Centre for Power Electronics Annual Conference held at the University of Warwick

5 - 6 July 2022

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 160 people attending over the two days of the face-to-face event. The Conference featured state of the art presentations from academic and industrial speakers, 2 Sponsors (Driving the Electric Revolution – Industrialisation Centres and Siemens Digital Software), 12 Exhibitors, 38 poster presentations from Early Career Researchers and panel sessions on the challenges facing the electric vehicle charging infrastructure and skills, training and future talent development in this growing industry.

The Conference Chair, Professor Layi Alatise (University of Warwick) welcomed participants to the event with an overview of the activities over the two days of the Conference. This was followed by Sponsor Introductions by **Driving the Electric Revolution – Industrialisation Centres** and **Siemens Digital Software**.

Day 1: Tuesday 5th July 2022

Keynote Presentation 1: Next Generation Power Modules: Challenges, Possibilities and Opportunities in Wind Turbine Applications - Professor Stig Munk Nielsen, Aalborg University

Professor Stig Munk Nielsen summarised key experiences working with Wide Bandgap (WBG) devices from ten years of research projects, resulting in the maturing of WBG power electronic converters.

Possibility of Next Generation Power Devices

- Near Future: Commercially available SiC MOSFETs of >3.3kV
- In Some Years: 10kV and 15kV SiC MOSFETs and SiC IGBT may be commercially available
- In the Long-Term: New Power Devices with >15kV capability may be possible

Opportunity of Using Next-Generation Power Devices

- Reduced power loss, cooling requirement, footprint
- Simplify medium voltage power converters
- Models of WBG devices available from manufacturers

Challenges of Using Next Generation Power Devices

- Learn to use tools as FEM, circuit simulator and data exchange for design phase
- Need experimental converter-level validation
- Reliability and robustness

Lecture 1: Additive Manufacturing in Power Electronics, Machines and Drives – Dr Nick Simpson, University of Bristol

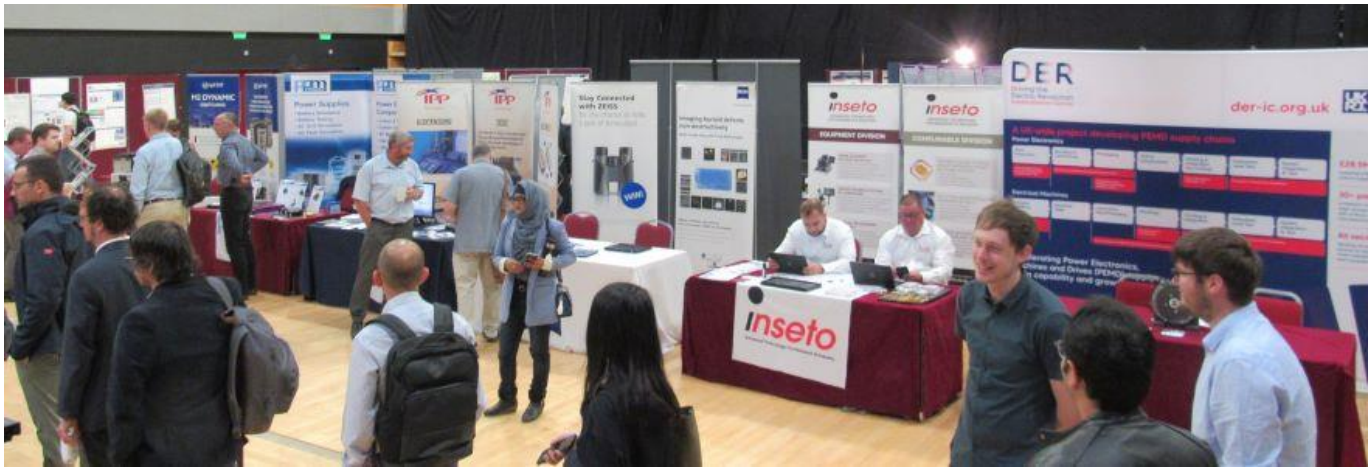
Dr Nick Simpson explained how metal additive manufacturing of copper and aluminium has brought new design and performance possibilities to electrical machine and wound passive component design in terms of AC loss reduction, thermal management, and use of high-temperature insulation coatings. This talk presented some of the latest advances in the field and discuss how the unparalleled geometric freedom on offer could be applied to high performance power electronics integration.

Lecture 2: Si Trench IGBTs and SiC MOSFETs: Automotive Applications – Dr Marina Antoniou, University of Warwick

Dr Marina Antoniou described how power devices are fundamental building blocks of any power electronic system providing an interface between electrical systems or enabling the control of power flow. For decades, Silicon has been dominating the field however, it is now widely recognised that the real

breakthrough in power electronics can be obtained by employing Wide Bandgap (WBG) semiconductor devices. Silicon Carbide (SiC) is a very promising material for high voltage electronics (above 1.2 kV). The automotive industry is shifting towards the 800V battery DC Link Voltage, where Si IGBTs and SiC MOSFETs are the current two competing devices to deliver this power. Si IGBTS are continually improving despite material limitations and absence of body diode. SiC MOSFETs is becoming established as the device of choice, however, device reliability issues and cost still limit its full potential.

Exhibitor Introductions (in addition to the Conference Sponsors)



- Accelonix
- Carl ZEISS Ltd
- ETPS Ltd
- F&K Delvotec Bondtechnik GmbH
- Inseto (UK) Ltd
- IPP Group Ltd
- ipTEST Ltd
- Magna Power Electronics
- PPM Power
- Rohde & Schwarz
- Surrey Ion Beam Centre
- TTPi

Keynote Presentation 2: Offshore Wind: Innovations and Opportunities - Dr Chong Ng, OREC

Dr Chong Ng highlighted that both the UK and EU have committed to an ambition net zero target by 2050. Along the pathway, UK has recently increased its offshore wind commitment to a 50GW OSW capacity by 2030 whiles EU is to hit 60GW installation target in the next 7-8 years. UK is expecting more than 80GW of OSW to be installed by 2050. To achieve these targets, offshore wind industry is driven toward innovative larger wind turbines, floating foundation technology, digitalisation & robotic inspection, greater grid integration, and new sustainable materials solutions.

Similar to the UK, and in many other countries who are to growing their offshore wind sector, lowering the levelised cost of energy (LCoE) remains absolute crucial to its success. From the lifetime cost point of view lower the OPEX is as, if not more, important as cutting down the CAPEX. Therefore, research on remote inspection using unmanned robotic operation or smart digital O&M technologies are crucial especially for further distance deployments.

Lecture 3: What do I work on for the Next 30 Years? Power Electronics, Renewables and the Path to 2050 – Dr Paul Judge, University of Edinburgh

For an early-stage academic, 2050 is approximately one career away. By then the UK (and hopefully most of the world) is expected to reach Net Zero, and to have fully decarbonised energy production and consumption. Power-electronics is one of the key technologies that is enabling the transformation required to reach this goal in sectors such as power-generation, energy storage, aerospace, and transport. At the same time power-electronics technology itself is continually improving at device, control, converter, and system level. Some of the key challenges and opportunities in power-electronics were discussed as this journey is made towards Net Zero, and how these might steer the research areas, career choices, and skills development requirements and of young academics and industry engineers.

Panel Session, Chaired by Iain Mosely, Nyobolt: The Challenges facing the Electric Vehicle Charging Infrastructure in Advance of Mass EV rollout?

EV adoption in the UK is growing fast with 14% of new registrations in 2022 being battery electric vehicles. This represents significant growth from 7.5% in 2021 and a few % in 2020. It is clear that electrification of mobility is now becoming mainstream and the question of how to charge your vehicle is key.

EV charging infrastructure rollout is well underway in the UK but still faces a number of challenges as technology matures. During the session the use cases and challenges of EV charging in both commercial and non-commercial applications were discussed, including charging speed, impact on the local grid, availability and reliability.

Challenges often lead to opportunities and the panel discussion also explored how some of the solutions to EV charging can underpin new business models as future energy systems become increasingly electrified.

Panel Members

- Nigel Jakeman – Turbo Power Systems (TPS)
- Professor Phil Mawby – University of Warwick
- Dr Saeed Jahdi – University of Bristol

Networking Dinner at The University of Warwick

Day 2: Wednesday 6th July 2022

Keynote Presentation 3: State of the Art Power Devices and Novel Concepts in SiC and GaN Power Devices – Professor Florin Udrea, University of Cambridge

Florin Udrea explained that the traditional power MOSFET has been largely replaced by a new class of power devices based on the Silicon Superjunction concept, while the Insulated Gate Bipolar Transistors (IGBTs) are now fabricated on 12 inch wafers and have access to the latest thin wafer/trench/fine dimension technologies. However most of the innovation in the field comes from the emergence of Wide Band Gap semiconductors – and in particular the Gallium Nitride and Silicon Carbide. Extensive research is also being carried out in single crystal Diamond and Gallium Oxide materials. The market of power devices has reached ~$35M with exponential growth in wide bandgap materials reaching CAGRs in excess of 30% in the next 3-5 years. This talk covered a range of wide bandgap semiconductor technologies and materials for power devices and gave a comparison between different technologies and materials for diverse power electronics applications. Integrated and multiple channel technologies for Gallium Nitride and superjunction and FINFET technologies for Silicon Carbide were discussed. The talk ended with an outline of the challenges for the power electronics future and a vision of different technologies for the next 10 years.

Driving the Electric Revolution Update – Venn Chesterton, UKRI and Dr Jon King – DER – Industrialisation Centres

Venn Chesterton explained how Driving the Electric Revolution is working to deliver ecosystems between organisations within the UK. Through collaborative funding this is growing and thus delivering impact to the UK in PEMD supply chains.

The importance of collaboration between organisations from academia, RTO and industry was stressed and the activities ongoing through Driving the Electric Revolution were described through setting up the Industrialisation Centres, establishing collaborative Supply Chain projects and creating opportunities in skills, training and future talent development.

Jon King outlined the status of the Driving the Electric Revolution – Industrialisation Centres, which are focusing on industry challenges, including manufacturing processes, power electronics scale-up, improved inverter performance, reduced life-cycle impact and extended validation capabilities. This was reinforced through the participation of David Moule of ZF Group

Coffee Break Challenge

Jon King introduced the Coffee Break Challenge to encourage networking and collaboration between industry and academia to address the following questions:

- Integration or Modularisation in PEMD Technologies?
- How do we accelerate cross-sector knowledge development?
- Are you working on something that is ready for industry partners?

It is the intention to establish an ongoing process to foster new opportunities for collaboration between industry and academia.

Keynote Presentation 4: Key Challenges in WBG Enabled Automotive Power Electronics – David Bock, BMW Group

This keynote presentation from David Bock gave an overview of the drive towards the development of an electric vehicle fleet with over half of BMW Group sales predicted to be EV by 2030. It was emphasised that every gram of CO2 counts and every improvement in efficiency will have a positive impact over the lifetime of the vehicle. For each 1W saved on a vehicle, for a lifetime of 10,000 operating hours, this is equivalent to a saving of 2.68kg of CO2. The @FutureBEV project, being supported by the APC, is focusing on the delivery

of SiC switch based 800V inverter solutions for BMW, implementing higher levels of integration with cooling systems and interfaces co-designed and power transmission with reduced cables and EMI, whilst considering sustainability and end of life recycling.

Lecture 4: Data-Driven Control of Power Controllers – Dr Jonathan Mayo-Maldonado, University of Sheffield

Dr Mayo-Maldonado explained that distributed renewable resources require the capability to observe and control the grid at a much finer scale of resolution, than has ever been necessary in the past. Specifically, distribution networks must become much more transparent to the grid operator, to avoid destabilising impacts from intermittent renewable resources. Under this context, data acquisition devices, as well as available data channels, permit the development of high-precision monitoring networks. Given this opportunity, we now face the challenge to reformulate the way in which we control power converters, to be able to use the available information and to act upon it. This implies passing from stand-alone model-based designs to data-driven controlled converter-network interconnections, which will be implemented in Smart Grid Technologies in large scale AC systems.

Lecture 5: Compact Modelling of GaN HEMTS – Dr Ke Li, Coventry University

In order to model Gallium Nitride High-Electron-Mobility Transistor (GaN-HEMT) switching transients and determine power losses, a compact model including device characteristics degradation (dynamic RDSon) was presented by Dr Ke Li. The model includes mathematical equations for device static and capacitance-voltage characteristics, and a behavioural voltage source for dynamic RDSon, which includes multiple RC units to represent various time constants for trapping and detrapping effect from 100 ns to 100 s range. All the required parameters in the model can be obtained by fitting method using a datasheet or experimental characterisation results. The model can be easily implemented into various simulation platforms (e.g. LTSpice, Matlab, EPSRC funded Virtual Prototyping software). By comparison with experimental measurements, the model is validated to accurately represent device switching transients as well as their spectrum in frequency domain until 100 MHz. With an overall difference less than 10%, the model also accurately represents device dynamic RDSon values under various duty cycles and switching frequencies until 1MHz. Our model improves 80% accuracy than a standard GaN-HEMT compact model excluding dynamic RDSon values, so designers can use our model to accurately obtain GaN-HEMT power losses due to trapping and detrapping effects for power electronics converters design.

Skills, Training and Future Talent Development in Power Electronics, Machines and Drives – Professor Volker Pickert, Newcastle University and Stewart Edmondson, UK Electronic Skills Foundation (UK-ESF)

Dr Volker Pickert said the the skills agenda has recently come to the fore as an important part of the government's 'Build back better' campaign, focused mainly on post-16 education and reshaping the training landscape. Much of this is being driven by the green agenda, which is reliant upon a future workforce with the skills, training and technological capability to deliver a carbon neutral world. Nowhere will this be more important than in the drive towards electrified transport and energy, where increased numbers of skilled engineers are required to maximise the economic, social and environmental benefits across multiple industrial sectors. The CDT in Sustainable Electric Propulsion is a university-industry collaborative initiative to train the next generation of technical specialists and leaders through an integrated programme of research, taught material and innovative cohort activities. The training philosophy that has been incorporated in the CDT was introduced that creates a new school of thinking amongst engineers and scientists, capable of leading the transformation from fossil fuel transport to sustainable and environmentally-friendly electric transport.

Stewart Edmondson explained that in the UK, the Electronics sector is big, valuable and growing; however, the demand for capable, employable graduates is currently outstripping supply. UK-ESF is an educational charity, launched in 2010, with both public and private seed-corn funding. We operate collaboratively with

major companies, leading universities and other organisations to tackle the skills shortage in the Electronics sector.

The UK-ESF ensures that more schoolchildren are aware of Electronics and the opportunities available, helping them to develop their interest through to university study. At university, we support undergraduates and prepare them for the workplace. Three of the UK-ESF supported undergraduates were invited to the Conference as an introduction to the world of power electronics.

A panel discussion then ensued to identify practical steps that can be taken to increase the number of students interested in pursuing a career in the field of power electronics, machines and drives.

Poster Prizes awarded to Early Career Researchers

- 1st prize: Development of Quasi-Vertical GaN-on-SiC MOSFETs by Jonathan Evans, Swansea University
- 2nd prize: Investigations of Silicone Gel used for Power Modules in Harsh Environment Operation by Mark Sherriff, University of Sheffield
- 3rd prize: On the Dynamic Robustness of SiC n-IGBTs and the Influence of Design by Ioannis Almpanis, University of Nottingham

CPE Conference 1st Prize Poster by Jonathan Evans of Swansea University presented buy Jose Ortiz-Gonzalez of the University of Warwick

Professor Layi Alatise thanked attendees at the Online Conference and hoped that a face-to-face event would be arranged in the future. He thanked Professor Mark Johnson at the University of Nottingham, the organising team at the University of Bristol (Joe Gillett, Xibo Yuan) and IMAPS-UK (Steve Riches, Martin Wickham) in putting the Conference together over the past year. The support of the Conference Sponsors and Exhibitors was acknowledged, along with the contributions from the Session Chairs and Panellists.

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