A method to find the 50-year extreme load during production

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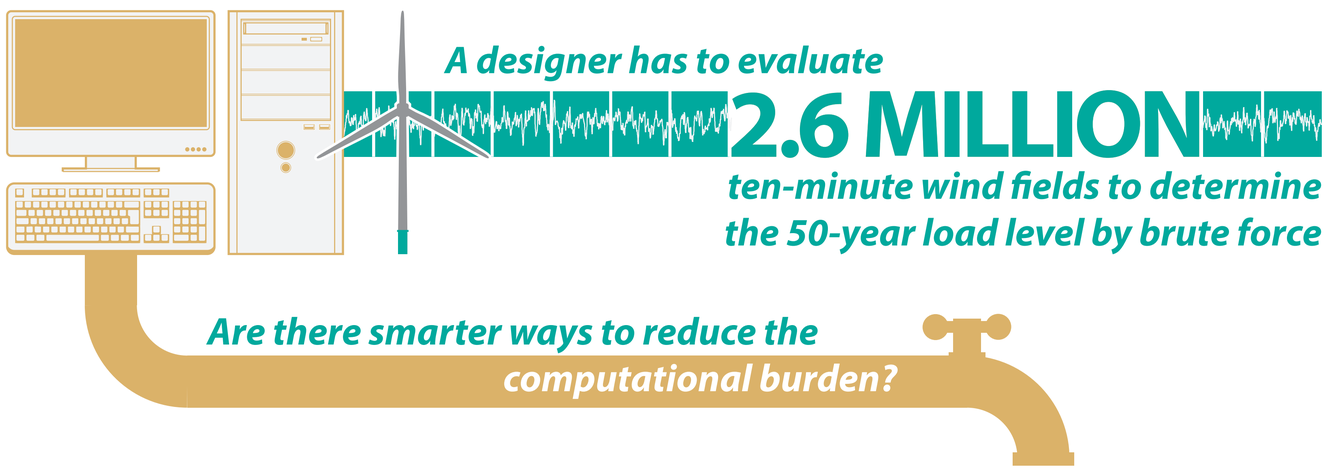
Abstract

An important yet difficult task in the design of wind turbines is to assess the extreme load behaviour, most notably to find the 50-year level. Where existing methods focus on ways to extrapolate from a small number of simulations, this paper proposes a different, more efficient approach. It combines generation of constrained gusts in random turbulence fields, Delaunay tessellation to assign probabilities and a genetic algorithm to find the conditions that produce the 50-year load. Results of the new method are compared to both Crude Monte Carlo and Importance Sampling, using the NREL 5MW reference turbine. We find that using a genetic algorithm is a promising approach, with only a small number of load cases to be evaluated and requiring no user input except for an appropriate fitness function.



CRUDE MONTE CARLO

Mean wind speed distribution, $f(U)$

U_i

Mean wind speeds are randomly drawn from their parent distribution, $f(U)$

Random turbulence is generated with a spectral method

10 min

Extremes are sorted and assigned a probability

Probability of exceedance

Since the 50-year probability is not reached, extrapolation is needed

50-year return period

Reference distribution
(Sandia, 5 million samples = 96 years)

IMPORTANCE SAMPLING

The designer sets a sampling distribution, $w(\mathbf{k})$, for the parameters $\mathbf{k} = [U, A, y_0, z_0]^T$

$\mathbf{k}_i$

Combinations of mean wind speed, U, gust amplitude, A, and gust position, y_0, z_0, are randomly drawn from $w(\mathbf{k})$

Conditionally random fields are generated with an embedded gust

1 min

Extremes are sorted and weighted with the ratio of the sampling distribution and the parent distribution: the likelihood ratio, $f(\mathbf{k})/w(\mathbf{k})$

Probability of exceedance

Reference distribution
(Sandia, 5 million samples = 96 years)

50-year return period

GENETIC ALGORITHM

First, a random population of genotypes is created. Later, only successful genotypes are allowed to procreate.

Successful genotypes

N-dimensional parameter space

$\mathbf{k}_i$

Each genotype is a combination of a mean wind speed, U, gust amplitude, A, and gust position, y_0, z_0

Conditionally random fields are generated with an embedded gust

1 min

Likelihood ratios are derived by using Delaunay tesselation

Probability of exceedance

Reference distribution
(Sandia, 5 million samples = 96 years)

Successful genotypes are kept and used to spawn a new generation

50-year return period

Simulated time to stay within a 3% error:

2 years | **2 weeks** | **2 days**

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