DAN-AERO MW: Preliminary results from Tjæreborg Enge

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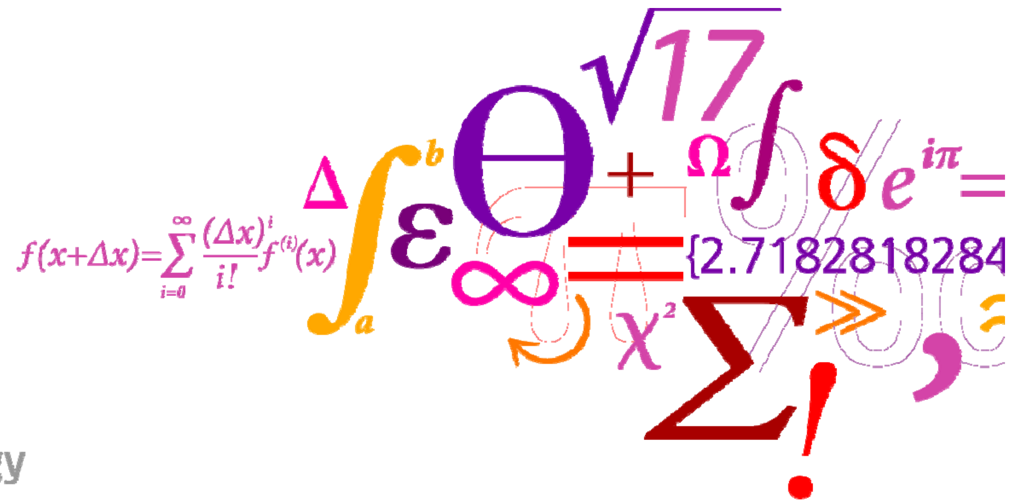


Risø DTU
National Laboratory for Sustainable Energy

Objectives

(√) Calibrate the obtained data.

Analyze the available data

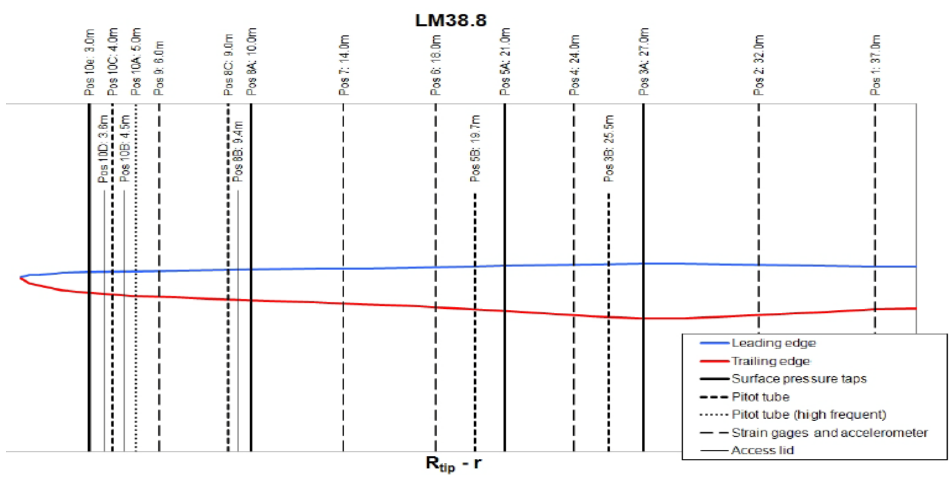
- Search for suitable benchmark cases that can be used for verifying various computational methods.

Outline

- The Tjæreborg Enge tests:
  - Instrumentation
  - Site layout
  - Available data
- Searching for suitable benchmark cases
  - Overview of possible test cases
  - Example of test case in comparison with CFD
- Conclusion & future work

The Tjæreborg Enge Tests

- Carried out on a 2.3 MW NM80 turbine in the summer of 2009
- Instrumentation of drive train, nacelle and tower:
  - Electrical power, rotational speed, yaw, pitch, blade position (35Hz)
  - Tower and shaft moments (35Hz)
- Instrumentation of blade:
  - 4 five-hole Pitot tubes (35Hz)
  - 10 strain gauges (35Hz)
  - 4x64 pressure taps (100Hz)
  - 56 microphones near the tip (50 kHz)

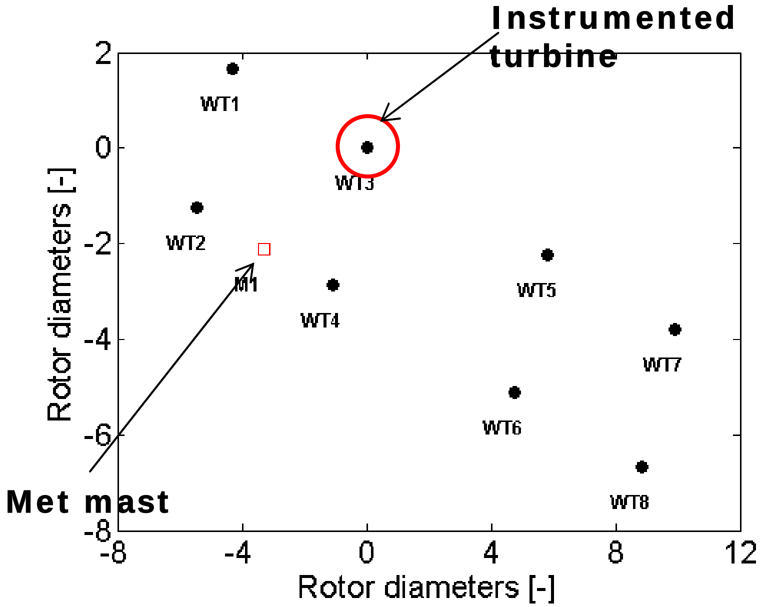


The Tjæreborg Enge Tests

- Instrumentation of met mast:
  - Wind speed and direction at various heights (35Hz)
  - Temperature at various heights (35Hz)
  - Pressure (35Hz)

- Available data from the experiment:
  - 350 time series of 10 minutes at 35 Hz (21000 samples)
  - 291 pressure tap recordings at 100 Hz (57000 samples)

- Additional data:
  - LiDAR measurements of wake (TOPFARM)
  - LIDAR measurements of inflow (WINDSCANNER)



Overview of possible benchmark cases

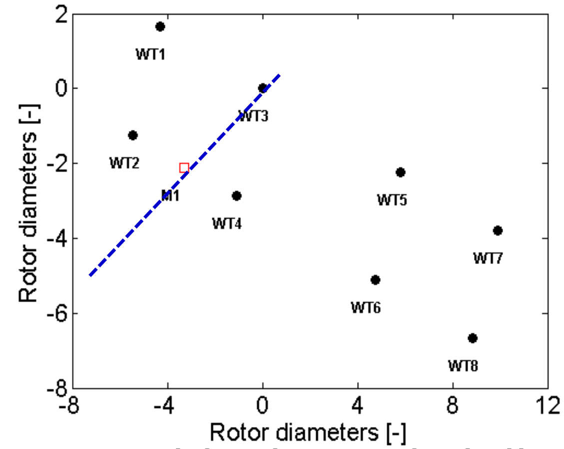
- No or very low wind shear
- Sheared inflow
- Yaw operation
- Partial or full wake operation
- A combination of the above situations

Very low wind shear – comparison with CFD

A case where the turbine was operating in a nearly uniform mean inflow was initially selected for comparison with CFD.

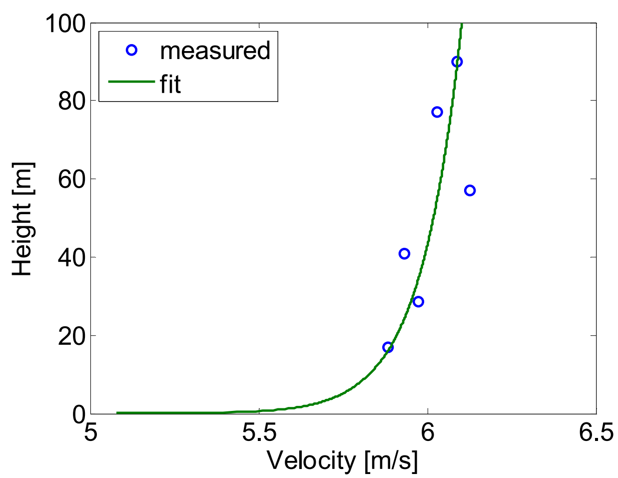
$$V_0(z) = V_\infty \left(\frac{z}{H} \right)^\alpha$$

$$\alpha = 0.02, \quad V_\infty = 6.2 m/s, \ TI \approx 10\%$$

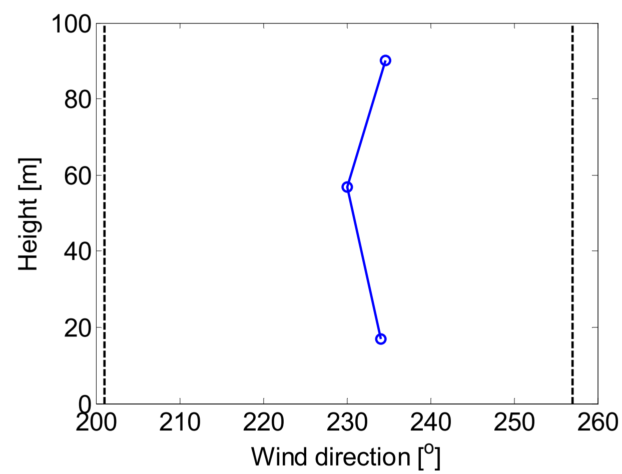


Layout with given wind direction

CFD assumptions : Uniform inflow, steady state, fully turbulent (no transition modelling)



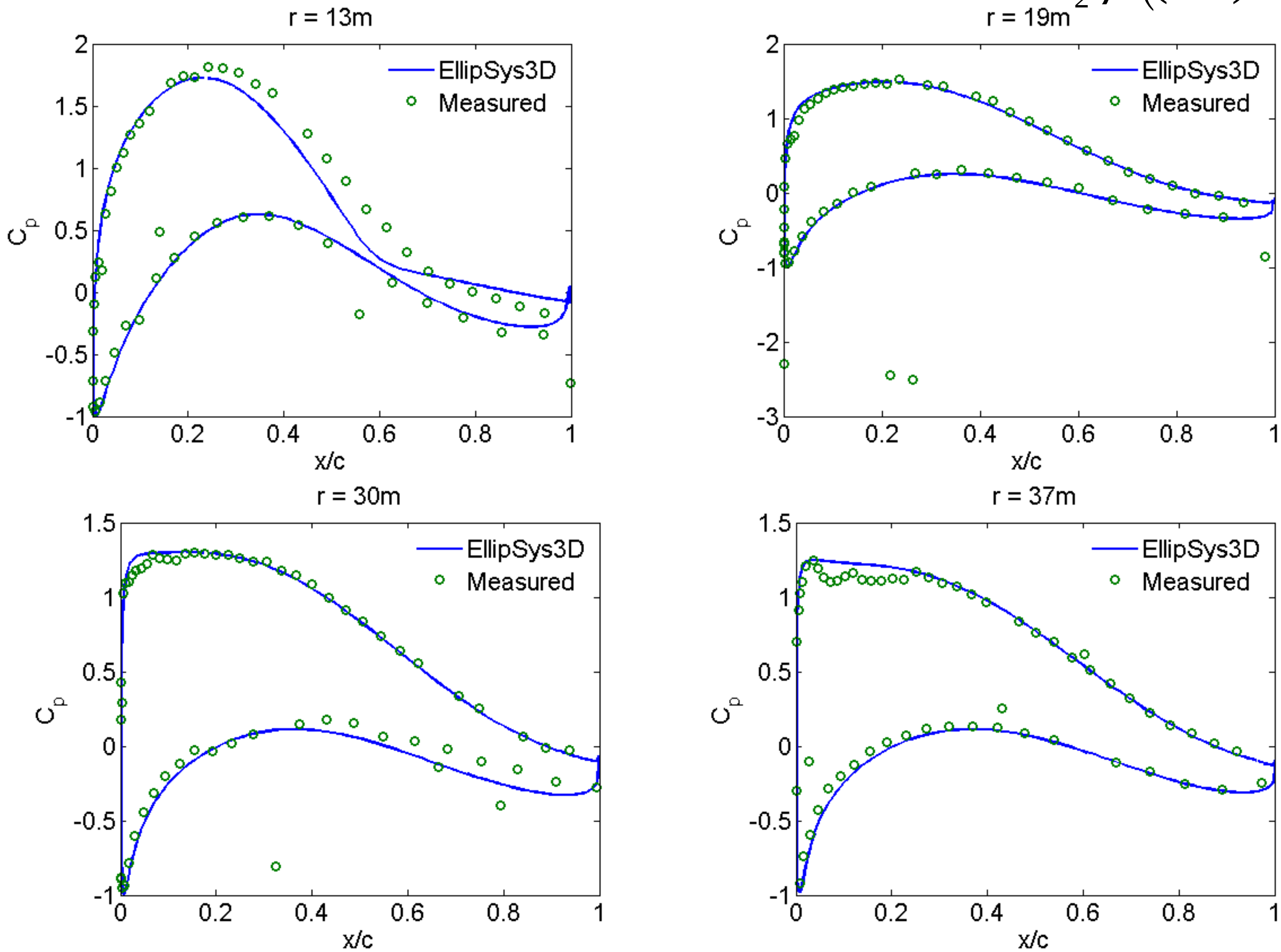
Inflow profile at met mast



Wind direction vs. height

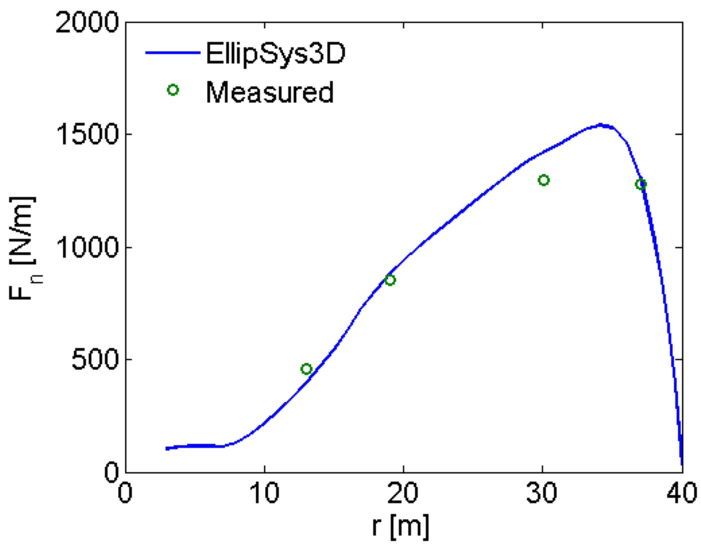
Very low wind shear – comparison with CFD

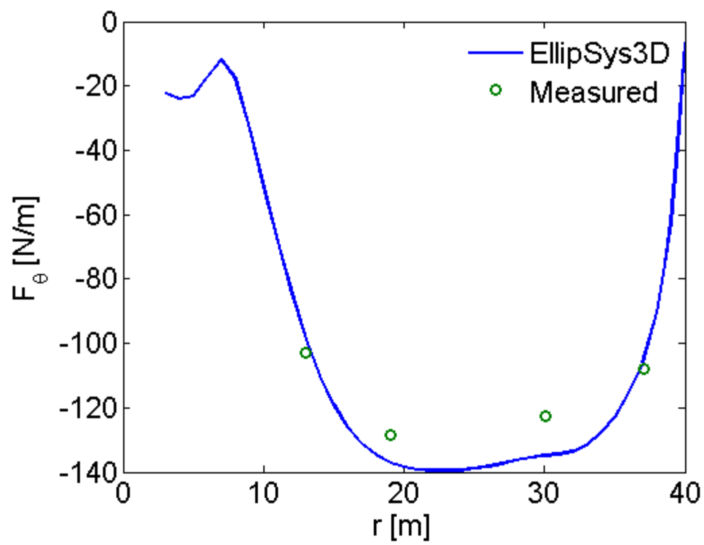
Comparison of measured and computed $c_p = \dfrac{\Delta p}{\frac{1}{2}\rho\left((r\Omega)^2 + V_\infty^2\right)}$



Very low wind shear – comparison with CFD

Comparison of measured and computed normal and tangential loading





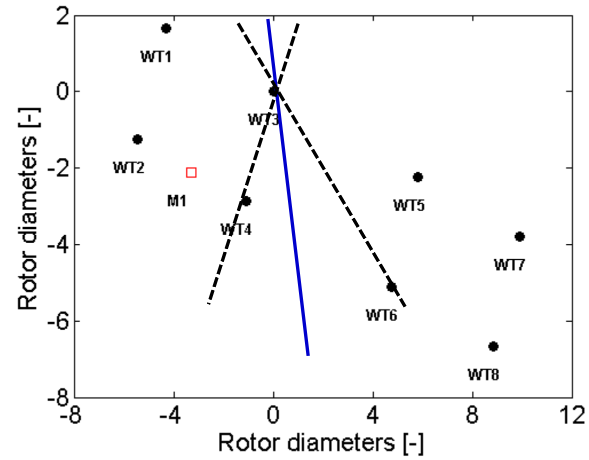
Sheared inflow

Next, cases where the turbine was operating in a sheared inflow was found using the following criteria:

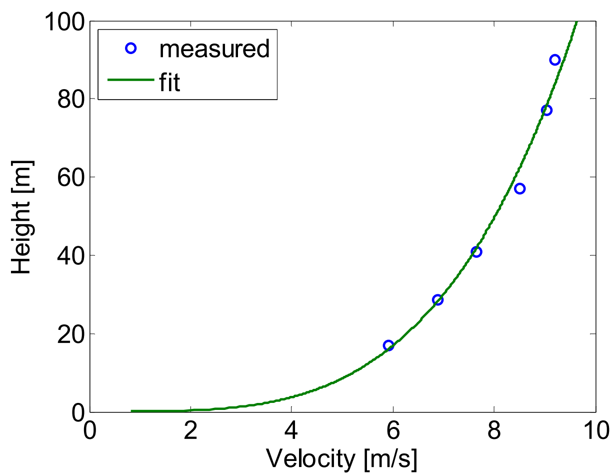
- Undisturbed inflow
- Low directional change
- Low yaw error

$$V_0(z) = V_\infty \left(\frac{z}{H} \right)^\alpha$$

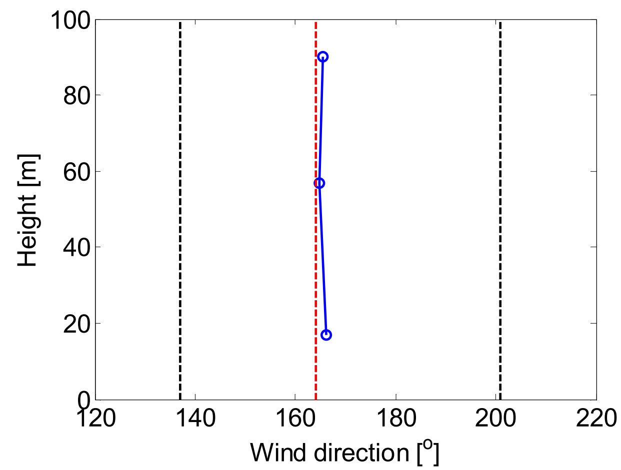
$$\alpha = 0.27, \quad V_\infty = 8.3 m/s, \; TI \approx 11\%$$



Layout with given wind direction



Inflow profile at met mast

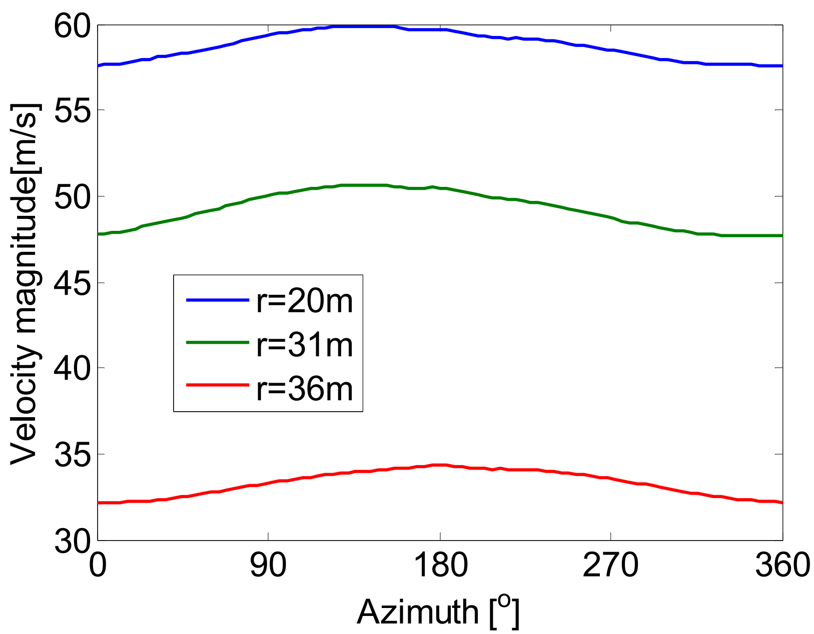


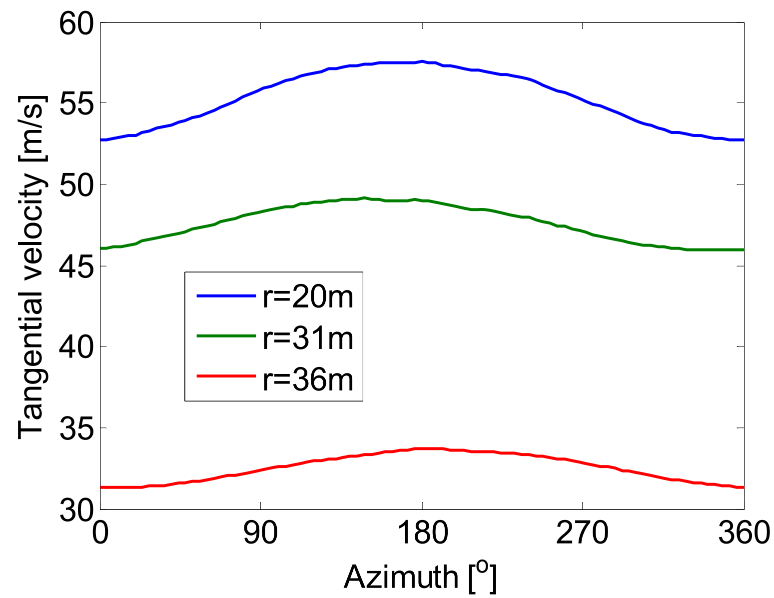
Wind direction vs. height

Sheared inflow

The velocity when the blade points upwards (0°) is lower than when pointing downwards (180°)???

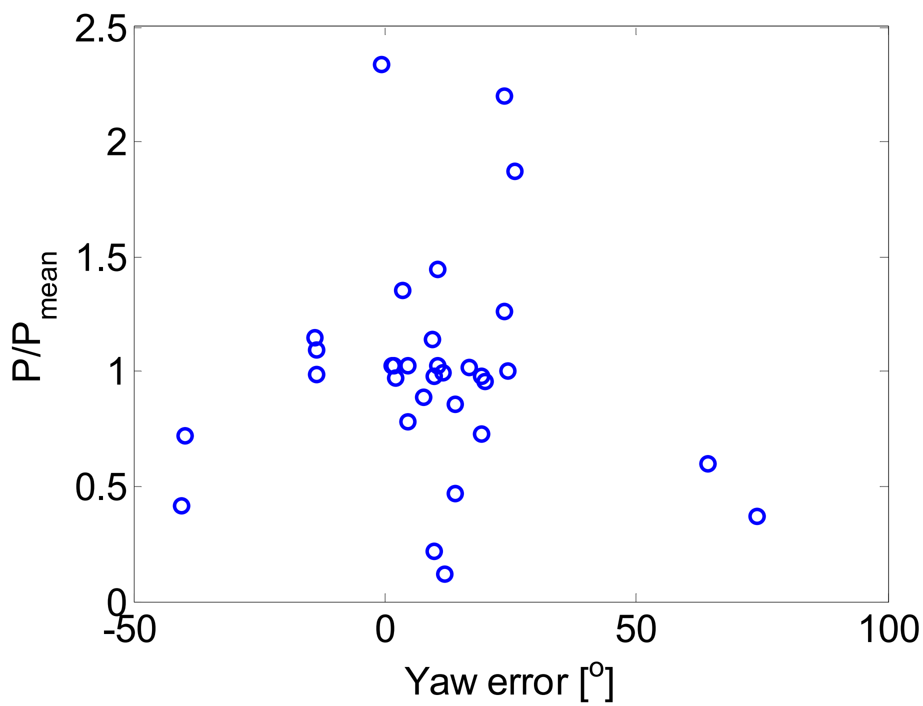
Apparently the turbine operates in yaw.





Influence of yaw error on power production

For each case with a inflow velocity V ± ΔV the fraction of the power to the mean power of all cases in the given velocity range is computed and plotted against the yaw error.



Relative power production as a function of measured yaw error

Conclusions & future work

- The first comparison between measurements and computations looks promising.
- Screening of database to find benchmark cases is in progress.
- Work is still needed before suitable cases with well known conditions are found.