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Load Extrapolation during operation for Wind Turbines

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ABSTRACT

In the recent years load extrapolation for wind turbines has been widely considered in the wind turbine industry. Loads on wind turbines during operations are normally dependent on the mean wind speed, the turbulence intensity and the type and settings of the control system. All these parameters must be taken into account when characteristic load effects during operation are determined. In the wind turbine standard IEC 61400-1 a method for load extrapolation using the peak over threshold method is recommended. In this paper this method is considered and some of the assumptions are examined. The statistical uncertainty related to the limited number of simulations of the response during operation is explored together with the influence of the threshold value.

KEYWORDS

Wind Turbines, Load Extrapolation.

1 INTRODUCTION

In the wind turbine standard IEC 61400-1 [1] a method for statistical extrapolation of load effects is described. The method is based on [2] and uses the peak over threshold method. However, according to [3] the choices of threshold value and distribution function for the local extremes have a significant influence on the loading. In [4] it is indicated that the statistical uncertainty related to the limited number of simulations also has a significant influence on the load effect.

In the present paper the method for statistical extrapolation of loads is investigated with respect to the threshold value, the statistical uncertainty and the time separation. The time separation is applied in order to secure that the individual peaks are independent.

2 LOAD EXTRAPOLATION

The method used for load extrapolation is based on the peak over threshold method where a 3-parameter Weibull distribution is fitted to the local extremes at each mean wind speed. The long-term distribution function for the global extremes is:

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$$F_{long-term}(l \mid T) = \int_{U_{in}}^{U_{out}} F_{local}(l \mid T, U)^{n(U)} f_U(U)\, dU \qquad (1)$$

where $n(U)$ is the expected number of extremes at each mean wind speed U. $f_U(U)$ is the density function for the mean wind speed. U_{in} and U_{out} are the cut-in and cut-out mean wind speeds, respectively (typically 5 and 25 m/s).

The distribution parameters in the local Weibull distributions can be determined by the Maximum-Likelihood Method where the parameters become asymptotically normally distributed stochastic variables with expected value equal to the Maximum Likelihood estimators. The covariance matrix for the distribution parameters can be determined by the Hessian matrix of the Log-likelihood function. A more detailed description of the method for load extrapolation can be found in [5].

The characteristic response with a recurrence period on 50 years can be determined with and without statistical uncertainty, where the later is obtained using First Order Reliability Methods (FORM), see e.g. [6].

3 RESULTS

In the following the flap bending moment for a pitch controlled wind turbine is considered.

Table 1 shows the results for calculation of the response for nine different combinations of simulation time, threshold value and time separation. The simulation time indicates the number of 10 min. simulations and the threshold value is given in standard deviations above the mean. Time separation indicates the minimum time between independent peaks. Case 1 without statistical uncertainty is used as reference.

Table 1: Characteristic response – Flap bending moment, pitch controlled wind turbine.

Case	Simulations	Threshold	Time separation	Without statistical	With statistical
1	**25**	**1.4**	**10 sec.**	**1.000**	**1.045**
2	5	1.4	10 sec.	1.114	1.450
3	10	1.4	10 sec.	1.000	1.114
4	100	1.4	10 sec.	0.914	0.923
5	25	1.4	5 sec.	1.017	1.053
6	25	1.4	15 sec.	1.002	1.057
7	25	1.4	30 sec.	0.923	0.992
8	25	2.0	10 sec.	0.920	0.996
9	25	2.5	10 sec.	0.773	0.845

It is seen from table 1 that the statistical uncertainty has a significant influence on the load effect when the number of simulations is limited. The statistical uncertainty gives 30% extra load effect for 5 simulations and 4.5% for 25 simulations.

The characteristic load effect seems to decrease with longer separation time between the extremes, which can be due to the elimination of the lower extremes. The same tendency is seen for the threshold value, where a higher threshold value also leads to a decrease in the characteristic load. Both a longer separation time and a higher threshold value leads to less extremes and more statistical uncertainty.

4 CONCLUSIONS

In this paper load extrapolation during operation of wind turbines is investigated. Calculation of the characteristic response for nine different combinations of simulation time, threshold value and separation time show that the statistical uncertainty has a large influence on the loading for limited number of simulations. For longer separation time and a higher threshold value the characteristic response seems to decrease. This could indicate that the lower extremes are not representative for the long-term distribution. This effect should be studied further.

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