Report on the Research Project OWID – Offshore Wind Design Parameter

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Offshore wind energy can play an important role to support the aim of producing 20% of the total electricity demand by renewable energies by 2020. Most of the projected German areas for the offshore use however lie far away from the coast in water depths up to 40m. For this situation no real experience is given. Even the Danish offshore North Sea wind farm "Horns Rev" erected in 2002 cannot be compared directly as it has a much shorter distance to the coast line of about 14-20km. The FINO1 platform which is installed in 2003 about 45km off the island Borkum is equipped with a met mast with a height of about 100m and records the long term meteorological and oceanographic conditions in the North Sea.

Within the project OWID the FINO-data are used to reduce incomplete knowledge when adapting wind turbines to the maritime conditions. We start with a thorough evaluation of the acquired FINO1 data with the focus on the mechanical loads a wind turbine is exposed to. In addition to the undisturbed wind field the disturbed wind stream within the wake field is simulated by CFD models as we think that the major part of the load origins in the wake area. Both undisturbed and disturbed wind fields are used to calculate the loads on a realistic offshore wind turbine with regard on the lay out and the life time.

To keep the project close-to-reality manufacturers of multi-megawatt wind turbines are included not only by giving financial support but also supplying realistic models of multi-megawatt wind turbines. The project shall result in proposals to improve the existing guidelines to minimise risks in the planning, building and operation phase of offshore turbines and to set up a reliable basis for financing and insurance of the scheduled projects in the German Bight.

Relevant Standards and Guidelines

At present external wind conditions in the offshore regime are defined in guidelines by GL, IEC and DNV.

DNV*	Design of Offshore Wind Turbine Structures, Ed. June 2004
IEC 61400-3*	Design Requirements for Offshore Wind Turbines, Working Draft, July 2005
GL	Guideline for the Certification of Offshore Wind Turbines, Ed. 2005

* in connection with IEC 61400-1 Design Requirements and DNV/ Risoe Guidelines for Design of Wind Turbines (onshore focused)

It is an usual approach within the guidelines to define a reference and average wind speed for certain classes together with parameters for different turbulence regimes. While the DNV and IEC guidelines still refer to the onshore related IEC-61400-1, the GL-Offshore already introduced a special subclass C with a lower assumption for the turbulence as can be seen from Fig. 1. For the standard classes a Rayleigh distribution of the wind speed is assumed, for the site specific class a Weibull distribution is used, based on individual measurements. For the FINO1 site Weibull parameters A=11.2m/s and k=2.26 have been found by an analysis of the data for the years 2004/2005.

Normal Wind Profile

Preliminary results shall be presented for two parameters of the normal wind conditions. The first one is the Normal Wind Profile (NWP) that is defined quite similar in the above mentioned guidelines. The mean wind speed V at height z is consistently given as a potential law

[1] Design Parameters and Load Assumptions for Offshore WEC in the German Bight on Basis of the FINO-measurements

$$V(z)=V_{hub}\,(z/z_{hub})^{a} \qquad (1)$$

and V_{hub} is the wind speed at hub height z_{hub}. Fig. 1 shows the “onshore” wind profile (a=0,2) according to IEC-61400-1 in comparison with the “offshore” profiles defined by the GL-guideline and IEC-61400-3 (a=0,14). In addition mean wind profiles as measured at the FINO1 platform during 2004 have been plotted. As could be expected, the “onshore” NWP according to IEC-61400-1 exaggerates the measured wind profile, while the assumption in the GL and IEC-61400-3 seems to reproduce the right trend compared with the measured mean wind profile and looks like a conservative assumption. The strong dependence of the profile on the atmospheric stability however is neglected. When T_{water} is less than T_{sea}, the measured profile exaggerates the profile of the GL and IEC-61400-3 drastically. It must be mentioned that these observations are preliminary and must be assured by a more detailed analysis during the OWID project.

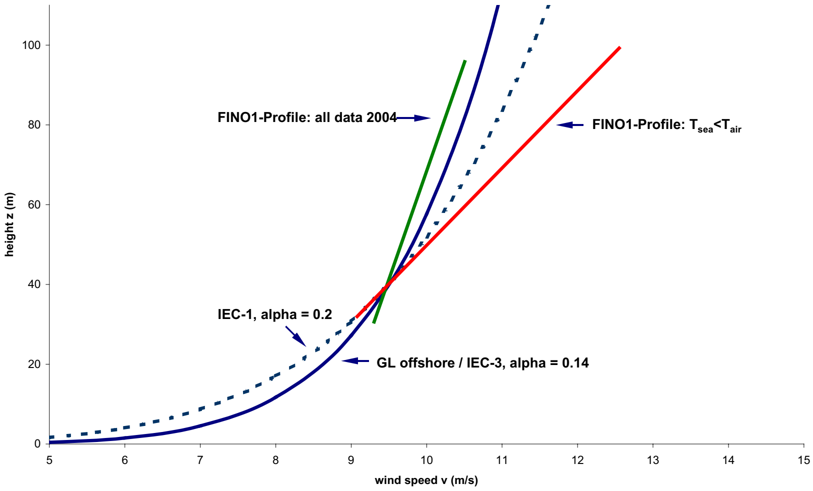

Fig. 1: Measured wind profiles at the FINO1-platform in comparison with the IEC-61400-1 and –3 and the GL-Offshore Guideline

Normal Turbulence Model

Turbulence intensity is one important parameter for the definition of the external load assumptions, normal turbulence is described within the Normal Wind Turbulence Model (NTM). It defines a monotone decline of the turbulence intensity with increasing wind speed. In the GL-guideline and IEC 61400-1 Ed. 2 it is defined as

$$\sigma_1 = I_{15}\,(15m/s + aV_{hub})/(a+1) \qquad (2)$$

with the class parameters a and I15. This leads to the functional behaviour as shown in Fig. 2 for the turbulence classes A and C. The turbulence definition in the IEC-61400-1 Ed. 3 is analytically different but reveals similar values for the considered cases. Again measured turbulence intensities at the FINO1 platform have been plotted for comparison. The values have been collected during January, July and December 2004 at the 100m level.

The intensities in the definition of turbulence class C as well as for turbulence class A seem to be an upper limit for the measured values. As a rough picture intensities are scattered around an average value of 5-8% for wind speeds above 8m/s, which is only half the value as given by class C. In contrast to the turbulence class model the lowest measured values can be found for wind speeds in between 8-10m/s and they are slightly increasing for higher wind speeds. The reason for this behaviour hasn’t been clarified up to now, one major effect will certainly stem from the influence of waves which produce a larger surface roughness for higher wind speeds. Again it must be stated that a further analysis of these effects is necessary and will be carried out during the project.

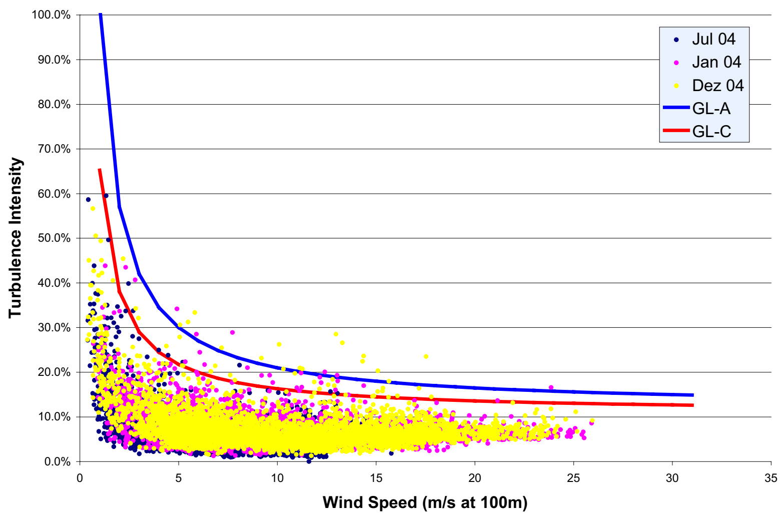

Fig. 2: Turbulence intensities according to GL-Offshore Guideline and measured at the FINO1 platform within 2004

Extreme Wind Conditions

Extreme wind conditions are defined in order to represent the basis for extreme overall loads, extreme load changes and extreme inhomogeneities of the load distribution. They are standardised as

- Extreme wind speed model (EWM)
- Extreme Operation Gust (EOG)
- Extreme Direction Change(EDC)
- Extreme Coherent Gust (ECG)
- Extreme Coherent Gust incl. Direction Change (ECD)
- Extreme Wind Shear (EWS)

Assessment of FINO-Data regarding Loads

	Load Parameter to be assessed	Data to be assessed from FINO-Data	Link to standards
1	mean extreme overall load	extrapolated maximum wind speed for a 10min interval	EWM
2	mean vertical load shear on the rotor	maximum value of vertikal wind speed and wind direction shear	EWS
3	turbulence intensity as a function of height	evaluation of the variance of the three wind components as a function of wave height, wave age and sea surface spectra	NTM
4	short term extreme loads	gust parameters depending on height	EOG,EDC
5	time constant for the occurence of extreme loads	derivation of the maximum wind speed increase during a gust	EOG, EDC

Tab. 1: Examples for an assessment of extreme wind conditions

A thorough analysis of the FINO1 data will be carried out in order to verify extreme load conditions for the offshore application. In Tab. 1 examples for the data analysis and the connected extreme wind parameters are given.

Outlook

The starting point for OWID is the measured “undisturbed” wind conditions at the FINO1 platform. For large offshore wind farms, wind conditions will be severely influenced by the wake area of the wind turbines. This extra turbulence may dominate the design conditions for certain situations. Therefore in a next step wind park effects will be simulated by using Computational Fluid Dynamics (CFD) methods [3,4]. Both undisturbed and disturbed (park effect) wind conditions are taken as input for modelling a 5MW wind turbine and study the effect on the layout. Together with an evaluation of life time effects this will be the basis for proposals to improve the definition of standard wind conditions in the guidelines.

References

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