal cycling of power devices and batteries gains great relevance.

Limiting thermal stress can be achieved by combining high performance cooling technics (jet impingements, phase-change-materials, etc.) and temperature- and reliability- oriented control algorithms (active thermal control, loss reduction strategies etc.). At design stage, achieving high power density call for the use of improved modelling technics for complex and multi-physic systems. Furthermore, lifetime estimation and condition monitoring play an important part in reliability assessment. To reach these targets, high performance temperature measurement, imaging systems, and estimators are required during design and for field monitoring.

The industrial and academic speakers involved in this special session will tackle these issues with both conceptual- and application- oriented presentations. Altogether, they cover a broad area of expertise, including reliability of PE and batteries, thermal-guided design & control strategies, cooling technics, temperature sensing, imaging, and estimation, electromobility, and PE systems.

**Marco Liserre (S'00-M'02-SM'07-F´13)** received the MSc and PhD degree in Electrical Engineering from the Bari Polytechnic, respectively in 1998 and 2002. He has been Associate Professor at Bari Polytechnic and from 2012 Professor in reliable power electronics at Aalborg University (Denmark). From 2013 he is Full Professor and he holds the Chair of Power Electronics at Kiel University (Germany). He has published 500 technical papers and a book. These works have received more than 40000 citations. Marco Liserre is listed in ISI Thomson report "The world's most influential scientific minds" from 2014. He has been awarded with a European Excellence Grant in 2013. He is leading a team of 20 Members cooperating with 20 industries and with an annual budget of 2 Million Euro.

He is member of IAS, PELS, PES and IES. He has been serving all these societies in different capacities. In PELS he is AdCom member (second mandate), Co-Editor of the IEEE Open Access Journal in Power Electronics, Associate Editor of TPEL and JESTPE, Guest Editor of Several Special Issues of JESTPE, Technical Committee Chairman of the new Committee on Electronic Power Grid Systems and Member of the IEEE Digital Committee. He has received 5 IEEE Society Awards, notable the 2014 Dr. Bimal Bose Energy Systems Award, the 2017 IEEE PELS Sustainable Energy Systems Technical Achievement Award and the 2018 IEEE-IES Mittelmann Achievement Award.

**Prof. Rik W. De Doncker (M'87 SM'99 F'01)** received his Ph.D. degree (summa cum laude) in electrical engineering from the Katholieke Universiteit Leuven, Leuven, Belgium in 1986. In 1987, he was appointed Visiting Associate Professor at the University of Wisconsin, Madison. In 1988, he joined the GE Corporate Research and Development Center, Schenectady, NY. In November 1994, he joined Silicon Power Corporation (formerly GE-SPCO) as Vice President Technology, developing world's first medium-voltage static transfer switch.

Since Oct. 1996, he is professor at RWTH Aachen University, Germany, where he leads the Institute for Power Electronics and Electrical Drives (ISEA). In Oct. 2006 he was appointed director of the E.ON Energy Research Center at RWTH Aachen University, where he also founded the Institute for Power Generation and Storage Systems (PGS). He is director of the RWTH CAMPUS Cluster Sustainable Energy and leads the German Federal Government BMBF Flexible Electrical Networks (FEN) Research CAMPUS. He has a doctor honoris causa degree of TU Riga, Latvia.

He has published over 600 technical papers and is holder of more than 70 patents. Dr. De Doncker is recipient of the IAS Outstanding Achievements Award and the IEEE Power Engineering Nari Hingorani Custom Power Award (2008). In 2010, he became member of the German National Platform for electro-mobility. He is the recipient of the 2013 Newell Power Electronics IEEE Technical Field Award, and the 2014 IEEE PELS Harry A. Owen Outstanding Service Award. In 2015 he was awarded Fellow status at RWTH University. In 2016 he became member of the German Academy of Science and Technology (ACATECH). 2017 he became Member of the International Advisory Board of French automotive research institute VEDECOM. In 2020 he was awarded the 2020 IEEE Medal in Power Engineering.

**Wednesday, October 13** **2:00PM-3:30PM**

## SS9 | Advances in SiC and GaN Grid Applications to Support EV and Renewable Energy

SESSION ORGANIZER:

**Dr. Victor Veliadis,** *Executive Director and CTO of PowerAmerica*

The power grid will soon need to accommodate a large EV charging infrastructure while at the same time incorporating more solar and wind energy sources. Panelists will address the following issues specific to medium voltage SiC technology in the context of grid capability:

- MV SiC MOSFET on-resistance, capacitance, and current ratings
- The design/modeling/fabrication of SiC Super junction (SJ) FETs and IGBTs
- Determine optimal SiC device for each grid application domain and device characteristics important to support the grid
- SiC SJ FETs and IGBTs in switching circuits
- Bipolar conduction induced defect generation is impacted by the higher current densities in SJ and IGBT devices

**Dr. Victor Veliadis** is Executive Director and CTO of PowerAmerica, which is a U.S. Department of Energy wide bandgap power electronics Manufacturing Innovation Institute. Dr. Veliadis manages a budget in excess of $30 million per year that he strategically allocates to over 35 industrial, University, and National-Laboratory projects, to catalyze WBG power electronics manufacturing, work-force development, job creation, and energy savings.

Dr. Veliadis has given over 60 invited presentations/tutorials, and keynotes at major conferences in India, Korea, China, Europe and the U.S. He is an IEEE Fellow and an IEEE EDS Distinguished Lecturer. Dr. Veliadis has 26 issued U.S. patents, 6 book chapters, and over 120 peer-reviewed technical publications to his credit. He is also Professor in Electrical and Computer Engineering at North Carolina State University. Dr. Veliadis received the Ph.D. degree in Electrical and Computer Engineering from Johns Hopkins University in 1995. Prior to taking an executive position at Power America in 2016, Dr. Veliadis spent 21 years in the semiconductor industry where his work included design, fabrication, and testing of 1-12 kV SiC SITs, JFETs, MOSFETs, Thyristors, and JBS and PiN diodes, as well as financial and operations management of a commercial foundry.

**Monday, October 11** **12:30PM-2:00PM**

## SS10 | Energy Access and Empower a Billion Lives: Technologies, Impact and Opportunities for PELS

SESSION ORGANIZERS:

**Deepak Divan,** *Professor, Georgia Institute of Technology*

**Jelena Popović,** *Associate Professor, Delft University of Technology*

**Issa Batarseh,** *Professor, University of Central Florida*

**Sanjib Kumar Panda,** *Associate Professor, National University of Singapore*

Ensuring universal, affordable, and sustainable energy access is one of the biggest societal challenges of our time. As of 2020, close to a billion people worldwide live without having access to electricity, and another two billion have unreliable access. The centralized electric grid is not the optimal choice for remote and rural applications, due to environmental impact, cost, mismatch to user needs and challenges around financial feasibility. Decentralized approaches, such as solar home systems and microgrids, have emerged as a response to shortcomings of the centralized grid approach, but affordability, scalability, interoperability, societal and technical sustainability remain as key challenges. Power electronic technology is one of the key enabling technologies for context-appropriate and sustainable energy access solutions. The IEEE Power Electronics Society (PELS) engaged with Energy Access through organizing a global challenge – Empower a Billion Lives (EBL-I), and by including Energy Access as a new and core topic in its long-range planning. Following on the success of the first EBL-I round, a strong expression of interest in the technologies underlying energy access, and a burgeoning need for decentralized power systems with more autonomous control, the Global Energy Access Forum and the Technical Committee – 12: Energy Access was formed by PELS to provide global technical leadership in this important area.

**Dr. Deepak Divan** is Professor, John E Pippin Chair, GRA Eminent Scholar and Director of the Center for Distributed Energy at the Georgia Institute of Technology in Atlanta, GA. His field of research is in the areas of power electronics, power systems, smart grids and distributed control of power systems. He works closely with utilities, industry and is actively involved in research, teaching, entrepreneurship and starting new ventures. Dr. Divan also serves as Founder and Chief Scientist at Varentec, in Santa Clara, CA, and was President and CTO from 2011-14, leading the company as it developed its suite of innovative distributed real-time grid control technologies. Varentec is funded by leading green-tech Venture Capital firm Khosla Ventures and renowned investor Bill Gates. Dr. Divan is an elected Member of the US National Academy of Engineering, member of the National Academies Board on Energy and Environmental Systems, a Fellow of the IEEE, past President of the IEEE Power Electronics Society, and is a recipient of the IEEE William E Newell Field Medal. He has 40 years of academic and industrial experience, 65 issued and pending patents, and over 400 refereed publications. He has founded or seeded several new ventures including Soft Switching Technologies, Innovolt, Varentec and Smart Wires, which together have raised >$160M in venture funding. He received his B. Tech from IIT Kanpur, and his MS and PhD degrees from the University of Calgary, Canada.

**Dr. Jelena Popović** received the Dipl. Ing. degree from the University of Belgrade, Serbia, and the Ph.D. degree from the Delft University of Technology, Delft, The Netherlands. From 2005 to 2011, she was with the European Center for Power Electronics (ECPE). From 2008 to 2017 she was with the Delft University of Technology as an Assistant Professor. In 2018 she co-founded a start-up in energy access, Klimop Energy. From October 2019, she joined the Power Electronics group of the University of Twente as a parttime Associate Professor. She has published more than 80 publications in scientific journals, magazines and conferences. She has co-authored strategic research agendas, technology roadmaps and white papers in the field of power electronics, energy efficiency, solid state lighting. Her recent interests are bottom-up solutions

**Dr. Issa Batarseh** is a Professor in the Department of Electrical and Computer Engineering at the University of Central Florida (UCF). He received the Ph.D., and M.S. in Electrical Engineering and the B.S. in Computer Engineering and Science from the University of Illinois at Chicago in 1983, '85 and '90, respectively. Dr. Batarseh's power electronics research focuses on the development of advanced systems for solar energy conversion to improve cost, power density, efficiency and performance. He is an inventor on 36 patents and author of more than 300 articles and 2 books. He has significant commercialization experience as a founder of two start-up companies involved solar energy conversion: Advanced Power Electronics Corp. (APECOR) and Petra Systems. He is also a fellow member in National Academy of Inventors (NAI), IEEE, and AAAS.

**Dr. Sanjib Kumar Panda** received B. Eng. Degree from the Sardar Vallabhbhai National Institute of Technology, South Gujarat University, India, in 1983, M.Tech. degree from the Indian Institute of Technology, Banaras Hindu University, Varanasi, India, in 1987, and the Ph.D. degree from the University of Cambridge, U.K., in 1991, all in electrical engineering. Since 1992, he has been holding a faculty position in the Department of Electrical and Computer Engineering, National University of Singapore and currently serving as an Associate Professor and Director of the Power & Energy Research Area. Dr. Panda has published more than 450 peer-reviewed research papers, co-authored one book and contributed to several book chapters, six patents and co-founders of three start-up companies. His research interests include sustainable energy technologies, condition and predictive maintenance for electrical infrastructures, net-zero and super-low energy buildings etc.

**Wednesday, October 13** **2:00PM-3:30PM**

## SS11 | Power Electronics Dominated Grids: Dynamic Modeling and Simulation for Reliable and Resilient Operation of Future Grids

SESSION ORGANIZERS:

**Suman Debnath,** *Oak Ridge National Laboratory (ORNL)*

**Kemal Celik,** *United States (US) Department of Energy (DOE)*

With increased penetration of power electronics based resources in the grid like photovoltaic (PV), energy storage systems (ESS), electric vehicle (EV) chargers, among others, there is a need to understand the impact on the reliability and resilient operation of future grids. Towards the same, next-generation tools and control methodologies are required for stable, reliable, and resilient operation of future grids. In this talk, the opportunities in future power grids with increased penetration of power electronics will be presented followed by the presentations on ongoing research activities in development of next-generation tools, models, and control functionalities.

**Suman Debnath** received his bachelors and masters from Indian Institute of Technology Madras (IIT Madras) in 2010, and doctoral degree from Purdue University in 2015. He has since been working with Oak Ridge National Laboratory and is a research and development (R&D) staff over there. He has published over 40 publications and has been awarded several projects worth millions. His research interests include applied mathematics for simulation, modeling, and control of power electronics in various applications (including high-voltage direct current systems, wind, PV, high-power drives, among others).

**Kemal Çelik** joined the Systems Integration group at Department of Energy/Solar Energy Technologies Office in 2015. He completed his master studies at Virgina Tech in 1991 and Ph.D. at Texas A&M in 1991. He worked at Pacific Gas and Electric for 8 years and at Nexant 18 years before joining SETO/SI group. Kemal has more than 25 years of professional experience working on a wide range of projects from analytical electric distribution and transmission network applications to web-based demand-side management applications, energy market solutions and distribution planning tools. He worked on electric utility control center applications as well as computer modeling, coding, and implementation of analytical algorithms for power transmission and distribution networks.

**Thursday, October 14** **10:30AM-12:00PM**

## SS12 | Advanced Design and Manufacturing Techniques for Electric Machines – Simulation and Test

SESSION ORGANIZER:

**Prof. David Lowther,** *Professor, McGill University*

The session is intended to provide a series of presentations highlighting the industrial needs and processes for electrical machine design and manufacture and recent university research which is targeted at addressing these needs. The topics covered will range from the design process, as illustrated by the V-cycle approach, and including the multi-physics performance of a proposed motor-drive system; the use of additive manufacturing technologies to enable the implementation of machine topologies which cannot be constructed using conventional, mostly subtractive, manufacturing techniques; and the use of state of the art machine learning techniques to enhance and assist in the design of novel electrical machine architectures. Finally, while "digital twin" technology is driving simulation to new levels and, hopefully, reducing the number of prototypes needed, the physical implementation must be tested to verify the performance of the real device and the issues involved in fast and accurate testing will be discussed.

**David Lowther** received a B.Sc. (Hons) degree in Electrical Engineering from King's College, London in 1970 and a Ph.D. in Electrical Engineering from Brighton Polytechnic in 1973. He was a Postdoctoral Research Assistant at Imperial College, London until 1979 working with C.J.Carpenter on the simulation and measurement of electromagnetic fields. In 1979, he moved to the Department of Electrical Engineering at McGill University and was promoted to the rank of Full Professor in 1986. He was Chair of the Department from 1998 to 2006. His research interests have centered on the simulation of low frequency electromagnetic devices and the computer implementation of the design process for such devices. In 1978, together with P.Silvester and E.Freeman, he founded of Infolytica Corporation, the first company with the specific goal of generating solutions to industrial level electromagnetic field problems on a personal computer. He has published over 300 papers in journals and conferences. He is currently the President of the International Compumag Society and is a Fellow of the Canadian Academy of Engineering, the Institute of Electrical and Electronic Engineers and the Institution of Engineering and Technology and a Technical Director with the Mechanical Analysis Division of Mentor Graphics, a Siemens Business.

**Thursday, October 14** **9:00AM-10:30AM**

## SS13 | Standard Development and Industry Engagement Update from IEEE Power Electronics Society

SESSION ORGANIZERS:

**Johan Enslin,** *Chair of PELSC, Clemson University*

**Matt Wilkowski,** *Vice chair of PELSC, EnaChip*

**Xu She,** *Secretary of PELCS, Carrier Corporation*

IEEE power electronics society (PELS) is the driving force behind numerous standard activities and international technology roadmap intiatives relating to power electronics. With the motivation of providing our community the latest update of the standard development within IEEE PELS as well as promoting better involvement especially from industry, this special session brings together the leading experts who are actively leading the development efforts of power electronics standards. The topics span from component (capacitor, magnetics, etc.) level development to system level integration (grid forming inverter, etc.).

**Dr. Johan H Enslin** is the Duke Energy Endowed Chaired Professor at Clemson University in North Charleston SC and Executive Director for the Energy Systems Program at the Zucker Family Graduate Education Center. He has combined a balanced industry and academic career with 40-year leadership experience in industry and academia throughout the USA, Europe and South Africa. Dr. Enslin's current research focusses mainly in the area of building a smarter, modern integrated AC & DC power grid with high penetration of converter-based generation. Among others he is evaluating the role and optimization of energy storage technologies in grid modernization initiatives, hybrid AC & DC power grids and Virtual Power Plants (VPPs). He is a registered Professional Engineer in South Africa, Fellow of the SAIEE and Fellow of the IEEE. He is currently serving as VP of Standards and AdCom member for the IEEE PELS Society.

**Matt Wilkowski** is the vice president of magnetics technology and product development for EnaChip. Matt has a MSEE from Lehigh University (1991) and a BEEE degree from Steven's Institute of technology (1979). Matty has been involved with the integration of magnetics into power delivery systems and devices for more than forty years. Matt is a past chairperson of the ETTC and IEC TC51. He is currently the chairperson of the ETTC working groups for Test for Magnetic Cores and Near Magnetic Field Characterization.

**Xu She** received the B.Sc. degree in electrical engineering, the B.A. degree in English, and the M.Sc. degree in electrical engineering from the Huazhong University of Science and Technology,Wuhan, China, in 2007 and 2009, respectively, and the Ph.D. degree in electrical engineering from North Carolina State University, Raleigh, NC, USA, in 2013. From 2013 to 2018, he was with GE Global Research center. He is now with Carrier Corporation. His research interests include emerging power electronics technologies, renewable energy systems, and microgrids. He has more than 70 papers and 30 patent families to his credit in these areas. Dr. She was the recipient a few pretigius awards from industry and IEEE, including the IEEE Industry Application Society Andrew W. Smith Outstanding Young Member Achievement Award in 2017 and GE Whitney Technical Achievement Award in 2018. He is the secretary of IEEE power electronics society standard committee.

**Thursday, October 14** **12:00PM-1:30PM**

## SS14 | Additive Manufacturing for Electric Machines

SESSION ORGANIZERS:

**Franco Leonardi,** *Ford Motor Company*

**Leyi Zhu,** *Ford Motor Company*

The special session will focus on what is currently available in terms of additive manufacturing solutions for electric machines, and also on what is coming in the near and far future.

**Franco Leonardi (M'96 – SM'19)** received the M.S. and the Ph.D degrees in electrical engineering from the Università degli Studi di Padova, Padova, Italy, in 1991 and 1995, respectively. From 1994 to 1996, he was a Research Associate at the University of Wisconsin-Madison, where his research focused on Doubly Salient PM machines. Since 1999, he has been with the Ford Research Laboratories, Ford Motor Company, Dearborn, MI, where he has been involved in the development of hybrid and electric vehicles. He is currently the supervisor of the Electric Machines and Power Electronics Research team. He has authored 28 US patents and 30+ international publications that received over 1800 citations.

**Leyi Zhu** is a Research Engineer at Research and Advanced Engineering, Ford Motor Company. His role includes the research and development of materials and processes for current and future electric machines. He received the B.S. degree in physics from Nanjing University, China, in 2002, and the Ph.D. degree in condensed matter physics from the Johns Hopkins University, USA, in 2010. Prior to joining Ford in 2012, he was a Postdoc Appointee at Argonne National Laboratory, USA, working on energy related materials. He has been granted 9 U.S. patents and has published more than 30 papers in premier journals.

**Wednesday, October 13** **2:00PM-3:30PM**

## SS15 | Future of Wide-Bandgap Devices SiC, GaN and Diamond and Their Emerging Applications in Power Electronics

SESSION ORGANIZER:

**Dr. Tanya Gachovska,** *Solantro Semiconductor Corp.*

The need for high-voltage devices operating at high frequencies and temperature is growing, especially for advanced power electronics. Si-based power devices has some limitations. They are not able to meet these requirements without connecting many devices in series and in parallel, using snubbers and expensive cooling systems. Thus, the market of Si power devices have started to decrease and wide band gap semiconductors have attracted considerable attention. Research into SiC, GaN, and diamond as materials for power devices has been carried out over the past two decades.

SiC, GaN and diamond have wide-bandgap energy resulting in higher breakdown strength for a given blocking voltage. Therfore, SiC, GaN and diamond defices have smaller drift layers or channel lengths as compared to Si devices. As a result, the storage of the minority carriers or the input and output capacitance and, therefore, the switching losses are reduced. This leads to an increase of the switching frequency high than 0.5 MHz, reducing power systems passive components size and cost. In the last 5 years, more companies manufacturing SiC and GaN have come to the market and new startup companies have arised. The prace of SiC and GaN devices have decrease draticaly and more application.

This special session will offer insights into the future and trends for SiC, GaN and diamond devices and their emerging applications in power electronics.

**Tanya Kirilova Gachovska** received her M.Eng., and Ph.D. degrees, all in Electrical Engineering, from the University of Ruse, Bulgaria, in 1995 and 2003. She earned her second Ph.D. Degree in Electrical Engineering (Power Electronics), at the University of Nebraska-Lincoln (UNL), Lincoln, USA in 2012. Her Ph.D. thesis was "Modeling of Power Semiconductor Devices". She worked as an Assistant Professor at the University of Ruse from 1999 to 2003. She conducted research from 2004 to 2006 and taught for a semester in 2006 at McGill University in Montréal. She worked as a Postdoctoral Research Scientist in the area of Pulsed Electric Fields at UNL from 2012 to 2013. During her Ph.D. studies at UNL, she taught various courses and labs, and continued a collaboration in Pulsed Electric Fields research with McGill University, University of Ruse, University of Djiali Liabes, Sidi Bel Abbes, Algeria and École Nationale Supérieure Agronomique, El Harrach, Algeria. She joined Solantro Semiconductor, Corp., Ottawa in 2013. Dr. Gachovska authored or coauthored more than 30 technical papers and conference presentations, two books, and two book chapters and holds a world patent in Pulsed Electric Fields. In 2019 Dr. Gachovska become a professional engineer of Ontario. She is the Chairs of IEEE-IAS Power Electronics Devices and Components Committee (PEDCC) and PELS Ottawa. She is PEDCC standard chair and chair for IEEE Standard for "Datasheet Parameters and Tests for Integrated Gate Drivers PEDCC". Dr. Gachovska is a senior IEEE member.

**Monday, October 11** **12:30PM-2:00PM**

## SS16 | Medium- and High-Voltage Gallium Nitride Power Devices

SESSION ORGANIZERS:

**Yuhao Zhang,** *Assistant Professor, Virginia Polytechnic Institute and State University*

**Dong Dong,** *Assistant Professor, Virginia Polytechnic Institute and State University*

After two decades of relentless development, GaN power high-electron-mobility transists (HEMTs) have been commercialized in voltage classes up to 650 V. In the last few years, strong momentum has emerged in industry and academia to extend the application space of GaN devices into the medium-voltage applications. Several industrial companies are developing 650-1200 V lateral GaN HEMTs, either discrete devices or modules. For example, VisIC is developing 800-1200 V GaN HEMT modules for EV applications. Meanwhile, 600-1200 V GaN transistors based on the vertical architecture are being manufactured on 100-mm GaN-on-GaN platform by several companies in the U. S. and Japan. For example, NexGen Power Systems has demonstrated the production of 650-1200 V vertical GaN JFETs with avalanche capabilities; Toyoda Gosei has demonstrated 1200 V vertical GaN MOSFETs with over 100 A current. In academia, high-voltage GaN devices have been demonstrated up to 10 kV recently. All these progresses suggest that the industrial medium-voltage GaN devices will be available to power electronics engineers very soon. This special session provides a timely overview of the state-of-the-art medium- and high-voltage GaN devices and an industry-centric discussion on the benefits and applications spaces of these coming devices.

**Dr. Yuhao Zhang** is an assistant professor at the Center for Power Electronics Systems (CPES), Virginia Tech. Before joining Virginia Tech, he worked as a postdoctoral associate at Massachusetts Institute of Techno logy (MIT) from 2017 to 2018. He received his Ph. D. and S. M., both in electrical engineering from MIT in 2017 and 2013, respectively. Prior to joining MIT, he received his B. S. in physics from Peking University in 2011 with the highest honor. His research interest is at the intersection of power electronics, micro/nano-electronic devices, and advanced semiconductor materials. He has published 70+ papers and holds 4 granted US patents. He is the receipient of 2021 National Science Foundation CAREER Award, 2019 IEEE George E. Smith Award, and 2017 MIT Microsystems Technology Laboratories Doctoral Dissertation Seminar Award. His research work has been covered by the media globally over 60 times.

**Dr. Dong Dong** received the B.S. degree from Tsinghua University, Beijing, China, in 2007, and the M.S. and Ph.D. degrees from Virginia Tech, Blacksburg, VA, USA, in 2009 and 2012, both in electrical engineering. From 2012 to 2018, he was with GE Global Resea rch Center (GRC), Niskayuna, NY, USA, as an Electrical Engineer. Since 2018, he has been an assistant professor with the Bradley Department of Electrical and Computer Engineering, Virginia Tech. He has published over 25 referred journal publications and more than 80 IEEE conference publications. He currently holds 28 granted US patents. He received two Prize Paper Awards from the IEEE TRANSACTIONS ON POWER ELECTRONICS and IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS. While at GE GRC, he received GE technology transition awards for solar inverter technology commercialization, gold-medallion patent innovation award, and multiple Above & Beyond Awards. The developed modular hybrid energy storage module (HESM) and modular stacked dc system technologies (MSDC) were reported by Naval Science and Technology "Future Force" and Journal of Petroleum Technology.

**Monday, October 11** **12:30PM-2:00PM**

## SS17 | Power Electronics-Based Technologies for grid Stabilization: Grid-Forming Inverters, Control of Inverter-Based Resources (IBRs), and Advanced Testing of IBRs

SESSION ORGANIZERS:

**Jing Wang,** *National Renewable Energy Laboratory*

**Andy Hoke,** *National Renewable Energy Laboratory*

Recently, power inverters with grid-forming capabilities have attracted broad interest because these inverters do not rely on external voltage sources to generate power, which pertains better stability and reliability than traditional grid-following DERs. Thus, research and development work on grid-forming inverter has extensively carried out in academia and industry. In this panel, we will first introduce the grid-forming inverter manufacture, ABB, to present their latest development in grid-forming battery inverters. Then, one researcher from Siemens will present their research work on performance comparison of different grid-forming control strategies. Apart from the grid-forming inverter related topic, power electronics control and hardware-in-the-loop is also covered. A senior researcher from NREL will demonstrate the operation of a transmission system (Maui in Hawaii) at and near 100% IBRs.

The professor from University of Alabama will share his latest research work on investigating many abnormal operations of IBRs and IBR plants and present an eye-opening discovery of the shortcomings of traditional *dq* control. In the end, the research engineer from NREL will present the advanced testing and validation of grid-connected inverters through power-hardware-in-the-loop simulation from small scale (single inverter) to large scale (100+) inverters. This panel will include power electronics-based technologies for grid stabilization, which will be informative, educational and insightful to learn the state-of-the-art and future directions of power electronics-based resources and systems.

**Jing Wang** is a Senior Research Engineer at the National Renewable Energy Laboratory. Her research focus on microgrid control and simulation, distributed energy resources (DERs) integration, and control of DER inverters. She has expertise in power and controller hardware-in-the-loop (HIL) evaluation of advanced distribution management system (ADMS), distributed energy resource management system (DERMS) and DERs for grid automation and control, and DER integration studies. She leads HIL evaluations for multiple projects that use ADMS testbed, and she is the key personnel at NREL developing ADMS testbed capabilities.

**Andy Hoke** is a Senior Engineer in the Power Systems Engineering Center at the National Renewable Energy Laboratory (NREL), where he has worked for the past ten years. He received the Ph.D. and M.S. degrees in Electrical, Computer, and Energy Engineering from the University of Colorado, Boulder, in 2016 and 2013, respectively. Dr. Hoke's expertise is in grid integration of power electronics and inverter-based renewable and distributed energy. His work includes advanced inverter controls design, hardware-in-the-loop testing and model development, and power systems modeling and simulation. He is the Chair of IEEE Standards 1547.1 and P2800.2, which contain the test and verification procedures to ensure DERs and inverter-based resources conform to the grid interconnection requirements of IEEE Standards 1547 and P2800, respectively. He is a registered professional engineer in the State of Colorado.

**Thursday, October 14** **10:30AM-12:00PM**

## SS18 | Additive Manufacturing for Electrical Machines and Power Converters Design

SESSION ORGANIZERS:

**Bulent Sarlioglu,** *Jean van Bladel Associate Professor, University of Wisconsin*

**Ayman El-Refaie,** *Werner Endowed Chair, Marquette University*

**Will Sixel,** *NASA Glenn Research Center in Cleveland*

In aircraft electrification, increasing the specific power and efficiency of electrical components is critical to make more electric/hybrid/electric propulsion physically and economically feasible. Additive manufacturing enables unique geometries that conventional manufacturing techniques cannot achieve. Additively-manufactured applications in electric machines and power electronics include permanent magnets, shafts, and housing designs, thermal management systems, integrated motor drives, additively manufactured coils, and highly optimized traditional designs. Additive manufacturing techniques also allow for increased design flexibility and co-design of related components and subcomponents, allowing for greater system-level performance optimization.

**Bulent Sarlioglu** is a Jean van Bladel Associate Professor with the University of Wisconsin-Madison and the Associate Director of the Wisconsin Electric Machines and Power Electronics Consortium. From 2000 to 2011, he was with Honeywell International Inc.'s Aerospace Division, Torrance, CA, USA, most recently as a Staff Systems Engineer.

His expertise includes electrical machines, drives, and power electronics, and he is the inventor or co-inventor of 20 U.S. patents and many international patents. In addition, he has more than 200 technical papers that are published in conference proceedings and journals. Dr. Sarlioglu was the recipient of the Honeywell's Outstanding Engineer Award in 2011, the NSF CAREER Award in 2016, and the 4th Grand Nagamori Award from Nagamori Foundation, Japan, in 2018.

Dr. Sarlioglu involves in many IEEE activities. He is currently one of the IEEE IAS distinguished lecturers. He serves as the Chair of the IAS Transportation Committee, Chair of PES Motor Subcommittee, one of the co-editors of the IEEE Electrification Magazine. Dr. Sarlioglu was the general Chair of ITEC 2018 and Technical Program Co-Chair for ECCE 2019, and special session chair in ECCE 2020. Dr. Sarlioglu is the recipient of IEEE PES Cyril Veinott Electromechanical Energy Award in 2021.

**Ayman M. El-Refaie** received the M.S. and Ph.D. degrees in electrical engineering from the University of Wisconsin Madison in 2002, and 2005 respectively. Between 2005 and 2016 he has been a principal engineer and a project leader at the Electrical Machines and Drives Lab at General Electric Global Research Center. Since January 2017 he joined Marquette University as the Werner Endowed Chair for Energy Sustainability. He has over 150 journal and conference publications. He has 48 issued US patents. His interests include electrical machines and drives with special focus on renewable energy and transportation electrification. He was the chair for the IEEE IAS Transportation Systems committee and an associate editor for the Electric Machines committee. He was a technical program chair for the IEEE 2011 Energy Conversion Conference and Exposition (ECCE). He was the general chair for ECCE 2014 and 2015 ECCE steering committee chair. He was the general chair of IEMDC 2019. He is the past chair of the IEEE IAS Industrial Power Conversion Systems Department and member of the IEEE Industry Applications Society executive board. He is an IEEE Fellow.

**William Sixel** received the B.S. degree in Engineering Mechanics in 2017 and the M.S. degree in Mechanical Engineering both from the University of Wisconsin-Madison in Madison, WI, USA. From 2017 to 2019, he worked as a research assistant with the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC). Mr. Sixel's master thesis was about 3-D additive manufactured heat exchanger for direct cooling of stator windings in electrical machines. His research interests include high power density electric machines for traction and electric aircraft applications and thermal management topologies for electric machines. He currently works as Aerospace Engineer at NASA Glenn Research Center in Cleveland, OH where he is responsible for thermal designs, prototype, and testing.

**Thursday, October 14** **12:00PM-1:30PM**

## SS19 | Experimental Verification versus Simulation

SESSION ORGANIZER:

**Peter Wung,** *Adjunct Professor, University of Dayton*

A fundamental issue that is inherent in engineering work regards how we can verify our theoretical calculations. For some applications, prototyping is relatively convenient, and the experimental results are preferred as proof that the theory is correct, but in the motor and drives world, while some prototyping is possible – most of those cases involve smaller machines and lower power drives as well as less demanding measurement accuracy; but electric machines and drives testing generally become more expensive and time consuming as the machine and drive rating increases, which require massive resources in terms of hardware, software, and manufacturing expertise to conduct valid experiments with confidence. In this era of powerful computational capabilities, many simulations tools have developed to the point where the accuracy of the simulation results have grown and the time it takes to do these simulation calculations have minimized over the years. Complex analysis of interconnected systems can also be done in a timelier manner, the development of HIL has made the simulation environment more flexible and more realistic. Ultimately, the question is whether the simulation results are trustworthy enough to be accepted as the proof of the proposed technical solution and design? Have the simulation software attained a level of accuracy which matches and/or surpasses the accuracy of experimental results?

Recently we have experienced a level of authors pushing back against the reviewers requiring experimental results to accompany simulation results as verification. The argument is that simulation results are as accurate as testing given the amount of naturally occurring uncertainties and errors which is naturally occurring in experimental testing.

This is a broad and complex topic involving a vast number of areas. Some initial assumptions must be made to limit the amount of issues which may impact the discussion and pare the discussion down to a manageable degree.

Even though this discussion is universally applicable to all areas of energy conversion engineering, we want to limit the present discussion to the motor and drives milieu. Simulations are de rigueur in certain industries, like in the power systems world, mainly due to the scale of the systems, the coupling effects between the components in the systems, and the economics and feasibility of testing; while other industries will happily test every product and prototype because manufacturing and testing prototypes are relatively straightforward and inexpensive. The motors and drives industry reside somewhere in the middle. Since the economics of manufacturing prototypes and creating a laboratory environment which meets the standards of experimental accuracy can be increasing daunting as the motor and drives increases in power rating – in the instance where the larger horsepower machines and special duty machines, it is almost impossible to experimentally test the design concept realistically, so most of the intermediate verification of designs or theory are indeed done with simulation. There is a grey area which exists as we move up the range of machine ratings, one useful result for this discussion is to decide on the tradeoff between the comparison of simulation and experimental accuracy and the cost of prototyping and testing.

**Prof. Wung** is an adjunct professor at the University of Dayton, specializing in the fields of Electrical Energy, Renewable Energy, Power Systems, and Electric Machines and Drives. He is the Chair of the IEEE Smart Grid Program and the Educator-In-Chief of the IEEE Smart Grid Academy.

Prof. Wung has over 25 years of industry experience in the electric motor and drives industry. Specializing in the areas of electric motor analysis, design, and manufacturing for GE Aviation, Regal Beloit Corporation EPC, AO Smith Electrical Products Company, Tecumseh Products Research Laboratory, Emerson Motor Company, and TECO-Westinghouse Motor Company.

He was awarded his PhD in Electrical Engineering from the Georgia Institute of Technology, Master's in Electrical Engineering from the Georgia Institute of Technology, and Bachelor of Science in Electrical Engineering from the University of Illinois Urbana-Champaign.

He is a Senior member of the IEEE.

**Tuesday, October 12** **2:00PM-2:30PM**

## SS20 | PV Inverter Reliability: Industry Status, Technical Gap, and Future Needs

SESSION ORGANIZERS:

**Zheyu Zhang,** *Assistant Professor, Clemson University*

**Ramanathan Thiagarajan,** *National Renewable Energy Laboratory*

Motivated by the fact that field data from PV power plant operators show that power electronics converter contributes most to operation and maintenance (O&M) events, responsible for between 43% and 70% of the service calls, it is essential to initialize a conversation focusing on the PV inverter reliability with a wide range of stakeholders' participation. This could benefit the research community to better understand the industry status, technical gap, and future needs. In this panel, the audience will hear diverse opinions shared by five distinguished panelists from PV power plant operators and PV inverter manufacturers to U.S. DOE Solar Energy Technologies Office and National Renewable Energy Laboratory, and their visions to improve PV inverter reliability in the field. This panel will include the effects of PV inverter reliability on the overall energy yield of PV Power plants from a PV plant operator. This will be followed by presentations on the effects of PV inverter design on inverter reliability by two leading PV inverter manufacturers. Following this, speakers from DOE and NREL will describe the past and current efforts on inverter reliability and standards development work performed within the DOE space.

**Dr. Zheyu Zhang** received the B.S. and M.S. degrees from Huazhong University of Science and Technology, Wuhan, China, and the Ph.D. degree from The University of Tennessee, Knoxville, TN, in 2008, 2011, and 2015, respectively, all in electrical engineering. He is the Warren H. Owen – Duke Energy Assistant Professor at Clemson University. He was a Research Assistant Professor in the Department of Electrical Engineering and Computer Science at the University of Tennessee, Knoxville from 2015 to 2018. Afterward, he joined General Electric Research as the Lead Power Electronics Engineer at Niskayuna, NY, USA from 2018 to 2019. He has published over 100 papers in the most prestigious journals and conference proceedings, filed over 10 patent applications, authored one book, and presented ten IEEE tutorial seminars and webinars. His research interests include wide band-gap-based power electronics characterization, reliability, and applications for electrified transportation, renewables, and energy storage systems. Dr. Zhang is currently the Standard Vice-Chair of IEEE IAS Power Electronics Devices and Components Committee, Associate Editor for IEEE Transactions on Power Electronics and IEEE Transactions on Industry Applications. He was the recipient of two prize paper awards from the IEEE IAS and IEEE PELS. He is a senior member of IEEE.

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

**Thursday, October 14** **10:30AM-12:00PM**

## SS21 | P2964 IEEE Standard for Datasheet Parameters and Tests for Integrated Gate Drivers

SESSION ORGANIZER:

**Dr. Tanya Gachovska,** *Solantro Semiconductor Corp.*

Power electronics applications employ power switches. Every switch requires a gate driver, a power amplifier that receives a low-power input from a controller and produces a high-current driving output for the gate of high-power switches such as an IGBT, MOSFET, JFET, or HEMT. Some gate drivers have protection features such as fast short-circuit protection (e.g. DESAT), active Miller clamp, shoot-through protection, shutdown, and overcurrent protection, which make them well-suited for both silicon and wide-bandgap power devices.

However, it is difficult to compare the IC gate drivers using their datasheet parameters. Every company names the drivers' pins and parameters with different approaches. The parameters are tested at different conditions and methodology or in most of the cases the conditions and the methodology are not given. Only some companies give the selected test circuits. IEEE-IAS-PEDCC has initiated a working group for a standard to provide datasheet parameters and tests for integrated gate drivers, which include non-isolated gate drive, level-shifted gate drive, and isolated gate drive. The standard scope includes terminology, mnemonic, and pins' description; parameters and definitions; and test methods and conditions to obtain the parameters. The special session will include an update on the working group.

**Tanya Kirilova Gachovska** received her M.Eng., and Ph.D. degrees, all in Electrical Engineering, from the University of Ruse, Bulgaria, in 1995 and 2003. She earned her second Ph.D. Degree in Electrical Engineering (Power Electronics), at the University of Nebraska-Lincoln (UNL), Lincoln, USA in 2012. Her Ph.D. thesis was "Modeling of Power Semiconductor Devices". She worked as an Assistant Professor at the University of Ruse from 1999 to 2003. She conducted research from 2004 to 2006 and taught for a semester in 2006 at McGill University in Montréal. She worked as a Postdoctoral Research Scientist in the area of Pulsed Electric Fields at UNL from 2012 to 2013. During her Ph.D. studies at UNL, she taught various courses and labs, and continued a collaboration in Pulsed Electric Fields research with McGill University, University of Ruse, University of Djiali Liabes, Sidi Bel Abbes, Algeria and École Nationale Supérieure Agronomique, El Harrach, Algeria. She joined Solantro Semiconductor, Corp., Ottawa in 2013. Dr. Gachovska authored or coauthored more than 30 technical papers and conference presentations, two books, and two book chapters and holds a world patent in Pulsed Electric Fields. In 2019 Dr. Gachovska become a professional engineer of Ontario. She is the Chairs of IEEE-IAS Power Electronics Devices and Components Committee (PEDCC) and PELS Ottawa. She is PEDCC standard chair and chair for IEEE Standard for "Datasheet Parameters and Tests for Integrated Gate Drivers PEDCC". Dr. Gachovska is a senior IEEE member.

**Wednesday, October 13** **2:00PM-3:30PM**

## SS22 | Grid Integration of Inverter-Based Distributed Energy Resources: Operation, Planning, and Guidelines

SESSION ORGANIZERS:

**Dr. Jianzhe Liu,** *Argonne National Laboratory (ANL)*

**Dr. Kun Zhu,** *Midcontinent Independent System Operator (MISO)*

**Dr. Jens C. Boemer,** *Electric Power Research Institute (EPRI)*

**Dr. Reza Ghaemi,** *General Electric Research (GER)*

**Dr. Xuan Wu,** *American Electric Power (AEP)*

The US power system will be undertaking an monumental transformation as it moves forward to being 100% clean energy powered by 2035. In the meantime, the extreme weather events and increasingly stressed loading conditions have put grid stability, reliability, and resilience at risk. The growing power electronics intensive inverter-based resources (IBRs) have a promising potential in contributing to the clean energy transformation while improving system performance. Challenges for IBRs grid integration inlcude: 1) how to design stability guaranteed control for the power electronics interfaced resources that usually have low inertia and high stochasticity; 2) the grid planning issue of IBR could be significantly different from the conventional ones; 3) what the industrial guidelines for IBRs integration would be in the future as they have already undertaken significant changes; 4) how we should control a large-scale fleet of IBRs as the problem is high-dimensional and computationally challenging; and 5) how we should optimize the location of energy storage systems given their critical role in IBR's grid integration and considering the numerous choice of location and capacity. This special session will provide useful industry insights into all the aforementioned issues.

**Dr. Jianzhe Liu** received the B.E. degree in electrical engineering from Huazhong University of Science and Technology, China, in 2012, and the Ph.D. degree in electrical and computer engineering from The Ohio State University, US, in 2017. Dr. Liu was a visiting scholar at Aalborg University, Denmark, in 2017. He is currently an Energy Systems Scientist at Argonne National Laboratory. His research interests include robust control and optimization for electric power systems. He is a chair of the Techncial Program Committee of 2021 IEEE 12th International Symposium on Power Electronics for Distributed Generation Systems (PEDG 2021).

**Dr. Kun Zhu** holds a Ph.D. in electrical engineering from Iowa State University. He has 20 years' experience in the power industry, including 17 years at MISO, an independent, not-for-profit organization that delivers safe, cost-effective electric power across 15 U.S. states and the Canadian province of Manitoba.

**Dr. Jens C. Boemer** received the Diploma degree in electrical engineering from the Technical University of Dortmund, Dortmund, Germany, in 2005, and the Ph.D. degree from the Delft University of Technology, Delft, the Netherlands, in 2016. He is currently a Principal Technical Leader with the Department of Grid Operations and Planning, Modeling and Simulation, Electric Power Research Institute, Palo Alto, CA, USA. His field of interest includes the grid integration of renewable energy resources with the focus on power system stability.

**Dr. Reza Ghaemi** received the Ph.D. degree in electrical engineering and the M.S. degree in mathematics from University of Michigan in 2010 and 2009 respectively. He was a visiting scholor at ETH in 2008. From 2010 to 2012 he was a post-doctoral associate in the Mechanical Engineering department at MIT, researching supervisory control of order-preserving systems and stochastic analysis of biological systems. He is presently a Senior Control Systems Engineer and project leader in the Controls and Optimization organization at GE Research. He has developed and led development of advanced control algorithms, real-time optimization engines, real-time estimation for different GE businesses as well as external programs. He has done research and published both in theory and practice in the area of fast model predictive control, robust model predictive control, supervisory control, distributed optimal control of the power grid, stochastic analysis of finite and infinite dimensional linear systems, advanced building control, control of power electronics systems, and flight path optimization systems. Dr. Ghaemi has received best paper in session awards at the IEEE ACC and CDC control conferences. He served as the chair of GE Controls Symposium in 2015 and 2016.

**Dr. Xuan Wu** received the M.S. degree from Arizona State University, Tempe, AZ, in 2013, and the Ph.D. degree from The Ohio State University, Columbus, OH, in 2018, both in electrical engineering field. Currently, he is a Principal Engineer at American Electric Power (AEP). His research interests include power system operation, planning, security & resilience, engineering and equipment. Xuan received AEP Key Contributor Awards in 2016 and 2021, IEEE PES Columbus Chapter Outstanding Engineer Award in 2017, and IEEE Transactions on Power Systems Best Paper Awards in 2020 and 2021. Xuan has published over 25 journal and conference papers and contributed to a number of AEP and IEEE standards. He is currently an Editor of IEEE Transactions on Power Delivery, an Editorial Board Member of International Transactions on Electrical Energy Systems, and a Guest Editor of Jounal of Mordern Power Systems and Clean Energy. Dr. Wu is the Representative of IEEE PES Region 2, an IEEE Senior Member, and a Registered Professional Engineer licensed in Ohio.

**Thursday, October 14** **9:00AM-10:30AM**

## SS23 | EMI and Insulation Related Challenges and Solutions for WBG -based Power Electronic Systems

SESSION ORGANIZERS:

**Bulent Sarlioglu,** *Associate Professor, University of Wisconsin*

**Jin Wang, Professor,** *Ohio State University*

Wide bandgap device-based power converters are expected to bring significant efficiency and power density improvements for a wide range of applications. Through the effort from both industry and academia, many circuit implementation and system-level related challenges for implementing WBG devices have been solved. But EMI and insulation degradation are still two significant concerns because of the high dv/dt and di/dt switching of WBG devices. Thus, the organizers of this proposed special session has invited speakers from NASA, industry and academia to present details of EMI and insulation related challenges and solutions.

**Bulent Sarlioglu** is a Jean van Bladel Associate Professor with the University of Wisconsin-Madison and the Associate Director of the Wisconsin Electric Machines and Power Electronics Consortium. From 2000 to 2011, he was with Honeywell International Inc.'s Aerospace Division, Torrance, CA, USA, most recently as a Staff Systems Engineer.

His expertise includes electrical machines, drives, and power electronics, and he is the inventor or co-inventor of 20 U.S. patents and many international patents. He has more than 200 technical papers that are published in conference proceedings and journals. Dr. Sarlioglu was the recipient of the Honeywell's Outstanding Engineer Award in 2011, the NSF CAREER Award in 2016, and the 4th Grand Nagamori Award from Nagamori Foundation, Japan, in 2018.

Dr. Sarlioglu involves in many IEEE activities. He is currently one of the IEEE IAS distinguished lecturers. He serves as the Chair of the IAS Transportation Committee, Chair of PES Motor Subcommittee, one of the co-editors of the IEEE Electrification Magazine. Dr. Sarlioglu was the general Chair of ITEC 2018 and Technical Program Co-Chair for ECCE 2019 and special session chair in ECCE 2020. Dr. Sarlioglu is the recipient of IEEE PES Cyril Veinott Electromechanical Energy Award in 2021.

**Jin Wang** (IEEE Fellow) received his Ph.D. degree from the Michigan State University in 2005. He worked at Ford for two years before joined the Ohio State University (OSU) in 2007 as an Assistant Professor. He became a Full Professor at OSU in 2017. His current research interests include wide bandgap power device based high-voltage and high-power converters, renewable energy integration, and transportation electrification. Dr. Wang has over 200 journal and conference papers and 9 patents.

Dr. Wang received the PELS Richard M. Bass Young Engineer Award in 2011, the National Science Foundation's CAREER Award in 2011, and the Nagamori Award in 2020.

Dr. Wang currently serves as the Chair for the Technical Committee on Aerospace Power (TC11). Before that, he had served as Chair for the Technical Committee on Emerging Technologies (2018~2020). Dr. Wang initiated the IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA) and served as the General Chair for the inaugural workshop in 2013 and the Steering Committee chair in 2014.

**Tuesday, October 12** **2:00PM-2:30PM**

## SS24 | Booming the Blue Economy: A New Era for Wave and Hydrokinetic Energy

SESSION ORGANIZERS:

**Dr. Yue Cao,** *Assistant Professor, Oregon State University*

**Dr. Jing Sun,** *Michael G. Parsons Collegiate Professor, Univ. of Michigan – Ann Arbor*

**Dr. Ted Brekken,** *Professor, Oregon State University; Co-Director, Pacific Marine Energy Center (PMEC)*

The Pacific Northwest (including Oregon, Washington, Alaska, and British Columbia-Vancouver area), among other global coastal regions, has access to abundant renewable energy embedded in ocean and river. The energy, known in either a wave form (vertical motion) or a current form (horizontal motion), still has limited power generation capacity to local grids due to several challenges, especially at the core of mechanical to electrical energy conversion. In 2019, the US Department of Energy (DOE) launched the Powering the Blue Economy initiative to explore the billions of dollars worth of such hydro energy potential alongside the coastline and riverine communities. This decade marks a new era for research and development to bring the highest efficiency, highest reliability, and lowest cost for such blue energy usage, enabling a wide range of adoption. In this session, four industry and one government panelists and three academia organizers will present and discuss the technology needs, innovations, and demonstrations of converter-level design, interdisciplinary control co-design, and system integration to the microgrid/grid connection. The panel organizers and panelists especially represent recently funded projects by the DOE ARPA-E SHARKS program and several DOE Water Power Technology Office initiatives.

**Dr. Yue Cao** is an Assistant Professor in Energy Systems Group at Oregon State University (OSU). He received the M.S. and Ph.D. degrees in Electrical Engineering from the University of Illinois at Urbana–Champaign (UIUC) in 2013 and 2017, respectively. He received the B.S. (Hons.) degree in Electrical Engineering with a second major in Mathematics from the University of Tennessee, Knoxville in 2011. Before joining OSU, he was a research scientist at Amazon Prime Air in Seattle, WA. He has been a power electronics engineer intern with Apple Special Projects Group, Halliburton Company, Flanders Electric, and Oak Ridge National Laboratory. His research interests include power electronics, motor drives, and energy storage with applications in renewable energy integration and transportation electrification. Dr. Cao is the Tutorials Chair of ECCE 2021 and the Special Sessions Chair of ECCE 2022. He is a board member and Award Chair of IEEE Power Electronics Society (PELS) TC11 Aerospace Power. He is currently an associate editor of IEEE Transactions on Transportation Electrification. He is a co-PI for DOE ARPA-E SHARKS hydrokinetic energy, and a co-PI for DOE WPTO wave energy.

**Dr. Jing Sun** is Michael G. Parsons Collegiate Professor of the Naval Architecture and Marine Engineering Department at the University of Michigan. She received her Ph.D. degree from the University of Southern California in 1989, and her B.S. and M.S. degrees from the University of Science and Technology of China. In 1989-1993, she was an assistant professor in the Electrical and Computer Engineering Department, Wayne State University. She joined Ford Research Laboratory in 1993 where she worked in the Powertrain Control Systems Department. After spending almost 10 years in industry, she came back to academia and joined the faculty of the College of Engineering at the University of Michigan in 2003. Her research interests include modeling, control, and optimization of dynamic systems, with applications to marine and automotive systems. Her current research focuses on real-time optimization and decision making for energy and transportation systems. She holds 42 US patents and has published over 300 peer reviewed journal and conference papers. She has co-authored a textbook on Robust Adaptive Control. She is a Fellow of National Academy of Inventors, IEEE, IFAC, and the Society of Naval Architects and Marine Engineers. She is a recipient of the 2003 IEEE Control System Technology Award. She is the Lead-PI for DOE ARPA-E SHARKS hydrokinetic energy.

**Ted K. A. Brekken** is a Professor in Energy Systems at Oregon State University. He received his B.S., M.S., and Ph.D. from the University of Minnesota in 1999, 2002, and 2005, respectively. He studied wind turbine control at the Norwegian University of Science and Technology in Trondheim, Norway in 2004-2005 on a Fulbright scholarship. His research interests include control and modeling of renewable energy systems and electrical system resilience. He is Director of the Wallace Energy Systems and Renewables Facility (WESRF). He has received the NSF CAREER award, the IEEE Power and Energy Outstanding Young Engineer award, and numerous teaching awards.

**Monday, October 11** **12:30PM-2:00PM**

## SS25 | Power Electronics Enabled Power System with High Penetration of Renewables

SESSION ORGANIZERS:

**Dr. Rui Yang,** *Senior Research Engineer, National Renewable Energy Laboratory (NREL)*

**Dr. Mahshid Amirabadi,** *Assistant Professor, Northeastern University*

The recent advancements in power electronics, solid-state technologies and artificial intelligence are reshaping the traditional view of power distribution systems. The number of power inverters and converters increases significantly due to the high penetration of renewable energy sources and energy storage devices. While much progress has been made in advancing power grids and power electronics technologies, less attention has been paid to bridging the gap between these two traditionally disjoint areas. This session will cover a broad range of contents in the area of power electronics enabled power systems, to address topics such as the impacts of high penetration of renewables and power converters to the power grid and electricity market.

**Dr. Rui Yang (M'15)** received the B.E. degree in electrical engineering from Tsinghua University, Beijing, China, in 2009, and the Ph.D. degree in electrical and computer engineering from Carnegie Mellon University, Pittsburgh, PA, USA, in 2014. She is currently a Senior Research Engineer with the Power Systems Engineering Center, National Renewable Energy Laboratory, Golden, CO, USA. Her research interests include advanced data analytics, machine learning, and optimization for power systems applications.

**Dr. Mahshid Amirabadi (S'05–M'13–SM'21)** received the B.S. degree in electrical engineering from Shahid Beheshti University, Tehran, Iran, in 2002, the M.S. degree in electrical engineering from the University of Tehran, Tehran, in 2006, and the Ph.D. degree in electrical engineering from Texas A&M University, College Station, TX, USA, in 2013.

She joined the University of Illinois at Chicago, Chicago, IL, USA, in 2013 as an Assistant Professor. Since August 2015, she has been with Northeastern University, Boston, MA, USA, where she is currently an Associate Professor. Her main research interests and experience include universal power converters, renewable energy systems, variable speed drives, and wireless power transfer systems.

Dr. Amirabadi was the recipient of the National Science Foundation CAREER Award in 2021. She currently serves as an Associate Editor for the IEEE Transactions on Power Electronics and IEEE Journal of Emerging and Selected Topics in Power Electronics.

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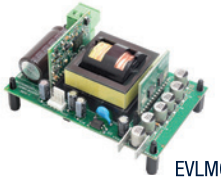

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# Tutorials

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**Sunday, October 10**

## 9AM1 | Photovoltaic Systems – From Basics to Advanced Grid Supportive Control

INSTRUCTORS: **Yongheng Yang**
*Zhejiang University, China*

Photovoltaic (PV) is one of the renewable favorites with a fast-growing rate, and much more are expected in the future. However, the massive installation of grid-connected PV systems creates many challenges to the grid. Many attempts have thus been made and being explored to better integrate PV systems as grid-friendly systems, which not only minimize the impact on the grid but also offer smart controllability and flexible manageability to enhance the grid performance. To master and then further advance the PV technology, we should understand the basics of PV systems like how the power conversion works, what the technological bottlenecks are, and what is the potential impact for largescale adoption of power electronic-based PV systems? And, how do we address the increasing issues outlined, e.g., by grid codes and standards, IEEE Std. 1547-2018, through advanced control strategies? The tutorial is proposed, and it is dedicated to tackling the technological challenges of nondeterministic power generation in grid-connected PV systems. It provides a step-by-step design of grid-friendly PV systems including the PV modules and power converters, and then a comprehensive understanding of the basics of PV systems. The focus is to innovate and improve the operability by means of advanced control to create more sustainable, grid-friendly, and reliable PV systems that comply with grid regulations and contribute to reducing the cost of energy. This enables the grid-supportive operation of PV systems, e.g., inertia emulation, to improve the grid performance. The tutorial is intended for intermediate and advanced audiences in the field of power electronics, engineers, and researchers, who are looking for advanced control solutions to power converters, especially focused on PV conversion systems for distributed generation. Researchers and engineers who seek for the basic knowledge for the PV technology are welcomed.

## 9AM2 | Pulse-Width-Modulation: with Freedom to Optimize EMI

INSTRUCTORS: **Dong Jiang[1], Zicheng Liu[1], Qiao Li[2]**
*[1]Huazhong University of Science and Technology, China; [2]Hunan University, China*

This tutorial focuses on studying of electromagnetic interference (EMI) reduction oriented advanced pulse-widthmodulation (PWM) technologies. EMI is a serious threat to the reliability and operation of the power electronics converters as motor drives. PWM is one of the most important factor for EMI in power electronics converters. Advanced PWM methods can be developed with freedom to optimize EMI and other parameters. In this tutorial, series work of advanced PWM which used freedom to optimize performance will be presented. The tutorial begins with the introduction of EMI problems and PWM technologies in power electronics converters. Then, PWM's impact on the converter performance is discussed for power losses, current ripple and EMI. With current ripple as the control target, the prediction model is studied as the basis for PWM. On the basis of the prediction model, variable switching frequency PWM (VSFPWM) is proposed. This method can improve the EMI and power losses together with control of current ripple or other related parameters. For the general issues of VSFPWM, including the impact on harmonics and feedback control will also be illustrated. For common-mode (CM) EMI issue, this tutorial is with special care. PWM can help to reduce the CM voltage of regular two-level converter, but cannot eliminate it theoretically. For three-level converter, zero CM PWM is possible but with many penalties. A novel zero-CM PWM method for paralleled converters is introduced, together with its further improving methods. This method can be integrated with electric machine and further improve the power density. This tutorial is based on the series work of the presenters' group as well as researchers all over the world. The major contents are included in the newly published book "Advanced Pulse-Width-Modulation: with Freedom to Optimize Power Electronics Converters" by Springer Press.

## 9AM3 | A MATLAB/Simulink Approach of Photovoltaic Power Systems: Designing, Modeling, Simulation, and Control

INSTRUCTORS: **Weidong Xiao[1],Jimmy Chih-Hsien Peng[2], Qiang Han[3]**
*[1]University of Sydney, Australia; [2]National University of Singapore; [3]BC Hydro, Canada*

This tutorial provides a practical introduction to photovoltaic (PV) power systems regarding the theoretical analysis, design, modelling, control, and simulation. The objective is to expose the audience to all facets of PV power systems with emphasis on the hands-on tools required for executing academic research and for meeting industry expectations. The development of this tutorial is based on the diverse experience and expertise of the presentation team in both the academia and power industry. The tutorial will first begin with the fundamentals of PV systems regarding theoretical analysis and design. The modelling includes two parts; one for simulation, and another for dynamic analysis. Based on the system dynamics, a control design approach for grid-forming inverters is introduced to guarantee the system stability and robustness in the presence of multiple PV systems. Finally, transient studies for transmission-level connected PV systems are presented. All analysis and simulation are conducted using function blocks in MATLAB\Simulink environment. After the tutorial, the audience shall be able to design a practical grid-tied PV power system, simulate its operation, and evaluate its performance via MATLAB\Simulink. The tutorial will be organized to facilitate smooth transitions from the fundamental and practical knowledge to more advanced subjects.

## 10AM1 | Emerging Bidirectional Switches and Their Impact on Future AC Power Converters and Applications

INSTRUCTORS: **Thomas M. Jahns[1], Bulent Sarlioglu[1], Johann W. Kolar[2], Jonas Huber[2], Victor Veliadis[3]**
*[1]University of Wisconsin – Madison, United States; [2]ETH Zurich, Switzerland; [3]PowerAmerica, United States*

This tutorial will introduce participants to the emerging technology of monolithic bidirectional (M-BD) power switches and the exciting opportunities they will open for future ac power converter topologies and their applications. Wide-bandgap (WBG) power semiconductor technology has opened the door to the development of long-sought monolithic bidirectional switches that can block voltage and conduct current in both polarities under full gate control in all four quadrants. Prototype versions of these M-BD devices produced in industrial and academic laboratories have been reported with ratings as high as ±1400V and ±100A. A section of this tutorial will be devoted to exposing participants to the underlying semiconductor technology of these M-BD switches including their operating principles, achievable terminal characteristics, technical challenges, and promising M-BD devices reported to date. Following this introduction to state-of-the-art M-BD switch technology, the tutorial will focus attention on the strong potential this new class of switches holds for having a major disruptive impact on the future of power electronics. In particular, this tutorial will focus on the exciting opportunities that these new switches provide for dramatically improving key performance metrics of future dc-ac and ac-ac power converters, including their power density, efficiency, EMI suppression, and (eventually) cost. Two of the well-known power converter classes that will be among the biggest beneficiaries of the future availability of M-BD switches are matrix converters (MCs) and current-source inverters (CSIs). While the appealing advantages of matrix converters for direct ac-ac power conversion have long been recognized, the unavailability of M-BD switches has prevented MCs using the baseline 3x3 matrix of ac switches from achieving wide commercial success. After reviewing the basic concepts associated with matrix converters and their control, attention will be focused on the opportunities that M-BD switches open for realizing the full commercial potential of future MCs in applications such as motor drives. Similarly, the future potential of new M-BD switches to revive long-neglected CSI technology will also be explored. Recent work has revealed a variety of appealing properties of CSI-based motor drives in a wide variety of dimensions including high-temperature operation, EMI suppression, and enhanced fault protection in permanent magnet machine drives. After reviewing the basic concepts of CSI technology for both ac-dc and dc-ac power converters, special attention will be focused on the game-changing potential of M-BD switches in future CSI-based integrated motor drives that combine motors and drives into the same housing. Finally, opportunities to realize the full potential of M-BD switches in promising new power converter topologies

will be explored. One particularly exciting development is their application in a new T-Type switching cell (TT-SC) topology that provides the basis for designing high-performance WBG-based threelevel voltage-source inverters that can achieve appealingly high power density and efficiency performance metrics. Other promising power converter applications of M-BD switches will also be reviewed. Tutorial participants can expect to leave this tutorial with valuable insights into the emerging technology of M-BD switches and the opportunities they open for more fully exploiting wide-bandgap switch technology to revolutionize the power electronics field.

## 10AM2 | Interaction Among the Grid-connected Converters through Their Synchronization Mechanism

INSTRUCTORS: **Marco Lissere[1], Grahame Holmes[2], Mario Paolone[3], Rongwu Zhu[4], Roberto Rosso[5]**
*[1]Christian-Albrechts-Universität zu Kiel, Germany; [2]RMIT University, Australia; [3]Swiss Federal Institute of Technology, Switzerland; [4]Harbin Institute of Technology, Shenzhen, China; [5]ENERCON, Germany*

Electrical power systems are currently transitioning from centralized structures, where most of the power generation comes from small numbers of large power rotating machines, to distributed structures, where much of the power generation comes from large numbers of small power-electronic-interfaced renewable resources. This increasing use of multi-functional power electronic converters (such as STATCOM, DVR, UPFC, UPS and Solid-state Transformer) is challenging the principles of electrical grid operation. One emerging area of concern is harmonic stability issues created by large numbers of grid-connected power converters, with converter synchronization to the grid emerging as a critical factor which can cause anomalous interactions between these converters. This tutorial considers this synchronization issue from the perspective of both the electrical power grid and the converter. The tutorial begins with the electrical grid perspective, looking at limitations of conventional grid modelling approaches in the presence of gridconnected converters, and then presenting advances that have been made in this area. Next, the tutorial reviews grid-synchronization from the converter perspective, looking at modelling issues, established gridsynchronization strategies and grid converter classification implications. The tutorial then presents power synchronization as an emerging alternative for Grid-Forming-Converters, and considers its benefits in comparison to a Phase-Locked-Loop approach. Finally, the tutorial presents the idea of selfsynchronization, where the converter synchronizes to internal control loop variables instead of measured voltages, to improve its stability and ride-through capability in the presence of grid harmonics and faults.

## 10AM3 | Wide Bandgap Power Electronics Based Electric Machine Drives

INSTRUCTORS: **Jin Wang[1], Yousef Abdullah[2]**
*[1]The Ohio State University, United States; [2]Kuwait University*

The demand on high performance high power density electric machine drive systems continues to grow as multiple industry sectors look to cut costs and improve power density and efficiency. For this reason, researchers and engineers have been working on wide bandgap (WBG) based power electronics circuits to meet the immediate needs of industry and satisfy future requirements. The following tutorial provides an in-depth look of challenges and status or WBG motor drives, covering topics on both circuit level and system level, which includes gate drive design, circuit layout, reflective wave, thermal design, EMI, leakage current, and insulation stress to motor windings with high dv/dt PWM. Two case studies, one on a 1.8 kVA integrated GaN based motor drive and the other on 7 kV 1 MVA SiC based motor drive, will be used as examples during the discussion.

## 10AM4 | Monitoring Power Module Degradation via Lifetime-Varying Parameters

INSTRUCTORS: **Christoph H. van der Broeck[1], Timothy A. Polom[2]**
*[1]FEV Europe GmbH, Germany; [2]Silicon Austria Labs GmbH, Austria*

This tutorial introduces and breaks down thermal response monitoring and degradation diagnosis techniques especially applicable to power electronic modules. Such monitoring technologies are essential in next-generation integrated power electronic systems that require reduced size, weight and cost while ensuring highly reliable operation over ever extending lifetimes. The introduced methodology ultimately enables realization of predictive maintenance strategies that utilize power converters fully until critical degradation thresholds are reached. They allow operating lifetimes of power conversion systems to be maximized or optimized according to engineering and availability constraints. Degradation mechanisms in power electronic modules occur at material interfaces in large part due to mismatches in thermal expansion coefficients. Resulting thermal cycles periodically induce strain at these material interfaces which, in turn, leads to fatigue, i.e., crack growth and delamination. In many cases, the growth of cracks and delamination occurs within the primary heat dissipation path of a power device, thus altering thermal response. The presented scheme of detection, localization, and overall quantification of different degradation mechanisms is based on systematically monitoring lifetime-varying electrothermal response properties and parameters. This tutorial has the objective to present and clarify details of the many promising research approaches that have been recently proposed to realize in situ health monitoring and diagnosis. After establishing motivation, this tutorial reviews electrothermal modeling approaches especially applicable to power modules and examines typical electrothermal response characteristics. Moving forward, it details thermal real-time monitoring systems that combine temperature data, extracted via sensors and temperature-sensitive electrical/optical parameters, with 3-D real-time models. It is demonstrated how the fusion of model and sensor data can detect abnormal thermal responses, which are linked to occurrences of degradation. Page 2 of 3 The tutorial provides an overview on thermal characterization technologies that measure thermal impedance in time and frequency domain. It is analyzed how thermal impedance reflects different degradation mechanisms and can serve as the focal point of a scheme to localize and quantify these mechanisms. Addressing the broad array of implementation options, the final part of the tutorial investigates real-time technologies that can extract life-time varying thermal parameters, in particular thermal impedance, during normal converter operation. It finally shows how extracted degradation sensitive data can be utilized for degradation diagnosis using artificial intelligence technologies.

## 11AM1 | Advances in Intelligent Solid-State DC Substations for Future Interconnected DC Grids

INSTRUCTORS: **Rik W. De Doncker, Jingxin Hu, Shenghui Cui, Johannes Voss, Philipp Joebges**
*RWTH Aachen University, Aachen, Germany*

The change of the electrical supply system to more environmental-friendly energy sources require the development of a new grid infrastructure. Next to the increasing penetration of large-scale renewable energy sources such as offshore wind farms, the change of consumer behavior in the distribution grids from consumer into producer due to the installation of decentralized generations will result in a bottleneck in the distribution grids. Local or regional balancing between loads and generations is found to be a cost effective solution for the future electrical distribution grids, which can be realized with direct current (DC) technology more efficiently and flexibly. The tutorial will focus on the latest advances and best practices of intelligent solid-state DC substations for future flexible DC grids, which covers a selection of key enabling technologies from converter topologies, optimized control, hardware-in-the-loop simulation techniques, to the development of megawatt mediumvoltage demonstrators. The presented advances are collected from a number of recent and ongoing research projects in the Institute for Power Generation and Storage Systems, which includes the Flexible Electrical Networks (FEN) Research Campus funded by the German Federal Ministry of Education and Research. Following a general introduction and a technology roadmap of flexible DC grids, the tutorial will elaborate the technologies of bidirectional isolated DC-DC converters for intelligent solid-state DC substations for

interconnection of DC grids at different voltage levels. It will start with dual-active bridge (DAB) based DC-DC converter topologies for LVDC-MVDC applications, where advanced modulation and control of DAB converters will also be discussed. This includes the instantaneous flux and current control method as well as the advanced black start-up and fault ride-through strategies for a highly dynamic and robust operation under both normal and fault conditions. Then, the development and control of an IGCT-based 5 kV, 5 MW DAB DC-DC converter will be presented. This includes the employment of the modified auxiliary-resonant commutated-pole circuit to ensure zerovoltage soft-switching of IGCT devices with snubber capacitors, and a novel anti-saturation detection and compensation methods for medium-frequency transformers. Considering the numerous benefits of the bipolar DC distribution, the tutorial will also present advances in power conversion technologies for bipolar LVDC and MVDC distribution systems. The concept of topological integration is adopted and demonstrated forstate-of-the-art AC-DC and DC-DC converterssuch as MMC and DAB, which enables a full bipolar operation capability on the DC side with a minimum count of additional components. The last section of the tutorial will deal with the real-time simulation and hardware-in-the-loop test for intelligent DC substations. Different modeling techniques will be discussed and compared with best practices in the real-time environment. A successful example of using the rapid-control-prototyping tool to develop a high-power medium-voltage modular DC-DC converter will be presented as well as the lessons learnt.

## 11AM3 | Optimised Electrical Machine Designs for E-Mobility Applications

INSTRUCTORS: **Mircea Popescu[1], Philip Mellor[2], Nick Simpson[2], James Goss, Melanie Michon[1], Jonathan Godbehere[1]**

*[1]Motor Design Ltd., United Kingdom; [2]University of Bristol, United Kingdom*

Transport electrification is seen as one of main solutions to reduce global CO2 emissions and increased demand of mechanical energy can be provided by electrical energy. The best energy conversion systems are undoubtedly the combination: electrical machines + power electronics + batteries. The increasing demand of full electric vehicles arises specific challenges in terms of design for manufacturing, low weight, material costs and material supply chain. There is a strong interest to reduce the volume and cost of active materials in propulsion motor technologies beyond their current state-of-art, with a strong focus on industrial feasibility for mass production. Potential solutions include increased motor speeds and higher pole numbers and/or the adoption of rare earth free typologies such as reluctance (switched and synchronous) and induction machines. As there can be significantly different usage and performance requirements across e-mobility applications adopting a common standard of motor design is unlikely to yield the optimum in terms of overall system efficiency and electric vehicle range. These considerations will be discussed and compared. Advances in fast switching power semiconductor devices and digital control have enabled high frequency operation of electrical machine drives, with fundamental operating frequencies exceeding 1 kHz being proposed. High frequency operation allows for greater mechanical speeds and designs with a larger number of magnetic poles, leading to a more compact electrical machine package for a given output requirement. However, high frequency operation results in a higher volumetric loss in he active components of the electrical machine; primarily as a result of induced circulating eddy currents in the stator laminations, winding conductors and the rotor. The non-uniform heating and reduction in efficiency associated with these AC loss effects represent a major hurdle to the successful development of compact high frequency electrical machine drives. The benefits and challenges associated with high frequency operation of electrical machines for aerospace and automotive applications will be reviewed and the techniques and design choices available to the designer to reduce high frequency loss effects and extract heat will be surveyed. Cutting-edge sensitivity analysis and multi-objective optimisation techniques will be applied in the design of an electric motor for a PHEV traction application. Each candidate solution will be evaluated in terms of electromagnetic, thermal and mechanical behaviour across the full operating envelope. The optimisation will generate a pareto front which allows efficiency over a drive cycle to be traded off against motor cost. This approach utilises a high performance or cloud computing infrastructure to deliver a truly revolutionary design workflow.

## 11AM4 | Conducted, Near-Field and Radiated EMI Emission Mitigation for Wide Bandgap Converters: Fundamentals, Modeling and Solutions

INSTRUCTORS: **Cong Li[1], Shuo Wang[2]**
*[1]GE Research, United States; [2]University of Florida, United States*

This seminar is part of a series of education activities initiated by IEEE EMC Society Special Committee 5 (SC5) – Power Electronics EMC. The purposes are to raise broader power electronics audiences' awareness of EMC, and connect advanced EMC technologies with WBG power electronics systems to enable low noise, high efficiency, and high power density solutions for future power conversion systems. This seminar is a comprehensive guide to provide engineers with techniques to develop and construct electromagnetically compatible Wide Bandgap (WBG) power electronic converters. The seminar provides a good opportunity for the fundamental theory, measurement, and suppression of electromagnetic interference (EMI) for WBG power electronics. It will have full coverage on the conducted emission, near field, and radiated EMI. The first section provides EMC theory and fundamentals for WBG power conversion, comparison of commonly used industrial EMI standards, techniques for common-mode (CM) and differential mode (DM) current separation, and practical CM/DM measurement methods. The second section focuses on a comprehensive 5-step EMC design process for WBG power converters' conducted emission EMI challenges: "SOLVE". SOLVE design flow begins with considerations on Selecting proper architectures based upon system ratings and EMC specifications. The next steps develop techniques for Obtaining component parasitics and Layout for the system EMI model. Vetting of different filter design aspects, including magnetic material selection, structure, and practical filter performance. The last step presents techniques and principles for packaging Enhancement. The third section focuses on the near field EMI generated from components in WBG power converters. The near field EMI can be generated from WBG power modules, transformers, inductors, and PCB traces. It can be coupled to other components in the converter to deteriorate the WBG converter's conductive and radiated EMI. With the high switching speeds and high switching frequencies of WBG power electronics to improve power density, the components are very close to each other, therefore the importance of understanding, measurement, and reduction of near field EMI cannot be overemphasized. The seminar will focus on the advancement of the theory, identification, and reduction of the near field EMI for WBG power electronics. The fourth section focus on the radiated EMI for WBG power electronics. The WBG device powered power electronics systems can achieve higher power densities than those with the 2 conventional Si devices. However, higher switching speed and higher switching frequencies lead to more significant radiated EMI. The radiated EMI can be over the limits from several to hundreds of MHz, which poses a big barrier to high power density power electronics design in the areas such as consumer electronics, electric vehicles, and the aviation industry, etc. This is especially important for most power electronics engineers who lack knowledge on the radiated EMI in power electronics systems. The seminar will focus on the advancement of the theory, measurement, and reduction techniques developed in recent years for the radiated EMI in WBG power electronics systems.

## 12PM1 | Applying Artificial Intelligence to Battery State Estimation

INSTRUCTORS: **Carlos Vidal[1], Phillip Kollmeyer[1], Javier Gazzarr[2]**
*[1]McMaster University, Canada; [2]MathWorks, United States*

This tutorial will teach the entire process necessary to create, test, and deploy machine learning algorithms which estimate battery state of charge or other states and properties of interest. Traditional state estimation methods depend on battery models that cannot always capture the complex nonlinear, temperaturedependent characteristics inherent in battery electrochemistry. Machine learning simplifies the process by treating the battery as a black box. The relation between states of interest and measured battery parameters are fit to a neural network, which is a series of matrix calculations containing hundreds or thousands of learnable parameters. Machine learning has potential to achieve better accuracy than conventional battery modeling and state estimation techniques and is a promising solution for a wide range of commercial and industrial applications. Battery state estimation and machine learning theory will first be introduced, along with a discussion of different types of machine learning methods that can be

applied to battery applications. Then the steps to create a machine learning algorithm – an experimental collection of data, defining network configuration and hyperparameters, training, and testing – will each be discussed in detail. A case study comparing a non-recurrent feedforward neural network with a recurrent, LSTM-based neural network will be provided, demonstrating that both network types can perform very well for realistic vehicle drive cycles over a wide range of temperatures. The tutorial will also include an interactive session where the attendees will train and test neural networks for the state-of-charge estimation via example data and code executing in MATLAB Online, which can run in any web browser. Following the training and testing process, the next step is to deploy the networks in hardware and evaluate their real-time performance and computational load. The method of saving a neural network as a MATLAB object for direct use in Simulink, auto-generation of C-code, and deployment to a real-time target, such as a battery management system, will be demonstrated. Example results showing processor time as a function of algorithm type and several learnable parameters will be given. It will provide insights into machine learning algorithms' suitability for large battery packs with a hundred or more cells. The tutorial will also provide several other examples of how to apply machine learning to battery applications, including (1) use of machine learning in place of equivalent circuit models, (2) estimation of temperature to reduce the need for physical sensors in a battery pack, and (3) state of health estimation.

## 12PM2 | Resiliency-Oriented Grid-Interactive Converters: Concepts, Design, and Field Implementation

INSTRUCTORS: **Xiaonan Lu[1], Jin Tan[2], Andy Hoke[2], Lisa Qi[3]**
*[1]Temple University, United States; [2]National Renewable Energy Laboratory, United States; "*
*[3]ABB Inc., United States*

As the penetration level of inverter-based distributed energy resources (DERs) increases rapidly, distribution grids, as the most significant 'grid-edge' for DER integration, play a crucial role in bridging the grid backbone (i.e., transmission system) to the end-users. Resilient and stable distribution grids are urgently needed to modernize electric power grids with high penetration of inverter-based resources (IBRs) and ensure operational continuity. Conventional grid-interactive power electronic converter design mainly focuses on satisfying the design constraints of individual converter units and the operational requirements at the single point of interconnection (POI). However, given the increasing penetration level of IBRs in modern power grids, converter systems should also be taken into account to meet the grid needs in a wider area. Furthermore, the concept of converter design has been tremendously advanced, considering the cross-domain and multi-disciplinary objectives. Particularly, on top of the conventional and legacy converter design constraints on power density, energy conversion efficiency, among others, additional considerations on the interactions among multiple converters (i.e., converter systems) should be highlighted, with special emphases on the coupling operation between converter hardware implementation (physical layer) and information exchange through communication interconnections (cyber layer), control design respecting the tradeoff between local control constraints satisfaction and interactive operation with neighboring converters, and fault-tolerant design and converter system resiliency enhancement coordinated with conventional protection schemes in a multi-timescale context. All these emerging design constraints call for a paradigm shift into a resiliency-oriented converter design framework. In this tutorial, the diversified and multi-disciplinary instructor team from academia, government national laboratories, and leading industry companies will introduce the resiliency-oriented modeling and control of grid-interactive converter, and the topics will range from fundamental concepts covering the necessary background knowledge to advanced applications and field deployment. The topics will echo the cutting-edge technologies and applications of grid-interactive converters, including hybrid and networked AC and DC microgrids, inverter-based renewable energy (e.g., photovoltaics) integration, resiliency enhancement, and protection coordination in inverter-dominated power grids, among others.

## 12PM3 | Cryogenic Power Electronics Design for Electrified Aircraft Propulsion

INSTRUCTORS: **Fei (Fred) Wang[1], Zheyu Zhang[2], Ruirui Chen[1], Shengyi Liu[3]**
*[1]University of Tennessee, United States; [2]Clemson University, United States; [3]Boeing Company, United States*

Cryogenic power electronics offer numerous game-changing benefits, including 1) improved performance of power semiconductor devices, such as silicon (Si)- and gallium nitride (GaN)- based, offering decreased specific on-state resistance and increased switching speed; 2) faster switching frequency operation at cryogenic temperature, greatly reducing the need for passive (e.g. EMI filtering); thereby reducing filter weight; 3) less cooling requirement at extremely low ambient temperatures, and 4) light and/or efficient busbar designs due to the low resistivity of conductors at cryogenic temperature. This seminar will provide several key perspectives for the cryogenic power electronics design from the component up to the converter level. First, the characteristics of critical components, including power semiconductors and magnetics, at cryogenic temperature are introduced. Second, special considerations, trade, and design studies of cryogenic power stage and filter are discussed. Then, two examples of a 40 kW Si-based and a 1 MW SiC-based cryogenically-cooled inverter system for electric aircraft propulsion are illustrated, with cooling design, safety considerations, and the protection scheme highlighted. Upon completion, seminar attendees will have a firm grasp on the cryogenic power electronics design and be provided with a range of possible options in order to better utilize the cryogenic cooling system in power converters.

## 12PM4 | Hybrid Semiconductor Switches based Power Modules, Converters, and Systems

INSTRUCTORS: **Fang Luo[1], Jiangbiao He[2]**
*[1]State University of New York at Stony Brook, United States; [2]University of Kentucky, United States*

Power semiconductor devices play a backbone role in the development of power electronics. Over the past decade, semiconductor devices have experienced rapid development, especially promoted by the emerging wide-bandgap device technologies. However, regardless of conventional Silicon (Si) devices or the new Gallium Nitride (GaN) and Silicon Carbide (SiC) devices, every type of semiconductor devices has its own pros and cons. To fully leverage their different characteristics, various hybrid power devices and modules have been proposed and developed in the past years, ranging from the device level to converter level, or even power electronics system level. As a matter of fact, many of the concepts of hybrid semiconductor switches have been successfully applied in industries, such as the monolithic integration of Si IGBTs and SiC anti-parallel diodes (i.e., co-pack), the Cascode JFET, and the "Si+SiC" hybrid three-level active neutral-point-clamped commercial modules. Numerous performance benefits have been achieved with such hybrid devices, modules, and converters, including efficiency and reliability improvement, EMI mitigation, cost reduction, etc. In this tutorial, we will start with a review of the development history of various hybrid semiconductor devices and the related successful commercial examples, followed by the new opportunities and challenges with the emerging wide bandgap devices. Afterwards, we will present "Si+SiC" hybrid switching devices at the power module level, review the operating principle, gate drivers, packaging, and performance evaluation. Furthermore, we will present various "Si+SiC" hybrid power converters, specifically including the hardware development, controls, and experimental verifications. Application examples include electric aircraft propulsions and interruptible power supplies for data center applications will be discussed. Finally, we will conclude the tutorial with a summary and Q&A session.

## 1PM1 | Design and Development of Scalable Battery Testers/Emulators and Their Applications for Future Transportation Electrification

INSTRUCTORS: **Sheldon Williamson[1], Uday Deshpande[2]**
*[1]Ontario Tech University, Canada; [2]D&V Electronics Ltd., Canada*

As electrified transport systems proliferate, batteries are increasingly becoming the critical element in the immediate and long-term technical and commercial success of these programs. Understanding of battery technology and its role in the applications is becoming crucial. While there have been many articles published on battery elements and systems, this tutorial approaches the problem from a user mindset. How do we use the various technology elements of battery models, calculations of charge and health to ensure a successful design outcome? Additionally, this tutorial will discuss how these elements apply to test and validation. Very few battery cell models are available in literature; most models are very generic or basic. Cell models are either based on equivalent circuit parameters, such as RC, R-RC, or based on SOC calculation – these are not enough to measure Ah-capacity fade, state-of-health (SOH), and/or end-of-life (EOL). Thermal modeling is used minimally in related literature for testers and emulators. Cell degradation assessment due to varying temperature gradients is not feasible – this is particularly true for fast charging applications; 1C and above. Hence, testers/emulators today are unable to provide boundary testing (near EOL), specifically for applications such as fast chargers and controller validation or BMS validation. This tutorial will present more realistic and practical electro-chemical and electro-thermal models for emulation and testing purposes. Performance modeling will be presented in order to test advanced machine learning (ML)-based battery management systems (BMS) and charger controllers. Stochastic models of battery cells will also be presented in this tutorial. In addition, SOC/SOH estimation models specific to emulator/tester applications, which affect instantaneous battery performance, will also be presented. Advanced thermal/EOL degradation models, which can be used to test BMS with battery health estimation and energy management, will also be presented for testing applications. Finally, the tutorial will include emulation of custom cell models and health-conscious fast charging algorithms, keeping the effects of temperature gradients in mind. Keeping these aspects in mind, the following key practical aspects will be presented: • Emulation at cell-level, module level, and pack level (including development of advanced, higherorder thermal models); • Estimation of SOC and SOH using advanced ML techniques; • Validation of BMS developmental steps with respect to hardware, firmware, and software; • Testing of newly developed algorithms (balancing, SOC, SOH, EOL, etc.); • Development of a new constant-temperature-constant voltage (CT-CV) algorithm; • Testing of fault cases (over-temperature, over-voltage, etc.); • Programmable standard and user-owned battery models; • Bidirectional power supply design (regenerative design) for high-power discharge; Constant-Voltage (CV), Current (CC), Power (CP), Series Resistance (CR) loading; • Real-time HIL (Simulation of high-voltage batteries at cell/module level; Real-time multi-cell battery simulations; Temperature simulations using isolated analog outputs and advanced models).

## 1PM2 | Printed Circuit Boards in Power Converter Applications: Design Considerations and Failure Mechanisms

INSTRUCTORS: **Ashish Arora, Yike Hu**
*Exponent, United States*

Printed Circuit Boards (PCBs) are the backbone of all electronic circuits and are ubiquitous in today's world in almost all applications. PCBs not only interconnect components through conductors routed through the board with traces and vias, but also provide electrical insulation between conductors of different potentials that are in different circuit nodes. Their use in power converter and energy storage applications gives rise to risks that do not necessarily exist in other lower power applications. While PCB failures are not very common, a propagating PCB failure in a power converter or energy storage application can trigger a cascading series of failures that spread to the system's energy storage component eventually resulting in a fire. Propagating PCB failures can occur due to a number of reasons such as contamination on the PCB, improper PCB layout or a failure of a component on the PCB itself. Design choices made during the development of a product, the cleanliness of the PCB manufacturing

process, the stresses applied to the PCB during a products assembly process etc. can all impact the probability of a PCB failure in the field. Understanding the causes of PCB failures and how these failures can propagate in an application allows for the design and manufacture of systems with more robust PCBs that have a lower probability of a catastrophic failure in the field. This tutorial will provide an overview of some of the requirements and challenges of designing and manufacturing PCBs specially for power converter and energy storage applications. The tutorial will also provide an overview of the types of PCBs, how PCBs are manufactured, how components get onto the PCBs and the standards that exist to evaluate the PCB manufacturing process. PCB failure mechanisms such as interconnect overheating, contamination, electrochemical migration, dendrite formation and conductive anodic filaments, tin whiskers and component over-heating will be reviewed. Case studies will provide examples of failures observed in the field and the means to mitigate them.

## 1PM3 | Defining, Modeling, and Optimizing for Energy Efficiency in 5G

INSTRUCTOR: **Brian Zahnstecher**
*PowerRox, United States*

With so much hype and news around the deployment of the next-generation broadband network (5G), it is quite alarming to find out much of the "promise" of 5G assumes the energy infrastructure exists to power all this new HW. More fundamentally, the payback estimates for these massive investments all assume the network can be fully utilized, while neglecting network bottlenecks because they relate to energy and not data throughput. The 5G Energy Gap and potential electrical grid destabilization is a risk to the entire deployment and all that is attached to it. This risk is broken down into the concepts of the Power Value Chain, Power Cost Factor, 5G Derate Factor, and other technical/business and even socioeconomic factors. This entry/intermediate-level seminar introduces these concepts in a simple, yet realistic way to break the complicated network down into manageable pieces for all stakeholders, then translate the unique inputs/requirements of each into the normalized, "universal currency" of energy. From there, both static and dynamic analyses can be performed to assess end-to-end network configurations and optimize each piece through the lens of energy efficiency.

# Technical Program

*The following Sessions cover all areas of technical interest to the practicing energy conversion professional.*

***Ask the authors questions using the Chat located next to each pre-recorded video.***

## Topic A: Renewable and Sustainable Energy Applications

### A01: Photovoltaic Systems

**1772 | Comparison of Modulation Techniques for a Single-Phase Full-Bridge Photovoltaic Micro-Inverter considering Reactive Power Capability**
Tobias Brinker, Lennart Hoffmann, Jens Friebe
*Leibniz Universität Hannover, Germany*

**1294 | Experimental Analysis of Laminated Bus Bars for Building-Integrated Photovoltaic Applications**
S. Ravyts[1], P. Nivelle[2], J. Carlous[2], R. Sabariego[3], M. Daenen[2], J. Driesen[3], J. Cappelle[1]
*[1]KU Leuven - Gent, Belgium; [2]Hasselt University, Belgium; [3]KU Leuven- Leuven, Belgium*

**1779 | Influence of DC/DC Stage on the Design of the Output Filter of the Inverter Stage in Two-Stage Grid-Connected PV Systems**
Branislav Stevanović[1], Santiago Cóbreces[2], Emanuel Serban[3], Pedro Alou[1], Martin Ordonez[3], Miroslav Vasić[1]
*[1]Universidad Politécnica de Madrid, Spain; [2]Universidad de Alcalá, Spain; [3]The University of British Columbia, Canada*

**1362 | Sizing Approach for a Single-Phase Grid-Connected Photovoltaic Converter with Active and Reactive Power Management**
Rosa Iris Viera-Díaz, Mario González-García, Ricardo Álvarez-Salas, Homero Miranda, Yuniel León-Ruiz
*Universidad Autónoma de San Luis Potosí, Mexico*

### A02: Renewable and Sustainable Energy Systems

**2422 | Economic Analysis for Hourly Dispatching Wind Energy Power Using Battery and Supercapacitor Hybrid Energy Storage System**
Pranoy Roy, JiangBiao He
*University of Kentucky, United States*

**1819 | A Single-Phase Enhanced Grid-Forming Controller with Converter Current Limiting**
Masoud Karimi-Ghartemani[1], Ali Zakerian[1], Sayed Ali Khajehoddin[2]
*[1]Mississippi State University, United States; [2]University of Alberta, Canada*

**1226 | Comparative Study of Transverse Flux Permanent Magnet Machines for Wind Power Applications**
R. Kumar[1], Z.Q. Zhu[1], A. Duke[2], A. Thomas[2], R. Clark[2], Z. Azar[2]
*[1]The University of Sheffield, United Kingdom; [2]Sheffield Siemens Gamesa Renewable Energy Research Centre, United Kingdom*

**2346 | Review of DC Offshore Wind Farm Topologies**
Kareem A. Noor Al-Deen, Hussain A. Hussain
*Kuwait University, Kuwait*

**1990 | Control Strategies for Variable Speed Operation of Pumped Storage Plants with Full-Size Converter Fed Synchronous Machines**
Raghbendra Tiwari[1], Roy Nilsen[1], Olve Mo[2]
*[1]Norwegian University of Science and Technology, Norway; [2]SINTEF Energy Research, Norway*

## A03: Power Converters for Renewable and Sustainable Energy Systems

**1328 | Flexible AC Phase Configurable NPC-Based Converter Topology**
Emanuel Serban[1,2], Jan Hammer[1], Cosmin Pondiche[2], Martin Ordonez[1]
*[1]The University of British Columbia, Canada; [2]EnerSys, Canada*

**2144 | Harmonics Compensation of the LCC in a Parallel LCC-VSCs Configuration for a Hybrid AC/DC Network**
Rouzbeh Reza Ahrabi, Yunwei Li
*University of Alberta, Canada*

**1192 | A Dual-Input Single-Output DC-DC Converter Topology for Renewable Energy Applications**
Pasan Gunawardena, Nie Hou, Dulika Nayanasiri, Yunwei Li
*University of Alberta, Canada*

**2016 | PWM Control of n-Phase Interleaved Current Fed Topology**
Sonam Acharya[1], Santanu Mishra[1], Arvind Tiwari[2]
*[1]Indian Institute of Technology Kanpur, India; [2]GE Research, United States*

## A04: Control of Photovoltaic Systems

**1563 | Analysis of Maximum Power Point Tracking in Four Different Modes for Multioutput Hybrid Bipolar Converter**
Nidhi Malhotra, Pawan Kumar, R.K. Singh
*Indian Institute of Technology (BHU), Varanasi, India*

**1904 | Discontinuous Modulation for Improved Thermal Balance of Three-Level 1500-V Photovoltaic Inverters under Low-Voltage Ride-Through**
Jinkui He[1], Ariya Sangwongwanich[1], Yongheng Yang[2], Zhongyi Quan[3], Yunwei Li[3], Francesco Iannuzzo[1]
*[1]Aalborg University, Denmark; [2]Zhejiang University, China; [3]University of Alberta, Canada*

**1482 | A Semi Discontinuous PWM Method for Mitigating Oscillation in a Three-Level Grid-Tied PV Inverter**
Zhaoxia Yang[1], Jianwu Zeng[1], Qixing Ren[2], Liangcai Wu[2], Zhengjun Liao[2]
*[1]Minnesota State University, United States; [2]Growatt New Energy Technology Co., Ltd., China*

**1864 | Hybrid MPPT Technique Based on MPC and PSO for PV Systems Subject to Partial Shading**
Angelo G. Santos, Filipe A.C. Bahia, Fabiano F. Costa, André P.N. Tahim, Leandro L.O. Carralero
*Federal University of Bahia, Brazil*

**1502 | A Reactive Power Control Optimization Scheme for the Power Imbalance of Cascaded Photovoltaic Converter**
Chu Wang, Min Chen, Yufei Jie
*Zhejiang University, China*

**1690 | An Improved PV to Isolated Port Differential Power Processing Architecture for Solar PV Applications**
Aqsa Rouf, Soumya Shubhra Nag
*Indian Institute of Technology Delhi, India*

**1389 | A Decentralized Adaptive Voltage Regulation Control Strategy Based on a Novel Modular Three-Phase Integrated PV Inverter**
Xinghua Dang, Shangzhi Pan, Xicai Pan, Jinwu Gong, Xiaolu Ge, Jingxiang Shi, Minglong Wang, Lidong Hao, Pengxin Jin
*Wuhan University, China*

## Session A05: Energy Storage Systems

**2053 | Cell Balancing of Li-Ion Battery Pack with Adaptive Generalised Extended State Observers for Electric Vehicle Applications**
Utkal Ranjan Muduli[1], Khaled Al Jaafari[1], Khalifa Al Hosani[1], Ranjan Kumar Behera[2], Rustem R. Khusnutdinov[3], Alfred R. Safin[3]
*[1]Khalifa University, United Arab Emirates; [2]Indian Institute of Technology Patna, India; [3]Kazan State Power Engineering University, Russia*

**1666 | Passivity Control in Modular Battery Energy Storage Systems**
Ezequiel Rodriguez[1], Ramon Leyva[2], Gaowen Liang[1], Glen G. Farivar[3], Josep Pou[1], Christopher D. Townsend[4], Naga Brahmendra Yadav Gorla[3]
*[1]Nanyang Technological University, Singapore; [2]Universitat Rovira i Virgili, Spain; [3]University of Western Australia, Australia*

**1299 | A Comparison of the Battery Fault Tolerance of Modular Multilevel Converters with Half-Bridge and Full-Bridge Submodules**
Gaowen Liang[1], Glen G. Farivar[1], Gorla Naga Brahmendra Yadav[1], Christopher D. Townsend[2], Salvador Ceballos[3], Hossein Dehghani Tafti[2], Josep Pou[1]
*[1]Nanyang Technological University, Singapore; [2]University of Western Australia, Australia; [3]Ikerlan Technology Research Centre (BRTA), Spain*

**1565 | Design, Control and Prototyping of a Bidirectional Dual Active Bridge Converter for Integrating a Sodium Metal Halide Battery into a Telecom Station**
Mario Porru[1,2], Alessandro Serpi[1,2], Alessandro Soldati[3], Luca Tassi[3], Alfonso Damiano[2]
*[1]NEPSY srl, Italy; [2]University of Cagliari, Italy; [3]University of Parma, Italy*

**1794 | Design of a 1500V Si IGBT/SiC MOSFET Hybrid Switch-Based Three-Level Active NPC Inverter**
Haichen Liu, Tiefu Zhao, Jim Gafford, Somasundaram Essakiappan, Madhav Manjrekar
*University of North Carolina Charlotte, United States*

**1894 | A Novel ZCS Bidirectional CUK Equalizer for Energy Balance of Battery Cells Connected in Series**
Xinchi He[1], Rui Ling[1], Dongxue Li[2]
*[1]Chongqing University, China; [2]Vicor Corporation, United States*

**1604 | Novel Battery Equalizer-Charger Symbiosis Structure Based on Three-Port DC-DC Converters**
Nguyen-Anh Nguyen, Phuong-Ha La, Ngoc-Thao Pham, Sung-Jin Choi
*University of Ulsan, Korea*

**1089 | Solar Water Pumping System with Captive Energy Storage Functionality**
Hina Parveen, Utkarsh Sharma, Bhim Singh
*Indian Institute of Technology Delhi, India*

## Session A06: Microgrids and Grid Integration of Renewables

**1373 | Mode Transition in DC Microgrids with Non-Dispatchable Sources**
S. Jaya, A.S. Vijay, Imran Khan, Anshuman Shukla, Suryanarayana Doolla
*Indian Institute of Technology Bombay, India*

**2215 | Subsynchronous Control Interaction Study Framework and Applications to Southern California Edison System**
Chaoyang Jing, Patricia Arons
*Southern California Edison, United States*

**1550 | A Simulation Platform for Testing the Monitoring Techniques of a Microgrid**
Mohd Aquib, Suryanarayana Doolla, Mukul C. Chandorkar
*Indian Institute of Technology Bombay, India*

**2248 | Design and Optimization Strategy to Size Resilient Stand-Alone Hybrid Microgrids in Various Climatic Conditions**
Norma Anglani[1], Giovanna Oriti[2], Ruth Fish[2], Douglas L. Van Bossuyt[2]
*[1]University of Pavia, Italy; [2]Naval Postgraduate School, United States*

**1807 | Dual Converter Operating with Floating Capacitors Connecting Open-End Winding Doubly-Fed Induction Generator to a DC Microgrid**
Emerson L. Soares[1], Cursino B. Jacobina[1], Nady Rocha[2], Victor Felipe M.B. Melo[2]
*[1]Federal University of Campina Grande, Brazil; [2]Federal University of Paraíba, Brazil*

**1246 | A New General Multi-Layout Energy Hub Management Model for Industrial and Commercial Multi-Energy Systems with Complex Configurations**
Mehrdad Aghamohamadi[1], Clement Chuah[1], Amin Mahmoudi[1], John K. Ward[2], Mohammed H. Haque[3]
*[1]Flinders University, Australia; [2]CSIRO, Australia; [3]University of South Australia, Australia*

**1859 | Sizing of Hybrid Supercapacitors for Off-Grid PV Applications**
Tarek Ibrahim[1], Tamas Kerekes[1], Dezso Sera[2], Sergiu Spataru[3], Daniel-Ioan Stroe[1]
*[1]Aalborg University, Denmark; [2]Queensland University of Technology, Australia; [3]Technical University of Denmark, Denmark*

**1841 | Dynamic Analysis of AC Microgrids with Constant Power Loads or Sources**
Mohammad Mahdavyfakhr, Navid Amiri, Hanqing Lin, Juri Jatskevich
*The University of British Columbia, Canada*

## Session A07: Power Electronics for Renewable Energy Systems

**2307 | Soft Switched High Gain Boost Converter for Low Voltage Applications**
Manikant Kumar, Kirti Mathuria, Vinod Kumar Yadav, Arun Kumar Verma
*Malaviya National Institute of Technology Jaipur, India*

**2132 | A Fully Symmetrical Three-Port Hybrid Converter for PV Systems**
Zhongting Tang[1], Yongheng Yang[2], Frede Blaabjerg[1]
*[1]Aalborg University, Denmark; [2]Zhejiang University, China*

**1098 | Experimental Verification of Three-Phase PV Inverter Using Multiple Bidirectional Choppers for Utility-Scale PV Systems**
Linyue Qiao, Yoshifumi Shimizu, Makoto Hagiwara
*Tokyo Institute of Technology, Japan*

**2471 | Optimal Design of Multi-Port DC/DC Converters for Low Power and High Frequency Applications**
Marzieh Karami[1], Guangqi Zhu[1], Rohit Baranwal[1], Vijay Bhavaraju[1], David W. Ganger[1], Cheng Luo[2]
*[1]Eaton, United States; [2]Eaton, China*

**2567 | Design and Testing of a Modular Back-to-Back Power Electronics Converter for Wave Energy Harvesting**
Mattia Mantellini[1], Riccardo Morici[1], Marcos Blanco[2], Marcos Lafoz[2], Gustavo Navarro[2], Luca Zarri[3]
*[1]OCEM Power Electronics, Italy; [2]CIEMAT, Spain; [3]University of Bologna, Italy*

**2447 | Design Considerations of 6.5kV Enabled Three-Level and 10kV Enabled Two-Level Medium Voltage SST**
Apoorv Agarwal, Anup Anurag, Nithin Kolli, Ashish Kumar, Subhashish Bhattacharya
*North Carolina State University, United States*

**1060 | Investigation of a New Alternate Arm Modular Multilevel Converter Topology for HVDC Applications**
Dereje Woldegiorgis, Alan Mantooth
*University of Arkansas, United States*

**1980 | A Hybrid GaN + Si Based Cascaded H-Bridge Multi-Level Inverter and PWM Scheme for Improved Efficiency**
Prince Kumar[1], D. Venkatramanan[1], Abhijit Kshirsagar[2], Ned Mohan[1]
*[1]University of Minnesota Twin Cities, United States; [2]Indian Institute of Technology Dharwad, India*

## Session A08: Control of Renewable Energy Systems

**1472 | Sliding Mode Control Based Energy Harvesting System for Low Power Applications**
Honorio Martinez Sarmiento[1], Maen Marji[1], Cheaheng Lim[1], Jonghoon Kim[2], Nan Wang[1], Woonki Na[1]
*[1]California State University Fresno, United States; [2]Chungnam National University, Korea*

**1998 | MPPT Novel Controller Based on Passivity for the PV Solar Panel-Boost Power Converter Combination**
J. Linares-Flores, A. Hernández-Méndez, J.A. Juárez-Abad, M.A. Contreras-Ordaz, C. García-Rodriguez
*Universidad Tecnológica de la Mixteca, Mexico*

**1200 | A New Kalman-Filter-Based Harmonic Current Suppression Method for the Virtual Oscillator Controlled Voltage Source Converters with LCL**
Siyi Luo[1], Weimin Wu[1], Koutroulis Eftychios[2], Frede Blaabjerg[3], Henry Shu-Hung Chung[4]
*[1]Shanghai Maritime Univerity, China; [2]Technical University of Crete, Greece; [3]Aalborg University, Denmark; [4]City University of Hong Kong, China*

**1300 | Transient Stability Enhancement for Virtual Synchronous Generator by Combining Direct Power Control**
Xuejiao Zhong[1], Yutao Lou[2], Tiliang Wen[1], Donghai Zhu[1], Xudong Zou[1], Xiang Guo[1]
*[1]Huazhong University of Science and Technology, China; [2]Shanghai Institute of Satellite Engineering, China*

**2334 Power-Synchronized Current Control for Grid-Connected Converters**
Xiao Wang, Xiongfei Wang
*Aalborg University, Denmark*

**1587 | A New Control Strategy Based on PLL to Enhance System Stability under Varying Output Power in Weak Grids**
Junliang Liu[1], Xiong Du[1], Yuming Liu[2], Dengfeng Li[2], Bo Zhang[1], Chenghui Tong[1]
*[1]Chongqing University, China; [2]State Grid Chongqing Electric Power Company, China*

**1323 240°-Clamped PWM in Three Phase Grid-Connected PV Converter Application**
Hafsa Qamar, Haleema Qamar, Rajapandian Ayyanar
*Arizona State University, United States*

## Session A09: Grid Integration of Renewables

**1656 | An Enhanced Double Quasi-PR Controller for Grid-Side Inverter with Long Transmission Cable**
Weibiao Wu[1], Ke Hu[2], Ming Zhang[1], Gujing Han[1]
*[1]Wuhan Textile University, China; [2]Huazhong University of Science and Technology, China*

**1066 | Circulating Current Analysis of Paralleled Grid-Connected Inverters Based on the Multi-Frequency Model**
Liguo Wu, Xinbo Ruan, Zhiheng Lin, Hao Zhang
*Nanjing University of Aeronautics and Astronautics, China*

**1647 | Comparison of Grid-Forming Converter Control Strategies**
Anant Narula, Massimo Bongiorno, Mebtu Beza
*Chalmers University of Technology, Sweden*

**2252 | Dynamic Impact of Voltage-Dependent Current Injection on Fault-Ride-Through of Grid-Following Converters**
Xinshuo Wang[1], Heng Wu[1], Xiongfei Wang[1], Laurids Dall[2], Jun Bum Kwon[3]
*[1]Aalborg University, Denmark; [2]Energinet, Denmark; [3]Ørsted, Denmark*

**1199 | A New Type of Three-Phase Asymmetric LCL Power Filter for Grid-Tied Voltage Source Inverter**
Weimin Wu[1], Yaozhong Zhang[1], Henry Shu-Hung Chung[2], Frede Blaabjerg[3]
*[1]Shanghai Maritime Univerity, China; [2]City University of Hong Kong, China; [3]Aalborg University, Denmark*

**1709 | Analysis of Overmodulation in Power Synchronization-Based Voltage Source Converters**
Federico Cecati[1], Sante Pugliese[1], Marco Liserre[1], Xiongfei Wang[2], Frede Blaabjerg[2]
*[1]Christian-Albrechts-Universität zu Kiel, Germany; [2]Aalborg University, Denmark*

**1428 | Empirical Evaluation of GPS Clock Accuracy for Isochronous Droop-Based Inverters**
Toby Meyers, Barry Mather
*National Renewable Energy Laboratory, United States*

## Session A10: Wind Enegy Systems

**1536 | Permanent Magnet Generators for Wind Application: An Analytical Investigation**
Seyed Payam Emami[1], Emad Roshandel[2], Amin Mahmoudi[2], Samad Taghipour Boroujeni[1], Solmaz Kahourzade[3]
*[1]Shahrekord University, Iran; [2]Flinders University, Australia; [3]University of South Australia, Australia*

**2298 | Aggregation of Wind Turbine Grid-Side Inverters by Voltage Angle and Cable Resonance Compensation**
Zichao Zhou[1], Xiongfei Wang[1], Yin Sun[2]
*[1]Aalborg University, Denmark; [2]Shell Global Solutions International B.V., The Netherlands*

**1393 | Research on Dynamic Reactive Power Coordinated Control Strategy of Doubly-Fed Wind Turbine Based on Improved Genetic Algorithm**
Sen Cui[1], Xiangwu Yan[1], Ruibo Li[1], Wenfei Chang[1], Waseem Aslam[2]
*[1]North China Electric Power University, China; [2]University of Sargodha, Pakistan*

**1485 | Power-Electronics-Based Mission Profile Emulator for DFIG-Based Wind Power Generation System**
Huichao Ge, Ke Ma
*Shanghai Jiao Tong University, China*

**1707 | Electromagnetic Study of Direct-Driven Wind Turbine Generators by Coupled Field- Circuit Simulations and Full-Scale Bench Tests**
Christoph Mülder[1], Fabian Müller[1], Andreas Thul[1], Kay Hameyer[1], Christoph Meier[2]
*[1]RWTH Aachen University, Germany; [2]Wobben Research and Development GmbH, Germany*

**2173 | Comparison of Active and Passive 9-Phase Wind Turbine Conversion System for an all DC Grid**
Omid Beik[1], Ahmad S. Al-Adsani[2]
*[1]McMasters University, Canada; [2]Public Authority for Applied Education and Training, Kuwait*

**2299 | Dynamic Model Validation and Harmonic Stability Analysis of Offshore Wind Power Plants**
Zichao Zhou[1], Xiongfei Wang[1], Fangzhou Zhao[1], Jan R. Svensson[2], Lukasz Kocewiak[3], Mikkel Peter Sidoroff Gryning[3], Aravind Mohanaveeramani[2]
*[1]Aalborg University, Denmark; [2]Power Grids Research Hitachi ABB Power Grids, Sweden; [3]Electrical Systems Ørsted Offshore A/S, Denmark*

## Session A11: Other Topics in Renewables

**1139 | An Amplitude-Modulated Pseudo-Random Binary Sequence Approach to Broadband Impedance Spectroscopy for Photovoltaic Module System Identification**
Linda Shelembe, Paul Barendse
*University of Cape Town, South Africa*

**1140 | A Quantitative Feedback Theory Approach to Converter-Based Broadband Impedance Spectroscopy for Online Condition Monitoring of Photovoltaic Modules**
Linda Shelembe, Paul Barendse
*University of Cape Town, South Africa*

**1368 | Light Intensity Modulation and Two-Port Network Analysis of Dynamic Response of Photovoltaic Module**
Thomas Link, Sean Youngblood, Lauren Boulay, S.M. Rakiul Islam, Eric Donkor, Sung-Yeul Park
*University of Connecticut, United States*

**1281 | A Traction Inverter Design for Increasing the DC Link Voltage in Electric Vehicles**
Hui Zhang
*State University of New York at Oswego, United States*

**1088 | HVDC Transmission of Offshore Wind Farm Using Current-Source Actively Commutated Converter with Very-Low-Capacity AC Network**
Zixin Li[1,2], Kedong Luan[1,2], Fei Xu[1,2], Fanqiang Gao[1,2], Cong Zhao[1,2], Ping Wang[1,2], Yaohua Li[1,2]
*[1]Chinese Academy of Sciences, China; [2]University of Chinese Academy of Sciences, China*

**1254 | Online Condition Monitoring of Fuel Cells (FC) by Implementing Electrical Impedance Spectroscopy Using a Switch-Mode DC-DC Converter**
Surprise Mahlangu, Paul Barendse
*University of Cape Town, South Africa*

**2294 | Power Switch Open-Circuit Fault-Diagnosis Based on a Shallow Long-Short Term Memory Neural Network: Investigation of an Interleaved Buck Converter for Electrolyser Applications**
Rahul Kumar[1], Shanal Kumar[1], Giansalvo Cirrincione[2], Maurizio Cirrincione[1], Damien Guilbert[3], Krishnil Ram[1], Ali Mohammadi[1]
*[1]The University of the South Pacific, Fiji; [2]University of Picardy Jules Verne, France; [3]University of Lorraine, France*

## Session A12: Architectures for Renewable and Hybrid Renewable Energy Systems

**2170 | Three-Port Multilevel Converter for Hourly Dispatching Solar PV Power with Battery Energy Storage System**
Pranoy Roy, JiangBiao He, Aaron Cramer
*University of Kentucky, United States*

**2513 | Synchronizing Control of Wind Turbine Driven Doubly Fed Induction Generator System with DG in Remote Area Involving Solar PV-Battery Energy Storage**
Sambasivaiah Puchalapalli, Bhim Singh
*Indian Institute of Technology Delhi, India*

**2459 | Smoothing of PV Output Power in Grid-Tied Energy Storage System with Model Predictive Control and Battery Lifetime Consideration**
Md Safayatullah, Qun Zhou, Issa Batarseh
*University of Central Florida, United States*

**1973 | A Direct AC/AC Modular Multilevel Cascade Converter Based on Bridge Cells with Distributed Energy Resources**
Bruno E. de O.B. Luna[1], Cursino B. Jacobina[2], Alexandre C. Oliveira[2], Nustenil S.M.L. Marinus[3]
*[1]Federal Rural University of the Semi-arid Region, Brazil; [2]Federal University of Campina Grande, Brazil; [3]Federal Institute of Education, Science and Technology of Ceará, Brazil*

**2188 | Optimization of Reactive Power Distribution in Series PV-Battery-Hybrid Systems**
Yiwei Pan[1], Ariya Sangwongwanich[1], Yongheng Yang[2], Frede Blaabjerg[1]
*[1]Aalborg University, Denmark; [2]Zhejiang University, China*

**1287 | Modular Differential Power Processing Architecture Utilizing Isolated Bus to Virtually Unify Photovoltaic Panel Characteristics in Large-Scale Systems**
Takumi Suzuki, Masatoshi Uno
*Ibaraki University, Japan*

## Session A13: Renewable Energy and Storage Systems

**1695 | An Efficient and Compact Single-Stage High-Frequency-Link Medium Voltage AC to DC Converter**
Harisyam P.V., Dibakar Das, Kaushik Basu
*Indian Institute of Science, India*

**1663 | Impact of Partial Power Processing Dual-Active Bridge Converter on Li-Ion Battery Storage Systems**
Hamzeh Beiranvand, Felix Hoffmann, Frederik Hahn, Marco Liserre
*Christian-Albrechts-Universität zu Kiel, Germany*

**2523 | Modular Wireless Power Transmission for Photovoltaic Subpanel System**
Yue Zheng, Zeyu Cheng, Chang Liu, Hongling Liu, Mahshid Amirabadi, Brad Lehman
*Northeastern University, United States*

**1664 | Design of an Isolated DC-DC Converter for PV Micro-Inverters with Planar Transformer and PCB Integrated Winding**
Tobias Manthey, Tobias Brinker, Jens Friebe
*Leibniz Universität Hannover, Germany*

**1803 | Hardware and Control Design Considerations for a Mobile 1 MW Input-Series Output-Parallel (ISOP) DC-DC Converter in Medium Voltage Range**
David Tatusch[1], Jens Friebe[1], Anton Gorodnichev[2], Daniel Haake[2], Fabian Schnabel[2], Marco Jung[3]
*[1]Leibniz Universität Hannover, Germany; [2]Fraunhofer Institute for Energy Economics and Energy System Technology, Germany; [3]Bonn-Rhein-Sieg University of Applied Sciences, Germany*

**2437 | Optimized AC/DC Dual Active Bridge Converter Using Monolithic SiC Bidirectional FET (BiDFET) for Solar PV Applications**
Suyash Sushilkumar Shah, Ramandeep Narwal, Subhashish Bhattacharya, Ajit Kanale, Tzu-Hsuan Cheng, Utkarsh Mehrotra, Aditi Agarwal, B. Jayant Baliga, Douglas C. Hopkins
*North Carolina State University, United States*

## Session A14: Applications for Renewable and Sustainable Energy Systems

**2233 | Reliable Method for the Measurement of Diffusion Capacitance in Solar Photovoltaic Cells**
Alireza Ramyar, Yasir Altheyabi, Al-Thaddeus Avestruz
*University of Michigan, United States*

**1593 | A Lead-Lag Filter for Virtual Synchronous Machines with Improved Electromechanical Damping**
Fabio Mandrile, Vincenzo Mallemaci, Enrico Carpaneto, Radu Bojoi
*Politecnico di Torino, Italy*

**2026 | Multisampling Based Grid Impedance Estimation for Two-Cell Interleaved Three-Phase Inverters**
Shan He, Dao Zhou, Xiongfei Wang, Frede Blaabjerg
*Aalborg University, Denmark*

**2424 | Levelized Cost of Energy Optimization in Hybrid PV Plants by Energy Storage for Ramp-Rate Control Operation**
Irene Peláez, Cristian Blanco, Andrés Suarez, Ángel Navarro, Pablo García
*University of Oviedo, Spain*

**1363 | Control Strategy to Attenuate Voltage Oscillations under Unbalanced Power Distribution in Large Scale Photovoltaic Cascaded Multilevel Converters**
Yuniel León-Ruiz, Mario González-García, Ricardo Álvarez-Salas, Víctor Cárdenas, Rosa Iris Viera-Díaz
*Universidad Autónoma de San Luis Potosí, Mexico*

# Topic B: Smart Grid and Utility Applications

## Session B01: Power Converters for Distributed Resources and Microgrids

**1924 | An Isolated Voltage Injection Based Hybrid Circuit Breaker for MVDC Applications**
Abdul Basit Mirza, Yalda Azadeh, Hongwu Peng, Fang Luo
*Stony Brook University, United States*

**2227 | Solid State Circuit Breaker Design with Discrete SiC MOSFETs for Aircraft Electrification Application**
Piranavan Suntharalingam, Armen Baronian
*Eaton, United States*

**2134 | Modeling of Solid-State Circuit Breaker during Current Interruption Phase**
Dehao Qin[1], Di Zhang[2], Chuanyang Li[3], Dong Dong[4], Yang Cao[3], Zheyu Zhang[1]
*[1]Clemson University, United States; [2]Naval Postgraduate School, United States; [3]University of Connecticut, United States; [4]Virginia Polytechnic Institute and State University, United States*

**1671 | Control of a Three-Phase Four-Wire Modular Multilevel Converter as a Grid Emulator in Fault Scenarios**
Ming Jia, Shenghui Cui, Katharina Hetzenecker, Jingxin Hu, Rik W. De Doncker
*RWTH Aachen University, Germany*

**2011 | A New Fully Soft-Switched, Single-Stage Bidirectional LLC Resonant Based AC/DC Converter for Hybrid Micro-Grid with Active Ripple Energy Storage**
Parham Mohamadi, John Lam
*York University, Canada*

**1975 | 3-Phase Back to Back Active Power Filter for a Multi-Generator Power System with Reduced DC-Link Capacitor**
Jongwan Kim[1], Jih-Sheng Lai[2]
*[1]Texas Instruments, United States; [2]Virginia Polytechnic Institute and State University, United States*

**2301 | Residual Power Transfer Capability Analysis of an MMC-SST under Submodule IGBT Open-Circuit Fault**
Jiajie Zang[1], Jiacheng Wang[1], Jianwen Zhang[2], Jianqiao Zhou[2], Jiahu Guo[2], Dongmin Xi[3]
*[1]Simon Fraser University, Canada; [2]Shanghai Jiao Tong University, China; [3]Inner Mongolia University of Technology, China*

## Session B02: V2G and G2V

**1181 Distributed Control Design for V2G in DC Fast Charging Stations**
Asal Zabetian-Hosseini, Geza Joos, Benoit Boulet
*McGill University, Canada*

**2500 | A New Modular Level-2 PEV Charger for Plug-In Electric Vehicle: Design and Implementation**
Laith Alkhawaldeh, Lingli Gong, Mohamed Youssef
*Ontario Tech University, Canada*

**2098 | lectric Vehicle Battery as Energy Storage Unit Consider Renewable Power Uncertainty**
Qiyun Dang, Di Wu, Benoit Boulet
*McGill Univesity, Canada*

**1339 | Passenger Weight Detection by Air Suspension Pressure Monitoring for Smart Grid Integration of Electric Buses**
Utz Spaeth, Heiko Fechtner, Michele Weisbach, Alexander Popp, Benedikt Schmuelling
*University of Wuppertal, Germany*

## Session B03: Control of DC Microgrids

**1950 | A Plug-and-Play Capable Multi-Agent Network for Distributed Consensus-Based Operation in DC Power Systems**
Anas Alseyat, Md Habib Ullah, Jae-Do Park
*University of Colorado Denver, United States*

**1777 | A Power Electronics-Based Power HIL Real Time Simulation Platform for Evaluating PV-BES Converters on DC Microgrids**
Isuru Jayawardana, Carl Ngai Man Ho
*University of Manitoba, Canada*

**1853 | Tertiary Control Method for Droop Controlled DC-DC Converters to Ensure Bounded Voltages in DC Microgrids**
Shrivatsal Sharma[1], Vishnu Mahadeva Iyer[2], Subhashish Bhattacharya[1], Jun Kikuchi[3], Ke Zou[3]
*[1]North Carolina State University, United States; [2]Indian Institute of Science, India; [3]Ford Motor Company, United States*

**2025 | Weighted Dynamic Aggregation Modeling of DC Microgrid Converters with Droop Control**
Aida Afshar Nia, Navid Shabanikia, S. Ali Khajehoddin
*University of Alberta, Canada*

**2495 | MAS-Based Distributed Load Restoration in Resilient Networked DC Microgids Systems**
Md Habib Ullah, Jae-Do Park
*University of Colorado Denver, United States*

## Session B04: Grid Intelligence for Unique Loading Scenarios

**1149 | Digital Twin for Self-Security of Smart Inverter**
Tareq Hossen, Mehmetcan Gursoy, Behrooz Mirafzal
*Kansas State University, United States*

**1348 | Comparative Investigation of System-Level Optimized Power Conversion System Architectures to Reduce LCOE for Large-Scale PV-Plus-Storage Farms**
Zheng An, Rajendra Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**2076 | A Model-Based Short-Term Load Forecast Methodology for Aggregated Power Consumption of Thermostatically Controlled Appliances in DSM**
Pegah Yazdkhasti, Chris P. Diduch
*University of New Brunswickick, Canada*

**1245 | Review on the State-of-the-Art Operation and Planning of Electric Vehicle Charging Stations in Electricity Distribution Systems**
Mehrdad Aghamohamadi[1], Amin Mahmoudi[1], John K. Ward[2], Mohammed H. Haque[3]
*[1]Flinders University, Australia; [2]CSIRO, Australia; [3]University of South Australia, Australia*

**1243 | Recourse-Based BCD Robust Integrated Bidding Strategy for Multi-Energy Systems under Uncertainties of Load and Energy Prices**
Mehrdad Aghamohamadi[1], Amin Mahmoudi[1], John K. Ward[2], Megan Sleep[1], Mohammed H. Haque[3]
*[1]Flinders University, Australia; [2]CSIRO, Australia; [3]University of South Australia, Australia*

**1069 | Multi-Terminal Soft Open Point with Anti-Islanding and Over-Current Protection Capability**
Han Deng[1], Yang Qi[2], Jingyang Fang[3], Vincent Debusschere[4], Yi Tang[1]
*[1]Nanyang Technological University, Singapore; [2]Northwestern Polytechnical University; [3]University of Kaiserslautern, Germany; [4]Grenoble Institute of Technology, France*

**1221 | Fault-Tolerant Distribution Network Enabled by Series Soft Open Point**
Yang Qi[1], Han Deng[2], Yi Tang[2]
*[1]Northwestern Polytechnical University, China; [2]Nanyang Technological University, Singapore*

## Session B05: Power Converter Utilization in Microgrids

**1489 | Reactive Power Allocation of PV Inverters for Voltage Support in Power Systems Based on Transactive Energy Approach**
Paychuda Kritprajun[1], Joshua C. Hambrick[2], Leon M. Tolbert[1], Yunting Liu[1], Jiaojiao Dong[1], Lin Zhu[1], Qihuan Dong[1], Kevin Schneider[3]
*[1]The The University of Tennessee Knoxville, United States; [2]Oak Ridge National Laboratory, United States; [3]Pacific Northwest National Laboratory, United States*

**1892 | Development of a Power Electronics-Based Testbed for a Flexible Combined Heat and Power System**
Haiguo Li[1], Dingrui Li[1], Zihan Gao[1], Yiwei Ma[1], Zhe Yang[1], Jingxin Wang[1], Fred Wang[1,2]
*[1]University of Tennessee Knoxville, United States; [2]Oak Ridge National Laboratory, United States*

**1292 | Optimal Sizing of Grid-Tied Residential Microgrids under Real-Time Pricing**
Rahmat Khezri[1], Amin Mahmoudi[1], Mohammad Hassan Khooban[2], Nesimi Ertugrul[3]
*[1]Flinders University, Australia; [2]Aarhus University, Denmark; [3]University of Adelaide, Australia*

**1742 | Active and Reactive Power Distribution for Cascaded-H-Bridge Microinverters under Island Microgrid**
Maohang Qiu, Mengxuan Wei, Shuai Yang, Xiaoyan Liu, Dong Cao
*University of Dayton, United States*

**2007 | Microgrid Light-Load Efficiency Improvement Based on Online-Inverter Detection**
Ali Sheykhi, Nima Amouzegar Ashtiani, S. Ali Khajehoddin
*University of Alberta, Canada*

**2267 | Reliability/Cost-Based Power Routing in Power Electronic-Based Power Systems**
Saeed Peyghami, Frede Blaabjerg
*Aalborg University, Denmark*

**1835 | Quickest Detection of Series Arc Faults on DC Microgrids**
Kaushik Gajula, Vu Le, Xiu Yao, Shaofeng Zou, Luis Herrera
*University at Buffalo, United States*

## Session B06: Smart Buildings and Energy Management Strategies

**1051 | A Novel Solar Harvesting Modular Wireless Sensor Mote for Green House Applications: Design & Implementation**
Lingli Gong, Anshuman Sharma, Jordan Henry, Mohamed Youssef
*Ontario Tech University, Canada*

**1326 | Smart Microgrid Architecture for Home Energy Management System**
Majed Shakir, Yevgen Biletskiy
*University of New Brunswick, Canada*

**1902 | Generalized Energy Storage Model-in-the-Loop Suitable for Energy Star and CTA-2045 Control Types**
Huangjie Gong[1], Evan S. Jones[1], A.H.M. Jakaria[2], Aminul Huque[2], Ajit Renjit[2], Dan M. Ionel[2]
*[1]University of Kentucky, United States; [2]Electric Power Research Institute, United States*

**2017 | A Dynamic Load Control Strategy for an Efficient Building Demand Response**
Konrad Erich Kork Schmitt, Ilham Osman, Rabindra Bhatta, Mahtab Murshed, Manohar Chamana, Stephen Bayne
*Texas Tech University, United States*

**2460 | Control Architectures of Solar-Powered HVAC Systems: A DC-DC Converter's Perspective**
Niraja Swaminathan, Bailey Sauter, Yue Cao
*Oregon State University, United States*

**2478 | Distributed Optimal Scheduling in Community-Scale Microgrids**
Maitreyee Marathe, Giri Venkataramanan
*University of Wisconsin Madison, United States*

**1401 | Energy Management and Optimal Planning of a Residential Microgrid with Time-of-Use Electricity Tariffs**
Rahmat Khezri[1], Amin Mahmoudi[1], Mohammed H. Haque[2], Kaveh Khalilpour[3]
*[1]Flinders University, Australia; [2]University of South Australia, Australia; [3]University of Technology Sydney, Australia*

**1714 | Capacity Optimization and Optimal Placement of Battery Energy Storage System for Solar PV Integrated Power Network**
Hassan I. Alhammad, Khalid A. Khan, Fahad Alismail, Muhammad Khalid
*King Fahd University of Petroleum and Minerals, Saudi Arabia*

## Session B07: Stability and Power Quality

**1374 | Impedance Modeling and Analysis of Grid Side Sampling Modular Multilevel Converter**
Bo Zhang[1], Xiong Du[1], Jingbo Zhao[2], Jiapei Zhou[3], Cheng Qian[1], Chengmao Du[1]
*[1]Chongqing University, China; [2]State Grid Jiangsu Electric Power Co., Ltd., China; [3]Global Energy Interconnection Research Institute, China*

**1398 | Transient Modeling of Phase-Locked Loop and its Applications in a Multi-VSCs Grid-Connected System**
Han Yan, Meng Huang, Xikun Fu, Yingjie Tang, Ju Sheng, Xiaoming Zha
*Wuhan University, China*

**1486 | A New Impedance-Based Modeling and Stability Analysis Approach for Power Oscillations between Grid-Forming Inverters**
Hanchao Liu, Zhe Chen, Maozhong Gong, Philip Hart, Yichao Zhang, Yukai Wang
*GE Research, United States*

**1142 | Utilization of Local Phasor Measurements for Interarea-Oscillation Damping with Utility-Scale PV Plant**
Mayur Basu, Jinho Kim, Robert M. Nelms, Eduard Muljadi
*Auburn University, United States*

**2336 | Frequency Selective Damping of Sub-Synchronous Oscillations for Grid-Forming Power Converters**
Ngoc Bao Lai[1], Leonardo Marin[2], Andrés Tarrasó[1], Gregory N. Baltas[1], Pedro Rodriguez[1]
*[1]Luxembourg Institute of Science and Technology, Luxembourg; [2]Universitat Politècnica de Catalunya, Spain*

**1228 | Extremum Seeking Control Based Resonant Frequency Estimation for a Grid-Tied Inverter with LCL Filter**
Yuheng Wu[1], Mohammad Mahmud[1], Yue Zhao[1], Radha Krishna Moorthy[2], Madhu Sudhan Chinthavali[2]
*[1]University of Arkansas, United States; [2]Oak Ridge National Laboratory, United States*

**2250 | Impedance Analysis of Voltage Source Converter Based on Voltage Modulated Matrix**
Chao Wu[1], Xiaoling Xiong[2], Frede Blaabjerg[1]
*[1]Aalborg University, Denmark; [2]North China Electric Power University, China*

## Session B08: Control of Distributed Resources and Microgrids

**1249 | Variable Step Size Modified Clipped Least Mean Square Adaptive Control for Power Quality Improvement for a Solar PV-BS Based Microgrid with Seamless Mode Transfer Capability**
Vivek Narayanan, Bhim Singh
*Indian Institute of Technology Delhi, India*

**1909 | Secondary Voltage and Frequency Regulation for Grid Re-Synchronization in Microgrid with Unified Virtual Oscillator Controlled Multi-Port Converters**
Md Rashed Hassan Bipu, M.A. Awal, Siye Cen, Salina Zabin, Mehnaz Akhter Khan, David Lubkeman, Iqbal Husain
*North Carolina State University, United States*

**2184 | Asymmetrical Voltage Support Control of Three-Phase Four-Wire Inverters with Zero Active Power Oscillation during Grid Faults**
Jun Ge[1], Zhikang Shuai[1], Xia Shen[1], Yu Feng[1], Huimin Zhao[1], Yang Shen[1], Z. John Shen[2]
*[1]Hunan University, China; [2]Illinois Institute of Technology, United States*

**2043 | Enhanced DC-Link Voltage Control in a Virtual Synchronous Generator-Based Building-to-Building Grid considering Islanded Mode Operation**
Mhret Berhe Gebremariam, Pablo Garcia Fernandez, Cristian Blanco Charro, Angel Navarro Rodríguez
*University of Oviedo, Spain*

**2190 | Control Strategy for Multiple Residential Solar PV Systems in Distribution Network with Improved Power Quality**
Yashi Singh, Bhim Singh, Sukumar Mishra
*Indian Institute of Technology Delhi, India*

**1968 | Secant-Based Flexible Power Point Tracking Algorithm for Degraded Photovoltaic Systems**
Anusha Kumaresan[1], Hossein Dehghani Tafti[2], Glen G. Farivar[1], Nandha Kumar Kandasamy[3], Josep Pou[1]
*[1]Nanyang Technological University, Singapore; [2]University of Western Australia, Australia; [3]Singapore Institute of Technology, Singapore*

**2106 | Parameters Stability Region Analysis of Diesel Generation Forming Hybrid Islanded Microgrid with High Penetration of Renewable Energy**
Xun Jiang[1], Meiqin Mao[1], Liuchen Chang[1], Peng Li[2], Yong Shi[1]
*[1]Hefei University of Technology, China; [2]North China Electric Power University, China*

## Session B09: Control of Renewable Energy Resources

**1404 | An Improved Proportional Resonant Controller for Current Harmonics Reduction and Power Ripples Mitigation of Self-Synchronized Grid-Tied PV System under Distorted Grid Voltages**
Manash Kumar Mishra, V.N. Lal
*Indian Institute of Technology (BHU), Varanasi, India*

**1653 | Control of Solar PV-Battery System to Limit in PCC Voltage Rise and for Power Quality Improvement**
Gaurav Modi, Bhim Singh, Yashi Singh
*Indian Institute of Technology Delhi, India*

**1978 | Review of Control Methods in Grid-Connected PV and Energy Storage System**
Md Safayatullah, Reza Rezaii, Mohamed Tamasas Elrais, Issa Batarseh
*University of Central Florida, United States*

**1219 | A Virtual SVPWM Based Power Control Scheme for Multi-Port DC-AC Converters in PV-Battery Hybrid Systems**
Jiangfeng Wang[1], Kai Sun[2], Yunwei Li[1]
*[1]University of Alberta, Canada; [2]Tsinghua University, China*

**2145 | Active Disturbance Rejection Control of Doubly-Fed Induction Generators Driven by Wind Turbines**
Matthew Penne[1], Wei Qiao[1], Liyan Qu[1], Lizhi Qu[1], Renke Huang[2], Qiuhua Huang[2]
*[1]University of Nebraska Lincoln, United States; [2]Pacific Northwest National Laboratory, United States*

**1257 | A Per-Phase Power Controller allowing Smooth Transitions to Islanded Operation**
Hossein Abedini, Tommaso Caldognetto, Paolo Mattavelli
*University of Padova, Italy*

**1605 | An Improved Energy Hub Model for Physical Layer in Energy Router**
Zilong Wang, Tong Liu, Wei Wang, Qicai Ren, Alian Chen
*Shandong University, China*

## Session B10: Control of Grid–Tied Inverters

**1037 | Complex Power Control Method for Grid-Forming Inverter in $\alpha\beta$-Domain**
Ko Oue, Shunya Sano, Toshiji Kato, Kaoru Inoue
*Doshisha University, Japan*

**2417 | Lyapunov Energy Function Based Direct Power Control of Synchronverters under Unbalanced Grid Voltage Conditions**
Vikram Roy Chowdhury, Deepak Divan
*Georgia Institute of Technology, United States*

**2361 | Resynchronization Strategy for a 200kVA Grid-Forming Power Converter**
Andres Tarraso[1], Ngoc Bao Lai[2], Pedro Rodriguez[2]
*[1]Universitat Politècnica de Catalunya, Spain; [2]Luxembourg Institute of Science and Technology, Luxembourg*

**1455 | Angle Droop Design for Grid-Forming Inverters considering Impacts of Virtual Impedance Control**
Le Kong[1], Yaosuo Xue[2], Liang Qiao[1], Fred Wang[1,2]
*[1]University of Tennessee Knoxville, United States; [2]Oak Ridge National Laboratory, United States*

**2115 | Switched-Boost Common-Ground Five-Level (SBCG5L) Grid-Connected Inverter with Single-Stage Dynamic Voltage Boosting Concept**
Reza Barzegarkhoo[1], Majid Farhangi[1], Ricardo P. Aguilera[1], Yam P. Siwakoti[1], Sze Sing Lee[2]
*[1]University of Technology Sydney, Australia; [2]Newcastle University in Singapore, Singapore*

**1194 | An Enhanced Single-Phase Self-Tuning Filter Based Open-Loop Frequency Estimator for Weak Grid**
Anant Kumar Vema[1], Hafiz Ahmed[2], Pedro Roncero-Sánchez[3], Pradyumn Chaturvedi[4]
*[1]National Institue of Technology Hamirpur, India; [2]Bangor University, United Kingdom; [3]Universidad de Castilla-La Mancha, Spain; [4]Visvesvaraya National Institute of Technology, India*

**1410 | Direct Charge Control Method for Mixed Conduction Mode (DCM and TPCM) Grid-Connected Inverter**
Pu Zhao, Qingxin Guan, Yu Zhang
*Huazhong University of Science and Technology, China*

## Session B11: Control of DC Microgrids

**1939 | Comparative Study of Coordinated Photovoltaic and Battery Control Strategies on the Battery Lifetime in Stand-Alone DC Microgrids**
Hein Wai Yan[1], Glen G. Farivar[1], Neha Beniwal[1], Naga Brahmendra Yadav Gorla[1], Hossein Dehghani Tafti[2], Salvador Ceballos[3], Josep Pou[1], Georgios Konstantinou[4]
*[1]Nanyang Technological University, Singapore; [2]University of Western Australia, Australia; [3]Basque Research and Technology Alliance, Spain; [4]University of New South Wales, Australia*

**2029 | Model Predictive Control for Current Sharing and Voltage Balancing in DC Microgrids**
Lalit Kishore Marepalli, Kaushik Gajula, Luis Herrera
*University at Buffalo, United States*

**1913 | Control Strategy for Effective Battery Utilization in a Stand-Alone DC Microgrid with Solar Energy**
Hein Wai Yan[1], Glen G. Farivar[1], Neha Beniwal[1], Naga Brahmendra Yadav Gorla[1], Hossein Dehghani Tafti[2], Salvador Ceballos[3], Josep Pou[1], Georgios Konstantinou[4]
*[1]Nanyang Technological University, Singapore; [2]University of Western Australia, Australia; [3]Basque Research and Technology Alliance, Spain; [4]University of New South Wales, Australia*

**1026 | Distributed Linear State Observer (DLSO)-Based Distributed Secondary Control for DC Microgrids under False Signal Attacks**
Yajie Jiang[1], Yun Yang[2], Siew-Chong Tan[3], Shu-Yuen Ron Hui[4]
*[1]The University of Hong Kong, China; [2]The Hong Kong Polytechnic University, China; [3]Nanyang Technological University, Singapore; [4]Imperial College London, United Kingdom*

**1439 | The Impact of PV Arrays Disturbances on the Performance of Droop Controllers in a DC Microgrid**
Niloofar Ghanbari, Subhashish Bhattacharya
*North Carolina State University, United States*

**2488 | Enhancing Distribution Grid Flexibility Using Active Power Distribution Node Converter Interfaces**
Alvaro Cardoza, Alexis Kwasinski
*University of Pittsburgh, United States*

**2415 | Feedback Linearization Based Direct Power Control of a Three-Phase Grid-Connected Inverter with Online Parameter Update**
Vikram Roy Chowdhury, Deepak Divan
*Georgia Institute of Technology, United States*

## Session B12: Microgrid Control

**1919 | Design Power Control Strategies of Grid-Forming Inverters for Microgrid Application**
Jing Wang
*National Renewable Energy Laboratory, United States*

**2283 | An Enhanced Control Strategy of Bidirectional Interlinking Converters in a Hybrid AC/DC Microgrid**
Qipeng Zheng, Fei Gao
*Shanghai Jiao Tong University, China*

**2555 | Coordination of Protection and Ride-Through Settings for Islanded Facility Microgrids**
Mark Vygoder[1], Farzad Banihashemi[1], Jacob Gudex[1], Robert M. Cuzner[1], Giovanna Oriti[2]
*[1]University of Wisconsin Milwaukee, United States; [2]Naval Postgraduate School, United States*

**1966 | Event-Triggered Self-Learning Control Scheme for Power Electronics Dominated Grid**
Mohsen Hosseinzadehtaher, Amin Y. Fard, Mohammad B. Shadmand
*University of Illinois Chicago, United States*

**1795 | Optimal Separation Method of Dynamic Microgrid Operation**
Xuefei Zhu, Jinho Kim, Eduard Muljadi, R. Mark Nelms
*Auburn University, United States*

**2049 | Improved Delay Compensation in Communication-Based Hierarchical Control of a Low Voltage 3-Phase AC Microgrid Using a Secondary Control Based on Smith Predictor**
Ángel Navarro-Rodríguez, Cristian Blanco, Pablo García, Mohammad Irfan Yousuf
*University of Oviedo, Spain*

**1789 | Analysis of a Complex-Valued Droop Method in AC Microgrids with Complete Steady-State Frequency Compensation Using dq-Decomposition**
Carlos Gómez-Aleixandre, Cristian Blanco, Andrés Suárez-González, Ángel Navarro-Rodríguez, Pablo García
*University of Oviedo, Spain*

## Session B13: Solid State Transformers

**1325 | Doubly-Fed Solid State Auto-Transformer (SSAT) Concept for Multi-Pulse Rectifiers**
Farhana Islam, Harish S. Krishnamoorthy
*University of Houston, United States*

**2004 | 500kVA Hybrid Solid State Transformer (HSST): Modelling and Control**
Sanjay Rajendran, Soumik Sen, Zhicheng Guo, Alex Q. Huang
*The University of Texas at Austin, United States*

**2397 | Design of Nanocrystalline Medium-Voltage Medium-Frequency Three-Phase Transformers for Grid-Connected Applications**
Roderick Amir Gomez Jimenez[1], Germán G. Oggier[2], Roberto A. Fantino[1], Juan Carlos Balda[1], Yue Zhao[1]
*[1]Unviersity of Arkansas, United States; [2]Universidad Nacional de Río Cuarto, Argentina*

**2556 | Insulation Design on High-Frequency Transformer for Solid-State Transformer**
Zheqing Li, Yi-Hsun Hsieh, Qiang Li, Fred C. Lee, Chunyang Zhao
*Virginia Polytechnic Institute and State University, United States*

**2569 | Virtual Prototyping Process for Assessment of Medium Voltage Grid-Connected Solid State Transformer Implementations**
Rounak Siddaiah[1], Mark Vygoder[1], Robert M. Cuzner[1], Juan C. Ordonez[2], Mauricio B. Chagas[2]
*[1]University of Wisconsin Milwaukee, United States; [2]Florida State University, United States*

**1721 | Design Considerations for a 50 kW Dual Bridge Series Resonant DC/DC Converter with Wide-Input Voltage Range for Solid-State Transformers**
Pramod Apte[1], Siqi Lin[1], Lukas Fraeger[2], Jens Friebe[1]
*[1]Leibniz Universität Hannover, Germany; [2]BLOCK Transformatoren-Elektronik GmbH, Germany*

**1574 | Enhanced CurrenT-Type P-HIL Interface Algorithm for Smart Transformers Testing**
Sante Pugliese[1], Marco Liserre[1], Giovanni De Carne[2]
*[1]Christian-Albrechts-Universität zu Kiel, Germany; [2]Karlsruhe Institute of Technology, Germany*

## Session B14: Power Converters for Distributed Resources and Microgrids

**2086 | A New Common-Ground Switched-Boost Five-Level Inverter Suitable for Both Single and Three-Phase Grid-Tied Applications**
Reza Barzegarkhoo, Yam P. Siwakoti, Ricardo P. Aguilera
*University of Technology Sydney, Australia*

**1971 | Design and Development of a Multi-Port Converter for Marine Microgrid Applications**
Md Rifat Kaisar Rachi, Siye Cen, Md Rashed Hassan Bipu, Mehnaz Akhter Khan, Iqbal Husain
*North Carolina State University, United States*

**1387 | Multi-Port DC-DC Converter for Interconnecting Bipolar DC Buses of Bipolar DC Distribution System**
Jun-Young Lee, Jee-Hoon Jung
*Ulsan National Institute of Science and Technology, Korea*

**2438 | A Multiport DC Transformer to Enable Flexible Scalable DC as a Service**
Mickael J. Mauger, Vikram Roy Chowdhury, Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**1518 | A Transformerless Bidirectional Charger for Light Electric Vehicles**
Jitendra Gupta, Bhim Singh, Muhammad Zarkab Farooqi
*Indian Institue of Technology Delhi, India*

**2452 | Design Considerations of Three Phase Active Front End Converter for 13.8 kV Asynchronous Microgrid Power Conditioning System enabled by Series Connection of Gen-3 10 kV SiC MOSFETs**
Nithin Kolli, Sanket Parashar, Raj Kumar Kokkonda, Anup Anurag, Ashish Kumar, Subhashish Bhattacharya, Victor Veliadis
*North Carolina State University, United States*

**1016 | Design of the Hybrid Flexible Power Supply System for AC Electric Arc Furnace**
Chongbin Zhao, Qirong Jiang
*Tsinghua University, China*

**1624 | An Ultra-Low Weight Bidirectional Back end PFC Topology**
Alex Sanchez, Asier Garcia-Bediaga, Itziar Alzuguren, Iñigo Zubitur, Alejandro Rujas
*Ikerlan Technology Research Centre (BRTA), Spain*

## Session B15: High Power, Power Electronic Systems for Utility Applications

**1911 | Solid State Transformers as Enhanced Smart Inverters for Power Quality Improvement in Active Distribution Networks**
Javad Khodabakhsh, Gerry Moschopoulos
*Western University, Canada*

**1044 | Continuous Operation of Wind Power Plants under DC Line Faults in Multi-Circuit HVDC Transmission System**
Mitsuyoshi Enomoto[1], Kenichiro Sano[1], Junya Kanno[2], Junichi Fukushima[2]
*[1]Tokyo Institute of Technology, Japan; [2]Tokyo Electric Power Company Holdings, Japan*

**2090 | A New Delta Hybrid Series STATCOM and DC Capacitor Voltage Balance Using Zero-Sequence Current**
Ibhan Chand Rath, Anshuman Shukla
*Indian Institute of Technology Bombay, India*

**2291 | Inductive Operation of the Low-Capacitance StatCom Using Modular Filter Inductor**
Glen G. Farivar[1], Christopher D. Townsend[2], Hossein Dehghani Tafti[2], Ezequiel Rodriguez[1], Josep Pou[1], Branislav Hredzak[3]
*[1]Nanyang Technological University, Singapore; [2]University of Western Australia, Australia; [3]University of New South Wales, Australia*

**1083 | A Bipolar Hybrid Circuit Breaker for Low-Voltage DC Circuits**
Sudipta Sen[1], Shahab Mehraeen[1], Keyue Smedley[2]
*[1]Louisiana State University, United States; [2]University of California Irvine, United States*

**1090 | Symmetries in Power Electronics**
Jingyang Fang, Stefan M. Goetz
*Duke University, United States*

## Session B16: Hybrid Transformers

**1121 | Magnetic Integration and Modeling of Hybrid Distribution Transformer**
Yibin Liu, Deliang Liang, Yhheng Wang, Lishi Zhang, Dawei Li, Yachen Gao, Zihao Wu, Chenxi Wang, Lutian Tang
*Xian Jiaotong University, China*

**1255 | Multiple Protection Strategies for Hybrid Distribution Transformer Based on DC-Link Voltage Fault-Tolerant Control**
Lishi Zhang, Deliang Liang, Qidong Wen, Hua Liu, Yibin Liu, Yachen Gao, Zihao Wu, Chenxi Wang, Lutian Tang
*[1]Xi'an Jiaotong University, China; [2]State Grid Shaanxi Electric Power Research Institute, China*

**2287 | Autonomous Fail-Normal Switch for Hybrid Transformers**
Emre Durna, Joseph Benzaquen, Rajendra Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**1619 | Active Transformer Functionalities including an Energy Storage System**
Jose David Vidal Leon[1], Andres Tarraso[1], Jose Ignacio Candela[1], Pedro Rodriguez[2]
*[1]Polytechnic University of Catalonia, Spain; [2]Luxembourg Institute of Science and Technology, Luxembourg*

**1118 | Hybrid Smart Transformer for Enhanced Power System Protection Against DC with Advanced Grid Support**
Moazzam Nazir[1], Johan H. Enslin[1], Klaehn Burkes[2]
*[1]Clemson University, United States; [2]Savannah River National Laboratory, United States*

# Topic C: Big Data, Machine Learning, Cyber Security and Design Automation

## Session C01: Big Data, Machine Learning, Cyber Security

**2480 | Intelligent Anomaly Mitigation in Cyber-Physical Inverter-Based Systems**
Asad Ali Khan[1], Sara Ahmed[1], Omar A. Beg[2]
*[1]University of Texas San Antonio, United States; [2]University of Texas Permian Basin, United States*

**2084 | Blockchain-Enabled Security Module for Transforming Conventional Inverters toward Firmware Security-Enhanced Smart Inverters**
Bohyun Ahn, Gomanth Bere, Seerin Ahmad, Jinchun Choi, Taesic Kim, Sung-won Park
*Texas A&M University Kingsville, United States*

**1150 | Load Power Estimation Using a Recurrent Neural Network for the Purpose of Computer Power Energy Efficiency Improvement**
Shinichi Kawaguchi
*Kanagawa Institute of Technology, Japan*

**2095 | Real-Time Implementation of GPU-Accelerated Neural Network Learning for Dynamic System Identification**
Nicholas Autobee, Amanda Rowsell, Patrick Bales-Parks, Jae-Do Park
*University of Colorado Denver, United States*

## Session C02: Artificial Intelligence and Machine Learning

**1371 | Efficient-ArcNet: Series AC Arc Fault Detection Using Lightweight Convolutional Neural Network**
Kamal Chandra Paul[1], Tiefu Zhao[1], Chen Chen[2], Yunsheng Ban[3], Yao Wang[3]
*[1]University of North Carolina Charlotte, United States; [2]University of Central Florida, United States; [3]Hebei University of Technology, China*

**1940 | Real-Time DC Pulsed Power Load Monitoring Using Simplified k-NN Algorithm**
Yue Ma[1], Atif Maqsood[2], Damian Oslebo[3], Keith Corzine[1]
*[1]University of California Santa Cruz, United States; [2]Dynapower Company, LLC, United States; [3]Naval Sea Systems Command, United States*

**2224 | Intelligent Prediction of States in Multi-Port Autonomous Reconfigurable Solar Power Plant (MARS)**
Suman Debnath, Shruti Kulkarni, Catherine Schuman
*Oak Ridge National Laboratory, United States*

**2474 | Detection of Stator Fault in Synchronous Reluctance Machines Using Shallow Neural Network**
Siwan Shachin Narayan[1], Rahul R. Kumar[1], Giansalvo Cirrincione[2], Maurizio Cirrincione[1]
*[1]The University of the South Pacific, Fiji; [2]University of Picardy Jule Verne, France*

**1683 | A Machine Learning Based Method to Efficiently Analyze the Cogging Torque under Manufacturing Tolerances**
Andrea Reales[1], Werner Jara[1], Gabriel Hermosilla[1], Carlos Madariaga[2], Juan Tapia[2], Gerd Bramerdorfer[3]
*[1]Pontificia Universidad Católica de Valparaiso, Chile; [2]Universidad de Concepcion, Chile; [3]Johannes Kepler University Linz, Austria*

## Session C03: Other Topics in Big Data, Machine Learning, Cyber Security and Design Automation

**1702 | Fast and Accurate Inductance Extraction for Power Module Layout Optimization Using Loop-Based Method**
Quang Le, Imam Al Razi, Yarui Peng, H. Alan Mantooth
*University of Arkansas, United States*

**2554 | On the Explainability of Black Box Data-Driven Controllers for Power Electronic Converters**
Subham Sahoo, Huai Wang, Frede Blaabjerg
*Aalborg University, Denmark*

**1346 | Using Machine Learning Technology to Online Predict the Maximum Common Mode Current of Three-Phase Motor Drive Inverter**
Ximu Zhang[1], Yang Huang[1], Jared Walden[1], Hua Bai[1], Fanning Jin[2], Xiaodong Shi[2], Bing Cheng[2]
*[1]University of Tennessee Knoxville, United States; [2]Mercedes-Benz R&D North America, Inc., United States*

## Session C04: Data Analysis for Batteries and Energy Storage

**1528 | Comparative Analysis on the Electrical State-of-Health Degradation of 21700 LiNiCoAlO2 Based on Alternating and Direct Currents**
Bongwoo Kwak[1], Myungbok Kim[1], Jonghoon Kim[2]
*[1]Korea Institute of Industrial Technology, Korea; [2]Chungnam National University, Korea*

**2292 | Artificial Intelligence-Based Hardware Fault Detection for Battery Balancing Circuits**
Kyoung-Tak Kim[1], Hyun-Jun Lee[1], Joung-hu Park[1], Gomanth Bere[2], Justin J. Ochoa[2], Taesic Kim[2]
*[1]Soongsil University, Korea; [2]Texas A&M University Kingsville, United States*

**1882 | Fast and Robust Estimation of Lithium-Ion Batteries State of Health Using Ensemble Learning**
Xin Sui, Shan He, Soren Byg Vilsen, Remus Teodorescu, Daniel-Ioan Stroe
*Aalborg University, Denmark*

**2396 | Lifetime Modeling and Analysis of Aqueous Organic Redox-Flow Batteries for Renewable Energy Application**
Zhongting Tang[1], Ariya Sangwongwanich[1], Yongheng Yang[2], Charlotte Overgaard Wilhelmsen[1], Sebastian Birkedal Kristensen[1], Jens Laurids Sørensen[1], Jens Muff[1], Frede Blaabjerg[1]
*[1]Aalborg University, Denmark; [2]Zhejiang University, China*

**1513 | A Bidirectional Cell-to-Buffer Battery Equalizer at Boundary Conduction Mode with Constant On-Time Control**
Yiqing Lu, Zhengqi Wei, Haoyu Wang
*ShanghaiTech University, China*

## Session C05: Cyber Security and Cyber Attacks

**1356 | Model-Based Cyber-Attack Detection for Voltage Source Converters in Island Microgrids**
Jinan Zhang, Jin Ye, Lulu Guo
*University of Georgia, United States*

**1865 | Detection and Mitigation of Cyber-Attacks against Power Measurement Channels Using LSTM Neural Networks**
Mitchell Wilson, Hisham Mahmood, Joseph Giordano
*Florida Polytechnic University, United States*

**1737 | Stability Investigation of Cooperative Controlled DC Microgrid under Stealth Cyber Attacks**
Minrui Leng[1], Subham Sahoo[2], Frede Blaabjerg[2]
*[1]Sichuan University, China; [2]Aalborg University, Denmark*

**1917 | An Active Detection Scheme for Sensor Spoofing in Grid-Tied PV Systems**
Hasan Ibrahim, Jorge Ramos-Ruiz, Jaewon Kim, Woo Hyun Ko, Tong Huang, Prasad Enjeti, P.R. Kumar, Le Xie
*Texas A&M University, United States*

**1286 | A Resilient Scheme for Mitigating False Data Injection Attacks in Distributed DC Microgrids**
Jingqiu Zhang[1], Guruprasanesh Raman[1], Gururaghav Raman[1], Jimmy Chih-Hsien Peng[1], Weidong Xiao[2]
*[1]National University of Singapore, Singapore; [2]The University of Sydney, Australia*

# Topic D: Transportation Electrification Applications

## Session D01: Electric Drivetrains

**1195 | Rule-Based Energy Management Strategy of a Power-Split Hybrid Electric Vehicle with LSTM Network Prediction Model**
Helia Jamali, Yue Wang, Yuhang Yang, Saeid Habibi, Ali Emadi
*McMaster University, Canada*

**2171 | Reconfigurable Cascaded Multilevel Converter: A New Topology for EV Powertrain**
Giulia Tresca[1], Riccardo Leuzzi[1], Andrea Formentini[2], Luca Rovere[3], Norma Anglani[1], Pericle Zanchetta[3]
*[1]Università di Pavià, Italy; [2]University of Genoa, Italy; [3]University of Nottingham, United Kingdom*

**1239 | Electromagnetic and Direct-Cooling Analysis of a Traction Motor**
John Wanjiku[1], Lan Ge[2], Zhiyuan Zhang[2], Kang Chang[2], Chengtao Wu[2], Fuliang Zhan[2]
*[1]Siemens Digital Industries Software, Canada; [2]Siemens Digital Industries Software, China*

**1297 | A Composite Converter with Reduced Power Electronics for Electric Powertrain Applications**
Xiaokang Zhang, Jean-Yves Gauthier, Xuefang Lin-Shi
*INSA-Lyon, France*

**2322 | Impact of Current Profiling for NVH Mitigation on Switched Reluctance Machine Drive Accessories**
Shuvajit Das[1], Anik Chowdhury[1], Md Ehsanul Haque[1], Md Tawhid Bin Tarek[1], Yilmaz Sozer[1], David Colavincenzo[2], Fernando Venegas[2], Jeffrey Geither[2]
*[1]The University of Akron, United States; [2]Bendix Commercial Vehicle Systems, United States*

## Session D02: Battery Management Systems for Transportation

**1174 | Model-Based Design Methodology for Capacitor-Based Equalization Circuits**
Francesco Porpora[1], Mauro Di Monaco[1], Giuseppe Tomasso[1], Matilde D'Arpino[2]
*[1]University of Cassino and Southern Lazio, Italy; [2]The Ohio State University, United States*

**2389 | Predictive Battery SoC Control for Dual Propulsion Differential Four Wheel Drive Electric Vehicle**
Utkal Ranjan Muduli[1], Khaled Al Jaafari[1], Ranjan Kumar Behera[2], Abdul R. Beig[1], Khalifa Al Hosani[1], Jamal Y. Alsawalhi[1]
*[1]Khalifa University, United Arab Emirates; [2]Indian Institute of Technology Patna, India*

**1768 | A New Design Optimization Method for Dynamic Inductive Power Transfer Systems utilizing a Neural Network**
Shuntaro Inoue, Reebal Nimri, Abhilash Kamineni, Regan Zane
*Utah State University, United States*

**1498 | A High-Density 5kW 800V to 48V DC/DC Converter for Vehicle Applications**
Xinyuan Du[1], Fei Diao[1], Yue Zhao[1], Kevin Uvodich[2], Nenad Miljkovic[2]
*[1]University of Arkansas, United States; [2]University of Illinois at Urbana-Champaign, United States*

## Session D03: Charging Techniques for Transportation

**2028 | A Lightweight Multilevel Power Converter for Electric Aircraft Drivetrain**
Samantha Coday, Nathan Ellis, Zitao Liao, Robert C.N. Pilawa-Podgurski
*University of California Berkeley, United States*

**2507 | Electrical Insulation Design and Qualification of a SiC-Based Generator-Rectifier Unit (GRU) for High-Altitude Operation**
Lakshmi Ravi[1], Jiewen Hu[1], Xingchen Zhao[1], Dong Dong[1], Rolando Burgos[1], Sriram Chandrasekaran[2], Saeed Alipour[2], Richard Eddins[3]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Raytheon Technologies, United States; [3]GE Aviation, United States*

**1049 | A New Multilevel Inverter under Distributed Unbalance DC Voltage for Electric Vehicle Applications**
Mohammad Bhuiya, Lingli Gong, Mohamed Z. Youssef
*Ontario Tech University, Canada*

**2021 | Open Device Fault Detection and Fail Safe Action Strategy for a Premium Class Electric Vehicle with a Dual Inverter fed Open Winding Motor**
Hiroaki Matsumori[1], Yuto Maeda[1], Takashi Kosaka[1], Nobuyuki Matsui[1], Hiroki Iwai[2], Teppei Tsuda[2], Subrata Saha[2]
*[1]Nagoya Institute of Technology, Japan; [2]Aisin Corporation, Japan*

## Session D04: Transportation Electrification – 1

**2501 | A Novel Buck-Boost Type DC-DC Converter Topology for Electric Vehicle Applications**
Mohammad Saleh Khan[1], Soumya Shubhra Nag[1], Anandarup Das[1], Changwoo Yoon[2]
*[1]Indian Institute of Technology Delhi, India; [2]Seoul National University of Science and Technology, Korea*

**1614 | Development of an Engine Starter Generator and Implementation of a Power Efficient Starting Procedure**
Lukas Killingseder[1], Wolfgang Gruber[2], Alexander Burgstaller[1], Martin Freudenthaler[1]
*[1]BRP-Rotax GmbH & Co. KG, Austria; [2]Johannes Kepler University Linz, Austria*

**1170 | Influence of the HV DC Bus Impedance on the Current Ripple Distribution in Electric Vehicles**
Michael Schlüter, Marius Gentejohann, Sibylle Dieckerhoff
*Technische Universität Berlin, Germany*

**1568 | A Real-Time Operational Cost Minimization Strategy for Energy Management of Fuel Cell Electric Vehicles**
Chao Jia, Junwei Cui, Wei Qiao, Liyan Qu
*University of Nebraska Lincoln, United States*

**1509 | Design and Analysis of a Flexible Multi-Output Wireless Power Transfer System with Variable Inductor**
Jin Zhao, Yonglin Zhang, Liang Qi
*Jiangsu University of Science and Technology, China*

**1352 | Analysis and Mitigation of Oscillations in Inductive Power Transfer Systems with Constant Voltage Load and Pulse Density Modulation**
Jiayu Zhou[1], Giuseppe Guidi[2], Kjell Ljokelsoy[2], Jon Are Suul[1,2]
*[1]Norwegian University of Science and Technology, Norway; [2]SINTEF Energy Research, Norway*

**2311 | Low-Frequency Oscillations Analysis in AC Railway Networks Using Eigenmode Identification**
Paul Frutos[1], Juan Manuel Guerrero[1], Iker Muniategui[2], Iban Vicente[2], Aitor Endemano[2], Fernando Briz[1]
*[1]University of Oviedo, Spain; [2]Ingeteam SA, Spain*

**1303 | Impedance Based Design Method for Interoperable Wireless Power Transfer Systems**
Denis Kraus[1], Marius Hassler[1], Grant Covic[2], Hans-Georg Herzog[1]
*[1]Technical University of Munich, Germany; [2]The University of Auckland, New Zealand*

## Session D05: Transportation Electrification – 2

**1738 | Development of a Fuel Cell Hybrid Electric Vertical Takeoff and Landing Aircraft Power Train**
Mengxuan Wei[1], Maohang Qiu[1], Shuai Yang[1], Xiaoyan Liu[1], Jeff Taylor[2], Dong Cao[1]
*[1]University of Dayton, United States; [2]Event 38 Unmanned Systems, United States*

**2352 | Phase Collaborative Interleaving Method to Reduce DC-Link Current Ripple in Switched Reluctance Machine Drive**
Md Ehsanul Haque[1], Anik Chowdhury[1], Shuvajit Das[1], Yilmaz Sozer[1], Fernando Venegas[2], David Colavincenzo[2]
*[1]The University of Akron, United States; [2]Bendix Commercial Vehicle Systems, United States*

**2509 | Comparison of Medium-Voltage High-Frequency Power Inverters for Aircraft Propulsion Drives**
Majid T. Fard, JiangBiao He
*University of Kentucky, United States*

**2314 | Mechanical Performance of Transverse Flux Machines at High Speeds of Operation**
Shuvajit Das[1], Anik Chowdhury[1], Teppei Tsuda[2], Naoto Saito[2], Subrata Saha[2], Yilmaz Sozer[1]
*[1]The University of Akron, United States; [2]Aisin Corporation, Japan*

**1972 | Multilevel Traction Converter Topology with Medium Frequency Isolation**
Bishwajyoti Purkayastha, Tanmoy Bhattacharya
*Indian Institute of Technology Kharagpur, India*

## Session D06: Transportation Electrification – 3

**1501 | Load Management Strategy for DC Fast Charging Stations**
Sony Susan Varghese[1], Geza Joos[1], Syed Qaseem Ali[2]
*[1]McGill University, Canada; [2]OPAL-RT Technologies, Inc., Canada*

**2328 | Position Fault Detection and Failover Method for UAM PMSM Control**
Taeyoen Lee[1], Heekwang Lee[2], Bonkil Koo[1], Kwanghee Nam[1]
*[1]Pohang University of Science and Technology, Korea; [2]Hyundai Motor Company, Korea*

**2430 | Fleet Speed Profile Optimization for Autonomous and Connected Vehicles**
Mohammad Arifur Rahman, Md Ehsanul Haque, Yilmaz Sozer, Ali Riza Ozdemir
*The University of Akron, United States*

**1247 | Design Methodology for a Transformerless Multilevel Inductive Power Transfer System**
Jaehong Lee[1], Myung-Yong Kim[2], Seung-Hwan Lee[1]
*[1]University of Seoul, Korea; [2]Korea Railroad Research Institute, Korea*

**1013 | Current Balancing of a Multi-Phase Inverter for Wireless Power Transfer Systems Based on Mutually Negatively Coupled Inductors**
Yiming Zhang[1], Yuanchao Wu[1], Shuxin Chen[2], Xin Li[2], Yi Tang[2]
*[1]Fuzhou University, China; [2]Nanyang Technological University, Singapore*

## Session D07: Electric Vehicle Charging

**2344 | Efficiency of Motor and Inverter Reconfigured as a Boost-Buck Connected Integrated BEV Charger**
Erik Hoevenaars[1], Marc Hiller[2]
*[1]Robert Bosch GmbH, Germany; [2]Karlsruhe Institute of Technology, Germany*

**1716 | Analysis and Design of a Multiport Converter Based Integrated On-Board Charger for Electric Vehicle Powertrains**
Arka Basu, Subhajyoti Mukherjee
*Indian Institute of Technology Bhubaneswar, India*

**1730 | Input Power Quality Control of Integrated On-Board Charger with Reduced DC-Link Capacitance**
Muhammad Zarkab, Bhim Singh, B.K. Panigrahi
*Indian Institute of Technology Delhi, India*

**1347 | A Flexible Resonant Converter Based Battery Charger with Power Relays**
Yuqi Wei, Alan Mantooth
*University of Arkansas, United States*

**1725 | A Two-Stage Standard On-Board Electric Vehicle Charger with Minimum Switch Count**
Soumya Ranjan Meher, Rajeev Kumar Singh
*Indian Institute of Technology (BHU), Varanasi, India*

## Session D08: EV Battery Management – 1

**1107 | A Battery Capacity Estimation Method Using Surface Temperature Change under Constant-Current Charge Scenario**
Jufeng Yang[1], Yingfeng Cai[1], Chris Mi[2]
*[1]Jiangsu University, China; [2]San Diego State University, United States*

**1288 | DAB Converter with Trapezoidal Wave Heating Capability for Lithium-Ion Battery of Electric Vehicles**
Yuta Sasama, Masatoshi Uno
*Ibaraki University, Japan*

**1632 | Stress-Constrained Fast Charging of Lithium-Ion Battery with Predictive Control**
Hao Zhong, Hongwen He, Zhongbao Wei
*Beijing Institute of Technology, China*

**1108 | State-of-Health Estimation for Lithium Iron Phosphate Batteries Based on Constant-Voltage Charge Data Using a Resistor-Inductor Network Based Equivalent Circuit Model**
Jufeng Yang[1], Yingfeng Cai[1], Chris Mi[2]
*[1]Jiangsu University, China; [2]San Diego State University, United States*

## Session D09: EV Battery Management – 2

**1554 | Multi-State Fusion Based Internal Short Circuit Fault Diagnostic for Lithium-Ion Battery**
Jian Hu, Zhongbao Wei, Hongwen He
*Beijing Institute of Technology, China*

**1039 | Parameter Identification of Lithium Battery Thermal Model Based on Two-Stage Forgetting Factor Least Square Method**
Marui Li[1], Chaoyu Dong[1,2], Yunfei Mu[1], Xiaohong Dong[3], Jingming Cao[1], Hongjie Jia[1]
*[1]Tianjin University, China; [2]Imperial College London, United Kingdom; [3]Hebei University, China*

**1727 | The Effect of Pulsed Current on the Lifetime of Lithium-Ion Batteries**
Xinrong Huang[1], Siyu Jin[1], Jinhao Meng[2], Remus Teodorescu[1], Daniel-Ioan Stroe[1]
*[1]Aalborg University, Denmark; [2]University of Electronic Science and Technology of China, China*

**2175 | Sorting Selection Balancing Control for the Modular Multilevel DC/DC Converter in Battery Swapping Stations**
Zhan Ma[1], Xiuqing Yi[2], Wei Li[1], Feng Gao[1], Fujia Yu[3]
*[1]Shandong University, China; [2]Shandong University of Traditional Chinese Medicine, China; [3]State Grid Binzhou Power Supply Company, China*

# Topic E: Power Converter Topologies

## Session E01: DC-DC Non-Isolated – 1

**2033 | Modified Split-Phase Switching with Improved Fly Capacitor Utilization in a 48V-to-POL Dual Inductor Hybrid-Dickson Converter**
Nathan M. Ellis, Robert C.N. Pilawa-Podgurski
*University of California Berkeley, United States*

**2504 | A Comparative Study of SiC JFET Super-Cascode Topologies**
Lee Gill, Luciano A. Garcia Rodriguez, Jacob Mueller, Jason Neely
*Sandia National Laboratories, United States*

**1692 | Non-Isolated DC-DC Converter Implementations Based on Piezoelectric Transformers**
Elaine Ng, Jessica D. Boles, Jeffrey H. Lang, David J. Perreault
*Massachusetts Institute of Technology, United States*

**1134 | A Single-Switch Capacitor Clamped Non-Resonant Linear Soft-Switching DC-DC Converter**
Yangbin Zeng, Hong Li, Haitao Du, Zhidong Qiu, Ziqi Chen
*Beijing Jiaotong University, China*

**1433 | Voltage Gain Control of a Switched-Resonator Converter Based on the 2:1 Switched-Capacitor Cell**
Dulika Nayanasiri, Yunwei Li
*University of Alberta, Canada*

## Session E02: DC-DC Isolated – 1

**2321 | Current Reduction by Tuning Split Ratio for a Three-Phase LLC Resonant Converter with Split Resonant Capacitors**
Kazuto Takagi, Yuuki Aoyagi, Akiteru Chiba
*GS Yuasa Infrastructure Systems Co., Ltd., Japan*

**1761 | Design Optimization of PCB-Winding Matrix Transformer for 400V/12V Unregulated LLC Converter**
Pranav Raj Prakash, Ahmed Nabih, Qiang Li
*Virginia Polytechnic Institute and State University, United States*

**1129 | Analytical Model of the Current Stress in Active-Bridge Active-Clamp Converter for More Electric Aircraft**
Alejandro Fernandez-Hernandez[1], Asier Garcia-Bediaga[1], Irma Villar[1], Gonzalo Abad[2]
*[1]Ikerlan Technology Research Centre (BRTA), Spain; [2]Mondragon Unibertsitatea, Spain*

**1765 | Bidirectional Resonant Frequency Tracking for CLLC Converters Based on Voltage Falling Edges**
Jun Min, Martin Ordonez
*The University of British Columbia, Canada*

**1163 | Controller-in-the-Loop of a Transformer Saturation Control for High-Power Three-Phase Dual-Active Bridge DC-DC Converters**
Johannes Voss, Raphael Mencher, Philipp Joebges, Jan Mathé, Rik W. De Doncker
*RWTH Aachen University, Germany*

## Session E03: DC-DC Isolated – 2

**1711 | A Modified Soft-Switched Push-Pull Topology with Phase-Shift Modulation**
Mandeep Singh Rana, Santanu K. Mishra, Hitesh Kumar
*Indian Institute of Technology Kanpur, India*

**1474 | Low-Profile and High-Efficiency 3 kW 400 V-48 V LLC Converter with a Matrix of Four Transformers and Inductors for 48V Power Architecture for Data Centers**
Ahmed Nabih, Qiang Li
*Virginia Polytechnic Institute and State University, United States*

**2442 | Time-Domain Analysis of a Low Q Three-Phase Series Resonant Converter**
Abirami Kalathy, Majid Pahlevani, Praveen Jain
*Queen's University, Canada*

**1849 | Optimized Synchronous Operation of Active-Clamp Bidirectional Flyback Based on GaN Devices for a Multi-Cell Multi-Port Structure**
Asier Garcia-Bediaga, Ander Avila, Itziar Alzuguren, Alejandro Rujas
*Ikerlan Technology Research Centre (BRTA), Spain*

**1984 | Control Strategies for Complete Soft-Switching of ICN Converters**
Mausamjeet Khatua, Khurram K. Afridi
*Cornell University, United States*

## Session E04: AC-DC Single Phase Converters – 1

**1241 | A Four-Phase 5 kW Interleaved Totem-Pole PFC Platform Based on SiC FETs and Controlled by SA4041 Digital Power Processor**
Gabriel Scarlatescu, Tanya Kirilova Gachovska, Tudor Lipan
*Solantro Semiconductors Corp., Canada*

**2008 | A CCM Bridgeless Single-Stage Soft-Switching AC-DC Converter for EV Charging Application**
Peyman Amiri[1], Wilson Eberle[1], Deepak Gautam[2], Chris Botting[2]
*[1]The University of British Columbia, Canada; [2]Delta-Q Technologies Inc., Canada*

**1970 | An Interleaved Bridgeless AC/DC Stacked SiC Switches Based LLC Converter with Semi-Active Rectifiers for EV High Voltage Battery Systems**
Mehdi Abbasi, John Lam
*York University, Canada*

**1126 | Power Decoupling Method Using Input Filters in a Matrix Converter for Isolated AC-DC Converters Fed by Single- or Three-Phase Supply**
Wataru Kodaka, Satoshi Ogasawara, Koji Orikawa
*Hokkaido University, Japan*

## Session E05: AC-DC and DC-AC Topologies and Control

**2014 | A Truly Universal Bridgeless Single-Stage Soft-Switching AC/DC Converter for EV On-Board Charging Application**
Peyman Amiri[1], Wilson Eberle[1], Deepak Gautam[2], Chris Botting[2]
*[1]The University of British Columbia, Canada; [2]Delta-Q Technologies Inc., Canada*

**2401 | A Multiport Converter for More Electric Aircraft with Hybrid AC-DC Electric Power System**
Javad Khodabakhsh, Gerry Moschopoulos
*Western University, Canada*

**2557 | A MHz LLC Converter Based Single-Stage Soft-Switching Isolated Inverter with Hybrid Modulation Method**
Hao Wen[1], Dong Jiao[1], Jih-Sheng Lai[1], Johan Strydom[2], Bing Lu[2]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Texas Instrument, United States*

**1959 | RF Band PWM Generator with High Efficiency and Wide-B and Control**
Tomohiro Yoneyama, Yu Hosoyamada, Shohei Kobayashi, Itsuo Yuzurihara
*Kyosan Electric Mfg. Co., Ltd., Japan*

## Session E06: DC-AC Multiphase Converters

**2528 | Model Predictive Control of a Double Stage AC-DC Converter for Grid-Interface of Vanadium Flow Batteries**
Savatore Riccardo Di Salvo[1], Matteo Bulzi[1], Jacopo Riccio[2], Riccardo Leuzzi[1], Pericle Zanchetta[1], Norma Anglani[1]
*[1]University of Pavia, Italy; [2]University of Nottingham, United Kingdom*

**1555 | Volume Comparison of Passive Components for Hard-Switching Current- and Voltage-Source-Inverters**
Benedikt Riegler, Annette Mütze
*Graz University of Technology, Austria*

**1740 | Bidirectional DC-AC Converter Using a High-Frequency Transformer with Multi-Frequency Decoupled Power Control**
Juan Zuniga, Marius Takongmo, Chatumal Perera, Vishwa Perera, John Salmon
*University of Alberta, Canada*

**1728 | A Hybrid Active Neutral Point Clamped Converter Consisting of Si IGBTs and GaN HEMTs for Auxiliary Systems of Electric Aircraft**
Leon Fauth[1,2], Christian Beckemeier[1,2], Jens Friebe[1,2]
*[1]Technische Universität Braunschweig, Germany; [2]Leibniz Universität Hannover, Germany*

## Session E07: Multilevel Converters – In Memory of Prof. Akira Nabae

**2123 | Adaptive High-Frequency Injection and Control Loops Design for Flying Capacitor Passive Cross-Connected Modular Multilevel Converter Based Drive Systems**
Massimiliano Biason, Riccardo Breda, Mattia Iurich, Simone Mazzer, Roberto Petrella
*University of Udine, Italy*

**1359 | Capacitor Voltage Ripple Suppression of the Switched Capacitor Modular Multilevel Converter**
Qichen Yang[1], Robson Bauwelz Gonzatti[1,2], Hamed Pourgharibshahi[1], Fang Peng[1]
*[1]Florida State University, United States; [2]Federal University of Itajuba, Brazil*

**2475 | A Hybrid Binary Multilevel Cascaded Inverter for Medium-Voltage Applications**
Jih-Sheng Lai[1], Bryan Gutierrez[1], Moonhyun Lee[2], Chih-Shen Yeh[3], Hao Wen[1], Dong Jiao[1], Zhengming Hou[1], Hsinche Hsieh[1]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Rivian, United States; [3]Transphorm, United States*

**1875 | Enhanced Interleaved PWM Scheme with Flux Compensation for Three-Parallel Connected Inverters**
Chenhui Zhang, Marius Takongmo, John Salmon
*University of Alberta, Canada*

**1828 | A Multi-Level Active Power Filter for Common-Mode Voltage Attenuation in Multi-Level Inverters**
Dongwoo Han[1], Fang Z. Peng[1], Suman Dwari[2]
*[1]Florida State University, United States; [2]Raytheon Technologies Research Center, United States*

## Session E08: DC-DC Non-Isolated – 2

**2374 | A 48-to-12 V Cascaded Multi-Resonant Switched Capacitor Converter with 4700 W/in3 Power Density and 98.9% Efficiency**
Ting Ge, Zichao Ye, Robert C.N. Pilawa-Podgurski
*University of California Berkeley, United States*

**2286 | A Transformerless Composite Step-Down DC-DC Converter with Wide Input Voltage Range**
Satyaki Mukherjee, Dragan Maksimović
*University of Colorado Boulder, United States*

**1330 | A Multi-Phase Cascaded Series-Parallel (CaSP) Hybrid Converter for Direct 48 V to Point-of-Load Applications**
Yicheng Zhu, Zichao Ye, Ting Ge, Rose Abramson, Robert C.N. Pilawa-Podgurski
*University of California Berkeley, United States*

**2218 | High-Efficiency Operation of a Bidirectional Non-Isolated DC-DC Converter Based on Flying-Capacitor Converters**
Kazuaki Tesaki, Makoto Hagiwara
*Tokyo Institute of Technology, Japan*

**1747 | A 92.7%-Efficiency 30A 48V-to-1V Dual-Path Hybrid Dickson Converter for PoL Applications**
Chen Chen, Jin Liu, Hoi Lee
*The University of Texas at Dallas, United States*

**1868 | A Merged H-Bridge Based Switched Tank Converter for Front-End Voltage Regulator Modules**
Jiawei Liang, Haoyu Wang, Hengzhao Yang
*ShanghaiTech University, China*

## Session E09: DC-DC Non-Isolated – 3

**1641 | A Hybrid Si/SiC Interleaved Bidirectional DC-DC Converter to Optimal Power Quality, Efficiency, and Cost Tradeoff**
Kun Qu, Chao Zhang, Weibin Chen, Bo Hu, Jing Chen, Jun Wang
*Hunan University, China*

**2023 | Analytic Model and Design Procedure of the Single-Secondary Trans-Inductor Voltage Regulator**
Hang Shao, Tao Zhao, Dianbo Fu, Daocheng Huang, Jinghai Zhou
*Monolithic Power Systems, Inc., United States*

**1405 | An Ultrahigh Step-Down DC-DC Converter Based on Switched-Capacitor and Coupled Inductor Techniques**
Longyang Yu[1], Chengzi Yang[1], Wei Mu[1], Fengtao Yang[1], Huaqing Li[1], Laili Wang[1], Yuquan Su[2], Chi Zhang[2]
*[1]Xi'an Jiaotong University, China; [2]MiSiliconn Semiconductor Technologies Co., Ltd., China*

**1493 | Input-Parallel-Output-Series Two-Stage Interleaved DC-DC Converter Using Coupled Inductors**
Yasuhiro Kodama, Hirotaka Koizumi
*Tokyo University of Science, Japan*

**1651 | Model-Free Predictive Control of Interleaved DC-DC Converters, Based on Ultra-Local Model, with Constant Switching Frequency**
Fernando Bento, Imed Jlassi, Antonio J. Marques Cardoso
*University of Beira Interior, Portugal*

**1621 | An Efficient and Compact Multi-Port Power Supply for Nano-Satellites**
Arnab Sarkar[1], Nachiketa Deshmukh[1], Pankaj Kumar[1], Sandeep Anand[2]
*[1]Indian Institute of Technology Kanpur, India; [2]Indian Institute of Technology Bombay, India*

## Session E10: DC-DC Isolated – 3

**1561 | Exact Analysis of Parallel Resonant DC-DC Converter Using Phase Shift Modulation**
Vishal Anand A.G.[1], Anirban Pal[2], Ranganathan Gurunathan[1], Kaushik Basu[2]
*[1]Bloom Energy (I) Pvt Ltd., India; [2]Indian Institute of Science, India*

**2010 | Single-Stage Saturable Inductive-Link Half-Bridge Point of Load Converter**
Tuhin Subhra Sasmal, Kalyan Yenduri, Pritam Das
*Binghamton University, United States*

**1436 | Multiplexing-Based Flyback Converter for Multi-Port USB Power Delivery with True Power-Sharing**
Xingyue Tian[1], Han Cui[1], Lingxiao Xue[2]
*[1]University of Tennessee Knoxville, United States; [2]Oak Ridge National Laboratory, United States*

**1045 | Transient Model and Elimination Method for DC Bias Current in Dual Active Bridge Converter**
Yangfan Chen, Yu Zhang
*Huazhong University of Science and Technology, China*

**1220 | Analysis of Synchronous-Rectification Switch Control for Active Class-E Rectifier**
Gwangyol Noh[1,2], Gyu Cheol Lim[3], Jung-Ik Ha[1]
*[1]Seoul National University, Korea; [2]Samsun Electronics, Korea; [3]Seoul National University Electric Power Research Institute, Korea*

**1426 | A Modified Three-Port Bidirectional LLC Resonant Converter for Renewable Power Systems**
Xi Chen, Issa Batarseh
*University of Central Florida, United States*

## Session E11: DC-DC Isolated – 4

**1603 | Startup Strategy for ISOP Hybrid DC Transformer Featuring Low Current and Voltage Stress**
Wei Wang, Zhiwei Chen, Tong Liu, Jie Chen, Zilong Wang, Qicai Ren, Alian Chen
*Shandong University, China*

**1549 | Regenerative Snubber Based Bootstrapped Gate Driver Power Supply for Multiple Input Flyback Converter**
Arnab Sarkar[1], Aditya Aman[2], Sandeep Anand[2]
*[1]Indian Institute of Technology Kanpur, India; [2]Indian Institute of Technology Bombay, India*

**1120 | A Constant Current Control Method with Improved Dynamic Performance for CLLC Converters**
Huan Chen, Kai Sun, Languang Lu, Shuoqi Wang, Hongsheng Chong, Yudi Qin
*Tsinghua University, China*

**1876 | A Switchable Rectifier-Based LLC Resonant Converter for Photovoltaic Applications**
Fahad Alaql, Reza Rezaii, Sahin Gullu, Mohamed Tamasas Elrais, Issa Batarseh
*University of Central Florida, United States*

**1349 | Multiple Operation Modes Based Stacked Structure LLC Converter for Very Wide Range Operation**
Yuqi Wei, Alan Mantooth
*University of Arkansas, United States*

**1718 | Five-Level T-Type Converter Based Fault-Tolerant Isolated DC-DC Topology Using WBG Devices**
Amin Ashraf Gandomi[1], Leila Parsa[1], Keith Corzine[1], Vahid Dargahi[2]
*[1]University of California Santa Cruz, United States; [2]University of Washington Tacoma, United States*

## Session E12: DC-DC Isolated – 5

**1829 | A Novel Structure of Fully Soft-Switched DC-DC Converter with Frequency Doubling Feature for High-Density Power Conversion**
Saikat Dey, Ashwin Chandwani, Ayan Mallik
*Arizona State University, United States*

**2362 | A Boost and LLC Resonant-Based Three-Port DC-DC Converter**
Fahad Alaql, Issa Batarseh
*University of Central Florida, United States*

**2479 | Characteristics of Buck/Boost Operation in an Isolated DC-DC Converter Based on a Phase-Shift Controlled High-Frequency Inverter**
Shohei Komeda, Masato Yamashita
*Tokyo University of Marine Science and Technology, Japan*

**2074 | 400V-to-48V GaN Modular LLC Resonant Converter with Planar Transformer**
Qingyun Huang[1], Qingxuan Ma[1], Alex Q. Huang[1], Michael de Rooij[2]
*[1]The University of Texas at Austin, United States; [2]Efficient Power Conversion Corporation, United States*

**1470 | A Dual-Transformer-Based DC-DC Converter for Wide Voltage Gain and Wide ZVS Range by Utilizing a Sub-Optimal Simplified Control**
Deliang Chen, Junjun Deng, Mingyang Li, Zhenpo Wang, Yang Li
*Beijing Institute of Technology, China*

**1152 | Unidirectional Active-Passive Bridge (APB) DC-DC Converter Based on Resonant Control: FSM, PMW Operation with Soft-Switching Range and Step Power Control Method**
Cao Anh Tuan, Takaharu Takeshita
*Nagoya Institute of Technology, Japan*

**1122 | Boost Assist Control of LLC Resonant Converter for Wide Voltage Range by Use of Secondary-Side MOSFETs with ZVS Using Reverse Recovery Current of Body Diodes**
Takae Shimada[1], Mizuki Nakahara[1], Takuya Ishigaki[2]
*[1]Hitachi, Ltd., Japan; [2]Hitachi Industrial Equipment Systems Co., Ltd., Japan*

## Session E13: DC-DC Isolated – 6

**2439 | Novel Transformer with Variable Leakage and Magnetizing Inductances**
Angshuman Sharma, Jonathan W. Kimball
*Missouri University of Science and Technology, United States*

**1148 | Effects of Parasitics on an Active Clamp Assisted Phase Shifted Full Bridge Converter Operation**
Manmohan Mahapatra, Anirban Pal, Kaushik Basu
*Indian Institute of Science, India*

**1390 | Dual Range Forward Topology for High Efficiency at Universal Mains**
Noam Ezra, Teng Long
*University of Cambridge, United Kingdom*

**1290 | Automatic Current Balancing Multi-Phase Reconfigurable LLC Converter with Wide Voltage Gain Range for On-Board Battery Charger**
Kakeru Koyama, Masatoshi Uno
*Ibaraki University, Japan*

**1594 | A Two-Stage DC-DC Converter with Wide Input Voltage Range Based on Magnetic Isolation Feedback Control**
Renxi Dong, Xinbo Ruan, Ye Xu, Jinyang Yu
*Nanjing University of Aeronautics and Astronautics, China*

**2482 | Current Harmonics Dead Time Design Method to Achieve ZVS with Non-Linear Output Capacitance**
Matthew Hansen, Abhilash Kamineni, Regan Zane
*Utah State University, United States*

**1944 | Variable Resonant and Switching Frequency Charging Control Strategy of LCC Converter with Wide Range Load**
Mengjie Qin, Wenjie Chen, Fan Zhang, Ye Aizhen, Yang Xu, Houran Mohamad Abou
*Xi'an Jiaotong University, China*

## Session E14: AC-DC Single Phase Converters – 2

**1598 | A New Hybrid Si/SiC CCM Totem Pole Bridgeless PFC Design Towards Optimal Performance and Cost Tradeoff**
Weibin Chen, Chao Zhang, Kun Qu, Bo Hu, Jing Chen, Jun Wang
*Hunan University, China*

**2323 | A Single-Stage Four-Phase Totem-Pole AC-DC Converter with Wide Voltage Range and Compact Integrated Magnetic Component**
Tat-Thang Le, Ramadhan Muhammad Hakim, Junyeong Park, Sewan Choi
*Seoul National University of Science and Technology, Korea*

**1879 | Paralleled Two-Stage Single-Phase AC-DC Converter Modules Utilizing a Second-Stage Input-Current Based Droop Control Strategy**
Danish Shahzad, Khurram K. Afridi
*Cornell University, United States*

**2111 | Modular Hybrid Step-Down PFC Converter for Direct AC/DC Conversion with Differential Power Processing in Data Centers**
Ratul Das, Hanh-Phuc Le
*University of California San Diego, United States*

**1424 | A Bulk-Capacitance Reduction Method Using Self-Driven Thyristor for AC-DC Converters**
Niu Jia[1], Han Cui[1], Lingxiao Xue[2]
*[1]University of Tennessee Knoxville, United States; [2]Oak Ridge National Laboratory, United States*

## Session E15: AC-DC Single Phase Converters – 3

**1095 | A Novel Transformerless Common-Ground AC/DC Switching Converter with Integral Fault Protection utilizing Active Isolation Techniques**
Clint Halsted, Madhav Manjrekar, Babak Parkhideh
*University of North Carolina Charlotte, United States*

**1801 | A Discretized Sampling Based Current Sensorless Control of Single-Phase Totem-Pole Power Factor Corrector**
Ashwin Chandwani[1], Saikat Dey[1], Ayan Mallik[1], Arun Sankar[2]
*[1]Arizona State University, United States; [2]Mercedes-Benz R&D North America, Inc., United States*

**1988 | Design and Implementation of 50V/400A Single-Stage Full-Bridge Synchronous Rectifier for Data Center Application**
Isaac Wong[1], Guangqi Zhu[2], Birger Pahl[2], Subhashish Bhattacharya[1]
*[1]North Carolina State University, United States; [2]Eaton, United States*

**2038 | Control Techniques for a Current-Mode-Controlled Merged-Energy-Buffer-Based Two-Stage Electrolytic-Free Offline LED Driver**
Maida Farooq[1], Firehiwot Gurara[1], Mausamjeet Khatua[1], Danish Shahzad[1], Saad Pervaiz[2], Khurram K. Afridi[1]
*[1]Cornell University, United States; [2]Texas Instruments, United States*

**1862 | Asymmetric Cascaded Transformer Multilevel AC-DC Converter**
Bruna S. Gehrke[1], Cursino B. Jacobina[1], Nayara B. de Freitas[2], Italo R.F.M.P. da Silva[3], Reuben P.R. Sousa[1]
*[1]Federal University of Campina Grande, Brazil; [2]INESC TEC, Portugal; [3]Federal University of Paraíba, Brazil*

## Session E16: AC-DC MultiPhase Converters – 1

**1273 | Implementation of an Isolated Phase-Modular-Designed Three-Phase PFC Rectifier Based on Single-Stage LLC Converter**
Mojtaba Forouzesh, Yan-Fei Liu, Paresh C. Sen
*Queen's University, Canada*

**1644 | Three-Phase PFC Converter with Reconfigurable LCL Filter**
Jalal Dadkhah[1], Carl N.M. Ho[1], Ken K.M. Siu[2], River Tin Ho Li[3]
*[1]University of Manitoba, Canada; [2]University of North Texas, United States; [3]Hong Kong Applied Science and Technology Research Institute Company Limited, Hong Kong*

**1583 | Isolated Three-Phase AC to DC Converter with Matrix Converter Applying Compensation for Voltage Error by Voltage-Based Commutation**
Satoshi Nakamura, Hiroki Watanabe, Shunsuke Takuma, Kashin Kiri, Jun-ichi Itoh
*Nagaoka University of Techonology, Japan*

**1843 | Unidirectional Five-Level Rectifiers for WECS Applications**
Amanda P. Monteiro[1], Cursino B. Jacobina[1], Filipe A.C. Bahia[2], Reuben P.R. Sousa[1]
*[1]Federal University of Campina Grande, Brazil; [2]Federal University of Bahia, Brazil*

**1215 | A Three-Phase Voltage Doubler Topology Consisted of Small Number of Switching Devices with Low Switching Frequency**
Mizuki Nakahara[1], Hirooki Tokoi[1], Hideto Takada[2], Hironori Oohashi[2]
*[1]Hitachi, Ltd., Japan; [2]Hitachi Industrial Equipment Systems Co., Ltd., Japan*

**1873 | Surge Voltage Reduction Method for DAB Matrix Converter Using Circulating Current in Whole Load Condition**
Shunsuke Takuma, Kashin Kiri, Hiroki Watanabe, Jun-ichi Itoh
*Nagaoka University of Technology, Japan*

**1976 | Ultra-Light Load Performance Enhancement of a 1 MVA SiC Medium Voltage Three Phase Rectifier**
Hanning Tang[1,2], Alex Huang[1]
*[1]The University of Texas at Austin, United States; [2]SharkNinja Operating LLC, United States*

**2070 | A Modular Three-Phase Diode Rectifier with High-Frequency Isolation and Sinusoidal Input Currents**
Erick I. Pool-Mazun, Jose Sandoval, Prasad Enjeti
*Texas A&M University, United States*

## Session E17: DC-AC Single Phase Converter – 1

**2436 | Improved Off-Time Discrete Control for DCM Grid-Tied Inverter with Accurate Average Current Model and considering Nonlinear Parasitic Capacitance**
Cheng Huang, Tomoyuki Mannen, Takanori Isobe
*University of Tsukuba, Japan*

**1137 | A High Performance High Frequency Inverter Architecture with Wide Load Range**
Chang Liu, Yueshi Guan, Yijie Wang, Dianguo Xu
*Harbin Institute of Technology, China*

**1589 | Design and Analysis of Resonant Inverter for a Wide Range of Input Voltage**
Junhyeong Lee, Jung-Ik Ha
*Seoul National University, Korea*

**1065 | A Wide Load Range ZVS Inverter for Radio Frequency Capacitively Coupled Plasma**
Si Chen[1], Xinbo Ruan[1], Ying Li[2]
*[1]Nanjing University of Aeronautics and Astronautics, China; [2]University of Nottingham, United Kingdom*

## Session E18: DC-AC Single Phase Converter – 2

**1954 | Improved Lifetime of GaN-Based Single Phase PV Inverter Using Dynamic Hardware Allocation**
Kamal Sabi, Daniel Costinett
*The University of Tennessee Knoxville, United States*

**2137 | Single-Stage Isolated Half-Bridge/Full-Bridge Converter for DC/AC Applications**
Laysa L. Souza[1], Diego Acevedo-Bueno[1], Montiê A. Vitorino[1], Edison R.C. da Silva[1], Jens Friebe[2], Antonio M.N. Lima[1]
*[1]Federal University of Campina Grande, Brazil; [2]Leibniz Universität Hannover, Germany*

**1705 | Multilevel Converter Based on Series and Parallel Connections Using High-Frequency Transformer**
Filipe V. Rocha[1], Cursino B. Jacobina[1], Nady Rocha[2]
*[1]Federal University of Campina Grande, Brazil; [2]Federal University of Paraíba, Brazil*

**1717 | Multilevel Converter Based on Series and Parallel Connections Using Floating Capacitor**
Filipe V. Rocha[1], Cursino B. Jacobina[1], Nady Rocha[2], Antonio de Paula Dias Queiroz[3]
*[1]Federal University of Campina Grande, Brazil; [2]Federal University of Paraíba, Brazil; [3]Federal Institute of Paraíba, Brazil*

**1059 | Accurate Power Loss Model of a Three Level ANPC Inverter Utilizing Hybrid Si/SiC Switching Devices**
Dereje Woldegiorgis, Alan Mantooth
*University of Arkansas, United States*

## Session E19: AC-AC Isolated

**2512 | Parallel Capacitive-Link Universal Converters with Low Current Stress and High Efficiency**
Junhao Luo[1], Khalegh Mozaffari[2], Brad Lehman[1], Mahshid Amirabadi[1]
*[1]Northeastern University, United States; [2]Enphase Energy, United States*

**1820 | PUC Converter Based on AC-DC-AC Multilevel Topologies with a Shared Leg**
Jean T. Cardoso, Cursino B. Jacobina, Phelipe L.S. Rodrigues, Antonio M.N. Lima
*Federal University of Campina Grande, Brazil*

**1087 | Investigation on Operational Range and Suitable Control for Single Phase to Three Phase Matrix Converter**
Tabish Nazir Mir[1], Bhim Singh[1], Abdul Hamid Bhat[2]
*[1]Indian Institute of Technology Delhi, India; [2]National Institute of Technology Srinagar, India*

**2103 | AC-DC-AC Converter with Shared Legs Based on Cascaded Six-Leg and Three-Leg Cells**
Alan S. Felinto, Cursino B. Jacobina
*Federal University of Campina Grande, Brazil*

**1457 | A Single-Phase AC-DC-AC Three-Leg Converter Hybrid with Two and Three Level Legs**
Nustenil S.M.L. Marinus[1], Reuben P.R. Jacobina[2], Nady Rocha[3], Alexandre C. Oliveira[2], Cursino B. Jacobina[2], Leonardo C. Pontes[1]
*[1]Federal Institute of Education, Science and Technology of Ceará, Brazil; [2]Federal University of Campina Grande, Brazil; [3]Federal University of Paraíba, Brazil*

**1676 | Three-Phase AC-AC X-Type Indirect Matrix Converters with Open-End Rectifier Stage**
André Wild S. Ramalho, Montiê A. Vitorino, Maurício B.R. Corrêa, Edgar R. Braga-Filho
*Federal University of Campina Grande, Brazil*

**2065 | Novel Comprehensive Control of Matrix Converters**
Galina Mirzaeva, Maria Seron, Graham Goodwin
*The University of Newcastle, Australia*

## Session E20: Multilevel Converters – Topologies – 1

**2119 | Modular Isolated Vertically Symmetric Dual Inductor Hybrid Converter for Differential Power Processing**
Ratul Das, Hanh-Phuc Le
*University of California San Diego, United States*

**1633 | Optimized Circulating Current Injection Control Scheme for Modular Multilevel Converters**
Govind Avinash Reddy, Anshuman Shukla
*Indian Institute of Technology Bombay, India*

**2105 | Three-Phase AC-DC-AC Converter with Shared Legs and High-Frequency Link**
Alan S. Felinto, Cursino B. Jacobina
*Federal University of Campina Grande, Brazil*

**1145 | Comprehensive Analysis of the Control Structures for MMC Applications**
Semih Isik, Mohammed Alharbi, Subhashish Bhattacharya
*North Carolina State University, United States*

**1677 | A Single-Phase 35-Levels Cascaded PUC Multilevel Inverter Fed by a Single DC-Source**
Samuel C.S. Júnior[1], Cursino Jacobina[1], Edgard L.L. Fabricio[2]
*[1]Federal University of Campina Grande, Brazil; [2]Federal Institute of Paraíba, Brazil*

**2100 | A Compact Design Using GaN Semiconductor Devices for a Flying Capacitor Five-Level Inverter**
Majid Farhangi[1], Yam P. Siwakoti[1], Reza Barzegarkhoo[1], Saad Ul Hasan[1], Dylan Lu[1], Dan Rogers[2]
*[1]University of Technology Sydney, Australia; [2]University of Oxford, United Kingdom*

**1488 | A GaN Based Four-Port Flying Capacitor Multilevel Converter**
Mohamed Tamasas Elrais, Issa Batarseh
*University of Central Florida, United States*

## Session E21: Multilevel Converters – Topologies – 2

**1648 | Transformer-Based Single-Phase AC-DC-AC Multilevel Converter for Voltage Step-Up Applications**
Rodrigo P. de Lacerda[1], Cursino B. Jacobina[1], Edgard L.L. Fabricio[2], Jean Torelli Cardoso[1]
*[1]Federal University of Campina Grande, Brazil; [2]Federal Institute of Paraíba, Brazil*

**1870 | A Seven-Level Inverter with Natural Balance and Boosting Capability**
Ronnan de B. Cardoso[1], Edison Roberto C. da Silva[2,3], Leonardo R. Limongi[1], André Elias L. da Costa[2]
*[1]Federal University of Pernambuco, Brazil; [2]Federal University of Campina Grande, Brazil; [3]Federal University of Paraíba, Brazil*

**1815 | Single-Phase AC-DC-AC Multilevel Five-Leg Converter Based on a High-Frequency Transformer**
Jean T. Cardoso, Cursino B. Jacobina, Phelipe L.S. Rodrigues, Antonio M.N. Lima
*Federal University of Campina Grande, Brazil*

**1464 | Hybrid Flying Capacitor Inverter Based on Array Bootstrap Driver for High Power Density Application**
Jingxiang Shi, Shangzhi Pan, Jinwu Gong, Zhipeng Yin, Xinghua Dang, Minglong Wang
*Wuhan University, China*

**1263 | Performance Assessment of a 13-Levels Self-Balanced Inverter Based on a Dual T-Type Topology**
S. Foti[1], A. Testa[1], S. De Caro[1], G. Scelba[2], A. Cusumano[2]
*[1]University of Messina, Italy; [2]University of Catania, Italy*

**2237 | AC-DC Single-Phase Multilevel Converters with Floating DC-Link and Reduced Controlled Switches**
Ulisses G. Lima[1], Cursino B. Jacobina[2], Reuben P.R. Sousa[1], Rodrigo P. de Lacerda[1]
*Federal University of Campina Grande, Brazil*

## Session E22: Multilevel Converters – Topologies – 3

**1355 | A Single-Phase Five-Level Grid-Connected Inverter for Photovoltaic Applications**
Jadyson J. Silva[1], Filipe A.C. Bahia[1], Andre P.N. Tahim[1], Darlan A. Fernandes[2], Fabiano F. Costa[1]
*[1]Federal University of Bahia, Brazil; [2]Federal University of Paraíba, Brazil*

**1496 | A Three-Level Neutral-Point Clamped Dual-Output Converter**
Ahmed S. Hussein, Amer Ghias
*Nanyang Technological University, Singapore*

**2113 | A Novel Seven Level Hybrid Fault Tolerant Converter**
Rajat Shahane, Satish Belkhode, Anshuman Shukla
*Indian Institute of Technology Bombay, India*

**1620 | A Six-Switch Five-Level Transformer-Less Inverter without Leakage Current for Grid-Tied PV System**
Jaber Fallah Ardashir[1], Mahdi Gasemi[1], Behrouz Rozmeh[1], Saeed Peyghami[2], Frede Blaabjerg[2]
*[1]Islamic Azad University, Iran; [2]Aalborg University, Denmark*

**2097 | A Novel Single-Source Single-Stage Switched-Boost Five-Level (S5B5L) Inverter with Dynamic Voltage Boosting Feature**
Majid Farhangi[1], Reza Barzegarkhoo[1], Yam P. Siwakoti[1], Dylan Lu[1], Sze Sing Lee[2]
*[1]University of Technology Sydney, Australia; [2]Newcastle University in Singapore, Singapore*

**1334 | A DAB Converter Constructed by Nine-Switch Five-Level Active-Neutral-Point-Clamped Bridges**
Na Gao, Yu Zhang, Zengguang Qiu, Qingxin Guan
*Huazhong University of Science and Technology, China*

**1106 | Comparison of an Interleaved Multi-Branch Inverter and a Four-Level Inverter with Variable Voltage Levels for Emulation of Three-Phase Machines**
Manuel Fischer, Yang Hu, Johannes Ruthardt, Philipp Ziegler, Jörg Roth-Stielow
*University of Stuttgart, Germany*

## Session E23: Multilevel Converters – Control – 1

**1958 | Open-Switch Fault Diagnosis in Four-Level Active Neutral-Point-Clamped Inverters**
Jonathan Pribadi, Dong-Choon Lee
*Yeungnam University, Korea*

**1443 | Model-Free Second-Order Sliding Mode Control for Grid-Connected Voltage Source Compact Multilevel Converters**
Mohammad Babaie, Kamal Al-Haddad
*École de technologie supérieure, Canada*

**1406 | Self-Balancing 3-Phase 5-Level Flying E-Type Inverter for Photovoltaic Applications**
M. di Benedetto[1], A. Lidozzi[1], L. Solero[1], F. Crescimbini[1], P.J. Grbović[2]
*[1]Roma Tre University, Italy; [2]University of Innsbruck, Austria*

**1629 | Constant Overlap-Time Based SMs Capacitor Voltage Balancing Scheme for Alternate Arm Converter**
Govind Avinash Reddy, Nageswara Rao Karaka, Anshuman Shukla
*Indian Institute of Technology Bombay, India*

**1469 | A Robust Ultra-Local Model Control with DC Capacitor Voltage-Balancing for PEC9 Inverter**
Meysam Gheisarnejad[1], Mohammad Sharifzadeh[2], Mohammad-Hassan Khooban[1], Kamal Al-Haddad[2]
*[1]Aarhus University, Denmark; [2]École de technologie supérieure, Canada*

**1467 | Convex Optimization-Based Vector Current Control Design for Grid-Connected Packed E-Cell Inverters**
Mahdieh S. Sadabadi[1], Mohammad Sharifzadeh[2], Majid Mehrasa[3], Seddik Bacha[3], Kamal Al-Haddad[2]
*[1]The University of Sheffield, United Kingdom; [2]École de Technologie Supérieure, Canada; [3]Université Grenoble Alpes, France*

**2253 | Hybrid Multilevel T-Type Inverter Exploiting a Nearest Level Modulation Technique**
S. Foti[1], A. Testa[1], S. De Caro[1], T. Scimone[1], G. Scelba[2], G. Scarcella[2]
*[1]University of Messina, Italy; [2]University of Catania, Italy*

## Session E24: Multilevel Converters – Control – 2

**2089 | Statcom Operation of Hybrid Series Converter and DC Capacitor Voltage Balance Technique**
Ibhan Chand Rath, Anshuman Shukla
*Indian Institute of Technology Bombay, India*

**1092 | Multiplexing the Level Provider of Multilevel Converters in Series-Parallel-Form Switch-Linear Hybrid Envelope Tracking Power Supply**
Peng Zhou, Xinbo Ruan, Ning Liu, Yazhou Wang
*Nanjing University of Aeronautics and Astronautics, China*

**1782 | A Novel Inter-Modulated Floating Carrier Level Shifted PWM Method for PUC9 Converter**
Kiavash Askari Noghani[1], Mostafa Abarzadeh[2], Alireza Javadi[3], Kamal Al-Haddad[1]
*[1]École de technologie supérieure, Canada; [2]SmartD Technologies Inc., Canada; [3]SUEZ Water Technologies & Solutions, Canada*

**2009 | Splitting of Voltage Reference between Half-Bridge and Full-Bridge Sub-Modules in Hybrid MMC**
Risabh Sarangi[1], Tanmoy Bhattacharya[2], Dheeman Chatterjee[2]
*[1]Indian Institute of Technology Kanpur, India; [2]Indian Institute of Technology Kharagpur, India*

**1462 | Circulating Current Control in Arm Link Enhanced Modular Multilevel Converter for Low-Voltage and Variable Frequency Applications**
Rodrigo Aguilar[1], Luca Tarisciotti[2], Javier Pereda[1]
*[1]Pontificia Universidad Católica de Chile, Chile; [2]Universidad Andrés Bello, Chile*

**2088 | Common-Mode Voltages Reduction Space Vector Modulation for Active Neutral-Point-Clamped Converter**
Jalal Amini, Mehrdad Moallem
*Simon Fraser University, Canada*

**1284 | Analysis and Implementation of a 5-Level Hybrid Inverter with Reduced Switching Devices Using Phase-Shifted PWM**
Almachius Kahwa, Hidemine Obara, Yasutaka Fujimoto
*Yokohama National University, Japan*

## Session E25: DC-AC Multi-Phase Converters – 2

**2148 | Overvoltage Mitigation Techniques for SiC-MOSFET Based High-Speed Drives: Comparison of Active Gate Driver and Output dv/dt Filter**
Jelena Loncarski[1], Francesca Maiullari[2], Rinaldo Consoletti[2], Vito Giuseppe Monopoli[2], Francesco Cupertino[2]
*[1]University of Bologna, Italy; [2]Politecnico di Bari, Italy*

**2413 | Discontinuous Space Vector Pulse Width Modulation for Six Switch Converter with Independent Control of Phase Voltages and Switching Device Stress Alleviation**
Josiah O. Haruna, Olorunfemi Ojo
*Tennessee Tech University, United States*

**1454 | Three-Phase Buck-Boost Inverter with Reduced Current Ripple**
Ashraf Ali Khan[1], Usman Ali Khan[2], Shehab Ahmed[1]
*[1]King Abdullah University of Science and Technology, Saudi Arabia; [2]Yonsei University, Korea*

**2238 | Optimum Injection of Second Harmonic Circulating Current for Reduction in SubModule Capacitor Voltage Ripple in Overmodulated MMC**
G. Veera Bharath, Poras T. Balsara
*The University of Texas at Dallas, United States*

**2581 | QCM-Enabled SiC Three-Phase Traction Inverter**
Yanfeng Shen, Yunlei Jiang, Luke Shillaber, Hui Zhao, Teng Long
*University of Cambridge, United Kingdom*

**1335 | Assessment of a Multi-Functional Converter System for Traction Electric Drives**
C. Alosa, F. Immovilli, E. Lorenzani
*University of Modena and Reggio Emilia, Italy*

**1756 | Role of Active Clamp Circuit in a DC/AC Isolated Converter Based on the Principle of Pulsating DC Link**
Daniele Marciano, Simone Palazzo, Giovanni Busatto, Annunziata Sanseverino, Francesco Velardi
*University of Cassino and Southern Lazio, Italy*

# Topic F: Control, Modeling and Optimization of Power Converters

## Session F01: Dynamic Modeling of Power Converters

**1967 | An Accurate Dynamic Characteristic Design Method for Boost Converter with PI Control Based on Motion Decomposition and Eigenvalue Configuration**
Hong Li[1], Zexi Zhou[1], Zhipeng Zhang[1], Guoen Cao[2], Yajing Zhang[3]
*[1]Beijing Jiaotong University, China; [2]Chinese Academy of Science, China; [3]Beijing Information Science and Technology University, China*

**2359 | Dynamic Phasor Model of Multi-Converter Systems**
Arash Nazari[1], Yaosuo Xue[2], Jayesh Kumar Motwani[1], Igor Cvetkovic[1], Dong Dong[1], Dushan Boroyevich[1]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Oak Ridge National Laboratory, United States*

**1775 | Frequency Domain Modelling of an LCLC Resonant Converter with Capacitive Output Filter under Hybrid Modulation**
Shahbaj Dhillon, Abhishek Awasthi, Praveen Jain
*Queen's University, Canada*

**1285 | Reduced-Order Equivalent Circuit Model of Series Resonant Converter considering the Interaction between Resonant Elements**
Xin Li[1], Shuxin Chen[1], Yi Tang[1], Yiming Zhang[2], Xin Zhang[3]
*[1]Nanyang Technological University, Singapore; [2]Fuzhou University, China; [3]Zhejiang University, China*

**2290 | Frequency Domain Modelling of an LCC Resonant Converter with Capacitive Output Filter**
Shahbaj Dhillon, Abhishek Awasthi, Praveen Jain
*Queen's University, Canada*

## Session F02: Reliability, Diagnostics and Fault Analysis of Power Converters

**1686 | Online Junction Temperature Monitoring of Power Semiconductor Devices Based on a Wheatstone Bridge**
Niklas Fritz[1], Maximilian Friedel[1], Rik W. De Doncker[1], Timothy A. Polom[2]
*[1]RWTH Aachen University, Germany; [2]Silicon Austria Labs GmbH, Austria*

**2337 | Junction Temperature Estimation of SiC MOSFETs During Inverter Operation Using Switching Times and On-State Voltages**
Daniel Herwig, Axel Mertens
*Leibniz Universität Hannover, Germany*

**1308 | "Plug-and-Play" Tiny AI-Empowered Output Filter Parameter Extraction Framework with Single RNN Cell for Digital Power**
Kelvin Yi-wen Hong[1], Henry Shu-hung Chung[1], Alan Wai-Lun Lo[2], Huai Wang[3]
*[1]City University of Hong Kong, China; [2]Chu Hai College of Higher Education, China; [3]Aalborg University, Denmark*

**1872 | Mode Analysis and Identification Scheme of Open-Circuit Fault in a Three-Phase DAB Converter**
Sagar Kumar Rastogi[1], Suyash Sushilkumar Shah[1], Brij N. Singh[2], Subhashish Bhattacharya[1]
*[1]North Carolina State University, United States; [2]John Deere, United States*

**2041 | On-State Voltage Measurement of High-Side Power Transistors in Three-Phase Four-Leg Inverter for In-Situ Prognostics**
Chondon Roy, Namwon Kim, James Gafford, Babak Parkhideh
*University of North Carolina Charlotte, United States*

## Session F03: Control of DC-DC Converters

**1338 | Current Sharing Control Strategy for Parallel-Connected H-Bridges DC-DC Converter: Modelling, Analysis and HIL Test**
Cristina Terlizzi[1], Stefano Bifaretti[1], Alessandro Lampasi[2]
*[1]University of Rome "Tor Vergata", Italy; [2]ENEA, DTT S.c.a.r.l., Italy*

**2055 | Improved Instantaneous Flux and Current Control for Three-Phase Dual-Active Bridge DC-DC Converters**
Rafael Goldbeck, Jingxin Hu, Rik W. De Doncker
*RWTH Aachen University, Germany*

**1430 | A Power Sharing Control Scheme with Fast-Dynamic Response for Input-Series Output-Parallel DAB DC-DC Converter**
Nie Hou, Pasan Gunawardena, Xuesong Wu, Li Ding, Yue Zhang, Yun Wei Li
*University of Alberta, Canada*

**2477 | A Decentralized Nonlinear Control Scheme for Modular Power Sharing in DC-DC Converters**
Soham Roy[1], Mansi Joisher[2], Alex J. Hanson[1]
*[1]The University of Texas at Austin, United States; [2]National Institute of Technology Karnataka, India*

## Session F04: Power Converter Modeling and Control

**2064 | Grid-Connected Self-Synchronizing Cascaded H-Bridge Inverters with Autonomous Power Sharing**
Soham Dutta[1], Minghui Lu[1], Branko Majmunovic[2], Rahul Mallik[1], Gab-Su Seo[3], Dragan Maksimović[2], Brian Johnson[1]
*[1]University of Washington, United States; [2]University of Colorado, United States; [3]National Renewable Energy Laboratory, United States*

**1982 | Input AC Voltage Sensorless Control Method for Single-Phase PFC Converter Using Frequency Estimator**
Seunghoon Baek[1], Chun-Gi Yun[2], Younghoon Cho[3]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Korea Electrical Manufacturers Association, Korea; [3]Konkuk University, Korea*

**1609 | Optimized PWM Scheme with Minimized Common-Mode Voltage Amplitude and Frequency in VSI-Fed Motor Drives**
Zhe Zhang, Ali M. Bazzi
*University of Connecticut, United States*

**2391 | Proximate Time-Optimal Control of Flying-Capacitor Multi-Level Converters Using a Fixed Frequency PID Framework**
Chandan Suthar[1], V. Inder Kumar[1], Faleh Alskran[2], Dragan Maksimović[1]
*[1]University of Colorado Boulder, United States; [2]Advanced Energy Industries, Inc., United States*

## Session F05: Power Converter Stability

**1735 | An Approach for Modeling and Stability Analysis of Single-Phase Microgrids**
Nima Amouzegar Ashtiani[1], S. Ali Khajehoddin[1], Masoud Karimi-Ghartemani[2]
*[1]University of Alberta, Canada; [2]Mississippi State University, United States*

**1962 | A Floquet Theory-Based Stability Analysis Method for Cascaded DC-DC Converters by Combining with the Describing Function of PWM Link**
Hong Li, Zhipeng Zhang, Zexi Zhou, Zhaoyi Chu, Yangbin Zeng, Zhidong Qiu
*Beijing Jiaotong University, China*

**1063 | Evaluating Small-Signal Synchronization Stability of Grid-Forming Converter through Complex Impedance Plane**
Jiale Yu[1], Han Deng[1], Yi Tang[1], Yang Qi[2], Xiong Liu[3]
*[1]Nanyang Technological University, Singapore; [2]Northwestern Polytechnical University, China; [3]Jinan University, China*

**1077 | Stability Analysis and Improvement of Three-Phase Grid-Tied Power Converters through the Generalized Phase Portraits Method**
Jiale Yu[1], Yi Tang[1], Jingyang Fang[2], Hongchang Li[3]
*[1]Nanyang Technological University, Singapore; [2]Duke University, United States; [3]Xinjiang University, China*

## Session F06: Power Converter EMI

**2522 | Identification and Validation of a Non Symmetrical System Level EMC Model for Power Electronics Converter**
Blazej Czerniewski[1,2], Jean-Luc Schanen[1], Herve Chazal[1], Pericle Zanchetta[2,3], Caio Fronseca de Freitas[4]
*[1]Université Grenoble Alpes, France; [2]University of Nottingham, United Kingdom; [3]University of Pavia, Italy; [4]Centrale Lille, France*

**1991 | PCB Winding Coupled Inductor Design for SiC-Based Soft-Switching Three-Phase C-DC Converter with Balance Technique**
Gibong Son, Zhengrong Huang, Qiang Li, Fred C. Lee
*Virginia Polytechnic Institute and State University, United States*

**2366 | Novel Common Mode Voltage Elimination Methods in Three-Phase Four-Wire Grid-Connected Inverters**
Alexander L. Julian[1], Giovanna Oriti[2]
*[1]Consultant, United States; [2]Naval Postgraduate School, United States*

**1856 | Electric Near Field Emission from a 1Mhz Power Converter for Electric Vehicles**
Yanwen Lai[1], Juntao Yao[1], Shuo Wang[1], Zheng Luo[2], Yiming Li[2]
*[1]University of Florida, United States; [2]Monolithic Power Systems, Inc., United States*

## Session F07: Converter Power Quality

**2296 | Parallel Differential Evolution Algorithm Accelerated by Graphics Processing Unit for Harmonic Minimization in Power Converters**
Kaiqi Ren, Fei He, Zhaoyuan Li, Kehu Yang
*China University of Mining and Technology, China*

**2473 | Decentralized PWM Interleaving for Ripple Minimization in Both Symmetric and Asymmetric Parallel-Connected DC-DC Converters**
Soham Dutta, Minghui Lu, Brian Johnson
*University of Washington, United States*

**1798 | Linear-System-Based Selective Harmonic Elimination Solution for Multilevel Inverters**
Concettina Buccella, Maria Gabriella Cimoroni, Carlo Cecati
*University of L'Aquila, Italy*

**1231 | Enhanced Modulation Technique for Power Quality Improvement of LED Drivers**
Huan Li[1], Weidong Xiao[1], Sinan Li[1], Jimmy Chih-Hsien Peng[2]
*[1]The University of Sydney, Australia; [2]National University of Singapore, Singapore*

## Session F08: Design and Control of Power Converters

**2199 | Switching Losses Minimized Harmonic Elimination for Two-Level Inverters**
Kehu Yang[1], Suna Pan[1], Huawei Li[2]
*[1]China University of Mining and Technology, China; [2]Beijing Institute of Aerospace Test Technology, China*

**1786 | Modeling and ZVS Constraints of the Hybrid-Bridge LLC Resonant Converter for MHz Level Operation**
Lingeshwaren Sobrayen[1,2], Patrick Dehem[2], Charif Karimi[1], Tanguy Phulpin[1], Daniel Sadarnac[1]
*[1]CentraleSupélec, France, France; [2]EnerSys, France*

**1437 | Splitting Inductance Tuning Method to Eliminate High Frequency Oscillation in Dual Active Bridge Converter**
Chang Wang, Jiasheng Huang, Gabriel Zsurzsan, Zhe Zhang
*Technical University of Denmark, Denmark*

**1916 | Minimizing Switching-On Current Spike through GaN in Low Power Applications**
Yajie Qiu, Jinseng Vanderkloot, Lucas Lu
*GaN Systems, Canada*

## Session F09: Power Converter Stability and Control

**1703 | System-Level Mapping of Modeling Methods for Stability Characterization in Microgrids**
Yubo Song[1], Subham Sahoo[1], Yongheng Yang[2], Frede Blaabjerg[1]
*[1]Aalborg University, Denmark; [2]Zhejiang University, China*

**1674 | A Modular Multilevel Converter as a Grid Emulator in Balanced and Unbalanced Scenarios Using a Delta-Wye Transformer**
Ming Jia, Shenghui Cui, Philipp Joebges, Rik W. De Doncker
*RWTH Aachen University, Germany*

**2271 | Transient Performance Evaluation of Grid-Forming Control for Railway Traction Converters considering Inter-Phase Operation**
Liang Zhao[1], Zheming Jin[2], Xiongfei Wang[1]
*[1]Aalborg University, Denmark; [2]Beijing Jiaotong University, China*

**2268 | Valley Current Control for the Flying Capacitor Voltage Balancing in the Three-Level Boost Converter with Variable Switching Frequency**
Branislav Stevanović, Pedro Alou, Miroslav Vasić
*Universidad Politécnica de Madrid, Spain*

**1634 | A State Trajectory Control Method for Switched-Capacitor-Based Resonant Converter with the Finite State Machine Controller**
Pan Wang[1], Rui Ling[1], Dongxue Li[2]
*[1]Chongqing University, China; [2]Vicor Corporation, United States*

## Session F10: Control Aspects of Grid-Connected Converters

**1070 | Dynamic Performance Limitation and Enhancement of Grid-Forming Converters**
Han Deng[1], Jingyang Fang[2], Yang Qi[3], Vincent Debusschere[4], Yi Tang[1]
*[1]Nanyang Technological University, Singapore; [2]University of Kaiserslautern, Germany; [3]Northwestern Polytechnical University; [4]Grenoble Institute of Technology, France*

**1823 | A Data-Driven Approach for Grid Synchronization Based on Deep Learning**
Mohammadreza Miranbeigi, Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**1253 | Operational Flexibility of the Modular Multilevel Converter under Unbalanced Grid Conditions**
Yu-chen Su, Hsuan-ming Li, Po-lin Chen, Po-tai Cheng
*National Tsing Hua University, Taiwan*

**2260 | Unified Control (UniCon) Strategies for Grid-Connected Inverters**
Mohammadreza Miranbeigi, Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**1745 | Grid-Tied Two PV LLC Converter with Dual MPPT Algorithm Based on the Adaptive Neuro Fuzzy Interface System (ANFIS)**
Sumana Ghosh, Issa Batarseh
*University of Central Florida, United States*

## Session F11: Power Converter Control

**2281 | New Predictive Current Control for Modular Multilevel Converters with Revised Prediction Model considering Common-Mode Voltage**
Yafei Yin, Zhenbin Zhang, Yuanxiang Sun, Zhen Li
*Shandong University, China*

**1880 | Direct Active-Balancing Control of Flying-Capacitor Voltages in an ANPC-Based Multilevel Inverter**
Vahid Dargahi[1], Arash Khoshkbar Sadigh[2]
*[1]University of Washington, United States; [2]The Pennsylvania State University, United States*

**1956 | Modelling and Controller Design for Three-Phase Four-Leg Three-Level T-Type Inverter**
Haoxin Yang, Li Zhang, Pengfei Tu, Yi Tang
*Nanyang Technological University, Singapore*

**1989 | Phase Control Using Network Node Voltage Feedback for Capacitor-Coupled Dual Active Bridge DC-DC Converters**
Sunghyuk Choi, Jin-Su Hong, Jung-Ik Ha
*Seoul National University, Korea*

**2370 | Inverter-Dominated Networked Microgrids with Marine Energy Resources and Energy Storage Systems for Coastal Community Resiliency Enhancement**
Yuxi Men[1], Yuhua Du[1], Xiaonan Lu[1], Jianzhe Liu[2], Feng Qiu[2]
*[1]Temple University, United States; [2]Argonne National Laboratory, United States*

**2162 | Shipboard Power Conversion System to Meet MIL-STD-1399 Limits for Pulsed Power Loads**
Giovanna Oriti[1], Alexander L. Julian[2], Daniel P. DeToma[3]
*[1]Naval Postgraduate School, United States; [2]Consultant, United States; [3]US Navy, United States*

## Session F12: Dynamic Modeling of Power Converters

**1997 | Accurate Small-Signal Modeling for Charge-Controlled LLC Resonant Converter**
Yi-Hsun Hsieh, Fred C. Lee
*Virginia Polytechnic Institute and State University, United States*

**2405 | An Improved Frequency Domain Based Analytical Model of Voltage-Fed Series LC-Parallel LC Resonant Converter with Capacitive Output Filter**
Aiswarya Mathew[1], Abhishek Awasthi[1], Praveen Jain[1], Shahbaj S. Dhillon[2], Majid Pahlevani[1]
*[1]Queen's University, Canada; [2]Voltsafe Inc., Canada*

**1027 | A Two-Stage Pulsed Power Supply with Ultra-Fast Dynamic Response and Low Input Current Ripple for Low-Frequency Pulsed Loads**
Ye Xu, Xinbo Ruan, Xinze Huang, Jinyang Yu, Hao Zhang
*Nanjing University of Aeronautics and Astronautics, China*

**1860 | Small-Signal Modeling and Output Impedance Analysis of Three Stage Synchronous Generator for More Electric Aircraft**
Chengxiang Zhang[1], Shuang Wang[1], Xinbo Ruan[1], Ming Yan[2], Donghua Wu[2]
*[1]Nanjing University of Aeronautics and Astronautics, China; [2]Shaanxi Aero Electric Co. Ltd., China*

**1601 | A Simplified Time-Domain Gain Model for CLLC Resonant Converter**
Yuliang Cao, Minh Ngo, Dong Dong, Rolando Burgos
*Virginia Polytechnic Institute and State University, United States*

## Session F13: Modulation of Power Converters

**1949 | Discontinuous Modulation of Cascaded H-Bridge StatComs considering Capacitor Voltage Oscillations**
Qingxiang Liu[1], Ezequiel Rodriguez[1], Glen G. Farivar[1], Josep Pou[1], Salvador Ceballos[2], Christopher D. Townsend[3], Ramon Leyva[4]
*[1]Nanyang Technological University, Singapore; [2]Basque Research and Technology Alliance, Spain; [3]University of Western Australia, Australia; [4]Universitat Rovira i Virgili, Spain*

**1209 | Quasi-Reference PWM for 3-Level Voltage Source Inverters**
Anatolii Tcai[1], Thiwanka Wijekoon[1], Jun-Hyung Jung[2], Marco Liserre[2]
*[1]Huawei Technologies Düsseldorf GmbH, Germany; [2]Christian-Albrechts-Universität zu Kiel, Germany*

**2515 | A Fault Tolerant Modulation Scheme to Eliminate DC Offset and Harmonic Fault Currents in the Balanced Inverter under Switch Short-Circuits Faults**
Zhouzhou Wang, Hao Zeng, Thomas M. Jahns, Bulent Sarlioglu
*University of Wisconsin Madison, United States*

**1397 | Common Mode Suppression Method of Current Source Back-to-Back Converter Based on Five-Segment Space Vector Modulation**
Kang Liu, Dong Jiang, Zicheng Liu, Ruodong Wang
*Huazhong University of Science and Technology, China*

**1627 | Novel Static Carrier Based Low Frequency Multilevel Modulations with Long Conduction Time: Analysis of Capacitor Voltage Balancing**
Corentin Darbas[1], Jean-Christophe Olivier[2], Nicolas Ginot[1], Frédéric Poitiers[1]
*[1]IETR, France; [2]IREENA, France*

## Session F14: Design and Control of Power Converters

**2062 | A Framework for High Density Converter Electrical-Thermal-Mechanical Co-Design and Co-Optimization for MEA Application**
Mustafeez ul Hassan, Zhao Yuan, Asif Imran Emon, Fang Luo
*Stony Brook University, United States*

**2411 | The ZVS Transition Analysis and Optimization for CLLC-Type Resonant DC Transformer**
Yuliang Cao, Minh Ngo, Dong Dong, Rolando Burgos
*Virginia Polytechnic Institute and State University, United States*

**1915 | Harmonic Compensation Control of Grid Interactive Inverters Based on Data-Driven Harmonic State Space Modeling**
Dongsen Sun, Shengyi Wang, Liang Du, Xiaonan Lu
*Temple University, United States*

**1309 | Preliminary Testing and Implementation of a Peak Current Mode Control Scheme for a Two-Phase, Dual Interleaved Buck-Boost Converter**
Kevin Cano-Pulido, Ismael Araujo-Vargas, Nancy Mondragón-Escamilla, Enrique Velázquez-Elizondo
*Instituto Politécnico Nacional, Mexico*

## Session F15: Utility Applications of Power Electronics

**1208 | DC Fault Current Estimation in a Multi-Terminal Hybrid MMC-HVDC System considering Fault Ride through Control**
Yi Xu[1], Liang Qin[1], Yi Zhang[2], Kaipei Liu[1], Frede Blaabjerg[2]
*[1]Wuhan University, China; [2]Aalborg University, Denmark*

**2341 | Power Device Losses in Two-Level Converters with Direct Current Controllers for Grid Connected Applications**
Jose Ortiz Gonzalez[1], Diego Pérez-Estévez[2], Ruizhu Wu[1], Jesús Doval-Gandoy[2], Phil Mawby[1], Olayiwola Alatise[1]
*[1]University of Warwick, United Kingdom; [2]University of Vigo, Spain*

**2194 | Real-Time Simulation Framework for Hardware-in-the-Loop Testing of Multi-Port Autonomous Reconfigurable Solar power plant (MARS)**
Zerui Dong[1], Suman Debnath[2], Wei Li[3], Qianxue Xia[4], Phani R.V. Marthi[2], Sudipta Chakraborty[1]
*[1]OPAL-RT Corporation, United States; [2]Oak Ridge National Laboratory, United States; [3]OPAL-RT Technologies, Inc., Canada; [4]Georgia Institute of Technology, United States*

**1109 | Design and Analysis of a High-Efficiency All-SiC Dynamic Voltage Restorer for Wide-Range Sag/Swell Mitigation**
Lorenzo Ceccarelli, Xinwei Xu, Gabriel Tibola, Jorge L. Duarte
*Eindhoven University of Technology, The Netherlands*

**1818 | Transformer-Less Alternative Topologies of a Unified Power Quality Conditioner with Embedded Hybrid Energy Storage**
Jose M. Piedra[1], Pablo García[2], Ramy Georgious[1], Geber Villa[2], Mhret Berhe Gebremariam[2]
*[1]ENFASYS, Spain; [2]University of Oviedo, Spain*

## Session F16: Other Topics in Design, Control, Modelling and Optimization of Power Converters

**1606 | A Remote Development Process and Platform for Power Electronic Systems**
Michael Starke, Bailu Xiao, Mitch Smith, Pankaj Bhowmik, Steven Campbell, Radha K. Moorthy, Benjamin Dean, Madhu Chinthavali
*Oak Ridge National Laboratory, United States*

**1920 | An Improved Low Speed Control Strategy for Permanent Magnet Synchronous Motor with Low Resolution Encoder**
Qiushi Zhang, Yin Fan
*Southeast University, China*

**2448 | A Novel Trapezoidal Slope Compensation Technique with Peak Current Mode Control for Power Converters Switching at MHz Frequencies**
Gnana Sambandam K.[1], Yu Yao[1], Harish S. Krishnamoorthy[1], Harshit Soni[2], Amitava Das[2]
*[1]University of Houston, United States; [2]Tagore Technology, United States*

**1753 | Performance Analysis of an Input-Series-Output-Parallel LLC Resonant Converter with Parameters Mismatch**
Qingxuan Ma, Qingyun Huang, Alex Q. Huang
*The University of Texas at Austin, United States*

**1179 | DC-Link Inductor Investigation for Series-Connected Current Source Converter**
Zijian Wang, Bowen Jiang, Qiang Wei
*Lakehead University, Canada*

**1499 | Toroidal Inductor Design and Comparison between Interleaved and Non-Interleaved 300 kW High Efficiency SiC Inverter**
Harish Suryanarayana[1], Maziar Mobarrez[1], Jacob Miscio[1], Xiaoqing Song[1], Arun Kadavelugu[1], Silvio Colombi[2]
*[1]ABB, United States; [2]ABB, Switzerland*

**2481 | Minimization of DC-Link Capacitance for a DC-Link Based Variable Speed Constant Frequency Aircraft Power System**
Goutham Selvaraj[1], Kaushik Rajashekara[1], Krishna Raj Ramachandran Potti[2]
*[1]University of Houston, United States; [2]Indian Institute of Technology Delhi, India*

## Session F17: Power Converter Modeling and Control – 1

**1130 | A Simple Common-Mode Voltage Reduction Method Based on Zero-Sequence Voltage Injection for a Back-to-Back Three-Level NPC Converter**
Xiaona Xu, Kui Wang, Zedong Zheng, Yongdong Li
*Tsinghua University, China*

**1157 | Design and Implementation of Bidirectional Voltage-Multiplier Front-End Converter for Switched Reluctance Motor Drive**
Hung-Chi Chen, Yu-Jen Lin
*National Yang Ming Chiao Tung University, Taiwan*

**2355 | Efficient Predictive Control Scheme for Optimal Operation of Five Level Four Switch Inverter**
Zhanfan Yu, Sally Sajadian
*Lafayette College, United States*

**1662 | A Carried-Based Space Vector Modulation Scheme for Si and SiC Based Enhanced Hybrid-ANPC Converter**
Satish Belkhode, Anshuman Shukla, Suryanarayana Doolla
*Indian Institute of Technology Bombay, India*

**1613 | A Commutation Method Free from Inrush Current for the Carrier-Based PWM Controlled Direct Matrix Converter**
Sahel Solemanifard, Yan-Xing Chen, Mohammadreza Lak, Tzung-Lin Lee
*National Sun Yat-sen University, Taiwan*

## Session F18: Power Converter Modeling and Control – 2

**1128 | Reactive Power Control to Minimize Inductor Current for Single Phase Dual Active Bridge DC/DC Converters**
Hamid Naseem, Jul-Ki Seok
*Yeungnam University, Korea*

**1630 | Predictive Control for an Active Magnetic Bearing System with Sensorless Position Control**
Luca Tarisciotti[1], Luca Papini[2], Constanza Ahumada[3], Paolo Bolognesi[2]
*[1]University Andres Bello, Chile; [2]University of Pisa, Italy; [3]University of Chile, Chile*

**1946 | Analysis and Control of Synchronous Rectification for MHz Class-E Resonant Rectifier with Load Variation**
Gyu Cheol Lim, Gwangyol Noh, Jung-Ik Ha
*Seoul National Univeristy, Korea*

**1723 | Design Oriented Analysis of Control Loops Interaction in Power Synchronization-Based Voltage Source Converter**
Federico Cecati[1], Marco Liserre[1], Yicheng Liao[2], Xiongfei Wang[2], Frede Blaabjerg[2]
*[1]Christian-Albrechts-Universität zu Kiel, Germany; [2]Aalborg University, Denmark*

**2379 | A Novel Modulation Technique for Pulsating DC Link Multistage Converter with Zero Voltage Transition Based on Different and Unrelated Switching Frequencies**
Daniele Marciano, Simone Palazzo, Carmine Abbate, Giovanni Busatto, Annunziata Sanseverino, Davide Tedesco, Francesco Velardi
*University of Cassino and Southern Lazio, Italy*

## Session F19: Power Converter Modeling and Control – 3

**1266 | A Novel Closed-Form Analytical Model for Zero-Voltage Switching (ZVS) Operation of a Totem Pole PFC with Hysteresis Current Control**
Marco Torrisi[1], Sebastiano Messina[1], Mario Cacciato[2]
*[1]STMicroelectronics, Italy; [2]University of Catania, Italy*

**1036 | Finite Control Set Model Predictive Control of a DC-DC Boost Converter Ensuring Time-Optimal Regulation and Controlled Output Voltage Deviation**
Thibaut Harzig, Brandon Grainger
*University of Pittsburgh, United States*

**1912 | A PWM Control Method for Reducing dv/dt in Cascaded Power Converters**
Mahima Gupta
*Portland State University, United States*

**2404 | Dispatchable Virtual-Oscillator-Controlled Inverters with Current-Limiting and MPPT Capabilities**
Minghui Lu[1], Rahul Mallik[1], Brian Johnson[1], Sairaj Dhople[2]
*[1]University of Washington, United States; [2]University of Minnesota, United States*

**2304 | Small Signal Stability Analysis of Paralleled Grid-Forming Islanded Voltage Regulated Inverters Using Self Synchronization**
Peishuo Mu, Brendan McGrath, Donald Grahame Holmes, Carlos Teixeira
*RMIT University, Australia*

## Session F20: Power Converter Modeling and Control – 4

**1780 | A Carrier-Based PWM to Achieve Minimum Flux of Coupled Inductor for Interleaved Three-Level Inverters**
Ruirui Chen[1], Fred Wang[1,2]
*[1]The University of Tennessee Knoxville, United States; [2]Oak Ridge National Laboratory, United States*

**2305 | Discrete Time Analysis of Dual Loop Stationary Frame Integral Dominant Voltage Regulated Inverters**
Haris Siraj, Brendan McGrath, Inam Ullah Nutkani
*RMIT University, Australia*

**1289 | Deep Reinforcement Learning Based Input Voltage Sharing Method for Input-Series Output-Parallel Dual Active Bridge Converter in DC Microgrids**
Yu Zeng[1], Ali Maswood[1], Josep Pou[1], Xin Zhang[2], Changjiang Sun[1], Zhan Li[1], Suvajit Mukherjee[2], Amit Kumar Gupta[2], Jiaxin Dong[1]
*[1]Nanyang Technology University, Singapore; [2]Zhejiang University, China; [3]Rolls-Royce@NTU Corporate Lab, Singapore*

**1343 | An LLC-Resonant Power Decoupling Strategy for a Quad-Active-Bridge Power Channel Based AC/DC Power Electronics Transformer**
Xiaohui Li[1], Linqian Cheng[1], Liqun He[1], Chudi Lin[1], Cheng Wang[2], Zhongkui Zhu[1]
*[1]Soochow University, China; [2]Nanjing University of Science and Technology, China*

**1595 | Zero-Sequence Circulating Current Suppression with Stand-Alone Feedforward Control for Power Hardware-in-the-Loop System**
Jun-Hyung Jung, Marius Langwasser, Sante Pugliese, Marco Liserre
*Christian-Albrechts-Universität zu Kiel, Germany*

**1353 | Variable Frequency Repetitive-Resonant Combined Control for Grid-Tied and Intentional Islanding Operations**
Marco di Benedetto, Alessandro Faro, Luca Bigarelli, Alessandro Lidozzi, Luca Solero
*Roma Tre University, C-PED, Italy*

## Session F21: Power Converter Stability

**2563 | Improved Bilinear Discrete-Time Modeling of the Single-Phase Dual Active Bridge DC-DC Converter**
Mohammad Tauquir Iqbal, Ali Iftekhar Maswood, Md Shafquat Ullah Khan, Yu Zeng
*Nanyang Technological University, Singapore*

**1596 | Interaction Analysis of Current Control Loops in MMC under Asymmetrical Grid Faults**
Jianglong Che, Meng Huang, Xiaoming Zha, Ju Sheng, Xikun Fu
*Wuhan University, China*

**1184 | Transient Angle Stability Prediction of Virtual Synchronous Generator Using LSTM Neural Network**
Yang Shen, Zhikang Shuai, Chao Shen, Xia Shen, Jun Ge
*Hunan University, China*

**1155 | Modeling and Rekasius Substitution Stability Analysis of the Multi-Terminal MMC-HVDC Cyber-Physical System**
Jingming Cao[1], Chaoyu Dong[1,2], Xiaodan Yu[1], Yunfei Mu[1], Qian Xiao[1], Hongjie Jia[1]
*[1]Tianjin University, China; [2]Imperial College London, United Kingdom*

**1275 | Region-Based Stability Analysis on DC MGs with Consensus-Based Secondary Control and Communication Delay**
Yuhua Du[1], Yuxi Men[1], Lizhi Ding[1], Xiaonan Lu[1], Bo Chen[2], Jianzhe Liu[2]
*[1]Temple University, United States; [2]Argonne National Laboratory, United States*

## Session F22: Control Aspects in Power Electronic Systems – 1

**2216 | Distributed Control for Modular Multilevel Converters Operated in Switching-Cycle Balancing Mode**
Boran Fan[1], Jun Wang[2], Yu Rong[1], Vladimir Mitrovic[1], Jianghui Yu[1], Slavko Mocevic[1], Rolando Burgos[1], Dushan Boroyevich[1]
*[1]Virginia Polytechnic Institute and State University, United States; [2]University of Nebraska Lincoln, United States*

**1523 | Decoupled Modulation Scheme for Three-Phase Four-Leg Four-Wire Three-Level T-Type Inverter**
Li Zhang, Haoxin Yang, Pengfei Tu, Yi Tang
*Nanyang Technological University, Singapore*

**1631 | Second-Order Sliding-Mode Controller for Boost Converters with Parameter Estimation**
Celiang Deng[1], Rui Ling[1], Dongxue Li[2]
*[1]Chongqing University, China; [2]Vicor Corporation, United States*

**2369 | Adaptive Pre-Synchronization and Discrete-Time Implementation for Unified Virtual Oscillator Control**
M.A. Awal, Md Rifat Kaisar Rachi, Md Rashed Hassan Bipu, Hui Yu, Iqbal Husain
*North Carolina State University, United States*

**2502 | An Improved Model-Free Finite Control Set Predictive Power Control for PWM Rectifiers**
Haitao Yang[1], Zeyu Min[1], Yongchang Zhang[1], Zeting Wang[1], Dong Jiang[2]
*[1]North China University of Technology, China; [2]Huazhong University of Science and Technology, China*

**1345 | Feed-Forward Compensation for Model Predictive Control in Tri-Port Current-Source Medium-Voltage String Inverters for PV-Plus-Storage Farms**
Zheng An, Rajendra Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

## Session F23: Control Aspects in Power Electronic Systems – 2

**1884 | A Control Method Based on Power Factor for Improving Output Voltage Stability and Efficiency of LLC Converter in Wide Range of Output Voltage and Load Impedance**
Kazuhiro Umetani[1], Kota Shimomura[1], Kenta Yamada[1], Taichi Kawakami[2], Ishihara Masataka[1], Eiji Hiraki[1]
*[1]Okayama University, Japan; [2]Osaka Prefecture University College of Technology, Japan*

**1110 | An Unequal Power Sharing Strategy for Capacitive- and Inductive-Coupling Inverters in Microgrid**
Wenyang Deng, Qinhao Li, Yongjun Zhang, Yingqi Yi, Guoquan Huang
*South China University of Technology, China*

**2525 | PWM Control of 3-Phase PFC Vienna Rectifier Derived from an Average Current-Based Control of Single-Phase PFC Boost Converter**
Lotfi Beghou, Miteshkuma Popat, Steven MacDonald
*Leonardo DRS, Canada*

**2392 | Computation-Cost-Invariant Universal Space-Vector Pulse-Width Modulation for Multilevel Inverters**
Fa Chen, Wei Qiao, Hongmei Wang, Liyan Qu
*University of Nebraska Lincoln, United States*

**1640 | Unified Cost Function Model Predictive Control for a Three-Stage Smart Transformer**
Luca Tarisciotti[1], Giampaolo Buticchi[2], Giovanni De Carne[3], Yang Jiajun[2], Chunyang Gu[2], Patrick Wheeler[4]
*[1]University Andres Bello, Chile; [2]University of Nottingham Ningbo, China; [3]Karlsruhe Institute of Technology, Germany; [4]University of Nottingham, United Kingdom*

## Session F24: Control Aspects in Power Electronic Systems – 3

**2339 | Oversampling Multi-Variable Control for Soft-Switching Solid-State Transformer**
Decheng Yan, Aniruddh Marellapudi, Rajendra Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**1068 | Complete Time-Delay Compensation Method for LCL-Type Grid-Connected Inverter with Capacitor-Current Active Damping**
Shaojie Li, Hua Lin, Xingwei Wang, Ting Hua
*Huazhong University of Science and Technology, China*

**2054 | Noise Mitigation in Control Effort in Three-Phase DC-AC Converters Using LQG/LTR Tracker**
Jesus D. Vasquez-Plaza, Juan F. Patarroyo-Montenegro, Andres F. Lopez-Chavarro, Enrique A. Sanabria-Torres, Daniel D. Campo-Ossa, Fabio Andrade
*University of Puerto Rico, Puerto Rico*

**1504vOutput Current Limiting for ON-OFF Controlled Very High Frequency Class E DC-DC Converter**
Ying Li, Xinbo Ruan, Si Chen
*Nanjing University of Aeronautics and Astronautics, China*

**1043 | A Constant Current Digital Control Method for Primary-Side Regulation Active-Clamp Flyback Converter in CCM Mode**
Chong Wang[1], Daying Sun[1], Xiang Zhang[1], Wenhua Gu[1], Sang Gui[2]
*[1]Nanjing University of Science and Technology, China; [2]Wuxi Taclink Optoelectronics Technology Company Limited, China*

**1800 | A Comparison between Single-Stage and Dual-Stage High-Gain GaN DC/DC Converters for Li-Ion Battery Modules**
Miguel Crespo[1], Pablo García[2], Konstantin Edl[3], Ramy Georgious[4], Cristian Blanco[2], Igor Cantero[1]
*[1]Cegasa, Spain; [2]University of Oviedo, Spain; [3]IsarAerospace Technologies GmbH, Germany; [4]ENFASYS, Spain*

## Session F25: Modeling and Control in Power Electronic Systems

**1811 | Data-Driven Modeling of Power-Electronics-Based Power Systems considering the Operating Points Variation**
Mengfan Zhang[1], Xiongfei Wang[1], Qianwen Xu[2]
*[1]Aalborg University, Denmark; [2]KTH Royal Institute of Technology, Sweden*

**1858 | Modeling and Impedance Analysis of a Turbine-Generator-Rectifier System with Electromechanical Dynamic Interactions in More Electric Aircraft**
Qing Lin[1], Bo Wen[1], Rolando Burgos[1], John Noon[2]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Moog Inc., United States*

**2265 | Comparison of Anti-Windup Alternatives for Parallel Controllers**
Cristina González Moral[1], Diego Fernández Laborda[2], Juan M. Guerrero Muñoz[2], Carlos Rivas[1], David Diaz Reigosa[2]
*[1]Electrotécnica Industrial y Naval S.L., Spain; [2]University of Oviedo, Spain*

**2039 | Adaptive Voltage Positioning Design of Single Stage 48/1V Sigma Converter for Fast Transient Response**
Xin Lou[1], Qiang Li[1], Mohamed H. Ahmed[2]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Texas Instruments, United States*

## Session F26: Power Converter EMI

**2388 | Common Mode EMI Analysis in Power Electronics Enabled Power System**
Ashik Amin, Tahmid Ibne Mannan, Seungdeog Choi
*Mississippi State University, United States*

**1056 | A Fully Integrated CM Choke with Improved DM Noise Attenuation**
Shiqi Jiang, Panbao Wang, Wei Wang, Wei Wei, Guihua Liu, Dianguo Xu
*Harbin Institute of Technology, China*

**1205 | Switching Transient Traced Scheme Based on Sinusoidal Waveform to Reduce EMI for IGBTs**
Jianan Chen, Dong Jiang, Wei Sun
*Huazhong University of Science and Technology, China*

**1749 | Planar Common-Mode EMI Filter Design and Optimization in a 100-kW SiC-Based Generator-Rectifier System for High-Altitude Operation**
Xingchen Zhao, Jiewen Hu, Lakshmi Ravi, Dong Dong, Rolando Burgos
*Virginia Polytechnic Institute and State University, United States*

## Session F27: Converter Power Quality

**2140 | Quantitative Analysis of Third-Harmonic Neutral-Point Current, Its Impacts, and Mitigation in Three-Level NPC Inverters**
D. Venkatramanan[1], V. Nimesh[2], Brian Johnson[2], Sairaj Dhople[1]
*[1]University of Minnesota, United States; [2]University of Washington, United States*

**2289 | Evaluation of Objective Functions Used in Bio-Inspired Harmonic Optimization Algorithms for Multilevel Converters**
Kaiqi Ren, Zhaoyuan Li, Kehu Yang
*China University of Mining and Technology, China*

**1741 | Four-Wire Active Power Filter Based on Asymmetric Cascaded H-Bridges**
Samuel C.S. Júnior[1], Cursino Jacobina[1], Edgard L.L. Fabricio[2]
*[1]Federal University of Campina Grande, Brazil; [2]Federal Institute of Paraíba, Brazil*

**2262 | Improved LCL Filter Design Procedure for Grid-Connected Voltage-Source Inverter System**
Xingyu Yang, Mohammad Alathamneh, R.M. Nelms
*Auburn University, United States*

## Session F28: Reliability, Diagnostics and Fault Analysis of Power Converters – 1

**1307 | A Family of Redundant-Switch Configurations for Improving Fault-Tolerant Feature of Power Converters**
Tohid Rahimi[1], Hossein Khoun Jahan[2], Saeed Peyghami[3], Ding Lei[1], Frede Blaabjerg[3], Pooya Davari[3]
*[1]Shandong University, China; [2]Azarbaijan Regional Electric Company, Iran; [3]Aalborg University, Denmark*

**1535 | Performance Evaluation of the Multiwinding Redundancy Approach in MTB DC-DC Converters**
Thiago Pereira, Felix Hoffmann, Marco Liserre
*Christian-Albrechts-Universität zu Kiel, Germany*

**1762 | Diagnosing Power Module Degradation with High-Resolution, Data-Driven Methods**
Christoph H. van der Broeck[1], Timothy A. Polom[2], Rik De Doncker[3]
*[1]FEV Europe GmbH, Germany; [2]Silicon Austria Labs GmbH, Austria; [3]RWTH Aachen University, Germany*

**2102 | Fault Detection and Management of the Three-Phase 4-Leg Voltage Source Inverter**
Mi Tang[1], Pericle Zanchetta[1], M. di Benedetto[2], A. Lidozzi[2], L. Solero[2]
*[1]University of Nottingham, United Kingdom; [2]Roma Tre University, Italy*

## Session F29: Reliability, Diagnostics and Fault Analysis of Power Converters – 2

**1787 | Employing the Generative Adversarial Networks (GAN) for Reliability Assessment of Converters**
Amirali Davoodi[1], Saeed Peyghami[1], Yongheng Yang[2], Tomislav Dragičević[3], Frede Blaabjerg[1]
*[1]Aalborg University, Denmark; [2]Zhejiang University, China; [3]Technical University of Denmark, Denmark*

**1298 | Reliability of Wind Turbine Power Modules Using High-Resolution Wind Data Reconstruction: A Digital Twin Concept**
Nikolaos Iosifidis[1], Yanghao Zhong[1], Borong Hu[2], Biyun Chen[3], Li Ran[1], Subhash Lakshminarayana[1], Chunjiang Jia[4], Paul McKeever[4], Chong Ng[4]
*[1]University of Warwick, United Kingdom; [2]University of Cambridge, United Kingdom; [3]Guangxi University, China; [4]Offshore Renewable Energy Catapult, United Kingdom*

**1511 | A Comparative Study on Converter-Level On-State Voltage Measurement Circuits for Power Semiconductor Devices**
Yingzhou Peng, Huai Wang
*Aalborg University, Denmark*

**1384 | An Ultra-Fast Short Circuit Protection for Three-Phase GaN Electric Drives**
Darian Verdy Retianza, Luc Spooren, Jeroen van Duivenbode, Henk Huisman
*Eindhoven University of Technology, The Netherlands*

**1788 | An Application of Feature Engineering and Machine Learning Algorithms on Condition Monitoring of SiC Converters**
Afshin Loghmani Moghaddam Toussi, Amir Sajjad Bahman, Francesco Iannuzzo, Frede Blaabjerg
*Aalborg University, Denmark*

# Topic G: Electrical Machines

## Session G01: Electric Machines in Transportation

**1766 | Experimental Investigation of a Slotless Skewed Stator with a Composite Winding Layer**
Suzanne Collins, Philip Mellor, Nick Simpson
*University of Bristol, United Kingdom*

**1577 | Optimization of an IPM Traction Motor considering the Electric Drive Unit System Requirements**
Jonathan Godbehere, Mircea Popescu, Melanie Michon
*Motor Design Ltd., United Kingdom*

**2001 | Comparison of Candidate Designs and Performance Optimization for an Electric Traction Motor Targeting 50 kW/L Power Density**
Nanjun Tang, Ian P. Brown
*Illinois Institute of Technology, United States*

**2402 | A Comprehensive Comparison of Concentrated Winding and Distributed Continuous Winding Machine Topologies for Hybrid Electric Vehicles**
Tausif Husain, Cong Ma, Narges Taran, Zhao Wan
*BorgWarner Inc., United States*

## Session G02: Permanent Magnet Machines – 1

**1625 | Effect of the Interaction of Different Manufacturing Imperfections on the Unbalanced Radial Forces in a Sub-Fractional HP Single-Phase BLDC Motor**
Nejat Saed, Stefan Leitner, Annette Mütze
*Graz University of Technology, Austria*

**2565 | Determination of the Symmetric Short-Circuit Currents of Synchronous Permanent Magnet Machines Using Magnetostatic Flux Maps**
Simone Ferrari, Paolo Ragazzo, Gaetano Dilevrano, Gianmario Pellegrino
*Politecnico di Torino, Italy*

**1320 | Cogging Torque Analysis in a Series Hybrid Variable Flux Machine Using Lumped Magnetic Circuits**
Dwaipayan Barman, Pragasen Pillay
*Concordia University, Canada*

**2142 | A Generalized Theory to Predict the Torque Harmonics in Permanent Magnet Machines**
Anant K. Singh[1], Ramakrishnan Raja[1], Tomy Sebastian[1], Kaushik Rajashekara[2]
*[1]Halla Mechatronics, United States; [2]University of Houston, United States*

## Session G03: Modeling of Electric Machines – 1

**2363 | The DQ-Theta Flux Map Model of Synchronous Machines**
Simone Ferrari, Gaetano Dilevrano, Paolo Ragazzo, Gianmario Pellegrino
*Politecnico di Torino, Italy*

**2272 | Fast Flux Mapping of PM and Synchronous Reluctance Machines: Method Description and Comparison with Full FEA Approach**
Matteo Carbonieri[1], Wen L. Soong[2], Amin Mahmoudi[3], Nicola Bianchi[1]
*[1]University of Padova, Italy; [2]University of Adelaide, Australia; [3]Flinders University, Australia*

**1165 | Optimization of a Line-Start Motor for Centrifugal Loads within Premium Efficiency According to IEC Standard**
Diego Troncon[1], Luigi Alberti[1], Leone Donazzan[2], Mauro Daneluzzi[2], Massimo Trova[2]
*[1]University of Padova, Italy; [2]Orange1 Spa, Italy*

**1947 | Optimum Design Study on HEFSM Using Variably Magnetizable PM with Low L/D Ratio and Novel PM Arrangement for EV/HEV Traction Applications**
Takeshi Okada, Mitsuru Saito, Takashi Kosaka, Hiroaki Matsumori, Nobuyuki Matsui
*Nagoya Institute of Technology, Japan*

## Session G04: Permanent Magnet Machines – 2

**1411 | Recent Advances in Analysis and Design of Axial Flux Permanent Magnet Electric Machines**
F.N.U. Nishanth[1], Joachim Van Verdeghem[2], Eric L. Severson[1]
*[1]University of Wisconsin Madison, United States; [2]Université catholique de Louvain, Belgium*

**2085 | Investigation of Asymmetric Axial-Flux Hybrid Excited Electrodynamic Wheels for Maglev Transportation**
Wei Qin[1], Ma Yuhua[2], Lv Gang[1], Wang Fuyao[1], Song Chengrui[1], Zhang Jielong[1]
*[1]Beijing Jiaotong University, China; [2]Taiyuan Institute of China Coal Technology and Engineering Group, China*

**2372 | A Survey on the Design and Analysis of Magnetic Screws**
Doha Mostafa, Hussain A. Hussain
*Kuwait University, Kuwait*

**2468 | Examination for a Hybrid Excitation Motor with Reverse Saliency while Having a Field Winding on a Rotor**
Ryusyo Nakazawa[1], Masatsugu Takemoto[2], Satoshi Ogasawara[1], Koji Orikawa[2]
*[1]Hokkaido University, Japan; [2]Okayama University, Japan*

## Session G05: Electric Machines: Fault Analysis

**2275 | Impact of Static and Dynamic Eccentricity on the Performance of Permanent Magnet Synchronous Machines with Modular Stator Core**
Danilo Riquelme[1], Werner Jara[1], Carlos Madariaga[2], Juan Tapia[2], Gerd Bramerdorfer[3], Javier Riedemann[4]
*[1]Pontificia Universidad Católica de Valparaiso, Chile; [2]University of Concepcion, Chile; [3]Johannes Kepler University Linz, Austria; [4]The University of Sheffield, United Kingdom*

**2463 | Performance of Dual Wound Synchronous Reluctance Machines for High Performance Applications considering Winding Faults**
Mazharul Chowdhury[1,2], Mohammad Islam[2], Iqbal Husain[1]
*[1]North Carolina State University, United States; [2]Halla Mechatronics, United States*

**1760 | Test Metrics and Damage Fingerprints in Multistranded Compressed Aluminium Windings**
Dominic North, Joshua Hoole, Nick Simpson, Philip Mellor
*University of Bristol, United Kingdom*

**1127 | An Investigation into the Diagnosis of Interturn Winding Faults in a Scaled-Down DFIG Using the MCSA and DWT of the Stator and Rotor Current**
Ester Hamatwi, Paul Barendse, Azeem Khan
*University of Cape Town, South Africa*

**1125 | Development of a Test Rig for Fault Studies on a Scaled-Down DFIG**
Ester Hamatwi, Paul Barendse, Azeem Khan
*University of Cape Town, South Africa*

## Session G06: Thermal Analysis of Electric Machines

**1564 | Model Calibration of Oil Jet and Oil Spray Cooling in Electrical Machines with Hairpin Windings**
Chuan Liu[1], Yew Chuan Chong[2], Melanie Michon[2], James Goss[2], David Gerada[1], Zeyuan Xu[1], Chris Gerada[1], He Zhang[3]
*[1]University of Nottingham, United Kingdom; [2]Motor Design Ltd., United Kingdom; [3]University of Nottingham Ningbo, China*

**2464 | Approaches for Improving Lumped Parameter Thermal Networks for Outer Rotor SPM Machines**
Daniel Wöckinger[1], Gerd Bramerdorfer[1], Silvio Vaschetto[2], Andrea Cavagnino[2], Alberto Tenconi[2], Wolfgang Amrhein[1], Frank Jeske[3]
*[1]Johannes Kepler University Linz, Austria; [2]Politecnico di Torino, Italy; [3]ebm-papst St. Georgen GmbH & Co. KG, Germany*

**2182 | Electromagnetic and Thermal Evaluation of Surface-Mounted PM Vernier Machines**
Mostafa Ahmadi Darmani[1], Silvio Vaschetto[1], Andrea Cavagnino[1], Mircea Popescu[2]
*[1]Politecnico di Torino, Italy; [2]Motor Design Ltd., United Kingdom*

**2183 | Comparison of Superposition Equivalent Loading Methods for Induction Machine Temperature Tests**
Silvio Vaschetto[1], Emmanuel Agamloh[2], Federica Graffeo[1], Andrea Cavagnino[1]
*[1]Politecnico di Torino, Italy; [2]Baylor University, United States*

## Session G07: Electric Machines Materials and Additive Manufacturing

**1771 | Additive Manufacturing of a Conformal Hybrid-Strand Concentrated Winding Topology for Minimal AC Loss in Electrical Machines**
Nick Simpson[1], Jakob Jung[2], Axel Helm[2], Phil Mellor[1]
*[1]University of Bristol, United Kingdom; [2]Additive Drives GmbH, Germany*

**1934 | Multi-Permeability Optimization Approach for the Iron Core of a Synchronous Reluctance Machine – an Application of Additive Manufacturing**
Thang Q. Pham, Shanelle N. Foster
*Michigan State University, United States*

**1650 | Selection of Soft Magnetic Composite Material for Electrical Machines Using 3D FEA Simulations**
Maged Ibrahim[1], Sumeet Singh[2], Dwaipayan Barman[2], Fabrice Bernier[1], Jean-Michel Lamarre[1], Serge Grenier[3], Pragasen Pillay[2]
*[1]National Research Council of Canada, Canada; [2]Concordia University, Canada; [3]Rio Tinto Fer et Titane, Canada*

**1722 | Flux Switching Permanent Magnet Motor with Metal Amorphous Nanocomposite Soft Magnetic Material and Rare Earth Free Permanent Magnets**
Satoru Simizu[1], Kevin Byerly[1], Kyle Schneider[1], Heonyoung Kim[2], Mark Nations[2], Sneha Narasimhan[2], Richard Beddingfield[2], Subhashish Bhattacharya[2], Michael E. McHenry[1]
*[1]Carnegie Mellon University, United States; [2]North Carolina State University, United States*

## Session G08: Loss Analysis in Electric Machines

**1048 | Experimental Determination of Conductor Lay and Impact on AC Loss in Volume Manufactured Machines Using X-Ray Computed Tomography**
Joshua Hoole[1], Nick Simpson[1], Philip H. Mellor[1], Abdeljalil Daanoune[2]
*[1]University of Bristol, United Kingdom; [2]hofer powertrain UK Ltd., United Kingdom*

**1645 | Loss Mitigation Techniques for a Novel Toroidal Permanent Magnet Motor**
Maged Ibrahim, Fabrice Bernier, Jean-Michel Lamarre
*National Research Council of Canada, Canada*

**1708 | Computationally Efficient Prediction of Statistical Variance in the AC Losses of Multi-Stranded Windings**
Philip Mellor, Joshua Hoole, Nick Simpson
*University of Bristol, United Kingdom*

**1802 | Experimental Evaluation of Iron Losses in Radial Flux Permanent Magnet Synchronous Machines**
Gereon Goldbeck, Gerd Bramerdorfer, Daniel Wöckinger, Christoph Dobler, Wolfgang Amrhein
*Johannes Kepler University Linz, Austria*

## Session G09: Noise and Vibrations in Electric Machines

**1809 | Effects of Stator Laminations on Acoustic Noise of Electrical Machines**
Issah Ibrahim, David Alister Lowther
*McGill University, Canada*

**1673 | Analysis of Claw Deflections and Radial Magnetic Forces in Low-Cost Sub-Fractional Horsepower BLDC Claw-Pole Motors**
Stefan Leitner, Nejat Saed, Annette Mütze
*Graz University of Technology, Austria*

**2319 | Dominant Spatial Order Airgap Force Based Current Profiling Coupled with Fast Vibration Prediction in Switched Reluctance Machines for NVH Mitigation**
Shuvajit Das[1], Md Ehsanul Haque[1], Anik Chowdhury[1], Yilmaz Sozer[1], David Colavincenzo[2], Fernando Venegas[2], Jeffrey Geither[2]
*[1]The University of Akron, United States; [2]Bendix Commercial Vehicle Systems, United States*

**2358 | Direct Acceleration Harmonic Control with Current Harmonics Injection Method to Reduce Acoustic Noise and Vibration in Switched Reluctance Machines**
Omer Gundogmus, Shuvajit Das, Anik Chowdhury, Abdul Wahab Bandarkar, Yilmaz Sozer
*The University of Akron, United States*

## Session G10: High Speed and Bearingless Machines

**1900 | Normalized Analytical Model of Stresses in a Surface Mounted Permanent Magnet Rotor**
Martin Johnson, Kyle Hanson, Eric L. Severson
*University of Wisconsin Madison, United States*

**1575 | Requirements for Full Passive Suspension on a Bearingless Motor with Electrodynamic Axial Stabilization and Radial Permanent Magnet Bearings**
Guilherme Cavalcante Rubio, Yusuke Fujii, Akira Chiba
*Tokyo Institute of Technology, Japan*

**1943 | Principles and Test Result of Novel Full Passive Magnetic Levitation Motor with Diamagnetic Disk**
Yoshiki Ozawa[1], Yusuke Fujii[1], Akira Chiba[1], Hiroya Sugimoto[2], Haruhiko Suzuki[3], Hannes Bleuler[4]
*[1]Tokyo Institute of Technology, Japan; [2]Tokyo Denki University, Japan; [3]Fukushima College, Japan; [4]EPFL, Switzerland*

**2288 | Analysis and Design of Multi-Phase Combined Windings for Bearingless Machines**
Anvar Khamitov, Eric L. Severson
*University of Wisconsin Madison, United States*

## Session G11: Electrical Machines – 1

**2315 | Design and Comparative Performance Analysis of Transverse Flux and Axial Flux Topologies for Permanent Magnet Synchronous Machines**
Anik Chowdhury[1], Shuvajit Das[1], Teppei Tsuda[2], Naoto Saito[2], Subrata Saha[2], Yilmaz Sozer[1]
*[1]The University of Akron, United States; [2]Aisin Corporation, Japan*

**2441 | Performance Comparison of Step Skew in Interior and Surface-Mount Permanent Magnet Machines**
Md Sariful Islam, Amina Shrestha, Mohammad Islam
*Halla Mechatronics, United States*

**1672 | Impact of Electric Field on Magnetic Flux Distribution in Electrical Machines with Very Large Size**
Siqi Lin, Amir Ebrahimi, Jens Friebe
*Leibniz Universität Hannover, Germany*

**2133 | PWM Torque Ripple Compensation for a Dual Three Phase Synchronous Machine**
Claudio Bianchini[1], Ambra Torreggiani[1], Matteo Davoli[2], Alberto Bellini[3], Ludovico Ortombina[4], Nicola Bianchi[4]
*[1]University of Modena and Reggio Emilia, Italy; [2]Raw Power srl, Italy; [3]University of Bologna, Italy; [4]University of Padova, Italy*

**1458 | On Shortening the Numerical Transient in Time-Stepping Finite Element Analysis of Induction Motors under Inter-Turn Short Circuit Faults**
Hossein Nejadi Koti, Zahra Valipoor, Hao Chen, Nabeel A. O. Demerdash
*Marquette University, United States*

**1321 | Design of an Outer Rotor PMSM with Soft Magnetic Composite Stator Core**
Mohanraj Muthusamy, Pragasen Pillay
*Concordia University, Canada*

**1655 | Novel Bent Steel Sheet Strip Based Two-Pole Single-Phase BLDC Motor Topology for Low-Cost Fan Applications**
Stefan Leitner, Nejat Saed, Annette Mütze
*Graz University of Technology, Austria*

## Session G12: Electrical Machines – 2

**2166 | Analytical Model of the Ferromagnetic Properties in Laminations Damaged by Cutting**
Zbigniew Gmyrek[1], Andrea Cavagnino[2]
*[1]Lodz University of Technology, Poland; [2]Politecnico di Torino, Italy*

**2036 | State Estimation and Run-Out Reduction for Magnetically Levitated Motor Systems**
Nathan Petersen, Timothy Slininger, Eric L. Severson
*University of Wisconsin Madison, United States*

**1394 | Comparison of the Flux Reversal and Vernier Hybrid Machine for a Hinged Wave Energy Converter**
Lewis Chambers[1], Nick Baker[1], Mike Galbraith[2], Edward Spooner[2]
*[1]Newcastle University, United Kingdom; [2]Fountain Design Limited, United Kingdom*

**2045 | Induction Motor Shaft-Frame Voltage Analysis**
Fernando J.T.E. Ferreira, José Alberto, Anibal T. de Almeida
*University of Coimbra, Portugal*

**2451 | Design Optimization and Performance Analysis of Bifilar Wound Switched Reluctance Motors**
Abdul Wahab Bandarkar[1], Muntasir Islam[1], Senol Sancar[1], Lavanya Vadamodala[1], Md Ehsanul Haque[1], Yilmaz Sozer[1], Reginald Garcia[2]
*[1]The University of Akron, United States; [2]Future Motors, United States*

**2263 | Influence of Constructive Parameters on the Performance of an Axial-Flux Induction Machine with Solid and Magnetically Anisotropic Rotor**
Carlos Madariaga[1], Juan Tapia[1], Nicolás Reyes[1], Werner Jara[2], Michele Degano[3]
*[1]University of Concepcion, Chile; [2]Pontificia Universidad Católica de Valparaiso, Chile; [3]University of Nottingham, United Kingdom*

**2191 | A Comparison of Cryogenic-Cooled and Superconducting Electrical Machines**
Marco Biasion[1], João F. P. Fernandes[2], Paulo José da Costa Branco[2], Silvio Vaschetto[1], Andrea Cavagnino[1], Alberto Tenconi[1]
*[1]Politecnico di Torino, Italy; [2]Universidade de Lisboa, Portugal*

## Session G13: Electrical Machines – 3

**1918 | Hybrid Solid State Switch for the Efficiency Improvement in Controlling AC Motors**
Yuzhi Zhang, Utkarsh Raheja, Pietro Cairoli
*ABB Inc., United States*

**1227 | 3D Thermal Network Modeling for Axial-Flux Permanent Magnet Machines with Experimental Validation**
Calvin Corey, William Wink
*Leonard DRS Naval Power Systems, United States*

**1778 | Modeling of Rotor Flux Barriers in a Brushless Doubly-Fed Reluctance Machine**
Shivang Agrawal, Hadi Chouhdry, Arijit Banerjee
*University of Illinois at Urbana-Champaign, United States*

**1922 | Partial Discharge Analysis and Insulation Design of High Speed Slotless Machine for Aerospace Applications**
Ritvik Chattopadhyay[1], Md Sariful Islam[2], Rajib Mikail[3], Iqbal Husain[1]
*[1]North Carolina State University, United States; [2]Halla Mechatronics, United States; [3]ABB, United States*

**2264 | Frequency-Domain Analysis and Design of Thomson-Coil Actuators**
Bruno Lequesne[1], Tyler Holp[2], Steve Schmalz[2], Michael Slepian[2], Hongbin Wang[2]
*[1]E-Motors Consulting, LLC, United States; [2]Eaton, United States*

**2193 | Design Optimization Procedure of Air-Cored Resonant Induction Machines**
Zhao Jin[1], Matteo F. Iacchetti[1], Alexander C. Smith[1], Rajesh P. Deodhar[2], Yoshiyuki Komi[3], Ahmad Anad Abduallah[2], Chiaki Umemura[3]
*[1]The University of Manchester, United Kingdom; [2]IMRA Europe SAS UK Research Centre, United Kingdom; [3]Aisin Seki Co., Ltd., Japan*

**2367 | Loss Minimization Control of an Electronic Pole Changing 4-Pole/2-Pole Induction Motor**
Taohid Latif[1], Mohamed Zubair M. Jaffar[2], Iqbal Husain[1]
*[1]North Carolina State University, United States; [2]FEV North America Inc., United States*

**2330 | Modelling and Build of an Integrated Linear Engine Generator Designed for Power Density**
Ramn Moeini Korbekandi, Nick J. Baker, Mehmet Kulan, Dawei Wu
[1]Newcastle University, United Kingdom; [2]University of Birmingham, United Kingdom

## Session G14: Modeling of Electric Machines – 2

**1242 | Simplified 3-D Hybrid Analytical Modelling of Magnet Temperature Distribution for Surface-Mounted PMSM with Segmented Magnets**
Dawei Liang[1], Z.Q. Zhu[1], J.H. Feng[2], S.Y. Guo[2], Y.F. Li[2], A.F. Zhao[2], J.W. Hou[2]
*[1]The University of Sheffield, United Kingdom; [2]CRRC Zhuzhou Institute Co. Ltd., China*

**1494 | Optimization of IM Rotor Bars Inclination Angle Using Analytical Model in Free FEA Software**
Thanh Tung To[1], Emad Roshandel[2], Amin Mahmoudi[2], Zhi Cao[2], Solmaz Kahourzade[1]
*[1]University of South Australia, Australia; [2]Flinders University, Australia*

**1510 | 2D Subdomain Model of the Ladder Linear Induction Machine with considering Saturation Effect**
Emad Roshandel[1], Amin Mahmoudi[1], Solmaz Kahourzade[2]
*[1]Flinders University, Australia; [2]University of South Australia, Australia*

**2254 | Loss Analysis of Induction Motors Fed by Inverters by Using Simple Models of Major and Minor Hysteresis Loops in Stator and Rotor Cores**
Katsumi Yamazaki, Yoshito Sato, Keigo Terauchi
*Chiba Institute of Technology, Japan*

**1042 | Analytical Magnetic Model for Variable-Flux Interior Permanent Magnet Synchronous Motors**
Bingnan Wang[1], Kyung-Hun Shin[1], Yuki Hidaka[2], Shota Kondo[2], Hideaki Arita[2], Kazumasa Ito[2]
*[1]Mitsubishi Electric Research Laboratories, United States; [2]Mitsubishi Electric Corporation, Japan*

**1684 | Hybrid Approach for the Modeling of Magnetic Force Excitations in Multipole Wind Turbine Generators considering Air Gap Imperfections**
Alexander Kern[1], Christoph Mülder[1], Kay Hameyer[2], Jianning Dong[1]
*[1]RWTH Aachen University, Germany; [2]Delft University of Technology, The Netherlands*

## Session G15: IPMSM and Synchronous Reluctance Machines

**1031 | Comparative Study of Three-Phase and Dual Three-Phase Machines considering PWM Effect**
Yawei Wang[1], Joshua Taylor[2], Berker Bilgin[2]
*[1]Huazhong University of Science and Technology, China; [2]McMaster University, Canada*

**1204 | Space-Vector State Dynamic Model of the Synchronous Reluctance Motor considering Self, Cross-Saturation and Iron Losses**
Angelo Accetta[1], Maurizio Cirrincione[2], Marcello Pucci[1], Antonino Sferlazza[3]
*[1]CNR-INM, Italy; [2]University of the South Pacific, Italy; [3]University of Palermo, Italy*

**1283 | Design of Notches on Rotor Surface to Minimize Cogging Torque in Dual-Layered IPMSM by Optimizing Squared Gap Flux Density Waveform**
Marika Kobayashi, Shigeo Morimoto, Masayuki Sanada, Yukinori Inoue
*Osaka Prefecture University, Japan*

**1617 | Permanent Magnet Eddy Current Loss Measurement at Higher Frequency and Temperature Effects under Ideal Sinusoidal and Non-Sinusoidal External Magnetic Fields**
Nijan Yogal[1], Christian Lehrmann[1], Markus Henke[2]
*[1]Physikalisch-Technische Bundesanstalt, Germany; [2]Technical University of Braunschweig, Germany*

**1852 | Combined Dimensional and Topology Optimization of Interior Permanent Magnet Synchronous Machine Rotors Using a Permanent Magnet Function Interpolation Method**
Feng Guo, Ian P. Brown
*Illinois Institute of Technology, United States*

**2154 | Comparative Analysis of Two Different Types of Blended Permanent Magnet Assisted Synchronous Reluctance Machine**
Qingqing Ma[1], Ayman EL-Refaie[1], Alireza Fatemi[2], Thomas Nehl[2]
*[1]Marquette University, United States; [2]General Motors, United States*

**2211 | Time-Efficient Multi-Physics Optimization Approaches for the Design of Synchronous Reluctance Motors**
Christophe De Gréef[1], Virginie Kluyskens[1], François Henrotte[1,2], Christophe Versèle[3], Christophe Geuzaine[2], Bruno Dehez[1]
*[1]Université catholique de Louvain, Belgium; [2]Université de Liège, Belgium; [3]Alstom Belgium, Belgium*

**2241 | Variable-Magnetization Interior Permanent Magnet Motor Yield Widely Variable Flux Due to Small Magnetizing Current and Operating at High Power over a Wide Speed Range**
Kazuto Sakai, Kyouhei Yoneda, Wataru Suzuki
*Toyo University, Japan*

## Session G16: Other Synchronous Machines – 1

**1040 | Multi-Objective Optimization of a Dual Stator Brushless Hybrid Excitation Motor Based on Response Surface Model and NSGA2**
Xu Wang, Ying Fan, Xingchi Lu, Qiushuo Chen
*Southeast University, China*

**1047 | Multi-Objective Optimization Design of Unequal Halbach Array Permanent Magnet Vernier Motor Based on Optimization Algorithm**
Qiushuo Chen, Ying Fan, Yutong Lei, Xu Wang
*Southeast University, China*

**1261 | Outer and Inner Rotor Line-Start Permanent-Magnet Synchronous Motors: An Electromagnetic and Thermal Comparison Study**
M.F. Palangar[1], Wen L. Soong[2], A. Mahmoudi[1]
*[1]Flinders University, Australia; [2]University of Adelaide, Australia*

**1388 | Performance Comparison of Large-Scale Design-Optimised Non-Overlap and Overlap Winding Wound Rotor Synchronous Generators**
Karen S. Garner, Maarten J. Kamper
*Stellenbosch University, South Africa*

**1483 | Study on Power Tracking Excitation Control and Parameters Sensitivity of Dual-Excited Synchronous Generator**
Guorui Xu[1], Zhenzhen Wang[1], Weili Li[2], Yang Zhan[1], Haisen Zhao[1], Yingli Luo[1]
*[1]North China Electric Power University, China; [2]Beijing Jiaotong University, China*

**1081 | Inter-Turn Short Circuit Fault Identification of Salient Pole Synchronous Generators by Descriptive Paradigm**
Hossein Ehya[1], Arne Nysveen[1], Jose A. Antonino-Daviu[2], Bilal Akin[3]
*[1]Norwegian University of Science and Technology, Norway; [2]Universitat Politecnica de Valencia, Spain; [3]The University of Texas at Dallas, United States*

## Session G17: Other Synchronous Machines – 2

**1893 | Comparison of Optimized Fault-Tolerant Modular Stator Machines with U-Shape and H-Shape Core Structure**
Eddy Perez[1], Werner Jara[1], Carlos Madariaga[2], Juan Tapia[2], Gerd Bramerdorfer[3], Javier Riedemann[4], Ilya Petrov[5], Juha Pyrhönen[5]
*[1]Pontificia Universidad Católica de Valparaiso, Chile; [2]University of Concepcion, Chile; [3]Johannes Kepler University Linz, Austria; [4]The University of Sheffield, United Kingdom; [5]Lappeenranta University of Technology, Finland*

**1983 | A Design Procedure for Hybrid Rotor PMSM to Achieve Wide Constant Power Speed Ratio**
Dheeraj Bobba, Bulent Sarlioglu
*University of Wisconsin Madison, United States*

**2063 | Design and Metamodel-Based Optimization of a High Power Density Wound Field Traction Motor**
Nanjun Tang, Dominick Sossong, Ian P. Brown
*Illinois Institute of Technology, United States*

**2201 | Design of High Torque Density Reduced-Rare-Earth Consequent Pole PMBLDC Motor for Ceiling Fan**
Sharankumar Shastri, Utkarsh Sharma, Bhim Singh
*Indian Institute of Technology Delhi, India*

**2558 | Design and Performance Comparison of Nine-Phase Ferrite Spoke Interior Permanent Magnet Machines with Concentrated Windings for Traction Applications**
Zhiwei Zhang
*The Ohio State University, United States*

**2022 | Performance Comparison of Consequent-Pole and Homopolar Consequent-Pole Bearingless Motors for Low Speed Applications**
Hiroya Sugimoto, Miyabi Terashima
*Tokyo Denki University, Japan*

## Session G18: Switched Reluctance and Flux Switching Machines

**1183 | A Novel MTPA Control Strategy for Multiple Torque Component Single Air Gap Magnetless Machines**
Shaofeng Jia, Xiaozhuang Dong, Deliang Liang, Shuai Feng
*Xi'an Jiaotong University, China*

**1223 | Optimal Design of a Novel Double-Stator Linear-Rotary Flux-Switching Permanent-Magnet Generator for Offshore Wind-Wave Energy Conversion**
Guozhen Zhang[1], Rui Nie[1], Jikai Si[1], Chun Gan[2], Yihua Hu[3]
*[1]Zhengzhou University, China; [2]Huazhong University of Science and Technology, China; [3]University of York, United Kingdom*

**1979 | Six-Phase Switched Reluctance Motors with Small Torque Ripple, Radial Force Ripple, DC Current Ripple, Copper Loss, and Number of Switches**
Takayuki Kusumi, Eiji Hiraki
*Okayama University, Japan*

**2150 | Design Methodology and Considerations to Energy Efficient Switched Reluctance Motor for Ceiling Fan Application**
Vipin Kumar Singh, Utkarsh Sharma, Bhim Singh, Sharankumar Shastri
*Indian Institute of Technology Delhi, India*

**2364 | Reliability Models to Estimate Mean Time to Failure of Switched Reluctance Machines**
Lavanya Vadamodala, Shuvajit Das, Anik Chowdhury, Abdul Wahab Bandarkar, Md Ehsanul Haque, Yilmaz Sozer
*The University of Akron, United States*

**2472 | An Experimental Verification of a Dual-Mode Reluctance Motor for Electric Vehicle Applications**
Kyohei Kiyota[1], Haruka Isogai[2], Kenji Amei[2], Takahisa Ohji[2]
*[1]Tokyo Institute of Technology, Japan; [2]University of Toyama, Japan*

**2532 | Analysis and Benchmarking of Radial Flux Cycloidal Magnetic Gears with Reduced Permanent Magnet Piece Count Using Consequent Poles**
Matthew Johnson[1], Shima Hasanpour[2], Matthew C. Gardner[3], Hamid A. Toliyat[2]
*[1]U.S. Army Research Laboratory, United States; [2]Texas A&M University, United States; [3]The University of Texas at Dallas, United States*

## Session G19: Actuators, Axial Flux and Linear Machines

**1785 | Statistical Analysis of Manufacturing Tolerances Effect on Axial-Flux Permanent Magnet Machines Cogging Torque**
Andrés Escobar[1], Gonzalo Sánchez[1], Werner Jara[1], Carlos Madariaga[2], Juan Tapia[2], Michele Degano[3], Javier Riedemann[4]
*[1]Pontificia Universidad Católica de Valparaiso, Chile; [2]University of Concepcion, Chile; [3]University of Nottingham, United Kingdom; [4]The University of Sheffield, United Kingdom*

**2013 | Design Optimization and Experimental Study of Coreless Axial-Flux PM Machines with Wave Winding PCB Stators**
Peng Han[1], Damien Lawhorn[1], Yaser Chulaee[1], Donovin Lewis[1], Greg Heins[2], Dan M. Ionel[1]
*[1]University of Kentucky, United States; [2]Regal Beloit Corporation, Australia*

**2214 | Design of a High Speed Printed Circuit Board Coreless Axial Flux Permanent Magnet Machine**
Federico Marcolini, Giulio De Donato, Fabio Giulii Capponi, Federico Caricchi
*Sapienza University of Rome, Italy*

**2160 | Design and Analysis of Double-Sided Thomson Coil Actuator for Extra Fast Opening Operation**
Ali Al-Qarni, Ayman EL-Refaie
*Marquette University, United States*

**2056 | Permanent Magnet Linear Generator Design for Surface Riding Wave Energy Converters**
Farid Naghavi[1], Shrikesh Sheshaprasad[1], Matthew Gardner[2], Aghamarshana Meduri[1], HeonYong Kang[1], Hamid Toliyat[1]
*[1]Texas A&M University, United States; [2]The University of Texas at Dallas, United States*

**2342 | On the Design and Stability of a Reluctance Actuator for Precision Motion Systems**
Mohammad Al Saaideh, Natheer Alatawneh, Mohammad Al Janaideh
*Memorial University, Canada*

**1172 | Planar Levitation and Propulsion of a Solid-State Craft over Conducting Surfaces**
Andrew W. Meldrum, Will Robertson, Wen L. Soong
*The University of Adelaide, Australia*

**1075 | Force and Torque Assessment in a Rotating to Linear Motion Magnetic Converter with Gearing Capability**
Mauro Andriollo, Simone Bernasconi, Andrea Tortella
*University of Padova, Italy*

## Session G20: Electrical Machines – 4

**1196 | Additively Manufactured Hollow Conductors for High Specific Power Electrical Machines: Aluminum vs Copper**
Fan Wu, Ayman M. EL-Refaie, Ali Al-Qarni
*Marquette University, United States*

**1258 | Rotor Loss and Temperature Field of Synchronous Condenser under Single-Phase Short Circuit Fault Affected by Different Materials of Rotor Slot Wedge**
Guorui Xu, Peidong Hu, Zhiqiang Li, Haisen Zhao, Yang Zhan
*North China Electric Power Uninversity, China*

**1821 | Studies of Measurement Uncertainties in the Characterization of Soft Magnetic Materials and Their Impact on the Electric Machine Performance Prediction**
Christoph Dobler, Daniel Wöckinger, Gerd Bramerdorfer, Gereon Goldbeck, Wolfgang Amrhein
*Johannes Kepler University Linz, Austria*

**1252 | Characteristics Evaluation of Magnetic Multiple Spur Gear for High Speed Motor Drive System**
Kohei Aiso[1], Kan Akatsu[2], Yasuaki Aoyama[3]
*[1]Shibaura Institute of Technology, Japan; [2]Yokohama National University, Japan; [3]Hitachi, Ltd., Japan*

**1992 | Design Optimization of a Very High Power Density Motor with a Reluctance Rotor and a Modular Stator Having PMs and Toroidal Windings**
Peng Han[1], Murat G. Kesgin[1], Dan M. Ionel[1], Rohan Gosalia[2], Nakul Shah[2], Charles J. Flynn[2], Chandra S. Goli[3], Somasundaram Essakiappan[3], Madhav Manjrekar[3]
*[1]University of Kentucky, United States; [2]QM Power, Inc., United States[3]University of North Carolina Charlotte, United States*

## Session G21: Noise and Vibrations in Electric Machines – 2

**1212 | Transient Stray Flux Analysis via MUSIC Methods for the Detection of Uniform Gearbox Teeth Wear Faults**
Israel Zamudio-Ramirez[1], Roque A. Osornio-Rios[1], Jose Antonino-Daviu[2]
*[1]Universidad Autonoma de Queretaro, Mexico; [2]Universitat Politecnica de Valencia, Spain*

**1302 | Analytical and Experimental Investigations of Magnetostriction Influence on Strain Measurement in Switched Reluctance Machines**
Yifei Cai[1], Haruki Sobue[1], Candra Adi Wigna[1], Akira Chiba[1], Kunihiro Senda[2], Souichiro Yoshizaki[3]
*[1]Tokyo Institute of Technology, Japan; [2]JFE Techno-Research Corporation, Japan; [3]JFE Steel Corporation, Japan*

**1585 | Reduction of Both of Radial Force and Torque Ripple in Double Inverter Fed PMSM**
Takumi Soeda, Hitoshi Haga
*Nagaoka University of Technology, Japan*

**1901 | Study on IPMSM Rotor Shape for Reduction of Harmonics and Vibration**
Seung-Hyeon Lee[1], In-Jun Yang[2], Si-Woo Song[2], Won-Ho Kim[1], Ik-sang Jang[3]
*[1]Gachon University, Korea; [2]Hanyang University, Korea; [3]Hyundai Mobis, Korea*

**1995 | Vibration Performance of a Power Electronic Transformer under Different Phase-Shift Modulation Methods**
Xiaokang Peng, Zicheng Liu, Dong Jiang
*Huazhong University of Science and Technology, China*

**2127 | Demagnetization Detection in PMSMs Using Search Coils Exploiting Machine's Symmetry**
Marcos Orviz Zapico[1], David Diaz Reigosa[1], Hyeon Jun Lee[2], Muhammad Saad Rafaq[2], Sang Bin Lee[2], Fernando Briz del Blanco[1]
*[1]University of Oviedo, Spain; [2]Korea University, Korea*

**2163 | Research on High Frequency Vibration Reduction Using Carrier Phase Shifted PWM for 4*3-Phase Windings Permanent Magnet Synchronous Motor**
She Yan, Qiyuan Wang, Yunsong Xu, Zicheng Liu, Haiyang Fang, Dong Jiang
*Huazhong University of Science and Technology, China*

**2266 | Air Gap Length Detection Method by Analysing Third-Order Harmonic Component of No-Load Line-Line Voltages on Three-Group and Three-Phase PMSMs**
Kodai Okazaki[1], Kan Akatsu[2], Kan Yang[2]
*[1]Mitsubishi Electric Co., Ltd., Japan; [2]Yokohama National University, Japan*

## Session G22: Modeling of Electric Machines – 3

**1097 | Analytical Modeling and Design Optimization of a Vernier Permanent Magnet Motor**
Bingnan Wang[1], Lei Zhou[1,2], Hongyu Wang[1], Chungwei Lin[1]
*[1]Mitsubishi Electric Research Laboratories, United States; [2]The University of Texas at Austin, United States*

**1207 | Characteristic Analysis of IPMSM for EV Traction considering the Effect of Field and Armature Excitations on AC Copper Loss**
Soo-Hwan Park, Jun-Woo Chin, Kyoung-Soo Cha, Jun-Yeol Ryu, Myung-Seop Lim
*Hanyang University, Korea*

**1236 | Cost-Efficient 2D Analysis for PM Eddy Current Loss in PMSM by Coupled A-Φand T-Ω Method**
Jun-Yeol Ryu, Jun-Woo Chin, Myung-Seop Lim
*Hanyang University, Korea*

**1237 | Efficiency Analysis of Brushless Doubly-Fed Induction Generator Based on Improved Steady-State Equivalent Circuit**
Yangsheng Zhang[1], Yi Liu[1], Wei Xu[1], Jose Rodriguez[2]
*[1]Huazhong University of Science and Technology, China; [2]Universidad Andres Bello, Chile*

**1646 | Development and Evaluation of a Power Hardware-in-the-Loop (PHIL) Emulator Testbench for Aerospace Applications**
He Song[1], John Noon[1], Igor Cvetkovic[1], Bo Wen[1], Srdjan Srdic[2], Gernot Pammer[2], Dushan Boroyevich[1], Rolando Burgos[1]
*[1]Virginia Polytechnic Institute and State University, United States; [2]EGSTON Power Electronics, Austria*

**2380 | A Generalized Prandtl-Ishlinskii Model for Hysteresis Modeling in Electromagnetic Devices**
Mohammad Al Saaideh, Natheer Alatawneh, Mohammad Al Janaideh
*Memorial University, Canada*

## Session G23: High Speed Machines – 1

**1144 | Rotor Reinforcement in High-Speed Motors by Polymer Composites**
Anthony Coppola, Alireza Fatemi
*General Motors, United States*

**1537 | Modeling and Optimal Design of a Very High Speed Motor Slotless Technology with Toroidal Winding for Serial Production**
Stephane Tavernier[1], Christophe Espanet[1], Gael Andrieux[2]
*[1]Moving Magnet Technologies, France; [2]Compact Power Motion GmbH, Germany*

**1687 | Design Approach of Hairpin Winding Motor with High Parallel Path Numbers**
Shaohong Zhu, Krzysztof Paciura, Richard Barden
*Cummins Inc., United Kingdom*

**1697 | Suppression of Winding AC Losses in High-Speed Permanent Magnet Machines by Novel Transposition Technologies**
Xinyue Chen, Haiyang Fang, Dawei Li, Ronghai Qu, Xinggang Fan, Haobo Hu
*Huazhong University of Science and Technology, China*

**1781 | High Speed Permanent Magnet Machine Design for Optimum Volumetric Power Density**
Zhentao Stephen Du, Jagadeesh Tangudu
*Raytheon Technologies Research Center, United States*

**1891 | Suspension Force Design Guidelines for Bearingless Permanent Magnet Machines**
Bharat Ramadas, Eric L. Severson
*University of Wisconsin Madison, United States*

**2073 | Bearingless Generator Design and Optimization for High-Speed Applications**
Imthiaz Ahmed, Eric L. Severson
*University of Wisconsin Madison, United States*

## Session G24: Electrical Machines – 5

**2080 | Modular Fault-Tolerant Machine Design with Improved Electromagnetic Isolation for Urban Air Mobility (UAM) Aircraft**
James Swanke, Hao Zeng, Thomas M. Jahns
*University of Wisconsin Madison, United States*

**2483 | Design and Analysis of a High Specific Power Outer Rotor Surface Mounted Permanent Magnet Machine Equipped with Additively Manufactured Windings**
Ali Al-Qarni, Ayman EL-Refaie, Fan Wu
*Marquette University, United States*

**1532 | Hybrid Spoke Permanent Magnet Synchronous Generator Design for Wind Power Generation System**
Dong-Ho Kim[1], Su-Yong Kim[2], In-Jun Yang[1], Si-Woo Song[1], Ju Lee[1], Won-Ho Kim[3]
*[1]Hanyang University, Korea; [2]Korea Electronics Technology Institute, Korea; [3]Gachon University, Korea*

**2326 | Performance and Cost Comparison of Conventional- and Vernier PM Wind Generators for Small-Scale Uncontrolled Passive Wind Energy Systems**
C.J.J. Labuschagne, M.J. Kamper
*Stellenbosch University, South Africa*

**1985 | Modular Modeling and Distributed Control of Permanent-Magnet Modular Motor Drives (MMDs) for Electric Aircraft Propulsion**
Hao Zeng, James Swanke, Thomas M. Jahns, Bulent Sarlioglu
*University of Wisconsin Madison, United States*

## Session G25: High Speed Machines – 2

**2027 | Current in PWM Converter-Fed Electric Machines Using Electromagnetic Finite Element Analysis On the Modeling of Bearing Voltage and**
Peng Han[1], Yibin Zhang[1], Murat G. Kesgin[1], Greg Heins[2], Dean Patterson[2], Mark Thiele[2], Dan M. Ionel[1]
*[1]University of Kentucky, United States; [2]Regal Beloit Corporation, Australia*

**2130 | Radial and Axial Inlet and Outlet Design for End Winding Cooling of High-Speed Integrated Flux-Switching Motor-Compressor**
Leyue Zhang, Hao Ding, Ahmed Hembel, Gregory Nellis, Bulent Sarlioglu
*University of Wisconsin Madison, United States*

**2138 | Application of Flat Rectangular Wire Concentrated Winding for AC Loss Reduction in Electrical Machines**
Shaohong Zhu, Krzysztof Paciura, Richard Barden
*Cummins Inc., United Kingdom*

**2387 | Multiphysics Optimization Model to Design High-Power Ultra-High-Speed Machine for Portable Mechanical Antenna Application**
Md Khurshedul Islam, Seungdeog Choi
*Mississippi State University, United States*

**2403 | Rotor Design for 2 Pole Bearingless Interior Permanent Magnet Slice Motor**
Krishan Kant, David L. Trumper
*Massachusetts Institute of Technology, United States*

**2408 | Analytical Calculation of the Mechanical Stress on IPMSM Bridges with Decomposition of the Centrifugal Force**
Guoyu Chu[1], Rukmi Dutta[1], John Fletcher[1], Howard Lovatt[2], M.F. Rahman[1]
*[1]University of New South Wales, Australia; [2]CSIRO, Australia*

**2492 | Modelling, Analysis and Design Considerations of Multi-Phase Bearingless Permanent Magnet Synchronous Machine**
Alessandro Marfoli, Mauro Di Nardo, Seamus Garvey, Michele Degano, Rajiv Vashisht, Robert Turnbull, Chris Gerada
*University of Nottingham, United Kingdom*

# Topic H: Electric Drives

## Session H01: PM Motor Drives – 1

**2120 | Practical Compensation Strategy for Accurate Torque Control in Mass-Produced High-Speed Traction IPM E-Drives**
Ran Cao[1], Dakai Hu[2], Yue Cao[1]
*[1]Oregon State University, United States; [2]The MathWorks, Inc., United States*

**2186 | Torque-Sensorless Identification of IPMSM Torque Map**
Hyung-June Cho[1], Joohyun Lee[1], Yong-Cheol Kwon[2], Seung-Ki Sul[1]
*[1]Seoul National University, Korea; [2]PLECKO Co., Ltd., Korea*

**2126 | Direct Flux and Load Angle Vector Control of Permanent Magnet Synchronous Motors**
Sandro Rubino, Fabio Mandrile, Luisa Tolosano, Eric Armando, Radu Bojoi
*Politecnico di Torino, Italy*

**1888 | Modeling and Compensation of Nonlinearity in Voltage-Source-Inverters Fed Dual Three-Phase PMSM Drives**
Kailiang Yu, Zheng Wang, Pengcheng Liu, Yihan Chen
*Southeast University, China*

## Session H02: Control for Electric Drives

**1079 | Gradient-Based Predictive Pulse Pattern Control**
Mirza Abdul Waris Begh[1], Petros Karamanakos[1], Tobias Geyer[2]
*[1]Tampere University, Finland; [2]ABB System Drives, Switzerland*

**1136 | A Computationally Efficient Robust Direct Model Predictive Control for Medium Voltage Induction Motor Drives**
Andrei Tregubov[1], Petros Karamanakos[1], Ludovico Ortombina[2]
*[1]Tampere University, Finland; [2]University of Padova, Italy*

**1553 | High Frequency Signal Injection Sensorless Control of Finite-Control-Set Model Predictive Control with Deadbeat Solution**
Ximeng Wu[1], Z.Q. Zhu[1], Nuno M.A. Freire[2]
*[1]The University of Sheffield, United Kingdom; [2]Siemens Gamesa Renewable Energy A/S, Denmark*

**2375 | A Direct Model Predictive Control Strategy for High-Performance Synchronous Reluctance Motor Drives**
Jacopo Riccio[1], Petros Karamanakos[2], Shafiq Odhano[3], Mi Tang[1], Mauro Di Nardo[1], Pericle Zanchetta[1,4]
*[1]University of Nottingham, United Kingdom; [2]Tampere University, Finland; [3]Newcastle University, United Kingdom; [4]Università degli Studi di Pavia, Italy*

## Session H03: New Technologies, Sensors, Reliability and Testing

**1847 | Multi-Core Microcontroller Hardware in the Loop System for Electric Machine Control**
Nicholas Krause[1], Antonio Di Gioia[2], Ian P. Brown[1]
*[1]Illinois Institute of Technology, United States; [2]IEMA US Inc., United States*

**2075 | Design of a Low-Latency Power Electronics-Based Power-HIL System for an EV Motor Controller**
Troy Eskilson, Carl Ngai Man Ho
*University of Manitoba, Canada*

**1073 | Inverter-Embedded Partial Discharge Testing for Reliability Enhancement of Stator Winding Insulation in Low Voltage Machines**
Hyeon-Jun Lee[1], Hanju Kim[1], Jigyun Jeong[1], Kibok Lee[2], Sang Bin Lee[1], Greg C. Stone[3]
*[1]Korea University, Korea; [2]Incheon National University, Korea; [3]Iris Power - A Qualitrol Company, Canada*

**2302 | E-Drive SiC MOSFET Inverter with Self Calibrating VON-Based Junction Temperature Estimator**
Fausto Stella, Paolo Pescetto, Gianmario Pellegrino
*Politecnico di Torino, Italy*

## Session H04: Sensorless Control of Electric Drives – 1

**2542 | Skin Effect of Squirrel Cage Induction Motor under High Frequency Signal Injection**
Joon-Hee Lee[1], Yong-Cheol Kwon[2], Seung-Ki Sul[1]
*[1]Seoul National University, Korea; [2]Plecko Co, Ltd., Korea*

**1755 | Design and Analysis of PLL Speed Estimator for Sensorless Rotor-Flux Oriented Control of Induction Motor Drives**
Prasun Mishra[1], Cristian Lascu[1], Michael Møller Bech[1], Bjorn Rannestad[2], Stig Munk-Neilsen
*[1]Aalborg University, Denmark; [2]KK Wind Solutions, Denmark*

**1030 | High Frequency Injection Transient Disturbance Mitigation for Sensorless Control of Salient Pole Machines**
Zhendong Zhang, Jacob Lamb
*Rockwell Automation, United States*

**1557 | Analysis of Rotor Eccentricity Effects on Saliency Tracking Based Sensorless Control of Permanent Magnet Synchronous Machine**
Ximeng Wu[1], Z.Q. Zhu[1], Yang Chen[1], Zhanyuan Wu[2]
*[1]The University of Sheffield, United Kingdom; [2]Siemens Gamesa Renewable Energy, United Kingdom*

## Session H05: Sensorless Control of Electric Drives – 2

**2493 | Switching Frequency Signal-Injection Sensorless Control Robust to Non-Ideal Characteristics of Inverter System for Dual Three-Phase PMSM**
Yoon-Ro Lee, Jiwon Yoo, Seung-Ki Sul
*Seoul National University, Korea*

**2510 | Gain Scheduling of Full-Order Flux Observer for Sensorless PMSM Drives considering Magnetic Spatial Harmonics**
Jiwon Yoo, Inhwi Hwang, Yoon-Ro Lee, Seung-Ki Sul
*Seoul National University, Korea*

**2519 | Rotor Initial Position Estimation Method of SMPMSM with Polarity Detection Based on Cross-Coupling Inductance Variation**
Hwigon Kim, Joohyun Lee, Seung-Ki Sul
*Seoul National University, Korea*

**2257 | Sensorless Control of a High-Speed PMSM with Rapid Acceleration for Air Compressors Using a High-Order Extended State Observer**
Mingjin Hu[1], Wenfei Yu[1], Jiaxing Lei[1], Zheng Wu[1], Wei Hua[2], Yinfeng Hu[2]
*[1]Southeast University - Nanjing, China; [2]Southeast University - Yancheng, China*

## Session H06: Electric Drive Switching

**2122 | Advances on Analysis, Modeling and Accurate Self-Commissioning Compensation of Inverter Dead-Time Distortion Based on a Physical Model**
Massimiliano Biason[1], Sandro Calligaro[2], Mattia Iurich[1], Roberto Petrella[1], Amir Shahdadi[1]
*[1]University of Udine, Italy; [2]Free University of Bozen, Italy*

**1495 | A New Space-Vector PWM Technique of Two-Level Inverter Fed Asymmetrical Six-Phase Machine: Analysis and Performance Evaluation**
Sayan Paul, Kaushik Basu
*Indian Institute of Science, India*

**1963 | New PWM Switching Strategy for a Dual Inverter Fed Open Winding Motor Drive System**
Yuto Maeda[1], Hiroaki Matsumori[1], Takashi Kosaka[1], Nobuyuki Matsui[1], Hiroki Iwai[2], Teppei Tsuda[2], Subrata Saha[2]
*[1]Nagoya Institute of Technology, Japan; [2]Aisin Corporation, Japan*

**2141 | A Real-Time Sinusoidal Voltage-Adjustment Power Supply System Based on Interleaved BUCK Converters with Enhanced Reference-Tracking Capability**
Xiaofeng Ding, Zhihui Zhao, Zhenyu Shan, Xinrong Song
*Beihang University, China*

## Session H07: PM Motor Drives – 2

**2246 | Variable DC-Link Control Strategy for Maximum Efficiency of Traction Motor Drives**
Paolo Pescetto[1], Andres Sierra-Gonzalez[2], Elena Trancho[2], Gianmario Pellegrino[1]
*[1]Politecnico di Torino, Italy; [2]Basque Research and Technology Alliance, Spain*

**2381 | Control of Dual Three-Phase IPMSM Drive with Cascaded DC-Link Capacitors for Third Generation EV**
Andres Sierra-Gonzalez[1], Paolo Pescetto[2], Elena Trancho[1], Edorta Ibarra[3], Gianmario Pellegrino[2], Fernando Alvarez-Gonzalez[1]
*[1]Basque Research and Technology Alliance, Spain; [2]Politecnico di Torino, Italy; [3]University of the Basque Country, Spain*

**2261 | A Novel Low-Speed Direct-Drive PMSM Control Strategy Based on a Two-DOF Structure**
Kun Cai[1], Jie Hu[1], Mingjin Hu[1], Danfeng Sun[2], Huajun Zhou[2], Kai Liu[1], Hao Hua[3], Wei Hua[1]
*[1]Southeast University, China; [2]Shanghai Aerospace Control Technology Institute, China; [3]Shanghai Jiao Tong University, China*

**2445 | Integrated High-Frequency SiC Based Modular Multi Three-Phase PMSM Drive for Automotive Range Extender**
Nicola Bianchi[1], Sandro Calligaro[2], Giorgio Maldini[3], Mattia Marson[4], Mattia Iurich[5], Roberto Petrella[5]
*[1]University of Padova, Italy; [2]Free University of Bozen, Italy; [3]Metasystem s.p.a., Italy; [4]Koala Electronics s.r.l., Italy; [5]University of Udine, Italy*

## Session H08: Electric Drives

**2368 | Selection of Rotor Position Sensor Resolution for Variable Frequency Drives Utilizing Fixed-Position-Based Speed Estimation**
Luigi Danilo Tornello[1], Giacomo Scelba[1], Giulio De Donato[2], Fabio Giulii Capponi[2], Giuseppe Scarcella[1], Mark Harbaugh[3]
*[1]University of Catania, Italy; [2]Sapienza University of Rome, Italy; [3]Rockwell Automation, United States*

**1262 | A Simple PWM Strategy for Three-Level NPC Converters in Aircraft Electric Starter/Generator System with Improved DC-Link Voltage Utilization and Reduced Common-Mode Voltage**
Feng Guo[1], Tao Yang[1], Seang Shen Yeoh[1], Serhiy Bozhko[1], Patrick Wheeler[1], Ahmed M. Diab[2]
*[1]University of Nottingham, United Kingdom; [2]University of Nottingham Ningbo, China*

**2249 | Performance Analysis of a Fault Isolation System for Fault-Tolerant Voltage-Fed PWM Motor Drives**
Luigi Danilo Tornello[1], Giacomo Scelba[1], Andrea Spampinato[2], Gianluigi Forte[2]
*[1]University of Catania, Italy; [2]STMicroelectronics, Italy*

**1846 | Evaluation of Topologies and Active Control Methods for Overvoltage Mitigation in SiC-Based Motor Drives**
Mohamed S. Diab, Wenzhi Zhou, Xibo Yuan
*University of Bristol, United Kingdom*

**1582 | Design and Benchmark of Passive and Active Inductors for a 7.5 kW Motor Drive**
Zhe Kong[1], Qian Wang[2], Guorong Zhu[1], Haoran Wang[2], Huai Wang[2]
*[1]Wuhan University of Technology, China; [2]Aalborg University, Denmark*

## Session H09: Induction Motor Drives

**1813 | A Multilevel Open-End Winding Six-Phase Induction Motor Drive Topology Based on Three Two-Level Three-Phase Inverters**
Emerson de L. Soares[1], Ayslan C.N. Maia[2], Cursino B. Jacobina[1], Nayara B. de Freitas[3], Nady Rocha[4], Antonio M.N. Lima[1]
*[1]Federal University of Campina Grande, Brazil; [2]Federal Institute of Education, Science and Technology of Ceará, Brazil; [3]INESC TEC, Portugal; [4]Federal University of Paraíba, Brazil*

**2094 | Analysis and Control of Six Switch Inverter Symmetrical Two-Phase Induction Motor (STPIM) Drive with Front End Single-Phase Boost Rectifier**
Josiah O. Haruna, Olorunfemi Ojo
*Tennessee Tech University, United States*

**1578 | Evaluation of the Output Voltage Harmonics of Typical PWM Methods in a Dual-Inverter Fed Open-End Winding Induction Motor with a Floating-Capacitor**
Akihito Mizukoshi[1], Hitoshi Haga[1], Eiichi Sakasegawa[2]
*[1]Nagaoka University of Technology, Japan; [2]National Institute of Technology, Kagoshima College, Japan*

**1996 | Parameter Identification of Inverter-Fed Induction Machines at Standstill Based on Signal Injection**
Anh Tan Nguyen, Van Nam Nguyen, Dong-Choon Lee
*Yeungnam University, Korea*

**1478 | Regenerating-Mode Stabilization of Indirect-Field-Orientation-Controlled Induction Motor for Inertial Load Drive**
Masaki Nagataki[1], Keiichiro Kondo[1], Osamu Yamazaki[2], Kazuaki Yuki[2], Yosuke Nakazawa[2]
*[1]Waseda University, Japan; [2]Toshiba Corporation, Japan*

**2357 | Field Weakening Operation of Open-Winding Induction Motor Dual Drives Using a Floating Capacitor Bridge Inverter**
Saeed Wdaan, Chatumal Perera, John Salmon
*University of Alberta, Canada*

**2297 | Torque Pulsation Reduction in Three-Phase Doubly Fed Induction Machine for Wireless Energy Transfer Applications**
Gabriele Rizzoli, Michele Mengoni, Giacomo Sala, Luca Zarri, Angelo Tani
*University of Bologna, Italy*

## Session H10: PM Motor Drives – 1

**1408 | Improved Controller Optimization of Flux-Weakening Strategy for Salient Permanent-Magnet Synchronous Motor Based on Genetic Algorithm**
Moustafa Magdi Ismail[1,2], Wei Xu[2], Yi Liu[2], Abdul Khalique Junejo[3], Mohamed G. Hussien[4]
*[1]Minia University, Egypt; [2]Huazhong University of Science and Technology, China; [3]Quaid-e-Awam University of Engineering, Science and Technology, Pakistan; [4]Tanta University, Egypt*

**2347 | Model Reference Adaptive Current Control Method for Dual Three Phase Permanent Magnet Synchronous Machine**
Anik Chowdhury, Md Ehsanul Haque, Shuvajit Das, Okan Boler, Yilmaz Sozer
*The University of Akron, United States*

**2550 | Comprehensive Efficiency Analysis of Current Source Inverter Based on CSI-Type Double Pulse Test and Genetic Algorithm**
Feida Chen, Sangwhee Lee, Thomas M. Jahns, Bulent Sarlioglu
*University of Wisconsin Madison, United States*

**1965 | Torque Ripple Minimization of PMSM Drive with Speed Ripple Feedback considering Non-Linearities of PMSM**
Byung Ryang Park, Gyu Cheol Lim, Jonghun Choi, Cheolmin Hwang, Jung-Ik Ha
*Seoul National University, Korea*

**1340 | Deadbeat Predictive Current Control considering Inverter Nonlinearity in Permanent Magnet Synchronous Machine**
Xin Yuan, Jiahao Chen, Yuefei Zuo, Christopher H.T. Lee
*Nanyang Technological University, Singapore*

**1364 | Harmonics Compensation for High Reliability under Grid Voltage Distortion Using Electrolytic Capacitor-Less Dual Inverter with Periodical Torque Fluctuation Load**
Yuuki Ohno, Hitoshi Haga
*Nagaoka University of Technology, Japan*

**2365 | Hall-Effect Sensors as Multipurpose Devices to Control, Monitor and Diagnose AC Permanent Magnet Synchronous Machines**
Daniel Fernandez[1], David Reigosa[1], Yonghyun Park[2], Sangbin Lee[3], Fernando Briz[1]
*[1]University of Oviedo, Spain; [2]Electree Co. Ltd., Korea; [3]Korea University, Korea*

## Session H11: Control of Electric Drives – 1

**1166 | Input-Output Feedback Linearization Control with On-Line Inductances Estimation of Synchronous Reluctance Motors**
Angelo Accetta[1], Maurizio Cirrincione[2], Filippo D'Ippolito[3], Marcello Pucci[1], Antonino Sferlazza[3]
*[1]CNR-INM, Italy; [2]University of the South Pacific, Fiji; [3]University of Palermo, Italy*

**2327 | Pseudo Multi Level Space Vector Modulation Technique for Multi Source Inverters**
O. Salari, K. Hashtrudi Zaad, A. Bakhshai, P. Jain
*Queen's University, Canada*

**1855 | Comparison of Fault-Tolerant Control Methods Reducing Torque Ripple of Multi-Phase BLDC Motor Drive System under Open-Phase Faults**
Hyeoncheol Park, Taeyun Kim, Yongsug Suh
*Jeonbuk National University, Korea*

**1921 | Parameter Sensitivity of Deadbeat Flux Vector Control for Six-Step Operation of Permanent Magnet Synchronous Machines**
Marc S. Petit[1], Bulent Sarlioglu[2]
*[1]Miller Electric Mfg., LLC, United States; [2]University of Wisconsin Madison, United States*

**1814 | Flux-Linkage Based Fundamental and Harmonic Current Control of Saturated Salient AC Machines**
Vinod Chowdary Peddi, Anno Yoo, Brent S. Gagas
*General Motors, United States*

**2276 | Driving Cycle Based Modelling and Control of Solar-Battery Fed RelSyn Motor Drive for Light Electric Vehicle with Energy Regeneration**
Saurabh Mishra, Anshul Varshney, Bhim Singh, Hina Parveen
*Indian Institute of Technology Delhi, India*

## Session H12: Control of Electric Drives – 2

**2153 | Finite Control Set Model-Based Predictive Current Control with Variable Sampling Interval for Induction Machine**
Qing Chen[1], Xiaonan Gao[1], Peter Stolze[2], Ralph Kennel[1]
*[1]Technical University of Munich, Germany; [2]MAN Energy Solutions SE, Germany*

**1838 | Two-Degree-of-Freedom Quasi-PIR Controller for Smooth Speed Control of Permanent Magnet Vernier Machine**
Yuefei Zuo, Jingwei Zhu, Xin Yuan, Christopher H.T. Lee
*Nanyang Technological University, Singapore*

**2491 | Online PI Current Controller Tuning Based on Machine High-Frequency Parameters**
Diego F. Laborda, Juan Manuel Guerrero, Marcos Orviz Zapico, Daniel Fernández, David Díaz Reigosa, Fernando Briz
*University of Oviedo, Spain*

**1799 | Parameter-Free Predictive Current Control for Synchronous Machine Controlled by High-Frequency Signal Injection Sensorless**
Hyeon-Seong Kim, Kibok Lee
*Incheon National University, Korea*

**1386 | Three-Phase Motor Drive Topology with the Fault-Tolerant Capability of Open-Circuit on the Multiplexing Bridge**
Xiangwen Sun, Zicheng Liu, Zhekai Li, Qianchen Sun, An Li, Dong Jiang
*Huazhong University of Science and Technology, China*

**1608 | Sensorless Acceleration Estimation and Acceleration Feedback Control to Improve the Disturbance Torque Rejection on Galvano Motor System**
Yi-Jen Lin[1], Po-Huan Chou[2], Chi-Jun Wu[1], Shih-Chin Yang[1]
*[1]National Taiwan University, Taiwan; [2]Industrial Technology Research Institute, Taiwan*

## Session H13: Sensorless Control of Drives

**1186 | High-Precision Sensorless Control Method with Fast Dynamic Response for High-Speed PMSM Based on Discrete-Time Back-EMF Deadbeat Observer**
Zhihao Song[1], Wenxi Yao[1], Kevin Lee[2]
*[1]Zhejiang University, China; [2]Eaton, United States*

**2354 | Phase Current Sensorless Control of Switched Reluctance Machines Using Dynamic Interleaving**
Md Ehsanul Haque[1], Anik Chowdhury[1], Okan Boler[1], Shuvajit Das[1], Yilmaz Sozer[1], Fernando Venegas[2], David Colavincenzo[2]
*[1]The University of Akron, United States; [2]Bendix Commercial Vehicle Systems, United States*

**1084 | Low-Speed Position Estimation of the Brushless Synchronous Starter/Generator by Using the Main Exciter as a Quasi Resolver**
Shuai Mao[1], Jianqiu Li[1], Xu Han[2], Weiguo Liu[2], Zunyan Hu[1], Liangfei Xu[1], Minggao Ouyang[1]
*[1]Tsinghua University, China; [2]Northwestern Polytechnical University, China*

**1085 | Adaptive Observer Design for Wide-Speed Sensorless IPMSM Drives via Equivalent Control Method**
Qilian Lin, Ling Liu, Han Song, Dongsong Jin, Deliang Liang, Shaofeng Jia
*Xi'an Jiaotong University, China*

**1531 | Experimental Investigation on the Self-Sensing Capability of Synchronous Machines for Signal Injection Sensorless Drives**
Matteo Berto, Luigi Alberti, Silverio Bolognani
*University of Padova, Italy*

**2128 | Use HF Signal Injection for Simultaneous Rotor Angle, Torque and Temperature Estimation in PMSMs**
Marcos Orviz Zapico, David Diaz Reigosa, Diego Fernández Laborda, Maria Martínez Gómez, Juan Manuel Guerrero Muñoz, Fernando Briz del Blanco
*University of Oviedo, Spain*

**1694 | Rotor Temperature Estimation for Saliency-Based Control of Induction Motors Using Symmetrical Transient Reluctance**
Eduardo Rodriguez Montero[1], Markus Vogelsberger[2], Thomas Wolbank[1]
*[1]Technical University of Vienna, Austria; [2]Bombardier Transportation Austria GmbH, Austria*

## Session H14: Diagnostics, Fault Tolerance and Reliability in Electric Drives

**1957 | Current-Sensor and Switch-Open Fault Diagnosis Based on Discriminative Machine Learning Model for PMSM Driving System**
Jae-Hoon Shim[1], Jun Lee[2], Jung-Ik Ha[1]
*[1]Seoul National University, Korea; [2]Samsung Electronics, Korea*

**1344 | A Novel SPWM-Based Common-Mode Voltage Elimination Modulation Method for Dual Three-Phase Motors**
Yang Huang[1], Ximu Zhang[1], Jared Walden[1], Hua Bai[1], Fanning Jin[2], Xiaodong Shi[2], Bing Cheng[2]
*[1]University of Tennessee Knoxville, United States; [2]Mercedes-Benz R&D North America, Inc., United States*

**1210 | A Novel Ring-Shaped Fractal Antenna for Partial Discharge Detection**
Yinka Leo Ogundiran, Antonio Griffo, Shubham Sundeep, Fernando Alvarez Gonzalez, Jiabin Wang
*The University of Sheffield, United Kingdom*

**1234 | An On-Line DC-Link Capacitance Estimation Method for Motor Drive System Based on Intermittent Active Control Strategy**
Tianze Meng, Pinjia Zhang
*Tsinghua University, China*

**2078 | Time-Domain Based Diagnosis of Stator Incipient Faults in DTC Driven Induction Motors Using External ElectroMagnetic Signatures**
Hassan H. Eldeeb[1,2,3], Caleb Secrest[1], Haisen Zhao[2,4], Osama A. Mohammed[2]
*[1]BorgWarner Inc., United States; [2]Florida International University, United States; [3]Ain Shams University, Egypt; [4]North China Electric Power University, China*

**2204 | Comparative Analysis of Torque Pulsations Measurement Methods for PMSM Drives**
Maria Martinez, Diego F. Laborda, David Reigosa, Fernando Briz
*University of Oviedo, Spain*

**1198 | Vibration and Loss Reduction of Permanent Magnet Synchronous Motor Driven by Synchronous PWM Control with Carrier Wave Phase Shifts**
Takafumi Hara[1], Shun Taniguchi[1], Toshiyuki Ajima[1], Masanori Sawahata[1], Masahiro Hori[1], Tsukagoshi Takaya[2], Katsuhiro Hoshino[2]
*[1]Hitachi, Ltd., Japan; [2]Hitachi Astemo, Ltd., Japan*

**1524 | Transient Hall Sensor Fault Compensation for Hall-Based Field Oriented Control Motor Drive**
Heng-Ching Lin, Jyun-You Chen, Guan-Ren Chen, Shih-Chin Yang
*National Taiwan University, Taiwan*

## Session H15: Medium Voltage and Drive Applications

**1272 | Novel Characterization of Si- and SiC-Based PWM Inverter Bearing Currents Using Probability Density Functions**
Ryan Collin, Alex Yokochi, Annette von Jouanne
*Baylor University, United States*

**2222 | Development of Inverter Duty Motor Bearings for Si- and SiC-Based Variable Frequency Drive Applications Including Advanced 4D Finite Element Modeling**
Annette von Jouanne, Ryan Collin, Madeline Stephens, Ben Phillips, Hellen Chen, Caleb Li, Emmanuel Agamloh, Alex Yokochi
*Baylor University, United States*

**1812 | Effect of Neutral Grounding Resistance on Grid-Tie Active Front End Power Converter Systems under Normal and Abnormal Conditions**
Zhijun Liu, Gary L. Skibinski
*Rockwell Automation, United States*

**2308 | Adjustable Speed Medium Voltage Drive Fed by a 24-Pulse AC-DC Converter and 5-Level Multi-Level Inverter**
Rohit Kumar, Bhim Singh, Piyush Kant, Vivek Narayanan
*Indian Institute of Technology Delhi, India*

**1135 | Modeling of Phase-Shifting Transformer Based on Space-Phasor Notations for the Applications in Medium Voltage Drives**
Srinivas Gude[1], River Chen[1], Sam Li[1], Yongqiang Lang[2]
*[1]Delta Electronics Inc., Taiwan; [2]Delta Electronics Inc., China*

**1588 | An Energy Recovery Scheme for RCD Snubber in the Series Configuration of IGBTs**
Mostafa Zarghani[1], Saeed Peyghami[2], Francesco Iannuzzo[2], Frede Blaabjerg[2], Shahriyar Kaboli[1]
*[1]Sharif University of Technology, Iran; [2]Aalborg University, Denmark*

## Session H16: Electric Drive Applications

**1382 | Adaptive-Observer-Based Sensor Fault Resilient Control for Single-Phase Grid-Connected Converters in High-Speed Railway Traction Systems**
Jinhui Xia[1], Ze Li[2], Yuanbo Guo[2], Xiaohua Zhang[2]
*[1]Zhejiang University, China; [2]Dalian University of Technology, China*

**2037 | A Stable and Robust DC Power System for More Electric Aircraft**
Galina Mirzaeva[1], Dmitry Miller[1], Graham Goodwin[1], Patrick Wheeler[2]
*[1]The University of Newcastle, Australia; [2]University of Nottingham, United Kingdom*

**1417 | A 1.2 kV 100 kW Four-Level ANPC Inverter with SiC Power Modules and Capacitor Voltage Balance for EV Traction Applications**
Jun Wang, Ian Laird, Xibo Yuan, Wenzhi Zhou
*University of Bristol, United Kingdom*

**2212 | BEV Range Improvement Using Highly Efficient Downsized DC-DC Converter**
Lei Hao[1], Chandra Namuduri[1], Chengwu Duan[2], Suresh Gopalakrishnan[1], Norman Bucknor[1]
*[1]General Motors, United States; [2]General Motors, China*

**1704 | Iron Losses Impact on High-Speed Drives**
Emilio Carfagna[1], Emilio Lorenzani[1], Karthik Debbadi[2], Sante Pugliese[2], Marco Liserre[2]
*[1]University of Modena and Reggio Emilia, Italy; [2]Christian-Albrechts-Universität zu Kiel, Germany*

**1268 | Integration and Cooling Strategies for WBG-Based Current-Source Inverters-Based Motor Drives**
Woongkul Lee, Renato A. Torres, Hang Dai, Thomas M. Jahns, Bulent Sarlioglu
*University of Wisconsin Madison, United States*

# Topic I: Power Semiconductor Devices

## Session I01: Power Module and Integration – In Memory of Prof. Braham Ferreira

**2538 | EMI Propagation Path Modeling of 3-Level T-Type NPC Power Module with Stacked DBC Enabled EMI Shielding**
Asif Imran Emon[1], Mustafeez Ul Hassan[1], Abdul Basit Mirza[1], Zhao Yuan[2], Fang Luo[1]
*[1]Stony Brook University, United States; [2]University of Arkansas, United States*

**1367 | Design and Analysis of a PCB-Embedded 1.2 kV SiC Half-Bridge Module**
Jack Knoll[1], Gibong Son[1], Christina DiMarino[1], Qiang Li[1], Hannes Stahr[2], Mike Morianz[2]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Austria Technologie & Systemtechnik AG, Austria*

**2117 | Design, Fabrication, and Testing of a 1.7 kV SiC Switching Cell for a High-Density Integrated Power Electronics Building Block (iPEBB)**
Narayanan Rajagopal[1], Christina DiMarino[1], Rolando Burgos[1], Taha Moaz[1], Igor Cvetkovic[1], Dushan Boroyevich[1], Olivier Mathieu[2]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Rogers Corporation, Germany*

**2398 | Layout, Packaging, and Efficiency Implications of a 1.7 kV Hybrid Si/SiC Reverse Blocking Switch Module in Soft-Switching Current Source Converters**
Aniruddh Marellapudi, Bradford Houska, Mickael J. Mauger, Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**1377 | A Novel SiC MOSFET Module for High-Power Soft-Switching Converter**
Xiaolei Luo, Min Chen
*Zhejiang University, China*

**1960 | Paralleling of Four 650V/60A GaN HEMTs for High Power Traction Drive Applications**
Partha Pratim Das, Subhransu Satpathy, Suyash Sushilkumar Shah, Subhashish Bhattacharya, Victor Veliadis
*North Carolina State University, United States*

## Session I02: WBG and UWBG Devices

**2503 | High Voltage Output Characteristics and Short Circuit Robustness of HV SiC MOSFETs**
Ashish Kumar, Raj Kokkonda Kumar, Subhashish Bhattacharya, Jayant Baliga, Victor Veliadis
*North Carolina State University, United States*

**1744 | 3.3 kV SiC JBS Diodes Employing a P2O5 Surface Passivation Treatment to Improve Electrical Characteristics**
Arne Benjamin Renz[1], Oliver James Vavasour[1], Vishal Ajit Shah[1], Vasantha Pathirana[2], Tanya Trajkovic[2], Yeganeh Bonyadi[3], Ruizhu Wu[1], Jose Angel Ortiz-Gonzalez[1], Xiaoyun Rong[1], Guy William Clarke Baker[1], Philip Mawby[1], Peter Michael Gammon[1]
*[1]University of Warwick, United Kingdom; [2]Cambridge Microelectronics Ltd., United Kingdom; [3]Lyra Electronics Ltd., United Kingdom*

**2406 | Static and Dynamic Characterization of 650 V GaN E-HEMTs in Room and Cryogenic Environments**
Mahmoud Mehrabankhomartash[1], Shiyuan Yin[1], Alfonso J. Cruz[1], Lukas Graber[1], Maryam Saeedifard[1], Simon Evans[2], Florian Kapaun[3], Ivan Revel[2], Gerhard Steiner[3], Ludovic Ybanez[2], Chanyeop Park[4]
*[1]Georgia Institute of Technology, United States; [2]Airbus, France; [3]Airbus, Germany; [4]Mississippi State University, United States*

**1827 | Performance Evaluation of Future T-Type PFC Rectifier and Inverter Systems with Monolithic Bidirectional 600V GaN Switches**
F. Vollmaier[1], N. Nain[2], J. Huber[2], J.W. Kolar[2], K.K. Leong[3], B. Pandya[3]
*[1]Silicon Austria Labs GmbH, Austria; [2]ETH Zürich, Switzerland; [3]Infineon Technologies AG, Austria*

**1350 | Performance Evaluation of 650 V SiC MOSFET under Low Temperature Operation**
Yuqi Wei, Md Maksudul Hossain, Xia Du, Rosten Sweeting, Alan Mantooth
*University of Arkansas, United States*

**1432 | Active-Device Losses in Resonant Power Converters: A Case Study with Class-E Inverters**
Nirmana Perera, Remco van Erp, Jessy Ançay, Armin Jafari, Elison Matioli
*École Polytechnique Fédérale de Lausanne, Switzerland*

## Session I03: Passive Components

**2269 | Permeability Engineered Soft Magnetics for Power Dense Energy Conversion**
Kevin Byerly[1], Satoru Simizu[1], Michael E. McHenry[1], Paul R. Ohodnicki[2], R. Byron Beddingfield[3], Subhashish Bhattacharya[3], Geraldo Nojima[4]
*[1]Carnegie Mellon University, United States; [2]University of Pittsburgh, United States; [3]North Carolina State University, United States; [4]Eaton, United States*

**2409 | Characterization of Inductor Magnetic Cores for Cryogenic Applications**
Shiyuan Yin[1], Mahmoud Mehrabankhomartash[1], Alfonso J. Cruz[1], Lukas Graber[1], Maryam Saeedifard[1], Simon Evans[2], Florian Kapaun[3], Ivan Revel[2], Gerhard Steiner[3], Ludovic Ybanez[2], Chanyeop Park[4]
*[1]Georgia Institute of Technology, United States; [2]Airbus, France; [3]Airbus, Germany; [4]Mississippi State University, United States*

**1369 | A Novel Measurement Method for DC Superimposition Characteristics of Three-Phase Coupled Inductors with Powder Cores**
Yamato Mishima[1], Tatsuya Aoki[1], Kazuya Matsuta[1], Jun Imaoka[1], Masayoshi Yamamoto[1], Kosuke Yoshimoto[2]
*[1]Nagoya University, Japan; [2]Daido Steel Co., Ltd., Japan*

**1638 | Condition Monitoring for Capacitors in Modular Multilevel Converter Based on High-Frequency Transient Analysis**
Hongjian Xia[1], Yi Zhang[2], Huai Wang[2], Minyou Chen[1], Wei Lai[1], Dan Luo[1], Yulong Hu[1]
*[1]Chongqing University, China; [2]Aalborg University, Denmark*

## Session I04: Gate Drivers – 1

**1293 | A Low Level-Clamped Active Gate Driver for Crosstalk Suppression of SiC MOSFET Based on dv/dt Detection**
Hong Li, Zhidong Qiu, Tiancong Shao, Yangbin Zeng, Haitao Du, Chengdong Yin
*Beijing Jiaotong University, China*

**1113 | Investigations on Online Junction Temperature Measurement for SiC-MOSFETs Using the Gate-Signal Injection Method**
Johannes Ruthardt, David Hirning, Kanuj Sharma, Maximilian Nitzsche, Philipp Ziegler, Manuel Fischer, Jörg Roth-Stielow
*University of Stuttgart, Germany*

**1806 | A High-Efficiency Charge-Pump Gate Drive Power Delivery Technique for Flying Capacitor Multi-Level Converters with Wide Operating Range**
Rahul K. Iyer, Nathan M. Ellis, Zichao Ye, Robert C.N. Pilawa-Podgurski
*University of California Berkeley, United States*

**2541 | Noise Immune Cascaded Gate Driver Solution for Driving High Speed GaN Power Devices**
Abdul Basit Mirza, Asif Imran Emon, Sama Salehi Vala, Fang Luo
*Stony Brook University, United States*

## Session I05: Gate Drivers – 2

**2240 | A Closed-Loop Current Source Gate Driver with Active Voltage Balancing Control for Series-Connected GaN HEMTs**
Zhengda Zhang, Chunhui Liu, Yunpeng Si, Yifu Liu, Mengzhi Wang, Qin Lei
*Arizona State University, United States*

**2498 | Design and Selection of Optimal Inductor for Current Source Gate Drivers**
Rajat Shahane, Satish Belkhode, Anshuman Shukla
*Indian Institute of Technology Bombay, India*

**1941 | Gate Driver for 10 kV SiC MOSFET Power Module with High-Speed Current Sensing**
Mark Cairnie, Christina DiMarino
*Virginia Polytechnic Institute and State University, United States*

**1881 | Active Control and Gate-Driver Design for Voltage Balancing of Both MOSFETs and Body-Diodes in Series-Connected SiC MOSFETs**
Xiang Lin, Lakshmi Ravi, Dong Dong, Rolando Burgos
*Virginia Polytechnic Institute and State University, United States*

**1225 | Balancing the Switching Losses of Paralleled SiC MOSFETs Using a Stepwise Gate Driver**
Christoph Lüdecke, Alireza Aghdaei, Michael Laumen, Rik W. De Doncker
*RWTH Aachen University, Germany*

**1547 | An Active Gate Driver for Dynamic Current Sharing of Paralleled SiC MOSFETs**
Xun Wang[1], Yang He[1], Junming Zhang[1], Shuai Shao[1], Han Li[2], Cheng Luo[2]
*[1]Zhejiang University, China; [2]Eaton, China*

## Session I06: Gate Drivers – 3

**2118 | Digital Gate Driving (DGD) is Double-Edged Sword: How to Avoid Huge Voltage Overshoots Caused by DGD for GaN FETs**
Ryunosuke Katada[1], Katsuhiro Hata[1], Yoshitaka Yamauchi[1], Ting-Wei Wang[1,2], Ryuzo Morikawa[1], Cheng-Hsuan Wu[1], Toru Sai[1], Po-Hung Chen[2], Makoto Takamiya[1]
*[1]The University of Tokyo, Japan; [2]National Chiao Tung University, Taiwan*

**1154 | A 1ns-Resolution Load Adaptive Digital Gate Driver IC with Integrated 500ksps ADC for Drive Pattern Selection and Functional Safety Targeting Dependable SiC Applications**
Shusuke Kawai, Takeshi Ueno, Hiroaki Ishihara, Satoshi Takaya, Koutaro Miyazaki, Kohei Onizuka
*Toshiba Corporation, Japan*

**2040 | An Intelligent Gate Driver with Self-Diagnosis and Prognosis for SiC MOSFETs**
Sanghun Kim, Dongwoo Han, Xiaofeng Dong, Hui Li, Jinyeong Moon, Yuan Li, Fang Z. Peng
*Florida State University, United States*

**2091 | Comparison of Gate-Drive Switching Control for GaN HEMT Power Devices**
Patrick Palmer[1], Edward Shelton[2], Mohammad Miri[1], Carissa King[1], Dan Rogers[2]
*[1]Simon Fraser University, Canada; [2]University of Oxford, United Kingdom*

**2395 | A Trajectory Control Gate Driver for Wide Band Gap Devices in Standard Packages**
Julien Morand, Julio Brandelero
*Mitsubishi Electric R&D Centre Europe, France*

**2156 | Gate-Source Voltage Analysis for Switching Crosstalk Evaluation in SiC MOSFETs Half-Bridge Converters**
Luciano Salvo[1], Mario Pulvirenti[1], Angelo Giuseppe Sciacca[1], Giacomo Scelba[2], Mario Cacciato[2]
*[1]STMicroelectronics, Italy; [2]University of Catania, Italy*

## Session I07: Magnetics – 1

**1476 | A Novel Magnetic Integrated Unit for a Full-Soft-Switching Full- Bridge Converter**
Cheng Deng[1], Li Tan[1], Andrés Escobar-Mejia[2]
*[1]Xiangtan University, China; [2]Universidad Tecnológica de Pereira, Colombia*

**2239 | Symmetric Four-Phase Inverse Coupled Inductors for GaN-Based Interleaving Four-Phase Point-of-Load Converters**
Longyang Yu[1], Wei Mu[1], Chengzi Yang[1], Lei Zhu[1], Zhiyuan Qi[1], Laili Wang[1], Yilong Yao[1], Yuquan Su[2], Chi Zhang[2]
*[1]Xi'an Jiaotong University, China; [2]MiSiliconn Semiconductor Technologies Co., Ltd., China*

**1414 | A Novel PCB-Embedded Coupled Inductor Structure for Integrated Voltage Regulator**
Feiyang Zhu, Qiang Li, Fred C. Lee
*Virginia Polytechnic Institute and State University, United States*

**2416 | An Integrated Magnetic Structure for Bi-Directional Two-Channel Interleaved Boost Converter with Coupled Inductor**
Abdul Basit Mirza, Asif Imran Emon, Sama Salehi Vala, Fang Luo
*Stony Brook University, United States*

**1481 | A Passive Integrated Unit for Parallel-Resonant Isolated Bidirectional DC-DC Converter**
Cheng Deng[1], Zhou You[1], Andrés Escobar-Mejia[2]
*[1]Xiangtan University, China; [2]Universidad Tecnológica de Pereira, Colombia*

**1477 | A Passive Integration Unit for Electronic Ballast with Multiresonant Converter**
Cheng Deng[1], Zhilin Zhou[1], Andrés Escobar-Mejia[2]
*[1]Xiangtan University, China; [2]Universidad Tecnológica de Pereira, Colombia*

## Session I08: Magnetics – 2

**1412 | An Accurate Analytical Model to Evaluate the Winding Loss of a Single-Layer Multi-Turn Planar Air-Core PCB-Inductor**
Mingdong Wu, Li Wang, Daniyal Ahmed, Meng Peng, Ling Mao
*Nanjing University of Aeronautics and Astronautics, China*

**1974 | Dimensional Effects of Core Loss and Design Considerations for High Frequency Magnetics**
Ahmed Nabih, Rimon Gadelrab, Qiang Li, Fred C. Lee
*Virginia Polytechnic Institute and State University, United States*

**1569 | An Integrated Planar Inductor Based on a Novel Magnetic Core Structure**
Shuting Feng, Yongmei Gan, Longyang Yu, Huaqing Li, Chaojie Li, Wei Mu
*Xi'an Jiaotong University, China*

**1100 | A Simple and Accurate Leakage Inductance Adjustment Method for Medium Frequency Transformer**
Xuan Guo, Chi Li, Zedong Zheng, Yongdong Li
*Tsinghua University, China*

**1416 | Modeling and Analysis of Multi-Phase Coupled Inductor Structures for Voltage Regulators**
Feiyang Zhu, Qiang Li, Fred C. Lee
*Virginia Polytechnic Institute and State University, United States*

## Session I09: Magnetics – 3

**2221 | Laminated Permanent Magnets Enable Compact Magnetic Components in Current Source Converters**
Xiangyu Han, Zheng An, Mickael J. Mauger, Joseph Benzaquen, Rajendra Prasad Kandula, Deepak Divan
*Georgia Institute of Technology, United States*

**2453 | Analysis and Suppression of Corner Electrical Field in Magnetic Flux Valve**
Junwei Cui, Chao Jia, Liyan Qu, Wei Qiao
*University of Nebraska Lincoln, United States*

**1203 | Compact Design of a Wide Bandwidth High Current Sensor Using Tilted Magnetic Field Sensors**
Philipp Ziegler, Yiru Zhao, Jörg Haarer, Johannes Ruthardt, Manuel Fischer, Jörg Roth-Stielow
*University of Stuttgart, Germany*

**1041 | Controlled Measurement Setup to Characterize a Magnetic Material up into Deep Saturation**
Jeremias Kaiser, Thomas Dürbaum
*Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*

**1616 | Design Methodology to Reduce the Lumped Winding Capacitance of Spiral Winding Transformer in LLC Converters**
Mingde Zhou, Haoyu Wang, Dongdong Shu
*ShanghaiTech University, China*

**2467 | A 700kHz 800V/14V GaN-Based DC-DC Converter with Optimized Integrated Transformer for Electrical Vehicles**
Huu Phuc Kieu[1], Donghan Lee[1], Sewan Choi[1], Sangjin Kim[2]
*[1]Seoul National University of Science and Technology, Korea; [2]Hyundai Motor Company, Korea*

## Session I10: Application of Power Modules

**1409 | Analytic Model of the Voltage Oscillation in a Power Conversion System with DC-Link Capacitors**
Shuang Zhao, Wibawa Chou
*Infineon Technologies AG, United States*

**1062 | Lithium-Ion Capacitors: Charge Delivery Capability and Voltage Dependence of Capacitance**
Hengzhao Yang
*ShanghaiTech University, China*

**2058 | Investigating the Effect of Multilevel Inverters on Motor Stator Insulation Stress**
Arshiah Yusuf Mirza, Hiep Nguyen, Ali M. Bazzi, Yang Cao
*University of Connecticut, United States*

**1229 | Electret: A Solution to Partial Discharge in Power Electronics Applications**
Farhina Haque, Omar Faruqe, Chanyeop Park
*Mississippi State University, United States*

**1713 | Linearly Scalable Cost-Efficient Parallel Method for High-Power Wide-Bandgap-Based Converters**
Shang Gao, Zheyu Zhang
*Clemson University, United States*

## Session I11: Semiconductor Devices

**1635 | Commercialization of Diamond Semiconductor Devices**
Manpuneet K. Benipal[1], Jesse Brown[1], Franz Koeck[2], Anna Zaniewski[1], Mohammad Faizan Ahmad[1], Robert Nemanich[2]
*[1]Advent Diamond, Inc., United States; [2]Arizona State University, United States*

**1544 | Analysis on Static Current Sharing of N-Paralleled Silicon Carbide MOSFETs**
Yang He[1], Xun Wang[1], Junming Zhang[1], Shuai Shao[1], Han Li[2], Cheng Luo[2]
*[1]Zhejiang University, China; [2]Eaton, China*

**1837 | Junction-Temperature Sensing of Paralleled SiC MOSFETs Utilizing Temperature Sensitive Optical Parameters**
Lukas A. Ruppert, Sven Kalker, Rik W. De Doncker
*RWTH Aachen University, Germany*

**2015 | Static and Dynamic Characteristics of SiC MOSFET under Extremely High Temperature**
Xiaohui Lu, Laili Wang, Zaojun Ma, Qingshou Yang
*Xi'an Jiaotong University, China*

**1357 | Reverse Recovery Testing of Small-Signal Schottky Diodes**
Weston D. Braun, Eric A. Stolt, Lei Gu, Juan M. Rivas-Davila
*Stanford University, United States*

**1431 | Analysis on Parasitic Capacitance to Prevent False Turn-On in GaN HEMT**
Toshihiro Iwaki, Takashi Sawada, Jun Imaoka, Masayoshi Yamamoto
*Nagoya University, Japan*

**1586 | Dominant Model Parameter Extraction for Analyzing Current Imbalance in Parallel Connected SiC MOSFETs**
Yohei Nakamura[1,3], Michihiro Shintani[2], Takashi Sato[3]
*[1]ROHM Co., Ltd., Japan; [2]Nara Institute of Science and Technology, Japan; [3]Kyoto University, Japan*

**2051 | Circuit-Semiconductor Dynamic Coupling Analysis for PiN Diode Reverse Recovery**
Ruiwen Chen[1], Zhi Yang[1], Xiaoli Tian[2], Mingyang Wang[1], Yu Pan[3], Sideng Hu[1]
*[1]Zhejiang University, China; [2]Chinese Academy of Sciences, China; [3]Shanghai Institute of Space Power-Sources, China*

## Session I12: Thermal Management

**1141 | Vascular Polymer Encapsulation for Integrated Thermal Management and Packaging of Electronics**
Anthony Coppola, Alireza Fatemi
*General Motors, United States*

**1903 | Directly Integrated Vapor Chamber as an Efficient Heat Spreader for High Heat Flux SiC MOSFET Dies in Power Modules**
Wei Mu[1], Binyu Wang[1], Shenghe Wang[2], Fengtao Yang[1], Dingkun Ma[1], Laili Wang[1]
*[1]Xi'an Jiaotong University, China; [2]State Grid Anhui Electric Power Co., Ltd., China*

**1375 | Thermal Management Strategy for IGBT Modules in PV Systems Based on the Benefit-Cost Ratio**
Cheng Qian[1], Xiong Du[1], Rui Du[1], Jun Zhang[2]
*[1]Chongqing University, China; [2]Hohai University, China*

**1774 | Multiscale Electrothermal Design of a Modular Multilevel Converter for Grid-Tied Applications**
Xuhui Feng[1], Ramchandra Kotecha[1], Sreekant Narumanchi[1], Akanksha Singh[1], Barry Mather[1], Ke Wang[2], Boxue Hu[2], Jin Wang[2]
*[1]National Renewable Energy Laboratory, United States; [2]The Ohio State University, United States*

**1191 | Experimental Characterization of Frequency-Domain Thermal Impedance for Power Module under Different Boundary Conditions**
Leheng Wang, Mengqi Xu, Ke Ma
*Shanghai Jiao Tong University, China*

**1850 | Thermal Dissipation Approach Comparison and Evaluation for SiC Surface Mount Devices**
Victoria Baker[1], Boran Fan[1], Jack Knoll[1], Rolando Burgos[1], Warren Chen[2]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Raytheon Technologies Research Center, United States*

**1696 | Influence Analysis of Thermally Conductive Epoxy Resin on the Electrical Design of a Compact AC/DC Converter**
Maximilian Nitzsche, Jörg Haarer, Julian Weimer, Dominik Koch, Jörg Roth-Stielow
*University of Stuttgart, Germany*

# Topic K: Emerging Technologies and Applications

## Session K01: Wireless Power Transfer – 1

**1400 | Analysis of a Wireless Power Transfer System with an Inverse Coupled Current Doubler Rectifier**
Lixin Shi, Alberto Delgado, Regina Ramos, Pedro Alou
*Universidad Politécnica de Madrid, Spain*

**2032 | Heuristic Algorithm-Based Design Method for Class-E Switching Circuits**
Wenqi Zhu, Yutaro Komiyama, Kien Nguyen, Hiroo Sekiya
*Chiba University, Japan*

**2351 | High Power, High Efficiency Wireless Power Transfer at 27.12 MHz Using CMCD Converters**
Jack Rademacher, Xin Zan, Al Avestruz
*University of Michigan, United States*

**1057 | Multi-Coil Constant Voltage Output Analysis Based on State Deconstruction for Wireless Power Transfer System**
Sheng Liu, Yue Feng, Hao Chen, Jiande Wu, Xiangning He
*Zhejiang University, China*

## Session K02: Measurements and Testing

**1636 | Microchannel-Based Calorimeter for Rapid and Accurate Loss Measurements on High-Efficiency Power Converters**
Remco van Erp, Nirmana Perera, Elison Matioli
*École Polytechnique Fédérale de Lausanne, Switzerland*

**1314 | Design and Operation of a Medium Voltage Pulse Test Apparatus for Short-Circuit Testing of DC Solid State Circuit Breakers**
Andy Schroedermeier, Andrew Rockhill
*Eaton, United States*

**1552 | Gate Driver Design for 1.2 kV SiC Module with PCB Integrated Rogowski Coil Protection Circuit**
Marco Stecca, Panagiotis Tiftikidis, Thiago Soeiro, Pavol Bauer
*Delft University of Technology, The Netherlands*

**2382 | Thermal-HIL Real-Time Testing Platform for Evaluating Cooling Systems of Power Rectifiers**
Carl Ngai Man Ho, Yin Fang, Yanming Xu, Isuru Jayawardana
*University of Manitoba, Canada*

## Session K03: Emerging Technologies and Applications – 1

**1420 | Efficiency Optimization of Wireless Power Transfer Systems Having Multiple Receivers with Cross-Coupling by Resonant Frequency Adjustment of Receivers**
Arpan Laha, Abirami Kalathy, Praveen Jain
*Queen's University, Canada*

**1701 | A 27.12-MHz kV-Scale Power Amplifier with a Tunable Multistage Matching Network for a Compact Ion-Beam Accelerator**
Yuetao Hou[1], Sreyam Sinha[1], Di Ni[1], Qing Ji[2], Arun Persaud[2], Peter Seidl[2], Thomas Schenkel[2], Amit Lal[1], Khurram K. Afridi[1]
*[1]Cornell University, United States; [2]Lawrence Berkeley National Laboratory, United States*

**2030 | Standing Wave Induced Field Focusing Transceiver for Wireless Capacitive Power Transfer**
Tanner Mingen, Matthew Pearce, Tyler Marcrum, Charles Van Neste
*Tennessee Tech University, United States*

**2466 | Energy Recovery Circuit for LC Cell Driver**
Jacob Huff, Miao Wang, Mark J. Scott
*Miami University, United States*

## Session K04: Wireless Power Transfer – 2

**1522 | A Modular Multilevel Converter Based Inductive Power Transfer System**
Wenwei Victor Wang, Feiyang Jackman Lin, Duleepa J. Thrimawithana, Grant Covic
*University of Auckland, New Zealand*

**1758 | Multiple-Transmitter with Phase-Shift and Dynamic ZVS Angle Controls at Fixed Operating Frequency for Cross-Interference Free Wireless Power Transfer Systems**
Kodai Matsuura, Masataka Ishihara, Akihiro Konishi, Kazuhiro Umetani, Eiji Hiraki
*Okayama University, Japan*

**2057 | Roadway Embeddable Multi-MHz Capacitive Wireless Charging System with Matching Network Realized Using Wiring Parasitics**
Sounak Maji, Sreyam Sinha, Khurram K. Afridi
*Cornell University, United States*

**2390 | A 13.56 MHz Bidirectional IPT System with Wirelessly Synchronised Transceivers for Ultra-Low Coupling Operation**
Nunzio Pucci, Juan M. Arteaga, Christopher H. Kwan, David C. Yates, Paul D. Mitcheson
*Imperial College London, United Kingdom*

**2202 | GaN-Based Wireless Charging System with Self-Driven Rectifier**
Federica Cammarata[1,2], Santi Agatino Rizzo[2], Giacomo Scelba[2], Giuseppe Longo[1], Filippo Scrimizzi[1], Giuseppe Ballarin[3]
*[1]STMicroelectronics, Italy; [2]University of Catania, Italy; [3]Wurth Elektronik, Italy*

**2318 | Wireless Power Transfer System with Variable Mutual Inductance Control for Battery Charging**
Ruibang Li[1], Chenxu Zhao[1], Yongbin Jiang[2], Min Wu[1], Shuting Feng[1], Laili Wang[1], Yunqing Pei[1], Hong Zhang[1]
*[1]Xi'an Jiaotong University, China; [2]UNISOC (Shanghai) Technologies Co., Ltd., China*

**1012 | Inverter Phase Current Balancing for Wireless Power Transfer Systems Based on Parallel Resonant Networks**
Yiming Zhang[1], Zhiwei Shen[1], Xin Li[2], Shuxin Chen[2], Yi Tang[2]
*[1]Fuzhou University, China; [2]Nanyang Technological University, Singapore*

**2210 | Analysis of Wireless Power Transfer System Employing Active Shielding with Virtual Inductance and Two-Port Equivalent Circuit**
Keita Furukawa, Keisuke Kusaka, Jun-ichi Itoh
*Nagaoka University of Technology, Japan*

## Session K05: Wireless Power Transfer – 3

**2047 | A Variable Compensation Inverter Rectifier (VCIR) Based Approach to Compensate for Coupling Variations in Wireless Power Transfer Systems**
Sreyam Sinha[1], Ashish Kumar[2], Khurram K. Afridi[1]
*[1]Cornell University, United States; [2]Texas Instruments, United States*

**1938 | Bidirectional Class E2 Resonant Converter in Wireless Power Transfer Systems**
Minki Kim, Jungwon Choi
*University of Minnesota Twin Cities, United States*

**1471 | A Control Strategy for ZVS Realization in LCC-S Compensated WPT System with Semi Bridgeless Active Rectifier for Wireless EV Charging**
Mingyang Li, Junjun Deng, Deliang Chen, Wenbo Wang, Zhenpo Wang, Yang Li
*Beijing Institution of Technology, China*

**1928 | An LCC-S Compensated Wireless Power Transfer System with Dual Switch-Controlled Capacitors for Multi-Frequency Receivers**
Ke Li, Wen Ding, Jiangnan Yuan
*Xi'an Jiaotong University, China*

**1341 | Parallel Contactless Transmission of Power and Rotor Temperature of Electrical Machines via Magnetically-Coupled Resonance and Capacitive Radio Frequency**
Liancheng Zhang[1], Shaoyu Cheng[2], Yilong Wang[3], Hassan H. Eldeeb[4], Guorui Xu[2], Haisen Zhao[2]
*[1]North China Institute of Aerospace Engineering, China; [2]North China Electric Power University, China; [3]Beijing Information Science and Technology University, China; [4]BorgWarner Noblesville Technical Center, United States*

**144 | Medium Voltage to Low Voltage Contactless Power Transformation for Data Centers**
Guangqi Zhu[1], Birger Pahl[1], Richard J. Fons[1], Isaac Wong[2], Subhashish Bhattacharya[2], Byron Beddingfield[2]
*[1]Eaton, United States; [2]North Carolina State University, United States*

**2231 | Adaptive Power Transmission for Multi-Target of Microwave Wireless Power Transmission System**
Xirui Zhu, Ke Jin, Jianying Ding, Yiwen Xiao
*Nanjing University of Aeronautics and Astronautics, China*

**1538 | Wireless Power Transfer System for Automatic Revolving Doors**
Mohamad Abou Houran, Xu Yang, Wenjie Chen, Ahsan Hanif, Alaaeldien Hassan, Mengjie Qin
*Xi'an Jiaotong University, China*

## Session K06: Energy Harvesting

**1329 | A Dual-Resonance Electromagnetic Vibration Energy Harvester for Wide Harvested Frequency Range**
Zhijie Feng, Han Peng, Yong Chen, Jiahua Chen, Kangyi Sun
*Huazhong University of Science and Technology, China*

**1250 | A Single-Stage Dual-Mode AC-DC Converter for Vibration Energy Harvesting with Uninterrupted Output**
Jiayong Yuan, Han Peng, Hanyi Sun, Hongfei Xiao
*Huazhong University of Science and Technology, China*

**1659 | A Coil Connection Switching Strategy for Maximum Power Delivery in Electromagnetic Vibration Energy Harvesting System**
Hongfei Xiao, Han Peng, Jiayong Yuan
*Huazhong University of Science and Technology, China*

**1546 | A Self Start-Up Circuit in Low Voltage Power Conversions for Electromagnetic Energy Harvesting with Optimized Power Distributions**
Jiahua Chen[1], Han Peng[1], Zhijie Feng[1], Kai Gao[2], Shaojing Wang[2], Peng Xu[2]
*[1]Huazhong University of Science and Technology, China; [2]State Grid Shanghai Electric Power Research Institute, China*

**2450 | Performance Comparison of Burst-Mode MPPT and Perturb and Observe MPPT Algorithms for Photovoltaic Energy Harvesting Applications**
F. Selin Bagci, Katherine A. Kim
*National Taiwan University, Taiwan*

## Session K07: Measurements and Testing

**1224 | A Simple Measurement Method of Common Source Inductance for GaN Devices**
Jiarui Wu[1], Xu Yang[1], Kangping Wang[1], Jiwen Wei[1], Zhiyuan Qi[1], Wenjie Chen[1], Qiaoliang Chen[2]
*[1]Xi'an Jiaotong University, China; [2]Longteng Semiconductor Co., Ltd., China*

**1332 | Film Capacitors ESL Extraction Based on SiC MOSFET Switching Transient Process**
Jianfeng Niu[1], Zejun He[2], Yun Lei[1], Mingyang Wang[1], Jing Zhou[1], Sideng Hu[1]
*[1]Zhejiang University, China; [2]Ningbo Jiangbei Gofront Herong Electric Co., Ltd., China*

**1487 | GaN-Based ±5kV/100kHz PWM Generator for Advanced Partial Discharge Characterization**
Zhicheng Guo, Tianxiang Chen, Ruiyang Yu, Alex Q. Huang
*The University of Texas at Austin, United States*

**1380 | An Effective Impedance-Phase Method for Sensorless Measurement of Li-Ion Battery Cells' Internal Temperature**
Ala A. Hussein[1], Abbas A. Fardoun[2]
*[1]Prince Mohammad Bin Fahd University, Saudi Arabia; [2]Al-Marref University, Lebanon*

**1381 | An Extended Kalman Filter with Exponential Thermoelectric Measurement Model for Sensorless Surface Temperature Estimation of Li-Ion Batteries**
Mahroo Sajid[1], Ali Wadi[1], Mamoun Abdel-Hafez[1], Ala A. Hussein[2]
*[1]American University of Sharjah, United Arab Emirates; [2]Prince Mohammad Bin Fahd University, Saudi Arabia*

## Session K08: Emerging Technologies and Applications – 2

**2559 | High-Performance Distributed Power Electronics Communication Network Design with 5 Gbps Data Rate and Sub-Nanosecond Synchronization Accuracy**
Yu Rong[1], Zhiyu Shen[2], Boran Fan[1], Vladimir Mitrovic[1], Jianghui Yu[1], Slavko Mocevic[1], Jun Wang[3], Dushan Boroyevich[1], Rolando Burgos[1]
*[1]Virginia Polytechnic Institute and State University, United States; [2]Delta Electronics (America) Ltd., United States; [3]University of Nebraska Lincoln, United States*

**1105 | Analysis and Design of a Latching Current Limiter Based on a SiC N-MOSFET**
Abraham López[1], Pablo F. Miaja[1], Manuel Arias[1], Arturo Fernández[2]
*[1]University of Oviedo, Spain; [2]European Space Agency, The Netherlands*

**1898 | Design and Development of Modular Hybrid DC Breaker Scheme for DC Distribution Systems**
D.K.J.S. Jayamaha[1], Ken K.M. Siu[2], Carl N.M. Ho[1], A.D. Rajapakse[1]
*[1]University of Manitoba, Canada; [2]University of North Texas, United States*

**2431 | High Density Power Converter Design for Pulsed NMR Applications**
Yu Yao, Harish S. Krishnamoorthy
*University of Houston, United States*

**1497 | Electrical Variable Capacitor of Reduced Switch Count and Voltage Stress for 13.56MHz RF Plasma System**
Juhwa Min, Yongsug Suh
*Jeonbuk National University, Korea*

**2109 | Parallel Operation of Gradient Power Amplifiers without Large Current-Sharing Reactor**
Mingyu Xue, Haicong Zhang, Bin Cao, Xu Chu
*Shanghai United-Imaging Healthcare Co.,Ltd., China*

## Session K09: Emerging Technologies and Applications – 3

**1441 | An Adjustable Stiffness Torsional Magnetic Spring with a Linear Stroke Length**
Dawei Che[1], Jonathan Z. Bird[1], Alex Hagmuller[2], Md Emrad Hossain[1]
*[1]Portland State University, United States; [2]Aquaharmonics Inc., United States*

**1173 | Auto-Tuning Control of a Switched-Mode Power Converter for Tailored Pulse-Shape Biased Plasma Etching Applications**
Qihao Yu, Erik Lemmen, Korneel Wijnands, Bas Vermulst
*Eindhoven University of Technology, The Netherlands*

**2457 | Liquid Conductor Electric Machines: A New Cooling Approach for Pulsed Power Applications**
Bryan Paul Ruddy[1], Yi Chen Mazumdar[2], Jason Yunhe Guan[3]
*[1]University of Auckland, New Zealand; [2]Georgia Institute of Technology, United States; [3]Fisher and Paykel Healthcare, New Zealand*

**1440 | Analysis and Experimental Testing of a New Type of Variable Stiffness Magnetic Spring with a Linear Stroke Length**
Md Emrad Hossain, Jonathan Z. Bird, Victor Albarran, Dawei Che
*Portland State University, United States*

**1530 | Harmonics Suppression Using a GaN-Based Flying-Capacitor Multilevel Inverter with PWM Operation at 13.6 MHz**
Fiqih Tri Fathulah Rusfa, Hideaki Fujita
*Tokyo Institute of Technology, Japan*

# Product Sessions

*These half-hour, industry-driven sessions, provide an in-depth look off the show floor from our exhibitors, showcasing their innovative products and services.*

**8:30AM-9:00 AM**

OPAL-RT TECHNOLOGIES

## Low Voltage Ride Through (LVDT) Capability of Solar Energy Inverters Using an FPGA-based Real-Time Simulator

This Hardware-in-the-Loop demo consists of an inverter controller for grid-connected solar energies and an OP4510 real-time simulator. The controller, developed by the GREENLAB of Hefei University of Technology, is capable of low-voltage ride through—while the Electric Hardware Solver (eHS) is running on the OP4510, and simulates the entire grid-connected solar-energy inverter in real-time on the FPGA at a time step of less than 250 nanoseconds. The design of circuit schematic is done using the new OPAL-RT Schematic Editor. The model receives the PWM gating signals from external controller via digital inputs, and feeds the voltage and current measurement to controller via analog outputs. Also, the HIL model can perform soft-start, soft-stop or soft-reset, as well as update the PID parameters of the external controller via RS232 protocol. Therefore, users can conduct numerous tests automatically using API scripts. Particularly, the scenario features allows the user to pre-define different levels of voltage-sag or the short-circuit level of the host grid for the requirement of low voltage ride through (LVDT) tests.

**9:00AM-9:30 AM**

STMicroelectronics

## Evolution of Power Delivery for Cloud Computing

New architectures and technologies are increasing power density and efficiency reducing TCO (Total Cost of Ownership.) From AC-DC to the Point of Load, we will look at the power delivery topologies leveraging ST's unique portfolio, the most complete in the market, with the latest innovations in GaN transistors and drivers.

**3:30PM-4:00PM**

GeneSiC™ SEMICONDUCTOR

## G3R™ SiC MOSFETs, Unparalleled Performance and Robustness

High-efficiency energy usage has become a critical deliverable in next-generation power converters and silicon carbide (SiC) power devices continue to be the key components driving this revolution. In this session, GeneSiC will discuss the superiority of its third-generation (G3R™) SiC MOSFETs, including the performance advantages, design considerations as well as the importance of quality and reliability in demanding applications.

# Student Demonstrations

*Student Demonstrations provide an opportunity for students from various universities and countries to showcase their emerging technology research outcomes and interact with academia and industry.*

## Hardware Competition

**High Power Density GaN-Based Online Uninterruptible Power Supply**
**Maida Farooq, Danish Shahzad, Prof. Khurram Afridi**
*Cornell University, USA*

**High Power Density GaN-Based Online Uninterruptible Power Supply**
**Mausamjeet Khatua, Prof. Khurram Afridi**
*Cornell University, USA*

**Demonstration of Power Sink with Wide Power-Bandwidth to Emulate Residential Loads**
**Hitesh Kumar, Prof. Santanu K. Mishra**
*Indian Institute of Technology Kanpur, India*

**Common Mode EMI Analysis in Power Electronics Enabled Power System**
**Ashik Amin, Tahmid Ibne Mannan, Prof. Seungdeog Choi**
*Mississippi State University, USA*

**Machine Learning Methods and Open-Source Database for Magnetic Core Loss Modeling**
**Haoran Li, Mian Liao, Shukai Wang, Prof. Minjie Chen**
*Princeton University, USA*

**Vertical-Stacked Liquid-Cooled 48 V-1 V CPU Voltage Regulator with Extreme Power Density**
**Youssef Elasser, Ping Wang, Prof. Minjie Chen, Dr. Jaeil Baek**
*Princeton University, USA*

**A 700kHz 800V/14V GaN-based Isolated DC-DC Converter with Optimized Integrated Transformer for Electrical Vehicles**
**Huu Phuc Kieu, Donghan Lee, Prof. Sewan Choi**
*Seoul National University of Science and Technology, South Korea*

**Blockchain-Enabled Security Module for Firmware Security-Enhanced Smart Inverter**
**BoHyun Ahn, Seerin Ahmad, Swathi Pedavalli, Prof. Taesic Kim**
*Texas A&M University-Kingsville, USA*

**Liquid Metal based Cooling for Power Electronics Systems with Inductor Integrated Magnetohydrodynamics Pump**
**Junchong Fan, Yue Zhang, Prof. Jin Wang**
*The Ohio State University, USA*

**Use of 3D Printing Technology to Improve the Voltage Distribution Across Inductor's Turns**
**Faisal Alsaif, Prof. Jin Wang**
*The Ohio State University,USA*

**Designing of Flying Capacitor (FC) Module based on GaN Chip**
**Pasan Gunawardena, Xuesong Wu, Prof. Yunwei Li**
*University of Alberta, Canada*

**High-Voltage, High-Current Pulse Generator**
**Xin Zan, Prof Al-Thaddeus Avestruz**
*University of Michigan, Ann Arbor, USA*

**High Performance Integrated Motor Drive using WBG-enabled Current-Source Converters**
**Renato Amorim Torres, Hang Dai, Prof. Bulent Sarlioglu, Prof. Thomas Jahns**
*University of Wisconsin-Madison, USA*

**Composite Hybrid Energy Storage System**
**Marium Rasheed, Josh Larsen, Prof. Regan Zane**
*Utah State University, USA*

## Software Competition

**Demonstration of Power Sink with Wide Power-Bandwidth to Emulate Residential Loads**
**Hitesh Kumar, Prof. Santanu K. Mishra**
*Indian Institute of Technology Kanpur, India*

**Machine Learning Methods and Open-Source Database for Magnetic Core Loss Modeling**
**Haoran Li, Mian Liao, Shukai Wang, Prof. Minjie Chen**
*Princeton University, USA*

**Blockchain-Enabled Security Module for Firmware Security-Enhanced Smart Inverter**
**BoHyun Ahn, Seerin Ahmad, Swathi Pedavalli, Prof. Taesic Kim**
*Texas A&M University-Kingsville, USA*

**PowerSynth an MCPMs layout Optimization Tool**
**Quang Le, Imam Al Razi, Tristan Evans, Prof. Alan Mantooth, Prof. Yarui Peng**
*University of Arkansas, USA*

**Active Life Balancing to Condition Li-ion Battery Packs**
**Marium Rasheed, Prof. Regan Zane**
Utah State University, USA

# Exhibitor Listing

Allegro MicroSystems

Bodo's Power Systems

Efficient Power Conversion Corporation

EGSTON Power Electronics

FREEDM Systems Center

GanPower International

GeneSiC

GMW Associates

Halla Mechatronics

How2Power.com

HVR Advanced Power Components Inc.

IEEE Future Networks

IEEE - Industrial Application Society

IEEE - Power Electronics Society

Infineon

Magna-Power

Magnetics

MathWorks

MDPI - Machines

OPAL RT

Payton America Inc

Picotest

Plexim, Inc

Powersim

Richardson RFPD

Rohde & Schwarz USA

Sanrex Corporation

STMicroelectronics

Taiwan Semiconductor Inc.

Vicor

Voltx.ai

Wiley

Wolfspeed

# ECCE 2022

IEEE ENERGY CONVERSION CONGRESS & EXPO Detroit, Michigan, USA Oct. 9-13

## IMPORTANT DATES

**January 15, 2022**
Digest submission

**May 1, 2022**
Author notification

**July 1, 2022**
Final papers with IEEE copyright forms


IEEE

IAS IEEE INDUSTRY APPLICATIONS SOCIETY Linking Research to Practice

pels IEEE POWER ELECTRONICS SOCIETY Powering a Sustainable Future


### General Chair

**Emmanuel Agamloh**
*Baylor University, USA*

### ECCE 2022 Technical Program Co-Chairs

**Navid R. Zargari**
*Rockwell Automation, Canada*

**Annette Muetze**
*Graz University of Technology, Austria*

**Andrea Cavagnino**
*Politecnico di Torino, Italy*

**Mohammad Islam**
*Halla Mechatronics, USA*

**Gerry Moschopoulos**
*University of Western Ontario, Canada*

**Brandon Grainger**
*University of Pittsburgh, USA*

**Contact email:**
**ecce2022tpc@gmail.com**


The Fourteenth Annual IEEE Energy Conversion Congress and Exposition (ECCE 2022) will be held in Detroit, Michigan, USA, from October 9 to October 13, 2022. ECCE is a pivotal international event on energy conversion. ECCE 2022 will feature both industry-driven and application-oriented technical sessions as well as an exposition. The conference will bring together practicing engineers, researchers and other professionals for interactive and multidisciplinary discussions on the latest advances in areas related to energy conversion.

Technical papers are solicited on any subject pertaining to the scope of the conference including, but not limited to, the following major topics:

### Energy Conversion Systems & Applications

- High power/voltage power conversion
- High voltage isolation techniques
- Energy harvesting
- Energy conversion for information technology and communication systems
- Energy efficiency for residential, commercial, and industrial applications
- Big data and artificial intelligence in energy conversion
- Renewable and alternative energy power electronic systems
- Smart grids, microgrids, and utility applications (HVDC, FACTS, and Solid State Transformers)
- Electrical energy storage
- Wireless power transfer

### Component, Converter & Subsystem Technologies

- Power electronic devices (silicon and wide bandgap) and applications
- Passive components and materials
- Power electronic packaging integration
- Reliability, advanced fault protection systems, diagnostics, prognostics, and health management
- Thermal management and advanced cooling technologies
- Electromagnetic interference and electromagnetic compatibility
- Power conversion topologies, modulation, and control
- Electrical drive systems and topologies and their control
- Rotating/linear electromechanical devices
- Enabling technologies for Industry 4.0: advanced manufacturing, additive manufacturing, digital twins, cloud design, big data analytics

**Digest Submission:** Prospective authors are requested to submit a single column, single spaced digest no longer than five (5) pages summarizing the proposed paper. The digest should include key equations, figures, tables, and references as appropriate, but no author names or affiliations. Digests not conforming to these requirements will be rejected without review. The digests must clearly state the objectives of the work, its significance in advancing the state of the art, and the methods and specific results in sufficient detail. All digests will go through a double-blind peer review process to ensure a confidential and fair review. The papers presented at the conference will be included in the IEEE Xplore Digital Library. Please refer to the conference website for a detailed list of technical topics and the digest submission method.

IEEE ENERGY CONVERSION CONGRESS & EXPO Detroit, Michigan, USA Oct. 9-13

# Call for Tutorials

## IMPORTANT DATES

**February 11, 2022**
Tutorial proposal due

**April 8, 2022**
Notification of acceptance

**July 1, 2022**
Full tutorials materials due

The 14th Annual IEEE Energy Conversion Congress and Exposition (ECCE 2022) will be held in Detroit, Michigan, USA, from October 9 to October 13, 2022. ECCE is a pivotal international event on energy conversion. It will bring together practicing engineers, researchers, and other professionals for interactive discussions on the latest advances in areas related to energy conversion.

The ECCE organizing committee invites proposals for tutorials to be presented at ECCE 2022. Each tutorial is 3 hours long, excluding break times. Each accepted tutorial will receive one conference registration together with an honorarium of $1,000. Presenters potentially may be expected to present both in-person and pre-recorded.

Please note that publication of a technical paper will still require a paid full registration. **All tutorial proposals should be submitted via the ECCE 2022 web portal under "Call for Tutorials".** Please follow the Tutorial Proposal Form on the website as a submission template. The proposals will be reviewed by a panel of subject matter experts.

One or more of the following elements are strongly encouraged in the tutorial proposals:

A. Industry led or co-hosted lectures;
B. Interactive instructor-audience approaches, including hands-on demonstrations and practices;
C. Application focused session on tools or methods for the practicing engineer.
D. ECCE 2022 regionally oriented topics at the host city, e.g. transportation electrification;
E. Collaborative cross-disciplinary topics and tutorial teams are welcome;
F. Topics that engage the audience in formats that serves to communicate with the attendees.

Tutorials considered to be less attractive to the audience are:

a) Topics that are too narrowly focused;
b) Lectures that are not balanced between theory and application;
c) Tutorial topics or teams presented previously in immediate past ECCE or other major IAS/PELS conferences;
d) Tutorials that narrowly focus on presenter's own research works that are already publicly available
e) Solicitation of a particular product or service.

Potential topic areas include but are not limited to:

## Energy Conversion Systems and Applications

- Renewable energy, including under-represented ocean-wave, tidal, geothermal
- Smart grids, micro-grids, nano-grids
- Electrical energy storage, including real physics or controlled virtual storage
- Energy conversion for information technology and communication systems
- Energy harvesting and conversion
- Smart and energy efficient buildings
- Energy efficiency for advanced manufacturing
- Big data and machine learning in energy conversion
- Cybersecurity in energy conversion systems
- Transportation electrification, including aircraft and urban aerial mobility
- Battery charging technologies
- Resiliency in energy systems

## Component, Converter and Subsystem Technologies

- Power electronic devices
- Power conversion topologies, modeling, and control
- Electric machines and drives
- Passive components, magnetics, and materials
- Packaging, integration, and advanced manufacturing
- EMI and EMC
- Thermal management, advanced cooling technologies
- Wireless power transfer
- High voltage power conversion, including insulation technologies
- Design automation or optimization
- Reliability, diagnostics, prognostics, and health management
- Fault-tolerant converters and systems

## Others

- Pedagogy for undergraduate learning or under-represented groups
- Post-COVID technology innovations
- Entrepreneurship, technology transfer, business management
- Use of standards for specific applications

IEEE

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pels IEEE POWER ELECTRONICS SOCIETY Powering a Sustainable Future

### General Chair

**Emmanuel Agamloh**
*Baylor University, USA*

### Tutorial Co-Chairs

**Pete Wung**
*University of Dayton, USA*

**Xu She**
*Carrier Corporation, USA*

**Xiaonan Lu**
*Temple University, USA*



www.ieee-ecce.org/2022 Detroit, Michigan, USA – October 9–13, 2022

IEEE ENERGY CONVERSION CONGRESS & EXPO 2022 Detroit, Michigan, USA Oct. 9-13

# Tutorial Proposal Form

**Format:** Maximum 5 pages. All pages are formatted to 8-1/2 by 11 inch or A4 paper with margins of one inch on every side. All texts use single space, Times New Roman, black ink, and a font size of 11 or 12.

## Recommended Sections:

### 1. Tutorial Title

### 2. Instructor Team

Name(s), affiliation(s), and contact information

### 3. Abstract

No more than 500 words. Accepted abstract will be published through the conference website, program, and proceedings.

### 4. Tutorial Outline

Outline shall only define the topics and subtopics. No detailed descriptions please. Time allocation and instructor breakdown by topics is recommended.

### 5. Lecture Style and Requirements

Briefly describe the tutorial format, which may include traditional lecture, software/hardware demonstration, interactive audience polls/quizzes, worksheets, discussion, etc. Note any equipment or space requirements beyond a laptop and projector. Also list the targeted audience and tutorial difficulty level, including any pre-requisite knowledge.

### 6.Instructor Biography

No more than 200 words for each person. Each biography shall include the qualifications most relevant to the proposal. Past tutorial/teaching experience and outcome can be highlighted. External website link can be included but may not be reviewed.

IEEE ENERGY CONVERSION CONGRESS & EXPO Detroit, Michigan, USA Oct. 9-13

# Call for Special Sessions

## IMPORTANT DATES

**April 1, 2022**
Special session proposal due

**May 20, 2022**
Notification of acceptance

**July 1, 2022**
Final session plan due

The 14th Annual IEEE Energy Conversion Congress and Exposition (ECCE 2022) will be held in Detroit, Michigan, USA, from October 9 to October 13, 2022. Special Sessions are solicited focusing on emerging technologies and industry-oriented topics. Industry and government organizers or speakers are of particular interest. Guest speakers will be invited on the day their session is scheduled. No written papers are required. Materials presented in the Special Sessions will not be included in the conference proceedings. Each session will be assigned either one or two 100-minute slot(s), subject to conference program scheduling.

Different session formats are solicited: 1) Formal presentations; 2) Informal talks with or without slides; 3) Full Q&A panel; 4) Debate; 5) Other creative or hybrid styles.

One or more of the following elements are strongly encouraged in the special session proposals: A) Significant industry or government involvement; B) Industrial application oriented; C) ECCE 2022 regionally oriented topics; D) Collaborative cross-disciplinary topics or teams; E) Creative formats that engage the audience, especially industry.

Factors considered as less attractive to the audience are: a) Non-emerging topics; b) Academic lectures; c) Similar teams with similar topics from the immediate past ECCE; d) Solicitation of a particular product or service; e) Unclear plans including unconfirmed speakers.

Potential topic areas include but are not limited to:

## Energy Conversion Systems and Applications

- Transportation electrification, including EV, trucks, aircraft, UAV, trains, ships
- Energy storage systems, including real or virtual storage
- Charging stations, vehicle to grid
- Additive manufacturing
- Renewable energy integration
- Smart grids, micro-grids, nano-grids
- Resiliency in energy systems
- Smart and energy efficient buildings
- Energy conversion for information technology
- Big data and machine learning in energy conversion
- Cybersecurity in energy conversion
- Design automation and optimization

## Components, Converters, and Subsystems

- Power semiconductor devices, magnetics, capacitances
- Power conversion topologies, modeling, and control
- Electric machines and drives
- Packaging, integration, and advanced manufacturing
- EMI and EMC
- Thermal management, advanced cooling technologies
- Wireless power transfer
- High voltage power conversion, including insulation technologies
- Reliability, diagnostics, prognostics, and health management

## Others

- Advanced testing and validation, including demo
- Standards development
- Education and career development
- Entrepreneurship, technology transfer, business management
- Post-COVID technology innovations

**Proposal Submission Guidelines:** All special session proposals must be submitted via the ECCE 2022 web portal under "**Call for Special Sessions**". Please follow the Proposal Form on the website as a submission template. The proposals will be reviewed by a panel of subject matter experts.

### General Chair

**Emmanuel Agamloh**
*Baylor University, USA*

### Special Session Co-Chairs

**Yue Cao**
*Oregon State University, USA*

**Sara Roggia**
*MagniX, USA*



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IEEE ENERGY CONVERSION CONGRESS & EXPO Detroit, Michigan, USA Oct. 9-13

# Special Session Proposal Form

**Format:** Maximum 5 pages. All pages are formatted to 8.5x11" or A4 paper with margins of one inch on every side. All texts use single space, Times New Roman, and a font size of 11 or 12. *A Word template will be posted on the official website under Call for Special Sessions.*

## Recommended Sections:

### 1. Special Session Title

### 2. Proposed Session Format

☐ Formal presentations ☐ Informal talks ☐ Full Q&A panel ☐ Debate

☐ Create own style – *see Call For Proposal.*

*Describe the format at a high level, and note any creative activities such as software/hardware demonstration, virtual tours, interactive audience polls, etc.*

### 3. Proposed Timing

☐ 100 minutes ☐ 2x100 minutes

### 4. Session Organizers

List name(s), title(s), affiliation(s), and email(s).

### 5. Session Speakers/Panelists

List names, titles, and affiliations. Clearly note each speaker's availability: choose "confirmed" or "tentative"; failure to do so will be treated as all tentative.

### 6. Abstract

No more than 500 words. Accepted abstract will be published through the conference website and program book.

### 7. Session Outline

Only list the proposed topics/titles/activities. No detailed descriptions necessary. Indicate time allocation and speaker breakdown, if possible.

### 8. Organizer Biography

No more than 200 words for each person. External website link can be included but may not be reviewed.

### 9. Speaker/Panelist Biography

No more than 200 words for each person. External website link can be included but may not be reviewed.

# SAVE THE DATE

2022

Detroit, Michigan, USA Oct. 9-13

ECCE

IEEE ENERGY CONVERSION CONGRESS & EXPO

## Detroit MICHIGAN USA

## OCTOBER 9-13 2022

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