

Centre for Power Electronics Annual Conference held at Newcastle Civic Centre on 8 - 9 July 2024

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 220 people attending over the two days of the in-person event. The Conference featured state of the art presentations from academic and industrial speakers, 3 Sponsors, 13 Exhibitors and 90 poster presentations from Early Career Researchers.

The Conference Chair, Volker Pickert (Newcastle University) and Director of the Centre for Power Electronics (CPE), Professor Xibo Yuan welcomed participants to the event with an overview of the CPE and an outline of the activities scheduled over the two days of the Conference.



Day 1: Monday 8th July 2024

Keynote Presentation 1: Power Electronics - Key Enabling Technology to Realising the Energy Transition - Professor Rik de Doncker, Aachen University

Concerns about climate change, geo-political issues and the liberalization of the energy market have been the main driving forces towards more decentralized power generation based on renewables (wind, PV) and high-energy CHP systems. International policies, such as the EU Green Deal, provide clear targets to reach CO₂ neutrality.

To cope with the volatile nature of these vast amounts of renewable power sources, the energy supply systems need to provide (1) storages of energy (2) automated demand response with sector coupling, and (3) flexible, controllable electrical power flow in meshed distribution grids. The presentation focused on power electronic solutions that enable meshed (cellular) DC distribution grid structures that are economically viable and reduce the overall ecological footprint as compared to classical AC solutions. The

prospect of critical material shortages in future (e.g. copper) were highlighted along with the expected reduction in PV prices.

Noteworthy is the fact that the legal framework for distribution grids allows DC networks to be built as private networks for prosumers (energy communities). As a new generation of wide bandgap power semiconductors are coming to market an outlook was given of further innovation, which benefits DC-based networks and energy supply systems.

Lecture 1: Challenges to Reduce the Size of Industrial Drives - Dr Richard Gibson, Product Development Director, Nidec Drive

Variable speed drives are essential to achieve Net Zero Targets. There has been significant development of the technology in these drives over the last 50 years. Recently the academic research focus has been on repurposing this technology into the electrification of transport. This presentation highlighted where new technologies developed for automotive can or cannot be adopted for industrial products. Reduction in size of the technology enables further adoption in new applications however there are conflicting component design and manufacturing challenges to overcome. The main challenges included:

- Minimise rectifier passive components
- Low cost, efficient High Frequency Filter
- Improved manufacturing modelling and assembly methods
- Standards updated to reflect Environmental Impact, Modern Technology and Product Design

Lecture 2: Wireless Power Transfer Techniques for Smart Home and Mobile Applications - Dr Haimeng Wu, Northumbria University

Wireless Power Transmission (WPT) stands at the forefront of contemporary power electronics, representing a pivotal technology capable of disseminating electrical power safely, flexibly, and economically without the constraints of traditional wiring. This innovation is pivotal for the global energy evolution, ensuring efficient utilization of renewable energy and playing a key role in the 5G, Internet of Things (IoT), and Metaverse era. Existing wireless solutions for smart home and mobile applications face limitations in delivering modest unidirectional power over short distances, requiring precise device placement to prevent misalignment, hindering effective power delivery.

This presentation showcased recent research advancements in WPT tailored specifically for smart home and mobile applications. The exploration of bidirectional power delivery techniques, leveraging resonant technology and Gallium Nitride (GaN) devices, has been undertaken to achieve longer-distance coverage and highly efficient power conversion. Additionally, the integration of metamaterial techniques has been investigated to further extend the reach of effective power delivery. The comprehensive case studies featuring both numerical simulations and experimental results were presented, providing compelling evidence of the efficacy of these technological innovations.

Lecture 3: The Next Generation of High Voltage Power Electronics: Opportunities for Gallium Oxide - Professor Martin Kuball, University of Bristol

High(er) voltage power semiconductor devices become of increasing interest in academia and industry. The UKRI Innovation and Knowledge Centre REWIRE will address this challenge, by pioneering and commercializing new wide and ultra wide bandgap semiconductor high voltage power electronics. Amongst the contenders, Gallium Oxide, a rather new material, has shown great device performances benefiting from its rather large bandgap well in excess of that of Silicon Carbide; as substrates are grown from the melt, this material has potential cost advantages compared to Silicon Carbide. The main challenges of low thermal conductivity, lack of workable p-type doping need to be addressed, along with the need to generate reliability data on prototype devices

Lecture 4: Advanced Electric Motor Drives - Dr Daisy Deng, Newcastle University

Electric Motor Drives (EMDs) are ubiquitous, powering everything from household appliances to high-power industrial machinery. There are an estimated 50 billion electric drives in operation worldwide, consuming roughly 45% of all electric energy. Unfortunately, many current EMDs prioritize cost over efficiency and sustainability. Replacing these drives with more efficient EMD systems could lead to significant energy savings, reduced resource exploitation, and contribute to achieving long-term sustainability goals for the UK and the world. Daisy presented research on rare earth free Switched Reluctance Motor Drives and Integrated Motor Drives. She also showed some collaborative research with Nidec Drives (Control Techniques) and Dyson on a EPSRC Prosperity Partnership to develop energy control strategies to reduce DC Link energy ripple.

Lecture 5: Sustainable Electric Vehicle Stations: An Introduction to the Future Electric Vehicle Energy Networks Supporting Renewables (FEVER) Research Project - Professor Martin Foster, University of Sheffield

The benefits of electric transportation are widely publicised and include reduced carbon emissions, improved utilisation of energy, decreased environmental impact and better health. However, the transition to electric transport is challenging due to fears over range, electrical network connectivity restrictions and uncertainties with cost and user experience. FEVER is an EPSRC sponsored collaborative research project between the Universities of Southampton, Sheffield, Surrey and Portsmouth investigating the viability of off-grid, renewable energy generation powered electric vehicle charging stations. A fully grid-independent EV charging solution can assist in alleviating existing national grid capacity constraints by facilitating the deployment of new renewable generation. A FEVER charging station will combine renewable generation (PV and wind) with short- and long-term energy storage through intelligent energy management and power electronics to balance supply and demand. The design and operation of a FEVER charging station will be informed by specific site requirements and user perspectives. The concept will be demonstrated through the construction of at least one FEVER charging station.

Day 2: Tuesday 9th July 2024

Professor Xibo Yuan introduced the Day 2 agenda. This was followed by an update from Paul Taylor of Power Electronics UK, who presented a provisional list of the following 7 Key Recommendations that are being generated from a survey of PEMD academics and industrialists:

- Strengthen UK Supply Chain to compete with imports
- Strengthen links between UK industry and academia to facilitate scale up
- Stimulate international cross border cooperation
- Stimulate new entries/products to support passive component supply chain
- Support a UK group to coordinate and promote the UK Power Electronics
- Advanced digitisation in Power Electronics
- Enhance the Power Electronics talent pipeline

Keynote Presentation 2: Semiconductors – Underpinning Power Electronics – Professor Anthony O’Neill, Newcastle University

Professor Anthony O’Neill provided a background to the evolution of semiconductors with an emphasis on the widespread application of MOSFETs. A perspective on the global semiconductor manufacturing capability was presented with an assessment of the UK-based contribution to this industry, which is required for economic and security reasons. Professor O’Neill postulated that a < 50nm CMOS foundry & mixed technology packaging for more than Moore, automotive, 5G, and Internet of Things (IoT) devices that rely on devices like power management, analog and display driver integrated circuits (ICs), MOSFETs, microcontroller units (MCUs) and sensors is needed.

In order to satisfy these requirements, a 200mm fab with 50,000 wafers/month is needed, which can cost as much as \$1 billion, including construction and equipment and getting a state-of-the-art >300mm fab is possible in ~10 years, but with a fab cost in the order of \$10-20 billion. The UK would need to invest at least \$7 billion would be consistent with comparators, based on investment as % of GDP.

Finally Silicon Carbide has shown promise for power electronics, but gate engineering needs to be optimised.

Oral Presentations from PhD Students

The following 6 presentations were made by PhD students:

- Calorimetric Measurement of Cryogenic Inverter Efficiency by Jack Bruford, University of Oxford
- From Packaging to Power Converter: Holistic Design and Implementation of a 60kW/l Ceramic Based SiC Converter by Zhaobo Zhang, University of Bristol
- High Temperature Electronics for Four Phase Inverter Current Monitoring by Jacob Kay, Durham University
- Ageing Parameter Detection for Condition Monitoring of SiC MOSFET based Drives by Uvais Mustafa, University of Nottingham
- A New Method for the Early Detection of Thermal Runaway in Large Scale Lithium-Ion Battery Packs by Joseph McDonald, Newcastle University
- Data Driven Battery State Estimation by Shalman Jesse Ojukwu, Newcastle University

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

- 1st prize – Zhaobo Zhang, University of Bristol
- 2nd prize – Jack Bruford, University of Oxford
- 3rd prize – Jacob Kay, Durham University



CPE 2024 Conference 1st Prize Oral Presentation awarded to Zhaobo Zhang of University of Bristol presented by Professor Xibo Yuan (Director of CPE) and Professor Volker Pickert (Newcastle University)

Lecture 6: Towards Zero Emissions Electric Aircraft through Superconducting DC Distribution Network - Professor Xiaoze Pei, University of Bath

Electrification of aviation will be central to achieve ambitious environmental targets for the reduction of carbon emission, fuel burn and noise. A revolutionary concept is a hydrogen-powered electric propulsion aircraft. The use of liquid hydrogen as the fuel source offers a cryogenic environment for the electric network, which opens new opportunities to exploit superconductivity to create a DC distribution network. A reliable high-power density and high efficiency cryogenic superconducting DC distribution network will be a key enabling and transformative technology to achieve large-scale hydrogen-powered electric aircraft. Safety and reliability are paramount considerations in the development of electric propulsion aircraft. This presentation focused on the system design, control, and fault protection for cryogenic and superconducting DC distribution networks. The Institute for Advanced Automotive Propulsion Systems (IAAPS) at University of Bath is a world-leading centre of excellence supporting the transport industry in the transition to net zero.

Lecture 7: Reliability Assessment of Trench SiC Power MOSFETs - Dr Saeed Jahdi, University of Bristol

The extraordinary properties of Silicon Carbide (SiC) material have led the SiC metal-oxide-semiconductor field-effect transistor (MOSFETs) to receive wide attention in power electronics. However, the improvement of figures of merit of SiC MOSFETs leads to new challenges to the device reliability. Most reliability studies to-date have only covered the planar structure of SiC power MOSFETs. However, the 3rd and 4th generation SiC MOSFETs, i.e., by manufacturers like Rohm & Infineon, are developing these MOSFETs in symmetrical and asymmetrical trench structures. In this presentation, the advantages and disadvantages of such novel structures in fabrication of SiC MOSFETs compared with the conventional planar gate structure were discussed. Reliability measurement results on the most critical reliability criteria were presented, covering the impact of dV/dt , spontaneous Crosstalk, positive and negative bias temperature instability (BTI), power cycling, avalanche breakdown, and short-circuit events. The measurement results were analysed in comparison with results of Silvaco TCAD data to explain the degradation and failure mechanisms.

Lecture 8: Power Electronics in Fusion Power Supply Systems - Finlay Christie, UK-AEA

Fusion energy is an emergent source of clean electrical power, with multiple prototype fusion power plants being designed around the world. Spherical Tokamak for Energy Production (STEP) is a UK Atomic Energy Authority (UKAEA) programme that will demonstrate the ability to generate net-positive electricity from fusion.

This presentation described the challenges of the development of the electrical infrastructure for STEP, specifically pointing towards the high volume of power electronic devices required for the design.

Two systems that possess the need for large capacity of devices, built around novel topologies are:

- The high voltage DC power supplies with high availability and rapid switch-off capability.
- The high current DC power supplies with high availability, supplying large inductive loads with a large range of control response time requirements from hours to milliseconds.

This presentation covered the application of power electronic devices to fusion power supply systems, illustrating the unique requirements of these power systems within the field of power plant design. Furthermore, this presentation discussed potential novel design approaches that could be used to reduce the expected cost, failure rate and inefficiency of the power supply systems while ensuring their effectiveness in a wide range of scenarios.

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

- 1st prize: Liquid Metal Fluidic Connection and Floating Die Structure for Ultra Low Thermomechanical Stress of SiC Power Electronics Packaging by Wei Mu, University of Cambridge
- 2nd prize: Optimisation of Wireless Power Transfer Systems using Resonant Techniques and Metamaterials by Feixuan Yang, Northumbria University
- 3rd prize: Design and Optimization of 3.3 kV Silicon Carbide Semi-Superjunction Schottky Power Devices by Kyrlo Melnyk, University of Warwick



CPE 2024 Conference 1st Prize Poster awarded to Wei Mu of University of Cambridge presented by Professor Xibo Yuan (Director CPE) and Professor Volker Pickert (Newcastle University)

Professor Volker Pickert thanked attendees at the Conference, Professor Mark Johnson at the University of Nottingham for support from the CPE Discretionary Fund, the other members of the CPE 2024 organising team (Xibo Yuan, Amanda Lane, Shafiq Odhano, Xu Deng, Layi Alatisse, Paul Evans, Joe Gillett, Steve Riches, Martin Wickham and Andy Bonner) in putting the Conference together over the past year. The support of the Sponsors and Exhibitors and Sponsorship of the Oral and Poster Prizes by the CDT for Sustainable Electric Propulsion were acknowledged, along with the contributions from the Session Chairs and Panellists.

Professor Antonio Griffo announced that the CPE Conference 2025 will be held in the University of Sheffield on 8-9th July 2025. Further details about the Conference will be provided in due course.

CPE 2024 Workshop on Power Electronics from Semiconductor Device Fabrication to Application

The CPE 2024 Conference was rounded off on Wednesday 10 July with a workshop at Newcastle University attended by 35 people on Power Electronics from Semiconductor Device Fabrication to Application. The workshop covered the following topics:

- Semiconductor Device Technology Ghosh, Swansea University
- Semiconductor Manufacturing by Owen Guy, Swansea University
- Semiconductor Device Packaging by Steve Riches, IMAPS-UK
- Reliability of Power Devices by Layi Alatise, University of Warwick
- Reliability of Packaging by Jose Ortiz-Gonzalez, University of Warwick
- Applications in Electric Drives by Xibo Yuan, Centre for Power Electronics

CPE 2024 Sponsors

- [SEP-CDT](#) – EPSRC Centre for Doctoral Training in Sustainable Electrical Propulsion –
- [DER-IC](#) – Driving the Electric Revolution – Industrialisation Centres
- [QPT](#) - Next generation of motor controllers

CPE 2024 Exhibitors

- [Accelonix](#) – supplies & supports a broad portfolio of equipment used for Power Semiconductor, Microelectronics and PCB Assembly.
- [Charcroft Electronics](#) - Specialist distributor of passives, interconnect, power, magnetics, optoelectronics and electromechanical components
- [Cupio Ltd](#) - Innovative Inspection, Production and Test Solutions
- [Custom Interconnect Ltd](#) – Electronics Manufacturing, Advanced Technologies, Design Services, Power Electronics for BEVs/PHEVs, Box Build and Rapid Prototypes
- [EPSRC Centre for Doctoral Training in Renewable Energy Northeast Universities \(ReNU\)](#) - Doctoral Training Centre in small-scale renewable and sustainable distributed energy.
- [ETPS Ltd](#) - specialise in programmable power supplies and test systems, catering for almost any DC or AC power, voltage or current requirement.
- [Inseto \(UK\) Ltd](#) - technical distributor of equipment, materials and adhesives used in the assembly of power electronics devices.
- [Julabo \(UK\) Ltd](#) - manufacturer of fluid-based temperature control units
- [PPM Power](#) - Power Electronics, Power Supplies, Test and Systems
- [Rohde and Schwarz UK Ltd](#) - Test and Measurement Solutions for Power Electronics Design
- [Siemens Digital Industrial Software](#) – assisting in digital transformation journey by streamlining processes, automating repetitive tasks and eliminating manual work
- [Tektronix](#) - designs and manufactures test and measurement solutions
- [Teledyne GmbH - Le Croy Division](#) - is a leading provider of oscilloscopes, protocol analyzers and related test and measurement solutions

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