A Review of Current Guidelines and Research on Wind Modelling for the Design of Offshore Wind Turbines

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ABSTRACT

The standards used in the design of offshore wind turbines, particularly the rotor-nacelle assembly, are based on those used for onshore wind turbines, and as a result simplifications regarding the marine boundary layer are made. Stability in the offshore marine environment has been shown to have a significant influence on the fatigue and wind energy calculations; however most of the current standards still assume neutral wind conditions. The methods used in the standards to determine the vertical wind profile are based Monin-Obukhov surface layer theory (MOST). Lower surface roughness and hence lower turbulence offshore can result in a reduction in the marine boundary layer height, as a result extrapolation of the profile above 60m may no longer be valid. The turbulence models used in the standards have also been developed for use onshore but recent work has shown that wind wave effects result may result in very different turbulence characteristics offshore. The following paper will focus on a review the current state of the art in offshore wind modelling and identify the gaps between best knowledge and best practice. Offshore wind data from the FINO platforms on the German coast will also be used to demonstrate the importance of including stability and thermal effects in offshore wind modelling. The data will also be used to demonstrate importance of non-logarithmic wind profiles.

KEY WORDS: Wind Turbines; Offshore; Guidelines; Stability; Turbulence; Wakes; FINO data base.

INTRODUCTION

This work has been performed as part of a research project to investigate and evaluate existing offshore wind standards, with special focus on the use of metocean data and forecasting products, and find ways to develop improved methods for forecasting the uncertainty elements and hence to obtain better energy production forecasts for offshore wind turbines. At present external wind conditions in the offshore regime are defined in guidelines by Det Norske Veritas (DNV), International Electrotechnical Committee (IEC) and Germanischer Lloyd (GL).

- DNV-OS-J101: Design of Offshore Wind Turbine Structures, September 2011
- DNV-RP-C205: Environmental Conditions & Environmental Loads, October 2010
- IEC 61400-1. Wind Turbines – Part 1: Design Requirements, 2005
- GL Guideline for the Certification of Offshore Wind Turbines, Ed. 2005

The American petroleum Institute (API, 2000) and the International Standards Organization (ISO, 2004) have developed standards relevant to offshore technologies. These standards do not specifically address offshore wind turbines; however considerable guidance is given for the design of offshore structures in general, particularly with regard to structural integrity. The API and ISO guidelines are referenced here for completeness but are not discussed in detail in this paper.

OFFSHORE WIND DATA

All the standards state that the wind conditions should preferably be determined from measurements at the site in question. The site conditions should then be correlated with long-term records from local meteorological stations. The IEC standards state that the measurement period should be sufficiently long to obtain reliable parameters but they do not specify a time period. The GL guidelines specify that a minimum measuring period 6 months is required, however if seasonal variations contribute significantly to the wind conditions, then the measurement period should account for this. The DNV-RP-C205 recommends that for design the wind climate database should cover a 10-year period or more of continuous data with sufficient time resolution. In the absence of suitable long term measurements they suggest that the wind velocity climate can be estimated from hindcast wind data and DNV-RP-C205 references the World Meteorological Organisation (WMO, 1983) to obtain the minimum requirements to hindcast models and their accuracy. The offshore wind standard DNV-OS-J101 however suggests that the 10 min mean value of wind speed should be obtained from several years of data.