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Fully Automated, Physics-based Analysis of SCADA Temperature Signals for Drivetrain Monitoring

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Abstract

It is well understood that SCADA data can be used as an input to condition monitoring algorithms, and in particular the analysis of trends in temperature signals has been shown as an effective means of early fault detection, allowing proactive inspection and maintenance to be planned.

Due to the dynamic operating characteristics of a wind turbine, including variations in ambient conditions as well as the turbine control, the thermal response of the individual components is relatively complex. Accurate fault detection therefore requires simulation of the turbine in its healthy operational state, and then comparison with measured temperatures in order to identify outliers and deviations.

Previous work has shown that machine learning techniques such as neural networks can be used to simulate the relationship between input variables and a response variable. However, such techniques suffer from some limitations including lack of transparency, the requirement for training sets covering prolonged periods and over-fitting.

This work aims to demonstrate that physics-based models can be used to model the thermal response of components inside the wind turbine with full transparency, low complexity and high accuracy. Using this approach, a number of faults have been detected across a wind turbine portfolio, including gearbox, main bearing and generator damage.

Objectives

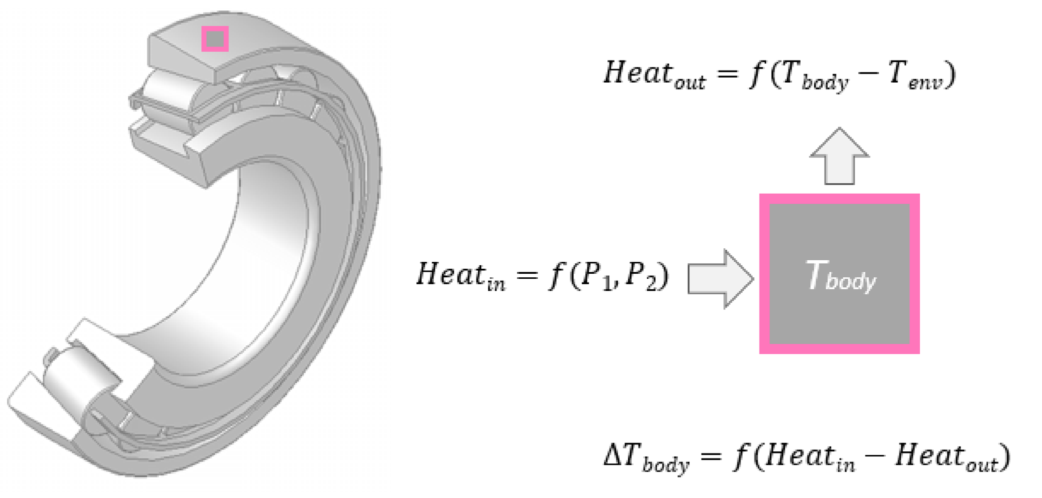
- Develop simple analytical models to describe the relationship between wind turbine operating conditions, environmental conditions and component temperature.
- Demonstrate how such models can be used to accurately detect incipient faults in critical components, triggering proactive inspection and repair.
- Achieve a system that can be used to analysis large fleets of wind turbines with full automation.

Methods

Physics-based models were used to simulate the thermal behaviour of various components within the wind turbine, with specific focus on drivetrain components including the main bearing and generator bearings. The models describe the relationship between heat input and temperature response of the system components using coefficients to describe heat transfer rates, heat coefficients and thermal inertia.

Referring to the sketch, SCADA variables P_1 and P_2 were used to calculate the heat input to the system. The heat loss was calculated as a function of the temperature difference between the body and its environment. Finally, the rate of change of body temperature was calculated using a thermal inertia coefficient, calculated for each individual turbine.

All coefficients were trained using reference datasets from **relatively short time periods**, and then used to predict future temperature response of the same components. Prediction and measurement were compared to produce residual values which in turn were **used to detect the presence of component faults**.



Where:

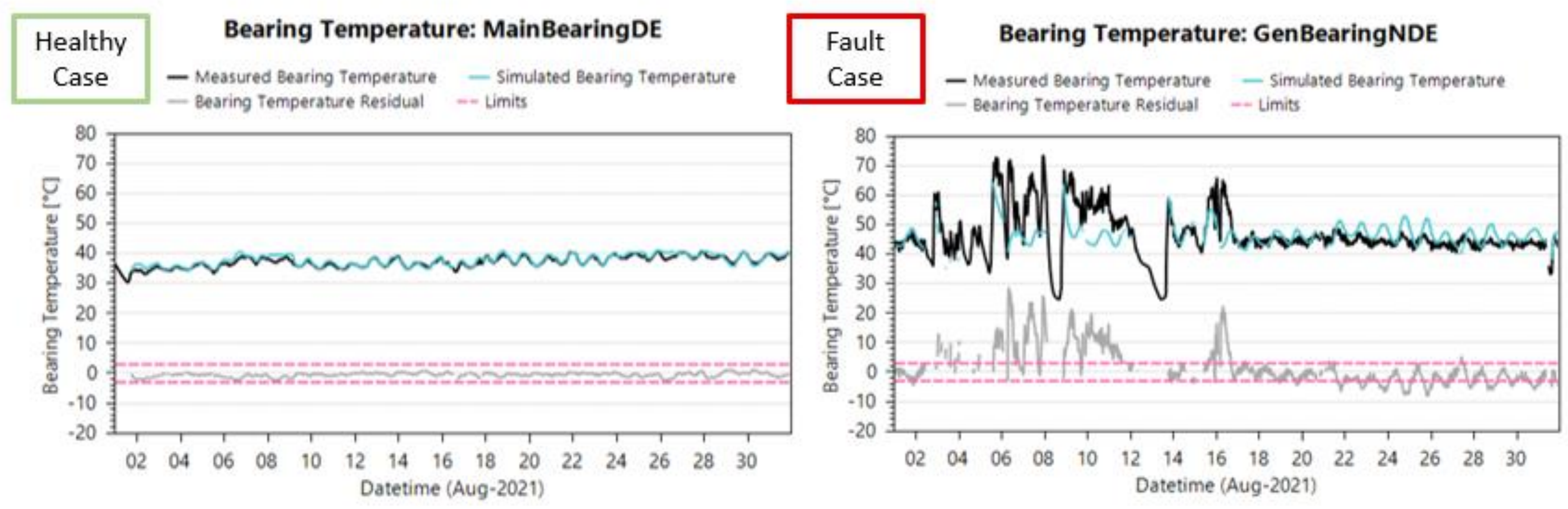
$Heat_{out}$ = Heat loss to environment [W]

$Heat_{in}$ = Heat input to body [W]

T_{body} = Body temperature [°C]

T_{env} = Environment temperature [°C]

P_1, P_2 = SCADA input variables



Results

The method was embedded in a software application developed by i4SEE TECH and connected to a centralised SCADA system managing data continuously for a portfolio of over 500MW of wind turbines operated by CGN Europe Energy. **By automating the entire process of data acquisition, model training, analysis, outlier detection and fault diagnosis, it was possible to detect a range of different faults.**

In some cases, these faults related to temperature sensor errors or problems with the turbine cooling system. Other cases related to failure in large mechanical components such as the main bearing or generator bearings. Depending on the specific details of the failure mechanism, it was shown that faults can be detected up to 12 months in advance. Results were fed directly into a digital tracking tool in order to record resulting inspection and service activities.

Conclusions

Due to the **high level of automation** achieved and the use of **available SCADA logs** accessed via existing data infrastructure, a scalable and cost-effective solution has been demonstrated. This has been used to regularly monitor a large global fleet of wind turbines. **The capability for detecting a range of faults from critical mechanical systems in the wind turbine can contribute significantly to improvements in overall fleet reliability and availability, reduction in costs for service and related logistics.**

References

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i4SEE TECH GmbH would like to express thanks to the Österreichische Forschungsfördergesellschaft (FFG) and Austrian Wirtschaftsservice (aws) for supporting this work.

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