# IPID4all Doctorate Research Exchange with Carl von Ossietzky Universität Oldenburg

**Feedback report**

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*Fixed and floating wind turbine wake analysis*

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## Introduction

Interaction between wind turbines in an array is becoming increasingly important as wind energy becomes a significant contributor to the energy supply worldwide. The arrangement of the turbines and direction of incoming flow dictate how the wakes merge and in turn, interact with successive turbines. Understanding the development of the flow field in the near- and far-wake can lead to increased knowledge of best practices when designing farms.

Offshore wind turbines are an attractive alternative to land-based wind energy options as the demand for renewable energy resources increases and abundance of land for farming decreases. Due to the complex characteristics introduced by the added degrees of freedom of the system, experimental analysis of the flow directly behind floating turbines is limited.

This project first investigates the wake interaction between fixed turbines in two and three turbine arrangements. It then follows procedures performed by Rockel, *et al.* (2017), performing experiments on two turbine arrangements of floating turbines with freedom of movement in the streamwise direction.

### Research Undertaken

The experiment took place in the semi-open wind tunnel at ForWind, University of Oldenburg. Eleven total arrangements of the wind turbines were used. For the fixed turbine cases, the arrangements consisted of 2 or 3 turbines to investigate wake interactions with spacing between the turbines of 2D and 4.5D in the spanwise and streamwise direction, respectively. Figure 1 shows one of the three turbine arrangements in the tunnel. The arrangements were then rotated by 10 and 20 degrees to investigate the effect of incident angle of the wind. Passive and active grids were used for each arrangement for inflow with two different turbulent intensities. Eleven hot-wires, at various locations in the spanwise direction and behind the hub of the turbines in the wall-normal direction, collected data at one, three, and five diameters downstream, as shown in Figure 2.

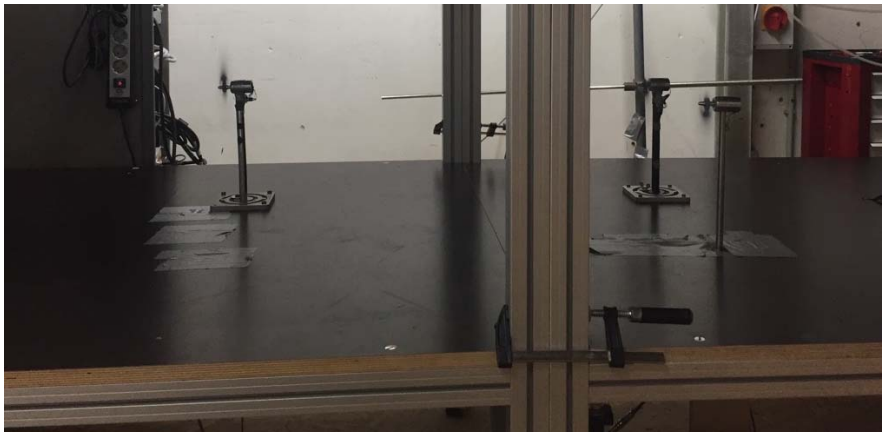

Figure 2. Three-turbine arrangement in the semi-open tunnel with fixed turbines.

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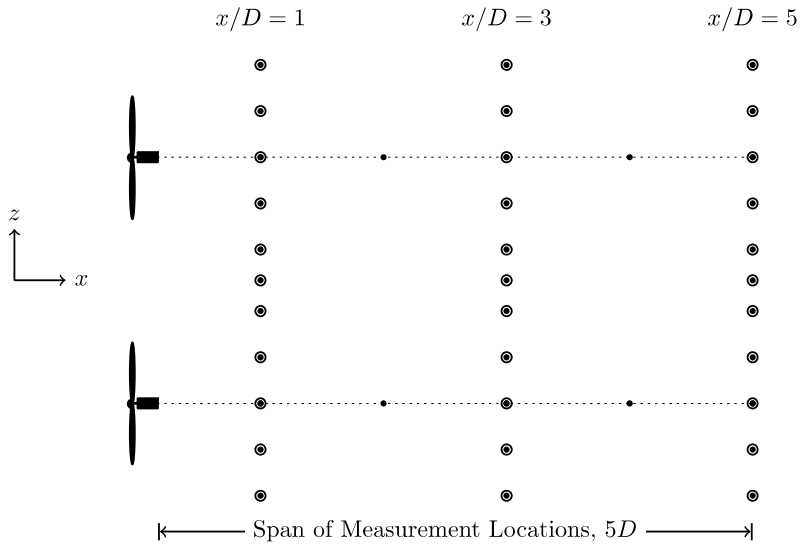


Figure 2. Hot-wire measurement locations in the spanwise and streamwise direction. All measurements were taken at the hub-height of the turbines.

All two turbine arrangements, 0, 10 and 20 degree rotation, were then performed with floating turbines, where free pitch motion was allowed. The floating turbine movement was monitored using an optical tracker placed directly above. Torque and rotational frequency were also measured for analysis of mechanical power. The experiments were conducted in September 2017. The results can be used for wake deficit analysis, incremental analysis, structure functions. The power output in relation to wake deficit, comparison of the floating and fixed wake flow fields, as well as the wake deficit as a function of turbine tracking can also be investigated.

**Personal Experience**

This was the first experiment that we performed in its entirety. We were both new to concepts and experimental procedures involved in hot-wire anemonetry, as well as general procedures for the wind tunnels at ForWind. It was a steep learning curve, but we now feel comfortable with general experimental procedures as well as specifics of hot-wire anemometry. Many graduate students from the ForWind group helped guide us through the process as we stumbled upon many hurdles.

We also enjoyed our time overseas outside of working at the university. As both of us have never been to Germany, this was a new cultural experience, which was also exciting and highly rewarding.

**Conclusions**

The experiment was successful with an extensive amount of data collected for the possibility of a multitude of analysis to be performed and allowing for further collaboration between the University of Oldenburg and Portland State University. The data collected relates to previous experiments and current research performed by graduate students at the University of Oldenburg.

**Outlook**

o As analysis is performed on this data, results can be published in journals such as Wind Energy or Renewable Energy.
o All data was collected during this exchange. Collaboration between the two groups will continue on this project over the next year as analysis is performed.
o The previously established relationship between University of Oldenburg and Portland State University will continue to be utilized for collaborations on projects. Also, with the new

technology available in the ForWind department, the University of Oldenburg will be increasingly considered for future wind turbine related research projects.

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