
Machine Learning + Operations Research for optimal counterfactual controller in wind turbines

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Abstract

Machine Learning (ML) models are increasingly used in businesses to detect faults and anomalies in complex systems. In this work, we take this approach a step further: once an anomaly is detected, we aim to identify the optimal control strategy that not only restores the system to a safe state but also minimizes the disruption or changes required to do so. We frame this challenge as a counterfactual problem: given an ML model that classifies system states as either "good" or "faulty," our goal is to determine the minimal adjustment to the system's features (i.e., its current status) necessary to return it to the "good" state.

To solve this, we leverage a mathematical model that finds the optimal counterfactual solution while respecting system-specific constraints. Notably, most counterfactual analysis in the literature focuses on individual cases where a person seeks to alter their status relative to a decision made by a classifier—such as for loan approval or medical diagnosis. In contrast, our work tackles an entirely different problem: optimizing counterfactuals for a complex energy system, specifically in the context of offshore wind turbine oil transformers.

We applied this novel methodology to the maintenance of offshore wind turbine oil transformers, demonstrating its impact through a real-world application in collaboration with our industrial partner, Vattenfall. Given the high cost and risks associated with offshore wind turbine maintenance, the ability to quickly and efficiently bring a system back to a safe state with minimal changes represents a significant innovation with the potential for substantial operational impact.

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