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PARAMETRIC MODELS FOR ESTIMATING WIND TURBINE FATIGUE LOADS FOR DESIGN

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ABSTRACT

International standards for wind turbine certification depend on finding long-term fatigue load distributions that are conservative with respect to the state of knowledge for a given system. Statistical models of loads for fatigue application are described and demonstrated using flap and edge blade-bending data from a commercial turbine in complex terrain. Distributions of rainflow-counted range data for each ten-minute segment are characterized by parameters related to their first three statistical moments (mean, coefficient of variation, and skewness). Quadratic Weibull distribution functions based on these three moments are shown to match the measured load distributions if the non-damaging low-amplitude ranges are first eliminated. The moments are mapped to the wind conditions with a two-dimensional regression over ten-minute average wind speed and turbulence intensity. With this mapping, the short-term distribution of ranges is known for any combination of average wind speed and turbulence intensity. The long-term distribution of ranges is determined by integrating over the annual distribution of input conditions. First, we study long-term loads derived by integration over wind speed distribution alone, using standard-specified turbulence levels. Next, we perform this integration over both wind speed and turbulence distribution for the example site. Results are compared between standard-driven and site-driven load estimates. Finally, using statistics based on the regression of the statistical moments over the input conditions, the uncertainty (due to the limited data set) in the long-term load distribution is represented by 95% confidence bounds on predicted loads.

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