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Site Assessment of the floating wind turbine Hywind Demo

Anja Eide Onstad[a], Marit Stokke[a], Lars Sætran[a,*]

[a]*Department of Energy and Process Engineering, Norwegian University of Science and Technology*

Abstract

This Site Assessment predicts which environmental conditions an object at the Hywind Demo site will be exposed to. The work is based on 2 years of data from a Seawatch buoy located at the site. By use of Gumbel distributions the 50 year extreme values of wind gust at 3.5 m height (30.5 m/s), ocean current speed at 20 m depth (1.4 m/s) and significant wave height (13.3 m) have been found.

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1. Introduction

In 2009 Statoil installed the world's first full-scale floating wind turbine off the coast of Karmøy in the North Sea. The Hywind Demo is a 2.3 MW floating turbine with a 65 m hub height and a rotor diameter of 82.4 m [1]. In order to estimate the expected wind energy output and costs of such a project it is crucial to predict the average wind speed at turbine hub heights [2].

This work aims to estimate the conditions of wind, ocean currents and waves at the Hywind Demo site, based on 2 years of data from a Seawatch buoy located 200 m west of the turbine, as displayed in Figure 1. Further, it is of special interest to estimate the extreme environmental conditions at the site in order to estimate the extreme loads on the turbine. For onshore wind the Measnet guidelines [4] are widely used for site assessments, and as there do not exist similar guidelines for offshore sites, these guidelines are used for the Hywind Demo site [5].

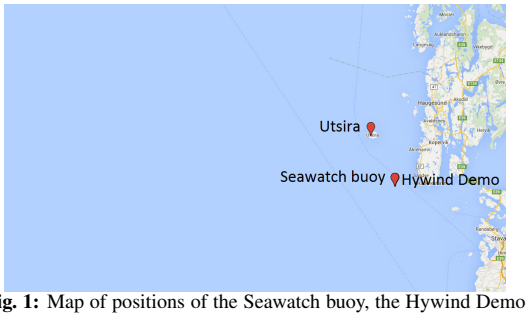

Fig. 1: Map of positions of the Seawatch buoy, the Hywind Demo turbine and the meteorological station at Utsira from Google Maps [3].

*Corresponding author
Email address: lars.satran@ntnu.no (Lars Sætran)

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2. The Seawatch buoy

The Seawatch buoy was deployed (59°08.42'N, 5°01.78'E) from August 13th 2009 until September 19th 2011. 76 % of the data from this time period are available. Data are stored as time series for parameters characterizing wind, ocean currents and waves. The overall height of the Seawatch buoy is 8.6 meters, the diameter is 1.76 meter and the weight is 710 kg [6].

Figure 2 is a schematic of the Seawatch buoy carrying instruments measuring the following metocean parameters [6]:

- Wind speed, direction and gust at 3.5 m above the sea level
- Wave height, period and direction relative to mean sea level
- Current speed and direction, from 3 to 180 m depth.
- Air pressure near the sea level
- Air temperature 3.5 m above sea level
- Air humidity 3.5 m above sea level
- Water temperature at 2 and 3 m depth
- Conductivity of the water at 2.0 m below the sea surface

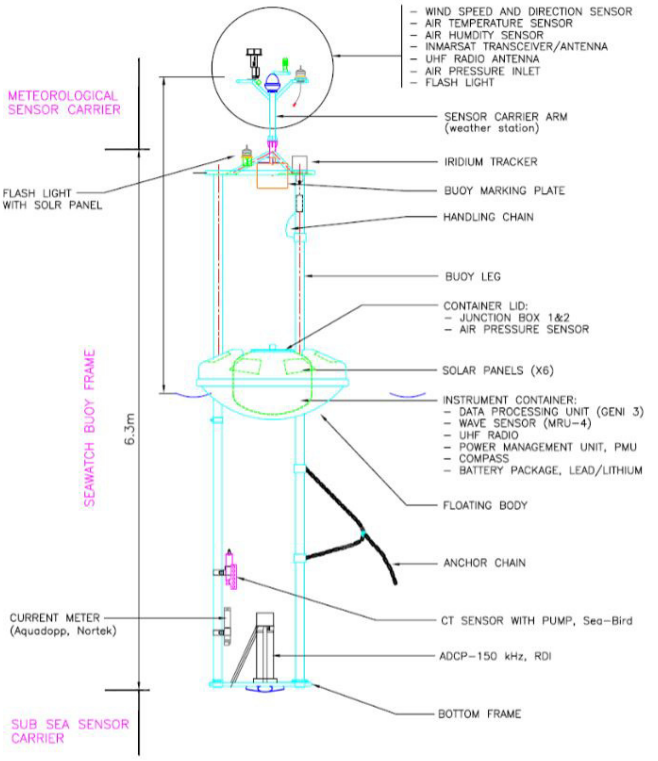

Fig. 2: The Seawatch buoy

3. Method

3.1. Wind speed profile

Wind data are measured every second at 3.5 m height and saved as 10-minute mean and 3 second gust values. The mean wind speed profile variation with height above the surface is described by the power law [7, 8, 9], with the power law exponent $\alpha = 0.11$, based on the recommendations and findings of DNV [8], Hsu et al. [10], Johnson [11] and Turk et al. [12]. Atmospheric stability is not considered in this work.

3.2. Long term extrapolation of the mean wind speed data

Measure-Correlate-Predict (MCP) algorithms analyze wind speed and direction data measured at a target site and a nearby reference site and find a relationship between the two data sets used to predict long term data at the target site [13]. In the following, the Matrix Time Series algorithm [13] is used to long term extrapolate the mean wind speed data from the buoy. 10 years of data from the nearby meteorological station Utsira have been used as reference data. Utsira is an island located approximately 20 km North of the Hywind demo site, as indicated in Figure 1. In order to evaluate the correlation between the buoy data and the reference data, the coefficient of determination, R^2, is calculated for both the wind speed and the wind direction correlation [14].

3.3. Ocean current

The depth at the Hywind site is 210 m. The current speed and direction have been measured every second with 10 m intervals down to 180 m and saved as 10 minute averages. The mean speed at all depths in addition to the no-slip condition at the bottom are used to obtain the velocity profile.

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