

# THE CORRELATION BETWEEN WIND TURBINE TURBULENCE AND PITCH FAILURE

Peter TAVNER, Yingning QIU, Athanasios KOROGIANNOS, Yanhui FENG

Energy Group, School of Engineering and Computing Sciences, Durham University, UK.

Corresponding author: [peter.tavner@durham.ac.uk](mailto:peter.tavner@durham.ac.uk)

## 1. INTRODUCTION

Quantitative studies on public survey of LWK database and WMEP have shown similar failure rate and downtime of different wind turbine sub-assemblies [1,2,3] as shown in figure 1. It clearly shows that the rotor blades, rotor hub and pitch mechanism are one of the important aspects to affect the wind turbine unreliability. In order to reduce the wind turbines' failure rate and then the down time to improve the wind turbine reliability, it is important to understand the failure mode and the corresponding root cause. Clear evidence has been shown in [4] that weather and location affects the failure rate of a wind turbine which indicates important considerations for both wind turbine design and wind farm location decision. This paper further investigates stochastic wind fluctuations, named wind turbulence, and their effects on pitch mechanism failures.

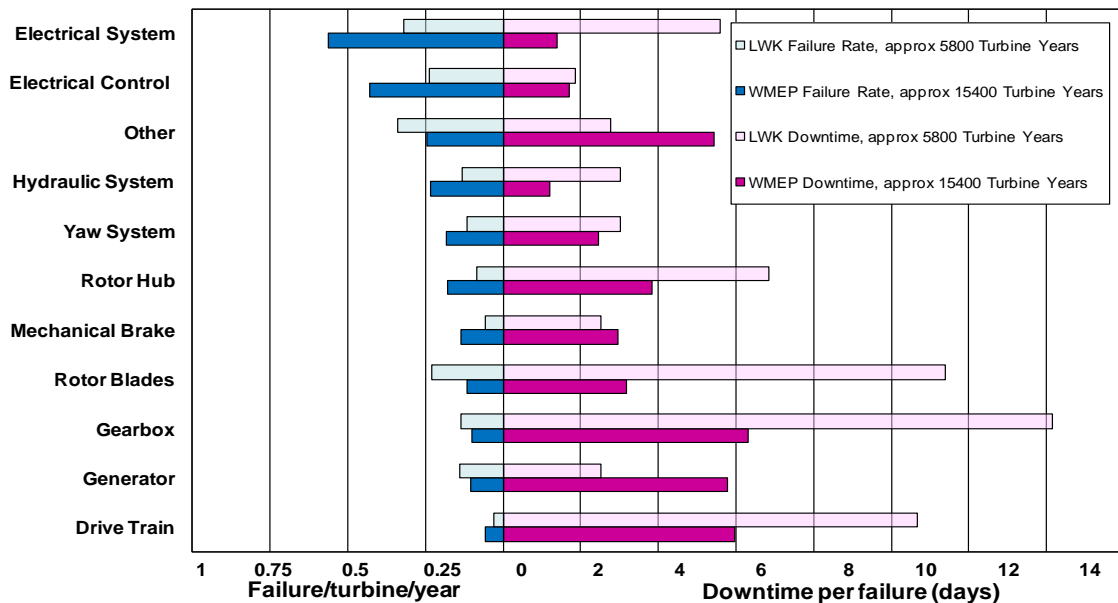
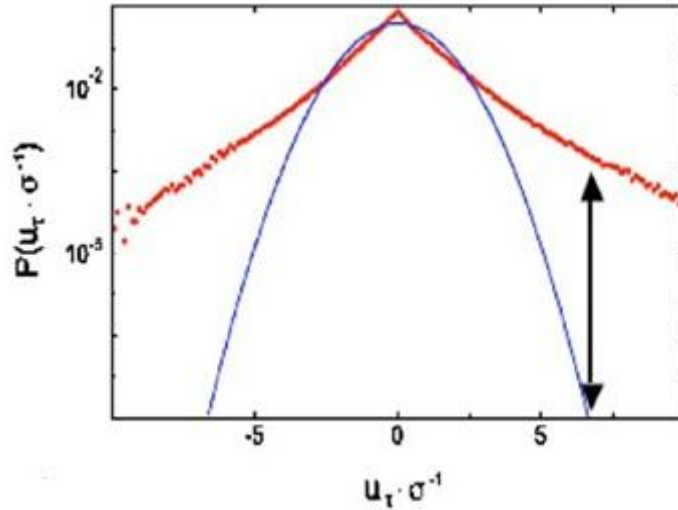


Figure 1. Failure/turbine/year and Downtime from 2 European WT Surveys over 13 years.

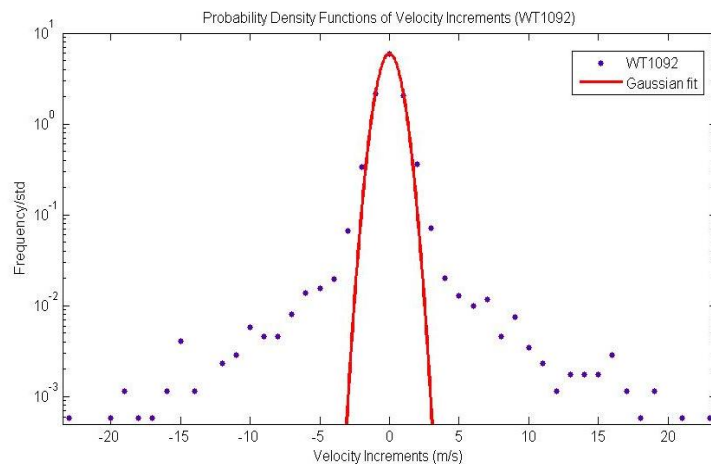
There are numbers of researches about wind turbulence [5-10], which shows the wind turbine control strategy is affected by wind fluctuation and so does the power curve. To investigate wind turbulence it is necessary to take accurate spatial and temporal wind speed measurements with high frequency sampling rate, as shown in Figure 2. It shows that the intermittent distribution of wind speed variation compared with a Gaussian distribution. It implies a high probability of wind fluctuation events with considerable magnitude deviation from mean wind speed. This occasional wind gust will introduce non-cyclic fatigue loads to the wind turbine components that are exposed to aerodynamic effects, such as the blades and pitch mechanism.



**Figure 2. Probability density function (PDF) of spatial transversal velocity increments over a distance of 10 m, for  $\tau=4$  s is compared to a Gaussian distribution (solid line)[8]0.**

## 2. INTRODUCTION of SCADA DATA

The signals from different subassemblies are collected by a wind turbine's Supervisory Control and Data Acquisition (SCADA) system in a relatively low sampling rate usually at 10 min intervals. Comparing to wind turbulence studies [9,10] which measures wind speed data with high resolution up to seconds, this sampling rate seems too low. However, the study [11] shows that the distributions of the wind speed fluctuation of different sampling rates are similar. In addition, the wind gust distribution using 10 minutes SCADA data from a large number of 1.5 MW, variable speed, WTs in a Spanish Wind Farm (WF) is shown in figure 3 and also compared with Gaussian distribution. 10 minutes averaged wind speed has similar distribution as shown in figure 2 which validates the investigation in this paper.



**Figure 3. Probability density function of wind speed from a WT SCADA**

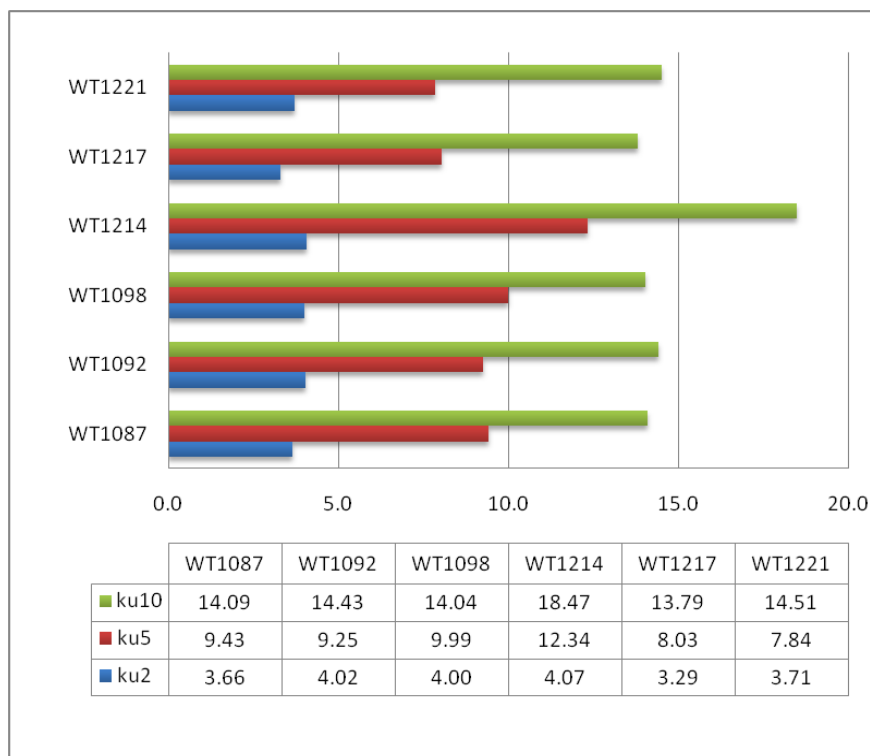
The wind turbine failures are recorded in the fault logs as a key information of SCADA database and are investigated within the EU FP7 ReliaWind projects [12]. The pitch failures are filtered from this SCADA database which covers 3 large wind farms in different locations with varying wind conditions.

## 3. WIND TURBINE TURBULENCE ANALYSIS

A simple statistical method as described in [8] has been used to identify the wind turbulence from 10 minute averaged SCADA data. In order to match the resolution of fault log which is in days, the standard deviation of the wind velocity increments are averaged daily. It is used as a numerical measure to wind turbulence by quantifying the distribution of wind velocity. Because of the 10 minutes average of wind speed, the majority of the SCADA wind speed variations were in the region of  $\pm 2\text{m/s}$  around the mean wind speed. So that the standard deviation of wind speed alone does not give a convincing measure of turbulence during a specific time interval. To overcome this difficulty in order to investigate high wind speed variation effects to pitch failure, a method to filter the wind speeds by setting different thresholds above mean wind speed is introduced. The wind speeds out of the range of  $u_w \pm \delta_{ur}$ , over a period of time  $t$  are extracted, where  $u_w$  is the mean wind speed and  $\delta_{ur}$  is the threshold. And then the standard deviation,  $ku_{\delta_{ur}}$ , of extracted wind speeds are obtained, which is named 'wind speed turbulence coefficient' to represent the measure of turbulence.

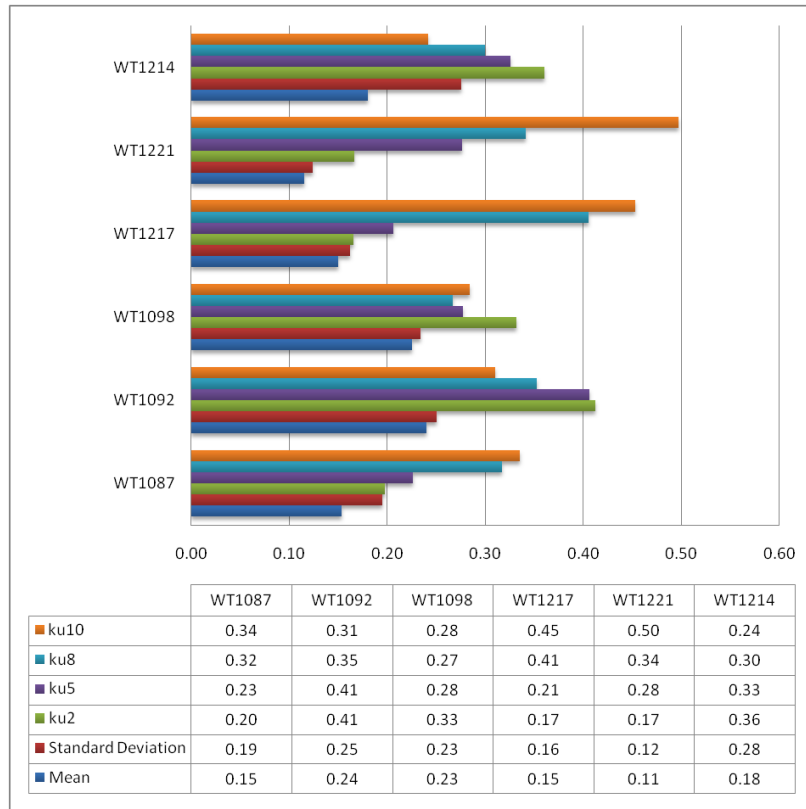
To identify whether WT pitch mechanism failures are caused by wind turbulence the pitch failure rates and wind turbulence coefficient of corresponding WTs were cross-correlated in time series using the methods described in **Error! Reference source not found., 11]**.

The wind turbulence coefficients,  $k_{u2}$ ,  $k_{u5}$ ,  $k_{u10}$ , for  $\pm 2$ ,  $\pm 5$  and  $\pm 10$  m/s deviations to mean wind speed respectively over the whole period of the study are shown in Figure 4 for six WTs with known pitch mechanism failures.



**Figure 4. Wind Speed Turbulence Coefficient over the total length of wind speed data**

The results of the cross-correlation between the pitch mechanism failures and wind turbulence coefficient time series for those six WTs are shown in Figure 5, together with their cross-correlations to the mean wind speed and the wind speed standard deviation in each case.



**Figure 5. Cross-correlation results of Pitch Mechanism Failures with Wind Speed Turbulence Coefficients**

It can be seen from Figure 4 that there is a significant degree of wind turbulence visible at the sites of all six WTs and that the value of  $k_{u10} > k_{u5} > k_{u2}$  in all six cases.

Figure 5 shows that for all six WTs greater cross-correlations between failures and the wind speed turbulence coefficients than that to mean wind speed or wind speed standard deviation are observed. The cross-correlations between failures and wind turbulence coefficients generally exceeded 30% and showed a Pearson test statistical significance for the sample size taken in excess of 99.9%.

#### 4. CONCLUSIONS

An early attempt to extract turbulence information from the slow SCADA data, available to operators, and correlate it with known failures has been presented. The results clearly show that turbulence is a root cause for pitch mechanism faults

- 10 min S CADA wind speed data yields significant wind turbulence data despite its long sampling interval.
- Six WTs from 3 WFs with pitch mechanism failures clearly showed a higher cross-correlation between failure and wind turbulence coefficient than with mean wind speed and wind speed standard deviation.
- The statistical significance of these results was in excess of 99.9%.

The work presents ideas for future study to improve our understanding in this area and mitigate the effects observed.

## 5. REFERENCES

- [1] Tavner P.J., Xiang J., Spinato F.: *Reliability analysis for wind turbines*, Wind Energy, 2007, 10, pp. 1–18.
- [2] Spinato, F. Tavner, P.J., van Bussel, G.J.W., Koutoulakos, E.: *Reliability of wind turbine subassemblies*, IET Renew. Power Gener., 2009, Vol. 3, Iss. 4, pp. 1–15.
- [3] Faulstich S., Hahn B.: *Comparison of different wind turbine concepts due to their effects on reliability*, UpWind, EU supported project nr. 019945(SES6), deliverable WP7.3.2, public report, Kassel, 2009.
- [4] Tavner, P J, Gindele, R, Faulstich, S, Hahn, B, Whittle, M W G, Greenwood, D M, *Study of effects of weather & location on wind turbine failure rates*, EWEC, Warsaw, 2010.
- [5] Madsen, P, Frandsen, S, *Wind induced failure of wind turbines*, Eng. Struct., Vol. 6, October 1984.
- [6] Mouzakis, F, Morfiadakis, E, Dellaportas, P, *Fatigue loading parameter identification of a wind turbine operating in complex terrain*, Journal of Wind Engineering & Industrial Aerodynamics, Vol 82, 1999, pp69-88.
- [7] Riziotis, V, Voutsinas, S, *Fatigue loads on wind turbines of different control strategies operating in complex terrain*, Journal of Wind Engineering & Industrial Aerodynamics, Vol 85, 2000, pp211-240.
- [8] Peinke, J, Barth, S, Bottcher, F, Heinemann, D, Lange, B, *Turbulence, a challenging problem for wind energy*, Physica A 338, 2004, p187-193.
- [9] Gottschall, J, Peinke, J, *Stochastic modeling of a wind turbine's power output with Special Respect to turbulent dynamics*, Journal of Physics: Conference Series 75, IOP Publishing, 2007.
- [10] Peinke, J, Anahua, E, Barth, S, Gontier, H, Schaffarczyk, A.P, Kleinhans, D, Friedrich, R, *Turbulence a challenging issue for the wind energy conversion*, European Wind Energy Conference, April 2008.
- [11] F. BOETTCHER, CH. RENNER, H.-P. WALDL and J. PEINKE, *On the statistics of wind gust*. Boundary-Layer Meteorology 108, 163-173, 2003.
- [12] Wilkinson M R et al, *Methodology and results of the ReliaWind reliability field study* Scientific Track Proceedings, EWEC 2010, Warsaw Poland.