POPULAR SCIENTIFIC ABSTRACT

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Data-driven proactive maintenance and asset management for energy distribution networks

Power and district heating networks constitute critical infrastructures that play central roles in the renewable energy transition of our society. The maintenance practices for many energy distribution network assets have historically been reactive. As the networks age failure becomes more frequent. These failures lead to supply disruptions, decreased reliability and energy efficiency, and economic losses. The central aim of this doctoral thesis is therefore to develop, improve, and demonstrate proactive maintenance technologies for energy distribution networks, effectively increasing technology readiness levels.

Energy distribution networks are governed by incomplete and limited failure data for assets whose observability is low. The majority of the contributions of the thesis therefore target these areas specifically. Through a collection of papers, this thesis suggests data representations, modeling approaches, and parameter estimation techniques that enable a shift in maintenance practices from reactive to proactive reliability-centered and predictive maintenance approaches.

The common denominator through most of the proposed methods is the use of third-party data to describe assets' environmental working conditions, feature engineering, and imbalanced learning techniques. Initial contributions focus on data-driven maintenance prioritization for cable replacement planning and planning thermographic inspections of district heating pipes, while later contributions reapply the central concepts for failure rate predictions and risk-based asset-maintenance planning.

The use of existing data and metering infrastructure is a requirement for all tools proposed in this thesis. Therefore, the thesis investigates the feasibility of integrating smart meter data into long and short-term proactive maintenance practices.

The developed tools are applied to and validated on data from several Danish energy distribution systems, showing the practical feasibility of the proposed tools. These results indicate a significant value in transitioning to data-driven reliability-centered maintenance approaches. They also show that asset management procedures may be improved and the models used to attune investments in asset maintenance. Nevertheless, the results also highlight several barriers to the deployment of proactive maintenance approaches in energy distribution systems. Specifically, the relative youth of district heating pipes makes it hard to discern among distributional assumptions regarding the pipes' time to failure distribution. While the results show that third-party proxy features and feature engineering improve failure predictions, these build on limited data and thus would benefit from validation on bigger and more comprehensive datasets. Additionally, incomplete tracking of time-varying features of the pipes and cables does not allow for detailed modeling of the time-varying effects of these features. Lastly, the use of smart meter data for long and short-term proactive maintenance is challenged by low data collection frequencies and relatively uncongested network conditions in power systems.