

An Overview of Methods and Applications for Data-Driven Predictive Maintenance in Fusion Devices

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Design activities for pilot fusion power plants are progressing worldwide, with the objective of demonstrating stable, reliable energy production and economic viability. The transition from ITER to next-generation fusion power plants marks a pivotal shift from a science-driven initiative to an industry- and technology-oriented programme. Consequently, future demonstration reactors, such as DEMO, must meet ambitious Reliability, Availability, Maintainability, and Inspectability

(RAMI) targets [1]. These include remote maintenance of the fusion core within acceptable time frames, routine operation with minimal unscheduled shutdowns, and an availability exceeding 50%, with a trajectory toward commercially viable levels. The Nuclear Fusion research unit (Infusion) at Ghent University supports this transition by developing data-driven predictive maintenance (PdM) strategies based on advanced statistical and machine learning techniques. This contribution illustrates the methodology through two representative use cases: (i) The development of a condition monitoring algorithm for circuit breakers in the ohmic heating circuit at JET, a critical component whose failure could lead to unexpected interruptions of plasma operation [2]. (ii) The estimation of the remaining useful life of beryllium tiles subjected to steady-state thermal loading, as an example of PdM applied to plasma-facing components, a subsystem whose unexpected failure can lead to several months of reactor downtime [3].

[1] Maisonnier, D. (2018). RAMI: The Main Challenge of Fusion Nuclear Technologies. *Fusion Engineering and Design*, 136, 1202–1208. <https://doi.org/10.1016/j.fusengdes.2018.04.102>

[2] L. Caputo et al. (2023). Predictive maintenance in fusion devices with an application to the ohmic heating circuit at JET. 30th IEEE Symposium on Fusion Engineering (SOFE 2023), Abstracts, Oxford, United Kingdom.

[3] L. Caputo et al. (2025). Predictive maintenance in fusion devices: Application to condition monitoring of plasma-facing components. 31st IEEE Symposium on Fusion Engineering (SOFE 2025), Abstracts, Cambridge, MA .

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