Wake Deflection Measurement in a Wind Tunnel with a Lidar WindScanner

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20.06.2019

Wind Energy Science Conference
17ᵗʰ June – 20ᵗʰ June 2019
Cork, Ireland
Overview

• Measurement Setup
• Measurement Cases
• Results
• Conclusion & Future Work
Measurement Setup

- Pitot Tube
- Wind Turbine Model
- WindScanner
Measurement Setup

• Position of the wind turbine model and the pitot tube
Measurement Setup

- Position of the wind turbine model and the pitot tube
### Measurement Cases

|                | Empty nozzle | Uniform passive grid | Boundary layer passive grid |
|----------------|--------------|----------------------|-----------------------------|
| TI [%]         | 0.5          | 2.6                  | 1.5                         |
| $\alpha$      | 0            | 0                    | 0.314                       |

#### Operational Conditions
- $\psi = -30^\circ, 0^\circ, 30^\circ$
- $U_{hub} = 7.5$ m/s

With and without the turbine
Measurement Cases

Wind Turbine model
- $D=0.58m$
- $h=0.77m$
- $c_T =0.83$
- 1.17D in front of the nozzle
- Blockage 2.7%

Pitot Tube
- 1.17D in front of the nozzle at hub height
- 1.82D next to the turbine (from the rotor axis)
Measurement Cases

WindScanner: $V_{LOS}$
- Vertical plane (10min, 7-8s per scan)
  - $S = 0D$ (no turbine) 1D, 2D, 3D, 5D, 7D, 10D
- Staring mode (10min) at hub height
  - $S = 0D$ (no turbine), 1D, 2D, 3D, 5D, 7D, 10D
- Horizontal plane (30min, 22s per scan)
Measurement Cases

- Data interpolated onto a vertical grid with a spacing of 7x7cm
Results

Vertical and horizontal scan with a boundary layer

- With turbine, $\psi = 30^\circ$
- Without turbine
Results: Inflow conditions

- $TI$ at multiple downstream distances
Results: Inflow conditions

- $u_{\text{mean}}$ at multiple downstream distances

Empty nozzle

Uniform passive grid

Boundary layer passive grid
Results: Vertical scan
- 2D

Empty nozzle

Uniform passive grid

Boundary layer passive grid
Results: Vertical scan
-7D

Empty nozzle

Uniform passive grid

Boundary layer passive grid

$\psi = -30^\circ$  $\psi = 0^\circ$  $\psi = 30^\circ$
Results: Vertical scan

\( \psi = -30^\circ \) \hspace{1cm} \( \psi = 0^\circ \) \hspace{1cm} \( \psi = 30^\circ \)

Empty nozzle

Uniform passive grid

Boundary layer passive grid
Results: Vertical scan

- $\psi = -30^\circ$ with an empty nozzle

1D

2D

3D

5D

7D

10D
Results: Vertical scan

- $\psi = -30^\circ$ with a boundary layer passive grid
Results: Wake deflections

- Wake center determined by calculating the potential power of a downstream turbine as described by Schottler et al. (2017b).
Results: Wake deflections

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![Graph showing wake deflections](chart.png)
Results: Wake deflections

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Conclusion & Future Work

Conclusion

• High spatial resolution obtained with the WindScanner
  • Development of the curled wake
  • Development of the boundary layer
• Slight wake asymmetry detected with a boundary layer
• Wake of the tower might be deflected due to the counter-vortex-pair
• Development of the kidney shaped wake starts sooner at an inflow condition with a boundary layer

Future Work

• Uncertainty analysis
• Analyze the spatial turbulence within the wake
• Validate measurements with numerical simulation
• Compare measurement data and numerical results with current existing yaw-control model (FLORIS model)
Acknowledgement

• This work is partly funded by the Federal Ministry for Economic Affairs and Energy according to a resolution by the German Federal Parliament in the scope of research project »CompactWindII« (Ref. Nr. 0325 492H).

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