DTU Library

Park power deficit due to atmospheric stability

Hansen, Kurt Schaldemose; Barthelmie, Rebecca; Ott, Søren; Larsen, Gunner Chr.

Publication date:
2012

Park power deficit due to atmospheric stability.

Kurt S. Hansen[1], Rebecca Barthelmie[2] , Søren Ott[3] & Gunner Larsen[3]

[1] Department of Wind Energy, DTU, 2800 Lyngby, Denmark;
e-mail: kuhan@dtu.dk

[2] Atmospheric Science and Sustainability,
Indiana University, Bloomington, Indiana 47405, USA.

[3] Department of Wind Energy, DTU

Summary: The purpose of this paper is to present a power deficit analysis based on offshore wind farm measurements with respect to the atmospheric stability classification. The result is used to validate wind farm prediction models under different inflow and atmospheric stability conditions.

ABSTRACT

Recent development of wind farm prediction tools combined with a robust classification of the atmospheric stability enables a validation based on measured annual energy production for a complete wind farm.
Grouping two or more wind turbines, results in a loss of energy production when the turbines operate in the wake of each other. The size of the wake deficit depends on wind direction, wind speed, turbulence, spacing, atmospheric stratification and operational characteristics of the wind turbine. Since the wake deficit can result in 10-20% power loss, it is extremely important to include the wake deficit in the wind farm optimization process.
Recent analysis of the wake deficit has been based on SCADA (Supervisory Control And Data Acquisition) recordings, obtained as 10 minute statistics from large wind farms. The recordings, used in this investigation, have been obtained from Horns Rev offshore wind farm [1] with a rectangular shape and uniform inflow conditions due to long offshore fetch. Performing wake deficit analysis on wind farms, situated in pastoral or complex terrain is much more complicated due to local terrain and thermal effects.
Figure 1 demonstrates a distinct relation between mean turbulence intensity and wind speed with respect to the stability classification for an undisturbed flow sector. The power deficit has been determined as 1- power ratio between two operating wind turbines in [2]. Previous investigations have revealed an average deficit distribution representing a large wind speed interval, but increasing the number of wind farm recordings combined with a robust classification, results in more detailed analysis. A power deficit distribution, as function of the inflow direction for three stability classes [1] is shown in Figure 2, where the width of the deficit distribution depends on the atmospheric stability. The main conclusion from Figure 2 is that a higher power deficit can be expected for stable stratification; which has been illustrated in Figure 3. Figure 3 illustrates the mean power deficit for 30° inflow sector along 6 rows, each consisting of 10 turbines. The deficit increases downstream and converges towards 0.35 - 0.4 for neutral to unstable conditions. The deficit increases towards 0.45 for stable and very stable conditions.

The mean park power has been determined for a 360° inflow sector with a sector size of 5°, for wind speed intervals between cut-in and rated wind speed. All the power values have been filtered before use, according to the guidelines given in [2]. Figure 4 shows the park power for 9±0.5 m/s for two stability conditions: vs–s and ns-vu representing the two distinct differences from Figure 3; 100% represents the reference production from the undisturbed turbines. The annual energy production, weighted to the local wind speed distribution, wind rose and the stability classification is reduced with approximately 2% and results in an estimated wind farm efficiency of 81%.

CONCLUSION

The analysis shows that the park power deficit is sensitive to the atmospheric stability. Analyzing SCADA data from the Horns Wind farm shows a reduction of the wind farm efficiency 2 % when including the atmospheric stability.

ACKNOWLEDGEMENTS

Research has been performed in part by EUDP 64010-0462 and funded by the Danish Energy Agency. We would like to acknowledge Vattenfall AB and DONG Energy A/S for using data from the Horns Rev offshore wind farm.

REFERENCES

[1] Hansen KS, Barthelmie RJ et.al., The impact of turbulence intensity and atmospheric stability on power deficits due to wind turbine wakes at Horns Rev wind farm, WIND ENERGY (2011) 10.1002/we.512

[2] Barthelmie RJ, Frandsen ST, Rathmann O, Hansen KS, Politis E, Prospathopoulos J, Schepers G, Rados K, Cabezón D, Schlez W, *Flow and wakes in large wind farms: Final report for UpWind WP8, Appendix 6: Guideline to wind farm wake analysis.* Report number Risø-R-1765(EN) February 2011

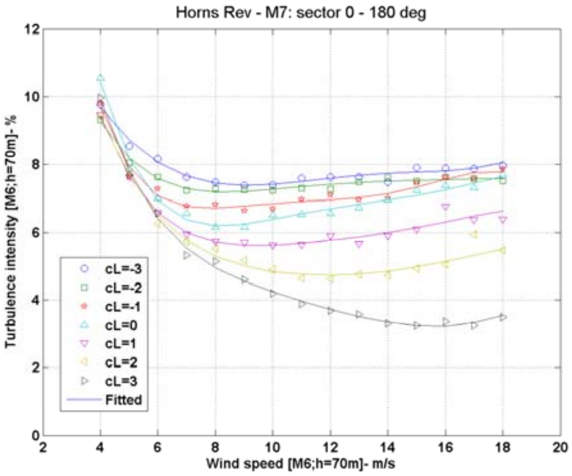

Figure 1: Turbulence intensity at Horns Rev, DK as function of wind speed for 7 atmospheric stability classes: vs, s, ns, n, nu, u & vu.

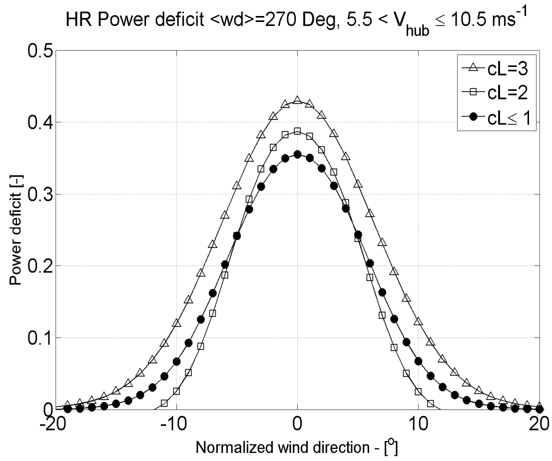

Figure 2: Fitted power deficit distribution for two 7D spaced offshore turbines at Horns Rev wind farm. The distribution has been determined for three stability classes: vs, s and ns-vu.

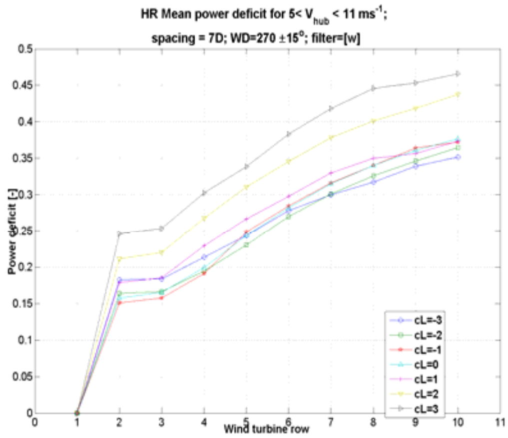

Figure 3: Power deficit along rows of turbines at Horns Rev wind farm for 7 stability classes: vs, s, ns, n, nu, u & vu.

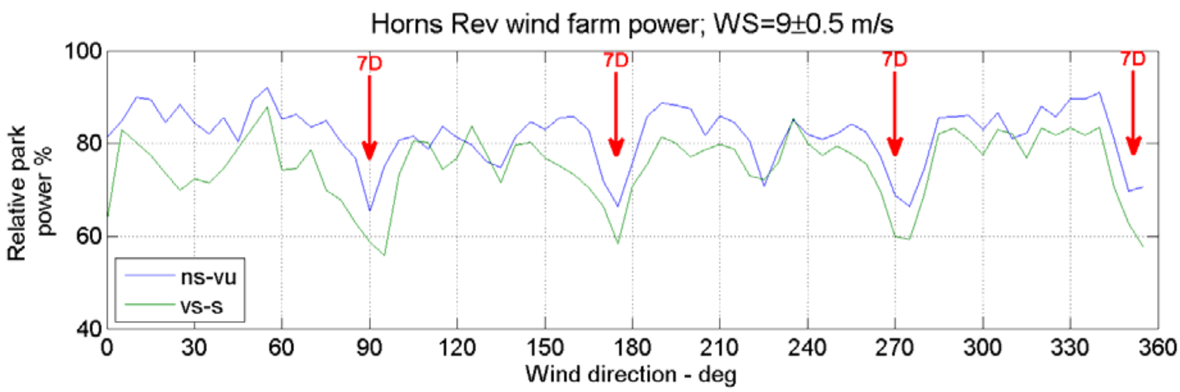

Figure 4: Average wind farm power for 9±0.5ms^{-1} for 0 - 360 deg inflow sector, with 100% as the reference power.