Scaled wind turbine setup in turbulent wind tunnel

MoWiTO 1.8 (Model Wind Turbine Oldenburg 1.8 m)

Frederik Berger, Lars Kröger, David Onnen, Vlaho Petrović and Martin Kühn

ForWind – Carl von Ossietzky University Oldenburg

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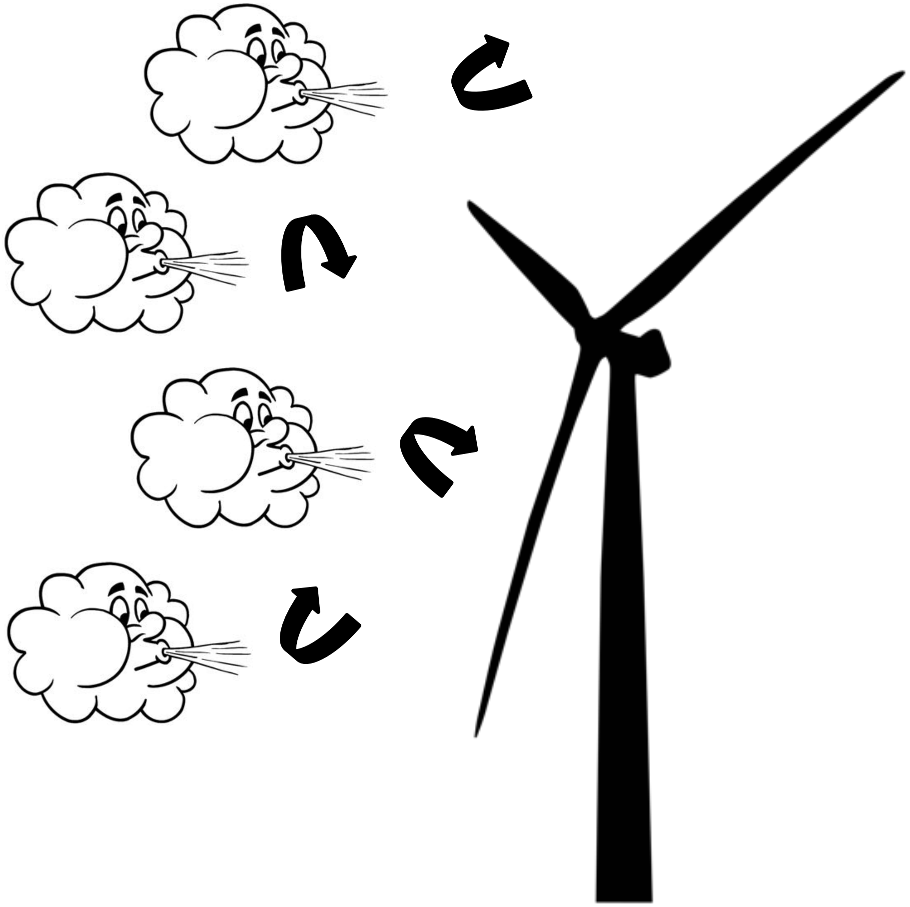
Motivation



- Interaction of turbulent wind w/ wind turbine in controlled wind tunnel environment:
  - Loads
  - Aerodynamics
  - Control

- Scaling objectives:
  1. Representative aerodynamic response in turbulence
  2. Realistic characteristic curves
  3. Characteristics Re insensitive

Scaling: Global Parameters

Parameters

- Based on NREL 5MW
- Keep design TSR (~7.5)
- Scaling parameters:
  - Length scaling

$$n_L = \frac{D_{\text{scaled}}}{D_{\text{refernce}}} = \frac{1.8\ \text{m}}{126\ \text{m}} = \mathbf{\frac{1}{70}}$$

  - Time scaling

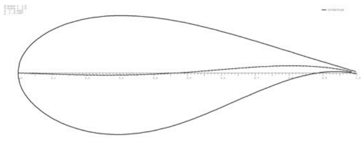
$$n_T = \frac{n_{\text{scaled}}}{n_{\text{reference}}} = \frac{600\ \text{rpm}}{12.1\ \text{rpm}} = \mathbf{49.6}$$

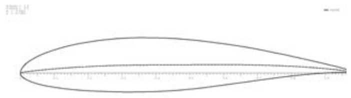
Rated values	Scaling factor	Reference	Scaled
Revolutions	$1 * n_T$	12.1 rpm	600 rpm
Power	$n_L^5 * n_T^3$	5 MW	363 W
Wind speed	$n_L * n_T$	11.4 m/s	8.1 m/s
Reynolds number	$n_L^2 * n_T$	$\sim 10^7$	$\sim 10^5$

Scaling: Aerodynamics

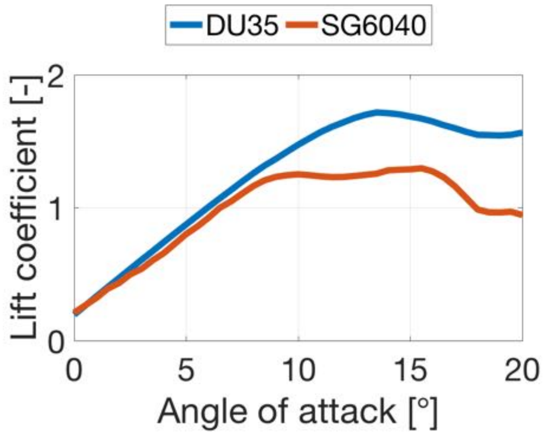
Exchange of airfoils

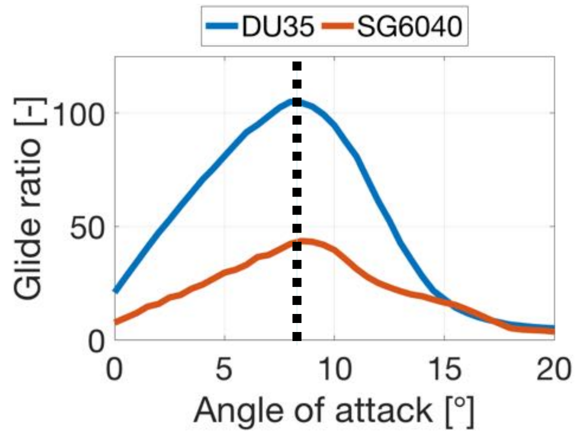
Root airfoil exchange



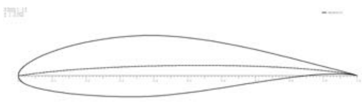


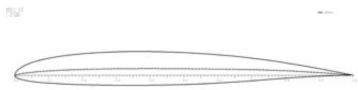
original	scaled
DU 99-W-350	SG6040
0.25 R - 0.32 R	0.2 R - 0.38 R
35 % thickness	16 % thickness



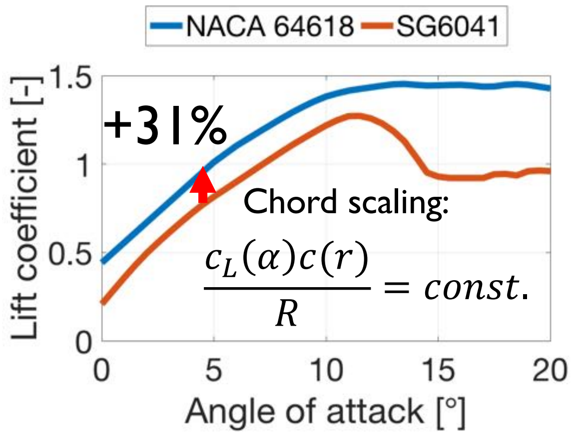


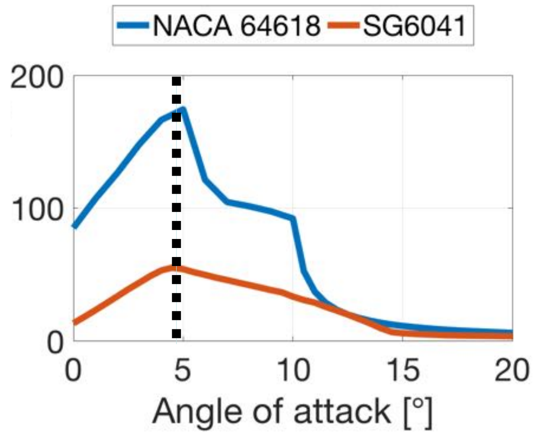
Tip and midspan airfoil exchange





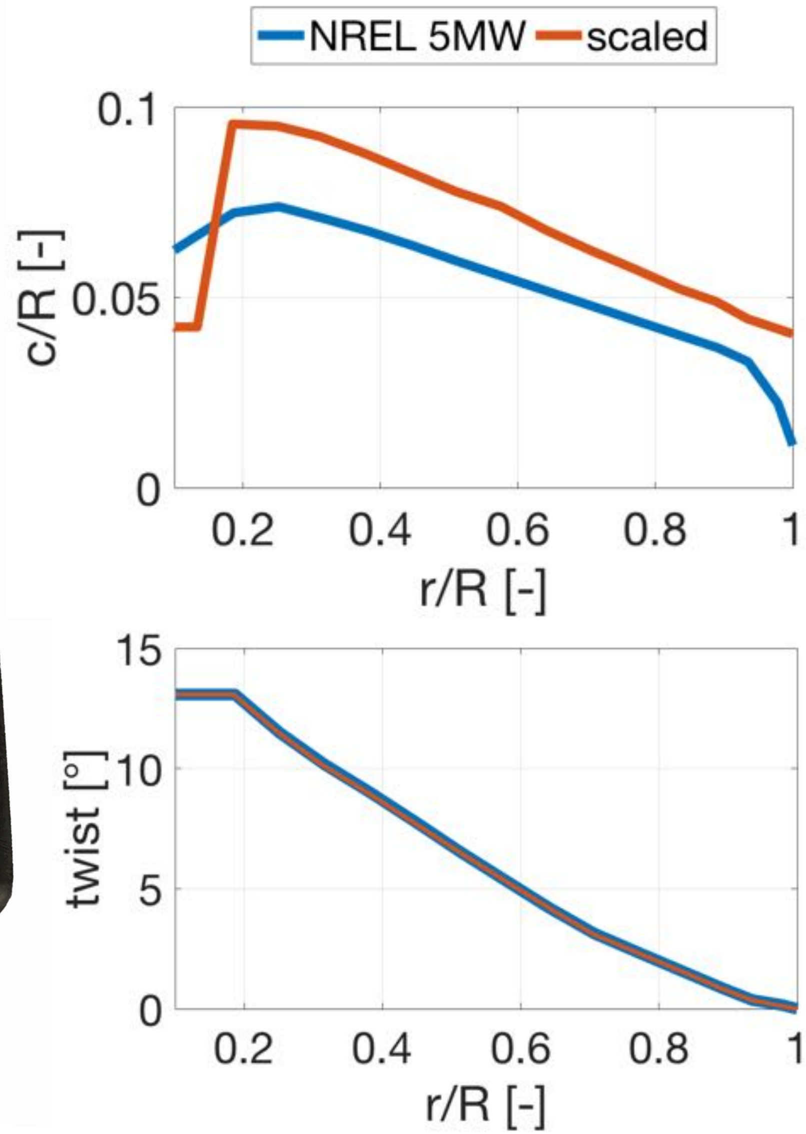
original	scaled
NACA 64618	SG6041
0.7 R - 1 R	0.5 R - 1 R
18 % thickness	10 % thickness



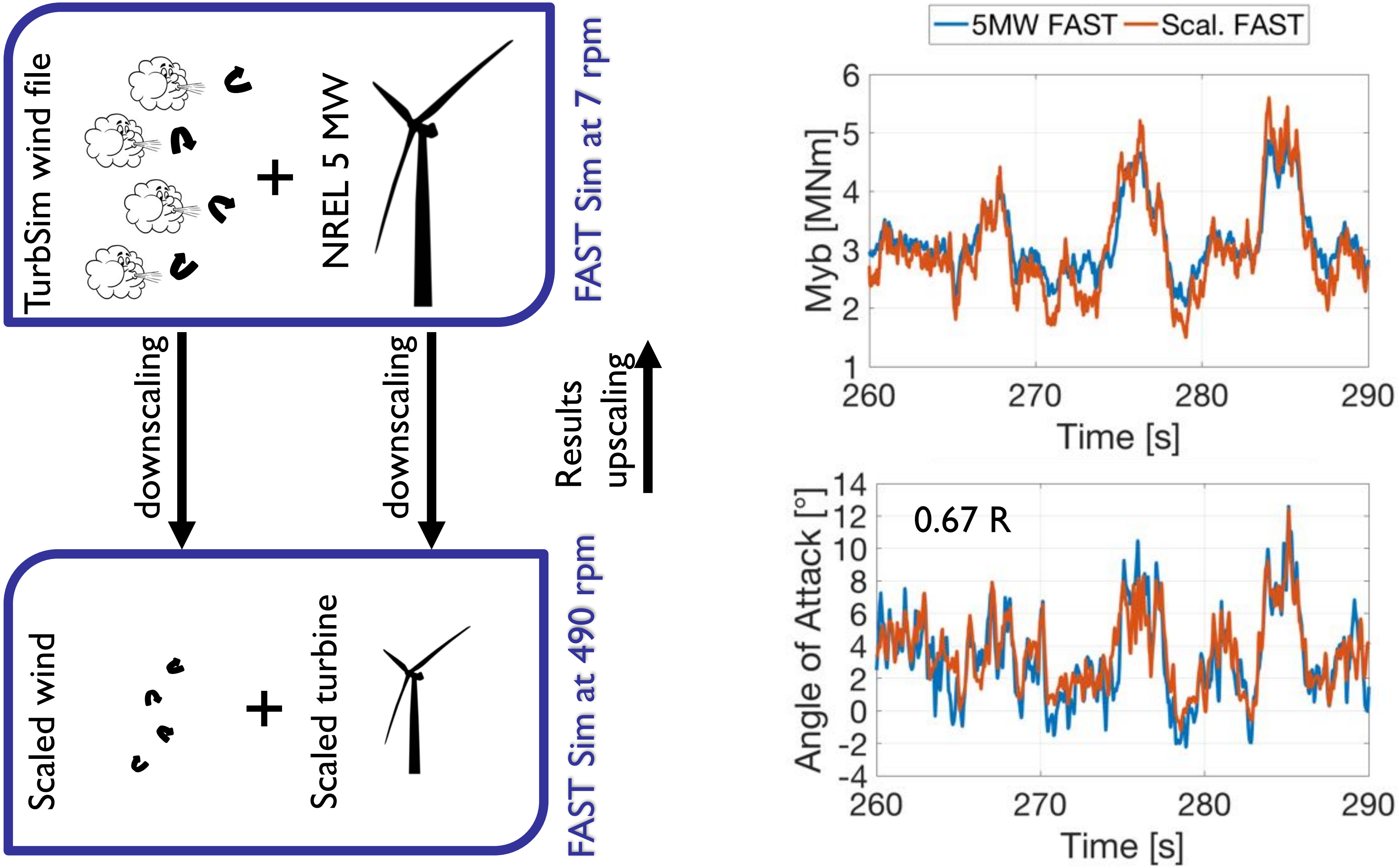


Blade design

- Carbon fiber with foam spar
- Composite blade weight ~160 g ($m_{\text{blade NREL 5MW}} / 70^3 = 52$ g)
- Glued on metal inlet
  - Flapwise strain gauge
  - Pitch motor housing
  - Pitch bearing shaft surface
- First eigenfrequency ~39 Hz



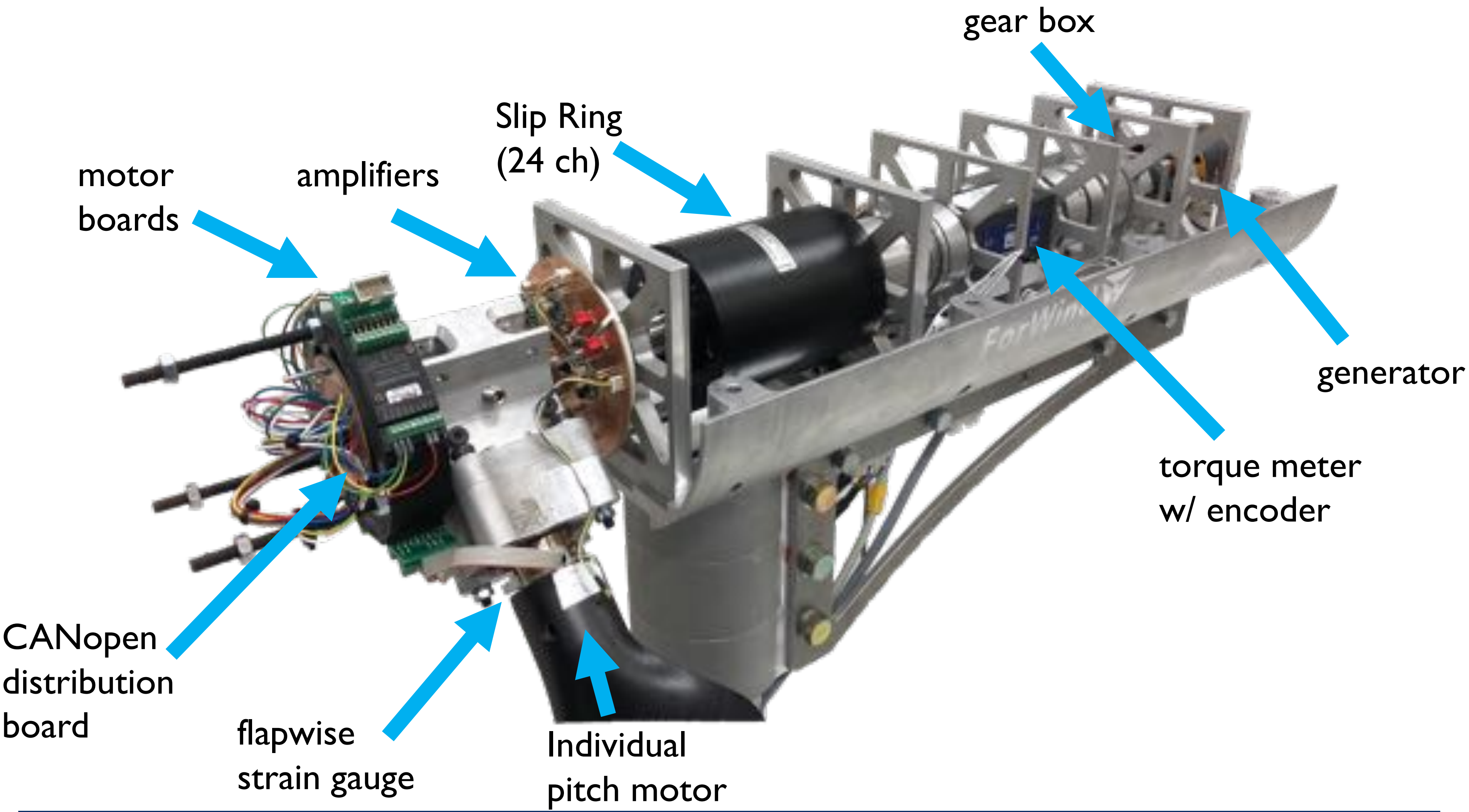
Objective 1: Aerodynamic response in turbulence



Turbine key facts

- **Sensors and actuators**:
  - Strain gauges at blade root (flapwise)
  - Strain gauges at tower base (fore-aft, side-side)
  - Torque meter with encoder
  - Individual pitch motors
  - Real time control and data acquisition
- **Operation**:
  - 400 – 600 rpm
  - Rated wind 8.1 m/s

Nacelle layout



Wind Tunnel at University Oldenburg

- WindLab; Dimensions (H x W x L) 3 x 3 x 30 m^3
- Open test section or closed test section
- V_{Wind} up to 42 m/s (closed) or 30 m/s (open)

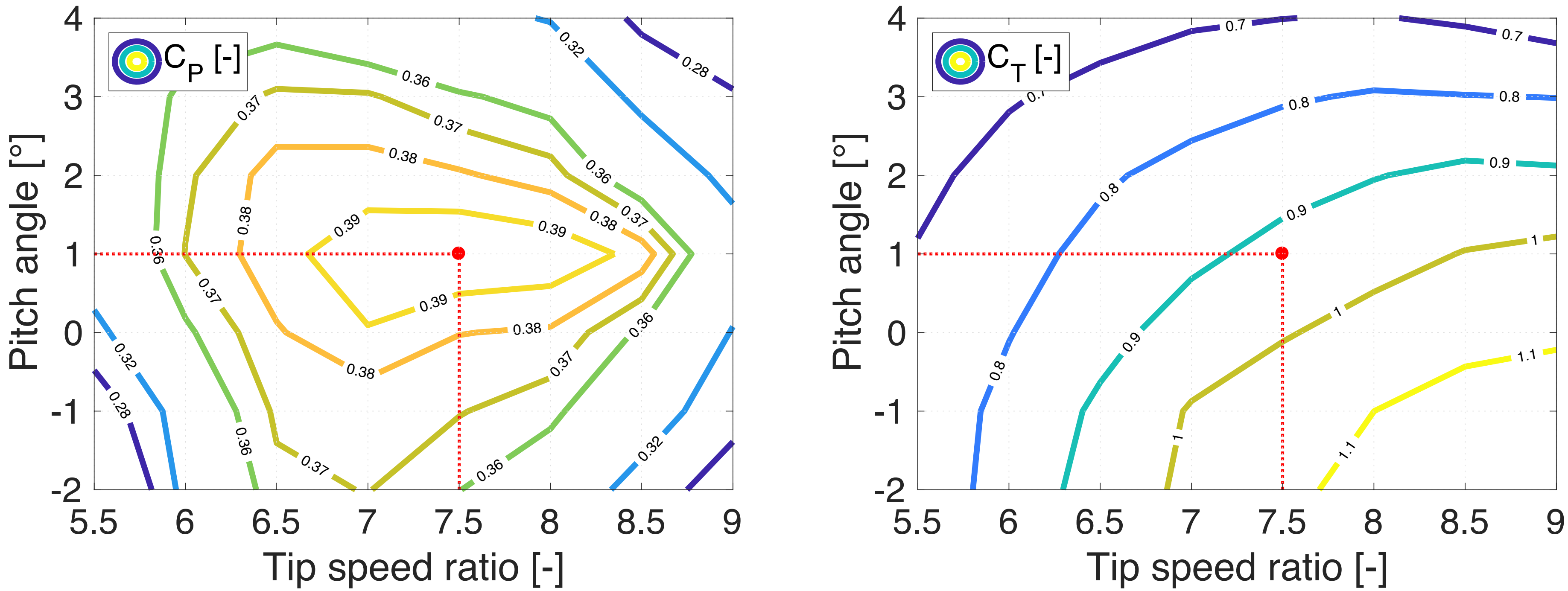
Active Grid

20 split axes with flaps in each, horizontal and vertical, direction

80 servomotors driving the axes

Reproduce turbulent wind patterns, e.g. based on free field measurements

Aerodynamic characterisation in wind tunnel



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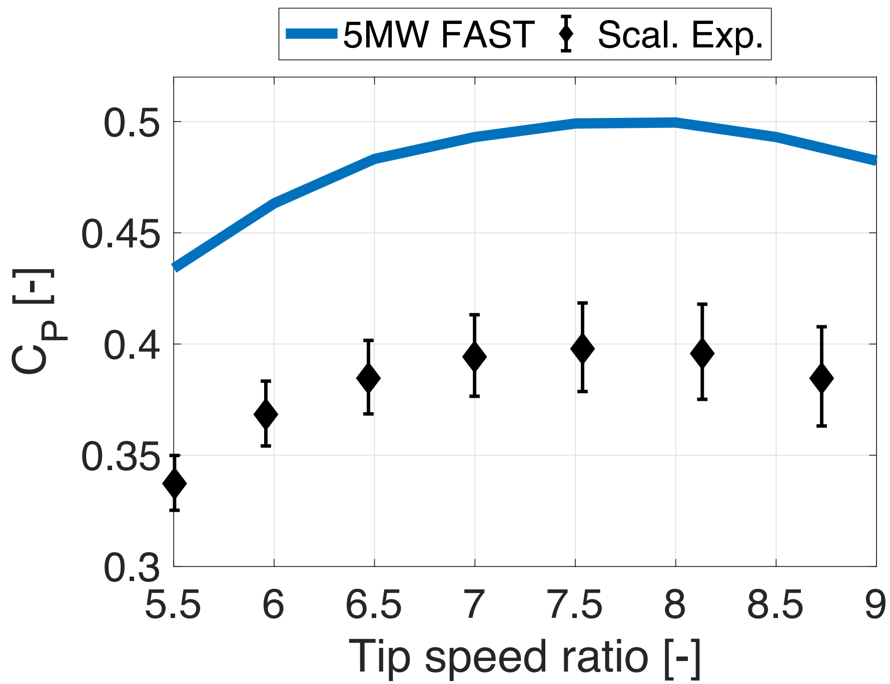
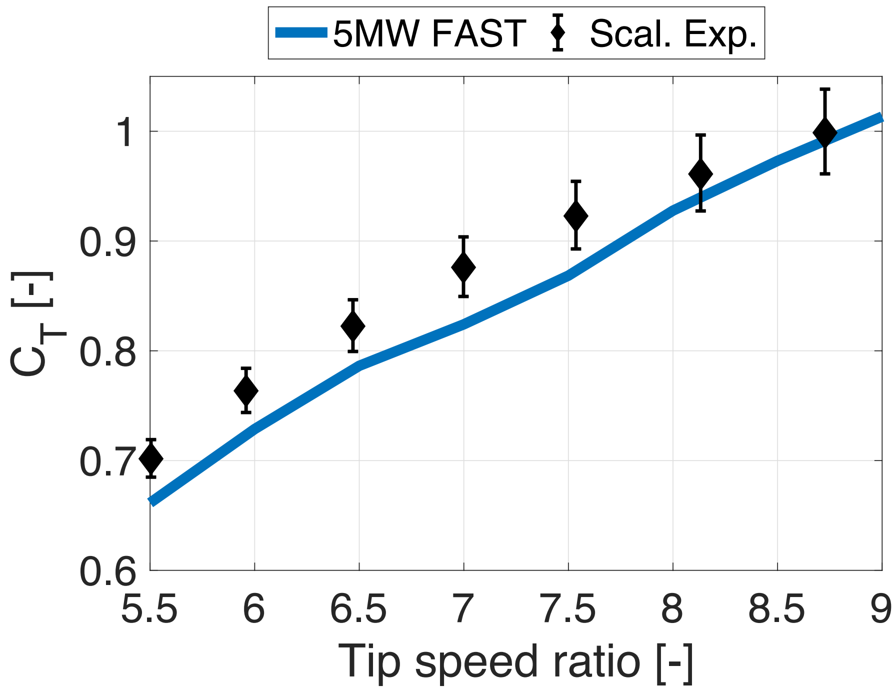
Objective 2:
C_p and C_t characteristic°



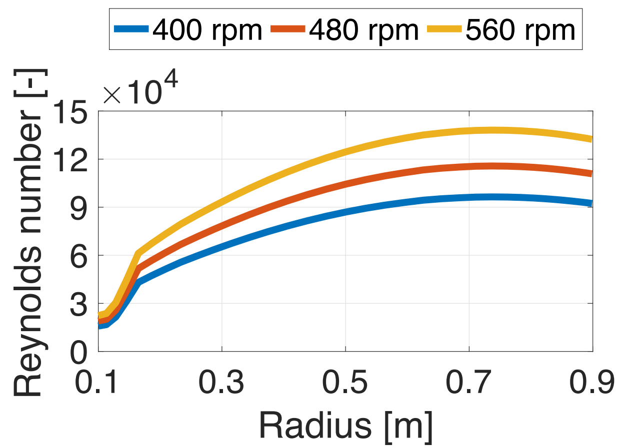


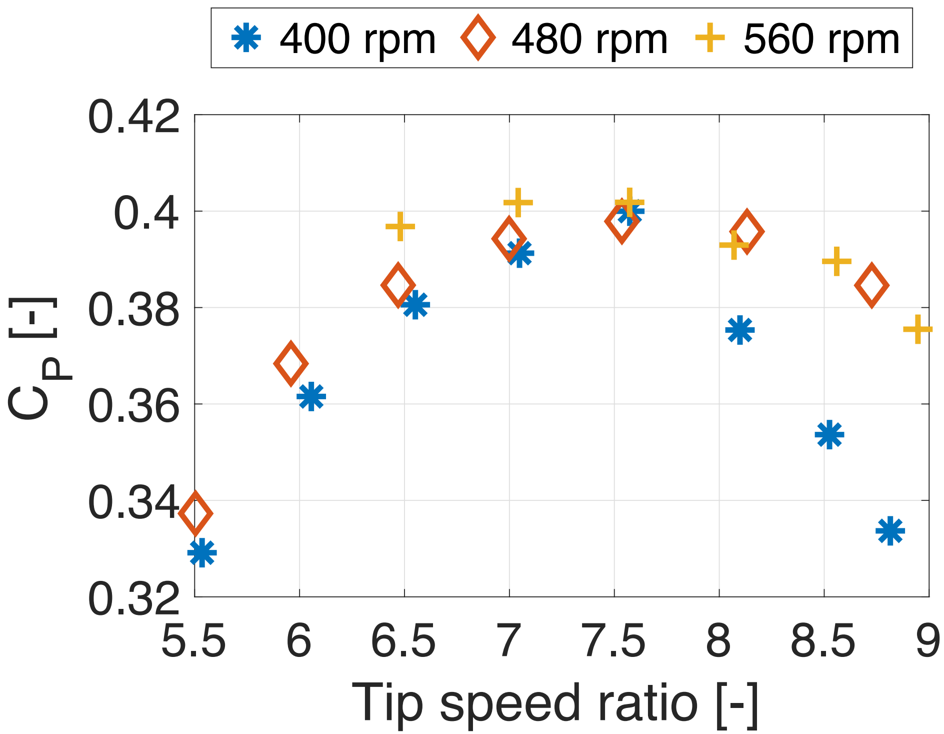
- Slope matches
- Offset due to difference in glide ratio of profiles

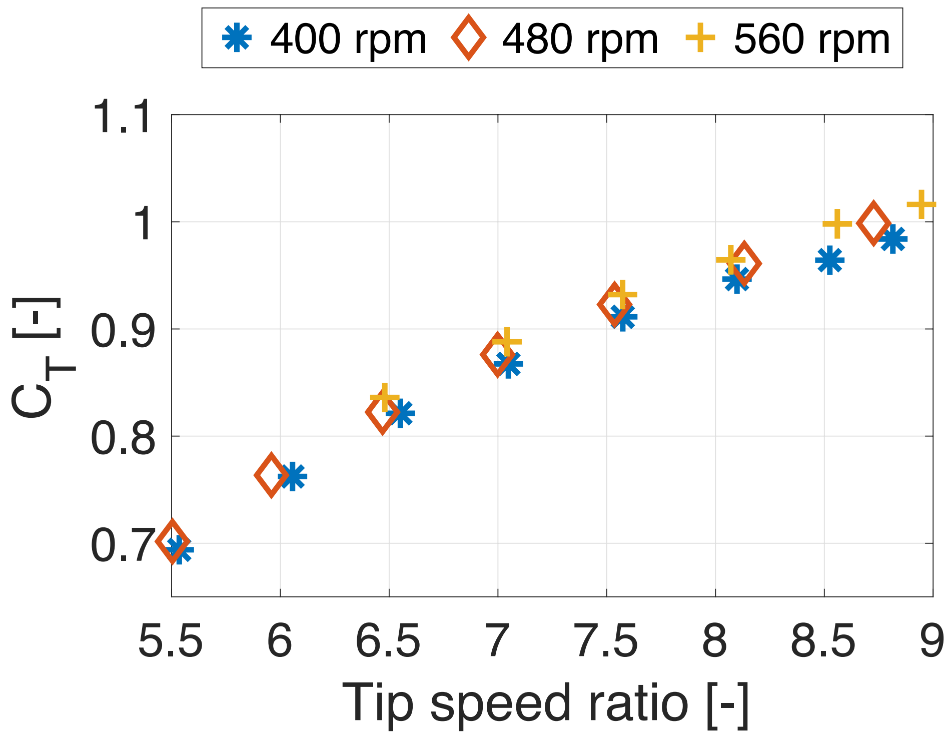
- Good match

Error bars indicate influence of ± 0.1 m/s in reference wind

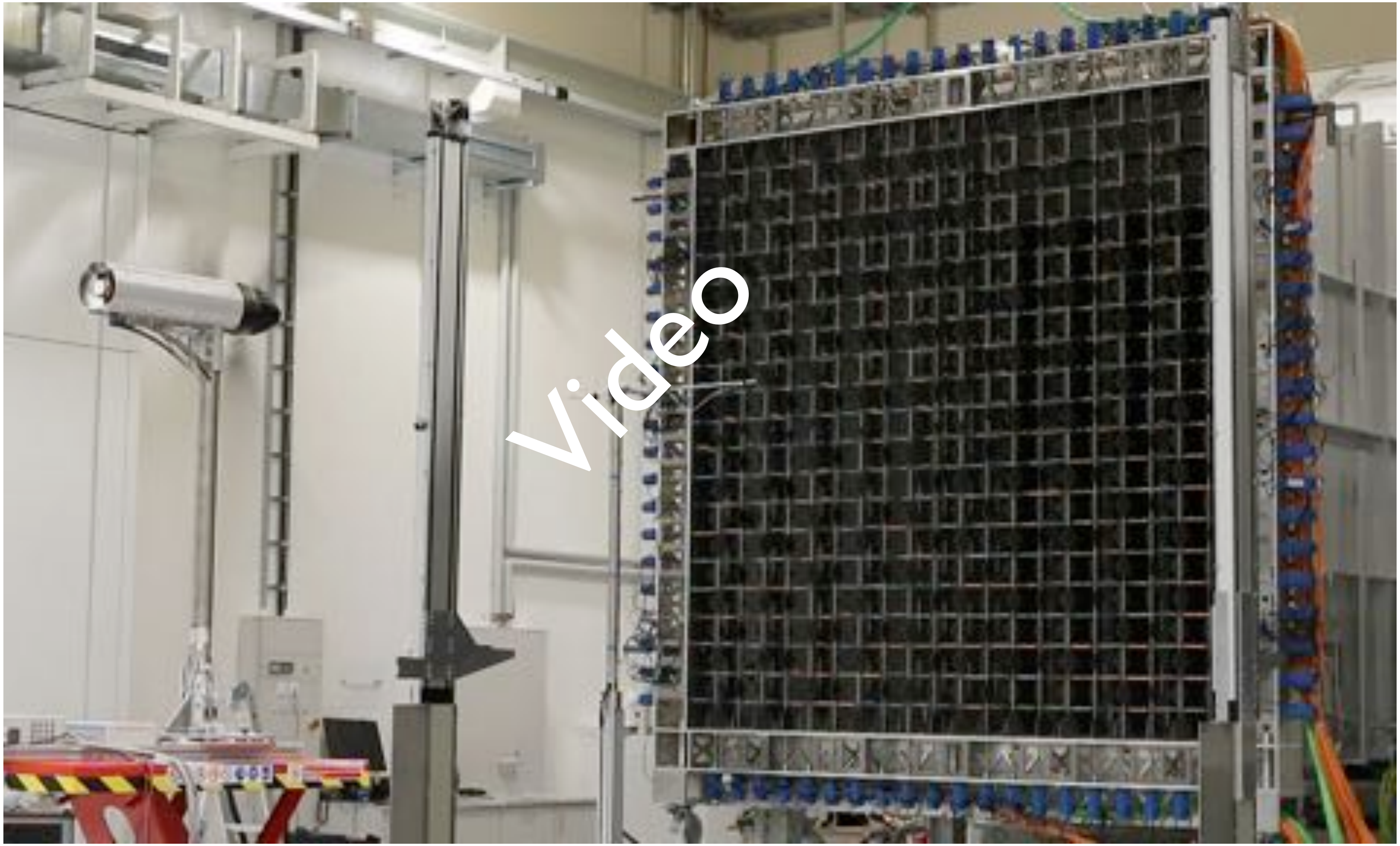
Objective 3: Influence of Reynolds number ✓





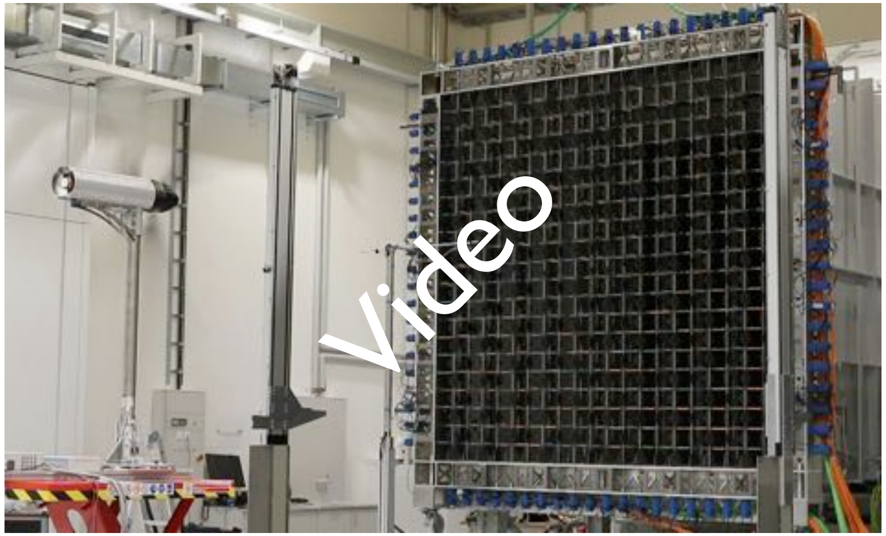


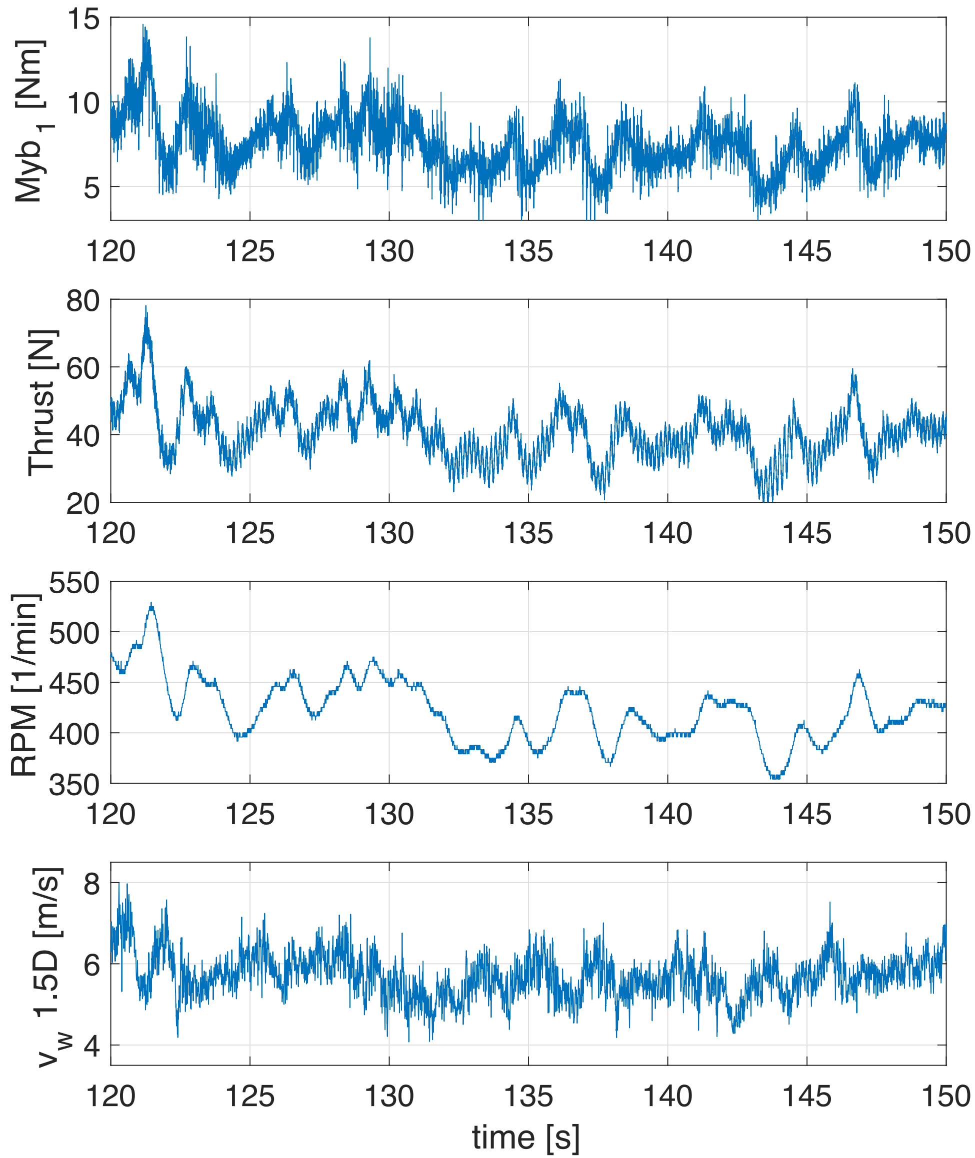
Experiments: Turbulent Inflow



Experiments: Turbulent Inflow

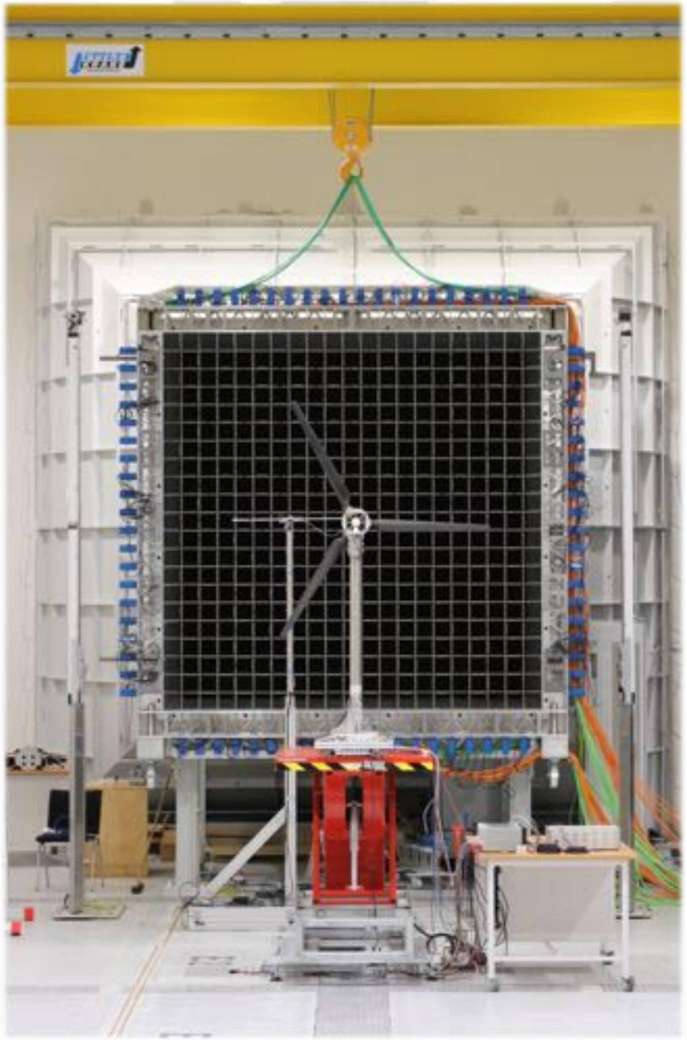
- Turbulent protocol based on free field measurement
- Mean wind velocity 5.7 m/s
- Turbulence intensity 10.4 %





Summary

- **Introduction of test setup** :
  - Model wind turbine (D=1.8 m)
    - Fully equipped with sensors
    - Blade aerodynamics and loads scalable to NREL 5 MW turbine
  - Wind tunnel with active turbulence grid
    - Reproduceable turbulent patterns
- **Planned experiments**:
    - Engineering models (e.g. dyn. inflow)
    - Turbulent inflow (temporal/spatial)
    - PIV investigations
    - Controller testing



Acknowledgements

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