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Tutorial Title

Design for Reliability: The Origin of Aging and Degradation in Advanced Power Modules and Emerging State of Health (SOH) Estimation Techniques.

Instructor Team

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Abstract

Designing modern power modules and power converters involves optimizing for a variety of performance metrics including switching efficiency, power density, maximum operating temperature, junction-to- coolant thermal resistance, lifetime, and cost. Many of these targets directly conflict with each other and require a multi-objective optimization strategy. While balancing electrical and thermal requirements is well understood, this tutorial will focus on strategies to introduce reliability optimization earlier in the design process and the failure modes in modern power converters. Common failure locations (e.g., wire bonds, solder interface) and mechanisms within traditional automotive power electronics package designs and reliability concerns associated with packaging at higher temperatures and higher heat fluxes will be discussed. Novel materials, manufacturing methods, and packaging solutions will be presented that increase overall power module package reliability. Modeling procedures will demonstrate optimization strategies for thermomechanical performance and validation methods to accelerated test profiles and operation profiles will be reviewed. The selection of an acceleration profile to highlight a real- word failure mechanism will be explored through several case studies. Key nondestructive and destructive evaluation techniques will be reviewed for their effectiveness, procedure difficulty, time, and cost. Not all components in a power converter circuit are equally impacted by aging, and there exist module or component level precursor and diagnostics, which are mostly electrical characterization. This tutorial will reveal the origin of aging and corresponding degradation in electrical and thermal performance associated with power modules and other circuit components. In addition to offline measurements, several emerging online state of health (SOH) estimation techniques applicable to active devices such as MOSFETs and IGBTS, and passive components will be discussed. The origin of degradation in a live circuit as well as how to determine the remaining life of a power converter using the concept of dynamic safe operating area (DSOA) will be presented. These offline and online techniques will finally be linked to build more robust power modules and converters.

Instructor Biography

Faisal Khan serves as the Principal/Chief Researcher for Power Electronics within the Center for Integrated Mobility Sciences at NREL. Faisal's broad research interests include designing power converters for emerging applications such as transportation, pulsed power and the biomedical field, as well as characterizing degradation/aging in power converters and components.

Douglas DeVoto leads reliability evaluation and prognostics research for automotive power electronics within NREL's Advanced Power Electronics and Electric Machines (APEEM) Group, with a focus on bonded interfaces and electrical interconnects. He has over 12 years of experience in accelerated testing, thermal, and thermomechanical FEA modeling for electric-drive vehicles and other applications.