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Validation of uncertainty in IEC damage calculations based on measurements from alpha ventus

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Abstract

The aim of this paper is to validate environmental assumptions used in the design of offshore wind turbines. This is done by comparing the load uncertainty (load variation) resulting from assumptions to full scale measurement data from a Senvion 5M turbine on a jacket substructure positioned in the offshore test field Alpha Ventus in the North Sea. The focus is put on fatigue loads occurring during power production. Sensors at the tower base and tower top of the turbine are evaluated. Simulations are performed by using the coupled simulation tool Flex5-Poseidon. Measurements over a period of 10 months are selected so that a high quality of reference data is ensured. Uncertainty from both measurements and simulations are determined by Monte Carlo experiments and evaluated by Bootstrap methods. Results show that a variation of damage from simulations is significant and that the presented method could be used for evaluation of assumptions used in the design process.

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Keywords: offshore, wind energy, validation, full scale, measurements, simulation, alpha ventus

1. Introduction

In the design process of offshore wind turbines, various simplifications of environmental conditions of usually conservative nature are applied in order to simplify the design process and limit the number of necessary load simulations. For example, one single representative value for turbulence intensity is chosen for each wind bin rather than considering a set of realistic combinations of wind speed and turbulence intensity. The question arises as to

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how far are the assumptions of environmental conditions able to take into account the overall impact of the environment on the wind turbine. Hence, this paper focusses on the validation of the loads resulting from the application of environmental assumptions in the design process. In order to validate the applied procedures, the loads resulting from assumptions are calculated by a previously validated simulation model and then compared to loads resulting from conditions in the real environment. In the presented work, focus is put on power production fatigue loads, as presented in the IEC 61400-3 design load case (DLC) 1.2 [1] at the tower top and tower base. This design load case covers a large range of environmental conditions. Therefore, focus is put on the analysis of the statistics of the resulting damage. Environmental and load measurements for the evaluation are available from the wind farm alpha ventus.

The presented work was performed within the research project OWEA Loads using data from the wind farm alpha ventus in the North Sea. A brief overview of the project, the available measurements as well as the applied simulation model is provided. Following this, the applied methodology for validation of assumptions is presented. This procedure is then applied to the available data from both measurements and simulations. Here, findings from the selection of measurements and the setup of simulations are shown, as well as the calculation of damage values from time series data from measurements and simulations. As soon as the resulting damage data is available from measurements and simulations, statistical evaluation is performed by application of Monte Carlo and Bootstrap procedures, which is presented. Finally, the results of statistics are presented and compared.

2. Regarded turbine and measurements

In this study, measurement data from a Senvion 5M turbine (5MW rated power) is used (Figure 1). The turbine is positioned on top of a jacket substructure (designed by OWEC TOWER AS) including four pairs of bracings. The turbine and substructure are equipped with a total of over 100 sensors providing detailed data of the status of the overall system including SCADA, loads, accelerations, environmental conditions and corrosion. The data is provided in 10 minute time series and both statistical as well as high resolution (up to 50 Hz) data is available through a project website. Additionally, environmental data from the close FINO 1 meteorological mast is used for the evaluation of environmental conditions. Strain gauges that are positioned around the upper and lower tower sections allow the calculation of tower base fore-aft bending moments ($M_{TB,FA}$) as well as the tower top resulting bending moment ($M_{TT,Mres}$) that are evaluated in this study.

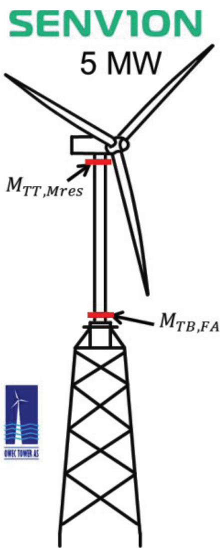

Figure 1: regarded turbine Senvion 5M and considered positions for load evaluation in this study, i.e. tower top resulting bending moment and tower base fore-aft bending moment

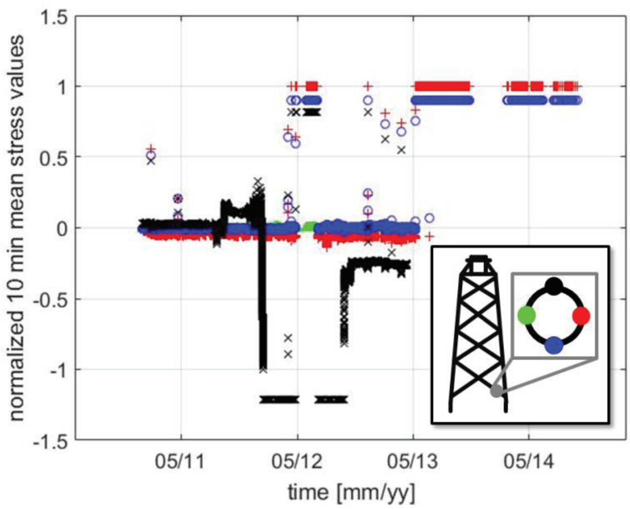

Figure 2: exemplary output of jacket brace strain gauges (ten minute mean stress values) below sea level from 2010 to 2014. The threshold for loads from environment is expected to be in the range of [-0.2, 0.2].