Prognostic-Driven Predictive Maintenance for Wind Turbines with Explainable AI Insights

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Background

Operations and Maintenance (O&M) activities make up a significant portion of the lifetime costs of wind farms, with up to 35% reported for some offshore developments [1]. Maintenance represents a large share of these costs and risks, making it essential for wind farm operators to optimize maintenance strategies. Predictive Maintenance (PdM) frameworks aim to predict equipment failures and integrate these prognostics into optimized maintenance schedules (figure 1 [2]. PdM reduces unplanned downtime, minimizes maintenance costs, and enhances the reliability of critical systems [3].

There is increasing interest in applying deep learning techniques to predict faults and anomalies in wind turbines for CBM [4]. However, an important shortcoming of deep learning models is their lack of transparency. They operate as black boxes and typically do not provide rationales for their predictions, which can lead to a lack of trust in predicted outputs. This has been recognised as one of the main factor currently limiting the adoption of such data-driven decision making approaches in practical applications in wind energy [5]. Explainable AI (XAI) models have been shown great potential for responsible and trustworthy decision making [2]. XAI can contribute to improved performance of AI models as explanations help trace issues and pitfalls in datasets and the behaviour of features, while also assisting O&M engineer to better trust predictions made by such models. Despite its enormous potential, the wind industry has seen very limited applications of XAI so far, which mainly focus on turbine power prediction, while limited attention has been received in the area of fault prediction.

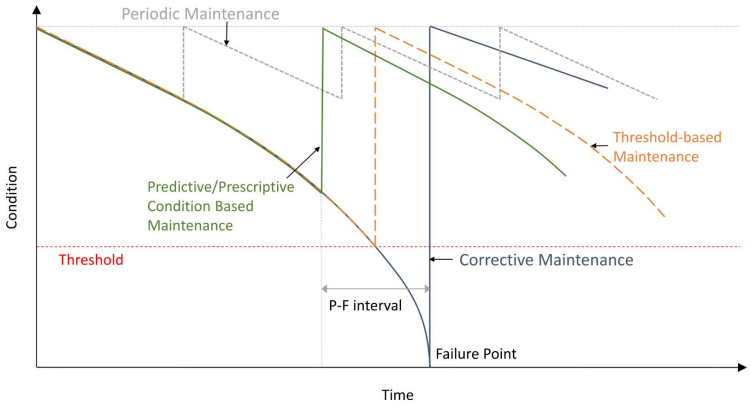

Figure 1: Turbine conditions for different maintenance strategies (adapted from [2])

Objective

The project aims to deliver an end-to-end XAI-driven predictive maintenance framework for wind turbines, combining explainable (RUL) prognostics with maintenance planning optimization. Ideally, insights from the XAI will help guide maintenance decisions. The overall goal is to foster trust in AI-driven solutions among O&M engineers.

References

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