VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Farzad Hosseinabadi**

The public defense will take place on **Friday 7th November 2025 at 6 pm** in room **I.0.02** (Building I, VUB Main Campus)

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ADVANCING RELIABILITY, CONDITION, AND HEALTH MONITORING OF SIC-BASED POWER ELECTRONICS APPLICATION

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Abstract of the PhD research

As the world increasingly relies on clean energy, electric transportation, and robust digital infrastructure, power electronics converters play a crucial role. These converters regulate and control electricity delivery, and any issues with them can lead to severe consequences, including system downtime, financial losses, and safety concerns. In PECs, a new type of semiconductor device, silicon carbide MOSFETs, has gained popularity due to their speed, efficiency, and compactness compared to traditional silicon-based devices. However, despite their benefits, SiC devices pose significant reliability challenges. Over time, they can experience electrical wear, packaging failures, and heat-related stresses that reduce their lifetime. This highlights the need for more effective ways to monitor their health and predict failures before they occur.

This thesis focuses on improving both the monitoring and lifetime prediction of wide bandgap semiconductors such as SiC MOSFETs. First, it evaluates the use of on-state resistance as a practical health indicator in a real industrial converter. While widely used in research, this parameter is shown to be highly sensitive to noise, operating conditions, and parasitic, limiting its effectiveness in real-world applications. To address these limitations, a new monitoring method based on saturation peak current is proposed. Experiments under accelerated stress conditions show that this method tracks device degradation more reliably, requires fewer sensors, and is less affected by temperature than traditional approaches.

Lifetime models help engineers estimate device lifetime under real conditions, guiding better design and maintenance. These models are built using accelerated aging tests, which speed up failures by stressing devices, but accelerated aging tests are costly, slow, and incomplete. Artificial neural networks address this by learning complex patterns and detecting subtle degradation that traditional models miss. This thesis develops a hybrid ANN-based lifetime prediction framework that integrates experimental data with physics-based synthetic datasets from accelerated tests. This approach not only reduces the time and cost of testing but also captures nonlinear degradation trends across multiple stress conditions and failure mechanisms, improving prediction accuracy and generalization.

The main contributions of this work are: (i) a comprehensive review of existing reliability and monitoring strategies for power converters, identifying key gaps; (ii) an industrial case study showing the practical challenges of using on-state resistance for health monitoring; (iii) the proposal and validation of a novel saturation current-based method that improves accuracy and reduces sensor needs; and (iv) the development of a hybrid ANN-based framework that makes lifetime prediction faster and more reliable.

By combining real-world experiments, new monitoring methods, and advanced modeling, this thesis provides a pathway toward safer, longer-lasting, and more cost-effective SiC-based power electronics converters in industries such as electric vehicles, renewable energy, and aerospace.