Extreme variance vs. turbulence: What can the IEC cover?

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**Abstract**

Here we demonstrate the effect of extreme variance events in wind turbine loads. From ten years of data, we analyze periods with variance exceeding the IEC extreme turbulence prescription. The variance is mainly due to the events, not turbulence, and these events additionally incur extreme shear. Loads from simulations of these events are compared with two design load cases of the IEC standard: the extreme turbulence (DLC 1.3) and the extreme shear (DLC 1.5). The extreme turbulence prescription exceeds most of the simulated loads, while the IEC's extreme shear prescription under-predicts simulated loads.

**Selection criteria of the events**

Turbulence intensity (%) of 10-minute horizontal wind speed measurements. The data is from a 100 m high mast in Høvsøre from a 10-year period (yellow dots). The curves show the IEC normal- and extreme turbulence model, class B (blue and green curves, respectively). The 40 selected events are TI values exceeding the extreme turbulence model (red dots).

**Extreme variance events**

The events typically include a sudden rise in wind speed; such ramps are the primary contribution to the extreme variance. The figures show peak detection (stars) of the wind speed signal at 3 different measurement heights. Notice how the peaks are lagged in time between the different heights, resulting in extreme vertical wind shear. The sudden wind speed increase occurs simultaneously at two different measurement masts in Høvsøre, ∼400 m apart. Thus, these high-variance events are large coherent structures with a sudden wind speed increase, rather than extreme stationary turbulence.

**Extreme turbulence vs. constrained turbulence**

The mean extreme moments as a function of mean wind speed from each simulation. The extreme moments are the absolute maxima for the tower base fore-aft moment.

**IEC Extreme turbulence vs. constrained turbulence**

The mean extreme moments from the IEC's extreme turbulence data set.

**IEC Extreme shear vs. extreme events**

The extreme moments as a function of mean wind speed. The extreme moments are the absolute maxima for both data sets. The tower base- and blade loads are higher for the extreme variance events (red area); data set.

**Conclusion**

- Wind speed variance is an important input parameter for wind turbine load simulations, although it is not only due to turbulence.
- The extreme variance events detected in this analysis are not extreme turbulence, but rather large-scale meteorological ramp-like events.
- The observed ‘wind ramps’ occur with a lag between measurement heights, leading to high short-term shear and extreme loads.
- The mean extreme loads from the IEC’s Design Load Case 1.3 (extreme shear) are higher than the simulated extreme variance events’ loads, except for the tower base fore-aft moment.
- The extreme loads from Design Load Case 1.5 (extreme shear) under-predict the tower base- and blade moments, compared to simulated events’ load magnitudes.

**References**