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PREDICTING THE LONG TERM DISTRIBUTION OF EXTREME LOADS FROM LIMITED DATA: COMPARING FULL INTEGRATION AND FIRST ORDER RELIABILITY METHODS

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Abstract

A source of concern in the performance of wind turbines is their susceptibility to both extreme loading and fatigue. Associated costs of measurement or calculation often limits the amount of available data. For a single constant steady-state wind condition (e.g., a specified mean wind speed), wind and response data may be available over time scales on the order of minutes or hours. Questions thus arise as to how these limited data should best be used/extrapolated to estimate the reliability of parts subjected to extreme and fatigue loads over a turbine's multiple-year lifetime.

Here we focus on methods for calculating the long term distribution of extreme loads. Several moment-based models have been developed, both by the authors and others, to estimate short term load distributions of the extremes from limited data. Continuing from this previous work, this paper explores methods for calculating the long term load distribution, from the short term statistics. Two general categories are examined: (1) robust full integration method, where numerical routines are used to directly integrate the conditional short term load distribution over the annual occurrence of wind speeds, and turbulence intensities and (2) routines that employ the approximate methods underlying first order reliability analysis. In the latter, contours of the critical combination of wind speed and turbulence intensity are found for prescribed reliability levels.

In this paper we summarize these two types of methods, the details of their implementations, and the tradeoffs between them. Also, starting from the general problem where the entire distribution of the three random variables (extreme load, wind speed, and turbulence intensity) are considered, a systematic analysis is undertaken to explore less complex models. The lower order models consider using a constant fractile of the short term extreme load distribution, turbulence intensity distribution, or both instead of the entire distribution. This results in reducing the problem from a three fold integration over extreme event, turbulence, and wind speed to a single fold integration, in the most reduced form, over only the annual distribution of mean wind speed. Here we examine the efficacy of these lower order models to account for a sufficient portion of the uncertainty, while reducing the necessary computations. Finally recommendations are given to guide the analyst when simpler, yet robust, methods which account for sufficient uncertainty in the analysis of extreme load events may be employed with confidence.