EPE'23 ECCE Europe- Tutorial Proposal

Reliability and Prognostics Towards Lifetime Improvement of Automotive Power Electronics

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Tutorial Objectives:

The requirement for clean and sustainable energy is one of the most crucial challenges confronting the European Union (EU) today. The EU has announced its intention to make Europe the world's first climate-neutral continent by 2050. To achieve this ambitious goal, the EU declares manufacturing 100% zero-emission cars within 2035. The fulfillment of the objective hugely depends on sustainable growth and demand for electric vehicles (EVs). However, EV customers are still anxious about the safety and lifetime of EVs, which is the primary hindrance to the widespread adoption of EVs. Therefore, to fulfill the safety and lifetime requirements in one-hand automotive original equipment manufacturers (OEMs) and EV components developers are looking for accurate and trustworthy estimation of the reliability of drivetrain components since accurate lifetime model of wide-bandgap (WBG) devices (i.e., SiC and GaN) are not yet mature. In addition, a universal lifetime model is also required to standardize the lifetime requirements and target. On the other hand, real-time prognostics and health monitoring (PHM) are being deployed to satisfy the service target lifetime and accomplish a longer lifetime. Nowadays, the advancement of sensorics and Industrial Internet of Things (IIoT) devices and network technologies enable intelligent edge monitoring to estimate remaining useful lifetime (RUL) in real-time and data-streaming to the cloud. The cloud leverages data from multiple EVs, forms big data analytics and machine-learning-based model, and takes necessary steps to enhance lifetime. However, the common technological barrier is that transmitting and storing all high-frequency signals is unrealistic: it is expensive at best, and more likely practically infeasible.

To this end, this tutorial aims to present several aspects and concepts regarding the lifetime modeling approach and PHM techniques to enable lifetime improvement of the e-drivetrain components while reducing headroom by lowering the derating of the devices. This tutorial will begin with a general overview of the e-drivetrain and its future prospects for integrated drivetrain converters. The tutorial will cover three different themes. Theme 1 will focus on standard reliability tests and their associated failure mechanisms. In addition, theme 1 will also address automotive mission profiles and the interpretation of test data for lifetime models. Theme 2 will present the approach toward developing a universal lifetime model. Theme 3 will focus on real-time PHM techniques and show a case-study result.

Target Audience:

The intended audience of the tutorial is Tier 1 / Tier 2 / Manufacturer; automotive OEMs, universities and R&D institutes who are involved in the design and development of powertrain converters and chargers, lifetime testing and verification.

Topical Outline:

Introduction to automotive power electronics (Estimated time: 30 minutes)
Presenter: Omar Hegazy

- Introduction to E-drivetrain architecture and PE converters
- Future development and trends of integrated PE converters
- Lifetime requirements and challenges towards longer lifetime

Theme 1: Lifetime Testing and modeling approach (Estimated time: 45 minutes)
Presenter: Alexander Otto, Sajib Chakraborty

- Introduction to the lifetime test- standards, methods and result interpretation
- Mission profile selection for automotive PE
- Lifetime models derived from test data

Theme 2: Simulation-based universal lifetime model (Estimated time: 30 minutes)
Presenter: Jan Albrecht

- Introduction to the Universal Lifetime Model (ULM)
- Methodology towards ULM implementation
- Utilization of ULM in automotive PE component's prognostics

Theme 3: Prognostics and health management for a longer lifetime (Estimated time: 30 minutes)
Presenter: Sajib Chakraborty

- Introduction to prognostics and health management (PHM) mechanism
- Data-driven approach: Intelligent data capturing and ML models
- Physics-of-failure-based (PoF) approach
- Case study results and discussion

Conclusions and outlook (Estimated time: 30 minutes)
Presenter: Omar Hegazy and Jan Albrecht

- Outlook: EV and automotive PE
- Conclusion on reliability
- Conclusion on PHM

Provisional Schedule of the Tutorial:
Schedule:

09:30 – 10:00	Introduction to automotive power electronics
10:00 – 10:45	Theme 1: Lifetime Testing and modeling approach
10:45 – 11:00	Coffee break
11.00 – 11:30	Theme 2: Simulation-based universal lifetime model
11:30 – 12:00	Theme 3: Prognostics and health management for a longer lifetime
12:00 – 12:30	Conclusions and outlook

About the Lecturers:

Omar Hegazy obtained his Ph.D. degree in July 2012 (with greatest distinction) from the Dept. of Electrical Engineering and Energy Technology (ETEC), Vrije Universiteit Brussel (VUB), Belgium. Prof. Hegazy is the head of EPOWERS- Efficient Power Electronics, Powertrain and Energy Solutions-Research Group at ETEC Dept., and at MOBI Research Centre, where he coordinates the research activities in this field in several national projects (e.g. via Flanders Make, VLAIO (ex. IWT), Innoviris, Flux50, etc.) and in European projects (e.g. SAFEDRIVE, UNPLUGGED, ELIPTIC, ORCA, ASSURED, HiFi-Elements, GHOST, HiPERFORM, CEVOLVER, OBELICS, ACHILES, LONGRUN, eCharge4drivers, iSTORMY, URBANIZED, HiEFFICIENT, NextETRUCK, SiC4GRID, ZEFES, EBRT2030, OpEVA, NEMOSHIP, etc.). Prof. Hegazy is also the manager of MOBI Core-Lab at Flanders Make organization. He is the author of more than 200 scientific publications and two patent applications. His fields of interest include power electronics, electrical machines, electric and (plug-in) hybrid electric vehicles, Digital Twin (DT), charging infrastructure, power/energy management strategies, FC (Hydrogen) powertrains, battery management systems (BMS), V2X systems, optimization techniques and Smart DC grid with renewable energy.

Sajib Chakraborty obtained his Ph.D. degree (with highest honors) from the Vrije Universiteit Brussel, Belgium in April 2022. Currently, he is a postdoctoral researcher and reliability project manager at EPOWER Research Group at ETEC Dept., and at MOBI Research Centre. He has been involved in different European and nationally funded projects, focusing on multi-fidelity modeling of power electronics converters, accelerated lifetime testing and reliability analysis of the EVs converters, digital twin design of the powertrain and AI-based modeling for PE converters and advanced battery management systems (BMS). He is the author of more than 50 scientific publications.

Jan Albrecht is a senior scientist in mechanical engineering and material science. He is working at Fraunhofer ENAS within the department of micro materials as well as for the Technical University Chemnitz. The research work of his research group –*component reliability*– is focused on simulation applying fracture and damage mechanics and related material characterizations.

Alexander Otto studied Electrical Engineering at the Chemnitz University of Technology, which he finished in 2009 by receiving his Diploma. Since 2009 he has been working at Fraunhofer Institute for Electronic Nano Systems ENAS. His research mainly focuses on the reliability testing of (power) electronic components and modules. Since 2019, he has been leading the group 'Lifetime testing and modeling.' In 2020, he received his Ph.D. from Chemnitz University of Technology.