PhD Thesis Offer

Development of a Family of Hybrid Models for Prognostics

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ANR PRCE Power-Twin Project

Context

The increasing complexity of power electronic systems and the diversity of their operating conditions make it challenging to predict component health under poorly represented or previously untested conditions. Modern prognostics approaches rely either on physics-based models or on data-driven methods, which are flexible but often fail in out-of-distribution scenarios. Hybrid approaches combining both paradigms have emerged as a promising direction to overcome these limitations.

This thesis is conducted within the framework of the ANR PRCE Power-Twin project, which aims to develop a digital twin for the diagnosis and prognosis of power module components, with particular attention to bonding wire degradation under variable load profiles.

Objectives

The main objective of this thesis is to extend the health state prediction capabilities of prognostic models to conditions that are poorly represented in training data or entirely unseen. This will be achieved through three complementary research directions, each structured around a core research question and a set of concrete tasks.

Task 1: Modern machine learning approaches are increasingly exploited to automate and optimize fault detection and classification. We propose to investigate methods that improve diagnostics under under-represented conditions, with a particular emphasis on distribution-free approaches.

Task 2: Building upon prior work on RUL estimation for power modules under variable load profiles combining experimental data, finite element simulations, and Markov chain-based models [1], two complementary approaches will be developed: Physics-stochastic hybrid approach [2]) and Physics-Informed Neural Networks (PINNs) [3].

Task 3: The objective of this task is to develop a decision-support model to assist in the selection of diagnostic and prognostic algorithms by jointly optimizing energy and computational costs. Two goals are pursued: (i) quantify the energy impact of model choices, and (ii) develop a model selection indicator integrating model accuracy, data quality, and computation time. The approach will draw on sensitivity analysis over the models of Tasks 1 and 2, followed by a multi-criteria decision-making framework [4] that supports users in prioritizing dimensions through hierarchical structuring and expert pairwise comparisons.

Submission Deadline

The CV, motivation letter, and transcripts are expected to be submitted by **15 June 2026** to zeina.al.masry@supmicrotech.fr and emanuel.aldea@universite-paris-saclay.fr.

Required Profile

- Master's degree (or equivalent) in data science, applied mathematics, electrical engineering, or a related field.
- Strong background in machine learning and/or statistical modeling.
- Good written and oral communication skills in English.

References

[1] M. Ghrabli, M. Bouarroudj, L. Chamoin, and E. Aldea, "Physics-informed Markov chains for remaining useful life prediction of wire bonds in power electronic modules," *Microelectronics Reliability*, vol. 167, p. 115644, Mar. 2025. `https://doi.org/10.1016/j.microrel.2025.115644`

[2] A. Bender, "A Multi-Model-Particle Filtering-Based Prognostic Approach to Consider Uncertainties in RUL Predictions," *Machines*, vol. 9, no. 10, p. 210, Sep. 2021. `https://doi.org/10.3390/machines9100210`

[3] L. Podina, M. Torabi Rad, and M. Kohandel, "Conformalized Physics-Informed Neural Networks," *arXiv preprint arXiv:2405.08111*, 2024. `https://doi.org/10.48550/arXiv.2405.08111`

[4] R. Ketfi, Z. Al Masry, N. Zerhouni, C. Devalland, "MS-DQI: A methodology for data quality assessment in medical sensor networks with a case study on a temperature sensor network for breast cancer detection,“ *Biomedical Signal Processing and Control*, vol. 117, 2026, 109650, ISSN 1746-8094, `https://doi.org/10.1016/j.bspc.2026.109650`