

IMPERIAL



Giving Wind Farms a Power-Up with AI

Craig Thompson
Kevin Gouder
Mike Graham

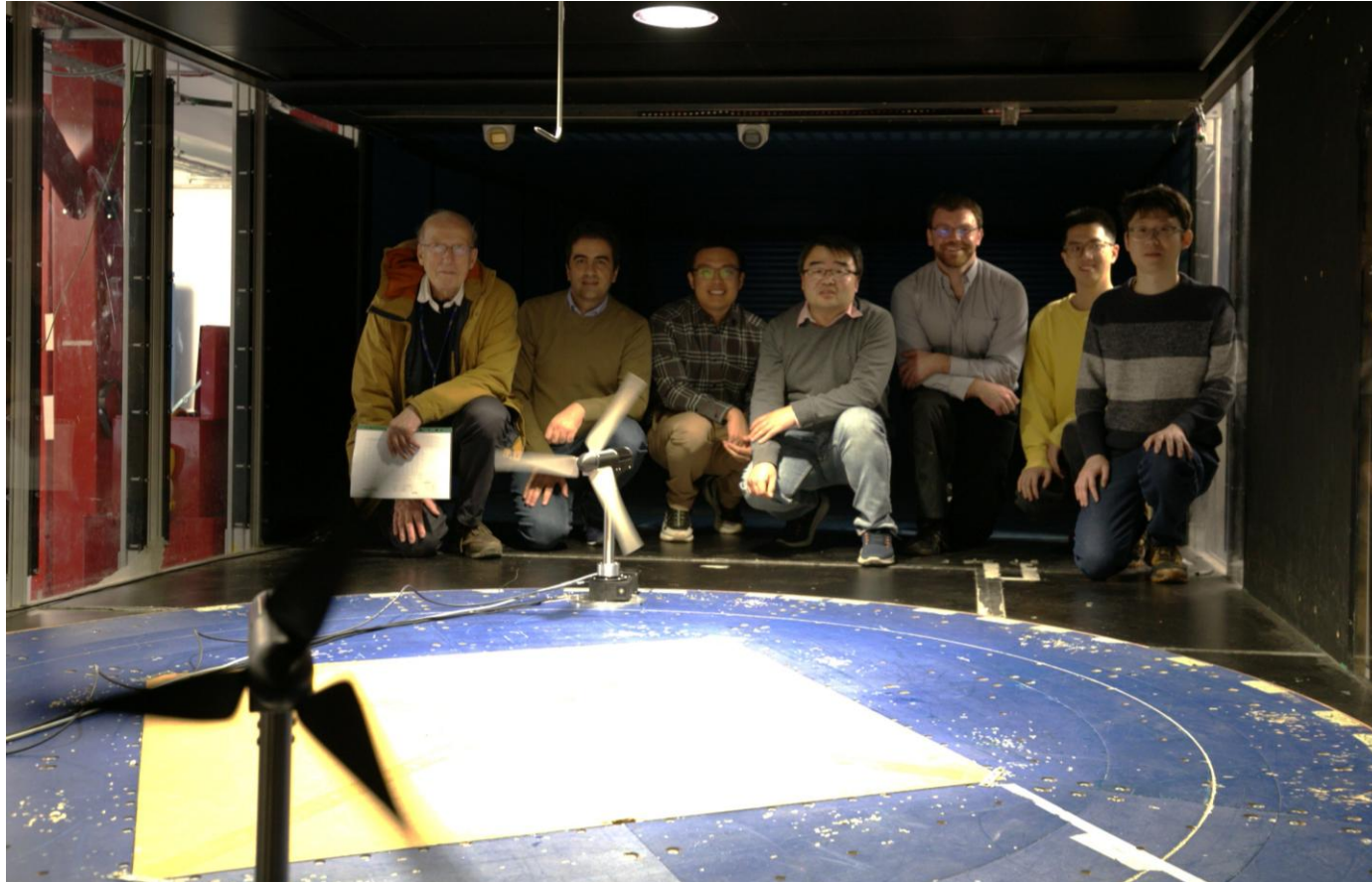
Yuhan Su
Weitao Yue
Hongyang Dong
Xiaowei Zhao

14/09/2026



Funded by
the European Union

The Team



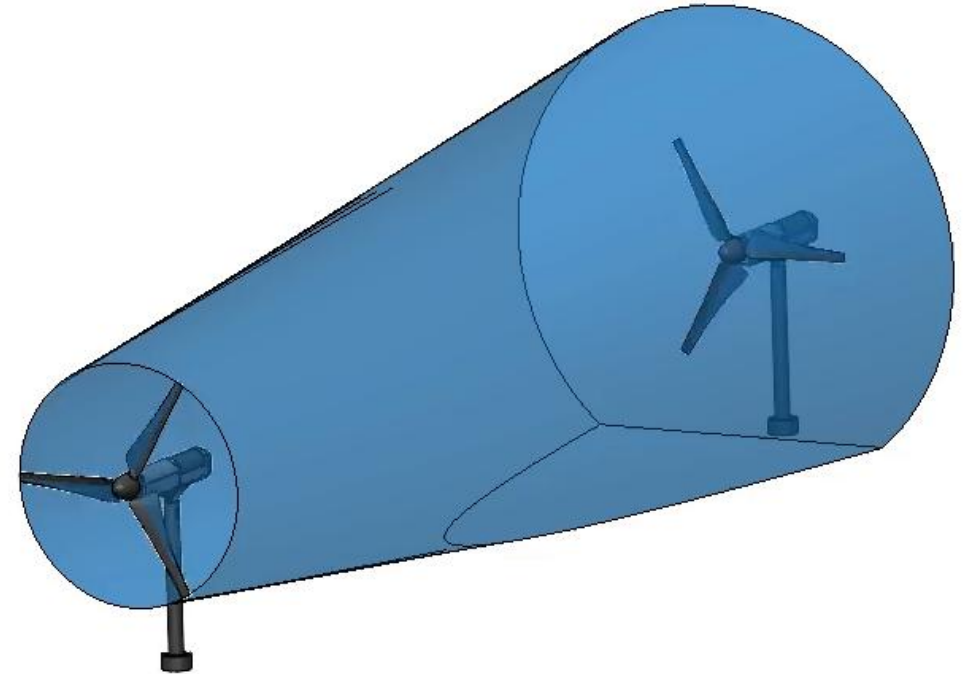
Agenda

- 1 Motivation
- 2 Wake steering?
- 3 Control algorithms
- 4 Experimental methodology
- 5 Results
- 6 Upcoming work

Motivation

The problem

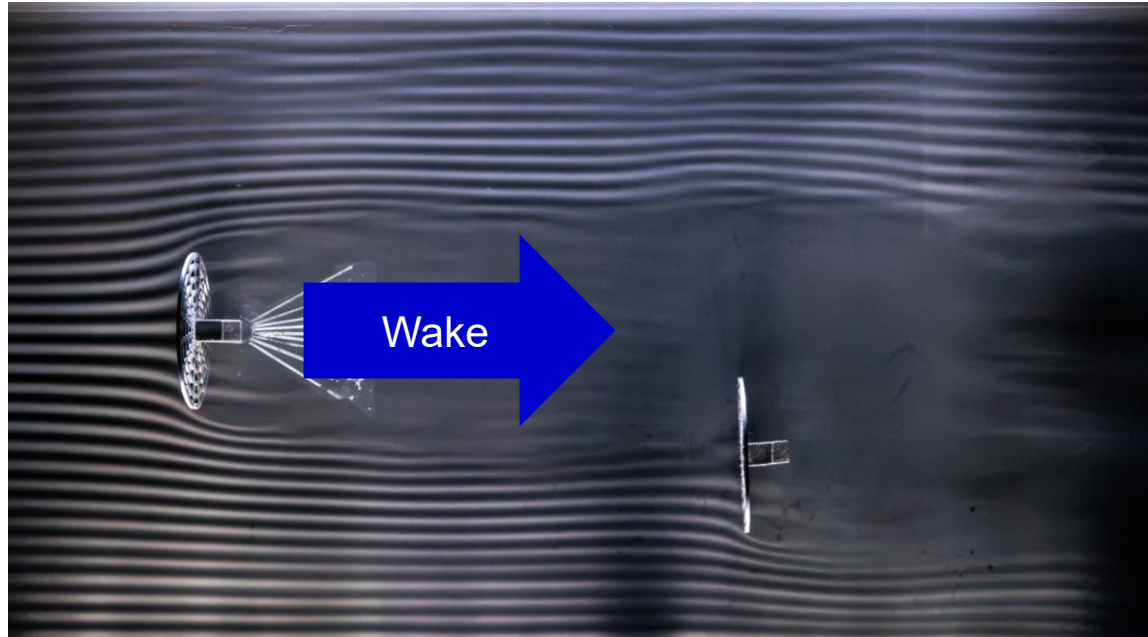
- Wind turbines operating in the wake of upstream turbines experience over:
- 35% reduction in power
- 50% increase in axial load fluctuations



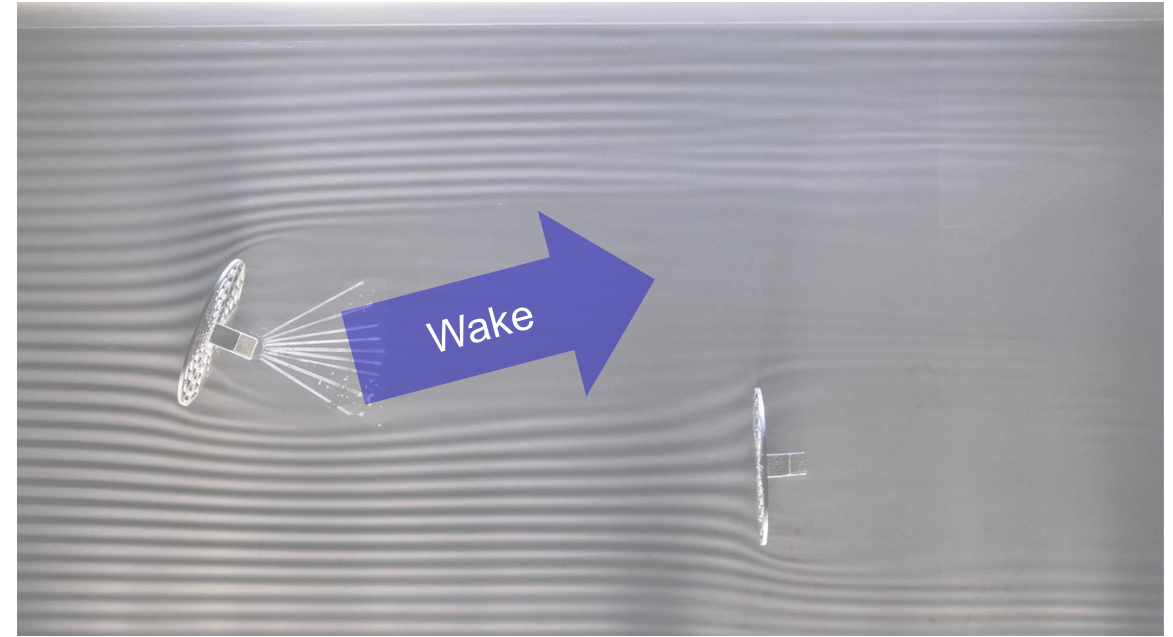
Wake Steering

A solution

Deliberately manoeuvre the wake of upstream turbines to mitigate losses



Greedy

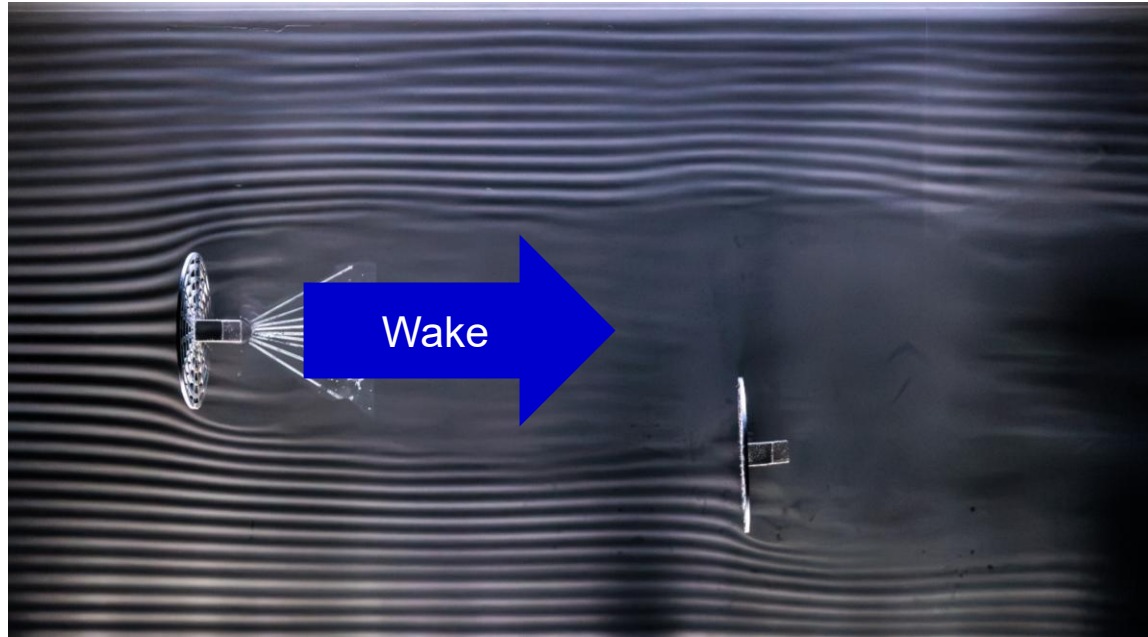


Wake steering

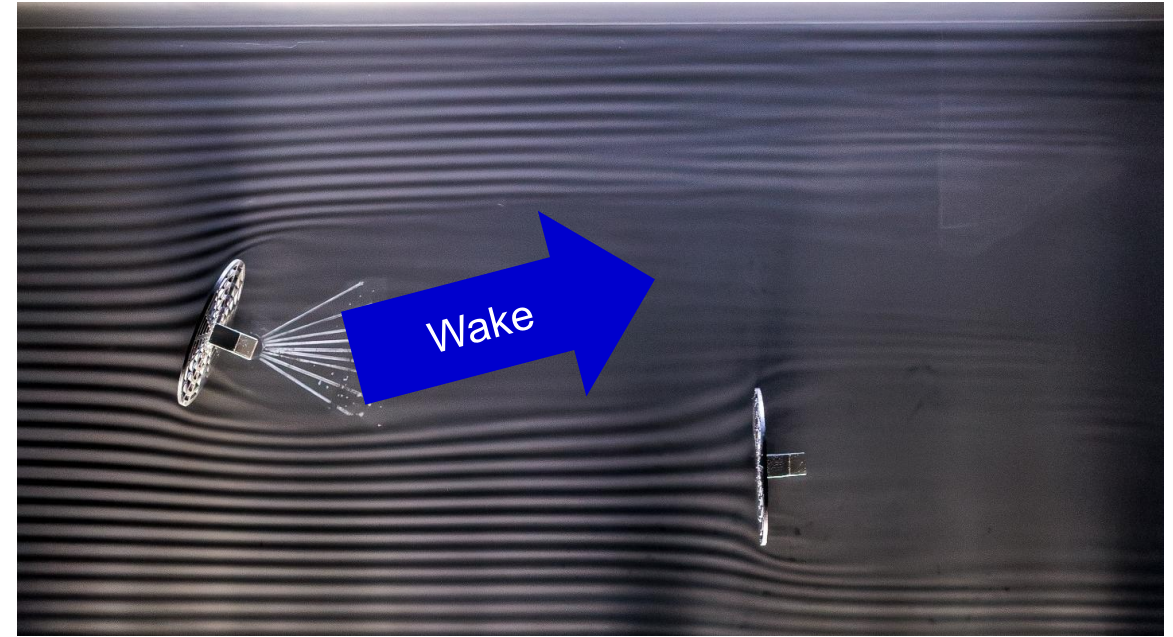
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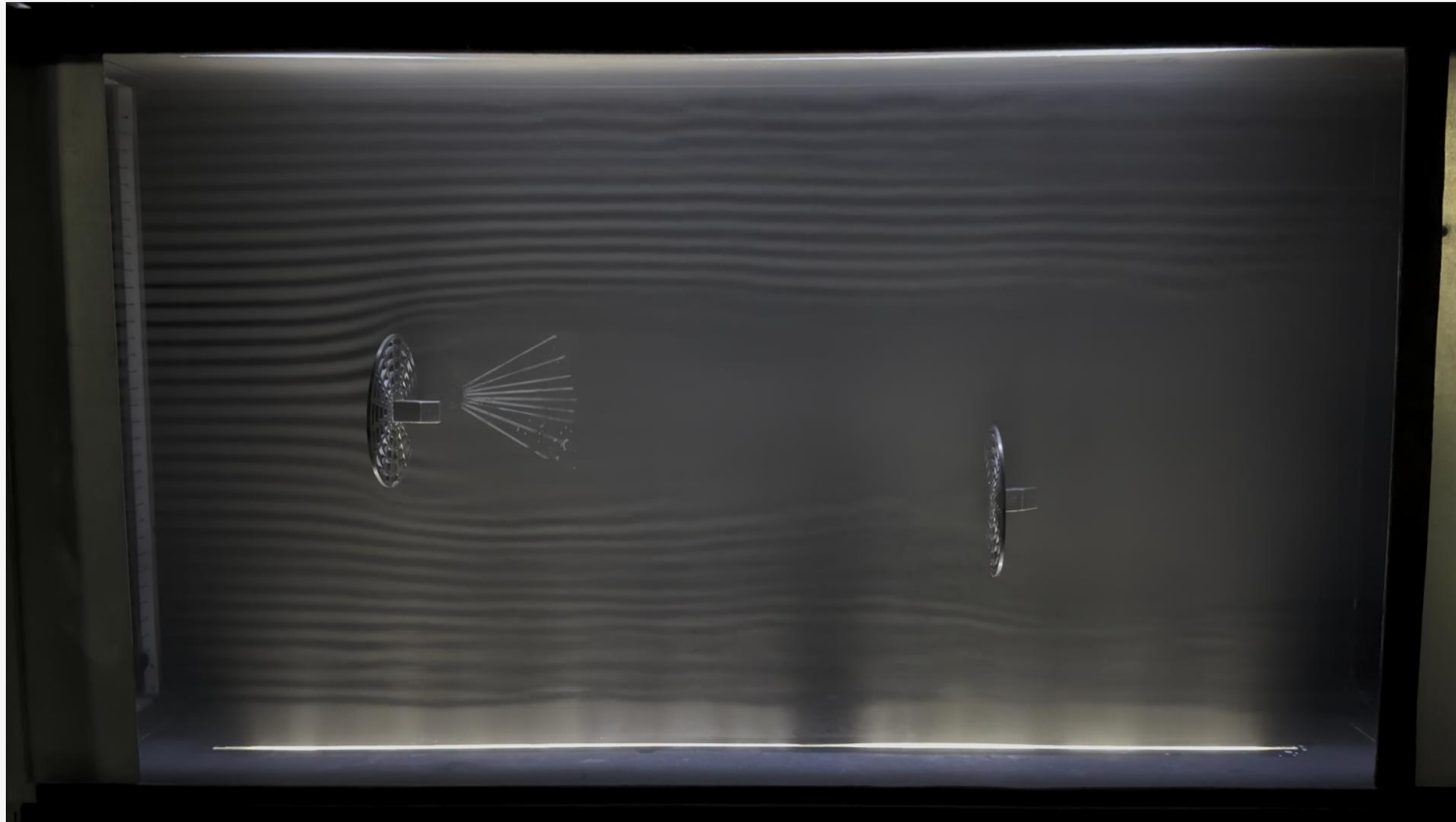


Wake steering

Wake Steering

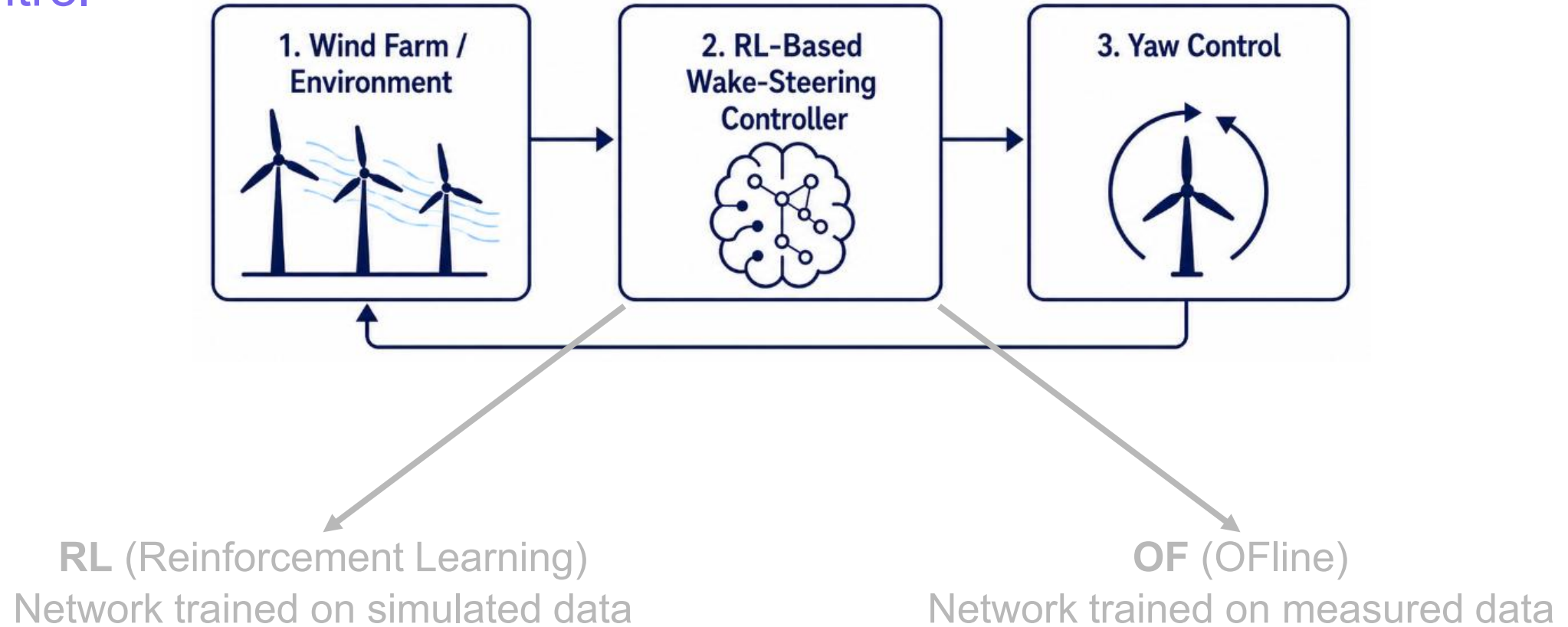
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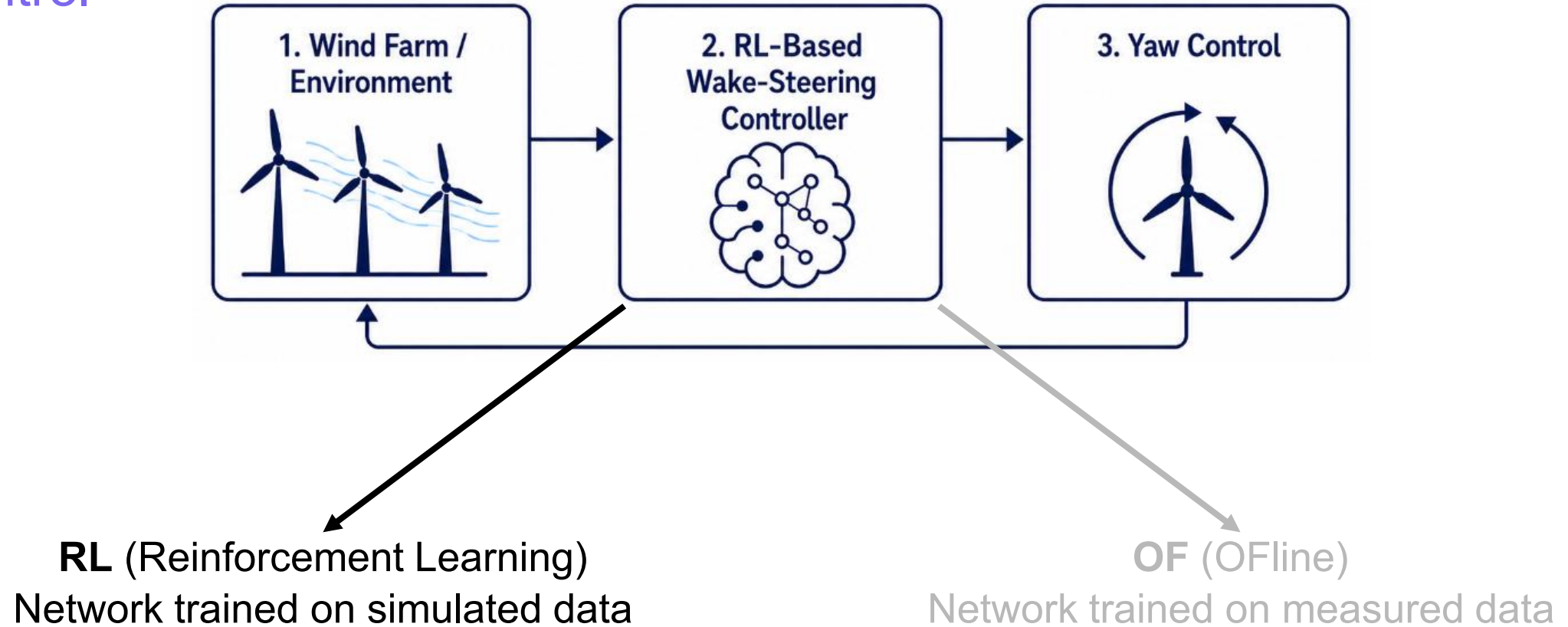
The Application

AI Control



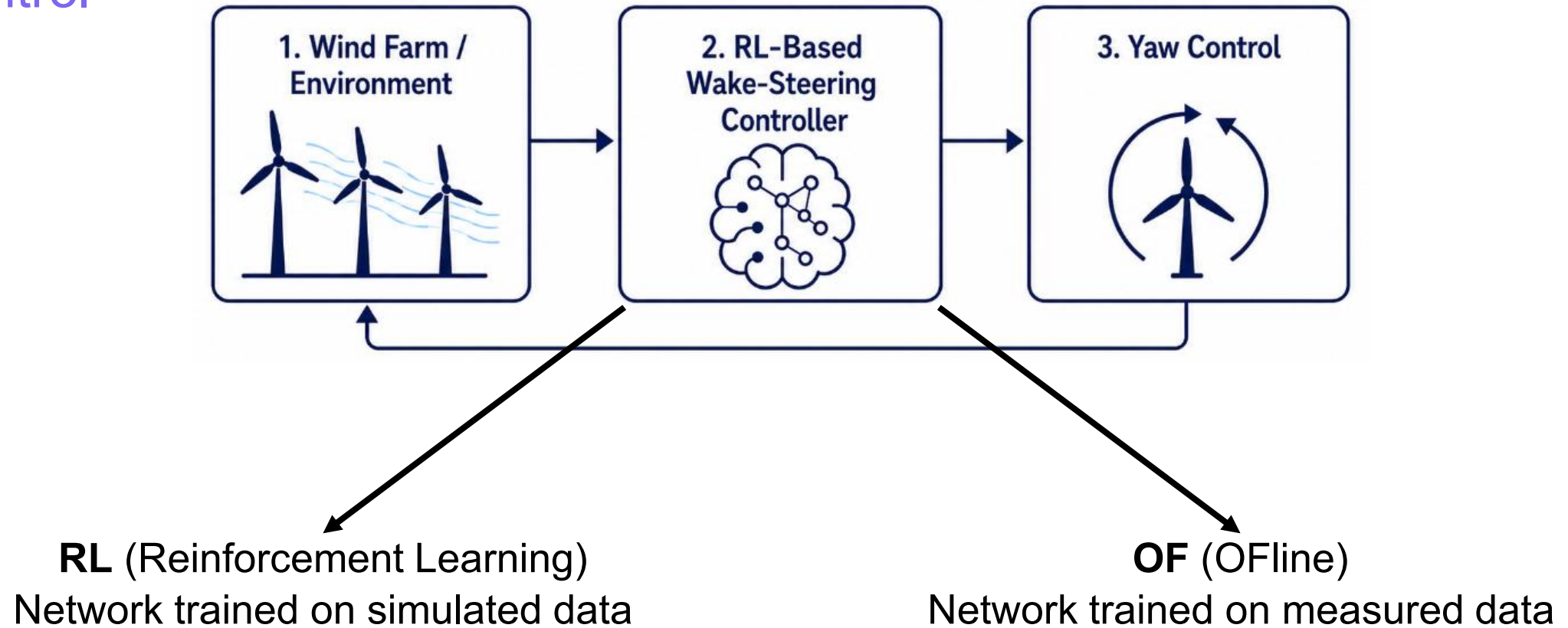
The Application

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The Application

AI Control



Experimental methodology

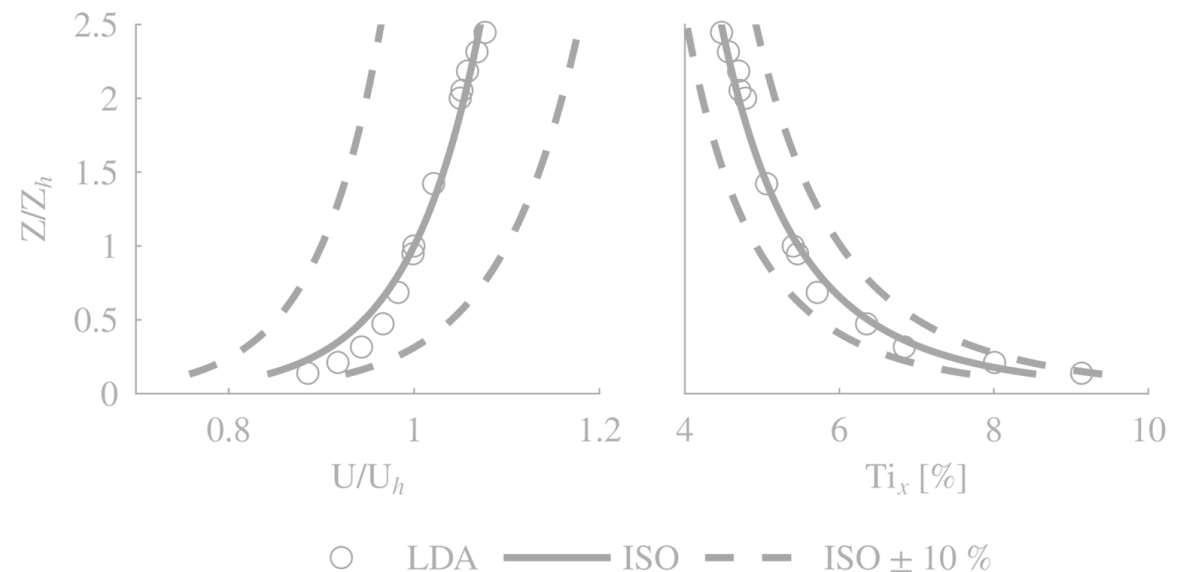
The tunnel

- 10' x 5'
- 1.5 m x 3 m x 20 m
- ABL generated using spires
- Match ISO marine
 - $U_h = 7.8 \text{ ms}^{-1}$
 - $T_i = 5.3 \%$
 - $L_x = \mathcal{O}(D)$



Irwin, H.: The design of spires for wind simulation, Journal of wind engineering and industrial aerodynamics, 7, 361–366, 1981.

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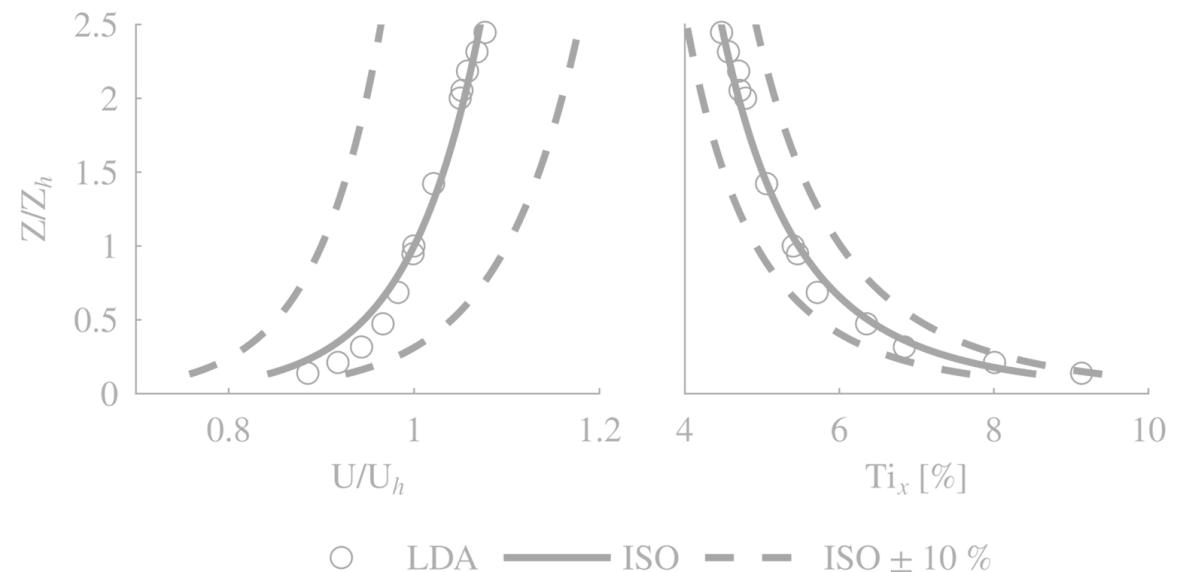
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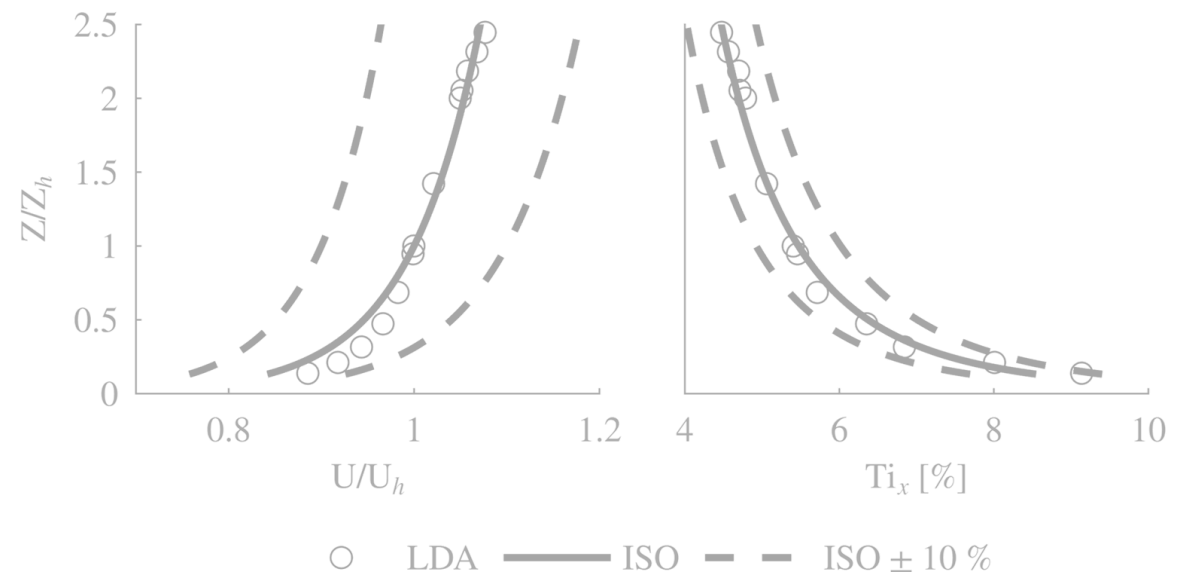
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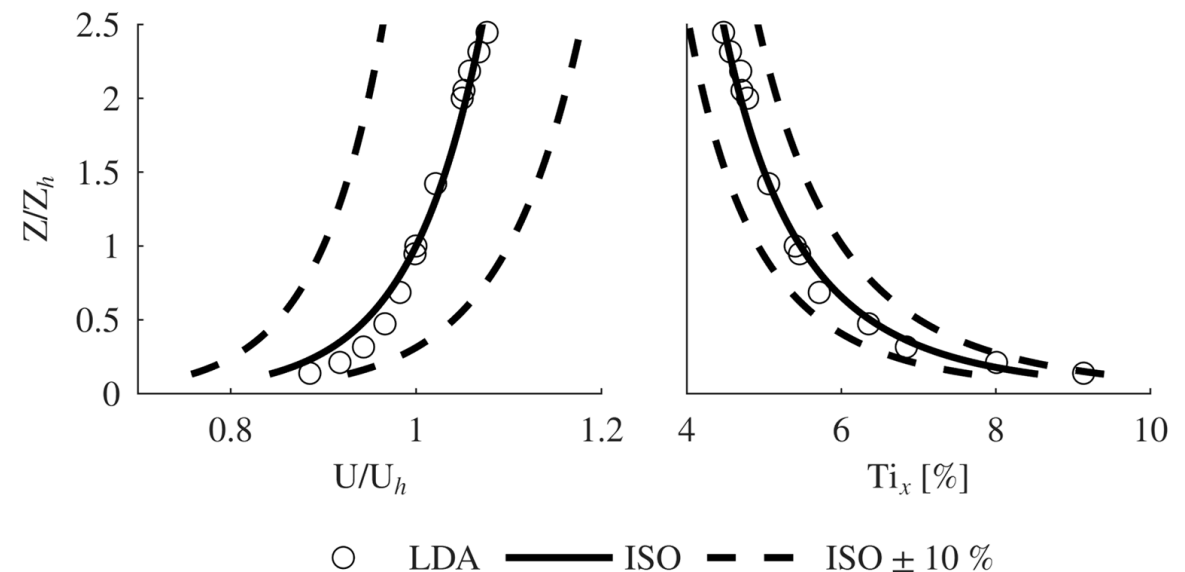
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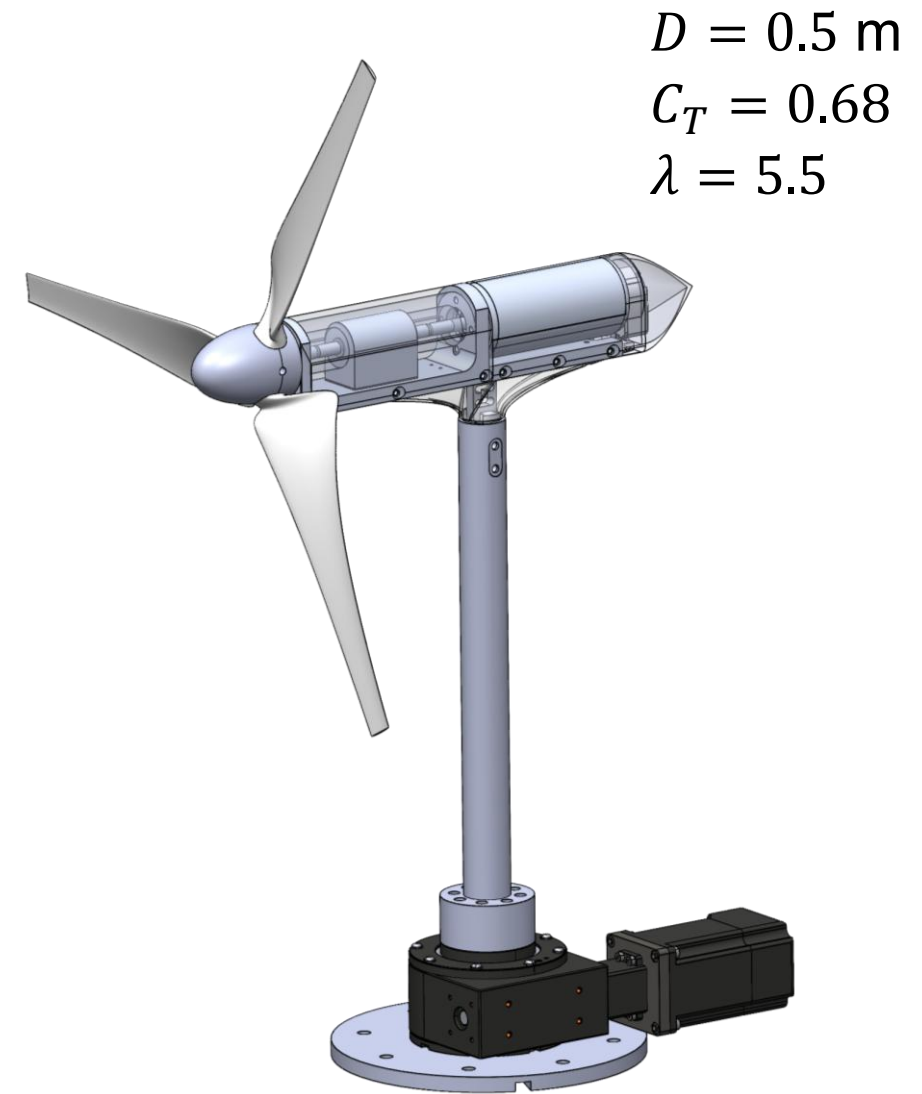
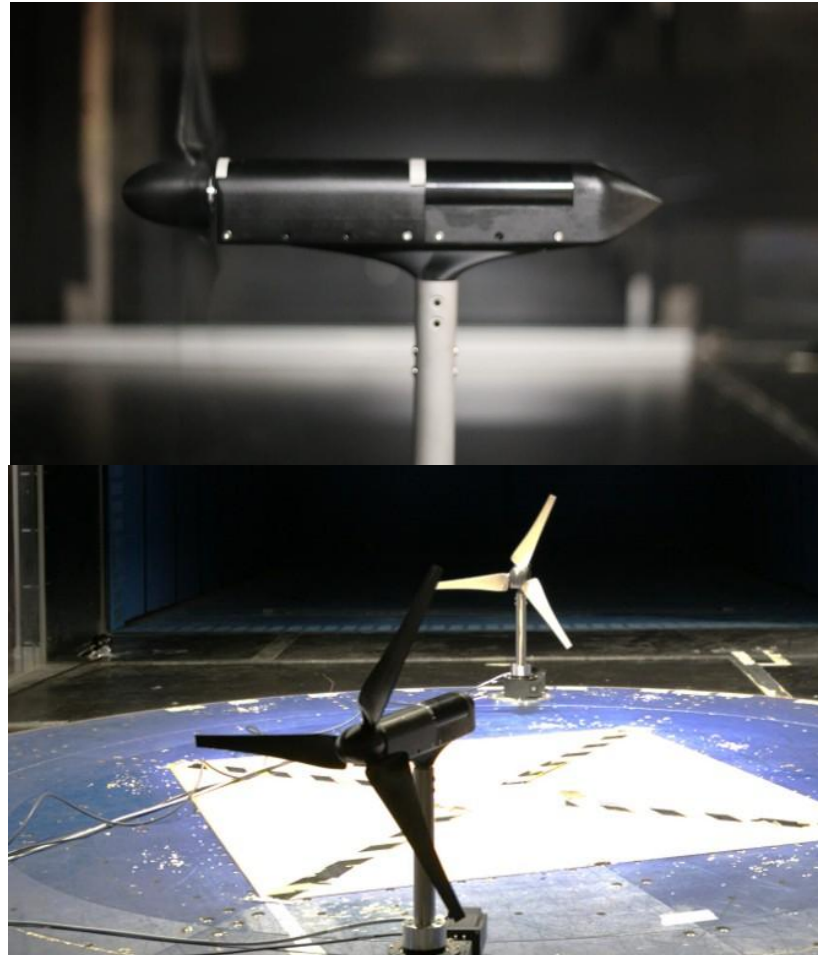
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Experimental methodology

The turbine

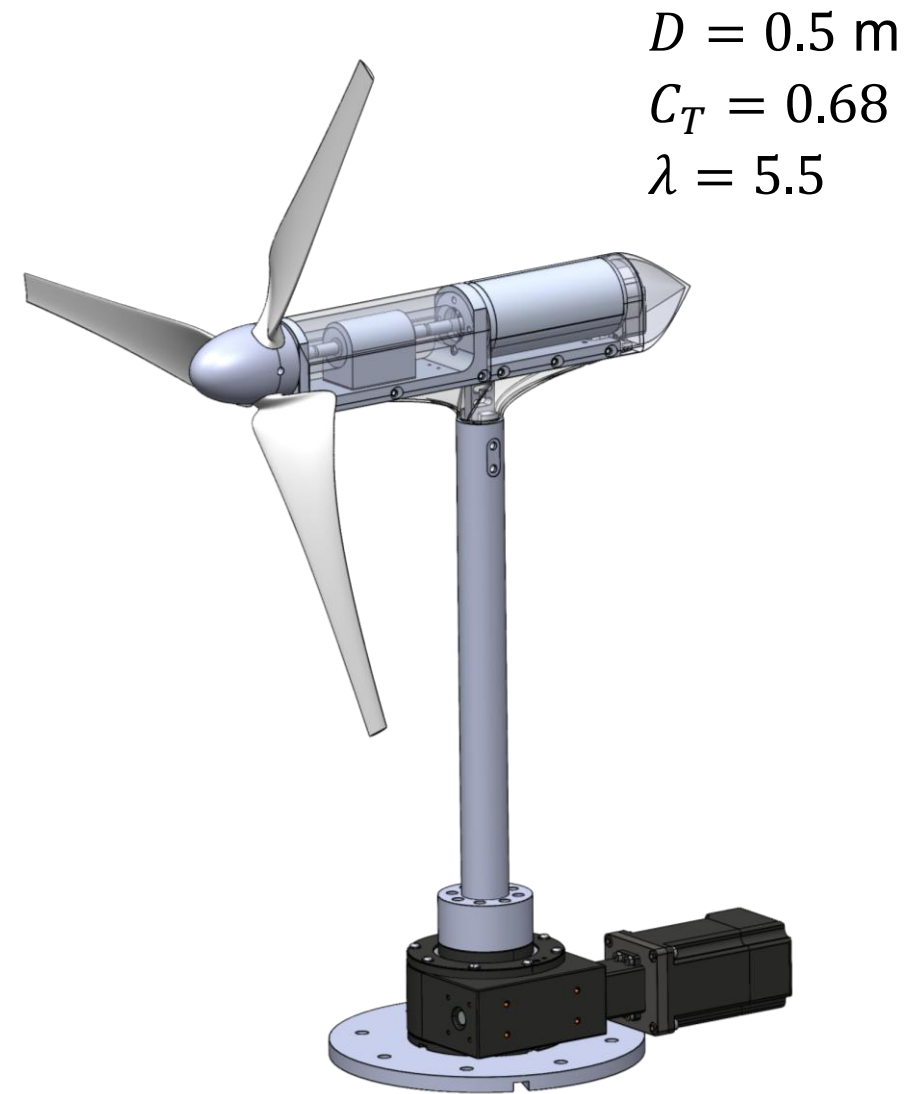
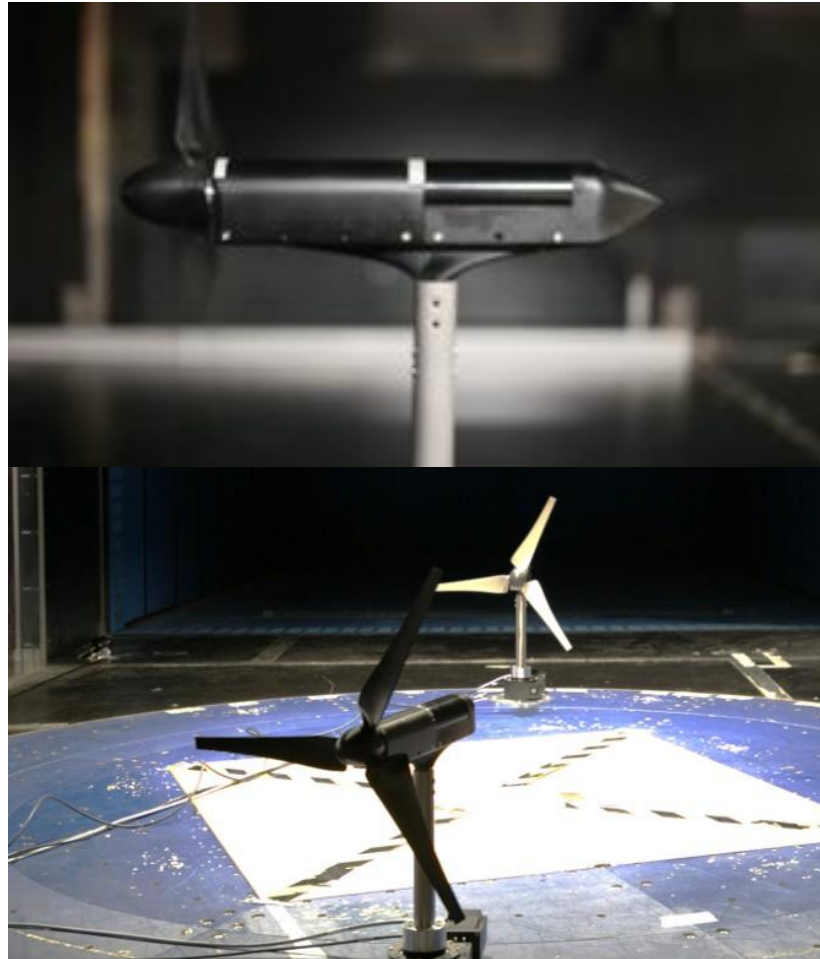
- 1:250 scale turbine
- Sensors
 - Torque
 - Angular velocity
 - Axial load
- Control
 - Yaw
 - Torque
 - Angular velocity



Experimental methodology

The turbine

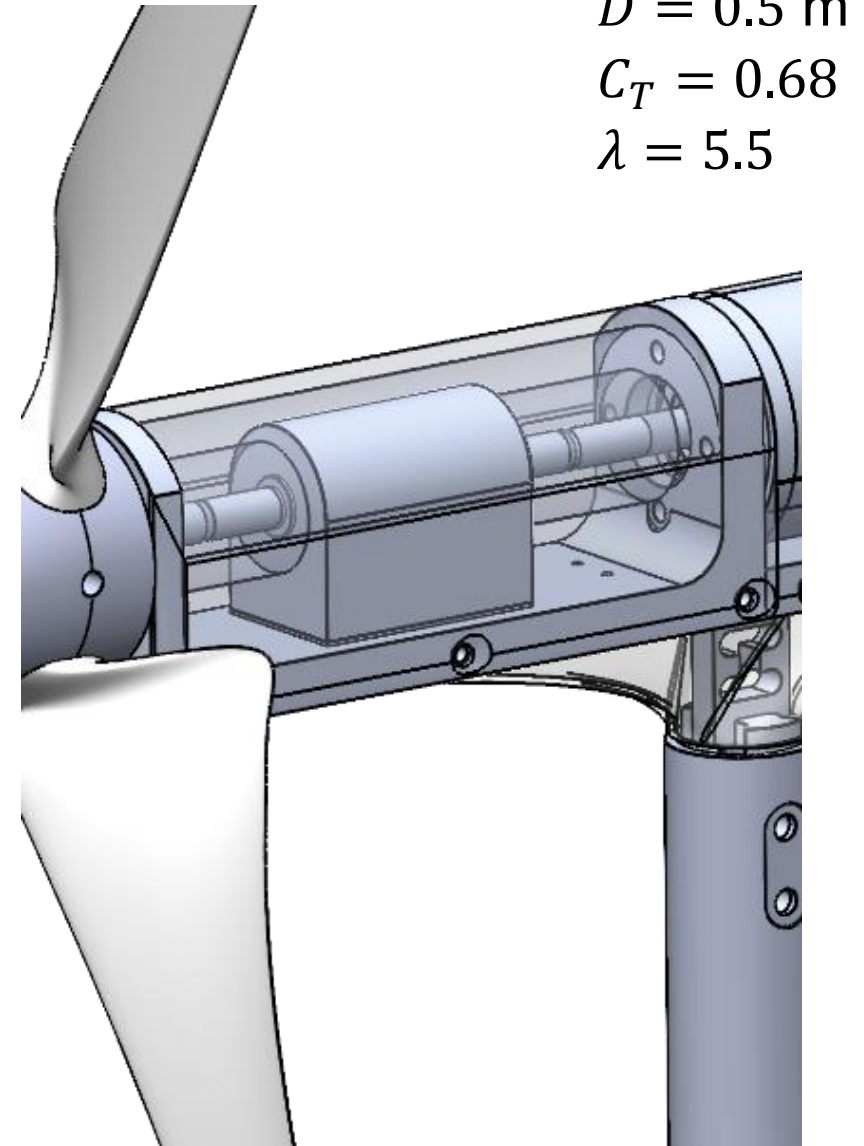
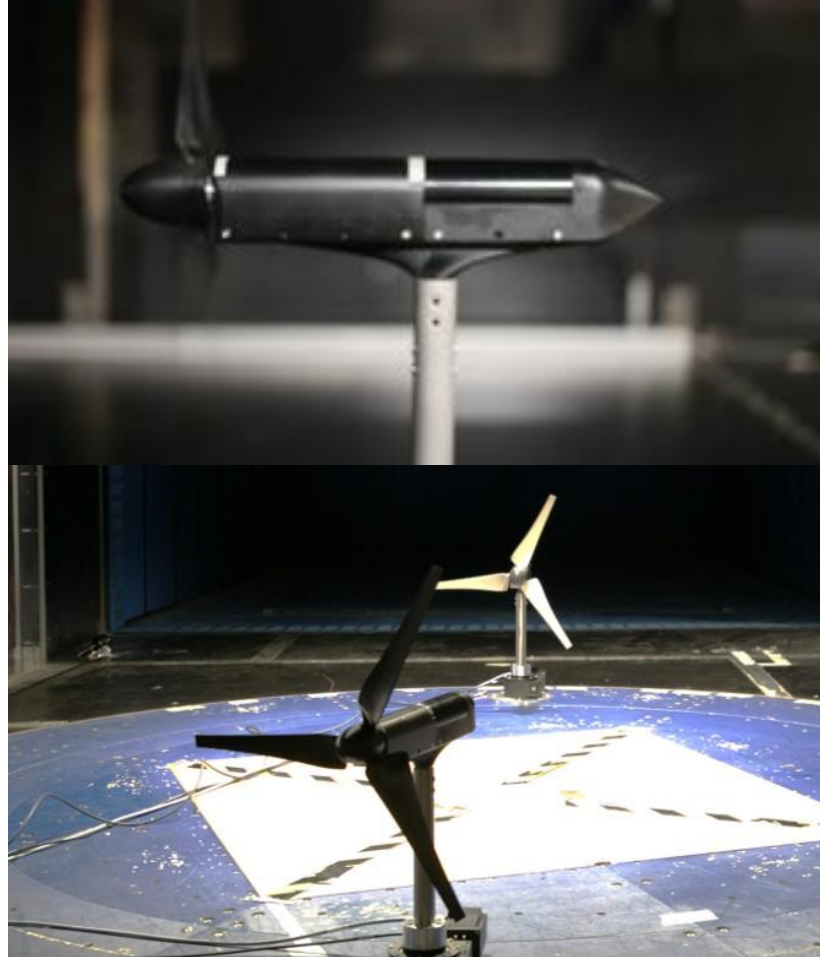
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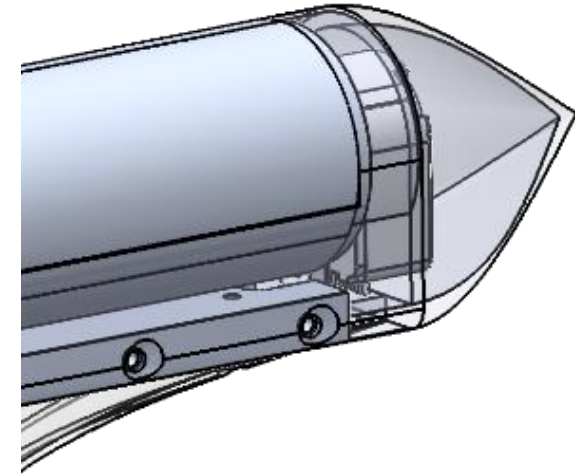
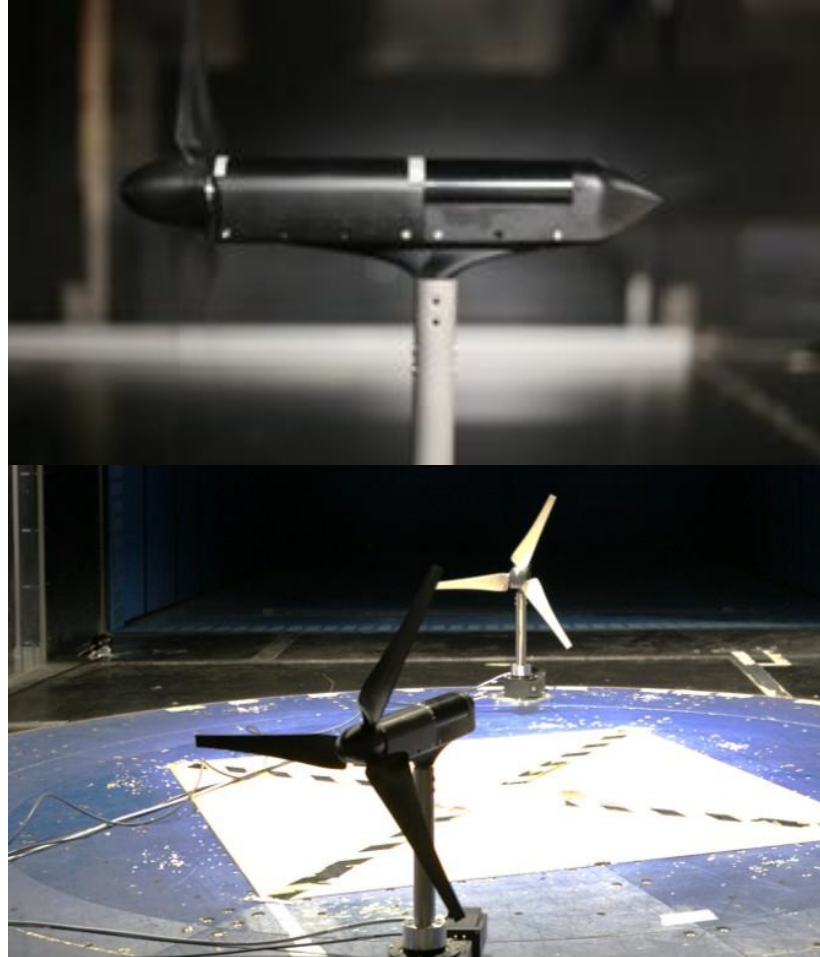
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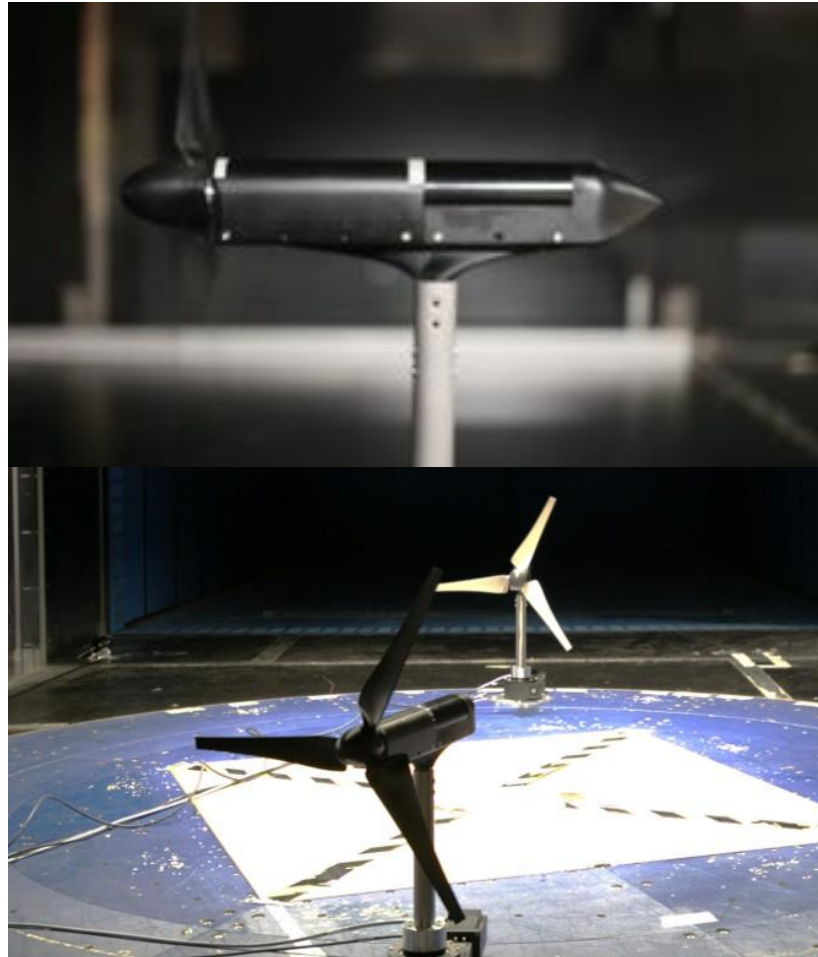


$$D = 0.5 \text{ m}$$
$$C_T = 0.68$$
$$\lambda = 5.5$$

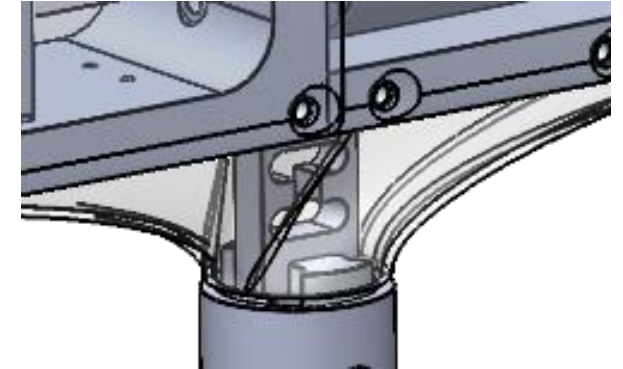
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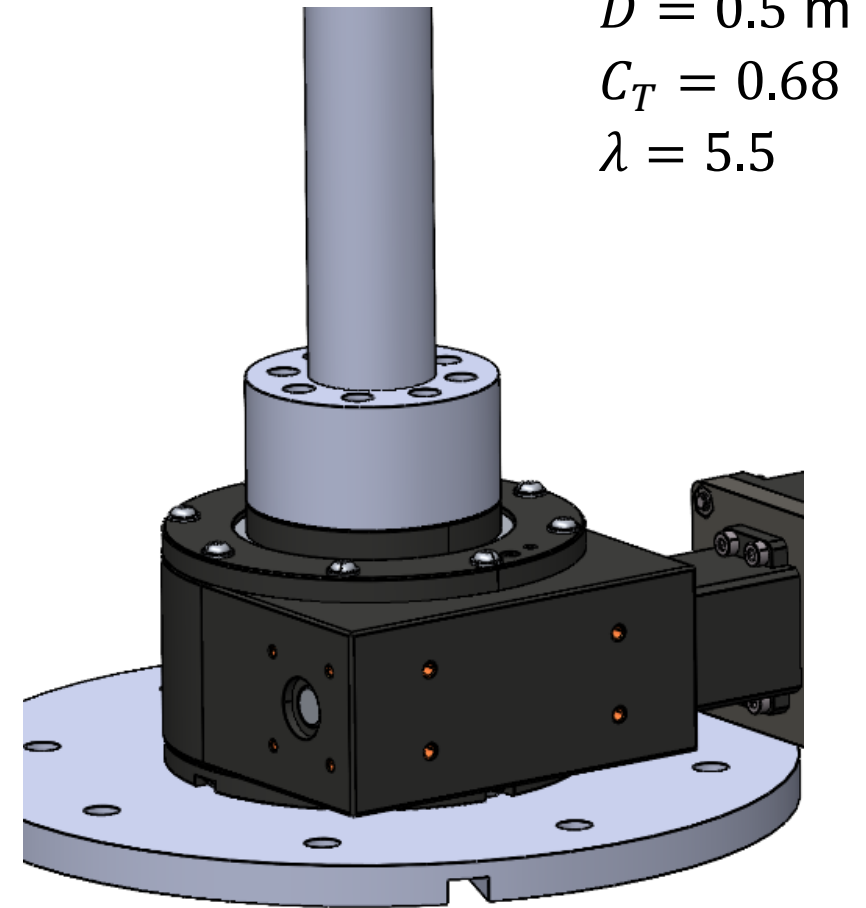
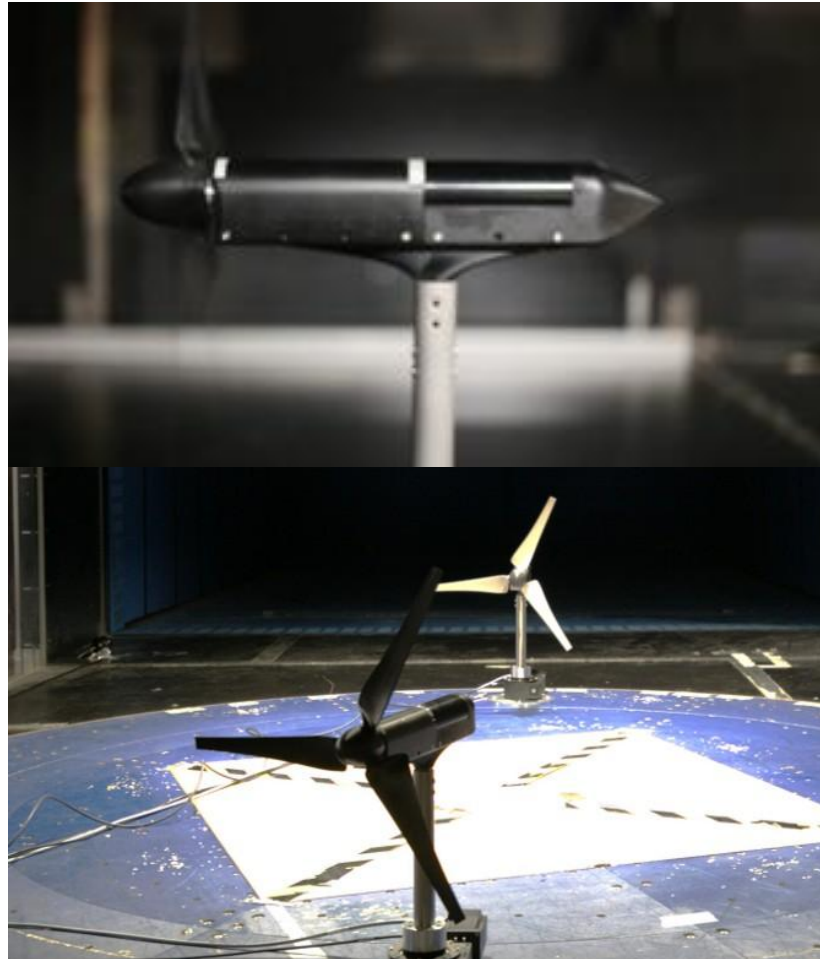
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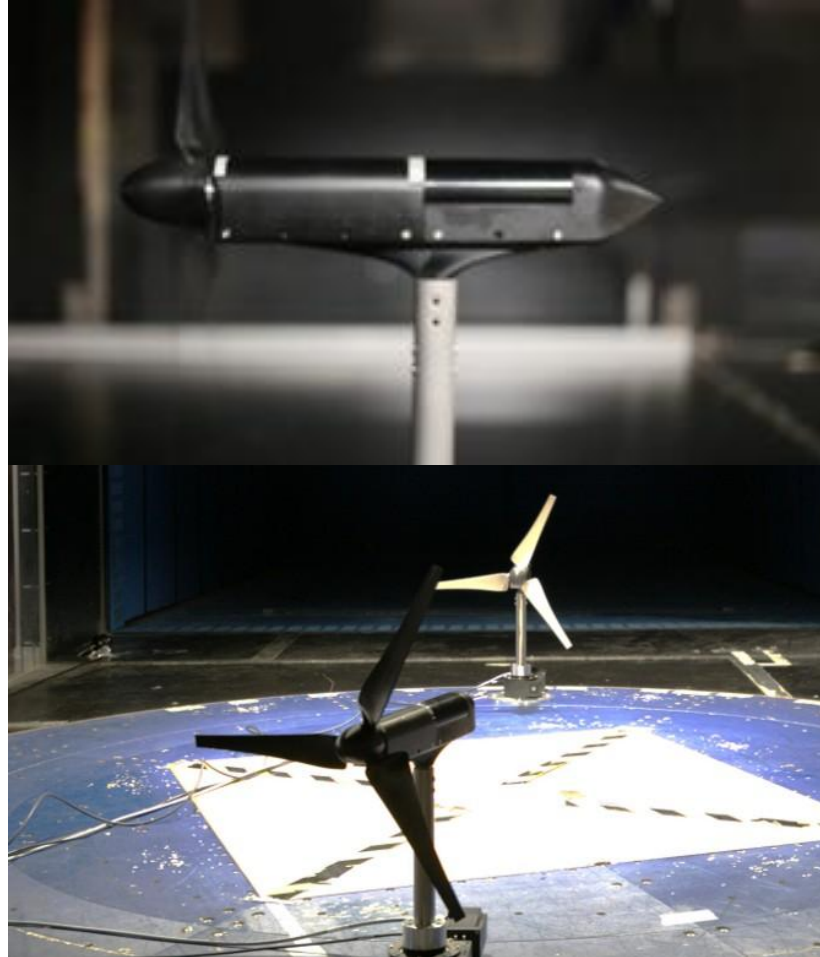
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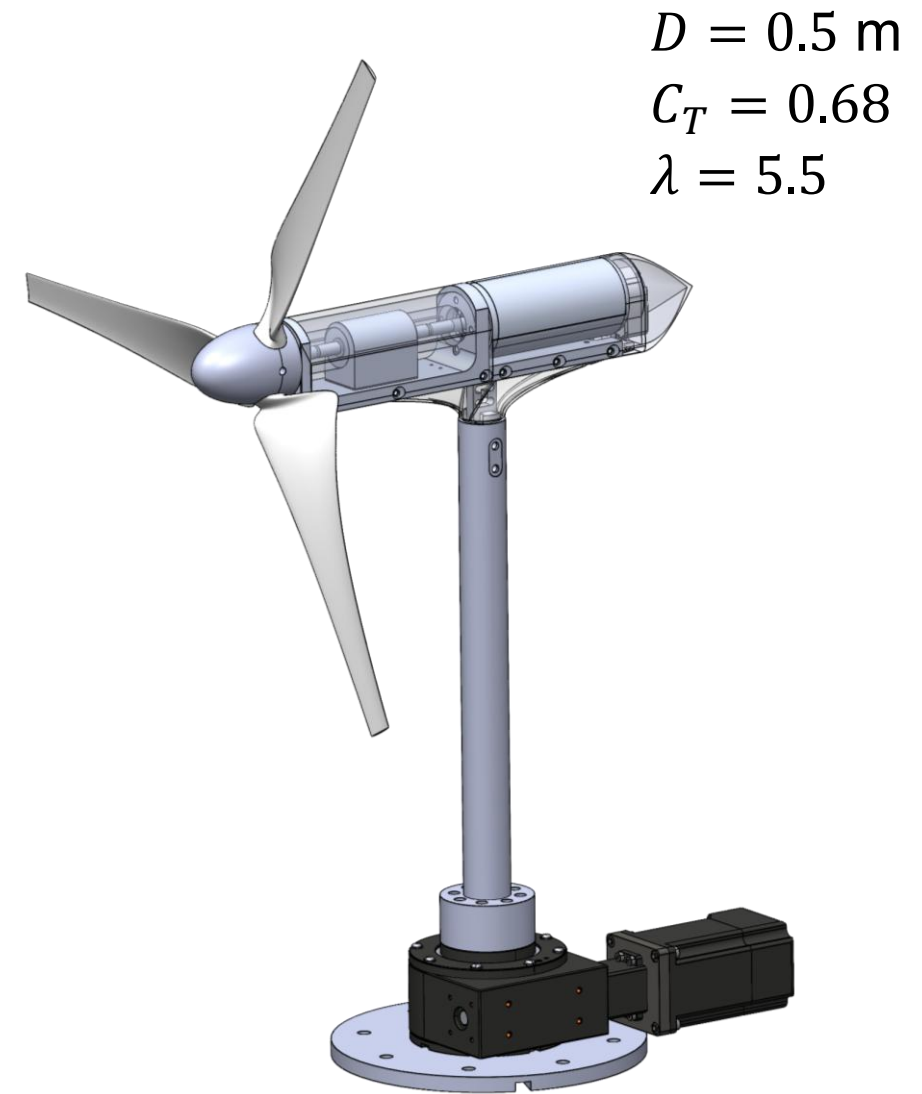
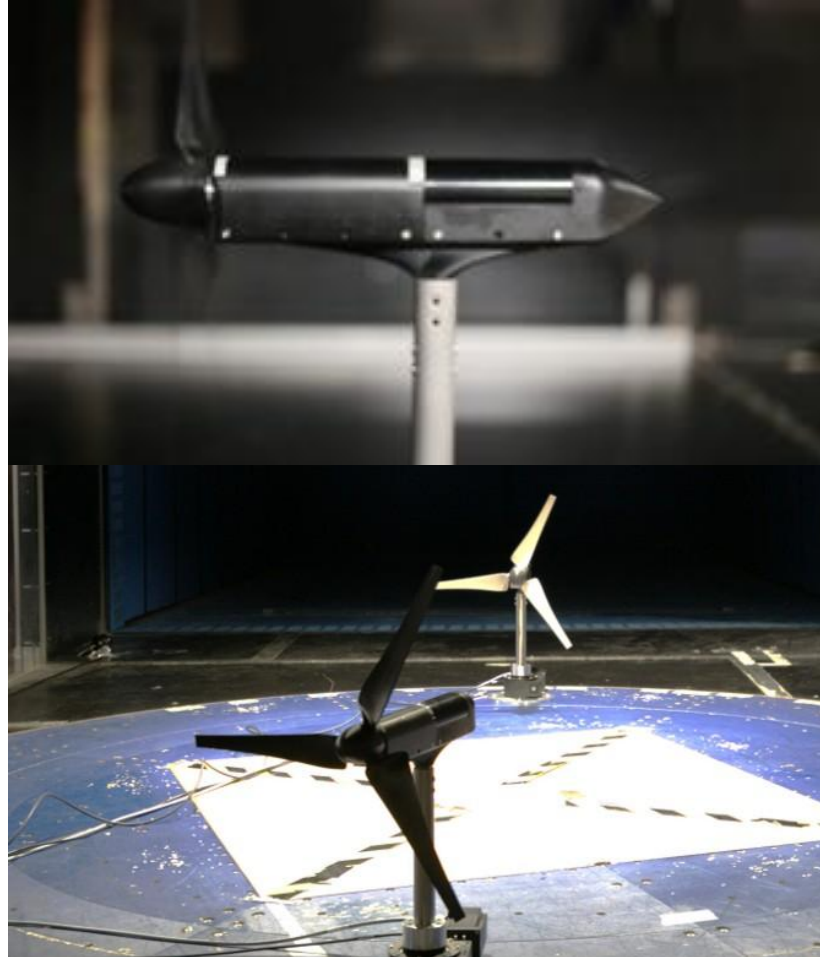


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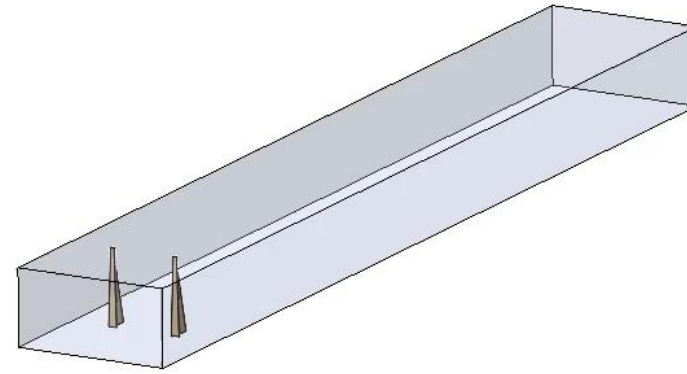
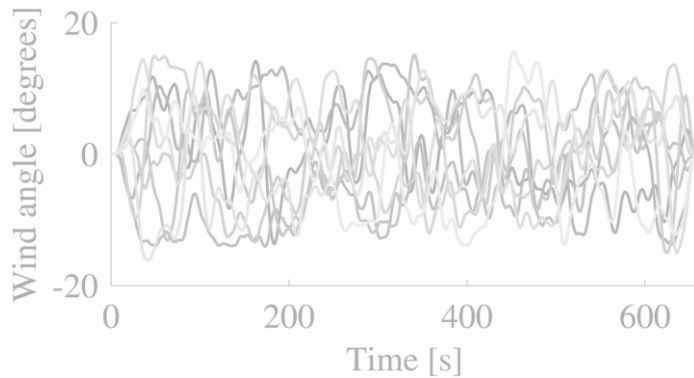
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Experimental methodology

The setup

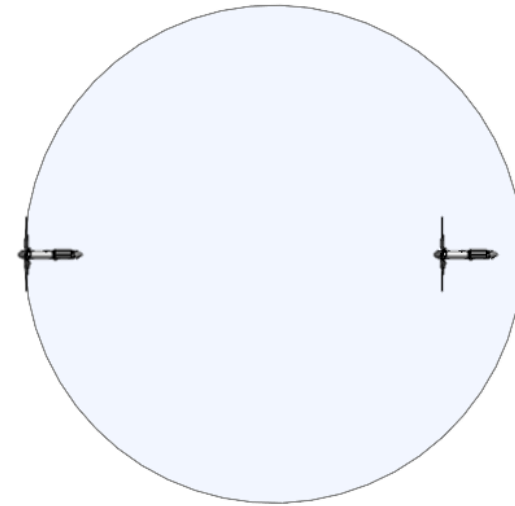
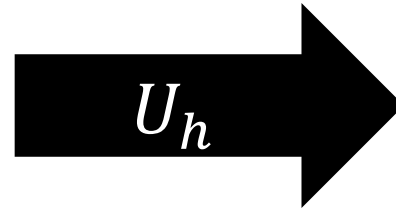
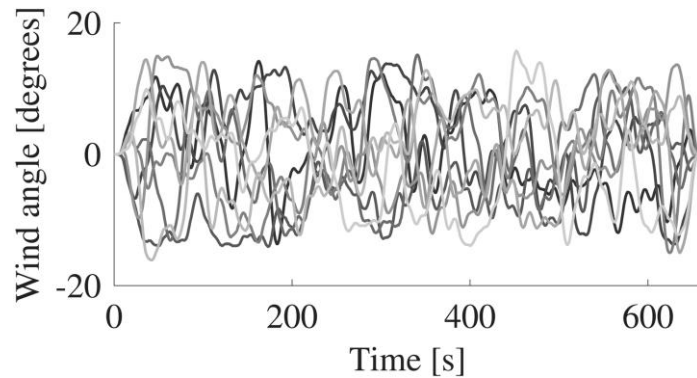
- Spires 32D upstream of the turbines
- Turbines 5D apart
- 9 wind profiles



Experimental methodology

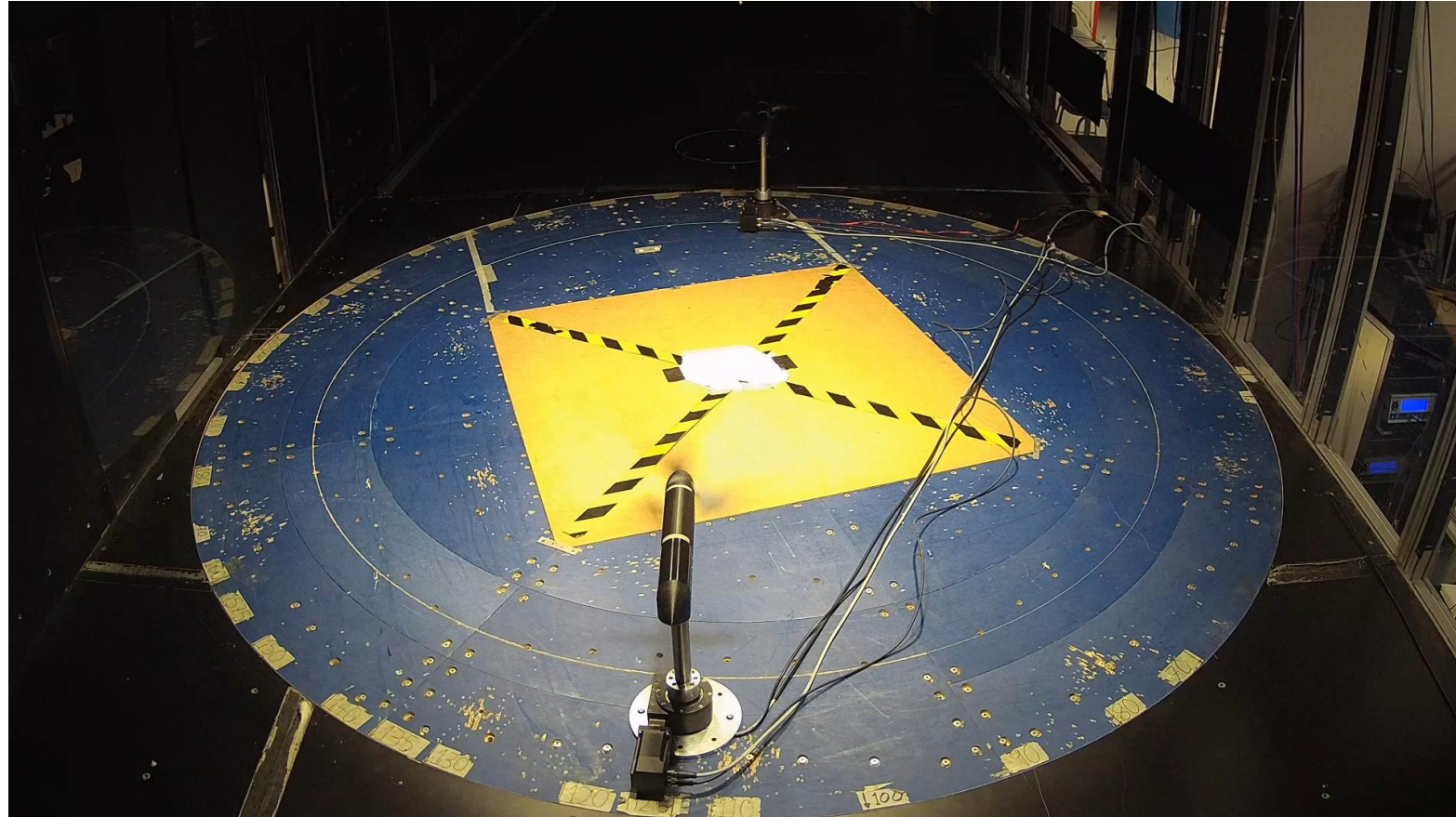
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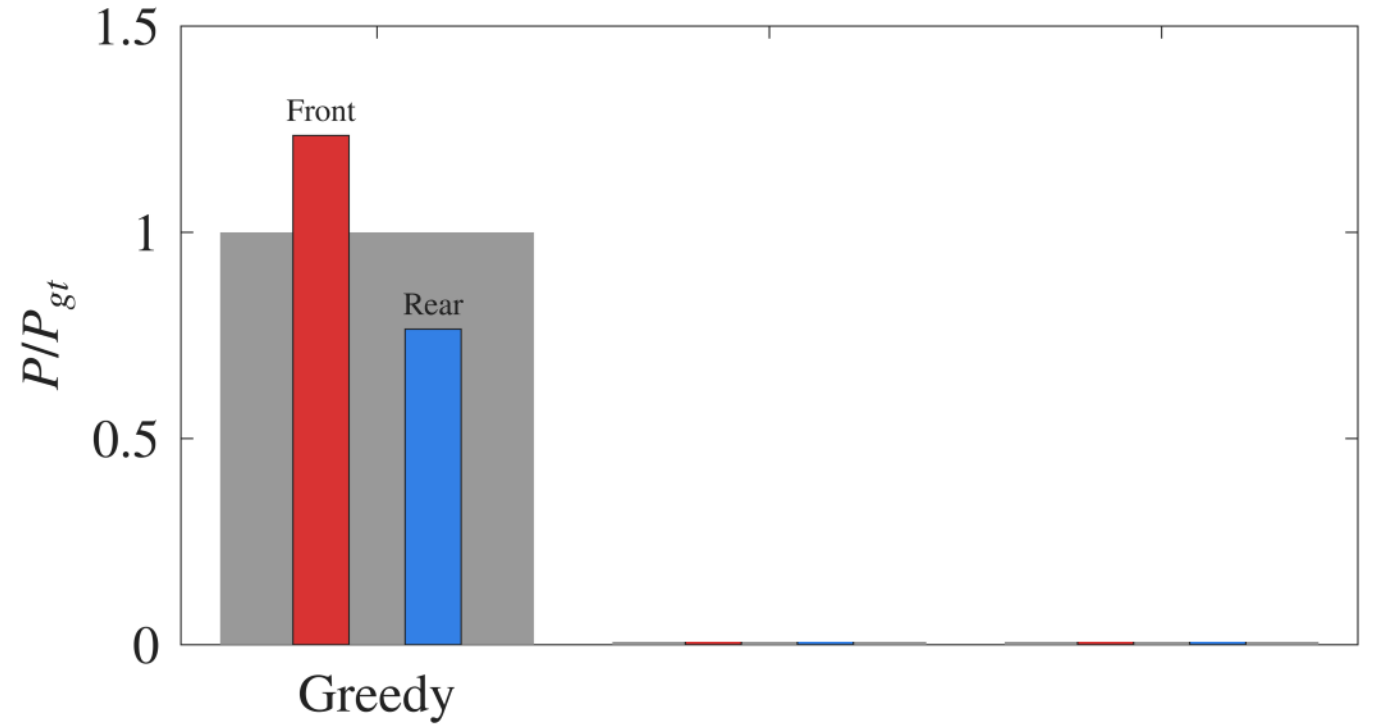
The setup



Results

Wake steering

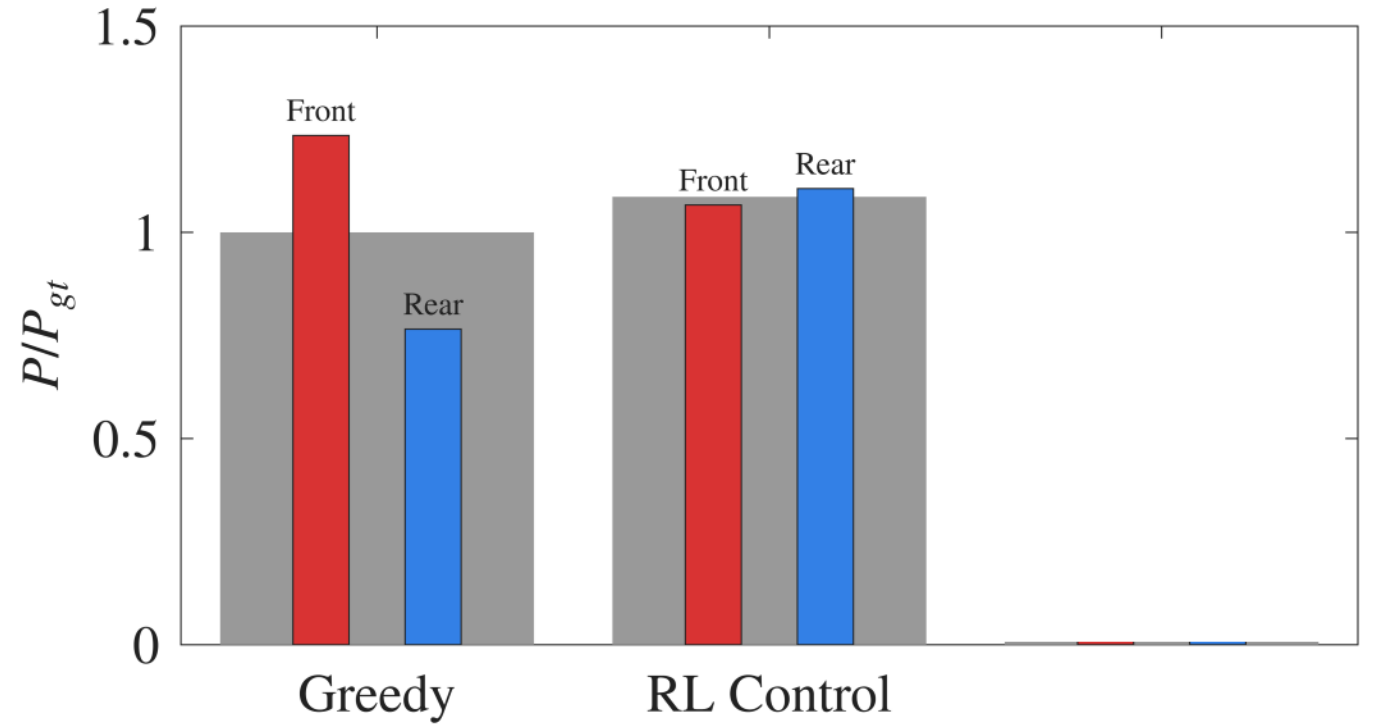
- 35% less power of rear turbine using greedy
- 8.6% increase in power using RL
- 10.7% increase in power using OF



Results

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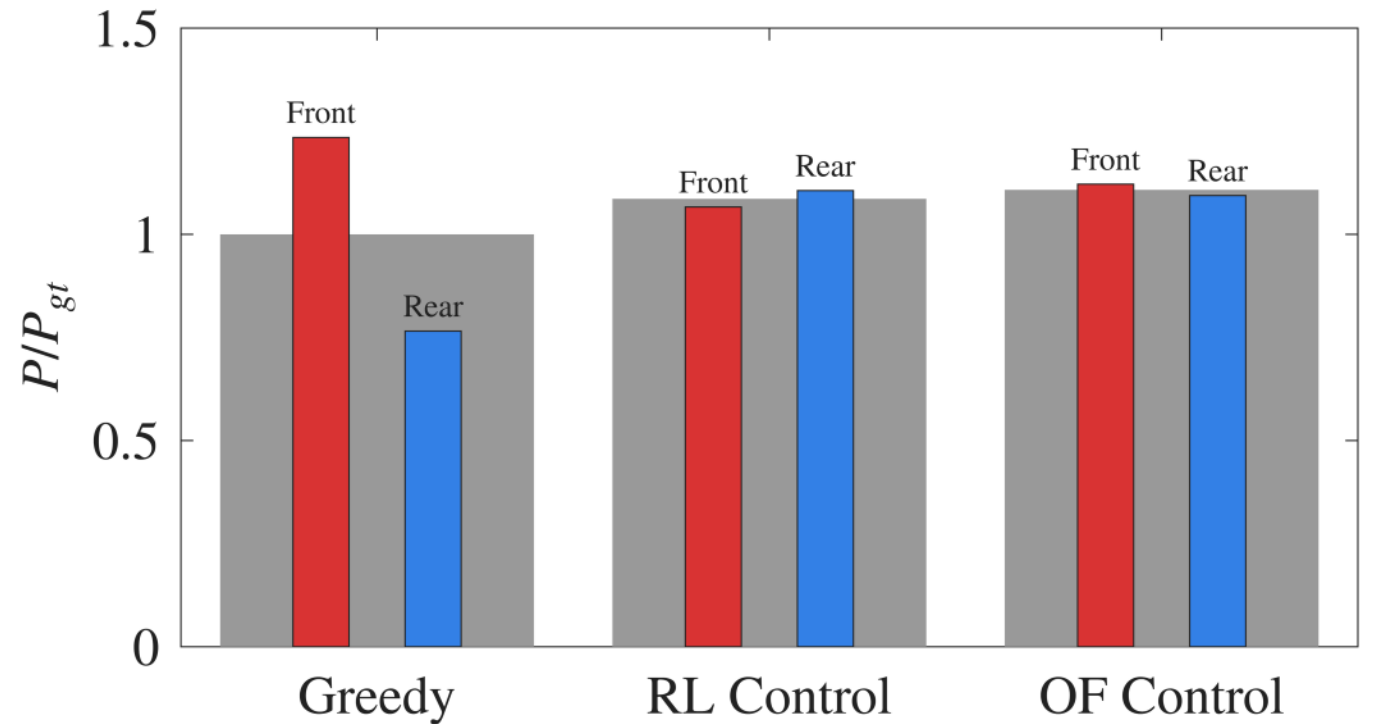
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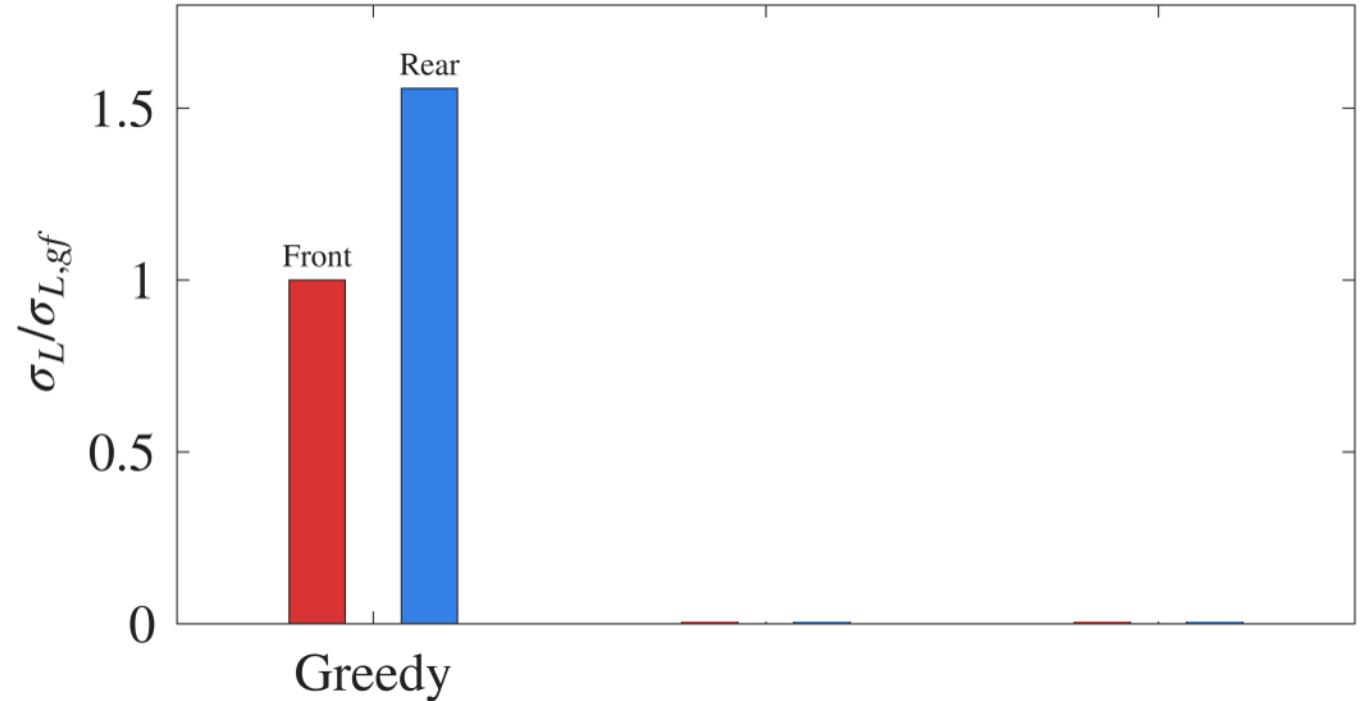
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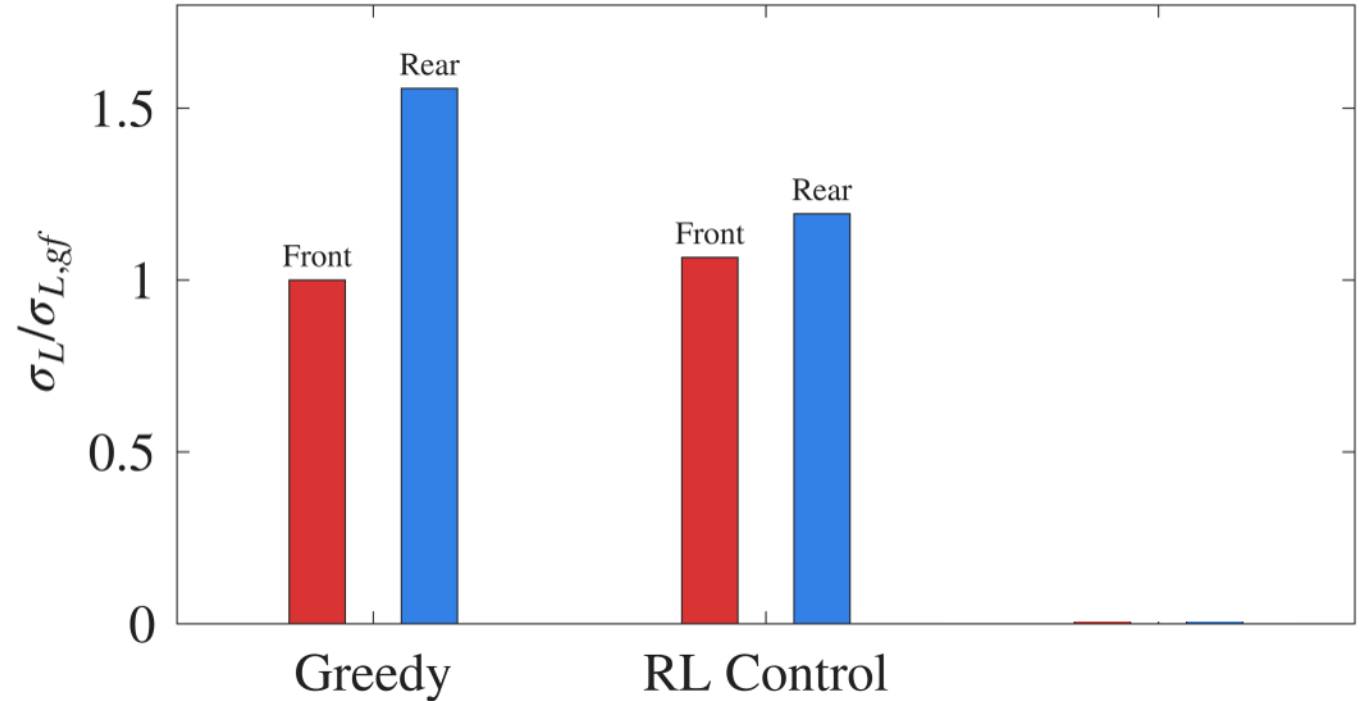
- 50% greater load fluctuations using greedy
- 23% reduction in rear turbine using RL
- 6.5% increase in front turbine using RL
- 20% reduction in rear turbine using OF
- 1% increase in front turbine using OF



Results

Wake steering

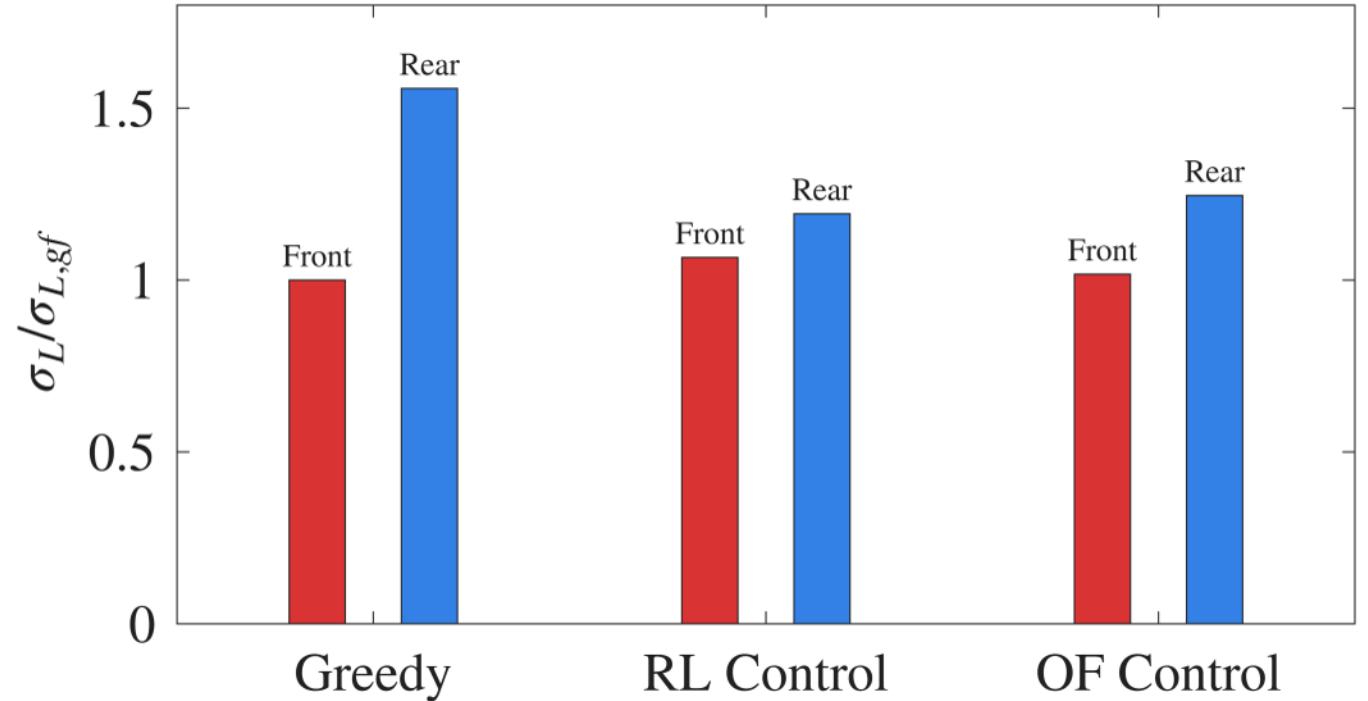
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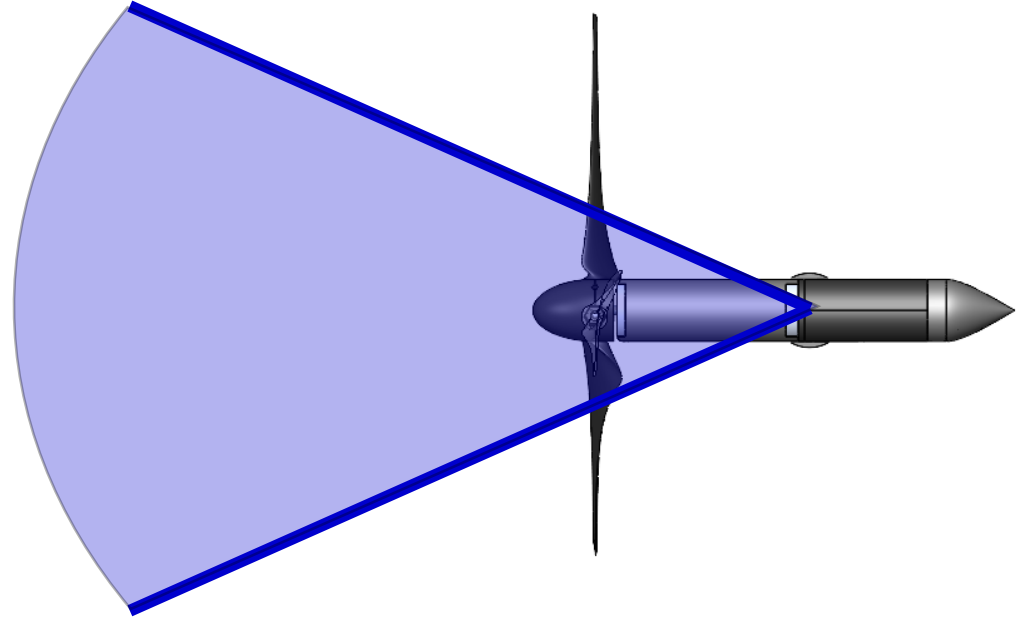
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Dead zone

Echoing full-scale turbines

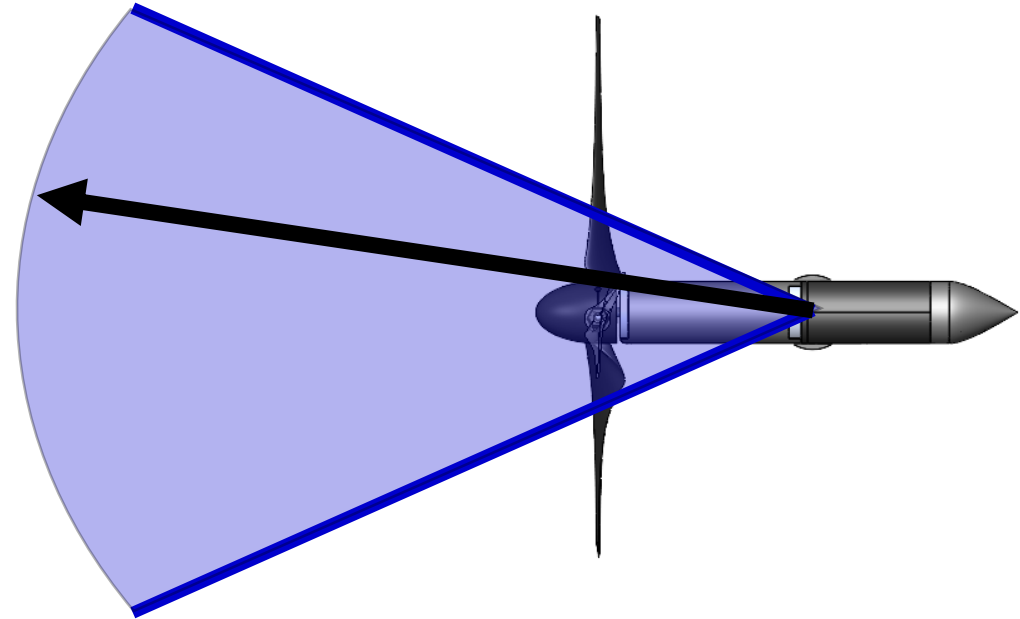
- Turbine has a dead zone of $|\theta| > 8^\circ$
- Turbine is given a set point of $\theta = 4^\circ$
- Turbine is given a set point of $\theta = 6^\circ$
- Turbine is given a set point of $\theta = 10^\circ$



Dead zone

Echoing full-scale turbines

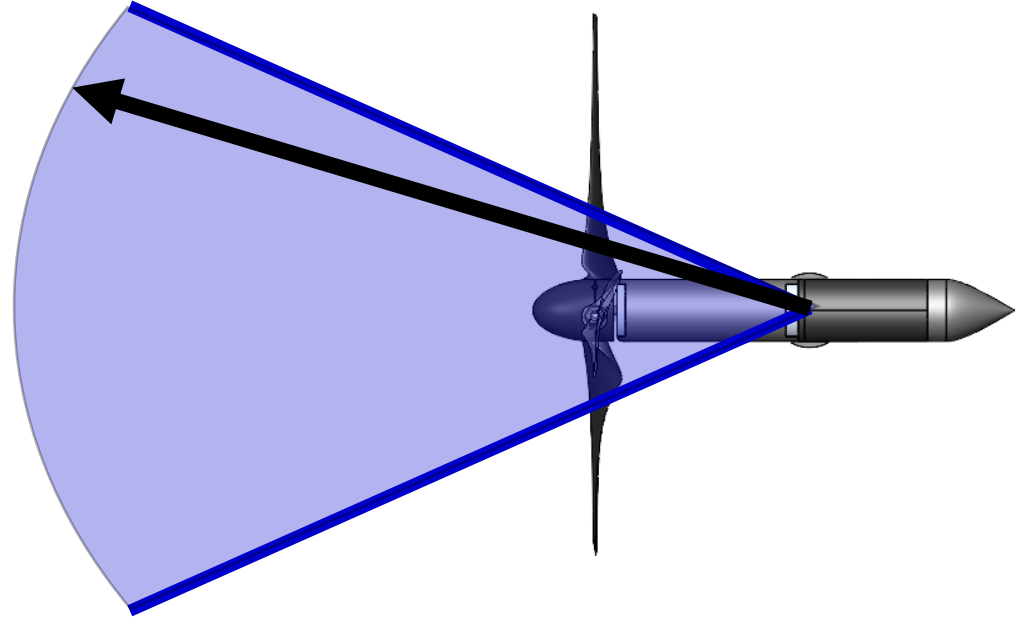
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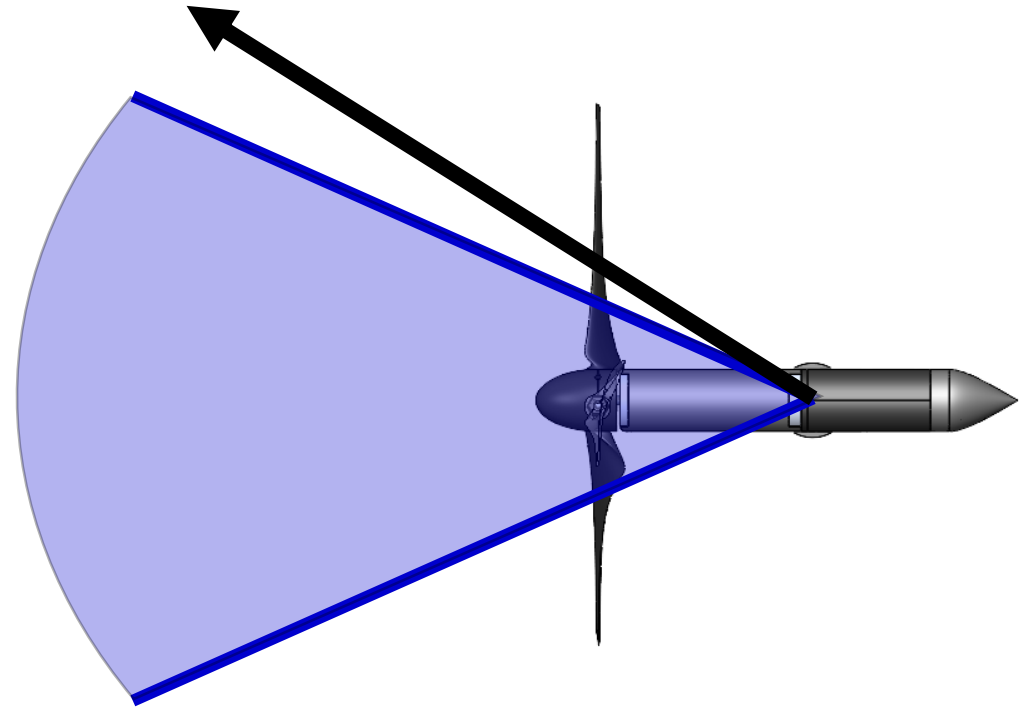
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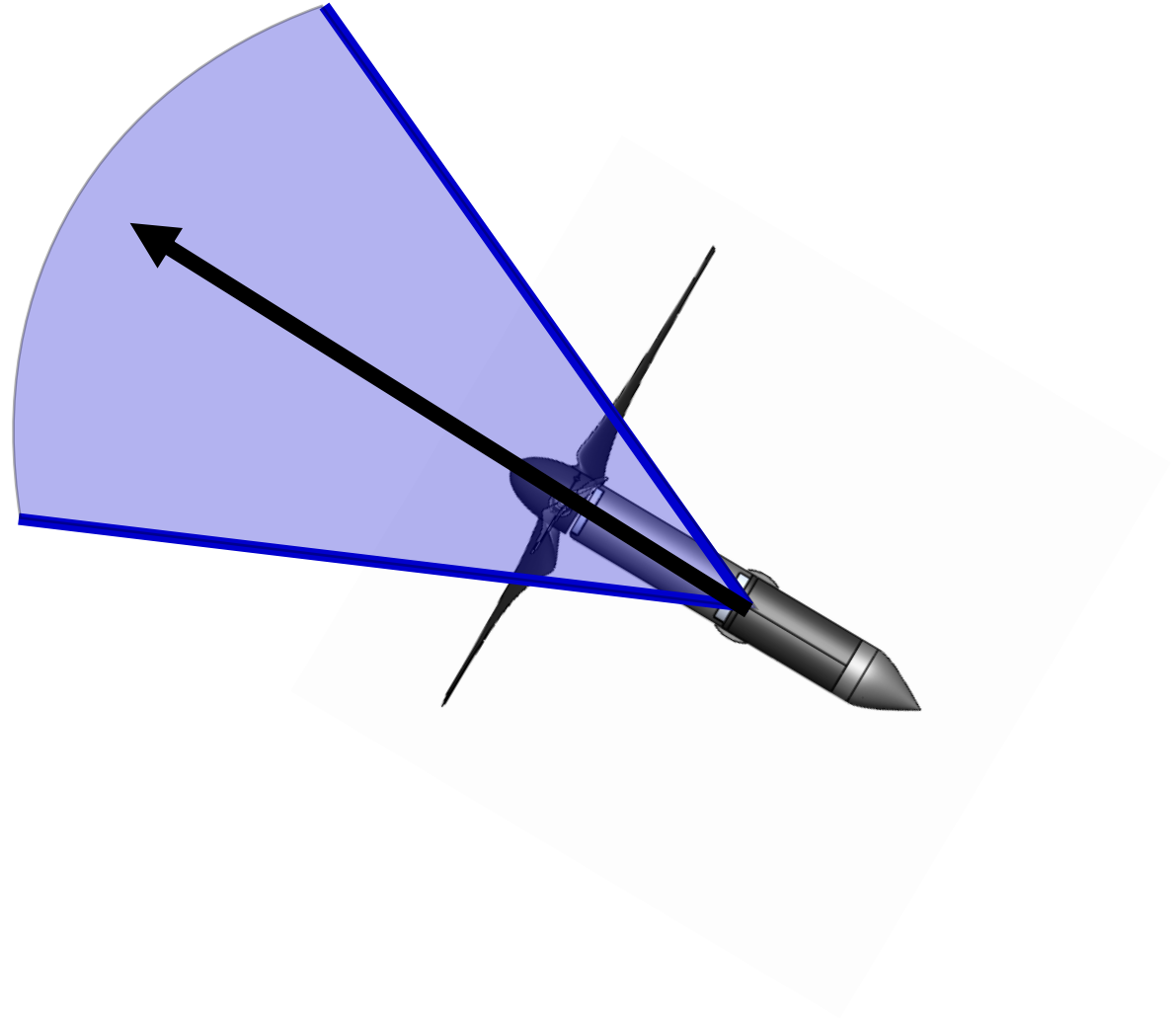
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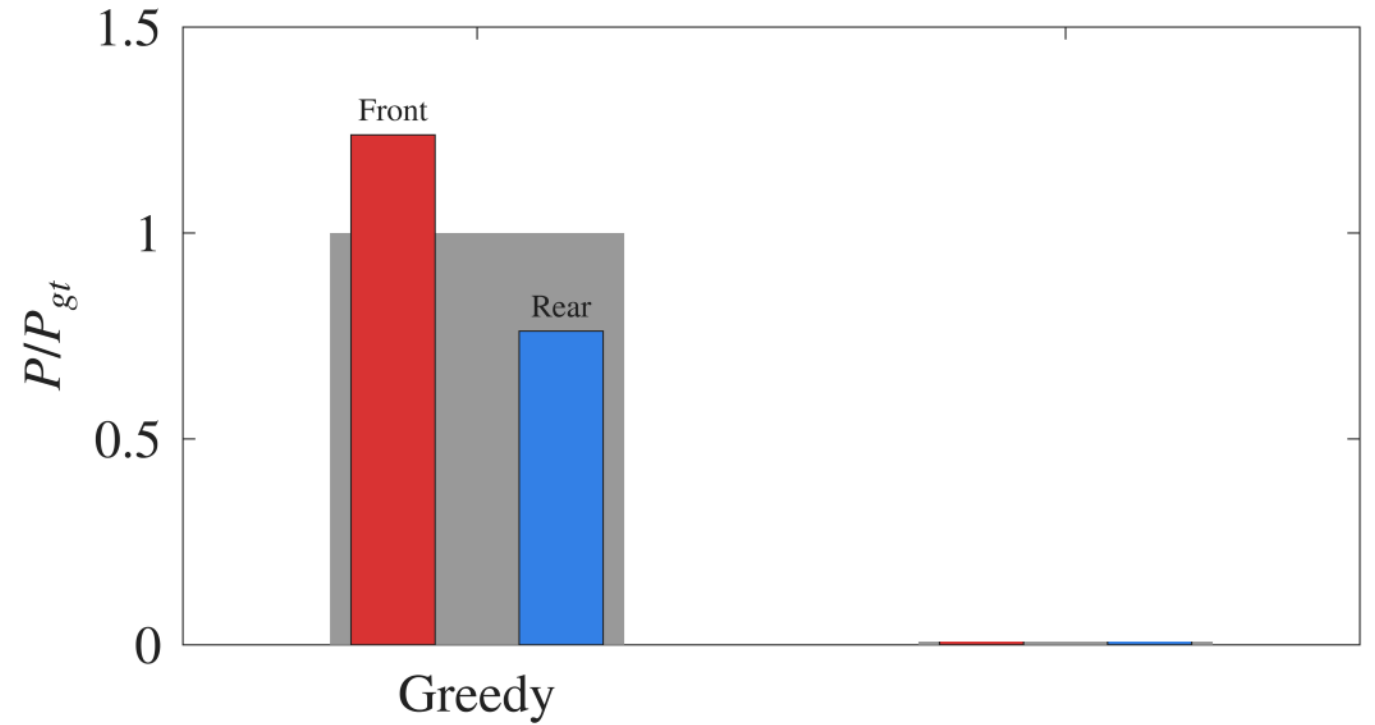
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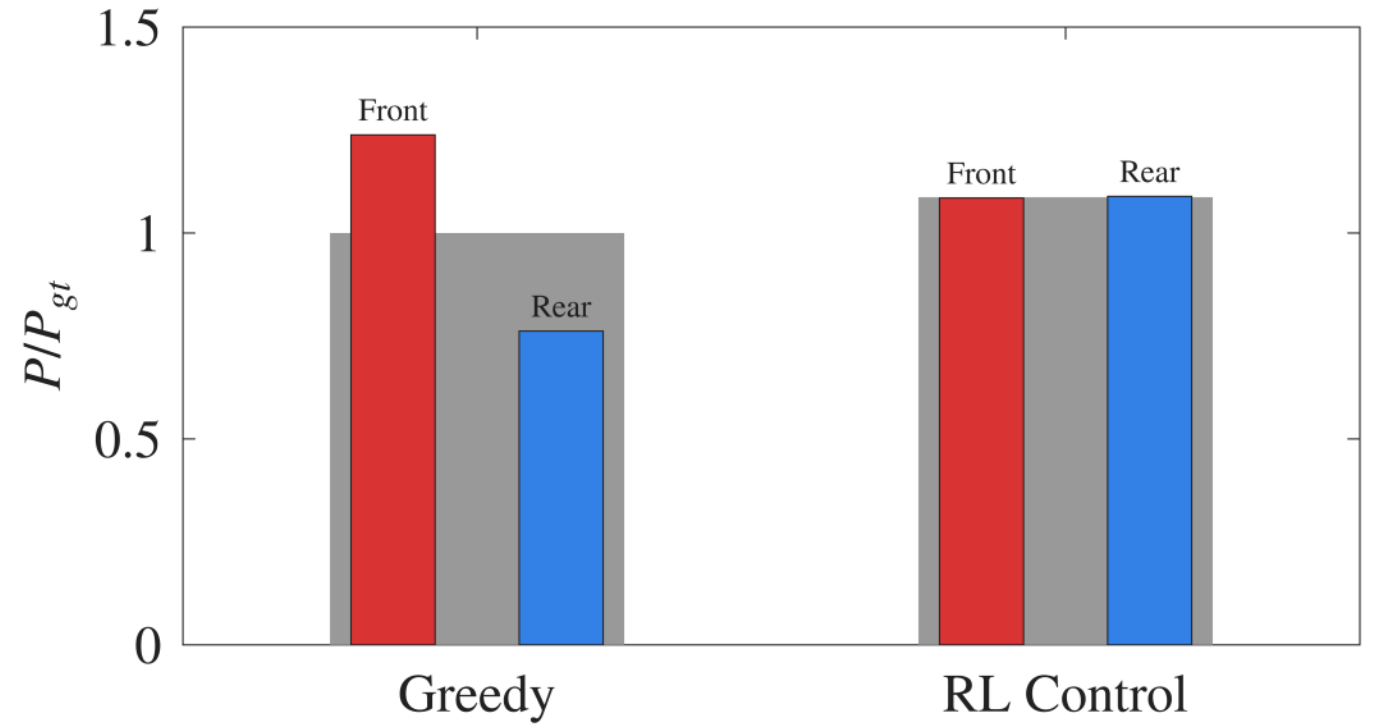
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- 8.7% increase in power
- No difference compared to $\theta > 0^\circ$



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Dead zone

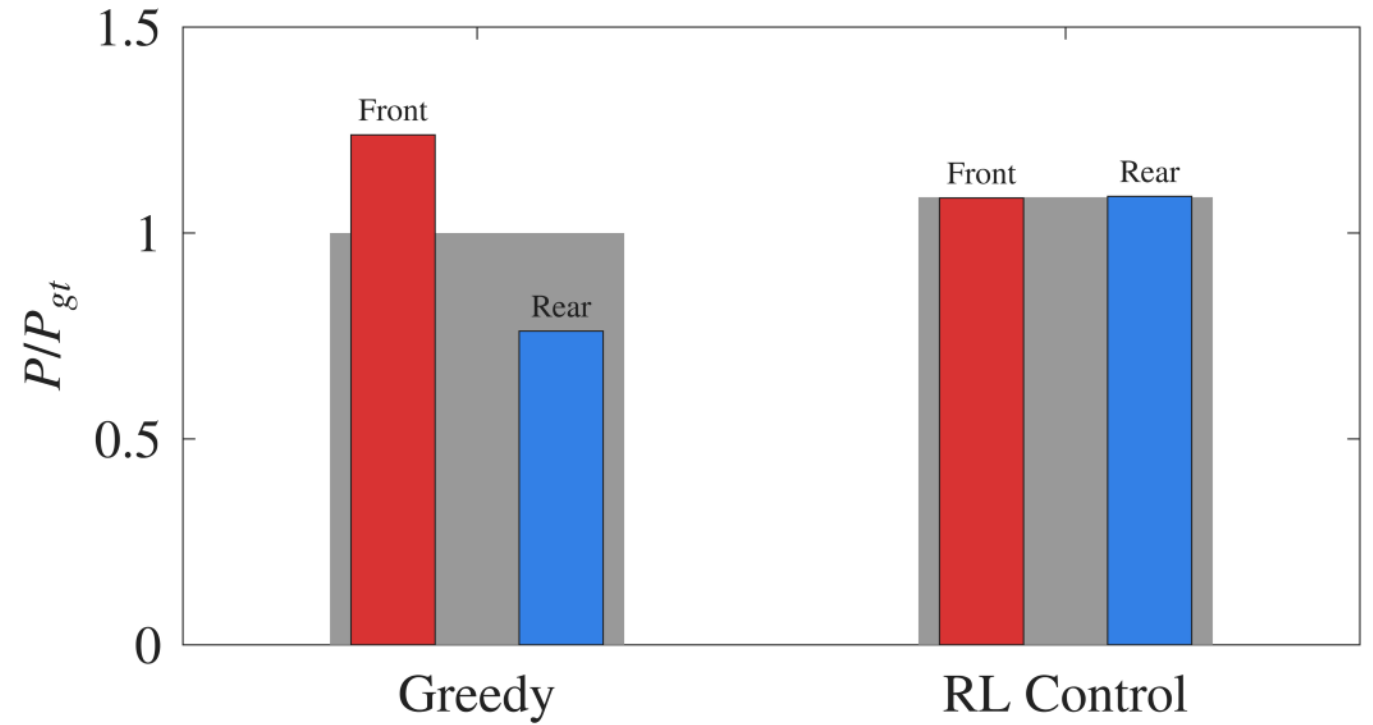
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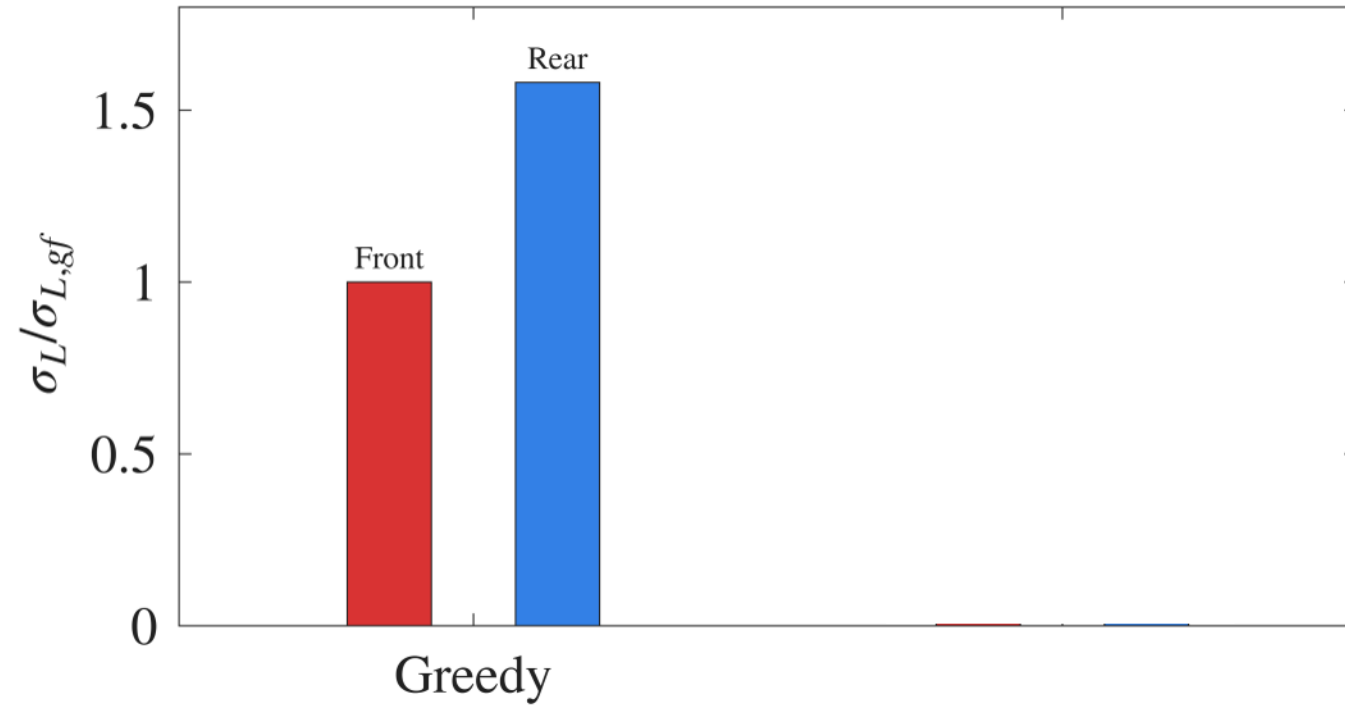
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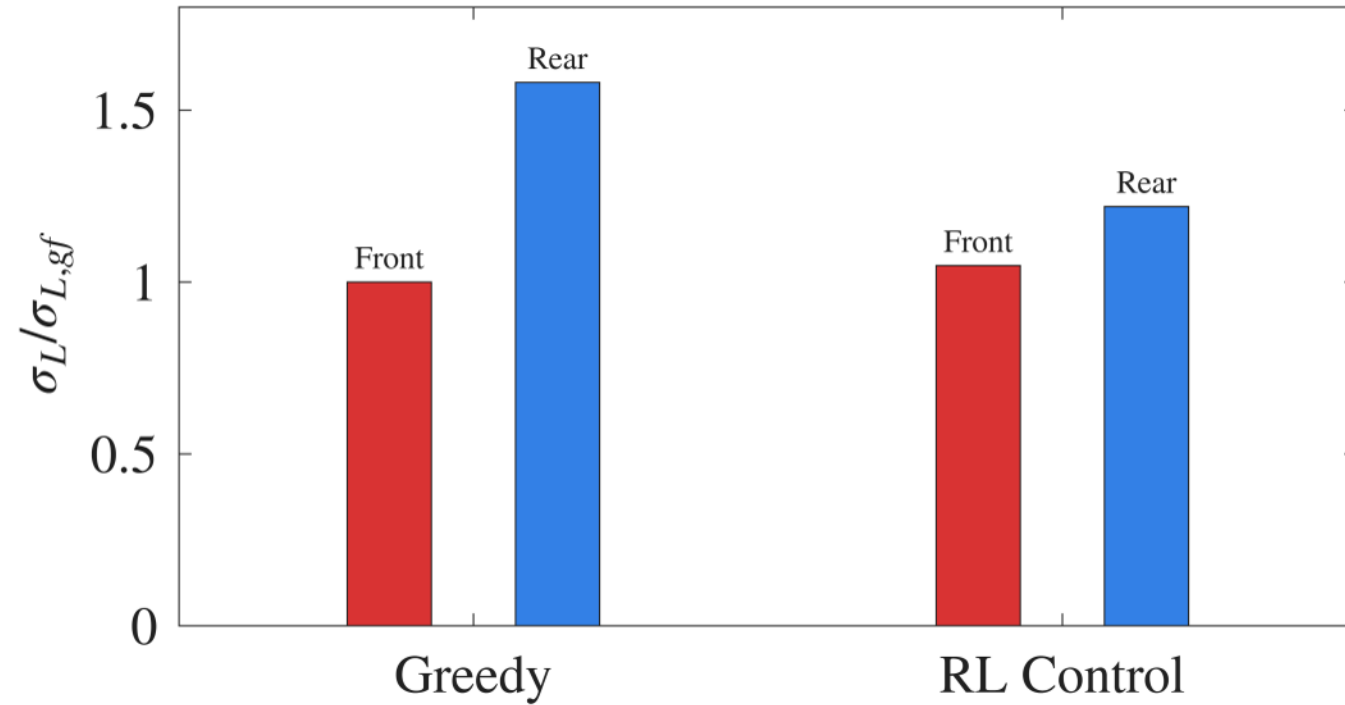
- Turbine holds position until $|\theta| > 8^\circ$
- 22% decrease in rear turbine
- 4% increase in front turbine
- Better load mitigation compared to $\theta > 0^\circ$



Results

Dead zone

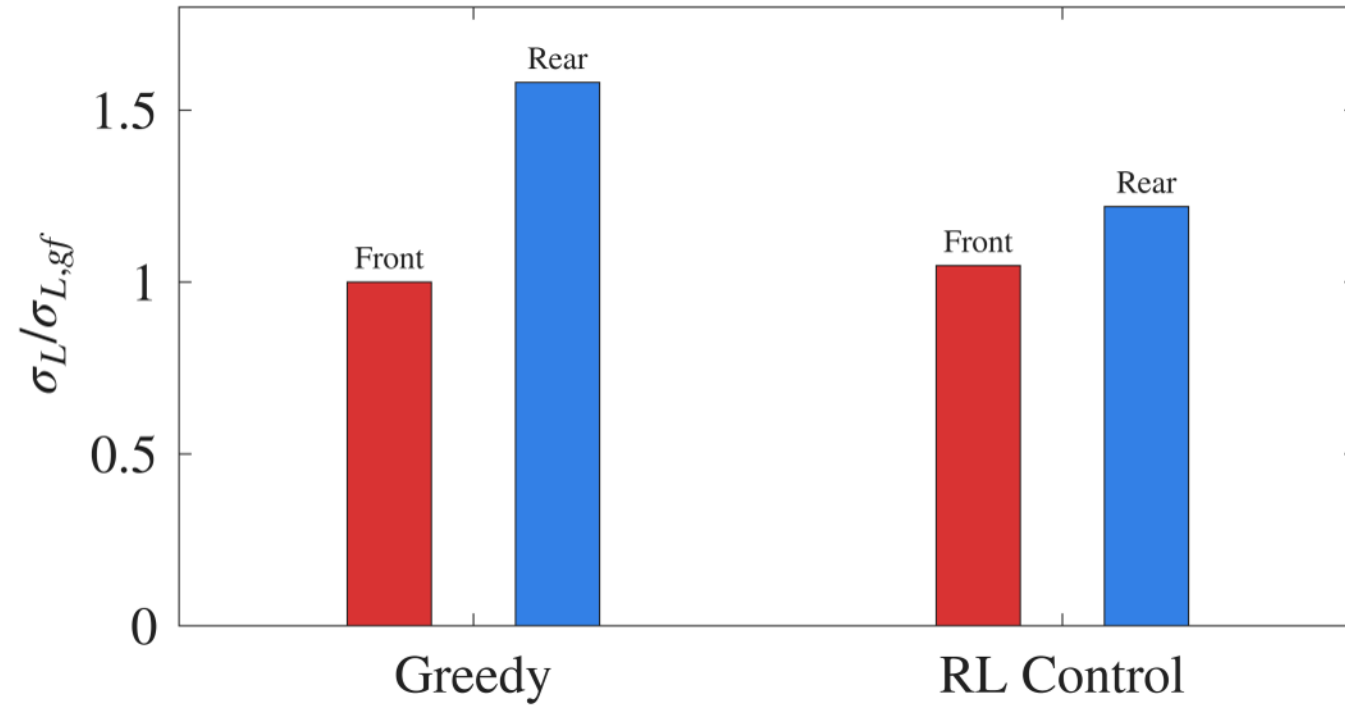
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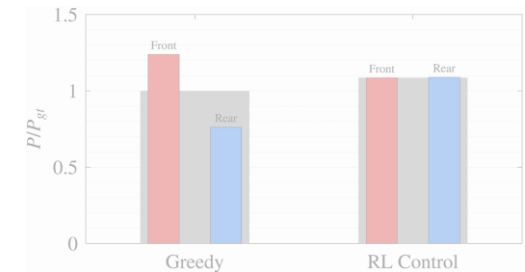
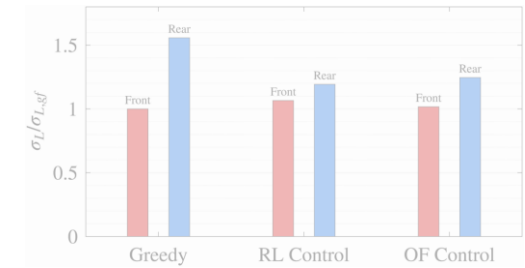
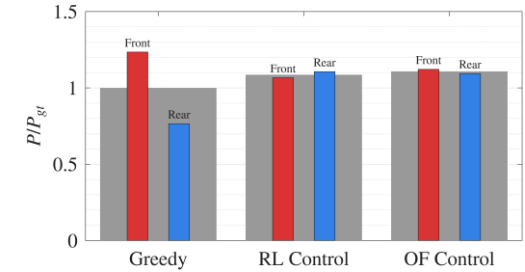
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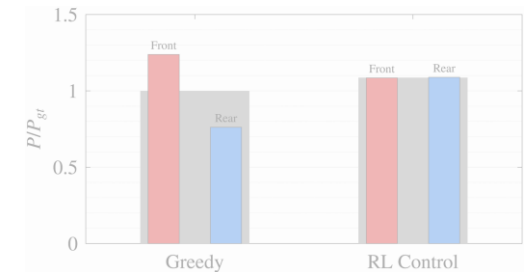
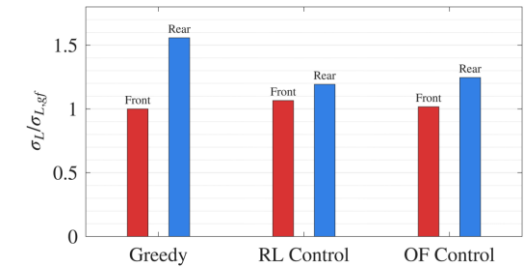
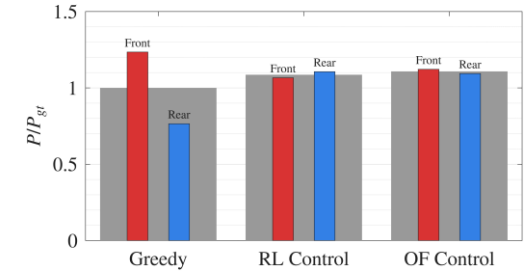
Conclusions

- Wake steering:
 - improved power production by over 10%
 - Decreased rear turbine load fluctuation by over 20%
- Introduction of $|\theta| > 8^\circ$ dead zone shows no difference in the performance increase of wake steering



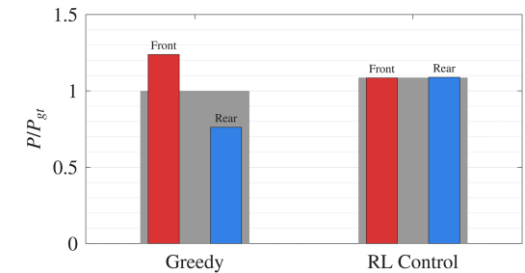
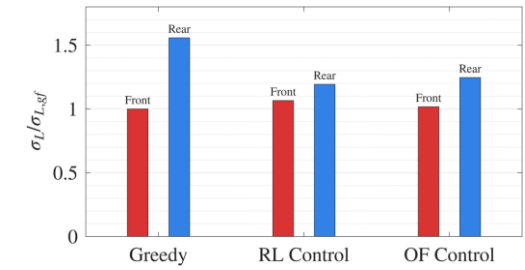
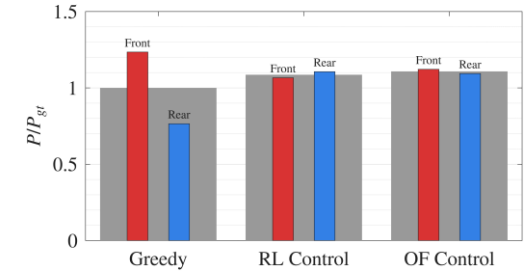
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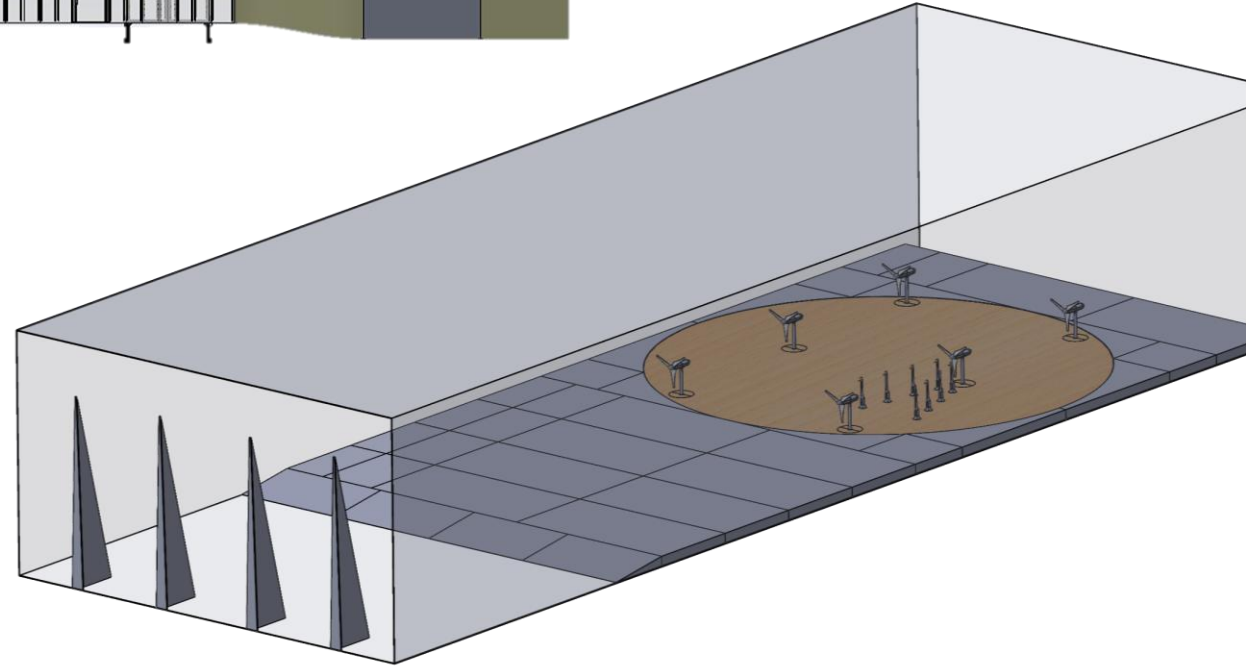
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Future work with ICONIC



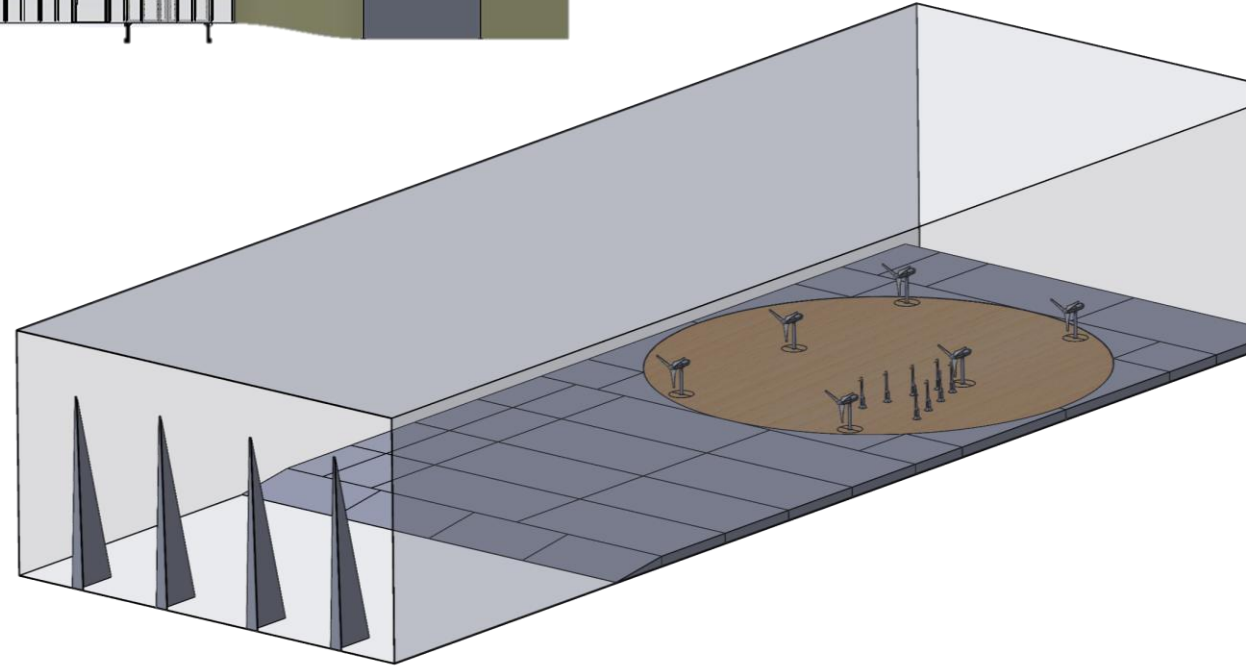
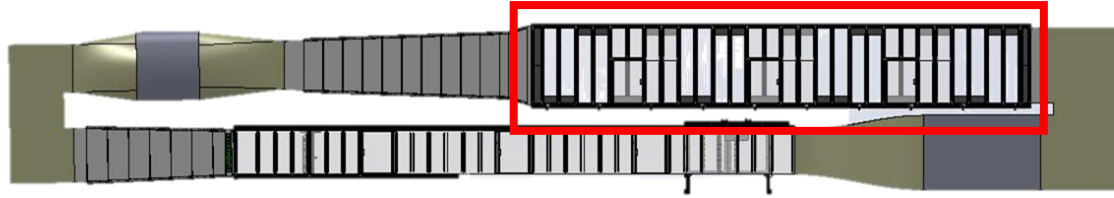
- Wake steering
- 6 turbines
- 8 MHP
- Active torque control
- Active yaw control



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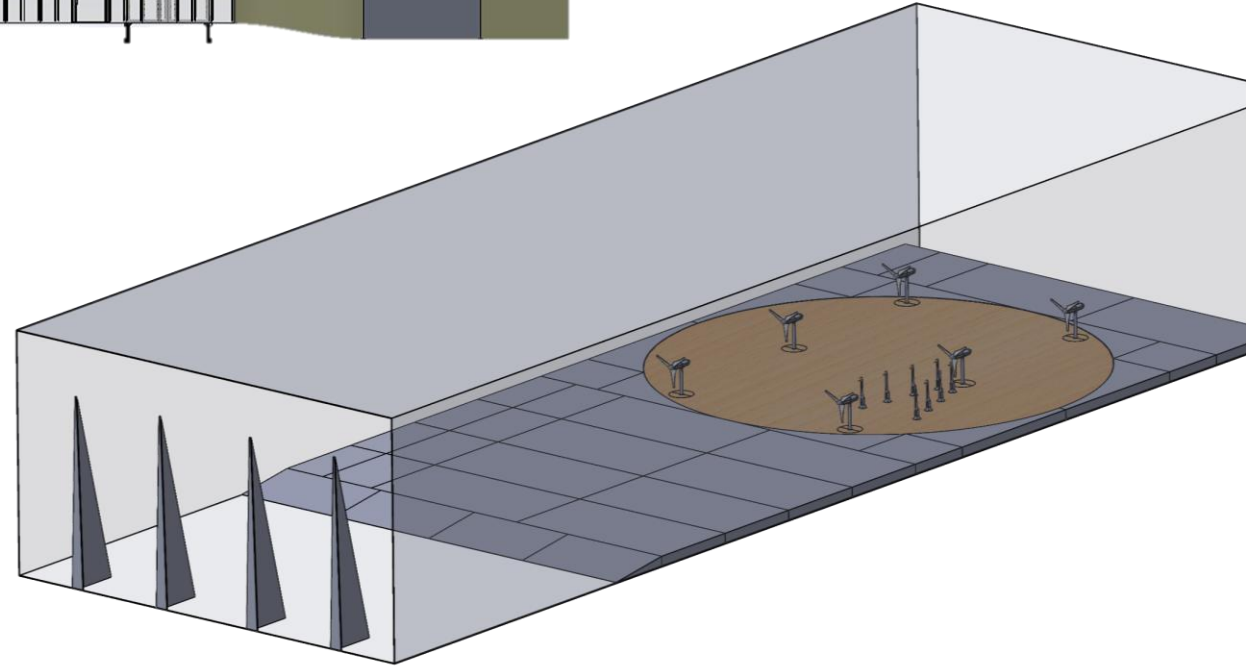
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Future work with ICONIC



- Wake steering
- 6 turbines
- 8 MHP
- Active torque control
- Active yaw control



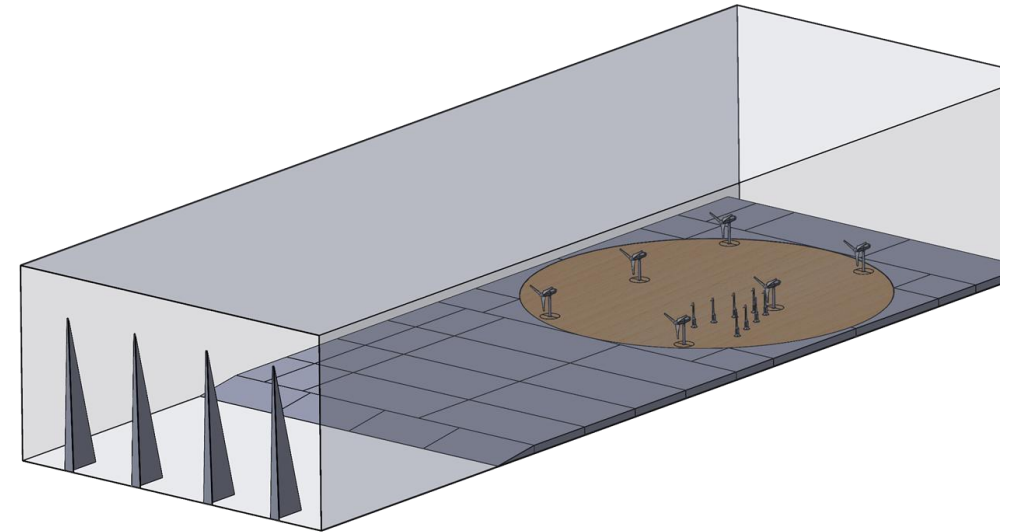
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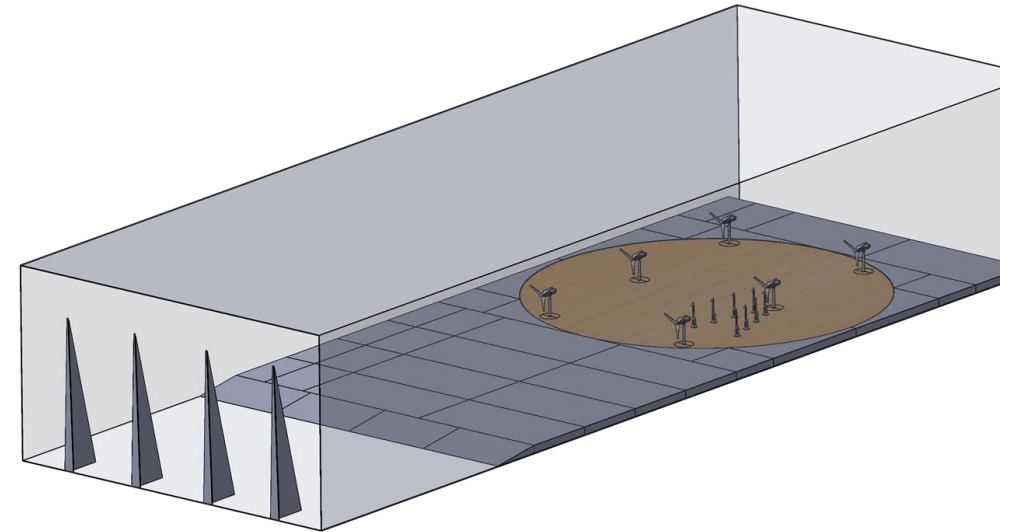
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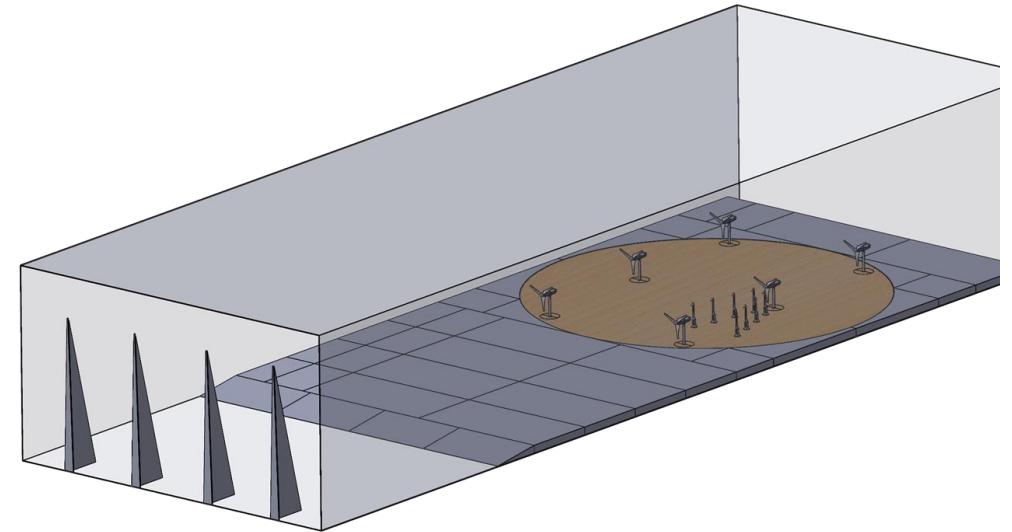
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IMPERIAL

Thank you

Giving Wind Farms a Power-Up with AI

14/09/2026