

Model validation of costal effects for an offshore wind farm

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Outline

- Background and introduction
- The wind farm;
- Data qualification;
- Inflow conditions;
- Wind speed gradient;
- Models and results;
- Conclusion & acknowledgement;



Introduction

• Background – WF SCADA analysis







Horns Rev1 WF 7-10D spacing



Lillgrund WF 3-5D spacing

Objectives: 1) Validation of our flow models 2) Benchmarking of flow models

Anholt offshore wind farm

- Access to Anholt wind farm SCADA data.
- Problematic to determine an inflow reference?







Short introduction to ANH



Layout

- Naming rows(=archs): A - P;
- Internal spacing: variable 5 – 7 D
- Primary wake directions: 228±5° & 165 - 185°



Challenges for large WF

are online.

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- Identification of wake deficit: Requires: "wake generating" wind turbines
- Uniform wind climate? Requires: 2-3 consecutive records.



ANH dataset



• ANH SCADA data; Turbine signals from A1 => P28; Periods: 2¹/₂ YR Signals: WSN, POA, YP, Pitch & RPM

• WRF data simulated

- Period: 2½ YR
 Levels: 65, 85, 101, 105, 125, 141, 185, 225, 275 & 315 m
- Signals: <WS>, <WD> & MO, TK & PB (h=82m)

Qualification of SCADA data

- 111 power curves have been filtered for
 - Curtailment/power boost:+/-;
 - Idling & parked;
 - Start / stop events;
- Yaw position have been calibrated for 9 turbines: (A01, A02, A03, A05, A16, A30, F29, P28 & P01);
- Power curve validation: A16;
- Calculation of equivalent wind speed for 111 turbines(wsi#);

Derived inflow condition: U_{park} & WD_{park}



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Question

• Can we explain and predict the gradient along the wind farm?





Prediction of the wind climate - WRF

- Mesoscale simulations using the Weather, Research and Forecasting (WRF) model.
- Domain: nested from 18km
 => 6 km => 2 km grid
 spacing covering DK
- Wind speed contours at h=10 m; Wdir ≈250°



Source: Pena, A., Hahmann, A. N. (2017). 30-year mesoscale model simulations for the "Noise from wind turbines and risk of cardiovascular disease" project. DTU Wind Energy E, Vol.. 0055



Prediction of the wind climate - WRF

 Output: 2½ years of hourly wind speed and direction was interpolated to 10 specified heights in the height range 65 – 315 m amsl near the wind farm.





Simulating of coastal effects with RANS





Simulated inflow conditions, U=9 m/s; Δ =10°; near neutral



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Contours of horizontal wind speed at hub height simulated by RANS & WRF.





Summary of gradient analysis

RowA	$\Delta U_{N,S}$	$\Delta U_{N,S}/U_{A15}$	
WDir≈260°	m/s	%	
SCADA (peak)	1.2	13.8	U _{A15} =8.7 m/s
WRF	0.98	9.8	U _{A15} =10 m/s
RANS	0.90	10.0	U _{A15} =9 m/s



Hasager, et.al., 2018. *Comparisons of winds from satellite SAR, WRF and SCADA to characterize coastal gradients and wind farm wake effects at Anholt wind farm*. From orbit.dtu.dk 2018

Questions

- Can we explain and predict the gradient along the wind farm?
- What are the consequences?
 - Wind speed distributions
 - SCADA data
 - WRF input combined with wake models
 - Park: quadratic & linear;
 - Larsen: quadratic & linear;
 - Fuga;

Questions

- Can we explain and predict the gradient along the wind farm?
- What are the consequences?
 - AEP_{ind} based on individual wind climates correlates well to a centered wind climate at F10;
 - AEP_{A10} based on the wind climate for A01 is reduced > 1% compared to AEP_{ind}
 - AEP_{F29} based on the wind climate for F29 is incrased >1% compared to AEP_{ind}

Source: Penã et. al. On wake modeling, wind-farm gradients and AEP predictions at the Anholt wind farm https://doi.org/10.5194/wes-3-191-2018



Conclusion

- We have established a robust dataset for ANH;
- Robust inflow conditions for large WF are difficult to identify while the inflow conditions are heavily influenced by coastal effects;
- We simulated the horizontal gradient with WRF and RANS for westerly inflow;
- The simulated gradient correlates well with the SCADA based observations;
- The AEP sensitivity analysis demonstrates the importance of choosing the correct reference position.



Acknowledgement

DTU acknowledge Ørsted A/S for granting access to the SCADA data from Anholt offshore wind farm.

Thanks for your attention

