Experimental validation of analytical wake and downstream turbine performance modelling

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MOTIVATION

- Wake effects in wind farms can cause significant power losses (up to 20%)
- Wind farm layout and control optimization can be applied to reduce losses
- Accurate, simple and fast tools to predict the wake flow are needed
- Comparison of wake models and small-scale turbine wind tunnel measurements to determine the most accurate wake model

EXPERIMENTAL SETUP

- Wind tunnel measurements at NTNU wind tunnel with a test section of 1.8m (height) x 2.7m (width) x 12.0m (length)

- Experiment 1: **Wake measurements**
  - Wake measurements behind small scale turbine (D=0.45m) at
    - Ambient turbulence intensities $I_a = 0.23\%, 10\%$
    - Upstream turbine pitch angles $\beta = 0°, 2°, 5°$
- Experiment 2: **Performance measurements**
  - Performance measurements of a two aligned small-scale turbines (D=0.90m)

Figure1 : Two alinged turbines in the NTNU wind tunnel

MODELLING METHODS

- Applied wake models:
  - Jensen
  - Frandsen
  - Ishihara
  - Bastankah & Porte Agel
  - Jensen-Gaussian Wake model (JGWM) [3]
- Adjustment of JGWM: Combination with Crespo and Hernandez turbulence model
- Application of wind tunnel blockage effect correction [2]
- Blade Element Momentum method with guaranteed convergence for performance modelling

RESULTS

Wake Modelling

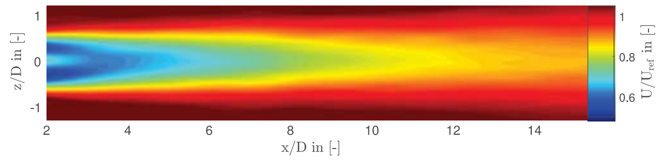

Figure 2: Wake measurement result at $I_a = 10\%$ and $\beta = 0°$ from $x/D = 2 - 15$

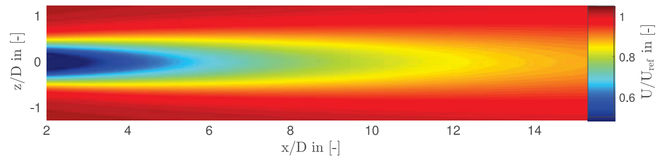

Figure 3: Adjusted Jensen-Gaussian Wake Model simulation result

- The adjusted JGWM shows the most accurate wake flow prediction at all test cases

Performance Modelling

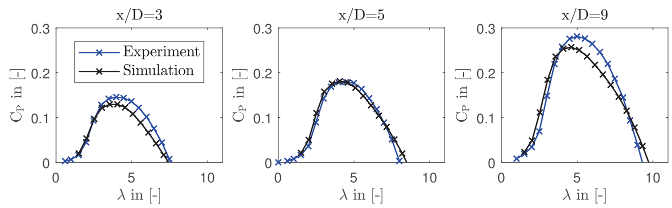

Figure 4: Downstream turbine power measurement and modelling comparison

- Average prediction error at design tip speed ratio amounts 6,8%

CONCLUSIONS

- An improvement of the Jensen-Gaussian Wake Model was proposed
- The adjusted Wake Model was found to give the most accurate wake flow prediction at all test cases
- Wake Model application on downstream turbine performance modelling resulted in a reasonable performance prediction

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