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Linking calculation of wakes from offshore wind farm cluster to the Danish power integration system

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Abstract

For the first time, the Danish power integration system takes into account of wake effects from large offshore wind farm clusters. The wake effect was calculated through an innovative, mesoscale wind-wave-wake coupled modeling system developed at DTU Wind Energy Department.

Objectives

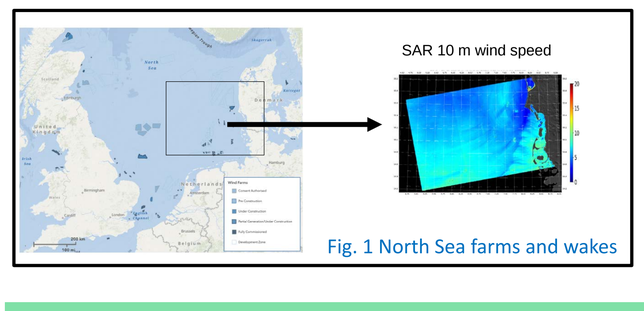


Fig. 1 North Sea farms and wakes

Offshore wind farm clusters are growing, see Fig. 1 for the crowdedness over part of the North Sea. Farms downwind of other farms suffer from reduced wind resource, namely the wake effect (e.g. Fig. 1). This farm-farm wake effect has never been taken into consideration in a power integration system.

In an offshore environment, winds interact with waves. This project also aims to answer how the interaction is between winds, waves, currents and wakes (Fig. 2, [1]), and how it will affect the power integration system. Eventually an optimized modeling system will be recommended for the offshore application.

Methods

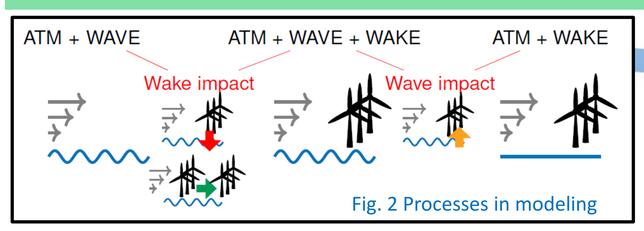


Fig. 2 Processes in modeling

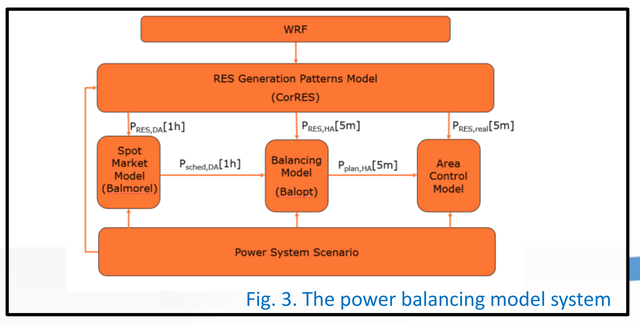
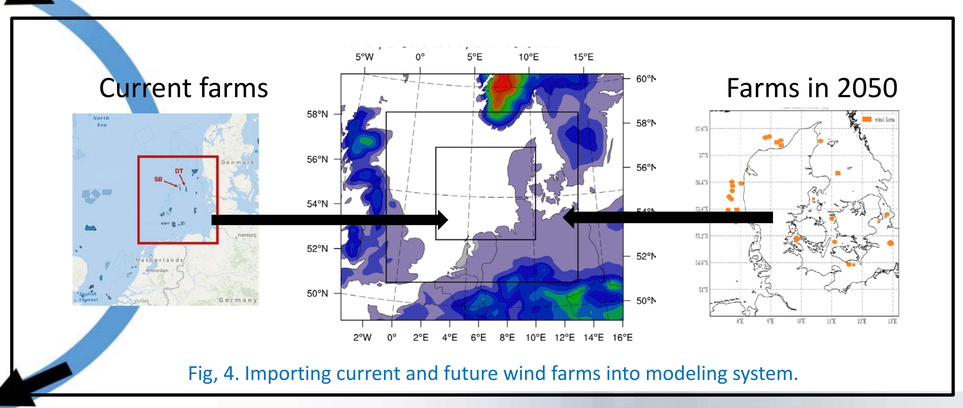


Fig. 3. The power balancing model system

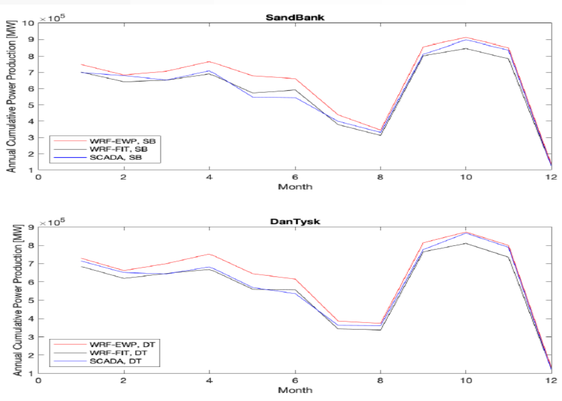


Fig, 4. Importing current and future wind farms into modeling system.

- Couple wind-wave-current-wake modeling (WRF-SWAN(WBLM)-ROMS-EWP/FITCH)[2,3]
- Power balancing model with coupled model input
- Long term modeling, using both climatologically representative year method [4] and statistical-dynamical downscaling method [1]
- For current, as well as future scenarios (2050)
- Calibration, verification and validation using measurements (SCADA at DanTysk (DT) and Sandbank (SB), numerous stations and SAR data)

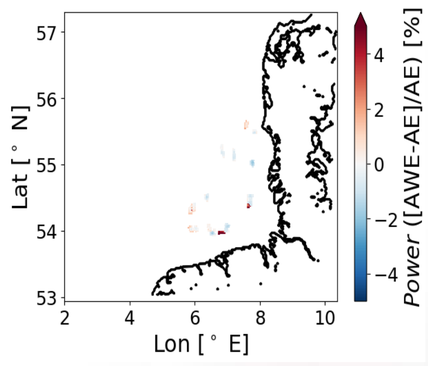
Results

Validation

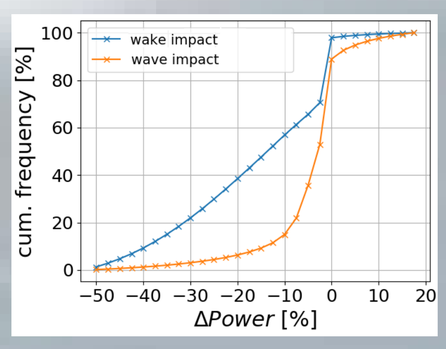


Fig, 5. Comparison of annual cumulative power production at Sandbank and DanTysk, **SCADA measurements and modeling** using both EWP and Fitch wake schemes [5].

Wave & farm wake effect



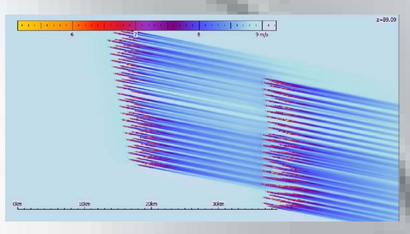
Fig, 6a. Long term **wave effect** on mean power production at wind farms using coupled model WRF-SWAN (WBLM)-EWP[1].



Fig, 6b. Cumulative frequency for changed power production due to **wave and wake effect, respectively**, using coupled model WRF-SWAN (WBLM)-EWP for current climate over domain in Fig6a[1].

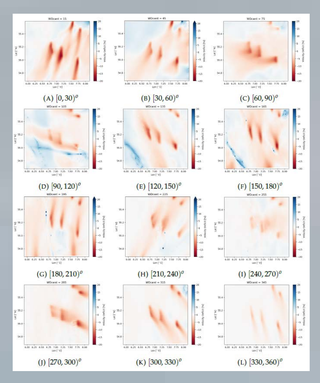
Wake effect

Turbine wake



Fig, 7a. Wind turbine wake calculated using **FUGA**, with wind from 330^{O}. The efficiency at Sandbank (left) is about 99%, and at DanTysk (right) is about 85%. Farm wake effect from Sandbank on DanTysk is about 6%.

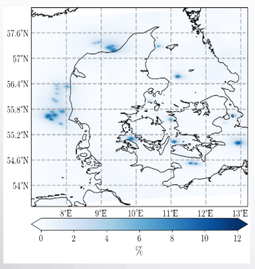
Farm wake



Fig, 7b. Monthly mean wind speed deficit at hub height for May 2018 using Fitch scheme based on prevailing direction around Sandbank and DanTysk [5]

Future Scenario 2050

Farm wake



Fig, 8. Relative reduction in average wind speed at 100 m caused by wind farm wakes using WRF-EWP scheme for the future **2050 scenario**. We assumed power density 6.34MW/km2, cf, Horns Rev 2.

Imbalancing

Fig, 9. Probability distribution function of the Real Time imbalance induced in the Danish power system in the year **2050**. Red curve is in case of no Intra-Hour balancing optimization. Intra-farm wakes are considered so far.

Conclusions

- A Robust wind-wave-ocean-wake coupled modeling system developed at DTU Wind Energy, providing real time meteorological, wave and ocean, and wake parameters.
- A first time model ready for input to power integration system, for current and future scenario. The model is of general use.
- The offshore wind farm cluster wake effect is considerable.

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