Damage Assessment of Floating Offshore Wind Turbines Using Response Surface Modeling

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Problem Description

Fatigue assessment for floating wind turbines is commonly established by comprehensive simulation studies of integrated time-domain simulations. Procedures which incorporate simplifications of the environment in order to limit the number of simulations typically lead to more conservative designs. An alternative approach is proposed here based on response surface modeling using Latin hypercube sampling and artificial neural networks (ANN). The presented method takes into account the statistical characteristics of environmental parameters during the systems lifetime (resulting in more realistic and accurate damage calculations) while keeping the numerical effort to a minimum.

Considered System and Environment

The considered system is the DTU10MW reference turbine positioned on the SWE TripleSpar. The turbine’s characteristic wind speeds $v_{\text{ref}} = 4$ m/s, $v_{\text{rated}} = 11.4$ m/s, $v_{\text{cut-out}} = 25$ m/s. Simulations are carried out in time domain using FAST8, using BEM for aerodynamics, first-order potential-flow theory for hydrodynamics and a quasi-static model with dynamic relaxation for mooring line forces (MoorDyn).

The environment is set up based on LIFE50+ site A (mild environmental conditions) design load case (DLC) 1.2 [1]. Measurement data based on the ANEMOC and CANDHIS buoy network is used as well as FINO1 data for turbulence intensity.

The variations of wind speed, turbulence intensity, wave height and wave period are considered in this study. Three load ranges are defined for differentiating between fundamentally different system behavior based on the controller mode: partial load range below rated wind speed (PLR), transitional load range around rated wind speed (TLR) and full load range above rated wind speed (FLR).

A reference case was established for comparison based on conservative assumptions of environmental conditions.

Response Surface Modeling (RSM)

The overall procedure used in this study is as follows:

1) Define simulation points using Latin hypercube sampling (LHS). We considered 3 different sample sizes for each load range: 50, 100 and 150.

2) Carry out simulations, calculate damage equivalent loads (DEL).

3) Based on the simulation results, determine a response surface using artificial neural network (ANN) regression. Then, evaluate the regression model at defined bin centers of the environmental model. As the regression results change with each run, 20 regression evaluations were performed and the statistics of the results are analyzed.

4) Weight all bin-center DELs according to the related bin occurrence probability. Then calculate the resulting DELs over lifetime.

Conclusions and Outlook

The first results of this initial, hypothetical study promise that a fully stochastic approach for fatigue assessment is possible and indicate the potential for a significant reduction of the fatigue load estimate. Future studies will focus on more accurate regression models and include more environmental conditions (e.g., wind direction, wind-wave misalignment, etc.).

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