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Energy systems on autonomous offshore measurement stations

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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 [1] 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 has 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.

Introduction

Wind speed varies with time and height above the sea surface. Elevation 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 profile is used for correction:

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

where z_0 is a roughness parameter that depends on the wave height [2]. Regular Wavescan buoys have one mast with a sensor carrier assembly on top, supporting the ultrasonic wind sensor 4.0 m above the sea surface. The Air Breeze turbine was mounted on top of a second mast, with a resultant hub height of 2.6 m above the sea surface as seen in Fig. 1.

Fig. 1: Turbine on buoy

Methods

The experimental set-up presented in Fig. 2 resembled the planned buoy configuration, where the wind turbine was wired to a battery bank and a thermal load that dissipated produced energy.

It turned out more convenient to measure electrical power compared to mechanical power as the turbine drive shaft was sealed in the turbine house casing, making it impossible to connect it to a torque gauge. Additionally, this solution made the lab test and the field test compatible since the buoy configuration would log current consumption and production, which is directly proportional to electric power.

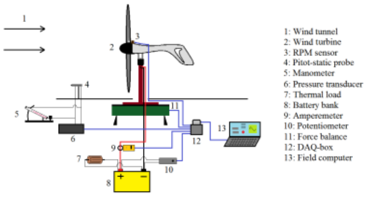

Fig. 2: Wind tunnel test-setup

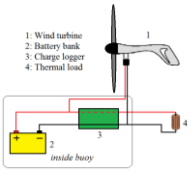

Fig. 3: Electrical configuration on buoy

The wind turbine and its complementary electrical system shown in Fig. 3 was wired isolated from the rest of the buoy in order to reduce sources of error that could disturb the measurements. The turbine was connected to a battery bank and a charge logger was used to monitor current flowing to and from the battery.

Results

The wind turbine was tested in a 2x3 sq. meter cross section wind tunnel and on the buoy located outside of Munkholmen in the Trondheim fjord. The field test period spanned from April 13th till May 25th 2015, with a gap of 10 days from May 8th, due to a malfunction on the wind sensor.

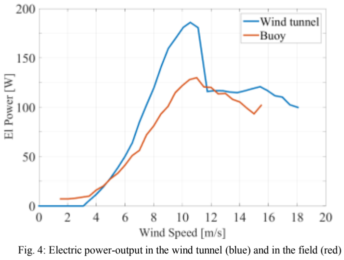

Fig. 4: Electric power-output in the wind tunnel (blue) and in the field (red)

Fig. 4 show a qualitative consistence between the electric power output from the wind tunnel test (blue) compared with the results from the test period on the buoy (red). Wind speeds below 1.5 m/s were discarded due to higher uncertainties associated to standard deviation in these bins relative to the other bins. The power output from the buoy peaked at 128 W. From cut-in speed up to rated wind speed, the output was approximately 35% lower than expected during ideal conditions.

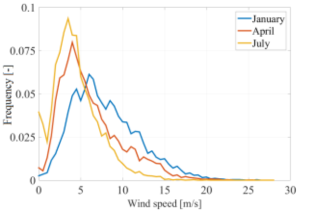

Fig. 5: Wind distributions

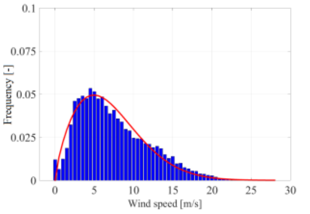

Fig. 6: Weibull fit for average March

Fig. 5 shows the ten year averaged, monthly wind distributions from Sula lighthouse outside the Norwegian coast for three selected months. As an example, the wind distribution and the fitted Weibull distribution for March are plotted in Fig. 6. The two distributions were quite consistent, thus the Weibull distribution was a reasonable assumption.

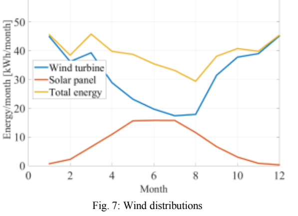

Fig. 7: Wind distributions

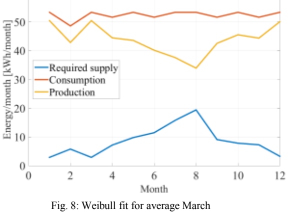

Fig. 8: Weibull fit for average March

Average wind power production on a monthly base at Sula was estimated with the extracted wind data. Solar production on the buoy was estimated with irradiation data from the Meteonorm solar engineering software for the same site. The results are presented in Fig. 7 along with solar and wind combined. When comparing total renewable energy production with energy consumption on board the buoy, presented in Fig. 8, the outcome was not a balanced energy budget. The figure shows a monthly additional energy requirement of 13 kWh on average, less in the winter and more in the summer.

References

[1] "Environmental Conditions and Environmental Loads," DNV-RP-C205, 2014.
[2] H. Bredemose, S. E. Larsen, D. Matha, A. Rettenmeier, E. Marino, and L. R. Sætran, "Offshore wind-wave climates and their scaling to lab conditions," MARINET, pp. 11-15, 2012.

Conclusion

- The solar panels and fuel cells already installed on the standard Wavescan buoys combined with an Air Breeze wind turbine would ensure autonomous operation for 24 months at the selected site, which is a significant improvement compared to the current 6 months operation capacity.
- To ensure a supply system based solely on renewable energy, the turbine area would have to be increased by 85% in order to balance the energy budget throughout the year.
- Alternatively, a second turbine could be introduced. In that case, it is recommended to mount the turbines at different elevations to avoid wake losses when the turbines are aligned with the wind speed direction, and to consider thrust data imparted on the buoy.