PO.049

Assessing Wind Speed Effects on Wind Turbine Reliability

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Abstract

Wind Turbine (WT) component degradation is in many cases directly related to the highly variable environmental conditions to which the turbines are exposed to. Understanding complicated component degradation processes under variable weather conditions, leads the way to developing advanced WT reliability models and failure prediction tools. These are capable of enhancing significantly Operation and Maintenance (O&M) strategies, decreasing costs and efforts.

This poster presents a profound study on the wind speed conditions that lead to failures of five main components. Failure data of modern WTs and meteorological data taken from the affected WT's Supervisory Control And Data Acquisition (SCADA) System, have been analysed and compared.

Objectives

As stated in Kuik et al. [1], there is still a significant research need to fully understand the effects of weather conditions on wind turbines and their complicated combinations and sequences. Many studies (e.g. [2] - [6]) have been carried out investigating the effects of wind speed on WT reliability.

The objectives are to overcome drawbacks of previous studies and analyse long- and short- term wind speed characteristics frequently causing component failures.

Main Objectives:

- Higher amount of analysed wind turbines
- Modern turbine technologies
- Meteorological data taken from the affected turbine's SCADA system
- Considering the actual time of failure occurrence

Data Base

Failure Data:

- 544 modern wind turbines located in Spain with 1088 operational years
- 0.85 MW -2 MW rated power each
- 150 failures, containing 30 failures for each of the five main components

SCADA Data:

- The 10-minute mean wind speed data at the exact moment of failure occurrence, or the closest 10-minute time step - and tracing back respectively 30 days and one year.

Methods

In order to characterise and compare the wind speed conditions, a calculation framework has been developed in *R*, as displayed in figure 1.

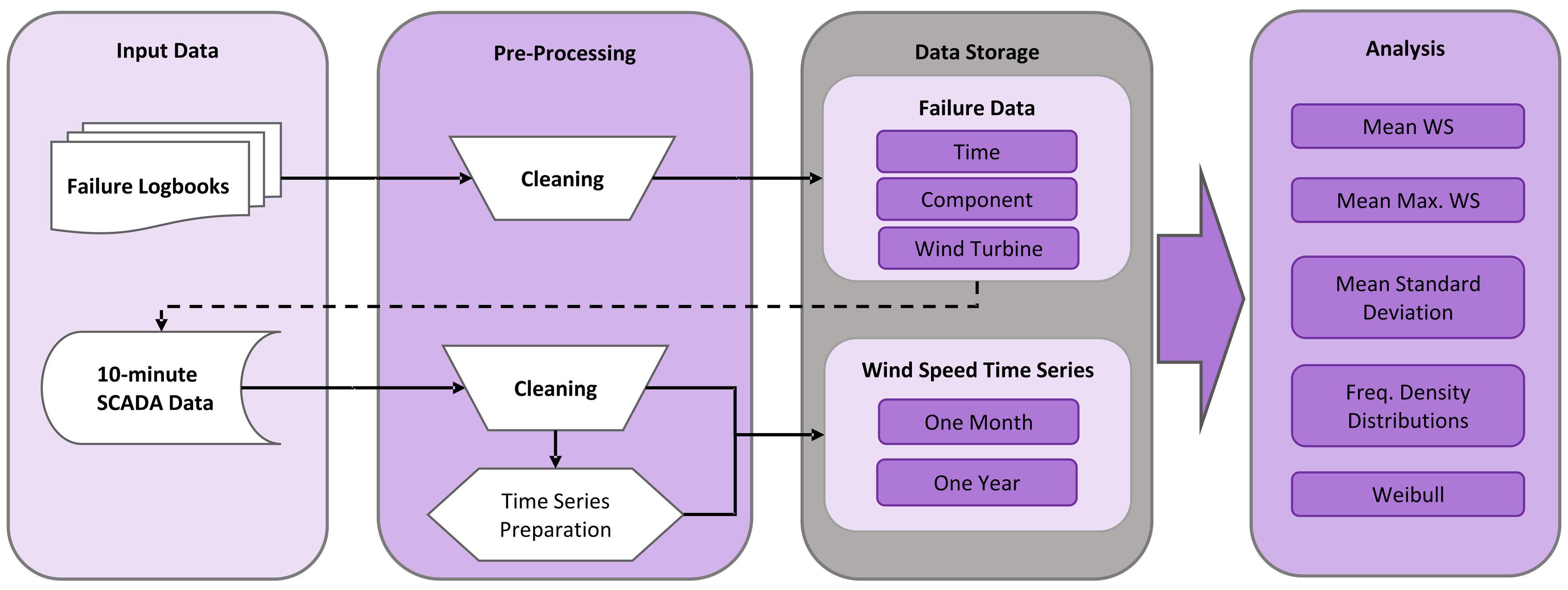

Figure 1: Methodology and Framework for the Wind Speed and Failure Analysis

The weak bi-modality in the data (see graphs on the right) was neglected, as it is not relevant for this purpose. The standard deviations indicate short term wind speed variations and are calculated after de-trending the time series using moving averages, and ensuring their stationarity. The SCADA data used in this study were of good quality and showed less than 0.005 % missing values. These did not influence the analysis, but could be interpolated using i.e. the R package *interp(),* [7].

References

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[3] Tavner P, Greenwood D M, Whittle M W G, Gindele R, Faulstich S and Hahn B 2013 Wind Energy 16 175-187

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[6] Wilkinson M, Van Delft T and Harman K 2012 European Wind Energy Conference

[6] Wilson G and McMillan D 2014 Safety, Reliability and Risk Analysis: Beyond the Horizon - Proceedings of the European Safety and Reliability Conference, ESREL 2013 801-809

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Results

The results of this study are displayed in figures 2 to 5, and tables 1 and 2.

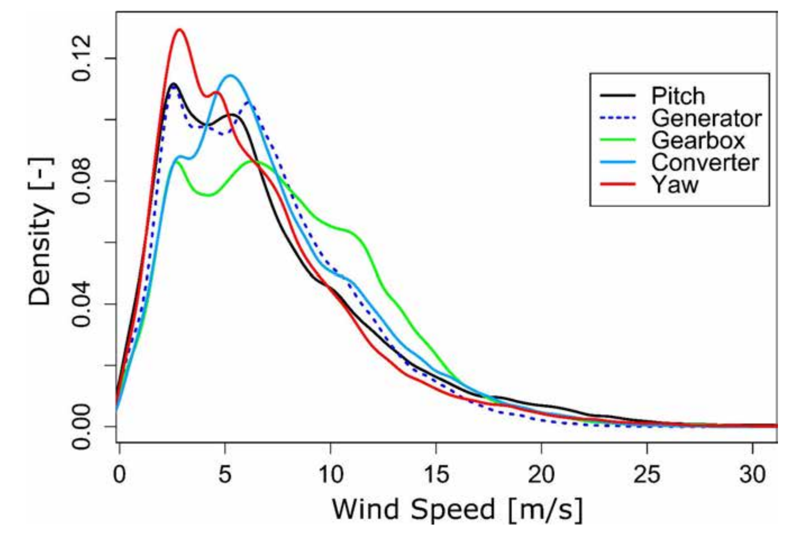

Figure 2: Frequency Density for one Month

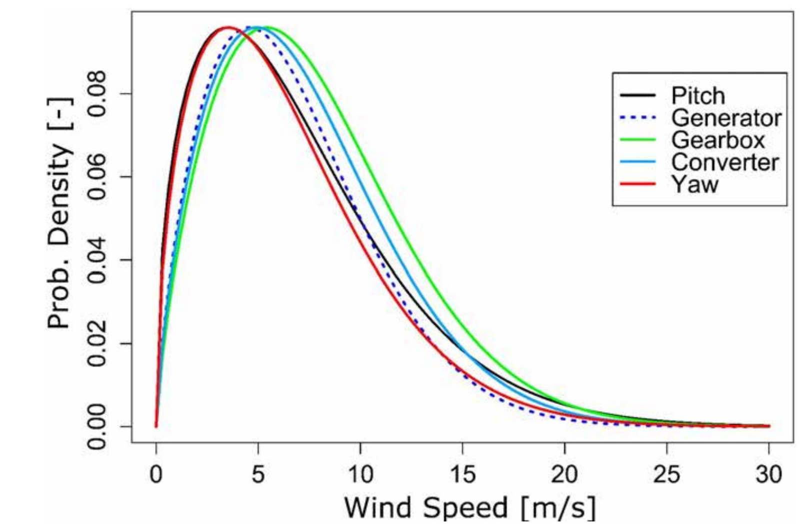

Figure 3: Weibull Distribution for one Month

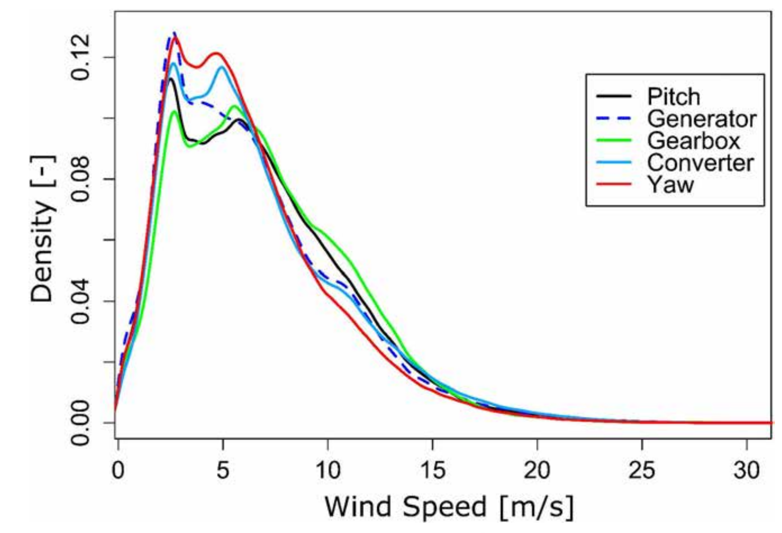

Figure 4: Frequency Density for one Year

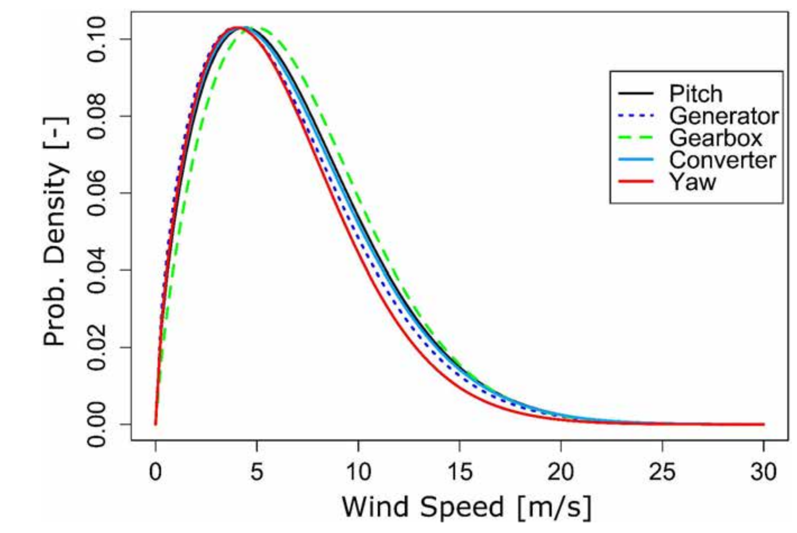

Figure 5: Weibull Distribution for one Year

Table 1: Wind Speed during 30 days before failure

Assembly	Mean (m/s)	Mean Max. (m/s)	Total Max. (m/s)	Stand. Deviation (m/s)
Pitch System	6.697	21.229	36.680	2.213
Generator	6.461	20.745	27.486	2.058
Gearbox	7.664	21.773	34.300	2.119
Converter	7.204	20.547	33.924	2.211
Yaw System	6.306	21.366	34.840	2.109

Table 2: Wind Speed during one year before failure

Assembly	Mean (m/s)	Mean Max. (m/s)	Total Max. (m/s)	Stand. Deviation (m/s)
Pitch System	6.541	29.109	36.680	1.970
Generator	6.220	26.894	33.662	2.168
Gearbox	6.772	26.002	34.920	2.009
Converter	6.426	26.823	33.924	2.114
Yaw System	5.980	27.336	34.840	2.028

Conclusions

Generally, increased mean wind speeds favoured failure occurrences of all components. Also, very often the conditions during one year and one month before failure are differing significantly. The main conclusions are presented below.

Assembly	Wind Speed Conditions affecting the Component
Pitch System	• During last year: very high mean wind speed • During last month: high changes in wind speed in combination with high mean wind speeds and very high peaks
Generator	• During last year: High wind speed variations, High mean and maximum wind speed values, • During last month: decreasing mean wind speed and variations → is less influenced by the short-term effects during the last month.
Gearbox	• During last year: Lower wind speed variability. Lower peaks, • During last month: Highest mean wind speeds and high peaks.
Converter	• During last year: High mean wind speed and variability. • During last month: Increasing mean wind speed and variability.
Yaw System	• Wind speed during the last month prior to failure did not differ significantly from throughout one year. → not significantly affected by wind speeds, rather by variable wind directions or other environmental parameters.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 642108.