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Analysis of extreme wind events at Høvsøre and the effect on wind turbine loads

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The IEC 61400-1 standards[1] for wind turbines prescribe a set of requirements to ensure that wind turbines are designed to defined reliability levels. These standards take into consideration extreme wind conditions and various operational turbine load regimes, and specify the damage a wind turbine may withstand over its lifetime. The standards include an extreme turbulence model (ETM), which gives the 50-year extreme ten-minute standard deviation of wind speed as function of ten-minute wind speed at hub height. Herein observations of high wind speed variance events, where the variance exceed the ETM level are analysed.

Inspection of these specific events shows that the measurements often include a sharp increase in wind speed, a ramp or a coherent gust-like structure. These structures give rise to the observed high wind speed variance, which is not resulting from extreme turbulence. The aim of this analysis is to answer the questions:

1. How are the wind-turbine loads affected by these events?
2. What atmospheric parameters give rise to the highest loads?

The data used for the analysis is from a 160 m tall lighting tower in Høvsøre[2], which is a measurement site approximately 2 km from the west coast of Denmark. The data consists of wind speed measurements from cup anemometers and directional data from wind vanes at 60 m, 100 m and 160 m.

A ten-year period with measurements from the western sector is used to identify events of high wind speed variance that exceed the ETM for a given 10-minute mean wind speed. The events are analysed and factors that might possibly contribute to extreme wind turbine loads, like wind-velocity jump, directional change and wind shear, are identified and quantified.

The wind speed measurements are low pass filtered and simulated with HAWC2[3], which is an aeroelastic software used to simulate wind turbine response in time domain. The simulations are made for the DTU 10 MW reference wind turbine[4].

Load analysis shows that the maximum tilt moment on the tower yaw bearing correlates well with the wind shear of the measurements. When these loads are compared with the extreme wind shear load case of the IEC standards, it is seen that they are of similar magnitude and in one case even higher.

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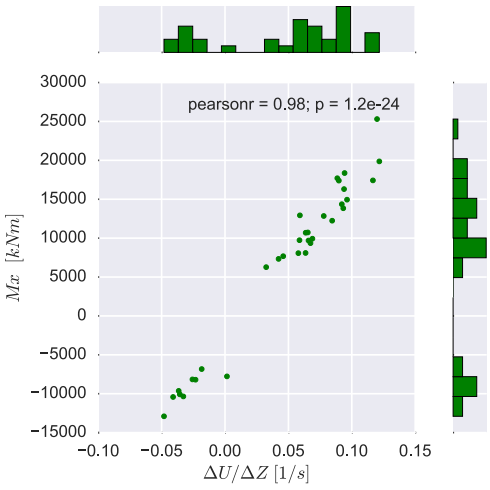

Figure 1: The maximum tilt moment of the tower yaw bearing against the wind shear of 33 high wind variance events.