Validation of an Integrated Simulation Method with High Resolution Load Measurements of the Offshore Wind Turbine REpower 5M at Alpha Ventus

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ABSTRACT

The validation of load simulations with offshore field measurements in the research wind farm Alpha Ventus, Germany, is presented in this paper. Simulations are carried out with the integrated load simulation tool Flex5-Poseidon, which treats the aerodynamics, hydrodynamics and elastic motion in a coupled dynamic analysis. The reference wind turbine is the REpower 5M with a jacket substructure installed in the North Sea, 45km offshore at 28m water depth. Comparisons are based on stresses and loads at the rotor blades, tower and substructure. High resolution measurements of a one year period form the basis for the comparison.

KEY WORDS

Offshore wind energy; integrated simulation; measurements; loads and dynamics; Alpha Ventus; validation; Flex5-Poseidon

INTRODUCTION

The design of offshore wind turbines with lattice support structures can be optimized using integrated load simulations. This means that the complete offshore wind turbine, including the support structure, is simulated with aerodynamic and hydrodynamic loads concurrently. Such methods have been developed and verified (Figure 1), but only a small number of offshore measurements, often with limited data, have been conducted to allow extensive validations (Ostermann, 2009).

The aim of this paper is to contribute to the validation of integrated load simulation tools (Figure 1). For this purpose the high resolution measurements at the offshore test site Alpha Ventus are analyzed in detail. The measurements are carried out at the nearby met-mast FINO1 and the wind turbine R4 which is a REpower 5M installed on a jacket substructure. A wide range of measurement devices have been installed. However, for this validation task the most important information are the environmental conditions and the load measurements. The loads and motions are monitored by strain gauges and accelerometers in the rotor blades, tower and jacket substructure. Most problematic is the derivation of accurate spatial environmental data for the simulations because only punctual measurements at the met mast or at the nacelle of the turbine are available. Simulations are carried out using Flex5-Poseidon (Kaufer, et al., 2009), a coupled integrated approach for dynamic load simulations of wind turbines in the version of the Stuttgart Wind Energy research group. A model of the REpower 5M has been created and includes the rotor-nacelle-assembly, tower, transition piece, jacket substructure, foundation and the control system.

The validation of Flex5-Poseidon consists of three phases. The first phase is a nacelle rotation under calm weather conditions. This simple load case enables also plausibility checks of the measurement data using hand calculations. The second phase is a direct simulation of a measured time series during quasi-steady environmental conditions. Such conditions support periodic system reactions. The results are presented in frequency and partly in time domain. The last phase shows the statistical comparisons of loads during normal operation using data from January 2011 until December 2011.

REFERENCE WIND TURBINE AND MEASUREMENT CAMPAIGN

Reference Wind Turbine: REpower 5M with Jacket

All simulations and measurement results are based on the REpower 5M wind turbine installed at the wind farm Alpha Ventus. The research wind turbine is located to the east of the met mast FINO1. The free stream inflow directions are from 190° to 260° and 280°-350° with respect to North. The turbine has a hub height of 92 m, a rotor diameter of 126 m and a rated power of 5MW. The total height from mudline to hub is 120 m. The jacket substructure including the transition piece has a length of 55.7 m. The four main legs are stiffened by four levels of x-bracings. The main legs are free flooded by sea water. Braces are sealed and filled with air. Marine growth up to 50 mm thickness occurs at the structure. The mean sea level is 28 m. The foundation consists of four...