Centre for Power Electronics Annual Conference held at the Jubilee Conference Centre, University of Nottingham

4 - 5 July 2023

The Centre for Power Electronics and IMAPS-UK organised the Annual Conference serving the Power Electronics, Machines and Drives (PEMD) Research and Development community, with over 180 people attending over the two days of the in-person event. The Conference featured state of the art presentations from academic and industrial speakers, 11 Exhibitors, 60 poster presentations from Early Career Researchers and a panel session on the Future Energy Strategy in Preparation for Net Zero in 2050.

The Conference Chair, Dr Paul Evans (University of Nottingham) and Director of the Centre for Power Electronics, Professor Xibo Yuan (University of Bristol) welcomed participants to the event with an overview of the CPE and of the activities over the two days of the Conference. This was the 10th anniversary of the CPE Conference, having started at the same venue. This was followed by an update from Paul Taylor of Dynex Semiconductor announcing the relaunch of Power Electronics UK, as a voice to represent the Power Electronics Industry in the UK.

Day 1: Tuesday 4th July 2023

Keynote Presentation 1: Medium Voltage SiC Based Power Electronics Design and Control for Grid Applications - Professor Fred Wang, University of Tennessee

This talk highlighted some of the special design and control issues of medium voltage SiC power electronics in grid applications. The benefits of using fast switching and low loss SiC in grid applications were introduced through benchmark comparison with Si technology both at the converter level and the system level. The impact of grid conditions on SiC converter design was discussed including grounding, unbalance, faults, and transient conditions through a case study on a 10 kV SiC MOSFET based 13.8 kV power conditioning system for distribution grids. Detailed design topics and prototyping were covered, including 10 kV SiC MOSFET characterization, gate driving and protection, high-voltage isolated power supply, controllers and sensors, high frequency transformers, inductors, and thermal management system. Special attention was paid to high dv/dt, insulation and partial discharge considerations.

Lecture 1: Vertical GaN: The Route to High Voltage (>650V) Devices – Dr Jon Evans, Swansea University

Dr Jon Evans (standing in for Professor Mike Jennings) summarised the desire to move away from silicon to Wide Bandgap Devices through reduction in conduction and switching losses. With a focus on GaN devices the relative attributes of lateral and vertical structures were compared and the key challenges of material quality and inversion layer mobilities were highlighted. Ongoing work at Swansea University was described through the development of advanced device structures, such as polarised super junctions and parallel channels with the aim of increasing blocking voltages >1.2kV.

Lecture 2: Using Computational Intelligence Techniques to Accelerate the Design Automation of Power Electronics - Professor Peter Wilson, University of Bath

Design Automation techniques for electronics design have become standard practice for many sectors in electronics, however have lagged behind in power electronics, until now. There has been an explosion of design tools and techniques aligned with the rapid increase in interest in power electronics with the adoption of wide bandgap technology leading to rapid research and innovation in the field. The term “Computational Intelligence” has been applied to the field of advanced computational techniques ranging from optimization (including heuristics and evolutionary algorithms) to the use of Artificial Neural Networks (ANNs) of various types. More recently there has been a rapid adoption of a variety of Machine Learning (ML) approaches for both design and analysis of data from simulation and experimental testing. In addition to these approaches, there are also rapid advances in computational platforms such as cloud and edge computing, GPUs and AI specific hardware to support significant increases in computational power able to be leveraged to solve these challenges. This talk provided an overview of computational intelligence techniques, implementation and platforms, and how they can be applied to power electronics.

Lecture 3: Data Driven, AI and ML in Prognostic and Diagnostic of Electrical Machines and Batteries - Dr Maher Al-Greer, Teeside University

This presentation explored the transformative impact of data-driven approaches, artificial intelligence (AI), and machine learning (ML) in prognostic and diagnostic applications for electrical machines and batteries. These components play crucial roles in diverse industries, but their performance and reliability depend on complex factors and failure modes. By leveraging data-driven techniques, AI, and ML, we can enhance prognostic capabilities and enable proactive maintenance, fault detection, and performance optimisation.

The presentation highlighted how data-driven approaches facilitate the collection, analysis, and interpretation of operational data from electrical machines and batteries. Using advanced AI algorithms and ML models, valuable insights can be extracted to estimate remaining useful life, predict failure modes, and identify critical degradation indicators. This talk focused on novel machine learning algorithms for fault

detection in Permanent Magnet Synchronous Machines (PMSMs) and data-driven AI algorithms for predicting the State of Health (SoH) and aging of Lithium-ion Batteries.

Keynote Presentation 2: Considerations for High Power Aerospace Applications - Giovanni Raimondi, Safran Group

Giovanni Raimondi introduced the strategic priority within the aerospace sector of decarbonising aviation through increasing adoption of inverter-fed brushless machine technology, increasing system voltages and diversification and distribution of energy sources (Generators, Fuel Cells and Batteries). The energy storage issue for aerospace was outlined in terms of the level of power that needs to be accommodated, which are being addressed through different hybrid and all-electric concepts. The challenges for power electronics in this changing scenario were discussed covering:

- Improved switching components
- Optimised converter topologies and control algorithms
- High performance harsh environment passive components
- Improved packaging for harsh environment, reduced weight and improved performance
- Filters with improved architecture and performance for reduced weight
- Soft switching or similar for reduced voltage perturbation
- Component topologies for high altitude operation
- Lightning protection components and methods
- Quick-sizing/pre-design tools
- Supply chain easement: more flexible and geographically distributed

Lecture 4: Offshore Wind Farm Integration using HVDC: System Configuration, Control and Protection - Professor Lie Xu, University of Strathclyde

Towards the national target of a “Net-Zero” energy network by 2050, the evolution of GB electrical power system will be driven by the change in generation, transmission, and consumption. By 2050, the majority of GB electrical loads will be powered by offshore wind, e.g., 50 GW by 2030 and 80+ GW by 2050. Similar in the EU, the targets for offshore wind are 60 GW by 2030, and 300 GW by 2050. Due to the transmission distance and size, and the existing onshore transmission infrastructure, many of the offshore wind farms in the UK and EU will be connected to the onshore network using HVDC transmission links. The talk introduced the latest research and development on HVDC transmission for integrating large offshore wind farms. The different HVDC system and converter configurations were described, and the main control, operation and protection arrangements for HVDC connected offshore wind farm systems were discussed. The concept and challenges of developing multi-terminal HVDC grid were outlined.

Panel Session, Chaired by Professor Layi Alatise, University of Warwick: Future Energy Strategy in Preparation for Net Zero in 2050.

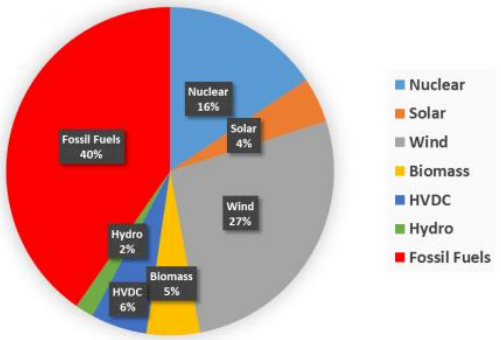
Panel Members

- Dr Iain Mosely, Nyobolt
- Professor Fred Wang, University of Tennessee
- Dr Saeed Jahdi – University of Bristol
- Professor Volker Pickert – Newcastle University

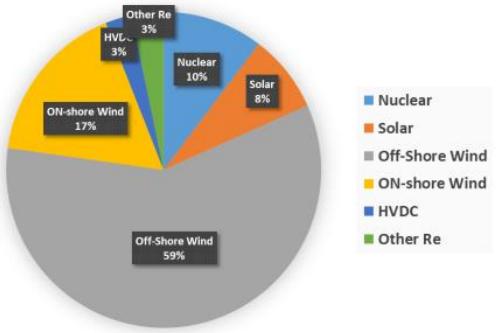
The questions proposed to the Panel included:

1. Do you agree with the energy mix proposed by the National Grid in the Future Energy Strategy (FES) – see below?
2. What would you propose as an alternative energy mix?
3. Where do you see hydrogen playing a role? (i.e. is it currently over-hyped or a critical solution)

4. Is hydrogen powered heating, aviation, HGV, EVs feasible?
5. Does the grid need rotating electrical machines or can power electronic converters give the required performance?
6. What should the UK be doing to strengthen its supply chains in PEMD as well as skills
7. Rank what manufacturing capacity UK should focus on:
    a. Semiconductors, Packaging, Passive Components, Electrical Machines, HVDC cables, Wind Turbines, Other



Energy Mix as of Today

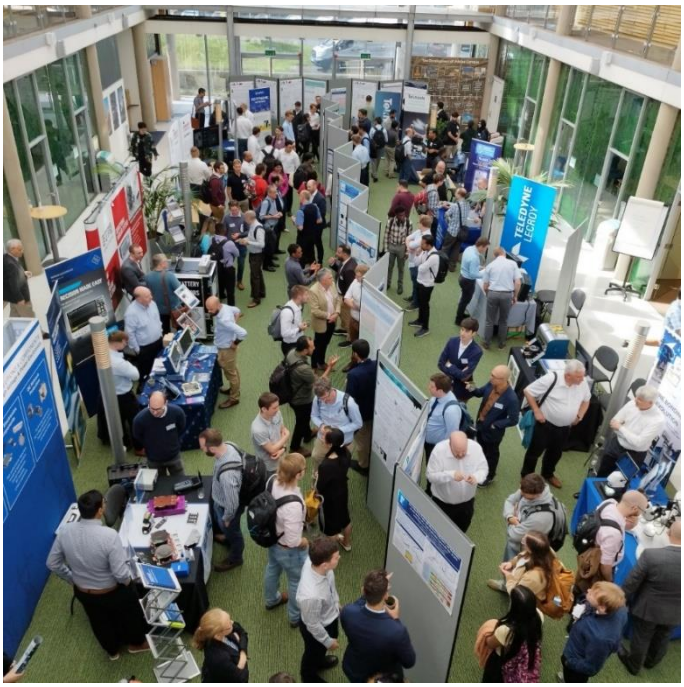


Energy mix predicted by National Grid in 2050

Within the time allotted, the Panel Members could only address some of the fundamental question raised, but the following points were highlighted:

- Need more efficiency to reduce demand on the grid, including the contribution from domestic solar panels and batteries
- Long term energy storage solutions need to be developed (e.g. Hydrogen)
- Other sources of energy generation should not be discounted – e.g. wave and geothermal
- Life cycle analysis is required to provide benchmarking of the carbon footprint

Exhibitor and Poster Session



CPE 2023 Exhibitors

- Accelonix
- Caltest Instruments Ltd
- Collins Aerospace
- ETPS Ltd
- Inseto (UK) Ltd
- ipTEST Ltd
- PPM Power
- Pyramid Engineering Services
- Rohde and Schwarz
- Tektronix
- Teledyne – Le Croy Division

Day 2: Wednesday 5th July 2023

Keynote Presentation 3: Topologies Comparison for Wind Turbine Electrolyser Power Supply - Dr Fisal Al Kayal, Dynex Semiconductor Ltd

Hydrogen electrolysers and renewable sources are designed to interface with a distributed grid network, providing a consistent supply of energy for electrolysis and a receptive network for energy generation (depending on the infrastructure). Electrolysis requires a DC source – Wind Turbines generate variable frequency AC. Dedicated renewable sources for Hydrogen generation offer alternative methods for transporting stored energy as a gas, as well as enabling system efficiencies and generation at the point of use. This presentation proposed an optimised power electronics architecture to generate Hydrogen from a dedicated wind source without the need for a grid connection.

Centre for Doctoral Training in Sustainable Electric Propulsion - Professor Volker Pickert, Newcastle University

The Centre for Doctoral Training in Sustainable Electric Propulsion (CDT SEP) is dedicated to cultivating a fresh mindset among engineers and scientists, empowering them to spearhead the transition from fossil fuel-based transportation to sustainable and environmentally-friendly electric transport.

This transformative initiative is a collaborative effort between Newcastle University and the University of Nottingham, fortified by the support of over 40 industrial and network partners. Together, they are committed to conducting cutting-edge research and providing comprehensive training opportunities of the highest quality.

Since its establishment in 2019, the CDT SEP has been instrumental in supporting the education and development of talented individuals. Over the course of 9.5 years, the program will fund 50 exceptional students, equipping them with the knowledge and skills necessary to drive sustainable electric propulsion forward.

Oral Presentations from PhD Students

The following 5 presentations were made by PhD students:

- Insulation Monitoring in Ungrounded Electrical System for More Electric Aircrafts by Yinka Leo Ogundiran, University of Sheffield

- A Symmetric Low Inductance High-power Density SiC Power Module for EV Applications by Haiyong Wan, University of Warwick
- Active Gate-Driving Pattern Requirements for High Current Silicon Carbide Half Bridge Modules by Mason Parker, University of Edinburgh
- Optimal Sizing of Hybrid-electric Aircraft Propulsion Systems by Robert Walmsley, University of Nottingham
- A Dual Output Discontinuous Conduction Mode SEPIC with Integrated Boost DC-DC Converter by Ben Stainthorpe, Newcastle University

Prizes awarded to PhD Students for Oral Presentations donated by the Centre for Doctoral Training in Sustainable Electric Propulsion

- 1st prize – Mason Parker, University of Edinburgh
- 2nd prize - Haiyong Wan, University of Warwick
- 3rd prize - Robert Walmsley, University of Nottingham

CPE 2023 Conference 1st Prize Oral Presentation awarded to Mason Parker of University of Edinburgh presented by Professor Xibo Yuan (University of Bristol) and Professor Volker Pickert (Newcastle University)

Keynote Presentation 4: Power Electronics for EV Chargers: Status and Trends - Dr Iain Mosely, Nyobolt

The eMobility revolution continues to gather pace with electrification underway in all application areas. Most domestic EV users don't need rapid charge times and this drives adoption of relatively low power solutions such as charging at home overnight or the workplace during the day. These chargers are now largely commoditised.

However, for commercial, fleet and industrial applications, the time required to charge the vehicle represents an asset unavailable for use which is a direct cost to the business . In these applications, short charge times are key to drive high availability of the vehicle.

This presentation discussed recent trends in much higher power charging systems where developments in battery chemistry can allow batteries to be charged in under five minutes without negatively impacting cycle life or safety. Adoption of these new technologies requires the power electronic systems to keep pace with much greater power capability than ever before. Electrification of mining is a key area for de-carbonisation and some of the solutions being developed in this space were explored to illustrate the importance of power electronics and the need for joined up system level thinking.

Lecture 5: Driving the Electric Revolution – Racing Ahead - Professor Derrick Holliday, Newcastle University

Driving the Electric Revolution (DER) is a UKRI-funded, national project with the vision to make the UK globally recognised as a Centre of Excellence in Power Electronics, Machines and Drives (PEMD) manufacturing processes. To achieve this, four Industrialisation Centres (DER-IC) have been established with the mission to provide a UK network of open-access facilities from which to grow world class design, manufacturing, test and validation capabilities. This UK-wide partnership includes over 30 Universities and Research and Technology Organisations, and offers access to over £300M of research and manufacturing equipment. The presentation focused on the progress and activity within the DER-ICs, highlighting their capabilities and using case studies to demonstrate how they can support industry through UK supply chain growth, new product development and introduction, and manufacturing process development.

Lecture 6: Automation of PCB Layout for Power Converters - Dr Cheng Zhang, University of Manchester

Almost all power electronics PCBs are still manually laid despite the “auto-routing” and “auto-placement” functions in CAD software are available many years ago. It is also a time and material consuming process that often requires experienced engineers to take iterations of development testing stages before the PCB design goes to mass production. We have been looking into generating the PCB layouts in an automated way and optimising for energy efficiency and density, thermal distributions, and other aspects. This will potentially help the industry to build tailor-made power converters suiting individual applications. Technically, the main difficulties are the unrestricted degree of freedom on both the solution space and versatile objectives. In this presentation, the feasibility and effectiveness considerations on algorithms and data structure in computer programming of automated PCB design will be discussed, and an in-progress open-source project PEPCB will be introduced. Examples of programme generated PCBs will be demonstrated.

Lecture 7: SiC Power Modules for More-Electric Aircraft Application - Professor Antonio Griffo, University of Sheffield

The trend for increased electrification in aircraft power system with requirements for higher on-board electric power presents many challenges for power electronics design. With power levels expected to reach up to several MWs, the commonly used 270V DC power supply in aircrafts appears inadequate and a move towards a higher ±540/1080V DC power supply is required. Two-level voltage source inverters dominate the majority of DC-AC inverters currently in use in MEAs, however, due to higher operating voltages, multi-level converters can become preferrable over the two-level in on-board motor drive applications. This work presented the design, manufacturing and testing processes of a 300A three-level neutral point clamped all SiC power module designed for more-electric aircraft applications, enabling future converters in MEA with DC voltage suitable for 540/1080V applications. Furthermore, a detailed modelling and characterisation of the parasitic inductances of the module was presented, analysing all the different current commutation loops. A methodology based on the measurements of the scattering S-parameters for the experimental measurement of parasitic inductances in complex multi-port modules was presented.

Poster Prizes awarded to Early Career Researchers donated by the Centre for Doctoral Training in Sustainable Electric Propulsion

- 1st prize: On Design and Simulation of Integrated Microchannel Cooling for Power Electronic Devices by Nikolaos Iosifidis, University of Warwick
- 2nd prize: Partial Discharge in Silicone Gel on Power Module Substrates in High Humidity Conditions by Mark Sherriff, University of Sheffield
- 3rd prize: Reliability Analysis of Power Electronics Modules with Parametric Model Order Reduction by Sheikh Hassan, University of Greenwich

CPE 2023 Conference 1st Prize Poster awarded to Nikolaos Iosifidis of University of Warwick presented by Professor Xibo Yuan (University of Bristol) and Professor Volker Pickert (Newcastle University)

Dr Paul Evans thanked attendees at the Conference, Professor Mark Johnson at the University of Nottingham for support from the CPE Discretionary Fund, the organising team at the University of Bristol (Joe Gillett, Xibo Yuan) and IMAPS-UK (Steve Riches, Martin Wickham and Andy Longford) in putting the Conference together over the past year. The support of the Exhibitors and Sponsorship of the Oral and Poster Prizes by the CDT for Sustainable Electric Propulsion was acknowledged, along with the contributions from the Session Chairs and Panellists.

Professor Volker Pickert (Newcastle University) announced that the CPE Conference will be held in Newcastle University in early July 2024. Further details about the Conference will be provided in due course.

Please use the following link to download the Presentations from the CPE 2023 Conference:

https://www.powerelectronics.ac.uk/events/event-highlights/annual-conference-invited-presentations/

For further information, please visit the Centre for Power Electronics (www.powerelectronics.ac.uk) and IMAPS-UK (www.imaps.org.uk).