LABORATOIRE D'ELECTROTECHNIQUE ET D'ELECTRONIQUE DE PUISSANCE DE LILLE

Master thesis, 2026-2027

Influence of Switching Conditions on the Aging of Active Power Devices

Supervisor(s): Florian Chevalier

Contact: florian.chevalier@univ-lille.fr

Context

In the field of engineering sciences, our objective is to identify and develop tools and methodologies for the optimal use of power components in the design of high-performance and reliable power converters over their service lifetime. This work may contribute to the laboratory's cross-cutting research theme on life-cycle analysis of power electronic systems.

Objective

The structural weaknesses of power devices have already been well identified, such as the gate oxide in MOSFETs and the gate–substrate junction in GaN GITs. Likewise, the consequences of the switching conditions associated with different converter topologies have been extensively documented, including switching oscillations under hard-switching conditions and voltage overshoots in flyback converters. Self-heating, which can lead to the degradation of device characteristics, may also be considered as an influential factor.

However, to date, no comparative study has been conducted on the evolution of device characteristics under two different switching conditions for a given device type and at an equivalent switched power level. Existing studies mainly address design considerations for increasing the power rating of a given converter topology, including thermal management and electromagnetic compatibility (EMC) recommendations.

The objective of this work is to determine the influence of the switching environment on the health state of the power device, with the aim of identifying the most suitable device structure for optimal and efficient power conversion. We will also seek to identify the most relevant health indicators for assessing the condition of the device and to establish suitable "device–converter" pairs for different operating ranges, including switching frequency, switched power, voltage and current slew rates.

The work will begin with a static characterization of the devices, including on-state resistance, transconductance, and, where relevant, turn-on and turn-off switching speeds. Their behavior will then be comparatively investigated in two converters operated under repetitive, non-destructive switching conditions, with moderate switching frequency, controlled temperature, limited power levels, and other appropriate constraints. A second static characterization will subsequently be performed to enable comparison with the initial measurements and to identify the device characteristic that is most significantly affected by the switching conditions.

The expected outcomes include the development of a "universal" static characterization test bench suitable for a wide range of power devices, the identification and prototyping of the two most relevant converter topologies, and the identification of the most relevant indicators for assessing device health.

Key word

Power electronics, Power devices, Switching conditions, Device health monitoring, Reliability

References

M. Lallart *et al.*, Transformer-Free, Off-the-Shelf Electrical Interface for Low-Voltage DC Energy Harvesting,IEEE Transactions on Industrial Electronics, 2018

M.L. Beye *et al.*, Active Gate Driver and Management of the Current Switching Speed in GaN Transistors During Tum-On, IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society, 2018

M. Meneghini *et al.*, GaN-based power devices: Physics, reliability, and perspectives, Journal of Applied Physics, 2021

Q. Song *et al.*, Robustness of Cascode GaN HEMTs under Repetitive Overvoltage and Surge Energy Stresses, 2021 IEEE Applied Power Electronics Conference and Exposition (APEC), 2021

A. Boutry et al., Design of a test package for high voltage SiC diodes, 2022 IEEE International Workshop on Integrated Power Packaging (IWIPP), 2022

Y. Zhang *et al.*, Multidimensional device architectures for efficient power electronics, Nature Electronics, 2022

J.P. Kozak *et al.*, Stability, Reliability, and Robustness of GaN Power Devices: A Review, IEEE Transactions on Power Electronics, 2023