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PO.147

Sensitivity of analytical wake models to parameter settings

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Introduction

Wind resource assessment needs reliable wake calculations. Each wake model has different adjusting parameters and even more ways to implement them numerically into different calculation tools. It is important to understand how those parameters should be adjusted in order to achieve good results for each site, and how sensitive the results are to the parameters. This presentation discusses the implementation of wake models in linear and CFD codes and compares the results and the sensitivities of the models.

Method

The linear tool WindPro and the CFD code WindSim are compared with two wake models which are the same in their implementation in both software:
Jensen model: [1] Accounts for different wake decay factors (WDC) that can be linked to the roughness or TI.
Larsen model: [2] Includes ambient turbulence intensity.

The parameters WDC (Jensen), TI (Larsen), sub-cycles, and rotor diameter influence are varied.
The yield reduction factor for the neighboring turbine rows is compared from model output and real production data for different sites offshore and onshore.

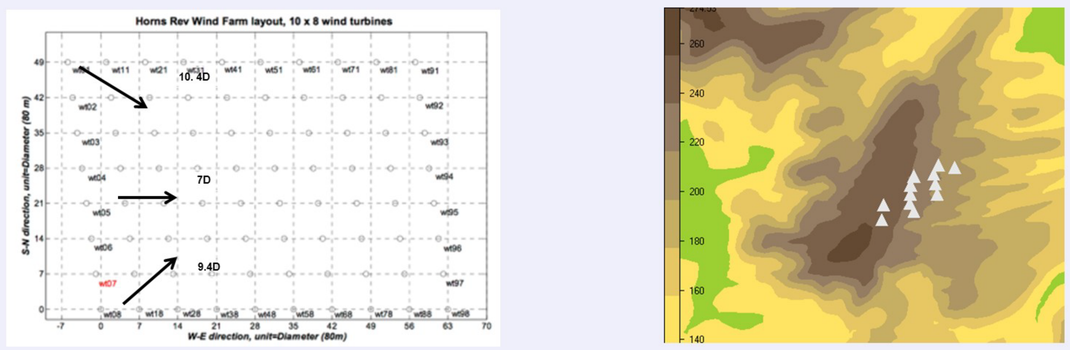


Fig. 1: Layout of the offshore wind farm Horns Rev with rotor spacing for different inflow sectors (left) and layout of the onshore windfarm (right) with different stages of development.*

Results Offshore

Sensitivity study Jensen

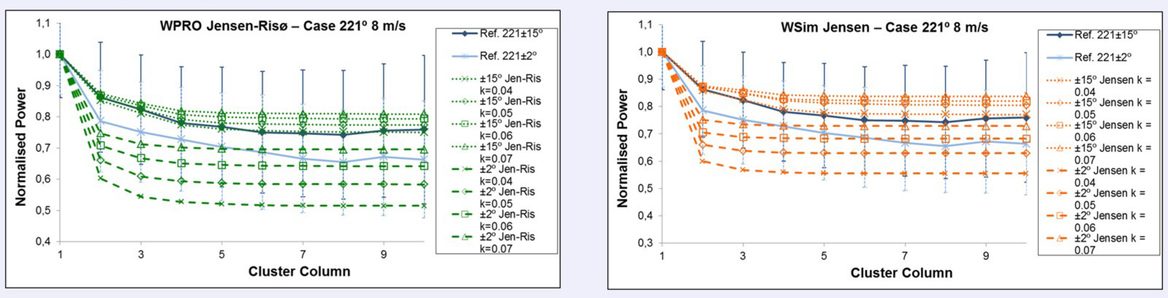
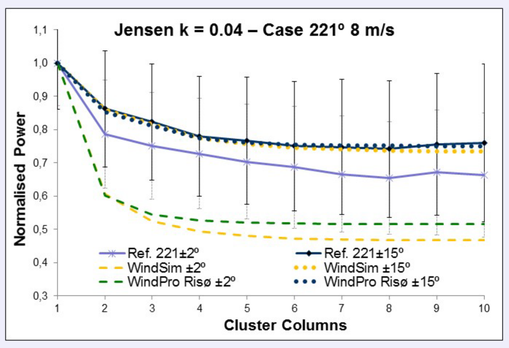


Fig. 2: Sensitivity study for the Jensen model using different wake decay constants for WindSim (left) and WindPro (right).

- WindSim generally gives lower wake effects
- The range of influence of the wake decay factor (WDC) is similar in both models
- **Averaging centerline ±15 :** analytical wake models are fine
- **Averaging centerline ±2:** not covered by model theory, bigger differences for analytical models and observations. Also, observations may include non-wake centerline measurements due to wake meandering



The underestimation of the wake effects in WindSim is reduced with a new multiple wakes calculation method. It averages the results of the linear sum and the sum of squares method as propsed in [3].

Fig. 3: Results Jensen model using WDC 0.04 for WindSim (yellow) and WindPro (green) with new wake summation

Sensitivity study Larsen

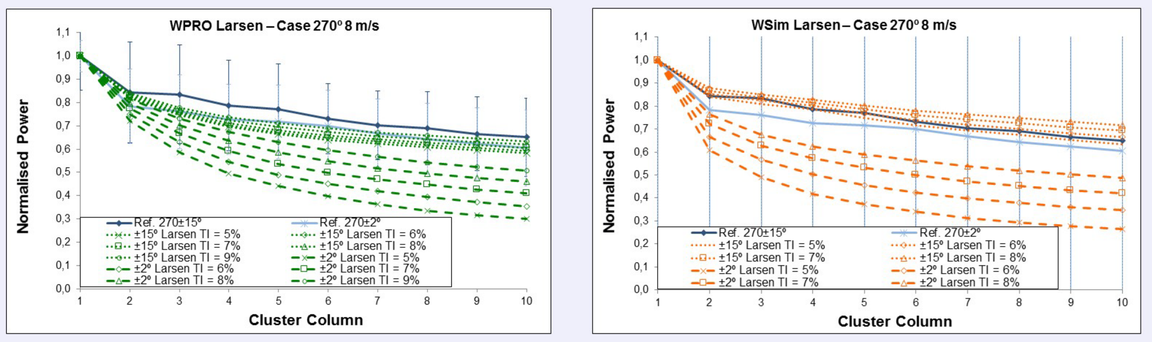


Fig. 4: Sensitivity study for the Larsen model, different TI values for WindSim (left) and WindPro (right).

- WindSim represents the trend better in the first columns for the Larsen model where WindPro overestimates the wake loss.
- Generally poorer match of the wake effects with the Larsen model.
- WindPro shows generally too high wake and WindSim too low wake effects for the Larsen model (±15 degree). Both models show again similar sensitivity to changes in TI as for the WDC in the Jensen model.

Jensen	Sector subcycles	Degree subcycles	Wake Losses (%)
12	1	30	21.48
12	2	15	5.69
12	3	10	11.67
12	4	7.5	11.02
12	5	6	6.92
12	6	5	9.57
12	8	3.75	10.02
12	10	3	8.96
12	12	2.5	9.35
12	15	2	9.84
12	20	1.5	8.84
12	30	1	9.45
12	40	0.75	9.35
12	50	0.6	9.20
12	60	0.5	9.33
12	120	0.25	9.28
12	300	0.1	9.30

Larsen	Sector subcycles	Degree subcycles	Wake Losses (%)
12	1	30	17.89
12	2	15	4.43
12	3	10	9.50
12	4	7.5	5.90
12	5	6	6.73
12	6	5	6.20
12	8	3.75	6.33
12	10	3	6.32
12	12	2.5	6.34
12	15	2	6.38
12	20	1.5	6.37
12	30	1	6.37

Fig. 5: Sensitivity study for the number of sub cycles needed for the Jensen (left) and Larsen (right) model.

The results get independent from number of subcycles in WindSim for the Jensen model with 1° (30 sub-cycles), for the Larsen model already with 5° (6 sub-cycles).

Results Onshore

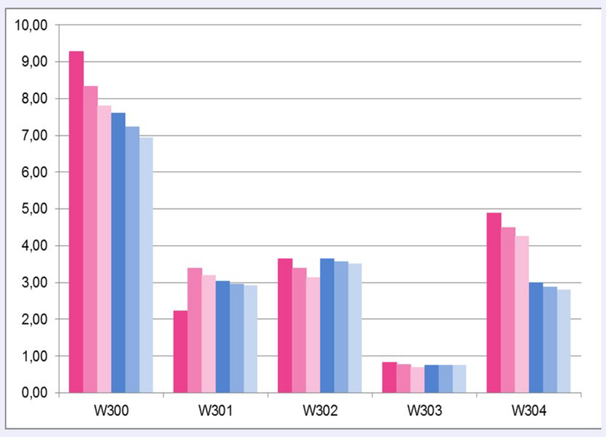


Fig. 6: Onshore sensitivity study for the Jensen model using different WDC values for WindSim (red) and WindPro (blue). Wake losses (in %) for the different turbines in the central row, before construction of the rest of the farm, were compared .

Comparing onshore windfarms is not trivial as the wind speed of WindPro and WindSim seen at the turbines is not the same. WindPro is based on weibull parameters while Windsim works with frequency distributions. To have the results as comparable as possible the rsf result file from WindSim was imported into WindPro and used for the calculation.

The total park effect decreases with increasing WDC. Stronger variations between WindSim and WindPro results are observed at single turbines according to their positions and calculation parameters. The general behaviour of the wake losses on the single turbines is similar in both models.

Conclusions

- It is not easy to do a fair comparison between the same wake models in different software; attention should be paid how the wind speed is inserted
- There is a high sensitivity regarding the choice of wake decay constant and TI in both models and the range of sensitivity is similar
- The Jensen model gives best results in both software packages and the results are comparable when different techniques of multiple wake addition are used

References

[1] Jensen, N.O.. A Note on Wind Generator Interaction. Risø-M-2411, Risø National Laboratory,Roskilde, Denmark, 1984.
[2] Larsen, G. C.. A Simple Wake Calculation Procedure. Risø-M-2760, Risø National Laboratory, Roskilde, Denmark, 1988.
[3] http://www.res-group.com/media/17992/Offshore%20Wake%20Modelling%20-%20Presentation%20at%20Renewable%20UK%20Offshore%202011.pdf
**Horns Rev, new data sets from 2005 to 2010, filtered by stability to contain only neutral cases (data courtesy Kurt S. Hansen, DTU Wind Energy)*