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Comparison of Measured and Simulated Structural Loads of an Offshore Wind Turbine at Alpha Ventus

Kolja Müller, Mario Reiber and Po Wen Cheng
Stuttgart Wind Energy, Institute of Aircraft Design, University of Stuttgart
Stuttgart, Baden Wurttemberg, Germany

A comparison of fatigue and extreme loads from simulations with full-scale measurements collected over a period of ten months in the offshore test field, Alpha Ventus, is presented in this paper. There are two goals of this study: (1) to check if the measured range of fatigue and extreme loads can be captured correctly by simulations when the variations of relevant environmental parameters are taken into account; and (2) to investigate if measured extreme loads can be reproduced by simulations when ten-minute averages of the environmental parameters are used. The results show a good overall match of loads when the variation of environmental parameters is considered but an insufficient match when the events of maximum load occurrence are compared.

INTRODUCTION

The site-specific design of offshore wind turbines requires the use of simplified assumptions of the environment in order to limit the number and detail of simulations to be performed. Additionally, a set of physical assumptions is implied in the various aero-servo-hydro-elastic models used for the simulation of the loads of offshore wind turbines. These include models for the wind and wave environment and models for the load transfer from the environment to the turbine and between system components.

The use of simplified environmental assumptions is generally justified by the use of conservative estimates for environmental parameters (Türk and Emeis, 2010). The verification and validation of the models used to describe offshore wind turbines involve code-to-code comparisons (Jonkman and Musial, 2010; Popko et al., 2012) and comparisons to scaled experimental data (Müller et al., 2014).

To complete the design process and learn from it, a thorough validation of physical models at full scale and subsequent environmental assumptions are necessary in order to identify shortcomings and highlight the potential for less conservative designs and/or additional simplifications within the process of site-specific project certification.

Söker et al. (2006) presented a procedure for full-scale load validation for onshore wind turbines. Guidance for load validation can also be taken from IEC TS 61400-13 (2001). Generally, the goal is to validate the models on the basis of specific environmental events, which has been done in previous studies (Yde et al., 2015; Zierath et al., 2014; Koukoura et al., 2013; Kaufer and Cheng, 2014). Regarding offshore wind turbines, a simplified set of load cases for load validation at full scale is presented:

(1) Gravity load case: Without environmental influence, turbine in parked or idling position, for sensor calibration.

(2) Nacelle or rotor revolution: Without environmental influence, for sensor calibration.

(3) Frequency domain comparison: Moderate environmental conditions (below rated wind speed, low turbulence intensity, and low wave height).

(4) Statistical load comparison: Average environmental data, compares the minimum, maximum, mean, and standard deviation of loads.

As part of the University of Stuttgart-led RAVE project, OWEA LOADS, the validity of simulation models and design procedures is investigated. Data is made available from the offshore test field, Alpha Ventus (DOTI, 2015), which provides a unique opportunity to validate both numerical models and environmental assumptions due to the extensive data of both turbine loads and simultaneous environmental conditions. Load measurements from the Senvion 5M turbine fixed on a jacket substructure are used along with the environmental measurements from the FINO1 platform (see Fig. 1).

For the considered turbine, Kaufer and Cheng (2014) carried out a full-scale validation of the simulation model describing the considered turbine and substructure on the basis of specific environmental conditions. On the basis of the full-scale measurements, state-of-the-art load validation was performed, and it was shown that the integrated simulation models for offshore wind turbines are able to capture relevant loads if the environmental conditions are comparable for both simulations and measurements (see load case 4 above).

In an overall validation procedure of the site-specific design of offshore wind turbines, the subsequent step in the model val-

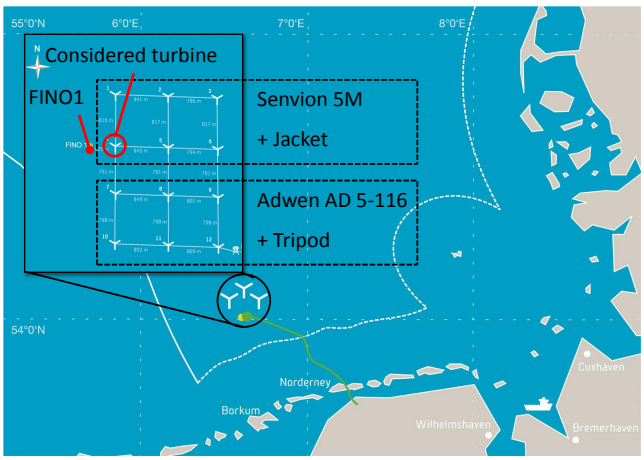

Fig. 1 Location and layout of Alpha Ventus (DOTI, 2015)

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