| Time | Harris Room<br>https://us02web.zoom.us/j/81081777350 | Jones Room<br>https://us02web.zoom.us/j/82230349891 | Broadway Room<br>https://us02web.zoom.us/j/86950338118 | Tour |
|---|---|---|---|---|
| **Monday, November 20** | | | | |
| 09:00 am -10:30 am | T1a: *Tutorial 1 - Virtual Machine Model and Grid Forming* | T2a: *Tutorial 2: Differential Power Processing for Eliminating Partial Shading Losses in Solar PV Systems* | T3a: *Tutorial 3: Electromagnetic Interference and Compatibility for Power Electronics Engineers* | |
| 10:30 am -11:00 am | *Morning Tea* | | | |
| 11:00 am -12:30 pm | T1b: *Tutorial 1: Virtual Machine Model and Grid Forming* | T2b: *Tutorial 2: Differential Power Processing for Eliminating Partial Shading Losses in Solar PV Systems* | T3b: *Tutorial 3: Electromagnetic Interference and Compatibility for Power Electronics Engineers* | |
| 12:30 pm -01:30 pm | *Lunch* | | | |
| 01:30 pm -01:45 pm | *IFEEC2023 Opening* | | | |
| 01:45 pm -03:00 pm | K1: *Keynote 1: Passive Components for Advancement of Power Electronics* | | | |
| 03:00 pm -03:30 pm | *Afternoon Tea* | | | |
| 03:30 pm -05:00 pm | TS1: *Technical Session 1: AC-DC Converters* | TS2: *Technical Session 2: GaN Devices and Applications* | TS3: *Technical Session 3: DC-DC Converters I* | |
| 05:00 pm -07:00 pm | SO1: *Welcome Reception* | | | OST1: *Off Site Tour 1: Endeavour Energy - Digital Substation* |
| 07:00 pm -08:15 pm | | | | |
| **Tuesday, November 21** | | | | |
| 09:00 am -10:30 am | SS1: *Special Session 1: Learning-based Design Optimization and Control Methods for Electrical Machines* | TS4: *Technical Session 4: Motor Drives I* | TS5: *Technical Session 5: DC-DC Converters II* | |
| 10:30 am -11:00 am | *Morning Tea* | | | |
| 11:00 am -11:45 am | K2: *Keynote 2 - Wireless Power Transfer Technologies* | | | |
| 11:45 am -12:30 pm | K3: *Keynote 3 - Power Electronics Engineers, the world is your oyster* | | | |
| 12:30 pm -01:30 pm | *Lunch* | | | |
| 01:30 pm -03:00 pm | P1: *Plenary Panel: Grid forming and Grid Following Inverters* | | OTS1: *Online Technical Session 1* | |
| 03:00 pm -03:30 pm | *Afternoon Tea* | | | |
| 03:30 pm-05:00 pm | TS6: *Technical Session 6: Wireless Power Transfer* | TS7: *Technical Session 7: Motor Drives II* | SS4: *Special Session 4 - Emerging Battery Technology for Electrified Transportation and Energy Storage Sectors* | |
| 05:00 pm -05:15 pm | | | | |
| **Wednesday, November 22** | | | | |
| 09:00 am -10:30 am | SS2: *Special Session 2: Grid-Transportation Integrated Energy* | TS8: *Technical Session 8: PV Systems* | TS9: *Technical Session 9: Transportation Electrification* | |

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|---|---|---|---|---|
| | *System* | | | |
| 10:30 am -11:00 am | *Morning Tea* | | | |
| 11:00 am -11:45 am | K4: *Keynote 4 - Impacts of grid-connected inverters in distribution networks: planning, regulations and standardisation* | | | |
| 11:45 am -12:30 pm | K5: *Keynote 5 - Advances in the Control of Grid Connected Power Electronic Converters* | | | |
| 12:30 pm -01:30 pm | *Lunch* | | | |
| 01:30 pm -03:00 pm | P2: *Plenary Panel 2: Microgrids and Energy Storage Systems* | | | |
| 03:00 pm -03:30 pm | *Afternoon Tea* | | | |
| 03:30 pm-05:00 pm | SS3: *Special Session 3: Reliability of Power Electronics Systems* | TS10: *Technical Session 10: Multilevel Converters* | IS1: *Invited Sessions 1* | |
| 06:00 pm -10:00 pm | SO2: *Banquet Awards Cruise* | | | |
| Thursday, November 23 | | | | |
| 08:45 am -09:00 am | TS11: *Technical Session 11: Advanced Control for Power Converters* | TS12: *Technical Session 12: SiC Devices and Applications* | | |
| 09:00 am -10:30 am | | | OTS3: *Online Technical Session 3* | |
| 10:30 am -11:00 am | *Morning Tea* | | | |
| 11:00 am -12:30 pm | TS13: *Technical Session 13: Power Electronics for Utility Interface* | TS14: *Technical Session 14: DC and Micro-grids* | TS15: *Technical Session 15: Applications of Power Electronics* | |
| 12:30 pm -01:30 pm | *Lunch* | | | |
| 01:30 pm -03:00 pm | P3: *Plenary Panel 3: Getting More Women into Power Engineering* | | | |
| 03:00 pm -03:30 pm | *Afternoon Tea* | | | |
| 03:30 pm -05:00 pm | WIE: *Women in Engineering Networking Event* | | | OST2: *Off Site Technical Tour 2: UTS Tech Lab - Botany* |
| 05:00 pm -06:00 pm | | | | |

# Monday, November 20

## Monday, November 20 9:00 - 10:30

### T1a: Tutorial 1 - Virtual Machine Model and Grid Forming

**Dr. Po-Hsu Huang, Wencheng Huang, Tom Neilson - Tesla USA**

Room: Harris Room

Chair: Weidong Xiao (University of Sydney & School of Electrical and Information Engineering, Australia)

As more wind and solar power replace fossil fuel generation, less mechanical inertia is available on the grid, removing a natural stability buffer in the case of a grid disturbance. Tesla's Virtual Machine Mode is designed to address these stability challenges by virtually emulating mechanical inertia. Megapack's built-in inverters with Virtual Machine Mode (VMM) create grid-forming dynamics that provide grid strength, respond to added and rejected loads and maintain quality voltage at the point of interconnection.

In this tutorial, we will discuss about Tesla's experience in developing Virtual Machine Mode. We intend to cover system controls and operations, power system stability enhancement, and project design experience.

## T2a: Tutorial 2: Differential Power Processing for Eliminating Partial Shading Losses in Solar PV Systems

**A/Prof. Yousef Mahmoud**
**Kennesaw State University, USA**

Room: Jones Room

Chair: Kosala Gunawardane (University of Technology Sydney, Australia)

Biography

Yousef Mahmoud (Senior Member, IEEE) is currently an Associate Professor at Kennesaw State University, GA, USA. He earned his Ph.D. degree in electrical and computer engineering from the University of Waterloo, Canada, in 2016. His research interests encompass solar photovoltaic systems, with a focus on modeling, efficiency optimization, power electronics, control, protection, and fault diagnosis.

Dr. Mahmoud serves as an Associate Editor for both the IEEE Transactions on Energy Conversion Journal and the IEEE Power Engineering Letters since 2021. He has earned recognition as a Star Reviewer of the IEEE Transactions on Energy Conversion and received the Best Paper Award at the IEEE International Renewable Energy Congress in 2017. Furthermore, Dr. Mahmoud is the holder of a sole-inventor US patent and has been included in the list of the World's Top 2% Scientists released by Stanford University. He is a full member of both IEEE-Eta Kappa Nu (IEEE-HKN) and Sigma Xi, as of 2021.

In addition to his academic achievements, Dr. Mahmoud has actively contributed to several IEEE conferences, including his roles as an international committee member and associate editor for the IEEE International Renewable Energy Congress.

Abstract

Partial shading stands as one of the primary culprits behind substantial power losses in solar PV systems, potentially resulting in a reduction of available power by more than 30%. This tutorial will delve into the concept, operational challenges, and recent advancements of one particularly promising and emerging solution to counteract the power losses attributed to partial shading-known as differential power processing (DPP) converters. DPP converters have the potential to revolutionize solar PV systems by reducing inclusion power losses and minimizing converter size.

The tutorial will also discuss the challenges hindering DPP converter growth and introduce promising solutions to enhance their performance. It covers coupling problems when operating multiple DPP converters and explores model-based approaches as potential solutions. This tutorial offers insights for students, engineers, academics, researchers, industry professionals, and entrepreneurs interested in the future of solar technology and the role of differential power processing converters.

## T3a: Tutorial 3: Electromagnetic Interference and Compatibility for Power Electronics Engineers

**Professor Graham Town**
**School of Engineering, Macquarie University, Australia**

Room: Broadway Room

Chair: Georgios Konstantinou (The University of New South Wales, Australia)

Biography

Graham Town is an electrical engineer with 8 years experience in the Australian electronics industry and over 30 years of distinguished contributions to engineering education and research. He was awarded a BE (Hons 1) from NSWIT (now UTS) in 1984, a PhD from the University of Sydney in 1992, and a Graduate Certificate in Leadership and Management (Higher Education) from Macquarie University in 2007. He established the undergraduate engineering program at Macquarie University, offered since 2004, where he is now an Emeritus Professor.

Professor Town has published extensively in diverse areas including NMR imaging, guided-wave optics and photonics, THz technology and applications, engineering education, power electronics, and e-transport. Prior to retirement in 2019 he led industry-supported research projects on power electronics for compact and efficient power conversion, and smart-grids with a focus on electric vehicle integration and management. He remains active in local and international interdisciplinary research collaborations, consulting, service to local and international professional engineering organisations, and STEM outreach to schools.

Professor Town is a Chartered Professional Engineer (Telecommunications, Electrical, Leadership), a Senior Member of the IEEE, a Fellow of the Institution of Engineers Australia, and a Fellow of the Royal Society of NSW.

Abstract

The increasing use of high speed power electronics in electrical power conversion and control is also increasing the potential for electromagnetic interference (EMI) with the operation of other electronic equipment. EMI is often difficult to diagnose yet can have serious consequences, especially for wireless systems used for sensing, communication and control of infrastructure, e.g. as in "smart grids". Consequently it is important for power electronics engineers to understand how and why EMI occurs, and methods for minimizing its impact.

Topics covered in this tutorial include: sources of EMI (electronic switching, electrical transients, etc.) characteristics of EMI generated by power electronic circuits (temporal and spectral properties, etc.), fundamentals of coupling mechanisms (conduction, induction, propagation) by which sources of EMI may interfere with the operation of electronic equipment, EMI standards and measurements, and practical strategies and techniques to minimise EMI and/or its impact on other electronic circuits, i.e. to maximise electromagnetic compatibility (EMC).

## Monday, November 20 10:30 - 11:00

### Morning Tea

## Monday, November 20 11:00 - 12:30

### T1b: Tutorial 1: Virtual Machine Model and Grid Forming

**Dr. Po-Hsu Huang, Wencheng Huang, Tom Neilson - Tesla USA**

Room: Harris Room

As more wind and solar power replace fossil fuel generation, less mechanical inertia is available on the grid, removing a natural stability buffer in the case of a grid disturbance. Tesla's Virtual Machine Mode is designed to address these stability challenges by virtually emulating mechanical inertia. Megapack's built-in inverters with Virtual Machine Mode (VMM) create grid-forming dynamics that provide grid strength, respond to added and rejected loads and maintain quality voltage at the point of interconnection.

In this tutorial, we will discuss about Tesla's experience in developing Virtual Machine Mode. We intend to cover system controls and operations, power system stability enhancement, and project design experience.

### T2b: Tutorial 2: Differential Power Processing for Eliminating Partial Shading Losses in Solar PV Systems

**A/Prof. Yousef Mahmoud**
**Kennesaw State University, USA**

Room: Jones Room

### T3b: Tutorial 3: Electromagnetic Interference and Compatibility for Power Electronics Engineers

**Professor Graham Town**
**School of Engineering, Macquarie University, Australia**

Room: Broadway Room

## Monday, November 20 12:30 - 1:30

### Lunch

## Monday, November 20 1:30 - 1:45

### IFEEC2023 Opening

Rooms: Harris Room, Jones Room

Chair: Dylan Lu (University of Technology Sydney, Australia)

# Monday, November 20 1:45 - 3:00

## K1: Keynote 1: Passive Components for Advancement of Power Electronics

**Prof. Toshihisa Shimizu**
**Tokyo Metropolitan University, Japan**

Rooms: Harris Room, Jones Room
Chair: Ha Pham (UTS, Australia)

Biography

Toshihisa Shimizu (Fellow, IEEE) received the B.E., M.E., and Dr.Eng. degrees in electrical engineering from Tokyo Metropolitan University, Hachioji, Japan, in 1978, 1980, and 1991, respectively.,He was a Visiting Professor with VPEC, Virginia Polytechnic Institute and State University, Virginia, USA, in 1998. In 1980, he joined Fuji Electric Corporate Research and Development, Ltd., as a Research Engineer. Since 1993, he has been with the Department of Electrical Engineering, Tokyo Metropolitan University, Hachioji, Japan. He is currently a Full Professor. His research interests include power converters, high-frequency inverters, photovoltaic power systems, modeling and reduction of EMI in power electronics, high power density converter design, and loss characterization of passive components.,Dr. Shimizu is a fellow member of IEEJ.

# Monday, November 20 3:00 - 3:30

## Afternoon Tea

# Monday, November 20 3:30 - 5:00

## TS1: Technical Session 1: AC-DC Converters

Room: Harris Room
Chair: Sinan Li (University of Sydney, Australia)

**3:30** ***Circulating Current Mitigation of Paralleled AC/DC Rectifiers with Zero-Sequence Compensation and Carrier Synchronization***
Yi-Hung Liao and Jiong-Ye Chen (National Central University, Taiwan)
With the rapid development of power electronics, the demand for high-power rectifiers is increasing. The use of parallel-connected modular rectifiers helps improve system performance and reduce costs. It not only increases the power capacity but also enhances the resilience of the power supply system. However, when there are mismatched parameters between rectifiers, circulating currents would be generated due to different PWM control strategies or switching timing among the rectifiers. This leads to current distortion and a decrease in system performance. In this paper, the 0-axis alpha-Beta feedback control method with carrier synchronization technique is proposed to mitigate circulating currents. Some simulation and experimental results are offered to verify the validity of the proposed circulating current control method.

*Presenter bio:* Yi-Hung Liao (M'08) received the M.S. and Ph.D. degrees in electrical engineering from National Tsing Hua University, Hsinchu, Taiwan, in 2000 and 2007, respectively. From 2008 to 2019, he has been a Faculty Member of electrical engineering at National Penghu University, Magong, Taiwan. Since 2019, he has been an Associate Professor of Electrical Engineering at National Central University, Taoyuan, Taiwan. His current research interests include power electronics, control systems, DSP-based and FPGA-based implementation of digital control, distributed energy resources and green energy applications.

**3:45** ***Dual Influence of Power-Synchronization Loop on the Stability of Virtual Synchronous Generators***
Shan Jiang (UNSW Sydney, Australia); Georgios Konstantinou (The University of New South Wales, Australia)
This paper analyzes the dual influence of the power-synchronization loop (PSL) on the stability of virtual synchronous generators (VSGs) and proposes two stability boundaries of VSG with respect to PSL parameters. In the VSG control structure, the PSL is crucial for providing inertia and damping characteristics by mimicking traditional synchronous generators. This paper demonstrates that the PSL affects the angular and synchronization stability of VSGs by simultaneously acting as swing equation emulator and reference phase generator. Angular instability is defined as the wide-range and low-frequency power/frequency oscillation due to inappropriate damping ratio decided by the swing equation, while synchronization instability is defined as the resonance caused by amplified phase angle dynamics introduced by synchronization loops, especially when dq transformations are applied. The dq frame small-signal model of the PSL is developed and incorporated in the impedance modeling of the VSG to derive stability boundaries pertaining to both instability modes.

**4:00** ***The Three-phase Four-Wire Grid-type Inverter Neutral line Current Ripple Derivation with SPWM***
Wen-Yen Li and Yaow-Ming Chen (National Taiwan University, Taiwan); Chien-Heng Shih (National Taiwan University & National Taiwan University1, Taiwan)
For the three-phase four-wire inverter topology which has the neutral line connected with the split capacitor configuration, the neutral line current suppression is an important topic since it will influence the split capacitor voltage. This article provides a new approach for the neutral line current ripple by the state of three phases switches. Computer simulations with MATLAB/SIMULINK environment of 5 KVA rated were performed to verify the theoretical analysis result.

**4:15** ***Flexible Active Power Decoupling Control Strategy for A Single-Stage Switched-Boost Grid-Connected Multilevel Inverter***
Majid Farhangi (University of Technology Sydney, Australia); Reza Barzegarkhoo (Christian-Albrechts-Universität zu Kiel, Germany); Ricardo P. Aguilera and Dylan Lu (University of Technology Sydney, Australia); Yam Siwakoti (University Technology of Sydney, Australia)
One of the vital requirements for battery, fuel-cell, and PV applications is ripple-free and steady DC power. Therefore, due to the difference in the instantaneous power at the DC and AC ports, a power decoupling strategy is necessary. Conventionally, active or passive buffer circuits are used to address this issue in DC-AC converters. Under ideal conditions, the DC input current has a double-line frequency (100~Hz or 120~Hz) ripple. Thus, a buffer circuit needs to compensate and inject a suitable voltage or current to cancel this undesirable input ripple. However, including an additional buffer circuit can increase the size and cost of the system. However, the same level of performance can be reached with some of the proposed single-stage DC-AC converters. In this regard, one of the limitations in the complete elimination of double-line frequency ripples on the DC input current is the increased

capacitor voltage ripple and increased voltage stress on the circuit components. To have better control of these tradeoffs, a flexible APD (FAPD) approach is introduced in this paper. The impact of the proposed control method has been investigated, and the performance of the system has been verified in simulation.

**4:30** ***A Switching Scheme for Optimal Trajectory Control in a Fully Soft Switching Single-Stage Isolated Three Phase AC/DC Converter***

Yusuf Kosesoy and Jan M. Schellekens (Eindhoven University of Technology, The Netherlands); Henk Huisman (Eindhoven University of Technology, Thailand)

A single-stage isolated three-phase AC to DC series-resonant converter is presented. It has the potential to achieve ideal performance through the implementation of optimal trajectory control techniques, leading to ensured soft switching and unity power factor for all three phases. However, in practical implementations, the presence of imperfections may result in a delay in the switching moments specified by control theory. This switching delay prevents the converter from reaching its full potential. In this paper, a novel switching scheme is presented for a fully zero-voltage switching series-resonant isolated three phase AC to DC converter to eliminate the effect of switching delays.

**4:45** ***Novel Continuous Transition of CCM and DCM Switching Control Method for Efficiency Improvement of PFC***

Yen-Shin Lai (Natl. Taipei U. of Tech., Taiwan); Yong-Yi Huang and Xiang-Yu Wu (National Taipei University of Technology, Taiwan)

A novel continuous transition of CCM and DCM switching control method for PFC is proposed in this paper. Continuous transition between CCM and DCM can be automatically achieved without requiring any additional zero crossing point detection circuit and thereby reducing the cost and losses. The proposed switching control method calculates the "quasi-SR" duty based upon the input and output voltages. As the "quasi-SR" duty is smaller than the complementary duty, the calculated "quasi-SR" duty is used for the synchronous rectification (SR) power device switching. Otherwise, conventional complementary duty is used. A 3 kW Totem-pole PFC is set-up for test. The experimental results show the efficiency can be significantly improved as input AC voltage = 110, 230 and 264 Vrms, and the 99.28% of peak efficiency is achieved.

## TS2: Technical Session 2: GaN Devices and Applications

Room: Jones Room

Chair: Youguang Guo (University of Technology Sydney, Australia)

**3:30** ***Design and Implementation of Input-Series/Output-Parallel 3.6 kW Half-Bridge Resonant Converter with GaN E-HEMT for High Input Voltage Applications***

Wei-Cheng Tai and Tsorng-Juu Liang (National Cheng Kung University, Taiwan); Guan-Ting Peng (Taiwan); Kai-Hui Chen and Yu-Chuan Chen (National Cheng Kung University, Taiwan)

GaN E-HEMTs are suitable for high efficiency and frequency operation due to their characteristic of lower on-resistance and fast switching, respectively. However, GaN E-HEMT is with limited voltage rating and is not suitable for high voltage applications. The half-bridge resonant converter with an input side in series and output side in parallel structure causing lower power switch voltage stress and output rectifier current stress is suitable for high input voltage and high power applications. Finally, a laboratory prototype with 500 kHz resonant frequency, input voltage of 740-800 V, output voltage of 200 V and rated power of 3.6 kW is implemented. Under input voltage of 800 V, the maximum and full load efficiencies are 96.1 % at 50 % load and 92.8 %, respectively.

**3:45** ***Optimal Planar Transformer Design Considerations for GaN-Based High Frequency Isolated Converters***

Cheng-Yu Tang (National Taipei University of Technology, Taiwan); Yu-Ching Tan (Elan Microelectronics Corporation, Taiwan)

This paper proposes the optimal planar transformer design considerations for high frequency isolated converters. Main considerations to design the optimal planar transformer can be highlighted as: (1) Separation distance of insulating layers. (2) The inter-winding and intra-winding capacitances. (3) The sequences of insulating layer. (4) The winding coverage. In this paper, four planar transformers with different insulating layer materials, sequences and winding coverages are developed and compared. The electromagnetic simulation software will be included for analysis. Besides, an active clamp flyback (ACF) converter with the zero-voltage switching (ZVS) feature will be designed and implemented for validations. Comprehensive analysis and comparisons of the four developed planar transformers will be presented. With the proposed analysis and optimal design, the voltage spike of switches can be eliminated with 2.49%. The circuit efficiency can be improved with 8.82%, whereas the maximum circuit efficiency with the proposed optimal planar transformer will be 92.64%.

*Presenter bio:* Cheng-Yu Tang (Member, IEEE) received the B.S. degree in electrical engineering from the National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan, in 2010, the M.S. degree in electrical engineering from the National Taipei University of Technology, Taipei, Taiwan, in 2012, and the Ph.D. degree from the Department of Electrical Engineering, National Taiwan University, Taipei, in 2016.,He is currently an Associate Professor with the Department of Electrical Engineering, National Taipei University of Technology. His research interests include switching power supplies, renewable energy systems, and power flow control.

**4:00** ***Design and Implementation of Improved SEPIC Bidirectional DC-DC Converter with Switched Inductors***

Po-Hsun Chiu, Yi-Hung Chen, Hsuan Liao and Jiann-Fuh Chen (National Cheng Kung University, Taiwan)

The objective of this paper is to modify the topology of the unidirectional non-coupled inductor modified SEPIC converter to a bidirectional topology and applied between the DC bus and the battery energy storage system. To improve the conversion ratio, active switched inductors are employed, eliminating the need for a coupled inductor or transformer. This approach offers several advantages, including continuous input current non-inverting input and output. Furthermore, by increasing the switching frequency and utilizing wide bandgap components such as gallium nitride (GaN) instead of Si-based MOSFETs, the converter's volume can be reduced while achieving high efficiency and excellent high-frequency characteristics. The paper will provide an analysis of the operational principles and present experimental results with the following specifications: low side voltage of 48V, high side voltage of 400V, switching frequency of 500kHz, and output power of 500W. The step-down mode achieves a peak efficiency of 93.7%, while the step-up mode reaches a peak efficiency of 90.9%.

**4:15** ***Efficiency and Leakage Current Evaluation of GaN Inverter fed PMSM Drive with Sine Wave Filter***

Seongmi Park (University of Konkuk, Korea (South)); TaeHoon Chin (Konkuk, Korea (South)); Byungju Bae (University of Konkuk, Korea (South)); Younghoon Cho (Konkuk University, Korea (South))

When Gallium Nitride (GaN) transistors are employed in an electric motor drive system, a higher leakage current compared to silicon transistors is induced in the bearing of the electric motor due to high dv/dt characteristics, which eventually appears as a bearing corrosion problem and shortens the life of the motor. To reduce the high dv/dt related problems, the output filter which is placed between an inverter and an electric motor is popularly studied in recent. This paper compares the efficiency and the leakage current performances of the GaN inverter fed permanent magnet synchronous motor (PMSM) drives with and without the sine wave filter. The cut-off frequency of the sine wave filter is much less than the switching frequency, so that the electric motor takes a motor-friendly voltage containing almost only fundamental components. The experimental results shows that the leakage current flowing through the earth connection path is reduced by 20.8% with the sine wave filter at the full load condition.

**4:30** ***Design Method of Leakage Inductance of MHz Toroidal Transformer for LLC Converters***

Jinxing Zhou (Hokkaido University & Electric Energy Conversion Lab., Japan); Koji Orikawa and Satoshi Ogasawara (Hokkaido University, Japan)

This paper proposed a design method for a toroidal transformer intended for LLC converters, whose leakage and magnetizing inductances can be designed independently. In the proposed transformer, the primary leakage inductance can be adjusted by varying the height of spacer between the primary and secondary winding, while the magnetizing inductance and secondary leakage inductance are constant. The error rate between the estimated primary leakage inductance derived from the approximation straight line and the actual primary leakage inductance of the prototype is 0.5%.

## TS3: Technical Session 3: DC-DC Converters I

Room: Broadway Room

Chair: Xiaolu Li (City University of Hong Kong, Hong Kong)

**3:30** ***A Three-Level LLC Resonant Converter with PFM and PWM Control for Battery Charging Application***

Jhih-Cheng Hu, Chun-Wei Huang, Ming-Shi Huang and Wei-Hsiang Hsu (National Taipei University of Technology, Taiwan)

In order to address wide voltage range of battery charger, this article proposes a wide output voltage range control for three-level LLC resonant converter (TL-LLC), including the pulse frequency modulation (PFM) and pulse width modulation (PWM). The operating principle of TL-LLC converter with three-level modulation is analyzed at first. However, LLC converter is usually utilized in PFM to adjust the voltage. This modulation method may cause the converter operates at high switching frequency for low output voltage, resulting in the large switching loss, magnetic component loss and poor electromagnetic interference. Thus, this paper utilized PWM control in TL-LLC converter and operated at maximum switching frequency to regulate the lower output voltage. After that, using the Matlab/Simulink to verify the proposed method for constant current (CC) and constant voltage (CV) conditions. Finally, a digitally controlled TL-LLC converter was constructed to verify the effectiveness of the proposed wide range voltage control method under the following conditions: rated power of 2.7kW, dc input voltage of 800VDC, dc output voltage of 48-109VDC. and maximum conversion efficiency is 94.6%.

**3:45** ***Design and Implementation of 3.5 kW Digital Controlled Battery Charge System***

Shi-Quan Chen, Tsorng-Juu Liang, Ming-Yang Cheng and Kuo-Fu Liao (National Cheng Kung University, Taiwan); Guan-Ting Peng (Taiwan); Kai-Hui Chen and Tzu-Yi Chan (National Cheng Kung University, Taiwan)

A digital controlled two-stage battery charge system is designed and implemented in this paper. The front-stage of the system is an interleaved boost power factor corrector which is used to reduce input current harmonic distortion and provides stable bus voltage. An isolated full-bridge resonant converter which can provide stable voltage and current to the battery is adopted in the rear-stage. The operating principles of both the power factor corrector and full-bridge resonant converter are discussed in detail. An adaptive frequency modulation method with input voltage ripple feed-forward control is adopted to reduce the double-line-frequency ripple.

**4:00** ***Design of a Bidirectional CLLC Resonant DC-DC Converter for Energy Storage System***

Chen-Yi Wu and Kuo-Yuan Lo (National Kaohsiung University of Science and Technology, Taiwan)

The objective of this paper is to propose a bidirectional full-bridge CLLC resonant DC-DC converter for energy storage system. This proposed converter includes two sets of full-bridge CLLC resonant converters, which are applied in the form of single input double output. In this paper, frequency modulation control is used to control the power flow from the energy storage system with CLLC resonant network. In addition, the individual power-handling capability is achieved by the duty control of the primary switches. Therefore, the ability of battery module voltage balancing is adopted in this converter. The CLLC resonant topology and interleaving operation are to ensure zero-voltage-switching over a wide power range and reduce the current ripple, respectively. Finally, the experimental results obtained from a 1-kW prototype circuit verify the performance of the proposed DC-DC converter.

*Presenter bio:* Kuo-Yuan Lo (Member, IEEE) received the B.S. degree in electrical engineering from the National Taipei University of Technology, Taipei, Taiwan, in 2003, the M.S. degree in electrical engineering from the National Cheng Kung University, Tainan, Taiwan, in 2006, and the Ph.D. degree in electrical engineering from the National Taiwan University, Taipei, in 2016. In 2018, he joined the National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan, where he is currently an Assistant Professor with the Department of Electrical Engineering. His research interests include power electronic converters and renewable energy.

**4:15** ***Design and Implementation of a Soft Switching Interleaved Inductor-Coupled Boost Converter with High Voltage Conversion Ratio***

Kuei-Hsiang Chao, Chang-De Wu and Jung-Han Chang (National Chin-Yi University of Technology, Taiwan)

This study sought to develop a converter with a high voltage conversion ratio, low input current ripple, low switch cross voltage, and low withstand current rating that can be used as a power conditioner to enhance conversion efficiency and reduce circuit cost. By using coupled inductors and a voltage-doubled capacitor to achieve a boosting effect, the converter does not increase the withstand voltage of the switches and diodes when boosting the voltage gain. Additionally, the converter uses an interleaved trigger signal controlling method in its circuit. This design lowers the input current ripple and current rating. To further enhance the conversion efficiency of the proposed interleaved inductor-coupled boost converter with high voltage conversion ratio, the present study applied soft switching techniques in designing the converter. A resonant branch was created in the converter's circuit structure. When used in conjunction with the existing trigger signal controlling method, the resonant branch could establish zero-voltage switching and zero-current switching in the circuit's main switches, subsequently lowering the switching loss and ultimately enhancing the conversion efficiency. This paper presents the design and analysis of the circuit for the proposed soft switching converter along with experimental validation to verify the feasibility of the proposed converter.

**4:30** ***Light-load Conversion Efficiency Enhancement for Three-Phase Dual Active Bridge DC-DC Converters***

Zhi-Xuan Chou and Han-Cheng Wu (National Sun Yat-sen University, Taiwan); Bo-Hsien Liu (National Sun Yat-sen University); Jen Hao Teng (National Sun Yat-sen University, Taiwan); Yao-Ching Hsieh (National Sun Yat-Sen University, Taiwan)

With the development of electric vehicles and energy storage systems, the future demand for bidirectional power converters is expected to increase significantly. However, bidirectional power converters typically exhibit low conversion efficiency under light-load conditions, which can lead to unnecessary energy consumption. This paper proposes a smart control scheme comprising single-phase and three-phase modes to enhance the light-load conversion efficiency of a Three-Phase Dual Active Bridge (TPDAB) DC-DC converter. The smart control scheme dynamically exchanges between the single-phase and three-phase modes based on the load conditions. Apart from improving light-load conversion efficiency, the proposed control method

also extends the service life of power switches by reducing their operation time, thus enhancing the overall reliability of the converter. A prototype of the TPDAB DC-DC converter is implemented in this paper, featuring a rated high voltage of 380V, a rated low voltage of 48V, and a rated power of 720W. Experimental results validate the effectiveness of the proposed smart control scheme, demonstrating an approximately 10% conversion efficiency enhancement at light loads for the implemented TPDAB DC-DC converter.

**4:45** ***Compensation Function Observer Based Model Predictive Control for Interleaved Boost Converter***

Jiang Tiantian (Fuzhou University & Quanzhou Institute of Equipment Manufacturing, Haixi Institutes, China)

Three-phase interleaved boost converter has the characteristics of small input current ripple and high power density. However, unknown external disturbances, temperature change can cause inductive device parameter mismatch and control performance degradation. To solve this problem, this paper proposes a model predictive control method based on compensation function observer (CFO). Firstly, the mathematical model of the boost converter is established, and a predictive model including parameter disturbance terms is constructed. Secondly, the CFO is designed to observe the disturbance terms in the system and compensate for the fixed errors of the traditional observer, thereby improving the accuracy of the system. Thirdly, to achieve better dynamic performance, both the inner and outer loops employ model predictive control (MPC). Finally, the effectiveness and superiority of the proposed method were validated through experimental tests on the dynamic performance and robustness of the boost converter.

# Monday, November 20 5:00 - 7:00

## SO1: Welcome Reception

**Aerial Function Centre Bar and Terrace**
**Ultimo**

Rooms: Broadway Room, Harris Room, Jones Room

# Monday, November 20 5:00 - 8:15

## OST1: Off Site Tour 1: Endeavour Energy - Digital Substation

Room: Tour

Chair: Naief M Almatrafi (University of Technology Sydney, Australia)

Endeavour Energy has agreed to provide a tour of their newly commissioned Digital Substation to IFEEC2023 delegates on Monday evening.

The tour is free but is strictly limited to the first 24 delegates to register.

Please register on-line before the conference at https://academiceventservices.com/registration/ifeec2023/ifeec2023-digital-substation-tour/ or on the sign-up sheet at registration until 3:30pm Monday if the tour isn't fully booked first.

Attendees should note:

- Meet at Registration Desk at 5:00pm for transfer to tour bus for a 5:15pm departure.
- We will arrive at the site at 6pm.
- The tour will conclude at 7:30pm
- The bus should return to the conference centre by 8:15pm.
- You will need enclosed footwear and be required to wear a hard hat and high visibility jacket on-site.
- IFEEC2023 will provide the needed safety items for you when you leave for the tour.

More details about the tour destination can be found at:

- https://www.endeavourenergy.com.au/news/industry-news/substations-go-digital
- https://www.endeavourenergy.com.au/in-the-community/works-in-your-area/south-erskine-park-substation
- https://www.itnews.com.au/news/endeavour-energy-debuts-digitised-substation-587663

# Tuesday, November 21

# Tuesday, November 21 9:00 - 10:30

## SS1: Special Session 1: Learning-based Design Optimization and Control Methods for Electrical Machines

Room: Harris Room

Chair: Gang Lei (University of Technology Sydney, Australia)

**9:00** ***Research on Electromagnetic Scattering of Buried Cables Based on FDTD Algorithm***

Shulei Xiong and Nana Duan (Xi'an Jiaotong University, China); Weijie Xu (State Grid Shaanxi Electric Power Co., Ltd., China)

The detection of buried cables is an important technology, and the research on the electromagnetic scattering characteristics of buried cables is its theoretical basis. In this paper, based on the two-dimensional Finite-Difference Time-Domain (FDTD) method, the surface current using Gaussian pulse waveform is used as the excitation source, and when the buried depth is constant, the half-space models of buried cables under several typical working conditions are established. The influence of these factors on the electromagnetic scattering characteristics is analyzed respectively. Results show that the increase of soil humidity will weaken the incident wave. When the humidity ranges from 0.1g/cm3 to 0.4g/cm3, the maximum magnitude decreases by about 12dB in turn. The coupling effect will occur when the cables are laid in parallel, and when the distance changes, it will affect the phase of the electric field at the collection point, but has little effect on the magnitude. After adding a layer of concrete cover of 50mm thickness, there is no significant

change, but the phase is shifted forward. In this paper, the cylindrical wave is generated by the surface current source, which reduces the calculation and programming complexity compared with the traditional way of introducing plane waves at the TF-SF boundary. This paper provides ideas and guidance for the accurate detection and imaging of buried cables.

**9:18** ***Review of Data-Driven Artificial Intelligence Applications in Electric Machines and Drive Systems***

Lin Liu, Youguang Guo, Gang Lei and Jianguo Zhu (University of Technology Sydney, Australia)

It is expected that the continuous advancements in learning algorithms and specialized embedded hardware platforms will establish data-driven artificial intelligence (AI) based tech-niques as standard tools for automating high-performance modelling, design, optimization and control of electric ma-chines and drive systems. Our research delves into the various AI-based numerical and analytical approaches employed in electric drive systems. Moreover, this review article systemati-cally summarizes the strengths and weaknesses of different algorithms in practical applications. More importantly, valua-ble insights into fostering the widespread adoption of AI in the automatic industry are further forwarded.

**9:36** ***A Data-driven Method for Iron Loss Estimation in Bearingless Permanent Magnet Synchronous Motors***

Kai Xu, Youguang Guo, Gang Lei and Jianguo Zhu (University of Technology Sydney, Australia)

This paper proposes a data-driven iron loss estimation method to reduce the calculation time of iron loss in bearingless permanent magnet synchronous motors (BPMSMs). The iron loss calculation dataset is obtained by design of experiments, and the iron loss prediction model is established under different input parameters and working conditions. Firstly, the stator core flux density changing rules at selected points are analyzed, and the flux density components of different parts of iron loss are studied. Secondly, the effects of temperature and frequency on iron loss are studied. Finally, a data-driven iron loss estimation method is established based on the nonlinear autoregressive exogenous (NARX) model using input current, frequency and temperature data. In the proposed method, the iron loss of BPMSM under all working conditions is considered, which significantly shortens the calculation time compared to the finite element analysis. This method can be used to quickly obtain the iron loss variation range of each speed and different working conditions and provide a basis for calculating motor efficiency and design optimization.

**9:54** ***Reinforcement Learning for Intelligent Control of AC Machine Drives: A Review***

Nabil Farah (School of Electrical and Data Engineering, University of Technology Sydney, NSW, Australia); Gang Lei (University of Technology Sydney, Australia); Jian Guo Zhu (University of Sydney, Australia); Youguang Guo (University of Technology Sydney, Australia)

Permanent magnet synchronous motors (PMSMs) are widely used in various industrial applications due to their high efficiency, compact size, and precise control capabilities. However, traditional control techniques often struggle to handle the nonlinearities and uncertainties associated with PMSM drives. Reinforcement learning (RL) based control approaches have offered a promising solution to address these challenges. This article reviews RL-based control of PMSM drives, delving into fundamental concepts, machine learning types, and RL frameworks. Challenges, drawbacks, and future directions for enhancing RL-based control methods are also discussed.

*Presenter bio:* Master student in electrical engineering UTeM

## TS4: Technical Session 4: Motor Drives I

Room: Jones Room

Chair: Md. Rabiul Islam (University of Wollongong, Australia)

**9:00** ***Demonstration of Ultra-High-Speed Magnetic Gear***

Emiri Asahina and Kenji Nakamura (Tohoku University, Japan)

In recent years, electrification has rapidly advanced in various fields toward realizing a decarbonized society, and the performance improvement of electric motors is strongly required. The development of high-speed motors over 50,000 rpm has been desired to reduce the size and weight and increase the power density. Magnetic gears can change speed and torque without mechanical contact. Thus, they have low vibration, acoustic noise, wear, and friction heating. These features are desirable for high-speed applications. Among various types of magnetic gears, a flux-modulated type magnetic gear has larger torque. This paper describes an ultra-high-speed flux-modulated type magnetic gear that can operate at 80,000 rpm and has a high-power density. The prototype test results show that the maximum efficiency of the prototype magnetic gear is 94.9% in the low-speed region, and 85% even at 80,000 rpm. Moreover, the power density of the prototype magnetic gear achieves about 4.5 kW/kg.

**9:15** ***Proposal of a Novel Air-Gap Structure for Magnet-Less 3-Axis Active Control-Type Magnetic Bearing with Cylindrical Rotor: Reducing Axial Length of Turbomachinery System***

Yuto Sho, Masatsugu Takemoto, Ren Tsunata and Jun Imai (Okayama University, Japan)

This paper proposes a novel airgap structure for magnetic bearing (MB) that realizes 70% smaller coil space area than that of a conventional MB for turbomachinery system. The proposed MB contributes to reducing the total axial length of a 3-axis MB by 17.9%. This means that the critical rotation speed can be increased, improving a serious problem for turbomachinery system that is required high-speed rotational speed. This paper shows comparison of suspension force between a conventional and the proposed MB, which is analyzed by 3D-FEA. Finally, superiority of the proposed MB is shown from various perspective.

**9:30** ***Hybrid topologies of non-permanent magnet-excited switched-reluctance motors with high torque capability for electric vehicle applications***

Vijina Abhijith (University of Technology Sydney & Education, Australia); Jahangir Hossain and Gang Lei (University of Technology Sydney, Australia); Premlal Ajikumar Sreelekha (Entuple E Mobility, India); Sandeep B Kadam (TechEmbers, India)

Switched reluctance motors (SRMs), which operate at high speeds, have optimal control and may enhance electrically driven performance with many overlapping phases, are becoming increasingly common in electric traction motors. This may be attributable to high power density and reliable torque per ampere. As an alternative to DC series and permanent magnet-based (PM) motors, the design and development of specialized electrical machines, like SRMs, have become more prevalent in recent years. In this study, a hybrid excited non-permanent magnet-assisted different topologies of switched reluctance motors for electric vehicle (EV) applications are designed, and their performance is evaluated. Due to its high torque performance, hybrid excitation of switched reluctance motors (HESRM) is in great demand in the EV industry. To improve the performance of SRMs, this technique is being used with PM-assisted excitation. This new hybrid excitation method improves torque performance without using rare-earth elements. This can be achieved by sending direct current (DC) through the chosen auxiliary poles. The innovative machine's simulated static and dynamic properties differ from conventional SRM drives with the same rating. As a result, two motor prototypes have been modified, and experimental analysis is used to confirm the concept's validity. The new topologies significantly outperform the existing ones regarding electromagnetic torque throughout all speed ranges. This machine is ideally suited for EV applications because of its fault tolerance, which allows for different control topologies and redundancy.

**9:45** ***Electric Motor Emulator Aided Motor Drive Design: A Case Study Under Resistance Unbalance Scenario***

Jia-Ming Zhong, Ming-Yuan Hsieh, Hsueh-Ju Wu and Yaow-Ming Chen (National Taiwan University, Taiwan)

This study aims to emulate the Surface Permanent Magnet Synchronous Motor (SPMSM) under the Resistance Unbalance scenario using the Electric Motor Emulator (EME) and subsequently provides a verification case for motor driver current controller design with EME. The paper first introduces and derives the resistance unbalance motor model for the model current calculation in EME. Then, the Dual Synchronous Reference Frame (DSRF) control method is employed to effectively regulate the positive and negative sequence current individually. Finally, through the utilization of the EME-based motor test-bench, the motor drive control verification is conducted, demonstrating that EME facilitates easy and reliable verification of motor driver designs.

**10:00** ***Magnetic Interaction Effect on Stall Torque of IPM-type Magnetic-Geared Generator***

Boqun Dai, Koki Ito and Kenji Nakamura (Tohoku University, Japan)

Magnetic-geared generators (MGGs) are expected to be applied to wind-power generation because of maintenance-free, high torque density, and efficiency. Among them, an interior permanent magnet (IPM)-type MGG has superior characteristics compared with a surface permanent magnet (SPM)-type MGG. The stall torque of the IPM-type changes with the current phase angle because of magnetic interaction, while the SPM-type keeps constant. This paper investigates the effect of magnetic interaction on the stall torque of IPM-type MGG using both a three-dimensional finite element method (3D-FEM) and experiments. In addition, since the stall torque can be improved by magnetic interaction, a novel high-speed rotor structure is proposed to maximize the effects of magnetic interaction to achieve the same stall torque while using fewer permanent magnets. The validity of the proposed new high-speed rotor structure is proved by using 3D-FEM.

**10:15** ***Study of 6-phase Pole Change Induction Motor with Double Inverter Drive***

Naoya Kato and Kan Akatsu (Yokohama National University, Japan)

Induction motors are attracting renewed attention as motors that do not use permanent magnets. Among them, 6-phase pole change induction motor (hereafter, 6-phase PCIM) can switch the number of poles from 8 to 4 by changing the rotating magnetic field. By switching the number of poles, the constant power range can be expanded in the same volume, and the induction motor can be made smaller than the rated 4-pole induction motor. However, there is a problem that torque shock occurs when switching the number of poles. This torque shock is caused by the first-order delay in the rise of the secondary magnetic flux. If both poles are driven simultaneously to suppress the torque shock, a voltage rise may occur, and the inverter output is limited. In this paper, a 6-phase PCIM mathematical model is used to generate command values that suppress torque shock and voltage rise. Using the command values, the effect of torque shock suppression during pole number switching was verified.

## TS5: Technical Session 5: DC-DC Converters II

Room: Broadway Room

Chair: Mohammad Al-Soeidat (Al-Hussein Bin Talal University, Jordan)

**9:00** ***Design and Implementation of Four Switches Bidirectional DC-DC Converter with Switched Inductors***

Yu-Sheng Luo, Kuan-Ting Lien, Hsuan Liao and Jiann-Fuh Chen (National Cheng Kung University, Taiwan)

This research presents a novel architecture for a bidirectional DC-DC converter. The primary purpose of converter is to facilitate energy transfer between battery side and DC bus. One of the key benefits of this architecture is its improved efficiency and reduced volume. To achieve this, the converter utilizes an active switched inductor structure. In the step-up mode, parallel charging and series discharging are accomplished by employing two sets of synchronous switches and two inductors. Conversely, in the step-down mode, series charging, and parallel discharging are achieved using the same configuration. To verify that the proposed architecture and control system are viable, a bidirectional DC-DC converter was developed using the TMS320F28379D as the controller. The converter operates with one low voltage input of 48 V on one side, and one high voltage of 400 V on the other side, the rated output power is designed to 500W, and a switching frequency of 500 kHz. The experimental results demonstrate promising performance, with an efficiency of up to 92.2% in step-up mode and 94.2% in the step-down mode. These findings highlight effectiveness of this architecture in achieving high efficiency energy transfer.

**9:15** ***Primary-Side Controlled Flyback Converter with Propagation-Delay Compensation***

Jui-Hung Lai, Tsorng-Juu Liang and Kai-Hui Chen (National Cheng Kung University, Taiwan); Guan-Ting Peng (Taiwan); Hsin-Chen Hsu (National Cheng Kung University, Taiwan)

Primary-side regulation (PSR) flyback converter has advantages of compact size, lower cost, and less power loss on devices because secondary-side feedback circuit is needless. In general, PSR flyback converter uses current sensing resistor to sense primary-side current peak value, and auxiliary winding to detect output diode conduction period, then output current can be estimated. However, it exists error between the sensing value and the real value of primary-side current peak value because of the time delay between power switch turn-off instant and output diode conducting instant. In prior researches, the compensation method of primary-side current peak value is to detect the delay period and estimate the current error with assuming that primary-side current increases linearly, but parasitic capacitances of power switch let primary-side current change nonlinearly actually. The current error compensation can be achieved by detecting the sink current of the gate driver circuit. Finally, the output current control is implemented with digital controller TMS320F28335, and applied to an input voltage at 130 V, output current of 5 A, output voltage of 12 V, and output power of 60 W flyback converter to verify the feasibility of proposed compensation method.

**9:30** ***Ultrahigh Voltage Gain DC-DC Converter based on Reformed Quadratic Boost Converter with Switched Capacitor and Coupled Inductor***

Milad Rezaie and Vahid Abbasi (Kermanshah University of Technology, Iran); Dylan Lu (University of Technology Sydney, Australia)

This paper presents a new ultrahigh voltage gain DC-DC converter composed of a reformed quadratic boost converter, a switched capacitor unit, and a coupled inductor. A secondary winding of the coupled inductor is unified with the switched capacitor and the leakage energy of the coupled inductor recycles through the output appropriately. The converter performance includes high voltage gain besides low voltage stress on its switch and diodes. In addition, it requires a small inductor on the input side that results in lower power loss. Its operations states and main equations are studied to investigate the converter properties. Using simulation in MATLAB Simulink the analysis is validated, and the results are used to demonstrate the suitable performance of the converter.

**9:45** ***Controllable Usage Rates for Switching-Mode Power Supply in Parallel***

Tsai-Fu Wu (Nat'l Tsing Hua University, Taiwan); Chien-Chih Hung, Jui-Yang Chiu and Yun-Hsiang Chang (National Tsing Hua University, Taiwan)

In this paper, a switching mode power supplies in parallel with adjustable usage rates is proposed. The usage rate can be adjusted depending on the temperature of power-on supplies. This design succeeds in distributing the heat loss equally to prolong the lifetime of the switching power supplies. The

output specification is 500 W/48 V, using LLC resonant topology, and also has the front-end stage, PFC, which is verified with the prototype.

*Presenter bio:* Yun-Hsiang Chang received the B.S. degree in electrical engineering from National Taiwan University of Science and Technology, Taipei, Taiwan, 2020. He is currently working toward the Ph.D. degree with the Department of Electrical Engineering, National Tsing Hua University, Hsinchu, Taiwan. His main research interest focuses on grid-connected and voltage source inverters.

**10:00** ***Automatic Voltage Equalizer Based on Load-Independent Class E2 Parallel Resonant DC-DC Converter***

Shizuna Oshima and Hirotaka Koizumi (Tokyo University of Science, Japan)

This paper proposes a new voltage equalizer based on a load-independent class E2 parallel resonant DC-DC converter. This circuit has a characteristic of equalizing the voltages between two battery modules without any control. It also maintains Zero-Voltage Switching (ZVS) throughout the entire equalization operation. Therefore, high-frequency operation can be realized, which enables immediate operation of equalization and downsizing of the circuit. Furthermore, since both modules are isolated by capacitors, the circuit is lighter and less expensive than transformer-isolated circuits. This paper describes the bidirectional operation of the load-independent class E2 parallel resonant DC-DC converter and its principle using equivalent circuit transformations. In addition, simulations and experiments have been conducted for voltage equalization between two modules consisting of 10 cells. As a result, voltage equalization without additional control and ZVS over the entire operation have been confirmed.

**10:15** ***Current Sensorless Online Load Estimation for Induction Heating Cooker***

Jhih-Cheng Hu, Ming-Shi Huang and Yi-Min Chen (National Taipei University of Technology, Taiwan); Chun-Wei Lin (Delta Electronic Inc, Taiwan)

This paper proposes a current sensorless online load estimation method for induction heating cooker (IHC) to detect the cookware status, such as cookware material or position. First, the operating principle of half-bridge series converter (HBSRC) is analyzed, and then using the signals during natural resonant period to estimate cookware equivalent electrical parameters. Furthermore, to derive the equations of equivalent inductance and resistance based on resonant capacitor voltage, and verify the proposed method in simulation software. This method only needs to sample the key signals of resonant capacitor voltage to reduce the calculation loading and time in software. Finally, a DSP-based HBSRC was built to verify the proposed current sensorless load estimation method. The effectiveness of the proposed method was verified by experimental results with different cookware material and equivalent heating coverage ratio (EHCR). The maximum error of estimated inductance and resistance were 8.4% and 9.1%, respectively, indicating that the proposed estimation method was effective and can distinguish whether to execute heating power control.

# Tuesday, November 21 10:30 - 11:00

## Morning Tea

# Tuesday, November 21 11:00 - 11:45

## K2: Keynote 2 - Wireless Power Transfer Technologies

**Prof. Ron Hui, The University of Hong Kong, China**

Rooms: Harris Room, Jones Room

Chair: Chi-Kwan Lee (University of Hong Kong, Hong Kong)

Biography

Shu Yuen Ron Hui (Fellow, IEEE) received the B.Sc. (hons.) degree in electrical and electronic engineering from the University of Birmingham, Birmingham, U.K., in 1984, and the D.I.C. and Ph.D. degrees in electrical engineering from the Imperial College London, London, U.K., in 1987.,He currently holds the MediaTek Endowed Professorship with Nanyang Technological University, Singapore, and a Chair Professorship with Imperial College London, London, U.K. He was previously Philip Wong Wilson Wong Professor with the University of Hong Kong. He has authored or coauthored more than 500 research papers, including 300 refereed journal publications. Over 120 of his patents have been adopted by the industry. His research interests include power electronics, wireless power, sustainable lighting, and smart grid. His inventions on wireless charging platform technology underpin key dimensions of Qi, the world's first wireless power standard, with freedom of positioning and localized charging features for wireless charging of consumer electronics. He also developed the photoelectrothermal theory for LED systems.,Dr. Hui was a recipient of the IEEE Rudolf Chope R&D Award and the IET achievement medal (The Crompton Medal) in 2010 and IEEE William E. Newell Power Electronics Award in 2015. He is a fellow of the Australian Academy of Technological Sciences and Engineering, U.S. National Academy of Inventors, and Royal Academy of Engineering, U.K.

# Tuesday, November 21 11:45 - 12:30

## K3: Keynote 3 - Power Electronics Engineers, the world is your oyster

**David Leal - Vice President of Business for the Southeast Asia - Delta Electronics**

Rooms: Harris Room, Jones Room

Abstract

Power Electronics is a wonder land that is playing a crucial role in the energy sector by enabling efficiency improvements, facilitating a renewable energy economy while also matching up with an energy storage revolution.

The Power Electronics area has been advancing considerably in the last fifty years but between the push from both the public and the private sectors to reach respective emission reduction targets wrapped together with a global pandemic, investment in this area in recent years has been unprecedented.

Delta Electronics is a globally recognized leader in power electronics, automation, and thermal management solutions. With a rich history dating back to 1971, Delta is known for its commitment to innovation, sustainability, and quality across a diverse range of industries. Delta Electronics has been in Australia since the late 1990's originally with a focus on Telecom power systems but has expanded rapidly in more recent years in Data centres, Industrial Automation and Electrical Infrastructure including Electric Vehicle charges.

As an engineer today you have an opportunity to play a vital role in addressing tomorrow's energy challenges while advancing a more sustainable and efficient energy world. As an employed there are unfortunately not enough of you with the result being that it is an exciting time to be an engineer!

Biography

David has over 20 years of experience in Power Electronics in the areas of engineering, manufacturing, sales and marketing and has played key roles in strategic planning, organizational development, establishing and building businesses in Asia Pacific, Europe and North America.

As the Vice President for SEA Business for Delta Electronics, David is responsible for all of Delta's sales and market activities in SEA, including Australia and New Zealand, covering P&L, strategy development and execution of business development activities.

David holds a Bachelor's degree in Electrical Engineering from the University of Sydney and a Postgraduate Certificate of Management from Macquarie Graduate School of Management.

# Tuesday, November 21 12:30 - 1:30

## Lunch

# Tuesday, November 21 1:30 - 3:00

## P1: Plenary Panel: Grid forming and Grid Following Inverters

**Prof. Ron Hui, University of Hong Kong, Hong Kong**

**Farhad Azizian, Delta Electronics, Australia**

**Dr. Mihai Ciobotaru, EcoJoule Energy, Australia**

**Prof. Donald Grahame Holmes, RMIT University, Australia**

**Prof. Firuz Zare, Queensland University of Technology, Australia**

Rooms: Harris Room, Jones Room

Chair: Ricardo Aguilera (UTS, Australia)

## OTS1: Online Technical Session 1

Room: Broadway Room

Chair: Yao-Ching Hsieh (National Sun Yat-Sen University, Taiwan)

Online presentation of technical papers to on-line and in-room audience.

**1:30** ***Surge Current Reduction in LLC Resonant Converter with PSM under Light Load Condition***

Moriyasu Ryo (Kyushu University, Japan); M. s. Hassan (Minia University, Egypt); Hideaki Funaki, Masahito Shoyama and Yuichi Noge (Kyushu University, Japan)

This study assumes the utilization of the LLC resonant converter as an on-board charger, employing both pulse frequency modulation (PFM) and phase shift modulation (PSM) together to extend the output voltage range. However, it has been observed that when operating the PSM under light load conditions, a surge current emerges in the output current. Through analysis, it has been determined that the surge current is caused by the deterioration of the main circuit characteristics due to the junction capacitance of the secondary diode. Therefore, secondary short-circuit control using a secondary-side active switch with PWM is proposed for surge current reduction. The article presents an explanation of the issue and introduces the suggested secondary short-circuit control strategy. Experimental findings demonstrate that the proposed control strategy effectively reduces the surge current.

**1:45** ***Analysis of plateau tandem solar cells***

Bernice Mae Yu Jeco-Espaldon and Yoshitaka Okada (The University of Tokyo, Japan)

Although compound III-V multijunction solar cells (MJSCs) have so far delivered the highest conversion efficiencies, the challenge to make them commercially available remains due to the high cost of III-V materials. Plateau multijunction solar cells (P-MJSCs) could reduce the cost of III-V-based MJSCs by utilizing less III-V upper subcell materials. In this work, we investigated the technical feasibility of plateau tandem solar cells by detailed balance limit calculation and quasi-2-dimensional SPICE modeling. Results revealed that for GaAs/Si and GaAs/Ge, the optimum bottom-to-top cell area ratios that could deliver the maximum efficiency are 1.5 and 1.1 at 40.1% and 41.8%, respectively. These efficiencies correspond to 18.2% and 2.6% increases, respectively, compared to the conventional design in which both top and bottom cell areas are equal.

**2:00** ***SHC-PWM Closed-Loop Control Based on PI Controllers for Active Power Filters***

Irati Ibanez Hidalgo (Tecnalia, Basque Research and Technology Alliance (BRTA), Spain); Ricardo Aguilera (UTS, Australia); Alain Sanchez-Ruiz (University of the Basque Country UPV EHU, Spain); Angel Perez-Basante (Tecnalia Basque Research and Technology Alliance, Spain); Salvador Ceballos (Tecnalia, Spain); Asier Zubizarreta (University of the Basque Country UPV EHU, Spain)

The increase of non-linear loads connected to the grid have led to the use of active power filters (APF) to reduce the low-order current harmonics injected by this kind of loads. In case of high-power medium-voltage applications, low switching frequency optimized modulators are preferred over standard carrier based-PWM. Therefore, in this work the selective harmonic control - PWM (SHC-PWM) modulation technique is used. SHC-PWM allows to synthesize low-order harmonics in amplitude and phase with low switching frequency. A closed-loop control system for APFs is proposed in order to address the control dynamic challenges related to low switching frequency modulation techniques. The closed-loop control uses a Kalman filter to estimate the harmonic currents in the grid side, a proportional-integral controller and SHC-PWM modulator based on artificial neural network. Simulation results are provided for a 3-level NPC converter to verify the effectiveness of the proposed control.

*Presenter bio:* Irati Ibanez Hidalgo received the B.Sc. degree and the M.Sc. degree in industrial engineering from the University of the Basque Country (UPV/EHU), Bilbao, Spain, in 2018 and 2020 respectively. She is currently pursuing the Ph.D. project about the implementation in real time of low-frequency modulation techniques for high-power converters. Since 2020, she has been with the Systems Engineering and Automation Department, University of the Basque Country (UPV/EHU), Spain, researching in the area of power electronics in collaboration with Tecnalia Research & Innovation, Derio, Spain and Ingeteam R&D Europe, Zamudio, Spain. From December 2022 to May 2023 she was a visiting researcher at the University of Technology Sydney, Sydney, Australia. Her research interests include active power filters, modulation and control of power converters, multi-level converters and low-frequency modulation techniques.

**2:15** ***A Single-Switch-Buck (SSB) PFC Converter with Continuous Input Current***

Maryam Pourmahdi-torghabe (University College Dublin (UCD), Ireland); Hamed Heydari-doostabad (University College Dublin, Ireland); Terence O Donnell (University College Dublin Belfield, Dublin 4, Ireland)

This paper proposes a novel single-switch-buck (SSB) power factor correction (PFC) rectifier. The proposed SSB PFC rectifier offers buck voltage gain ratio, a low number of components (only one switch), low voltage stress across semiconductors, high efficiency, and the prominent feature of continuous input current without the need for additional filters or complex control systems. These characteristics make it an attractive solution for various applications in the field of power electronics. The performance of the proposed rectifier is verified by simulation results under 130 W and 220 Vrms to 30 Vdc, which demonstrate its high efficiency, low total harmonic distortion, and excellent power factor under various input and output conditions.

**2:30** ***The DC-Link Voltage Double Line Frequency Ripple Reduction for AC-DC Converters***

Ying-Ting Huang, Zhi-Jun Jiang, Guan-Yu Chen and Cheng-Yu Tang (National Taipei University of Technology, Taiwan); Yaow-Ming Chen (National Taiwan University, Taiwan)

This paper proposes a control method of reducing the dc-link voltage double line frequency ripple in AC-DC converters. The proposed method utilizes variable duty cycle control, allowing for a reduction in the dc-link capacitance, thereby decreasing the size and cost of the converter. Additionally, the proposed control method eliminates the need for a current sensor, which is typically required in conventional harmonic input current injection techniques. This paper provides detailed mathematical analyses and design procedures for a boost PFC converter with the proposed control method. Furthermore, computer simulation results are included, and experimental results are currently being conducted and will be presented in the final paper to validate the effectiveness and performance of the proposed control method.

# Tuesday, November 21 3:00 - 3:30

## Afternoon Tea

# Tuesday, November 21 3:30 - 5:00

## TS6: Technical Session 6: Wireless Power Transfer

Room: Harris Room

Chair: Chen Ching-Jan (National Taiwan University, Taiwan)

**3:30** ***Magnetic Field Distribution Prediction of Wireless Power Transfer Based on Machine Learning***

Heng Zhang (The University of Hong Kong, Hong Kong); Chi-Kwan Lee (University of Hong Kong, Hong Kong); Liangxi He (301 Hakingwong & The University of Hong Kong, Hong Kong); Manwen Liao (The University of Hong Kong, Hong Kong)

Wireless power transfer (WPT) is becoming increasingly critical for electronic devices and electric vehicles, making it essential to predict the magnetic field distribution during the design process. However, traditional methods of predicting WPT magnetic field distribution suffer from numerous drawbacks, including time-consuming computations, inaccurate models, and imprecise results. With the rise of Artificial Intelligence (AI), its ability to deliver quick computations and control makes it highly attractive for WPT parameter optimization. Therefore, this paper proposes a method of predicting the magnetic field distribution of WPT based on machine learning. The U-Net was adapted to train the coil output parameter under the input parameters of the designed coil. The output parameter is the spatial magnetic field distribution map, which is useful in identifying safe design parameters within the safe magnetic field threshold. Our training results reveal that our model takes an average of about 3.2 ms with a normalized image prediction error of 0.0034 to calculate the results, compared to an average computation time of approximately 23.74 s by COMSOL.

*Presenter bio:* Heng Zhang received the B.Eng. degree in 2017, and the M.Eng. degree in 2020, both in Electrical Engineering and Automation, from Taiyuan University of Technology, Taiyuan, Shanxi, China. From 2021 to 2022, he was a research assistant with the Chinese University of Hong Kong, Hong Kong. He is currently working toward the Ph.D. degree in electrical and electronic engineering from the University of Hong Kong, Hong Kong.

**3:45** ***Boosting Efficiency of Wireless Power Transfer in a Near-to-Receiver Manner: Metamaterials versus Relay Coils***

Jiali Zhou and Heng Zhang (The University of Hong Kong, Hong Kong); Chi-Kwan Lee (University of Hong Kong, Hong Kong)

Incorporating relay coils and metamaterials are two effective methods to improve the power transfer efficiency or extend the range of high transfer efficiency without altering the original wireless power transfer (WPT) system. This paper performs a comparative study on the potential efficiency improvement of a relay coil and a metamaterial slab in a two-coil WPT system featuring asymmetric dimensions of transmitter and receiver coils. In particular, the relay coil or the metamaterial slab is compactly integrated into the WPT system with identical dimensions to the receiver coil and less than one-fifth of its own dimension away from the receiver coil. Theoretical analysis reveals that the WPT system using metamaterial slabs can be more efficient than one using relay coils, provided the metamaterial slab is designed with suitable effective permeability. Verification of the conclusion is achieved through results of combined numerical and finite element simulations.

**4:00** ***Wireless Power Transfer System with the Auxiliary Resonant Commutated Pole Converter for Reducing Radiated Emissions***

Rintaro Kusui, Keisuke Kusaka, Hiroki Watanabe and Jun-ichi Itoh (Nagaoka University of Technology, Japan)

This paper proposes a WPT system with an auxiliary resonant commutated pole (ARCP) converter with selective harmonic elimination (SHE) on the primary and secondary sides. The ARCP converter reduces switching losses on main devices, and the SHE reduces coil current harmonics components that cause radiated emissions. The operation of the proposed system is demonstrated by simulation and experiment. As a result, it is confirmed that the harmonics below the 13th order are reduced by more than 40 dB in the simulation. In addition, the experimental results with the prototype of the three-pulse SHE-PWM mention that all switching achieved zero voltage switching.

*Presenter bio:* Rintaro Kusui (S'19) received his B.S. degree in electrical, electronics and information engineering from Nagaoka University of Technology, Niigata, Japan in 2020. Presently, he is a Ph.D. candidate at Nagaoka University of Technology, Niigata, Japan. He is the student member of IEEJ and IEEE.

**4:15** ***Design and Implementation of a 6.78-MHz Wireless Charger for E-bike Applications***

Yun-Yen Chen and Huang-Jen Chiu (National Taiwan University of Science and Technology, Taiwan); Yu Chen Liu (National Taipei University of

Technology,Taiwan); Chen Chen, Kai-De Chen and Yi-Hung Fang (LITEON TECH, Taiwan)
This paper presents a significant contribution in the development of a high-efficiency, high-power-density wireless charger for E-bikes. By utilizing a 6.78 MHz switching frequency and employing wide band gap devices (GaN) and Schottky diodes, the system achieves remarkable advancements in power component selection, leading to reduced switching losses and improved performance. Moreover, the integration of high-frequency magnetic materials in the coils enhances coupling and minimizes the impact on the surrounding magnetic field. The use of Maxwell analysis software enables accurate simulation and optimization of the circuit, coil, and core design. By addressing phase-related challenges through the implementation of an auxiliary circuit, the issue of voltage switching is effectively mitigated. Ultimately, the achieved wireless charger for E-bikes stands out with its 110V input/output voltage, 240W output power, 6.78 MHz switching frequency, and an impressive maximum efficiency of 92.45%. This research contributes significantly to the advancement of wireless charging technology for E-bikes, offering valuable insights for further development and practical applications in the field .

**4:30** ***Modular Multiport Converter with Flexible Output Forms and Simple Control***
Xiaolu Li and Chi K. Tse (City University of Hong Kong, Hong Kong); Dylan Lu (University of Technology Sydney, Australia)
This paper proposes a modular multiport converter that offers flexible output forms, a simple control scheme, and high scalability at the output side. The converter's output ports can provide a range of output forms, including dc, ac with different operating frequencies, and changeable output forms (ac to dc or dc to ac), making it suitable for multiple application scenarios. The converter's topology design effectively avoids the cross-regulation problem among the output ports, which significantly reduces control complexity. Thanks to its modular circuit configuration and simplified control scheme, the converter has high scalability. To verify the theoretical analysis, an illustrative converter with three output ports is built in PSIM. The results demonstrate the effectiveness of the proposed converter in providing flexible and scalable power conversion solutions for various applications.

# Tuesday, November 21 3:30 - 5:15

## TS7: Technical Session 7: Motor Drives II

Room: Jones Room
Chair: Gang Lei (University of Technology Sydney, Australia)

**3:30** ***Position Sensorless Estimation for Surface Permanent Magnet Synchronous Motors Using Eddy Currents with Loads at a Low speed***
Yuki Miki and Mutuwo Tomita (National Institute of Technology, Gifu College, Japan); Masaru Hasegawa (Chubu University, Japan); Shinji Doki (Nagoya University, Japan)
The position sensorless control of surface permanent magnet synchronous motors (SPMSM) at a standstill and in low-speed regions is challenging because the motor has no magnetic saliency. Thus, the method using the block commutation drive method to overcome this problem has been proposed; however, the rotor position is only estimated every 60 degrees owing to the features of the block commutation drive method. This study proposes a novel rotor position sensorless estimation method by pasting the conductive non-magnetic materials on the rotor. When the high-frequency voltage is applied, eddy currents flow in the materials and the inductance slightly changes depending on the rotor position. The rotor position estimation of 360 degrees in which the sinusoidal vector control commutation is necessary rather than the block commutation drive method is realized using these inductance changes. Based on experimental results, the rotor position estimation error is only approximately 6 degrees, although the rotor velocity is 1.59% of the rated velocity and 12% of the rated load is applied.

*Presenter bio:* Mr. Yuki Miki was born in Aichi, Japan in 2002. He graduated from "Department of Electrical and Computer Engineering of National Institute of Technology, Gifu College", Gifu, Japan, and received the associate degree, in 2023. He currently researches for receiving the Bachelor of Engineering degree from "Advanced Course of National Institute of Technology, Gifu College". He is a student member of Institute of Electrical Engineering of Japan.

**3:45** ***Design and Control Strategy of Galvanic Isolated Two-stage Power Supply for Motor Drive***
Chi-Yuan Huang and Yaow-Ming Chen (National Taiwan University, Taiwan)
This paper provides the design and control strategy to achieve high efficiency for a two-stage converter as the voltage source for the motor drive. The proposed design procedure is based on matching the load profile as well as the maximum power limit by the motor. The front-end LLC provides the galvanic isolation capability and high transfer efficiency, while the back-end buck converter provides voltage step-down ability for an extended output voltage range. To further improve the efficiency under different voltage and current profiles, a special control strategy with high efficiency is proposed for a two-stage LLC-Buck converter. Finally, a 200W prototype circuit with both simulation and experimental results is provided to prove the feasibility of the proposed design and control strategy.

**4:00** ***Investigation of Multipole Transverse-Flux-type Switched Reluctance Motor***
Ayumi Nagai and Kenji Nakamura (Tohoku University, Japan)
Switched reluctance motors (SRMs) consist of only stator and rotor cores, and windings. Thus, they have a simple and robust structure, and low cost. However, torque density and efficiency of SRMs are generally inferior to those of permanent magnet synchronous motors (PMSMs). This paper focuses on transverse-flux-type SRMs (TFSRMs), which have larger torque than conventional radial-flux-type SRMs (RFSRMs). This paper discusses a relationship between the number of poles and torque using a simple magnetic circuit.

**4:15** ***Power Quality and Speed Performance Improvements for Small Film Capacitor-Based IPMSM Drives***
Tian-Hua Liu and Sheng-Hsien Cheng (National Taiwan University of Science and Technology, Taiwan)
This paper proposes using a small film capacitor in an IPMSM drive system as well as a fifth-order band-pass filtering active-damping control to improve the input power quality of an AC/DC rectifier. By using a small film capacitor, the drive system's volume and cost are reduced and the DC-link capacitor's life is extended. Furthermore, we propose using a fractional-delay periodic controller to improve the dynamic speed responses of a small-film DC-link capacitor IPMSM drive systems. A digital signal processor, TMS-320F 28035, manufactured by Texas Instruments, is used as a control center for this paper's drive system. Experimental results validate the theoretical analysis.

**4:30** ***Cogging Torque Cancellation by Combination of Multiplying Wave Magnets in Axial Gap Motor***
Daisuke Sato, Wataru Kitagawa and Takaharu Takeshita (Nagoya Institute of Technology, Japan)
This paper proposes the optimization of magnet shape combination and cogging torque cancellation method for a double rotor-single stator axial gap motor. The motor consists of a central stator sandwiched between two rotors from both sides. Since the two axially opposite surfaces are torque-generating surfaces, the motor is expected to generate a high torque density in a flat structure. On the other hand, cogging torque is a major issue because it determines the quality of the motor. Previously, the authors proposed a method to reduce the cogging torque while maintaining the torque by designing the magnet shape in the shape of multiplying wave. In this study, the authors optimize the combination of the multiplied-wave magnet shapes of the top and bottom rotors. In addition, we design a magnet shape that inverts the phase of the harmonic component of the cogging torque generated

between the top and bottom rotors and the stator. As a result, the proposed model can significantly reduce the cogging torque while maintaining almost the same torque as the basic model.

**4:45** ***Model Predictive Control for Suppression of Zero-Sequence Current in Open-End Winding Induction Motors***

Jaime A Guzmán (Universidad Técnica Federico Santa María, Chile); Cesar Silva, Gonzalo Carvajal and Juan Carlos Agüero (Universidad Tecnica Federico Santa Maria, Chile)

This paper presents a Model Predictive Control approach for Open-End Winding Induction Motors with common DC link fed inverters, focusing on suppressing zero-sequence current. Zero-sequence currents can be generated from phenomena like inverter modulation and back EMF harmonics. A discrete model of the motor and a formulation of the optimal control problem are laid out, including constraint formulation for the system voltages and currents, making no assumptions of how the zero-sequence current is generated. Using the proposed scheme an over 3 times reduction of the amplitude of the zero-sequence current was observed with no assumptions of the source of the perturbations made by the controller. This research aims to be a definition of a model predictive control strategy for the OEWIM.

**5:00** ***Derivation of Non-uniformly Distributed Look-up Table for PMSM Model Simulation***

Fang-Yi Lin and Yaow-Ming Chen (National Taiwan University, Taiwan)

This paper aim to propose a method to improve the look-up table in order to get simulation result with higher fidelity.

# Tuesday, November 21 3:30 - 5:00

## SS4: Special Session 4 - Emerging Battery Technology for Electrified Transportation and Energy Storage Sectors

Room: Broadway Room

Chair: Khay W. See (Institute of Superconductor and Electronic Materials, University of Wollongong, Australia)

**3:30** ***Fuzzy Virtual Inertia Control Based Frequency Regulation of Power Systems with Offshore Wind Farms and Energy Storage Systems***

Miaosong Gu (Economic Research Institute of State Grid Zhejiang Electric Power Co., China); Lifeng Qiu and Zhongjiang Chen (Zhejiang HuaYun Electric Power Engineering Design & Consultation Co., China); Rong Bian and Guoqiang Li (Economic Research Institute of State Grid Zhejiang Electric Power Co., China); Wenke Jiang, Zekai Ma and Xiao Qi (Jinan University, China)

Increasing penetration of renewable energy decreases the inertial level of power systems. The virtual inertia control of energy storage systems and renewable power generations effectively deals with the low inertia problem. With the increasingly perfect inertia market, it is significant for grid operators to optimize the virtual inertia cost. Therefore, this paper proposes a fuzzy virtual inertia control method, which dynamically adjusts the virtual inertia with the variation of the frequency deviation and the rate of change of frequency. Furthermore, in addition to the reduction of the inertia cost, the proposed method could also improve the performance of frequency regulation. Finally, the simulation results are analyzed to demonstrate the effectiveness of the proposed control method.

**3:48** ***Optimized Training Options of a Deep Learning Model for Lithium-Ion Battery State of Charge Estimation***

Yuyue Li, Ping Ding and Linfeng Zheng (Jinan University, China)

Lithium-ion batteries are currently considered as an ideal power source for electrified transportation and energy storage systems. Accurately estimating the state of charge (SOC) of batteries is crucial for the safety and reliability of battery operations. Due to the non-linear and time-varying relationship between the measured battery voltages and their corresponding SOCs, it urgently requires an intelligent approach to accurately estimate the SOC. This paper optimizes the training options of a deep learning model, the gate recurrent unit model, for battery SOC estimation method. The establishment steps of a deep learning model is firstly presented, followed by presenting the SOC estimation results based on the initial model. Different training options of the deep learning model, including the epoch, learning rate parameters, and activation function, etc., are then systematically analyzed. Through the comparative analysis of different training options, optimized parameters are applied in the model to improve the accuracy of battery SOC estimation. Finally, the optimization rate is proposed to quantitively evaluate the improvement of the optimized model. Verification results indicate that the optimized model can effectively decrease the estimation errors compared with the initial model.

**4:06** ***State of Charge Estimation of Lithium-Ion Batteries Based on Back Propagation-Particle Swarm Optimization***

Ping Ding, Weixiong Wu and Linfeng Zheng (Jinan University, China)

The method of scientifically estimating the state of charge (SOC) of lithium-ion batteries has always been one of the most challenging problems in the field of batteries and relevant application areas, such as new energy vehicles and energy storage systems. In this paper, the particle swarm optimization (PSO) algorithm and the back-propagation (BP) network algorithm have been combined through optimizing the traditional BP network algorithm to estimate the SOC of lithium-ion batteries. The combination of BP-PSO compensates for the limitations of the traditional BP neural network by using the good global search and optimization features of the PSO algorithm, thus improving the estimation accuracy. This paper compares the performance of traditional BP algorithm and the BP-PSO algorithm through simulation tests using an automotive battery packs dataset. The results show that the classical BP algorithm has the correlation index of 0.94 and the root mean square error (RMSE) of approximately 0.07, while the correlation index and the RMSE of the proposed BP-PSO algorithm are about 0.99 and 0.01, respectively, indicating the effectiveness of the proposed method.

**4:24** ***A Comprehensive Review About Machine Learning For Battery Packs Remaining Useful Life Prediction***

Yunlong Han, Gang Lei and Li Li (University of Technology Sydney, Australia); Linfeng Zheng (Jinan University, China)

Battery pack Remaining Useful Life (RUL) prediction stands at the crossroads of technology and sustainability in electrified transportation and energy storage. This review journeys through the landscape of RUL prediction, from the traditional empirical models to the cutting-edge machine learning techniques. It is a technical analysis and a narrative of evolution, challenges, and possibilities. The paper delves into the complexities of data quality, algorithm intricacy, and real-world applicability, casting a critical eye on the road ahead. It calls for collaboration, innovation, and a shared vision for a future where battery systems are efficient and resonate with our broader sustainability goals.

**4:42** ***Comparative Study on Incremental Capacity Analysis with Machine Learning Algorithms for State of Health Estimation of Lithium-Ion Batteries***

Linfeng Zheng and Xianli Guo (Jinan University, China)

The state of health (SOH) of lithium-ion batteries is a critical metric that indicates the degradation level and remaining capacity of batteries. Incremental

capacity analysis (ICA) method transforms relatively even battery charging or discharging curves as easily identifiable incremental capacity (IC) peaks. There usually exists a high correlation between the SOH and IC peaks, which provides an efficient means for battery SOH estimation. Machine learning algorithms are usually employed with the ICA method to determine the correlation. This paper mainly employs IC peaks with different machine learning algorithms, including Gaussian process regression (GPR), support vector machine, and regression tree for battery SOH estimation. The performance of the three algorithms in terms of estimation accuracy, R-squared, training time, and prediction speed is comprehensively compared and analyzed. The validation results show that the GPR method presents a superior performance in comparison with the other two algorithms.

# Wednesday, November 22

## Wednesday, November 22 9:00 - 10:30

### SS2: Special Session 2: Grid-Transportation Integrated Energy System

Room: Harris Room

Chair: Majid Farhangi (University of Technology Sydney, Australia)

**9:00** ***Fuzzy-Based Model Predictive Control for Bidirectional Charging of EV: An Adaptive Weighting Factor Algorithm***

Tingting He and Mingli Wu (Beijing Jiaotong University, China); Dylan Lu (University of Technology Sydney, Australia); Shuo Wang (Beijing Institute of Technology, China); Jianguo Zhu (University of Technology Sydney, Australia)

Model predictive control strategy is an advanced control algorithm for bidirectional active and reactive power flow in electric vehicles. However, tuning the weighting factor is a time-consuming process and its value is constant for various working conditions. To solve this problem, fuzzy control is applied to generate an adaptive weighting factor to meet all unexpected requirements. A two-stage bidirectional charger is built in Matlab/Simulink with the proposed fuzzy model predictive control. Simulation results show that dynamic performance can be achieved in the proposed method. The total harmonic distortion of the grid current is limited to 5%. The weighting factor can be adjusted online according to different demands. No tuning procedure of the weighting factor is required.

**9:18** ***Enhanced Electricity Demand Forecasting in Australia using a CNN-LSTM Model with Heating and Cooling Degree Days Data***

Laial Alsmadi, Gang Lei and Li Li (University of Technology Sydney, Australia)

In this paper, we present a hybrid deep-learning forecasting method based on heating and cooling degree days data to predict the electricity demand in Australia. The proposed model integrates convolutional neural network (CNN) and long short-term memory (LSTM) models to improve electricity prediction accuracy. The proposed model performance is comprehensively compared with a few conventional forecast methods, including deep neural networks (DNN) model. The results show that the mean absolute error and mean absolute percentage error of the prediction have been reduced by using the proposed hybrid model.

**9:36** ***An Empirical Understanding of Usage for Battery Swapping Electric Taxis in Beijing***

Dingsong Cui, Zhenpo Wang, Shuo Wang and Peng Liu (Beijing Institute of Technology, China); Zhaosheng Zhang (Institute of Technology, China); Changhong Shao (Beiqi Foton Motor Co., LTD, China); David Dorrell (University of the Witwatersrand at Johannesburg, South Africa)

Battery Swapping Mode (BSM) has emerged as an effective approach for enhancing the daily driving range of electric vehicles (EVs), particularly in applications involving public services such as taxis and trucks. However, there remains uncertainty regarding the characteristics of BSM usage patterns and the distinctions between BSM and fast-charging methods. Thus, the primary objective of this paper is to present empirical evidence derived from real-world operational data. This evidence-based analysis delves into the dynamics of energy refueling behaviors and driving patterns associated with BSM. The insights gained from this study have the potential to inspire local policymakers, aiding them in comprehending the significance of BSM efforts and leveraging historical insights to formulate effective developmental strategies.

**9:54** ***Wide Range Output with Switch-Controlled Capacitor in Wireless Power Transfer System for Electric Vehicle Charging***

Runzhuo Zhang and Junjun Deng (Beijing Institute of Technology, China); Na Fu (Beijing Huairou Laboratory, China); Shuo Wang and Zhenyuan Zhang (Beijing Institute of Technology, China)

In this paper, an electric vehicle wireless charging technology based on switch-controlled capacitor (SCC) under the three-phase-shift (TPS) control strategy is proposed. Due to the existence of non-negligible harmonics in LCC-LCC compensation wireless power transfer (WPT) systems, a time domain model based on fundamental harmonic approximation (FHA) taking higher harmonics into account is proposed. In order to improve the efficiency of LCC-LCC compensation topology, the load matching is analyzed. Furthermore, the primary side of the series compensation capacitor is designed to use the SCC technology, which effectively lowers the inverter's output current by ensuring that all MOSFETs realize ZVS. Finally, a simulation model is built on MATLAB/Simulink to verify the effectiveness of the proposed strategy.

**10:12** ***Control Method of Command Deviation Considering Electric Vehicles Participating in Power Grid dispatching***

Qianxin Ma and Wenjing Xue (North China Electric Power University, China); Ye Yang (State Grid Electric Vehicle Service Company, China)

Under the background of "double carbon", a large number of electric vehicles (EVs) provide flexible and adjustable resources for the grid. However, due to the randomness of the trips, the actual power response of each cluster of EVs can not fully follow the guidance power command issued by the power grid. This condition produces a deviation value. In order to reduce the deviation value, this paper takes the economic optimization of power grid as the objective function, and proposes a command execution deviation control method considering the participation of EVs in demand response. The power grid is divided into residential area, office area and commercial area. When the EVs dispatching has deviation, the deviation control in the region is adopted, and if the deviation still exists after the deviation control in the region, the cross-regional deviation control is carried out. Finally, the feasibility of the method is verified by an example.

**10:30** ***Optimisation design of on-grid hybrid power supply system for electric vehicle battery swapping station***

Lumbumba Taty-Etienne Nyamayoka (University of Witwatersrand & Witwatersrand, South Africa); Lesedi M Masisi (Concordia University, Canada); David Dorrell (University of the Witwatersrand at Johannesburg, South Africa); Shuo Wang (Beijing Institute of Technology, China)

This paper presents an optimised design for an on-grid photovoltaic power supply system to be used in an electric vehicle battery swapping station. The paper explores how integrating photovoltaic generator systems with battery-swapping stations can enhance their sustainability, reliability, and cost-effectiveness. The aim is to minimize the life cycle cost of the grid-connected photovoltaic power supply system and the cost of electricity purchased from the utility grid while maximizing its reliability constraints. Using mixed integer linear programming, the most optimal values for the decision variables

were identified. The optimization results showed a total life cycle cost of R 362934.25, an optimal energy consumption from the utility grid of 782.698 kWh, and an optimal number of 244 solar panels. This results in a daily energy saving of up to 60.01% compared to the baseline, and an economic benefit of R 1034273.25 over the project lifetime. Varying the weighing factor affects the multi-objective optimization sizing of the proposed system, and the optimal weighting factor is between 0.327 and 0.713 for the best cost-effectiveness.

## TS8: Technical Session 8: PV Systems

Room: Jones Room

Chair: Yang Du (James Cook University, Australia)

**9:00** ***Fast Global Maximum Power Point Tracking for Photovoltaic Generation Systems Under Partial Shading Conditions***

Han-Cheng Wu and Jen Hao Teng (National Sun Yat-sen University, Taiwan); Wei-Hao Huang (NSYSU, Taiwan)

Conventional Maximum Power Point Tracking (MPPT) methods for Photovoltaic Generation Systems (PVGSs) fail to prevent the system from operating at Local Maximum Power Points (LMPP) under Partial Shading Conditions (PSCs), resulting in decreased overall efficiency. To address this issue, a Global MPPT (GMPPT) featuring a segmental Prediction and Jump (P&J) method is proposed in this paper. The technique aims to determine the segment of the GMPP by utilizing two measured voltages and currents from one voltage segment, along with the characteristic output function of the PVGS. Using the Newton-Raphson method, the proposed segmental P&J method directly calculates the solar irradiance (S) and the number of solar cells connected in series (N). With S and N, the segmental P&J method can predict the possible voltage segment and jump to it. The voltages and currents in the jumping voltage segment are then measured, and S and N are estimated again until the segment of GMPP is determined. A GMPPT is then used to track the actual GMPP in the determined GMPP segment. Experimental results demonstrate that the proposed method efficiently achieves a high tracking accuracy.

**9:15** ***Power Balance of a Delta-Connected CHB Converter with MPC for Photovoltaic Systems***

Rodrigo Cuzmar Leiva (University of Technology, Sydney, Australia); Pablo Poblete (University of Technology Sydney, Australia); Ricardo Aguilera (UTS, Australia); Javier Pereda (Pontificia Universidad Católica de Chile, Australia); Dylan Lu (University of Technology Sydney, Australia)

Cascaded H-Bridge (CHB) converters are attractive candidates for next generation photovoltaic (PV) inverters. The overall plant can be divided in several PV strings that can be connected to each H-bridge cell. However, due to variability on solar irradiance conditions, each PV string may present different maximum available power levels, which difficult the overall converter operation. In this work, both inter-bridge and inter-cluster power imbalance are directly considered into the optimal control problem by designing a suitable system reference. Thus, the intercluster power imbalance is tackled by enforcing the converter to operate with a proper circulating current component. Moreover, the inter-cell imbalance power is achieved by governing the duty cycles independently.

**9:30** ***A Multi-Port Converter with Multi-Directional Power Flow Control Strategies for PV Power and Energy Storage Systems***

Cheng-Yu Tang (National Taipei University of Technology, Taiwan); Ta-Nien Sun (Delta Electronics, Taiwan); Da-De Shih (National Taipei University of Technology, Taiwan)

In this paper, a multi-port converter (MPC) integrated with multi-directional power flow control (MDPFC) strategies is proposed. Compare to individual converter structures, the proposed MPC can decrease the circuit cost and complexity in multi power source applications. In the meantime, the PV power is considered for the proposed MPC while the MPPT function is realized. In order to overcome the unpredictable PV characteristics and load conditions, the battery module is adopted. In order to regulate the energy between the PV array, the battery and the load, the MDPFC strategies are developed in this paper. Moreover, the MDPFC can realized by the digital signal processor (DSP) without adding extra circuit and components. Compare to existed circuit topologies, the developed MPC and MDPFC can achieve the maximum energy utilization with only one inductor and limited circuit components. Finally, a 500W prototype hardware circuit will be implemented to verify the performance and feasibility of the proposed MPC. From the experimental validations, the peak circuit efficiency and the full-load efficiency are 97.22% and 96.3%, respectively.

*Presenter bio:* Cheng-Yu Tang (Member, IEEE) received the B.S. degree in electrical engineering from the National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan, in 2010, the M.S. degree in electrical engineering from the National Taipei University of Technology, Taipei, Taiwan, in 2012, and the Ph.D. degree from the Department of Electrical Engineering, National Taiwan University, Taipei, in 2016.,He is currently an Associate Professor with the Department of Electrical Engineering, National Taipei University of Technology. His research interests include switching power supplies, renewable energy systems, and power flow control.

**9:45** ***Balancing Simulation Speed and Accuracy for Grid-connected Photovoltaic Power Systems***

Shuang Jiao (University of Sydney, Australia); Po-Hsu Huang (Tesla, USA); Weidong Xiao (The University of Sydney, Australia); Sinan Li and Jinghang Li (University of Sydney, Australia)

This paper develops efficient algorithms for balancing simulation accuracy and speed in time-domain simulation of high-frequency power electronic converters. Time-domain simulation requires careful selection of step size and solvers for numerical accuracy and stability. To achieve an optimal balance between simulation accuracy and speed, a Discrete Network Model is proposed by splitting the system into multiple sub- networks and building equivalent models for individual compo- nents with decoupling between stages. This significantly improves simulation efficiency while accurately capturing switching rip- ples. A case study in MATLAB/Simulink verifies the feasibility and effectiveness of the proposed method for simulating a three-phase grid-connected photovoltaic system by comparing it to conventional methods.

**10:00** ***Investigation of Photovoltaic Panel Degradation Affected by Dust in Jordan***

Mohammad Al-Soeidat (Al-Hussein Bin Talal University, Jordan); Habes Khawaldeh (Al Al-Bayt University, Jordan); Dylan Lu (University of Technology Sydney, Australia)

The impact of dust on photovoltaic (PV) panel output power performance and energy generation is investigated in this study. The characteristic of the PV panel is analysed for the dusted and clean panel and then compared with similar PV panels that have been affected by dust for a long time in the south of Jordan in the middle of the desert. The examined PV panels, which were uncleaned for two months, show 13.08% less energy generation compared to clean panels where, some panels suffer from hot spots and cracks after six months. A string of four PV panels containing three cracked panels generates 20% less energy than the sum of the generated power from the panels individually.

**10:15** ***Photovoltaic Hot Spot Detection System Using Deep Convolutional Neural Networks***

Ahmad Alzahrani (Najran University, Saudi Arabia)

Solar energy is a significant renewable energy source known for its environmental benefits and low maintenance requirements. However, the performance of solar energy systems can be affected by issues like hot spots, which hinder energy generation efficiency. To tackle this problem, a novel technique employing deep convolutional neural networks has been developed. This approach enables early detection of hot spots, achieving an impressive 96.8% detection rate through rigorous training and testing. The proposed approach uses Alexnet network, which is tested and validated to yield promising results.

## TS9: Technical Session 9: Transportation Electrification

Room: Broadway Room

Chair: Khay W. See (Institute of Superconductor and Electronic Materials, University of Wollongong, Australia)

**9:00** ***A SiC-MOSFET Based Bidirectional EV Charger for V2X Application***

Herman Chang, Dedong Shao, Zhi Yang and Yuyang Mao (Wanbang Digital Energy Co., Ltd, China); Muhammad Humayun (Wanbang Digital Energy Co., Ltd., China)

Demand for electric vehicle (EV) chargers has surged due to rapid EV production growth. At Star Charge, V2X (Vehicle to Load/Grid/Home) technology has emerged as a key research domain to harness the bidirectional power transmission of EV chargers and power batteries. This study describes the pre-stage DC-AC topology and control strategy for the V2X charging system. In order to achieve zero voltage switching (ZVS), the control strategy employed triple phase shift modulation and addressed startup inrush current with a phase-shift angle algorithm. A SiC-MOSFET-based \SI{11}{kW} V2X charger and its control strategy were tested under various operating conditions to confirm their efficacy.

**9:15** ***A brief study on the utilization of regenerative power in cases of bus voltage droppage***

Kentaro Nishi (Research and Development Center, Japan & East Japan Railway Company, Japan); Rika Saito (Electrical System Integration Office & East Japan Railway Company, Japan); Yosuke Kohata (Research and Development Center & East Japan Railway Company, Japan); Takashi Yoshinaga (Researcher and Development Center & East Japan Railway Company, Japan)

On a DC electric railway, regenerative power is supplied to and from other trains running in the vicinity. However, when other trains are not running nearby, the voltage of a train that is conducting regenerative power rises, and regenerative power is controlled to prevent excessive voltage. From the perspective of energy effectiveness, for the test we verified the exchange of regenerative power between trains when bus voltage drops. We analyze and report verification results both at normal voltage and at a voltage drop.

**9:30** ***Battery pack design based on an origami sandwich structure for the enhanced cooling and mechanical performances in electric vehicles***

Ruifeng Li (Swinburne University of Technology, Australia); Guoxing Lu (Faculty of Science, Engineering and Technology, Hawthorn, China); Weixiang Shen (Swinburne University of Technology, Australia)

This paper introduces an integrated design approach for electric vehicles (EVs) to enhance cooling and crashworthiness performances simultaneously. The proposed design incorporates an origami sandwich structure (OSS) within a battery module consisting of three cells connected in series. The study explores the effects of the folding angle (θ) on the performances, and it is revealed that implementing OSS-based cooling channels with θ=40° results in a reduction of maximum temperature by 4.3°C under 5C fast discharging condition and a remarkable improvement in peak crushing force and impact energy absorption compared to a flat channel. Moreover, the performances can be further improved with the rising folding angle (θ). A comparison of different origami channels and a flat channel from various perspectives indicates that the origami channel with a folding angle of 20° or 30° yield the most optimized designs.

**9:45** ***A Novel Adaptive Digital Filter–Based Energy Management Strategy Applied to Hybrid Energy Storage System for Electric Vehicles***

Chang-Hua Lin (National Taiwan University of Science & Technology, Taiwan); Yu-Lin Lee and Chun-Cheng Chen (National Taiwan University of Science and Technology, Taiwan); Jenn-Jong Shieh (Feng Chia University, Taiwan)

This paper introduces a new hybrid energy storage system (HESS) and an adaptive digital filter-based energy management strategy (ADFBEMS) for electric vehicles (EVs). The HESS consists of a lithium-ion supercapacitor (SC) and a battery module. A synchronous rectification interleaved boost converter connects the SC to the battery module, enabling power distribution. The ADFBEMS employs a sliding discrete fast Fourier transform (SDFFT) to track the instantaneous load spectrum and a low-pass filter with adaptive cut-off frequency for load distribution based on frequency. The SCs handle the high-frequency load component, while the battery module supplies the remaining load. A MATLAB model is developed to validate the proposed HESS with ADFBEMS through hardware experiments using the worldwide harmonized light vehicles test cycle (WLTC) Class 1. Simulation and experimental results demonstrate the effectiveness of the proposed system by comparing it with the traditional fixed cut-off frequency energy management strategy. The proposed HESS with ADFBEMS reduces ΔPstress and the high-frequency ratio (HFR) by 11.06% and 27.46%, respectively, contributing to an extended battery module lifetime.

**10:00** ***Graph-Based Optimization of Electric Motorcycle Battery Swapping Station Locations: A Case Study in Busan, South Korea***

Taehoon Kim, Joon Kim, Mingyu Kwon and Kyoung-yong Park (Korea Institute of Industrial Technology, Korea (South))

The market for electric motorcycles, which is an alternative solution to address the greenhouse gas emissions and noise issues of internal combustion engine motorcycles, is gradually gaining momentum. However, electric motorcycles face challenges such as limited driving range and long charging times, which calls for the need for battery swapping stations. Currently, the infrastructure for these stations is still in its early stages of development. In this study, we conducted research on optimizing the locations of battery swapping stations to facilitate the widespread adoption of electric motorcycles. We utilized graphs to analyze the existing battery swapping stations and electric motorcycle usage data, which helped us identify potential locations for new stations. We then represented the distances between candidate station locations and the traffic volume using graph-based visualization. Subsequently, we optimized the number of battery stations and idle charging time through an integer model based on the graph data. This is expected to enhance user satisfaction and contribute to the efficient utilization of charging stations

# Wednesday, November 22 10:30 - 11:00

## Morning Tea

# Wednesday, November 22 11:00 - 11:45

## K4: Keynote 4 - Impacts of grid-connected inverters in distribution networks: planning, regulations and standardisation

**Prof. Firuz Zare, Queensland University of Technology, Australia**

Rooms: Harris Room, Jones Room

Biography

Prof Firuz Zare is the Head of School of Electrical Engineering and Robotics and has spent over 20 years in three main organisations - academia, industry and international standardisation committees as a leader, project manager and senior specialist. Prof Zare has team-building, management and leadership experience in emerging and multidisciplinary research and teaching activities, cross-institutional research and technology projects and national and international standardisation committees.

Prof Zare has been collaborating with several international research centres and industry in Australia, Europe, the USA and Japan in the fields of Energy Conversion Systems and Nanosecond Pulsed Power Technology.

His core research areas are:

1. Advanced Power Converter Topology and Control in Grid Connected Renewable Energy, Motor Drives and Energy Storage Systems
2. Electromagnetic Interferences and Harmonics in Power Systems
3. Addressing Standardisation and Emerging Issues of Future Grids
4. Pulsed Power Systems for Bioelectrics and Industrial Applications

# Wednesday, November 22 11:45 - 12:30

## K5: Keynote 5 - Advances in the Control of Grid Connected Power Electronic Converters

**Prof. Donald Grahame Holmes, RMIT University, Australia**

Rooms: Harris Room, Jones Room

Chair: Georgios Konstantinou (The University of New South Wales, Australia)

Biography

Grahame Holmes (M'87-SM'03) received the B.S. degree and the M.S. degree in power systems engineering from the University of Melbourne, Melbourne, Australia, in 1974 and 1979, respectively, and the Ph.D. degree in pulse width modulation (PWM) theory for power electronic converters from Monash University, Clayton, Australia, in 1998.,In 1984, he joined Monash University, where he established and directed the Power Electronics Group for over 25 years. In 2010, he moved to RMIT University (Royal Melbourne Institute of Technology) to take up a professorial chair in Smart Energy. He has a strong commitment and interest in the control and operation of electrical power converters His research interests include fundamental modulation theory and its application to the operation of energy conversion systems, current regulators for drive systems and PWM rectifiers, active filter systems for quality of supply improvement, resonant converters, current-source inverters for drive systems, and multilevel converters. He has made a significant contribution to the understanding of PWM theory through his publications and has developed close ties with the international research community in the area. He has published well over 150 papers at international conferences and in professional journals, and regularly reviews papers for all major IEEE Transactions in his area. He has also coauthored a major reference textbook on PWM theory with Prof. T. Lipo of the University of Wisconsin-Madison.,Prof. Holmes is an active member of the Industrial Power Converter and Industrial Drive Committees of the Industrial Applications Society of the IEEE, and is a member-at-large of the Adcom of the IEEE Power Electronics Society.

# Wednesday, November 22 12:30 - 1:30

## Lunch

# Wednesday, November 22 1:30 - 3:00

## P2: Plenary Panel 2: Microgrids and Energy Storage Systems

**Dr. Mihai Ciobotaru (Principal Control Engineer - Ecojule Energy);**
**Romele Constantino (Senior Future Grid Engineer -Endeavor Energy);**
**Robert Nicholson (General Manager - Pitt&Sherri);**
**Emiile Abdurahman (CEO - Vellocet Clean Energy Pty Ltd)**

Rooms: Harris Room, Jones Room

Chair: Jahangir Hossain (University of Technology Sydney, Australia)

# Wednesday, November 22 3:00 - 3:30

## Afternoon Tea

# Wednesday, November 22 3:30 - 5:00

## SS3: Special Session 3: Reliability of Power Electronics Systems

Room: Harris Room

Chair: Dylan Lu (University of Technology Sydney, Australia)

**3:30** ***Reliability Assessment of Selected Boost-Converter-Based Three-Port DC/DC Converters***

Dylan Lu and Hamzeh Aljarajreh (University of Technology Sydney, Australia); Mohammad Al-Soeidat (Al-Hussein Bin Talal University, Jordan)

This paper presents the calculation, through the part-count method, and a comparison of converter failure rates of several typical and previously reported three-port DC/DC converters using both MIL-HDBK-217F and AS/NZS IEC 61709:2019 standards. This paper aims to compare the differences between the two standards in assessing the failure rates of components, hence the overall failure rate of the power converter circuitry.

**3:48** ***Reliability of Submodules in Modular Multilevel Converters Considering Periodic Preventive Maintenance for MVDC Applications***

Yumeng Tian (UNSW Sydney, Australia); Georgios Konstantinou (The University of New South Wales, Australia)

Due to the reduced number of sub-modules (SMs), modular multilevel converters (MMCs) for medium-voltage DC (MVDC) applications cannot provide the same redundant level as high-voltage DC (HVDC) systems. Therefore, reliability becomes a significant issue in MVDC systems. To ensure the proper operation of converters, periodic preventive maintenance (PPM) has been implemented in MMCs. Considering the maintenance interval and redundant design, this work provides an evaluation of converter reliability with multiple SM topologies. It is demonstrated that, the 3-level SMs can provide higher reliability than 2-level SMs and the converters operating under active redundant scheme require more frequent maintenance than passive mode. Based on the analysis, the optimal redundancy design can be identified for a specific maintenance strategy in each SM.

**4:06** ***High-Efficiency Microinverter With Interleaved Switching and Asymmetrical Unipolar Modulation***

Che-Yu Lu and Ming-Yueh Hsieh (National United University, Taiwan)

This paper introduces a high-efficiency two-stage power microinverter. In the dc-dc stage, a three-phase interleaved inverse buck-type converter is adopted to regulate the dc-bus voltage and improve the input ripples. A band-stop filter and a PR controller are employed to eliminate the double-line frequency ripple. Furthermore, a highly reliable inverter combines an H-bridge topology and two low-frequency switches. Interleaved switching and asymmetrical unipolar modulation are used to improve conversion efficiency. The high and low switching frequency legs synchronization minimizes distortion on the output voltage waveform. Finally, all control algorithms are implemented in a TI DSP TMS320F28069 chip. A 2 kW prototype utilizing GaN devices has been developed and verified. The average efficiency of the overall system achieves 98%.

**4:24** ***Enhanced Voltage-Following Strategy to Reduce Switching Loss for Programmable Electronic Loads with Shared DC Bus***

Tzu-Hsuan Ho, Chia-Chou Chang and Yaow-Ming Chen (National Taiwan University, Taiwan)

This paper presents an enhanced voltage-following strategy (EVFS) designed specifically for programmable electronic loads (PEL) that share their DC bus with the converter under test (CUT). Based on the voltage-following strategy (VFS), the EVFS is proposed to reduce the switching counts, whereas the switching losses can be reduced. Through simulation and experimental analysis, it can be observed that the EVFS achieves a substantial reduction in switching counts. Finally, both simulation and experimental results verify the performance and feasibility of the proposed EVFS.

**4:42** ***Three-phase Inverter with Front-End SEPIC Converter (PLECS-Based)***

Amit Hasan Pranto, Rhea Johnson, Sruthi Supriya, Md Anamul Hoque, Md Raizul Islam and Hamzeh Aljarajreh (University of Technology Sydney, Australia)

This project looks at the design and performance of a Three-phase inverter with a front-end SEPIC converter for grid-connected PV systems, using the power electronics software PLECS. The two-stage DC to AC converter has an input voltage of 150V and is designed to have a single-phase voltage of 230V, three-phase voltage of 400V, power of 10kW per phase, and maximum efficiency. The performance of the designed circuit is analyzed in terms of desired output voltage and power, efficiency of conversion, loss distribution in the switches, harmonics, and switch junction temperatures. The results of the study show that the circuit achieves an overall conversion efficiency of 94.8% and exhibits low harmonics and temperature stresses on the components while delivering a steady output voltage and power.

## TS10: Technical Session 10: Multilevel Converters

Room: Jones Room

Chair: Ricardo Aguilera (UTS, Australia)

**3:30** ***Impact of Virtual Arm Impedance on Small-Signal Stability of Modular Multilevel Converters***

Ye Zhu (The University of New South Wales, Australia); Shan Jiang (UNSW Sydney, Australia); Georgios Konstantinou (The University of New South Wales, Australia)

Inclusion of virtual impedance is an effective approach to mitigate small-signal oscillations in power converters without increasing manufacturing cost. This paper utilizes the second-harmonic circulating current in a modular multilevel converter (MMC) to generate virtual arm impedance and enhance system stability. The proposed method includes both resistance and reactance components, which can be combined to emulate a virtual impedance with flexible magnitude and phase. The active damping effect of different virtual impedance magnitude and phase is compared by both theoretical impedance-based stability analysis and real-time simulation results. It is shown that the virtual reactance is the predominant component in improve system stability, of which the optimal value can be derived according to system stability margin. Understanding the stability impact of magnitude and phase of the virtual arm impedance can facilitate the design of active damping schemes of MMCs under specific grid conditions.

**3:45** ***Real-time Implementation of Online Adaptive Space Vector Modulation for a Three-level NPC Inverter***

Victor T. T. Lam, Nart Gashi and Georgios Papafotiou (Eindhoven University of Technology, The Netherlands)

This paper presents the concept and real-time implementation of a new modulation method for a three-level neutral-point-clamped (NPC) inverter, called online adaptive space vector modulation (oaSVM). It is based on SVM but explores any triangle containing the reference voltage and chooses three voltage vectors that improve the trade-off between inverter switching losses and load current THD. The corresponding mixed-integer optimization problem has a combinatorial complexity and is solved using a branch and bound method which is implemented for real-time execution on an FPGA. The loss-THD trade-off of oaSVM and SVM are compared in MATLAB-simulations. Hardware-in-the-loop (HIL) simulations on a system-on-chip (SoC) consisting of a CPU and FPGA show execution times that make this implementation suitable for real-time applications.

**4:00** ***Capacitor Voltage Compensation of Flying Capacitor Multi-Level Converter for High-Speed Current Control***

Ryuga Koyama (University of Chiba, Japan); Kenji Natori and Yukihiko Sato (Chiba University, Japan)
Carrier frequency of N-level flying capacitor converter (FCMLC) is equivalently (N-1) times higher than that of the 2-level converter with the same carrier frequency, resulting in extension of control bandwidth. However, updating the command value in that equivalent carrier period causes capacitor voltages to deviate from predetermined voltages. It is caused by mismatch between charging and discharging time of flying capacitors. Unbalanced flying capacitor voltages cause problems such as increase of harmonics in the output current and applying high voltages to the devices. In this study, we derive the relationship between the flying capacitor voltages and output current and propose a compensation method for capacitor voltages based on this relationship.

**4:15** ***A Level-Increment Unit for Multilevel Inverter based on Cross-Connected Sources***
Mandeep Singh (Thapar Institute of Engineering and Technology, India); Niraj Kumar Dewangan (Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, India); Krishna Kumar Gupta (Thapar Institute of Engineering and Technology, India)
Multilevel inverters (MLIs) are growing as a potential solution for DC to AC power conversion. This work describes the design and implementation of a single-phase newly developed multilevel inverter configuration that combines a cross-connected sources (CCS) based MLI and a half-bridge inverter with a considerable decrease in the component count for a large number of output voltage levels. The level-increment circuit (LIC) is a type of half-bridge inverter that boosts the output voltage levels in the CCS-MLI topology by nearly twice. The aforesaid approach minimises the amount of power switching devices utilised compared to conventional topologies, resulting in higher output voltage levels by minimising the THD and dv/dt stress on the load. The proposed configuration can be designed to operate in both symmetrical and asymmetrical source patterns. Symmetrical arrangement allows for the formation of four more levels in each sequence with addition of each pair of switches to the basic module. The concept has been studied using MATLAB/Simulink and a laboratory prototype.

*Presenter bio:* Mandeep Singh graduated in 1998 and completed his Masters in 2001 in the field of Instrumentation Engineering from Panjab University Chandigarh. After serving in CDAC for two years, he joined Thapar University in 2003 as Asst. Prof. in Electrical & Instrumentation Engineering department.He completed his PhD in 2014 in Biomedical Imaging. Currently he is Associate Professor and is a Senior Member of IEEE.

**4:30** ***Nearest level Modulation Technique based Multilevel Inverter with Less Switches***
Vijay Sirohi, Tejinder Singh Saggu and Jagdish Kumar (Punjab Engineering College, India)
Voltage source inverters are frequently used in a variety of power conversion applications, including microgrids, HVDC, and renewable energy. Multilevel inverters (MLIs) are the most often used converters for high and medium-power applications across all renewable energy applications. These inverters operate without a transformer and have built-in characteristics, including high voltage quality, reduced dv/dt stress, a modular design, and high voltage quality. These inverters have undergone extensive development over the past three decades, with a focus on numerous different combinations. This article proposes a new seven-level inverter configuration with fewer switches. The effectiveness of the suggested inverter is assessed employing the Nearest Level Modulation (NLM) method. MATLAB is used to verify the suggested inverter, and several simulation results have been presented. To ensure that the outcomes of the simulation are relevant, a hardware design of the proposed MLI has been built, and satisfactory results have been presented.

# IS1: Invited Sessions 1

Room: Broadway Room
Chair: Weidong Xiao (University of Sydney & School of Electrical and Information Engineering, Australia)

**3:30** ***Enhanced Control of Photovoltaic Voltage Regarding Mixed Conduction Modes of Power Interfaces***
Yuezhu Lu (University of Sydney, Australia); Weidong Xiao (University of Sydney & School of Electrical and Information Engineering, Australia); Dylan Lu (University of Technology Sydney, Australia); Xiaochao Li (Xiamen University, China)
The photovoltaic power output is characterized by a nonlinear and time-variant behaviour that changes significantly with the operating condition and environmental variables, e.g., solar irradiance and temperature. The switching operation of power interfaces is also nonlinear, time-variant, and load-dependence, inevitably experiencing both the continuous and discontinuous conduction modes (CCM/DCM) to accommodate the power variation. These lead to a difficult control problem and compromise the performance of maximum power point tracking (MPPT). This paper provides a comprehensive analysis of the system dynamics and proposes a universal but simple control law to support consistently stable, fast, and robust control operations.

**3:45** ***Data Preprocessing and Machine Learning Approaches in Battery's State of Charge and State of Health Estimation: A Review***
Xinyu Gu (University of Wollongong, Australia); Khay W. See (Institute of Superconductor and Electronic Materials, University of Wollongong, Australia); Yunpeng Wang (Azure Mining Technology Pty Ltd, Australia); Caiyun Zang (China Coal Technology and Engineering Group, China); Xiuze Zhou (Hithink RoyalFlush Information Network Co Ltd, Australia)
This work provides a comprehensive review of data preprocessing and machine learning approaches applied to estimate a battery's state of charge (SOC) and state of health (SOH) over the past five years. The standard procedure for preprocessing battery time series data and the associated techniques to address inherent challenges are described. Dominant machine learning architectures and their applications in SOC and SOH estimation are explored. Additionally, potential directions for future research are highlighted.

**4:00** ***Simulation of Synchronous Condenser Retrofitted Diesel Generator with Synchro-Self-Shifting Clutch***
Ashley Mauro and Yang Du (James Cook University, Australia); Alan Louis (Ergon Energy Network, Australia)
Synchronous condensers (SC) have great potential for application in modern electricity systems. They can support high penetration of distributed energy resources (DER) and ensure power system security, especially in low-inertia power systems. The study examines the performance of integrating SCs into diesel generators with Synchro-Self-Shifting (SSS) clutches. The findings reveal SCs as promising alternatives to traditional diesel generators, particularly in scenarios with frequent load changes, offering robust performance in terms of rate of change of frequency (ROCOF) compliance, short circuit current and inertia response for inverter-based microgrid. The impact of SSS on excitation voltage has also been examined.

**4:15** ***Simulating and Deploying Model Predictive Control for Regional Microgrids***
Jai Wilson and Yang Du (James Cook University, Australia); Alan Louis (Ergon Energy Network, Australia)
The concept of a microgrid, which enables local communities to harness renewable energy and enhance energy security while reducing costs, has gained significant attention from both academia and governmental agencies. This study explores the feasibility of implementing a microgrid Energy Management System (EMS) for the Fringe of Grid First Nations community in Far North Queensland. The project is motivated by the aim to reduce electricity expenses for regional communities while contributing to a low-carbon energy future. Using a model predictive control (MPC) EMS developed in MATLAB, the research demonstrates the potential of an economic MPC EMS to substantially decrease electricity costs for small communities. The study further illustrates the successful deployment of the EMS on a cost-effective Raspberry Pi 4, serving as a proof of concept for its integration with external embedded systems, such as microgrid controllers.

**4:30** ***Battery Energy Storage Control Using Reinforcement Learning***

Elliott Basso and Yang Du (James Cook University, Australia)

With the increasing adoption of solar PV installations in Australian households, the availability of cheap renewable power during the day has surged. However, the challenge lies in rising electricity prices during morning and evening peak-consumption times. This project assessed the feasibility and profitability of using a Reinforcement Learning (RL) controller in a Battery Energy Storage System (BESS) to make cost-effective decisions by purchasing power when it's inexpensive and selling when it's costly. MATLAB/Simulink is used to create a BESS simulation model integrated into the electricity market, with the RL agent trained using normalized observation data and a reward function. Benchmarking demonstrated the RL controller's consistent outperformance of the timer-based controller in various market scenarios, emphasizing its adaptability and profitability advantages, particularly in volatile markets.

# Wednesday, November 22 6:00 - 10:00

## SO2: Banquet Awards Cruise

**M.V. Captain Cook 3**
**Darling Harbour Convention Jetty at 6pm sharp.**
**Guides will be available at the registration desk from 5pm to escort you to the boat.**
**See https://ifeec2023.org/banquet/ for more details.**

Rooms: Broadway Room, Harris Room, Jones Room

# Thursday, November 23

# Thursday, November 23 8:45 - 10:30

## TS11: Technical Session 11: Advanced Control for Power Converters

Room: Harris Room

Chair: Tingting He (Beijing Jiaotong University, China)

**8:45** ***A ZVS-PWM Full-Bridge Series-Resonant DC/AC Converter***

Chien-Ming Wang, Yu-Ting Lai and I-Hsiang Wang (National Ilan University, Taiwan)

A soft-switching series-resonant inverter without additional auxiliary switch is proposed. The proposed circuit topology is simple because it is configured by four power switches, a resonant tank, and an output filter. The resonant tank not only generates a sinewave voltage waveform with lower high frequency harmonics but provides zero voltage switching function on all power switches. Thus, the configuration of low switch loss, low cost, and low EMI can be achieved. The simple sinusoidal pulse width modulation (SPWM) control method is used in the proposed converter to provide well system dynamic regulation. A design example of 600W DC/AC inverter is examined to assess the DC/AC converter performance and it provides high power efficiency above 96.3% under the rated power.

**9:00** ***Adaptive Droop Controlled-VSCs in MVDC Distribution Systems with ESS Engagement***

Pingyang Sun (UNSW Sydney, Australia); Watcharakorn Pinthurat (Rajamangala University of Technology Tawan-ok, Thailand); Gen Li (DTU, Denmark); Muhammad Khalid (King Fahd University of Petroleum and Minerals, Saudi Arabia); Graham Town (Macquarie University, Australia); Georgios Konstantinou (The University of New South Wales, Australia)

A novel adaptive droop control (ADC) is proposed in this paper for voltage source converter (VSC)-based medium-voltage direct current (MVDC) distribution systems. The proposed ADC can achieve MVDC bus voltage management and power sharing between VSCs with overloading operation consideration, solving the issue that all VSCs on the rectifier/inverter side reach their power limits concurrently after a large system disturbance. It is accomplished by factoring in the real-time power/voltage values at VSC stations and a newly introduced extended power component. This component is contingent on the actual operational state of the energy storage systems (ESSs) in MVDC systems and inversely correlated with the power delivered/absorbed by the ESSs. The effectiveness of proposed ADC is confirmed through an MVDC distribution system model built in RTDS real-time digital simulators.

**9:15** ***An Edge-Capturing Pulse Signal Measurement Method for Low-Latency and High-Efficiency Applications***

Ming-Yuan Hsieh, Hsueh-Ju Wu and Yaow-Ming Chen (National Taiwan University, Taiwan)

The paper presents the edge-time difference average filtering (EDAF) method, an innovative voltage-sensing technique for switching pulse signals. Unlike conventional voltage sensing (CVS) methods, EDAF significantly enhances the sampled signal quality and delay reduction when dealing with pulse signals. EDAF utilizes the features of pulse signals and the event capture module in the microcontroller to timestamp both edges of the pulse signal accurately for the proposed algorithm calculation. This circumvents the need for high-performance analog-digital converters (ADCs) and low-pass filters (LPFs), bolstering overall performance. The principle of operation and analysis of the EDAF is comprehensively detailed. Computer simulation is provided to verify the performance of the proposed EDAF method.

**9:30** ***Signal Wireless Carrier Synchronization Using Power Line for Interleaving in Power Converters***

Keita Ohata, Hiroki Watanabe and Jun-ichi Itoh (Nagaoka University of Technology, Japan)

This paper proposes a carrier synchronization method that does not require synchronous signal lines and a time synchronization module such as a GNSS module. For interleaved and multilevel operation, all carriers must be synchronized in order to align the switching timing. In a distributed control system with multiple controllers, signal lines or additional time modules are required for synchronization, resulting in reduced maintainability and cost. In this paper, carrier synchronization is performed by superimposing a synchronization signal on the power line. The proposed control method is demonstrated by simulation, showing that the synchronization accuracy is within 1.5 μs. Especially, This method is effective in realizing electrified systems in severe conditions such as in the sectors of construction machinery, aircraft, and aerospace.

**9:45** ***Machine Learning-based Hosting Capacity Analysis and Forecasting in Low-Voltage Networks***

Md Tariqul Islam, Jahangir Hossain and Md Ahasan Habib (University of Technology Sydney, Australia)
This paper proposes a hosting capacity analysis and forecasting model for power distribution networks based on machine learning algorithms. The forecasting model is built using a variety of machine learning techniques, including multiple linear regression (MLR), multivariate linear regression (MVLR), and support vector machine (SVM). Pearson's correlation coefficient is used to select input features from a set of input variables. For estimating the hosting capacity of distributed energy resources (DERs), the study uses the IEEE 13 bus network as a test system. The results show that the MVLR provides better performance than other comparable models in terms of very low mean absolute percentage error (0.15%), root mean square error (12.93), and 97% accuracy for hosting capacity prediction. The proposed approach allows grid operators to successfully manage the integration of DERs into the electricity distribution system by accurately estimating and forecasting hosting capacity.

## TS12: Technical Session 12: SiC Devices and Applications

Room: Jones Room

Chair: Chi-Kwan Lee (University of Hong Kong, Hong Kong)

**8:45** ***An Efficiency Study of SiC-MOSFET Based Three-Level NPC Inverters***

Yong-Hong Sie, Po-Jui Huang, Yong-Hong Sie and Pei-Wen Lee (National Sun Yat-sen University, Taiwan); Mohammadreza Lak (Yuan Ze University, Taiwan); Tzung-Lin Lee (National Sun Yat-sen University, Taiwan)

The demand for high-performance inverters is also growing with the increasing renewable energy usage. Among various inverters topologies, the three-level neutral point clamped inverters (3LNI) are widely used due to higher voltage capability and lower output voltage harmonics. The Itype, T-type, and Active-type are well-known types of 3LNIs. This article derives the required mathematical formulas for efficiency analysis for the types above. Besides, it shows how using silicon Carbide (SiC) power devices can improve 3LNIs performance in high power/voltage range. In this regard, an experimental set-up with 800V DC voltage, the line-to-line voltage of 380Vrms, 8.8A output phase current, and 40 kHz switching frequency has been developed. The experimental results conform to mathematical calculations and demonstrates that the efficiency and power density of the SiC-based 3LTI can improve up to 98% and 8.5W/inch3, respectively.

**9:00** ***A dv/dt filter design based on the Voltage Reflection Theory at SiC converter***

Hanju Cha and Dongmin Kim (Chungnam National University, Korea (South))

This paper analyzes a voltage surge generation at the end of cable in an inverter-cable-high impedance load system, and the analysis is based on the voltage reflection theory. Cable parameters are estimated by using the network analyzer, and the whole system is simulated for generation of voltage surge. A 150 V unit pulse of SiC buck converter is injected over several cable lengths to a high impedance load. Voltage surge in terms of the ratio of rising time to the propagation time are analyzed. In addition, the excessive voltage surge at the cable end is mitigated by adding a dv/dt filter at the inverter output to increase rise time of PWM pulses. An effective dv/dt filter is proposed and verified through an experiment. Using a cable with a characteristics impedance of 80.2 ohm and a propagation delay of 44.2 ns, the dv/dt filter is able to reduce a voltage surge of 300V to 173V which corresponds to percentage reduction of 42.3%.

**9:15** ***Design and Implementation of Three-Phase Three-Level T-Type Inverter with Grid-Following Control***

Yeow-Heng Yeoh, Tsorng-Juu Liang and Wen-Chung Chen (National Cheng Kung University, Taiwan); Guan-Ting Peng (Taiwan); Kai-Hui Chen and Yi-Fu Chen (National Cheng Kung University, Taiwan)

The three-phase three-level T-type inverter topology is commonly adopted in DC-AC inverters due to the advantages of few components, lower switching losses, and low output voltage harmonic. In this paper, a grid-tied three-phase three-level T-type inverter with grid-following control strategy in time domain is studied and implemented. Only three-phase inductor current signals are required to control the output current phase angle with respect to grid voltage for regulating the real power and reactive power fed to the grid. The operating principles and characteristics of the three-phase three-level T-type inverter is analyzed initially. Then, the design of the LCL filter and grid-following control strategy are described. Finally, the experimental prototype with digital signal processor TMS320F28335 is implemented to verify the theoretical feasibility with DC input voltage of 800 V, grid phase voltage of 220 Vrms, output phase current of 9 Arms, rated power of 6 kVA, and switching frequency of 40 kHz. The experimental results show that the highest efficiency is 98.4 %. The inverter is able to provide 6 kW real power, leading and lagging 6 kVAR reactive power to grid with total harmonic distortion in current less than 5 %.

**9:30** ***Design and Implementation of Two-Stage Boost and Full-Bridge Resonant Converter for Wide-Range APMs***

Chia-Yu Chen, Tsorng-Juu Liang and Kuo-Fu Liao (National Cheng Kung University, Taiwan); Guan-Ting Peng (Taiwan); Kai-Hui Chen and Chi-Hung Cheng (National Cheng Kung University, Taiwan)

A two-stage converter with wide-range is implemented with silicon carbide power devices in this paper. The first stage is a boost converter and the second stage is a full-bridge resonant converter. According to the output voltage range of the system, the corresponding output voltage range through pulse width modulation control is designed for the first-stage converter. In this way, the second-stage converter can be operated through near series resonant frequency control, the magnetizing inductance can be designed to be large to reduce circulating current, and with the synchronous rectification technology of the secondary side, the overall system efficiency can be improved.

# Thursday, November 23 9:00 - 10:30

## OTS3: Online Technical Session 3

Room: Broadway Room

Chair: Gang Lei (University of Technology Sydney, Australia)

**9:00** ***Adaptive Dead Time Control Strategy for Closed-Loop TCM GaN-Based Buck Converters***

Phuc Dinh Nguyen (National Taiwan University of Science and Technology, Taiwan); Yu-Chen Liu (National Taipei University of Technology, Taiwan); Huang-Jen Chiu (National Taiwan University of Science and Technology, Taiwan)

Gallium nitride (GaN) offers the advantages of high switching speeds and low on-resistance, which makes it suitable for extensive use in high-frequency applications requiring high power density and high efficiency. GaN-based high-frequency DC-DC buck converters typically employ the triangular current mode (TCM) to realize zero-voltage switching (ZVS) and reduce the inductor size. However, as the switching frequency increases, the effect of the dead time becomes greater. In addition, the ZVS of a device depends on the output power, which makes the design of dead time complex. Traditionally, the design of dead time is based on the worst condition; thus, the dead time is too long in the normal condition; this increases the duty loss and reduces the

overall performance dramatically. To reduce the dead time loss in GaN-based TCM buck converters, an adaptive dead time control strategy is proposed in this paper to optimize the dead time in the entire power range. The experimental results demonstrate that adaptive dead time control can improve the overall efficiency compared with fixed dead time control, and the total loss was reduced by 9.2% at 200 W.

*Presenter bio:* Research interests include high efficiency and high power density converter, multi-level converter, digital control of power converter and magnetic components design.

**9:15** ***Model Predictive Controller for Simplified Split Source Boost Inverters***

Mokhtar Aly (Aswan University, Egypt & Universidad Técnica Federico Santa María, Chile); Ahmed Aqle Shawky (Aswan University, Egypt & APEARC, Egypt); Fernanda Carnielutti Action (Federal University of Santa Maria, Brazil); Margarita Norambuena (Technical University Federico Santa Maria, Chile); Eltaib Abdeen D. Ibrahim (High Institute for Engineering and Technology in Sohag, Egypt); Cristian Garcia (Universidad de Talca, Chile); Samir Kouro (Ryerson University, Canada); Jose Rodriguez (Universidad San Sebastian, Chile)

Impedance source inverters have proven single-stage power conversion with reduced components compared with two-stage inverters. Single-phase split-source inverters (SSI) are attractive topologies with boost capability as well as few components count. A simplified SSI (S3I) has been presented for eliminating the diodes from traditional SSIs. However, the S3I requires the control of several quantities, which makes the classical control more complex and challenging to design. Therefore, a model predictive controller (MPC) is proposed in this paper for S3I inverters in photovoltaic (PV) applications to control multiple objectives with a simplified design procedure. The obtained results verify the fast-tracking ability, the simple design, and the control of multiple objectives simultaneously.

*Presenter bio:* Mokhtar Aly (Senior Member, IEEE) received the B.Sc. and M.Sc. degrees in electrical engineering from Aswan University, Aswan, Egypt, in 2007, and 2012 respectively and the Ph.D. degree from Kyushu University, Japan in 2017. He is currently Professor with San Sebastián University, Chile.

**9:30** ***Low Modulation Index Operation of a Nine-Level T-Type Converter***

Ibrahim Harbi and Mostafa Ahmed (Technical University of Munich, Germany); Mohamed Abdelrahem (Assiut University, Egypt); Jose Rodriguez (Universidad San Sebastian, Chile); Ralph Kennel (Technical University of Munich, Germany)

This paper presents a study on a recently proposed multilevel converter (MLC) that offers significant advantages over alternative nine-level configurations in terms of component requirements, losses, and efficiency. However, a key challenge encountered by this converter arises from the difficulty in achieving balanced operation of the flying capacitors (FCs) and the dc-link at low modulation index, due to the absence of redundant states in this operating region. To overcome this challenge, this paper presents a method based on pulse width modulation (PWM) to enables proper operation in this region by seamlessly transitioning to a five-level mode without introducing transients in the FCs' voltage. Importantly, this method is realized without the need for complex control techniques, ensuring simplicity in implementation. The proposed approach is experimentally validated, demonstrating its effectiveness in achieving reliable operation at low modulation index while maintaining the stability of the FCs' voltage. This study contributes to enhancing the operational capabilities of the nine-level converter, enabling its effective utilization in various practical applications.

*Presenter bio:* Ibrahim Harbi received the B.Sc. (Hons.) and M.Sc. degrees in electrical engineering from Menoufia University, Shebin El-Koum, Egypt, in 2012 and 2016, respectively. He is currently working toward the Dr. Ing degree with the Chair of High-Power Converter Systems, Technical University of Munich, Munich, Germany. His research interests include multilevel converter topologies and control, predictive control of power electronics converters, and photovoltaic energy systems. He received a highly prestigious scholarship from the German Academic Exchange Service (DAAD) with the program German-Egyptian Research Long-Term Scholarship in 2018 to pursue the Ph.D. degree. He is a Reviewer for several leading conferences and journals, including IEEE Transactions on Industrial Electronics and IEEE Access.

**9:45** ***A Modular Four-Port DC-DC converter for Battery Management Systems***

Muhammad Mubashir Alam (University of Technology, Sydney, Australia); Dylan Lu (University of Technology Sydney, Australia); Priyabrata Shaw (Eaton India Innovation Center, India); Yam Siwakoti (University Technology of Sydney, Australia)

A novel modular four-port dc-dc converter (FPC) is proposed in this paper, which is capable of integrating the photovoltaic (PV), voltage balancing and charging of multiple batteries using a single-inductor in a modular converter structure for the battery management system (BMS). The proposed topology is competent to work under single-input single-output (SISO), dual-input single-output (DISO), and single-input dual-output (SIDO) modes based on the PV, battery, and load availability. These operating modes are analyzed under various conditions of the sources (PV and battery) and load, and the steady-state analysis is performed for the proposed FPC to obtain the output voltage expressions. Finally, the simulation results are presented using the LTspice simulator under various operating modes to verify the working of the proposed modular FPC.

*Presenter bio:* I am currently pursuing PhD. in Electronics Engineering from UTS, Australia.

# Thursday, November 23 10:30 - 11:00

## Morning Tea

# Thursday, November 23 11:00 - 12:30

## TS13: Technical Session 13: Power Electronics for Utility Interface

Room: Harris Room

Chair: Felipe Arraño-Vargas (UNSW Sydney, Australia)

**11:00** ***DΣ-based Grid-connected Converter with Reactive Power Compensation***

Yun-Hsiang Chang (National Tsing Hua University, Taiwan); Tsai-Fu Wu (Nat'l Tsing Hua University, Taiwan); Anumeha Kumari and Jui-Yang Chiu (National Tsing Hua University, Taiwan)

This paper proposes a power compensation method to improve reactive power consumed by the filter during the grid integration of conventional converters. The control method includes the estimation model of real power and virtual power, and discusses the relationship among instantaneous power, active power, reactive power, and converter side current. By estimating the reactive power injected into the grid, the power required to compensate for the next switching cycle is calculated to adjust the actual power injected into the grid. This control method can improve the reactive power consumed by the filter when a general converter is connected to the grid. Finally, Matlab/Simulink simulation results are used to verify the feasibility of the proposed control method.

*Presenter bio:* Yun-Hsiang Chang received the B.S. degree in electrical engineering from National Taiwan University of Science and Technology, Taipei, Taiwan, 2020. He is currently working toward the Ph.D. degree with the Department of Electrical Engineering, National Tsing Hua University, Hsinchu, Taiwan. His main research interest focuses on grid-connected and voltage source inverters.

**11:15** ***Single-Phase Soft-Switching Unified Power Quality Conditioner Based on Three-Arm Converter***

Maoh-Chin Jiang, Kao-Yi Lu, Guan-Yi Wu and Chung-Hsi Lin (National Ilan University, Taiwan)

This paper presents a soft-switching single-phase unified power quality conditioner (UPQC) based on a three-arm converter. The topology uses a soft-switching series and shunt active power filter with a shared arm to reduce the number of main switches and employs simple resonant units to reduce switching losses and improve system efficiency. The soft-switching series active power filter can compensate for the grid voltage fluctuation such as voltage swell, voltage sag, over-voltage, under-voltage, and harmonics. The soft-switching shunt active power filter can mitigate the harmonic current and achieve a unity power factor at the grid side. Besides, using simple resonant units, all main switches of the high-frequency arm are operated at zero-voltage-switching (ZVS) turn-on, while all auxiliary switches are operated at zero-current-switching (ZCS) turn-off; otherwise, the low-frequency arm operated at line frequency switching can reduce the switching losses significantly. Finally, some experimental results are presented to verify the feasibility of the proposed system.

**11:30** ***A Modulation Method with Low Distortion for Isolated Three-phase AC-DC Matrix Converters***

Tzu-Yen Hsu, Jun-Tong Kuo and Bo-Yi Li (National Sun Yat-sen University, Taiwan); Mohammadreza Lak (Yuan Ze University, Taiwan); Tzung-Lin Lee (National Sun Yat-sen University, Taiwan)

This paper proposes a carrier-based symmetric eight-segment pulse width modulation (8SPWM) for the isolated three-phase AC-DC matrix converter to improve the quality of the three-phase input current. Moreover, it proposes a multi-step hybrid commutation strategy with improved transient response to avoid the short-circuit at the input terminal and the open-circuit at the output terminal caused by the bidirectional switch during commutation. The experimental results validate the effectiveness of the proposed modulation method and commutation strategy.

**11:45** ***Limitations in Impedance Reshaping of Grid Forming Converters for Instability Prevention***

Chirag Ramgopal Shah (Norwegian University of Science and Technology, Norway); Marta Molinas (NTNU, Norway); Roy Nilsen (Norwegian University of Science and Technology, Norway); Mohammad Amin (Enchanted Rock LLC, USA)

Under a weak grid scenario, Grid Forming (GFM) converters have superior impedance-based small-signal stability compared to Grid Following (GFL) converters. The underlying assumption in defining a weak grid has traditionally been consideration of the inductive behaviour of the power grid load. In this paper, it is shown that, in presence of a non-inductive grid load, impedance-based small-signal instability is unavoidable in specific condition for Virtual Synchronous Machine (VSM)-based GFM. To prevent such instability, the classical way is to reshape the impedance through controller re-tuning in the frequency range of concern. For this purpose, the impedance reshaping capability of GFM is analysed and sensitivity analysis is performed with different control parameters. The simulation results are presented to verify the risk of unavoidable impedance-based small-signal instability due to very limited impedance reshaping capability of the GFM controller.

**12:00** ***Analysis of Neutral Line Current Ripple Effective Value for Three-Phase Four-Wire Grid-Connected Inverters***

Chien-Heng Shih (National Taiwan University & National Taiwan University1, Taiwan); Yaow-Ming Chen and Wen-Yen Li (National Taiwan University, Taiwan)

This article provides a derivation for the neutral line current ripple effective value. For the three-phase four-wire inverter topology which has the neutral line connected with the split capacitor configuration, the neutral line current ripple affects the ripple on the split capacitor voltage. Excessive neutral line current ripple increases loss on the neutral line and necessitates using neutral inductor to reduce the ripple. Computer simulations with Matlab/Simulink to verify the theoretical analysis result.

**12:15** ***Design Considerations for Virtual Impedance and Virtual Synchronous Generators in Inverter-Based Generators***

Naief M Almatrafi, Dylan Lu, Li Li and Hamzeh Aljarajreh (University of Technology Sydney, Australia)

Integrating variable energy resources plays a vital role in achieving energy sustainability and transitioning away from fossil fuels for a greener environment. However, numerous challenges hinder the widespread utilization of these resources. A prominent challenge lies in their interface with the grid through power electronic devices, necessitating intricate control systems to emulate conventional synchronous generators. This paper addresses the integration challenges, identifies current limitations in control methods, and highlights the critical functionalities of virtual impedance and virtual synchronous generators. Additionally, the paper presents design considerations for virtual impedance and virtual synchronous machines, aiming to identify the gaps in general guidelines and diverse approaches for implementing these technologies. Finally, the paper outlines future directions for the design of virtual impedance and virtual synchronous generators.

## TS14: Technical Session 14: DC and Micro-grids

Room: Jones Room

Chair: Li Li (University of Technology Sydney, Australia)

**11:00** ***A Review: Controlling Techniques of DC Microgrids***

Bawantha Indrajith Bandara Polgolle Mudiyanselage, Hasith Jayasinghe and Kosala Gunawardane (University of Technology Sydney, Australia)

DC microgrids have emerged as an efficient power system design approach in academia and industry, offering the potential to integrate Distributed Energy Resources (DERs) even in challenging locations such as offshore platforms and rural villages. The intermittent nature of DERs poses integration challenges for conventional power systems. In contrast, DC microgrids can accommodate these uncontrollable behaviors. This paper provides a comprehensive overview of controlling techniques for DC microgrids, focusing on centralized, decentralized, and distributed controlling methods. Each controlling approach possesses unique advantages and disadvantages that must be carefully evaluated when selecting an appropriate control strategy. The objective of this paper is to provide researchers a comprehensive understanding of the available controlling methods in terms of the communication architecture in DC microgrids, facilitating informed in decision-making on their respective research procedures.

**11:15** ***Lessons Learned from Previous Cyberattacks on Energy Systems - Global and Australian Context***

Kapila Susantha, Dylan Lu and Xu Wang (University of Technology Sydney, Australia)

The threat landscape for cyberattacks has grown dramatically as the energy sector's reliance on digital technology and networked systems has grown. Previous attacks on energy infrastructure have highlighted the significance of comprehensive cybersecurity methods and learning from past mistakes. This conference paper examines the lessons learnt from prior cyberattacks on energy systems, with an emphasis on noteworthy case studies such as the Ukraine power grid attack, the TRITON/TRISYS malware attack on Saudi industrial systems, and several other breaches around the world, and in Australia. The study examines these occurrences to illustrate the techniques used by threat actors, the vulnerabilities exploited, and the repercussions felt in the energy industry. These case studies give helpful guidance for improving cybersecurity measures in the energy business. Common themes, challenges, and recommendations derived from these incidents are discussed, including the role of insider threats, the significance of information sharing and collaboration, the need for continuous monitoring and incident response capabilities, and the integration of secure coding practices in energy system development. The findings presented in this paper serve as a valuable resource for policymakers, energy sector professionals, and cybersecurity experts

seeking to safeguard critical energy infrastructure. By leveraging the lessons learned from previous cyberattacks, stakeholders can proactively strengthen resilience, mitigate risks, and ensure the reliable operation of energy systems in an increasingly interconnected world.

**11:30** ***Phase-Lagging Operation in a Buck-Type Current Unfolding Converter with Discontinuous Conduction Mode***

Tomoyuki Mannen, Boseung Seo and Takanori Isobe (University of Tsukuba, Japan); Ha Pham (UTS, Australia)

This paper proposes a three-phase inverter using the current unfolding principle with discontinuous conduction mode (DCM). The proposed inverter is expected to raise efficiency by reducing the total number of switching compared with popular inverters. The inverter can also reduce the number and size of passive components resulting in miniaturizing the inverter size. In addition, the operation with discontinuous conduction mode proposed in this paper enables the proposed inverter to operate under a low power factor. The operation validity of the proposed inverter is confirmed through simulations and experiments. The simulation result of the DCM operation exhibits good sinusoidal waveforms compared with that of the CCM. It is expected that the proposed inverter can achieve high efficiency and reduce the size and number of passive components at the same time.

*Presenter bio:* MANNEN, Tomoyuki received the B.S., M.S., and the Ph.D of Eng. degrees from Tokyo Institute of Technology, Tokyo, Japan, in 2012, 2014, and 2017, respectively, all in electrical engineering. Dr. MANNEN joined Tokyo Metropolitan University in 2017 as a Postdoctoral Researcher, and Tokyo University of Science in 2018 as an Assistant Professor. Since 2019, Dr. MANNEN has been an Assistant Professor in the department of Applied Physics at University of Tsukuba, Japan. Their research interests include power converter topology and control utilizing the full potential of power devices, especially for grid-connection converters and circuit breakers.

## TS15: Technical Session 15: Applications of Power Electronics

Room: Broadway Room

Chair: Mohammad Al-Soeidat (Al-Hussein Bin Talal University, Jordan)

**11:00** ***Extended-Duty-Ratio Class DE Voltage-Source Parallel Resonant Inverter***

Ryunosuke Yamada, Yuma Mitsusada and Hirotaka Koizumi (Tokyo University of Science, Japan)

In this research, duty ratio of class DE voltage-source parallel resonant inverter is extended. This inverter achieves zero voltage switching (ZVS) and zero voltage derivative switching (ZVDS) at turning on. Therefore, this circuit drives with high power conversion efficiency in high operating frequency. Because of extended duty ratio, circuit design specifications are more flexible. This paper presents waveform equations, design procedure, simulation results, and experiment results.

**11:15** ***Modelling and Design of Power Flow Controller of Three-Phase Hybrid Transformer***

TaeHoon Chin (Konkuk, Korea (South)); Younghoon Cho (Konkuk University, Korea (South))

In this article, a power flow control method of a three-phase hybrid transformer is proposed to maintain good power quality. Considering the practical impedances of the transformer, the power converter equivalent circuit of the hybrid transformer is derived, and the voltage equation, active power, and reactive power are analyzed. Based on the analysis, the power flow controller is designed in the z-domain. They are implemented in the synchronous reference frame. The AC/DC converter controls the dc-link voltage and the transmission-line reactive power flow. The DC/AC inverter regulates the input voltage of the AC/DC converter and the transmission-line active power flow. The simulation results verify the effectiveness of the proposed power flow control.

**11:30** ***A Master-Slave Distributed Power Management Architecture for Dynamic Voltage and Frequency Scaling (DVFS) for Low Power Microprocessor***

Yen-Ming Chen and Chen Ching-Jan (National Taiwan University, Taiwan)

This paper presents an effective master-slave distributed voltage and frequency modulation circuit for processors in system-on-chip (SoC). This work achieves dynamic voltage and frequency scaling (DVFS) in a compact, simple, and scalable architecture. This all-digital control method does not need additional analog parts, such as comparators or analog reference voltages. This makes it more suitable for being integrated with digital circuits in the multi-core processor. The proposed work can provide independent power supply levels to different power domains, especially in sub-1V low voltage conditions, minimizing energy per operation. The proposed prototype circuit was fabricated in a 28-nm CMOS process.

**11:45** ***Development of the Power Storage System with Emergency Generation Function***

Yosuke Kohata (Research and Development Center & East Japan Railway Company, Japan); Kentaro Nishi (Research and Development Center, Japan & East Japan Railway Company, Japan); Tomoko Hosaka (Electrical System Integration Office, Japan & East Japan Railway Company, Japan)

Requirements for supplying power to stations are stable power transmission and guarantee emergency power source, etc.. We have been constructing a system that meets these requirements in a variety of facilities such as static power switching equipment and emergency generators. However, static power switching equipment and emergency generators have issues in a maintainability and environmental performance. To resolve these issues, we have developed a power storage system equipped with an emergency generation function by replacing the two function with a single battery. Moreover, this system acquires a peak-cutting function by connecting solar power generation equipment with an energy management system. This system is now under trial in the Isogo Station on the Negishi Line to evaluate its energy-saving effect and overall performance. According to our calculations, we can cut energy use by 14 % under-this system.

**12:00** ***Non-contact energy harvester using rotation of roller conveyor and its application to ZigBee based wireless communication module***

Atsushi Nakajima and Kazushi Ohmura (Tokyo Denki University, Japan); Yuichiro Honda and Takanori Okazaki (Tokyo Rikosha Co., Ltd., Japan); Daiki Satou and Shigeo Masukawa (Tokyo Denki University, Japan)

Recent years, the progress of Internet of Things (IoT) has attracted attention, and its introduction is being considered in various fields of industry. Many companies seek to improve services by using IoT to improve the intelligence of factories or logistics systems. When installing IoT devices in factories and logistics systems, there are several problems such as installation of power supply costs and wiring costs. Therefore, the authors have proposed one of the unique energy harvesting technology solutions that can supply power from the factory's conductive roller conveyor without physical contact. The proposed energy harvester is driven by eddy currents from a rotating conductive roller conveyor. The rectifier after the generator boosts generated voltage double and supply energy to operate wireless device. The ZigBee based wireless communication module received energy from the energy harvester can communicate with other side host wireless communication module. If this system is applied in factories or distribution centers around the world, it may be taken the merits that reducing cost or valuable information service. In this paper the authors discuss about to improve generation performance and operating ZigBee based wireless communication modules by generated electricity.

**12:15** ***A Novel Extended Endurance System for Unmanned Aerial Vehicle***

Yu-Lin Lee (National Taiwan University of Science and Technology, Taiwan); Chang-Hua Lin (National Taiwan University of Science &

Technology, Taiwan); Kai-Jun Pai (National Taiwan Normal University, Taiwan); Jenn-Jong Shieh (Feng Chia University, Taiwan)
This study focuses on improving flight duration in unmanned aerial vehicles (UAVs) by enhancing battery utilization and propose proposes an extended endurance system (EES) based on the lithium-ion battery (LiB) and the lithium-ion capacitor (LiC) for UAV power system. The proposed system connects two energy storage elements using a buck-boost converter, with the LiC on the input side and the LiB on the output side of the converter. A novel control strategy is developed to improve the UAV's flight duration by extending the proposed system's endurance. This strategy utilizes the LiC to provide additional energy to the load once the LiB is depleted. Moreover, the flight duration is further extended beyond what is achievable by the LiB's extra energy alone, thanks to a phenomenon called concentration polarization. The proposed EES is validated through hardware experiments. The results demonstrate that the proposed EES significantly enhances LiB utilization and prolongs the UAV's flight duration. Specifically, the hovering flight duration is improved by 95.6%, while the durations for hovering and changing altitude conditions are increased by 27.7% and 27.2%, respectively.

# Thursday, November 23 12:30 - 1:30

## Lunch

# Thursday, November 23 1:30 - 3:00

## P3: Plenary Panel 3: Getting More Women into Power Engineering

**A/Prof. Rukmi Dutta (UNSW);**
**Vilde Kvaalsvold (Energy Advisory Engineer - KPMG Australia);**
**Dr. Sara Deilami (Senior Lecturer - MCU);**
**Sankika Tennakoon (Principal Engineer - AEMO);**
**Ruth Poon (General Manager, Wurth Electronics Australia)**

Rooms: Harris Room, Jones Room
Chair: Kosala Gunawardane (University of Technology Sydney, Australia)

# Thursday, November 23 3:00 - 3:30

## Afternoon Tea

# Thursday, November 23 3:30 - 5:00

## WIE: Women in Engineering Networking Event

**Kosala Gunawardane - coordinator**

**All IEEC2023 delegates are invited to attend.**

Rooms: Broadway Room, Harris Room, Jones Room
Chair: Kosala Gunawardane (University of Technology Sydney, Australia)

# Thursday, November 23 3:30 - 6:00

## OST2: Off Site Technical Tour 2: UTS Tech Lab - Botany

Room: Tour
Chair: Ricardo Aguilera (UTS, Australia)

Limited to 24 people.

Sign up at Registration desk before 3:30pm Wednesday.

Meet at the Registration Desk at 3:15pm on Thursday for transfer to tour bus for 3:30pm departure. Tour should return approximately 6:00pm.

UTS Tech Lab is a multidisciplinary research facility that supports bespoke industry-led partnerships designed to drive innovation and growth in engineering and IT.

Partners gain access to cutting-edge equipment, funding opportunities, world-class research talent and the ability to commercialise foreground IP.

For more information on the UTS Tech Lab see https://techlab.uts.edu.au/