Failure and Remaining Useful Life Prediction of Wind Turbine Components

Sofia Koukoura[1], James Carroll[2], Alasdair McDonald[3]

CDT Wind Energy Systems, Rm 3.36, Royal College Building
University of Strathclyde, 204 George Street, Glasgow, G1 1XW

[1]sofia.koukoura@strath.ac.uk, [2]james.carroll@strath.ac.uk, [3]alasdair.mcdonald@strath.ac.uk

University of Strathclyde Engineering

Introduction

Reducing the cost of energy from wind is an important challenge the industry faces today. Operation and maintenance costs constitute up to 30% of the total cost of energy from wind in large wind farms[1]. Increasing the wind turbine availability and therefore reducing these costs, can be achieved through the successful detection of incipient faults before they become catastrophic failures. Consequently, condition monitoring systems are increasingly being developed and integrated in wind farms.

Background

Modern wind turbines are equipped with the following systems for the online active remote monitoring and control of their components.

SCADA (Low frequency)	Condition Monitoring (High Frequency)
• Temperature, oil debris, vibration • Environmental conditions • Fault logs	• Vibration monitoring • Mainly concerns drive train (gears and bearings)

Earlier detection, diagnosis and prognosis of faults in an accurate automated process is still a challenge. SCADA and condition monitoring systems operate independently. An integrated engineering support tool will potentially give valuable operational information.

Objective

The aim of this project is to create a novel tool for predicting failure and the remaining useful life of wind turbine components through signal processing, machine learning and AI techniques.

Methodology/Project Outline

Population for analysis:
Turbine Type | Component Failure

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Find trends at varying times prior to component failure based on:
High Frequency Vibration Data | 10 min SCADA Data | Power Curve Data

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Learning algorithms and state of the art ensemble techniques to learn the behaviour characteristics of the trends. Computational intelligence techniques will be used for prognosis of degradation.

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Failure and remaining useful life prediction

Case Study

- The case study concerns the first steps of the project outline (analysis of high frequency data).
- Type of failure: Intermediate speed shaft gear tooth failure.
- Signal processing analysis: Synchronously sampled order tracking.
- Data: High frequency acceleration on intermediate speed shaft, on various time periods before failure (Figure 1).

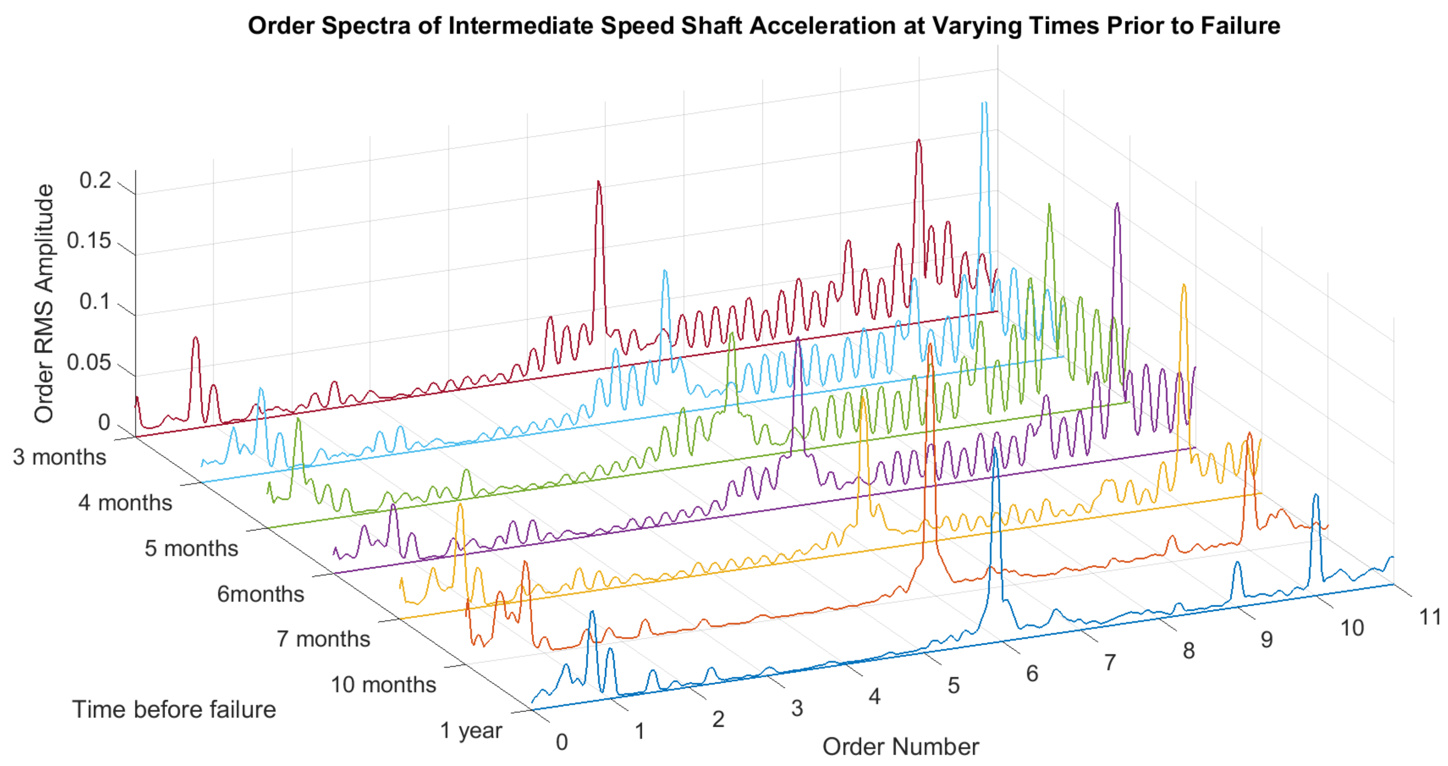

Figure 1: Spectra at Varying Times Prior to Failure

- The damaged tooth will produce an amplitude modulation of its associated gear mesh frequency each time it passes through the mesh.
- Sidebands appear as a result of this modulation.
- The sideband energy ratio algorithm can auto-detect sidebands associated with gear defects[2].

$$SER = \frac{\sum_{i=1}^{6} Sideband\ Amplitude_i}{Center\ Mesh\ Frequency\ Amplitude}$$

- SER value is typically less than 1 for a healthy gear mesh (Figure 2).

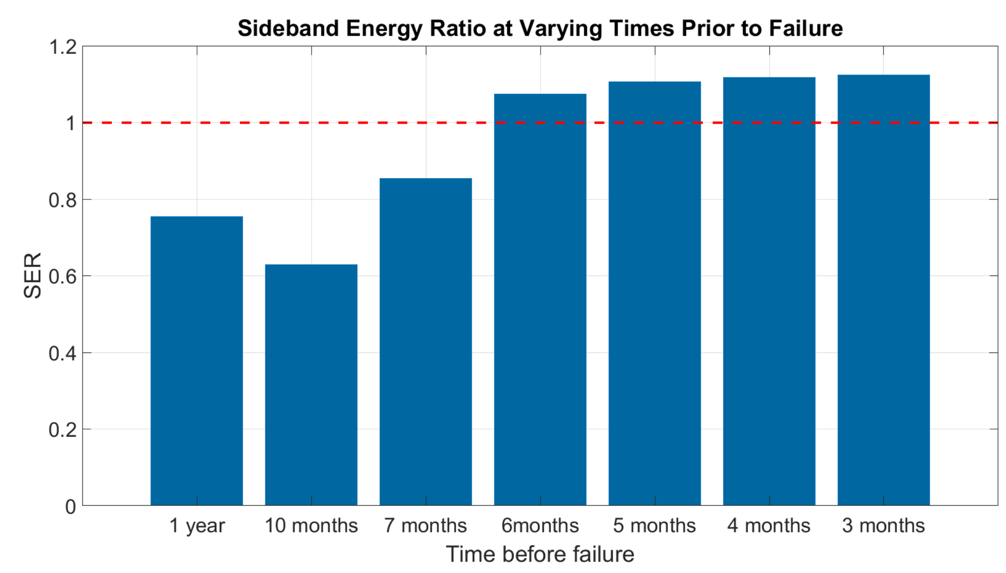

Figure 2: Sideband Energy Ratio at Varying Times Prior to Failure

Conclusion

- Sidebands rise around gear mesh frequency close to timing of fault .
- SER sensitive to changes relative to gear mesh frequency.
- Detection of warning 5 months before failure.
- Accurate spectral representation and automatic peak detection is challenging.
- SER is not strictly monotonically increasing closer to fault so other metrics for signal analysis should be examined.

Future Work

- Various feature extraction methods should be investigated, both in time domain and frequency domain.
- Other component case studies (e.g. bearings) will be carried out.
- The next steps of the project outline will be followed in order to perform failure forecasting as early as possible and successful remaining useful life prediction of wind turbine components.

References

[1]Crabtree, C.J., Zappalá, D. and Hogg, S.I., 2015. Wind energy: UK experiences and offshore operational challenges. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, p.0957650915597560, [2]Sheng, S., 2012. Wind turbine gearbox condition monitoring round robin study–Vibration analysis. Contract, 303, pp.275-3000.

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