Yawed Wind Turbines

An Experimental Study on the Far Wake Development behind a Yawed Wind Turbine

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Motivation

~35% Power drop

- Nysted, x/D = 10.3 (278 ± 2.5°)
- Horns Rev, x/D = 7.0 (270 ± 2.5°)

What can be done to limit wake effects?

Wind farm layout

Turbine design

Control strategies:
- Yaw control
- Pitch control
- TSR control

Picture: Bel Air Aviation Denmark – Helicopter Services
Yawed Wind Turbine Project

Influence of yaw misalignment on the wake development

Collaboration project

Experimental Campaign

Different rotor designs
Same wind tunnel
Single turbine and multiple turbine arrays
Yawed Wind Turbine Project
Model wind turbines

**NTNU**
- Diameter: 0.89m
- NREL S826
- Small hub & tower
- CCW rotation

**Small NTNU**
- Diameter: 0.45m
- NREL S826
- Relative Big hub & tower
- CCW rotation

**ForWind**
- Diameter: 0.58m
- SD 7003
- Low blockage
- CW rotation
Model wind turbines

Streamwise velocity 6D behind +30° yawed turbine
Model wind turbines

Streamwise velocity 6D behind +30° yawed turbine
Publications

“Comparative study on the wake deflection behind yawed wind turbine models”
Published in Journal of Physics: Conf. Series

“Wind tunnel experiments on wind turbine wakes in yaw: Effects of inflow turbulence and shear”
Posted as discussion paper on Wind Energy Science

“Wind tunnel experiments on wind turbine wakes in yaw: Redefining the wake width”
Posted as discussion paper on Wind Energy Science

“Blind test 5 - The wake behind a yawed model wind turbine”
In process

“Performance and loads of two interacting wind turbines operated at different yaw”
In process

“An Experimental Study on the Far Wake Development behind a Yawed Wind Turbine”
Experimental setup

TI = 0.23%
$U_{inlet} = 10.0 \, \text{m/s}$

$\gamma = 30^\circ$

Full wake scans

Line Wakes 1-15D

LDV
Experimental setup
Results
Results

\[ \frac{z}{D} \]

\[ \frac{x}{D} \]

- \( \gamma = 30^\circ \), 2D Gaussian fit
- \( \gamma = 30^\circ \), 3D Av. power method
- \( \gamma = \pm 30^\circ \), JCM model predictions
- \( \gamma = \pm 30^\circ \), BPA model predictions
- \( \gamma = 20^\circ \), 3D Av. power method
- \( \gamma = 10^\circ \), 3D Av. power method
- \( \gamma = 0^\circ \), 3D Av. power method
- \( \gamma = -30^\circ \), 3D Av. power method
Conclusions

Rotor size and turbine dimension have large influence on wake shape

Wake behind yawed turbine is complex and asymmetric

Larger wake deflection from line wake analysis

Analytical wake models over predict wake deflection
Thank you for the attention!

I’m looking forward to your Questions

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