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Energy systems on an autonomous offshore measurement station

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Abstract

In this study, a performance test has been performed on a 200 W marine wind turbine, both in a wind tunnel, and mounted on a Wavescan ocean buoy in a coastal location near Trondheim. Long term wind data satisfying the DNV-RP-C205 recommended practice for describing environmental conditions and environmental loads have been extracted from the Eklima database subordinated the Norwegian Meteorological Institute for a selected location called Sula weather station outside of the Norwegian coast. 10 years of data from Sula and a one-month performance test near Trondheim formed the basis for monthly wind energy estimates at the Sula site. Energy estimates for solar production on the Wavescan have been carried out at the same site utilizing the solar engineering software Meteonorm.

The motivation of the study is to ensure continuous energy supply on remote measurement station enabling one-year autonomous operation. This criterion has proven obtainable at the selected site with an energy system consisting of the solar panels and fuel cells already installed on the standard Wavescan buoys combined with an Air Breeze wind turbine. Estimates show a monthly solar and wind energy production of 44.1 kWh on average, versus a monthly energy demand of 52.8 kWh on average. An alternative solution relying solely on renewable energy resources is to increase the turbine rotor area by 85%, or to introduce a second turbine.

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Keywords: Wind turbine; Eklima; Performance test; Energy estimates; Autonomous operation;

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1. Introduction

Various autonomous offshore measurement stations with different energy systems are deployed around the world. The FINO-platforms situated in the North Sea are powered with diesel generators [1]. Buoys can also fit smaller diesel generators. The Oder Bank and Fehmarn Belt are measurement buoys located in the Baltic Sea that are powered with a combination of diesel generators, solar cells and small wind turbines [2]. Another common energy supply on smaller buoys are batteries, which can be found on the Ocean Station Papa and the Kuroshio Extension Observatory located in the north Pacific [3]. The Wavescan buoy, which is applied in this study is traditionally powered with a combination of batteries and solar panels.

The Wavescan buoy is a floating observation platform with facilities for measuring water current, wave characteristics and also wind speed and wind direction. Since the last couple of years, Lidars have been deployed on the Wavescan buoys. The Lidar-buoys are primarily used for measurement of offshore wind profiles in conjunction with development of offshore wind farms. One of the challenges introduced is the power demand of the Lidar, which is extensive relative to the energy demand of the Wavescan buoy.

The Lidar applied is the ZephIR 300 which has a monthly energy consumption of 50 kWh [4] on average. The overall monthly energy consumption of the Lidar and the rest of the buoy is 52 kWh [5]. Wavescan buoys are usually equipped with four Solara solar panels for power generation. The panels generate 7.5 kWh on average on a monthly base when located in the Norwegian Sea outside of Trondheim. Four chargeable Powersafe lead acid batteries and four Saft lithium backup batteries are installed. The total battery capacity is approximately 13 kWh [5]. In order to make balance in the energy budget, four Efoy Pro 2400 Duo methanol fuel cells capable of sustaining buoy operation for approximately six months without refueling have been installed, combined with solar and batteries.

A small scale wind turbine was selected for testing, first in the wind tunnel at the Norwegian University of Science and Technology (NTNU) and later in the field, mounted on the Wavescan buoy. The system was tested under controlled conditions at a site outside of the pier in the Trondheim fjord. The field test will be used as a base to estimate energy production at a chosen location where long-term wind and solar irradiation data is available as open-access. Finally, the power production of the solar panels and fuel cells already available on the buoy was taken into account and different solutions for a self-sustaining energy system are discussed.

1.1 Wind profile

Wind speed varies with time and height above the sea surface. Therefore, it is important to specify the reference height H where the measurement is done, and the averaging time for the wind speed. According to DNV-RP-C205 recommended practice for describing environmental conditions and environmental loads [6], the wind climate of a certain site can be expressed in terms of the 10-minute mean wind velocity $U(H)$ at the reference height. The wind velocities occurring within 10 minutes can be considered normally distributed around the mean with a given standard deviation σ, which describes the turbulence in the wind. If one wish to know the wind velocity at a certain elevation z, one should correct the velocity at the reference elevation according to the wind profile. Correction is especially important close to the sea surface, even for small elevation differences, due to the sharp gradient of the wind profile close to the surface. In this study, the commonly used logarithmic is used for correction:

$$U(z) = U(H)\left(1 + \frac{\ln(z/H)}{\ln(H/z_0)}\right) \tag{1}$$

where z_0 is a roughness parameter that depends on the wave height, which in turn depends on the wind velocity [7]. The roughness parameter is solved implicitly from the Charnock relationship parametrization:

$$z_0 = \frac{A_C}{g}\left(\frac{k_a U(z)}{\ln(z/z_0)}\right) \tag{2}$$