The Importance of Adding the Temporal Component to Wake Losses – a Verification Study

Wiebke Langreder, Henrik S. Pedersen, Adit N. Kishore

EMD International A/S
Motivation

• We have seen umpteen validation of wake models and umpteen interpretation of the result
• Most validations concentrate on the total number and not on the temporal behaviour
• Spot market: Time is money
• Wake losses depend on stability, thus time of the day
• But how much does the park efficiency vary with time of the day?
• How can we model that?
Setting the scene

- **Ultimate truth:** production data (10-minute SCADA data)
- **Data filtering:**
  - WTG operates flawless: no error or sub-optimal events
  - Exclude wind speeds near cut-in and rated wind speed
  - Only data where all WTGs operate
- **Focus on wake sector**
The Sites (1/3)

“Onshore – single row”

- Denmark: Krogstrup Enge
- 4 WTGs
- 3D distance
- Input to model:
  - nacelle wind speed WTG1
The Sites (2/3)

“Offshore”

• > 60 WTGs, 4.5 D apart downwind
• Special aspect: 5 WTGs are equipped with an iSpin *
• Consequently we know:
  • Real production
  • Real wind speed
  • Real turbulence intensity
• Wind speed at WTG 1 will be used

At 5 positions

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* Spinner anemometer, see https://www.romowind.com/
The Sites (3/3)

“Onshore – multiple row”

• Egypt: El Zayt
• 100 WTGs, 3 x 14 D
• Upwind mast used as model input
The wake model set-up

All calculations are time-varying driven by:

• Site 1: Nacelle ws
• Site 2: iSpin WTG1
• Site 3: mast

The configuration of the NO Jensen model varies:

1. Omni-directional fixed WDC (wake decay constant)
   • WDC 0.075 onshore / 0.04 offshore (DTU recommendation)
   • WDC adjusted to average TI (based on roughness and HH)

2. Time-varying WDC adjusted to TI per time-step
   • WDC = 0.4 TI
   • Site 1 (Krogstrup Enge, DK) only: Experimental WDC = 0.8 TI plus adjusting changing WDC per row
What to look for?

Step 1: Do we see diurnals?
- Wind speed, turbulence
- Measured park performance: Production of downwind WTG normalized to production of free WTG - *per time stamp*
Step 1: Sanity Check

Site 1: Onshore
- single row

Site 2: Offshore

Site 3: Onshore
- multiple row
What to look for?

Step 1: Do we see diurnals?
• Wind speed, turbulence
• Measured park efficiency

Step 2: Can we model?
• In terms of absolute production
• In terms of diurnals

But we do not necessarily see diurnals in park efficiency
Model performance:

Ratio of modelled to measured production on WTG level

Under-prediction of wake

Over-prediction of wake
Modelling Diurnals: Site 3 El Zayt

![Diagram of Site 3 El Zayt]

- Measured
- Fixed WDC 0.075, WTG2
- Fixed WDC 0.064, WTG2
- Time-varying WDC factor 0.4, WTG2

![Graphs comparing park and model performance]

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What to look for?

Step 1: Do we see diurnals?
- Wind speed, turbulence
- Measured park efficiency

Step 2: Can we model?
- In terms of absolute production
- In terms of diurnals

Step 3: What does that mean in terms of money?
Financial implication

- Site 2 – offshore: Nord Pool spot market
- Only production in waked sector is analyzed
- Comparing modelled to measured production

<table>
<thead>
<tr>
<th></th>
<th>Deviation from measured earning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed WDC 0.04</td>
<td>7.8%</td>
</tr>
<tr>
<td>Fixed WDC 0.0354</td>
<td>4.1%</td>
</tr>
<tr>
<td>Time-varying WDC</td>
<td>0.7%</td>
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</tbody>
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Conclusion

• Clearly time-varying WDC best on all sites
• Clear financial impact can be shown
• Site 1 (single row) can be solved with experimental solution
• Diurnal TI pattern not necessarily a proxy for production diurnals

• Of course: More projects needed for validation! WP3 projects (with 10-minute SCADA data) will be analyzed
Contact Detail

Wiebke Langreder
Head of Wind Consulting
EMD International A/S
+45 9635 4444
wl@emd.dk
Yes, wake losses are dependent of the width of the sector.

Yes, we did (some) analysis – example Site 1 (single row)