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Temporal Wake Modeling Validation with iSpin Measurement

Henrik S Pedersen (1), Wiebke Langreder (1), Adit N Kishore (1), Harald Hohlen (2)
(1) EMD International A/S, (2) ROMO Wind A/S

EMD International

Abstract

Improving the quality of pre-construction yield assessments to match the post-construction yield situation demands the precise quantification of wake losses and effects. This becomes more and more important as individual projects grow.

Both, computational power and advanced measurement technology have opened doors to the development and validation of more advanced tools/methods. Benchmark cases have increased the insight in the effects of turbulence intensity on the wake decay constant (WDC) and consequently wake losses.

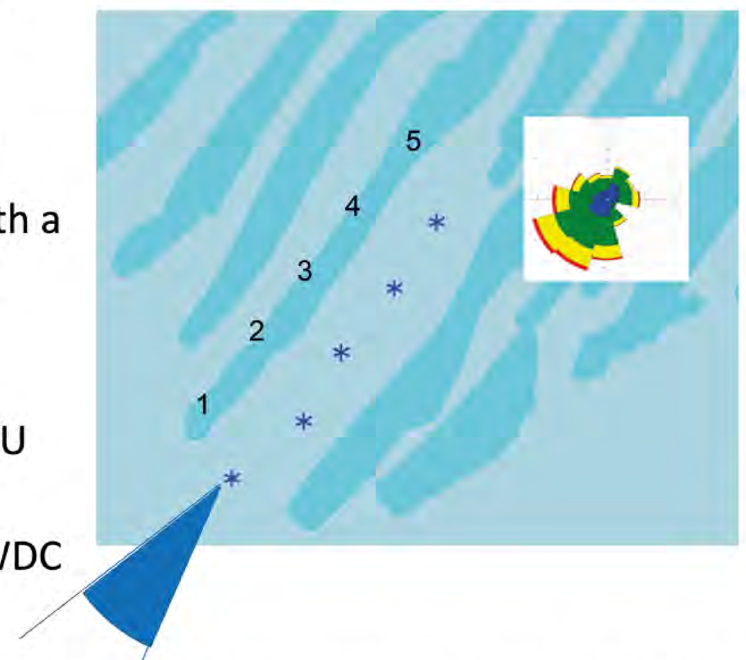
The study presented here shows simulated and measured wake conditions at multiple locations inside a large offshore windfarm. As validation tool for this post-construction assessment the innovative spinner anemometer technology (iSpin) [3] is used, which enables to measure the precise wind speed, wind direction and turbulence intensity. iSpin measurements of wind conditions together with SCADA data of production are compared to wake modeling results. The wake model uses the measured inlet conditions of wind speed, direction and turbulence intensity. Three model setups are compared with the measured wind speed and the SCADA data. Firstly, the model uses an average recommended wake decay constant (WDC) for offshore conditions. Second WDC is a constant derived from measured turbulence, and the third, which adjusts the WDC every 10 minutes based on the measured turbulence[1].

Method

The wind conditions at five operating turbine positions inside a large offshore wind farm are measured with the iSpin systems. The offshore wind farm consists of more than 60 WTGs. The five WTGs under consideration have a spacing of approximately 4.5 rotor dimeter downwind. The wind speed and turbulence intensity measurements from WTG 1, which is undisturbed in main wind direction, is used for the wake model setup.

The wake calculations are performed using the N.O. Jensen model [2] in two different variants, (1) with a constant WDC, corresponding to DTU's recommendations for offshore application and (2) with a time-varying WDC, where the WDC is adjusted every time step according to the measured turbulence intensity (TI).

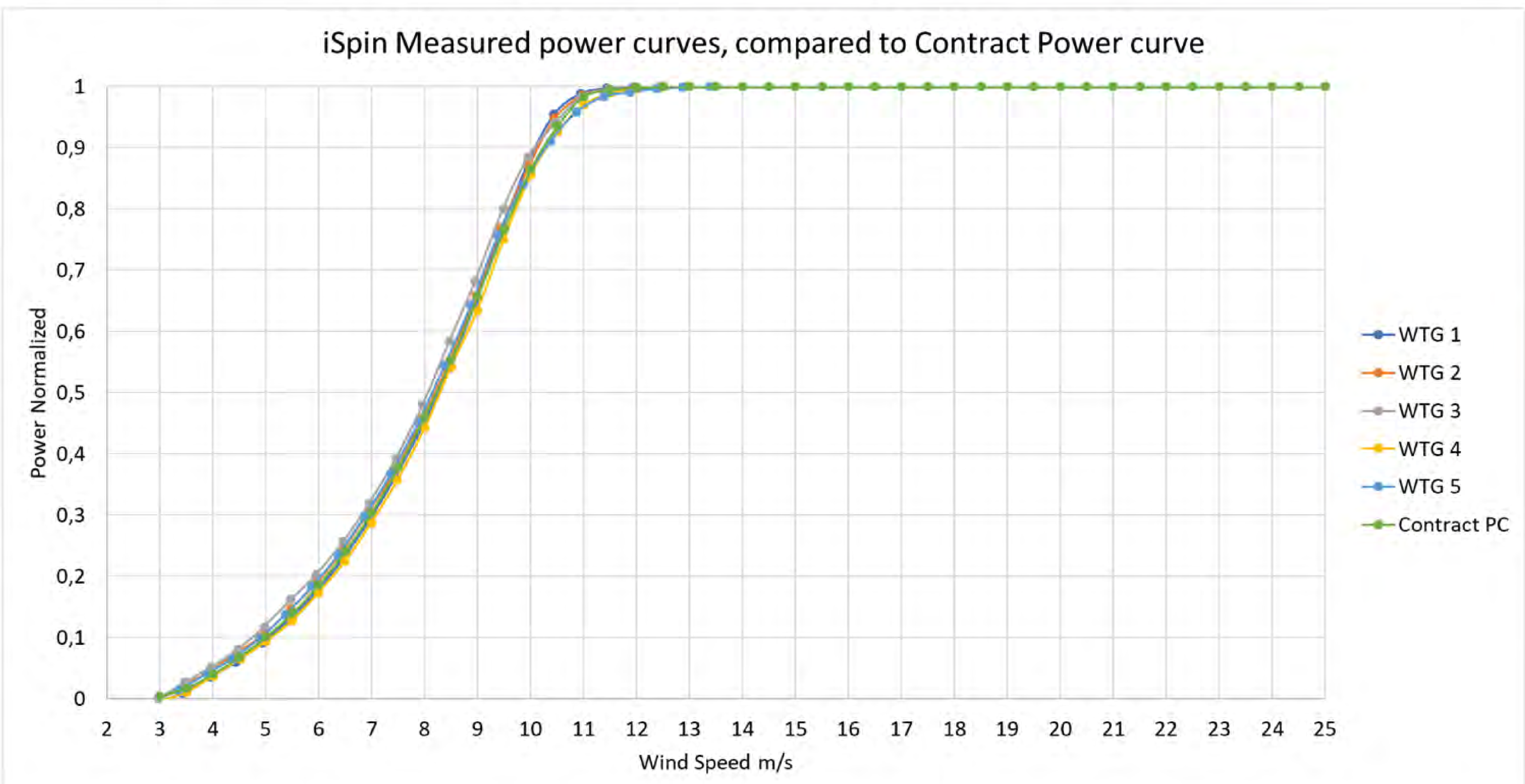
1. Omni-directional constant WDC 0.04 offshore (DTU recommendation)
2. Time-varying WDC adjusted to TI per time-step WDC = 0.4 x TI



The velocity deficit is directly measured via iSpin systems and cross-checked through the production data from individual turbines. The measured wake losses are compared with the modeled wake losses for the duration of one full year.

Results

As a first step the iSpin measurements are validated, against the operational performance of the turbines, and found to be capable to measure wind speed inside the wind farm with very low uncertainty, as the system is capable of measuring the power curves within 2% of the warranted power curve, NB this system is part of the iSpin PTP project where the free wind speed calibration of the turbine type were derived from an on-shore turbine using a hub height met-mast.

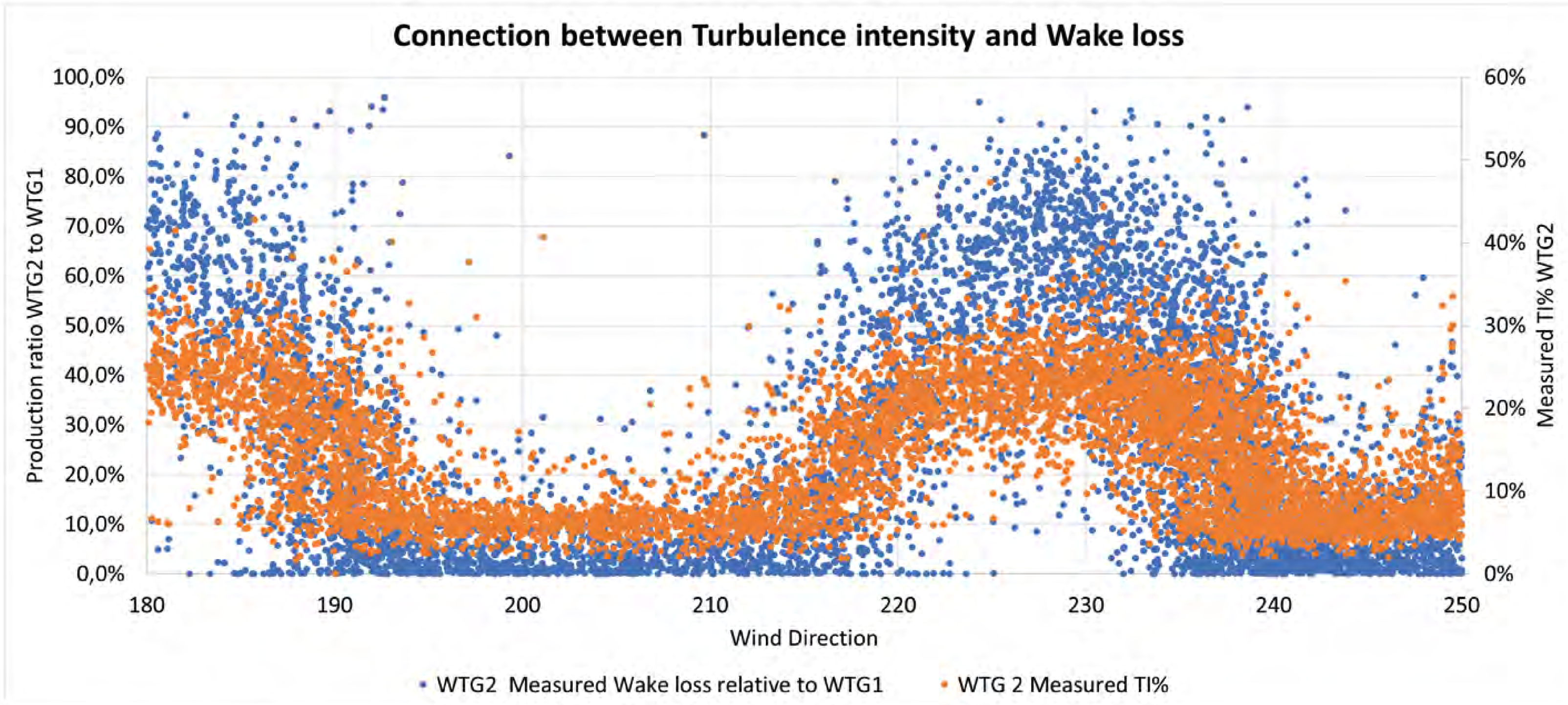


With a reliable wind speed measurement inside the offshore wind farm its possible the investigate the measured wake losses, down stream measured turbulence intensity, and from the advanced time domain wind modeling, compare measured wake losses to calculated.

Results (continued)

From the analyzed data a strong correlation is observed between measured turbulence and wake losses.

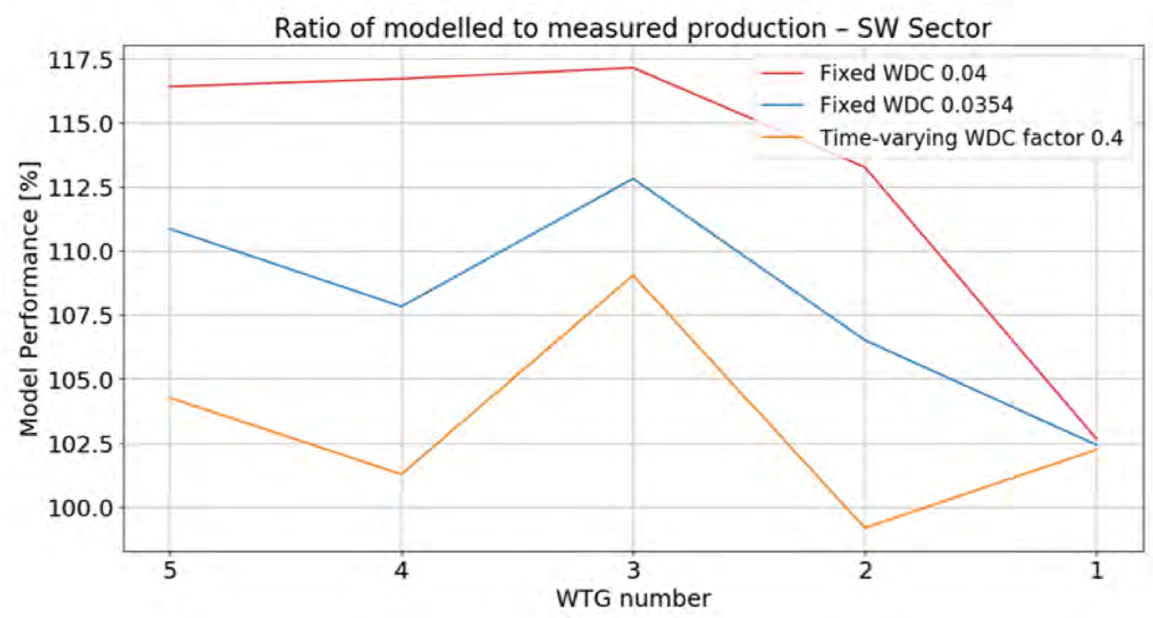
Below figure illustrates measured turbulence intensity at WTG2, covering data from 180 degrees to 250 degrees, so both when WTG2 is in direct wake of WTG1 "230degrees" and in free undisturbed wind conditions. The measured turbulence is illustrated as a function of Wake loss as measured on WTG2 in terms of ratio to measured production from WTG1 on concurrent measured data.

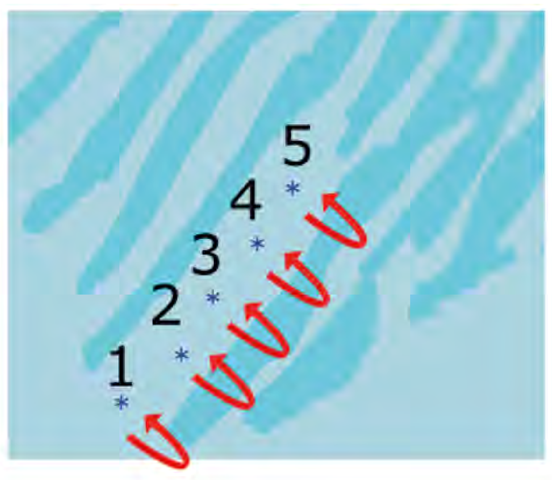


Wake modeling:

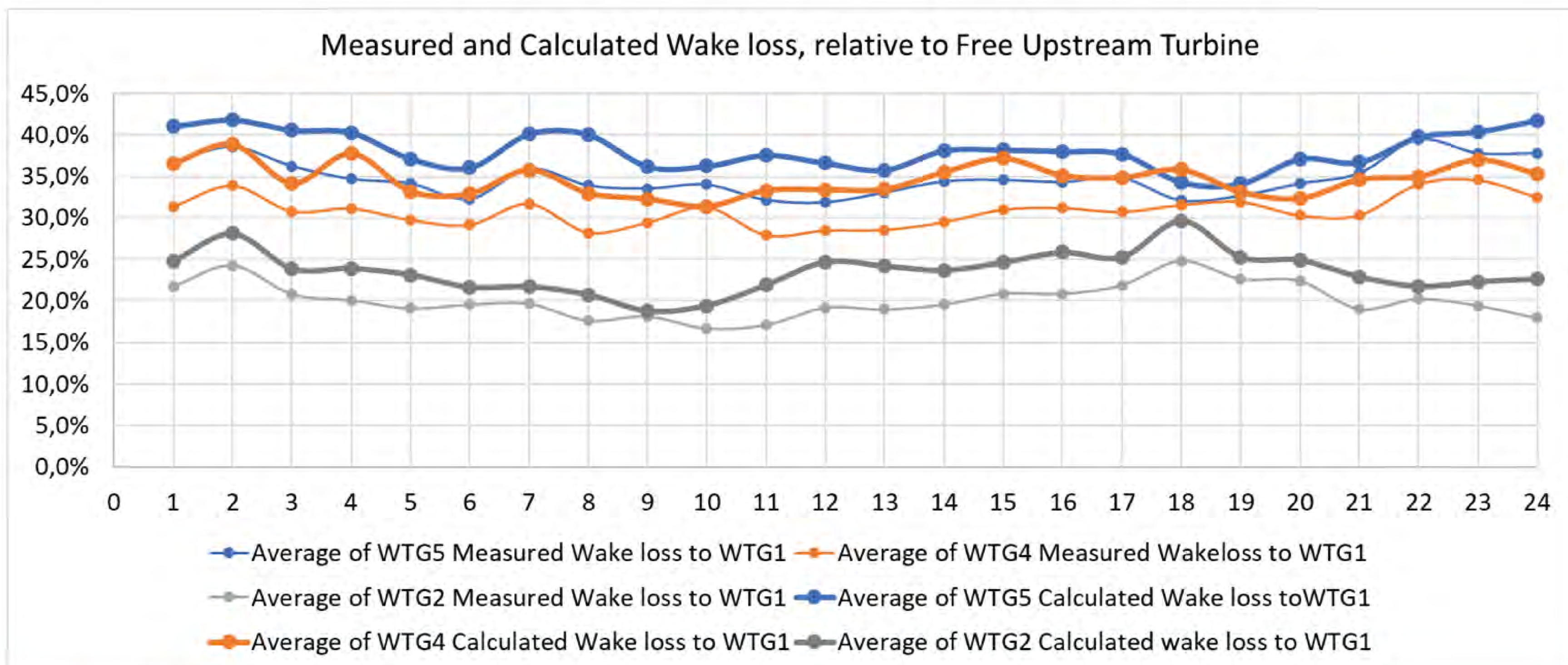
For three different model setups the calculated losses have been compared to the measured production for each turbine.

The smallest bias, when comparing the calculated production to the actual measured production, was achieved by using the time dependent measured turbulence intensity as inputs for a time varying park calculation.





Looking into the daily average variation in wake loss - which is related to the turbulence intensity variation through the day - we also see that the wake model using the measured turbulence in each 10min time step provides the best results. This model provides the strongest correlation to the hourly measured wake losses and can mimic the 10% daily variation.



Conclusions

The measured wind conditions by iSpin are successfully validated with the actual production, confirming the accuracy of the reduced measured wind speeds inside the farm.

Using the wind speed and turbulence measured at the front turbine allowed to validate the accuracy of the temporal wake model. Compared to other evaluated WDC this model resulted in the smallest bias compared to measurements.

In a next step, the evaluation of temporal wake models for very high ambient turbulence sites will be performed to confirm that measured TI% for such site also gives the lowerst wake model errors.

References

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