Wind farm wake effects on the wind conditions and the fatigue loads of the offshore wind farm Alpha Ventus



Marcos Ortensi

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1. Motivation

Offshore wind energy will play a meaningful part in the efforts against climate change and in the green energy transition. Therefore, it is very important to study the uncertainties and risks of this source.



2. Objective

To analyze how wakes from an offshore wind farm affect the wind conditions and fatigue loads of wind farms in the vicinity. Data from FINO1 and Alpha Ventus were used to answer the two research questions:

Which are the long-term effects of wakes from surrounding wind farms on wind conditions at FINO1?

How the wakes from the nearby wind farms Borkum Riffgrund 1 and Trianel Windpark Borkum I impact the performance and fatigue loads of Alpha Ventus?



Source: https://www.4coffshore.com/offshorewind/



3. Methodology

In order to compare the effects caused by the wind farms on wind speed and turbulence intensity, four measurement phases have been defined according to the commissioning dates of the wind farms of the cluster in area N2.



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4. Wake effect on wind speed - time series

Wakes are a consequence of the extraction of kinetic energy from the wind, therefore the wind speed in wakes are reduced compared to undisturbed winds.



5. Wake effect on turbulence intensity – time series

Besides the reduction in wind speed, wakes also make downstream winds more turbulent. This is evidenced by an increase in turbulence intensity.



5. Wake effect on turbulence intensity – polar plot

The average turbulence intensity during each measurement phase for the 15-degree wind direction bins clearly shows the wind farms wake effects.





6. Effect of turbulence on Alpha Ventus' performance

In general, increased turbulence intensity causes an adverse effect on the performance of wind turbines. Turbulence impacts the power curve mainly at wind speeds slightly lower than the rated wind speed. However, this effect it can't be asserted because of the change on rated power in phase 3.



7. Wake effect on damage equivalent loads

Damage equivalent load and standard deviation are correlated, because as higher the standard deviation in a time series, as higher will be the ranges for the cycle counting and, consequently, as higher will be the damage equivalent load.



8. Wake effect on 20-year extrapolated DEL

In order to verify the wake effect on fatigue loads for the whole lifetime of Alpha Ventus, the load spectra of phases 2 and 3 were extrapolated for 20 years and DEL was calculated for the entire wind speed range.



AEP [GWh]	
Phase 2	27.3
Phase 3	24.4





9. Conclusions

• **Discernible decrease** in the mean wind speed and a **significant increase** in the mean turbulence intensity caused by the **offshore wind farms**.

• Wakes from Borkum Riffgrund 1 and Trianel Windpark Borkum I affect the performance of Alpha Ventus. No significant impact in mean values, but clear increase in standard deviation.

• The **increased TI** caused by the wakes is responsible for the **increase in the fatigue loads**. At wind speeds below the rated speed, DEL is higher during phase 3.

• The reduction in rated power **reduced the overall fatigue damage**. However, the consequent **reduction in AEP** makes the **kWh** produced under wake effects **more harmful** to the turbine, compared to free flow conditions.



Thank you.

