Maintenance polar and marine traffic analysis on an existing wind farm

Authors: Lorenzo Colone*, Anand Natarajan*, Nikolay Dimitrov* and Thomas Buhl*

***Technical University of Denmark Department of Wind Energy, Risø Campus Frederiksborgvej 399, 4000 Roskilde, Denmark**

Introduction

– Maintenance activities are based on short term and long term weather forecasts whose derivation relies on historical site-specific data analysis, typically supplied by meteorological masts installed in the area before the construction phase is initiated. Wind-wave statistical correlation is used to predict weather windows both on an annual scale and a monthly scale where the sea state is here represented by wind speed, direction and significant wave height. The objective of this work is a static prediction of weather windows based on the statistics typically available to operators when planning maintenance. Results are compared with real site measurements from two nacelle anemometers and utilized together with the past history of marine traffic analysis within an offshore wind farm.

Problem

– Known parameters : 1. Annual wind speed statistics conditional to wind direction $P(u \mid \theta)$ and marginal wind direction probability $P(\theta)$; 2. Distribution of the wind speed conditional on the month of the year represented by quantiles (percentage of time the wind speed is below a given value $P(U < u)$; 3. Annual and monthly wave statistical distributions for each direction as a function of mean wind speed. The aim is to define a measure of site accessibility conditional to wind speed and direction as driving parameter.

Annual analysis

– The aim is to derive a probability of maintenance $P_{m,\theta}(\theta)$ on an annual scale as the probability of having significant wave height conditional to wind speed below a certain threshold $h_{s0} = 2\,m$. The wind speed range is $u = [0{,}12]\,m/s$. Using statistical data described together with Figure 1 the information needed can be extracted. The probability of maintenance is a measure of the chances to visit the wind farm when knowledge about wind direction is provided. The site accessibility is total percentage of hours the sea state is below the thresholds defined.

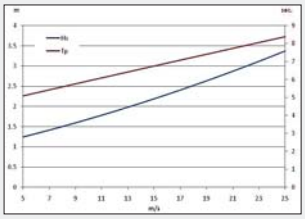

Figure 1 : Significant wave height $h_s(u)$ and wave period $T(u)$ as functions of mean wind speed u

$$P_{m,\theta}(\theta) = P(h_s(u) \le h_{s_0} \mid \theta) = \int_{u_0}^{u_1} p(u \mid \theta)\, p(h_s(u) \le h_{s_0} \mid u, \theta)\, du$$

$$a_\theta(\theta) = P(\theta)\, P_{m,\theta}(\theta) \qquad a = \int_0^{2\pi} a_\theta(\theta)\, d\theta$$

Definition of probability of maintenance $P_{m,\theta}(\theta)$, site accessibility $a_\theta(\theta)$ and the total accessibility as percentage of hours a as a function of wind direction

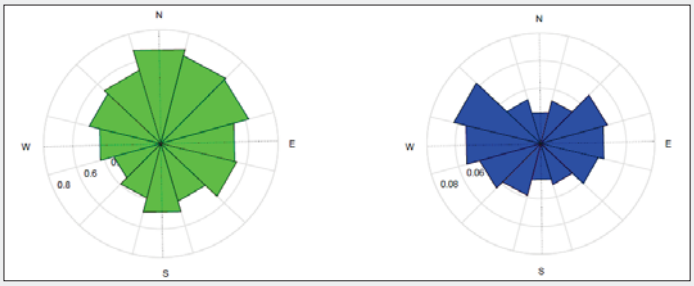

Figure 2 : On the left the probability of maintenance conditional to each direction (green) and on the right (blue) the site accessibility expressed in terms of fraction of hours over one year reference period

Monthly analysis

The transition annual to monthly is performed by combining annual and monthly statistics. From annual data is possible to infer a marginal wind direction distribution for each month $P_i(\theta)$ where i indicates the month. In order to account for a seasonal dependence, monthly wind roses are generated by introducing a random seasonal directional wind speed variability and a distribution $P_i(u \mid \theta)$ is generated for each month. Both $P_i(\theta)$ and $P_i(u \mid \theta)$ satisfy the annual constraints. This is achieved by setting up a non linear constrained system and assuming $P_i(u \mid \theta)$ to be Weibull distributed for each direction for each month. Similarities in the wind speed distribution and directional dependence are encountered between predicted wind roses and real measurements recorded in 2012 and 2013 from two cup anemometers installed on two different turbine nacelle.

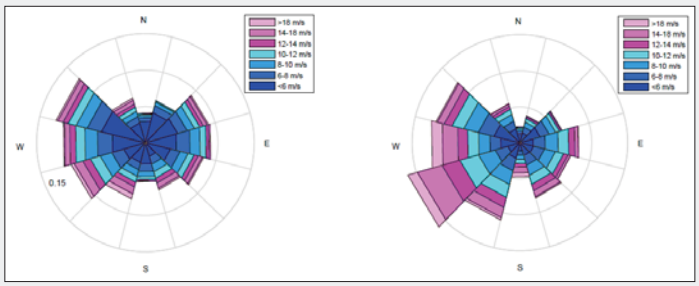

Figure 3 : Example of predicted from historical data wind roses in June and November assuming a random seasonal wind speed variation for each month and direction to match the annual data available.

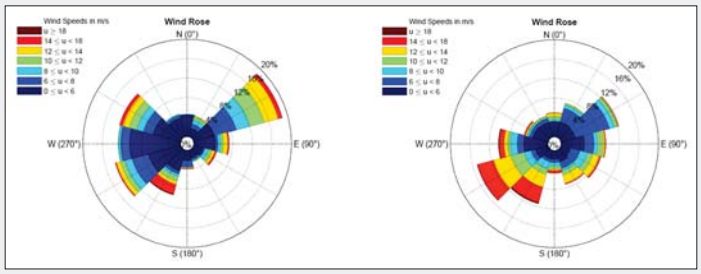

Figure 4 : Example of wind roses in June and November from cup anemometer installed on a turbine nacelle during 2013

Marine Traffic

Marine vessels analysis is used to verify the correspondence between the period of maintenance activity and site accessibility derived from predicted weather windows. Only transport data from heavy vessel activity is considered. Heavy vessels are assumed to be solely deployed for maintenance scope. An analysis is carried out to determine the frequency of visits and the duration of stay for each wind turbine. A vessel is considered to carry out maintenance activity if it is positioned in a radius around the turbine $r < 150\,m$ and the navigation speed $v < 1\,knot$. Cases where the stationary time is less than $2\,hrs$ have not been accounted as such. The effective hours of maintenance are exponentially distributed, meaning that serious activities are performed less frequently than ordinary minor repairs which, however, require medium large sized vessels to be deployed. The analysis allows the estimation of possible maintenance conditions and expected annual turbine downtime.

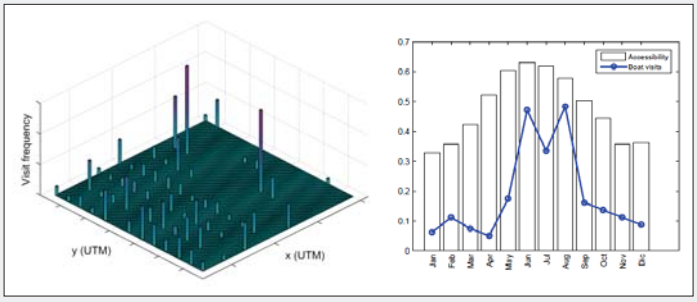

Figure 5 : Left - boat visits frequency histogram wind farm layout. Coordinates in UTM. Right – monthly total site accessibility from predicted roses and histogram real maintenance activity (boat visits s.f. = 2)

Conclusion

In this work historical metocean data measured by a met mast is processed to extract information utilized for planning maintenance. The mean wind speed and significant wave height are used herein to obtain a statistical description and define directional probabilities of maintenance over a certain reference period. The monthly site accessibility is then used to validate actual vessel deployment in the area. The activity is finalized comparing predicted favorable weather period occurrences against heavy vessel visits, showing that the highest probability maintenance corresponds to the period where visits are intensified. Predicted wind roses and measured mean wind speeds show statistical variations which turn into a statistical uncertainty when planning maintenance activities. This procedure is useful when planning long term maintenance activities within a wind farm and historical sea state information is limited.

References

[1] Hagen Brede, Simonsen Ingve, Hofmann Matthias, Muskulus Michael. A multivariate Markov weather model for O&M simulation of Oshore wind parks. Energy Procedia; 2013. p. 137-147.
[2] Scheu Matti, Matha Denis, Hofmann Matthias, Muskulus Michael. Maintenance strategies for large oshore wind farm. Energy Procedia; 2012. p. 281-288.
[3] Anastasiou K., Tsekos C. Persistence statistics of marine environmental parameters from Markov theory, Part 1: Analysis in discrete time; 1996. p. 187-199
[4] Koukoura Christina, Validated Loads Prediction Models for Oshore Wind Turbines for Enhanced Component Reliability, DTU Wind Energy PhD Thesis, 2014
[5] Jose A. Carta, Penelope Ramirez, Celia Bueno. A joint probability density function of wind speed and direction for wind energy analysis; Science Direct; 2008. p. 1309-1320
[6] Eunshin B., Yu Ding, Season-dependend condition based maintenance for a wind turbine using partially osberved Markof observed decision process. IEEE transactions on power systems; 2010
[7] Danish Marittime Authority, http://www.dma.dk/Sider/Home.aspx
[8] Marine Trac, http://www.marinetrac.com/
[10]Johannessen Kenneth, Meling Trond Stokka, Hayer Sverre. Joint Distribution forWind andWaves in the Northern North Sea. Statoil, Stavanger Norway; International Oshore and Polar Engineering Conference; 2001. ISBN 1880653516

Aknowledgment

This project has received funding from the European Unions Horizon 2020 research and innovation program under the Marie Sklodowska- Curie grant agreement No 642108.