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Load Extrapolation during Operation for Wind Turbines

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Introduction

Load extrapolation for wind turbines during operation has in the recent years been widely considered in the wind turbine industry. Loads on wind turbines during operation are among others dependent on:

• Mean wind speed

• Turbulence intensity

• Type and settings of the control system

The effect from these parameters must be taken into account when the characteristic load effects are determined.

Results

As a case study is the characteristic response calculated for the flap bending moment of a pitch controlled wind turbine. The response is calculated for different combinations of:

• Simulation time (number of 10 min. simulations)

• Threshold value (std. above the mean value)

• Separation time (time between independent peaks)

In the tables are the normalized response with a 50 year return period given.

Variation with respect to simulation time

Simulations	Without statistical uncertainty	With statistical uncertainty
5	1.114	1.450
10	1.000	1.114
25	1.000	1.045
100	0.914	0.923

Variation with respect to threshold value

Threshold	Without statistical uncertainty	With statistical uncertainty
1.4	1.000	1.045
2.0	0.920	0.996
2.5	0.773	0.845

Variation with respect to separation time

Separation time	Without statistical uncertainty	With statistical uncertainty
5 sec.	1.017	1.053
10 sec.	1.000	1.045
15 sec.	1.002	1.057
30 sec.	0.923	0.992

Method

The characteristic response is calculated based on the peak over threshold method and a Weibull distribution is fitted to the local (10 min.) extremes.

$$F_{local}\left(l\,|\,T,U\right)=1-\exp\left(-\left(\frac{l-\gamma}{\beta}\right)^{\alpha}\right)$$

The parameters in the distribution function α, β and γ are obtained for each mean wind speed U. The distribution parameters α and β are obtained by the Maximum-Likelihood Method.

The long-term distribution of the response is determined by integrating over the wind speeds during operation.
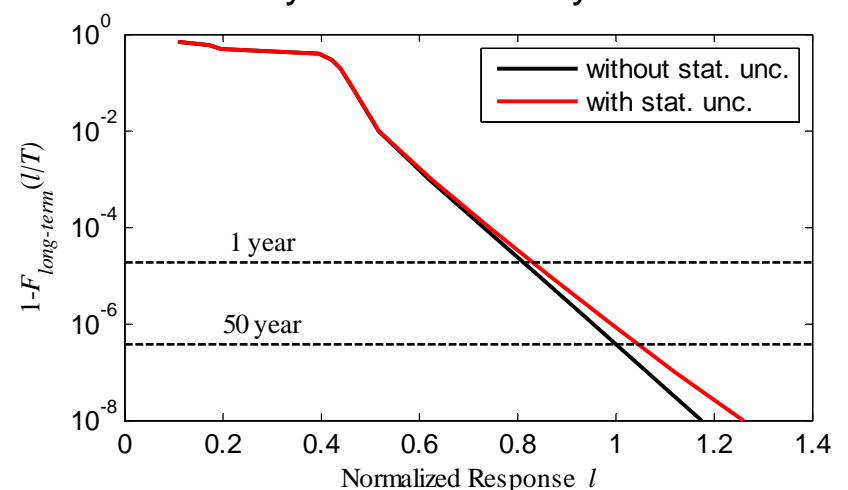
$$F_{long-term}\left(l\,|\,T\right)=\int_{U_{in}}^{U_{out}} F_{local}\left(l\,|\,T,U\right)^{n(U)} f_{U}\left(U\right)dU$$

where n is the expected number of independent extremes within 10 min. simulation.

The characteristic response with a recurrence period T_r = 50 years is obtained for the probability.

$$F_{long-term}\left(L_c\,|\,T\right)=1-\frac{T}{60\cdot 24\cdot 365\cdot T_r}$$

where T is the length of each simulation (10 min.). The statistical uncertainty is calculated by FORM.

Conclusion

• Large statistical uncertainty for limited simulations

• Decrease in characteristic response with higher threshold value

• Small change in characteristic response for small variations of separation time

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