Review of “Exploring Wake Interactions in a Counterrotating Dual Rotor System for different Yaw configurations: An Experimental Study” by Jannis Maus et al.

General comments

The manuscript addresses wake interaction effects in counter-rotating dual-rotor wind turbines. The topic is timely and relevant to the wind energy community, particularly for improving understanding of complex wake dynamics in advanced turbine configurations. The study is based on an wide-ranging wind tunnel measurement campaign and provides high-quality experimental wake data, which are unique and valuable for the scientific community.

One of the main strengths of the manuscript is the quality and scope of the experimental campaign. The presented dataset represents a significant contribution and will be of interest for the validation of numerical models. The overall structure of the manuscript is clear and the paper can generally be followed without major difficulties.

However, the manuscript is overall rather descriptive, especially the chapter describing the experimental results. While a wide range of operating conditions is investigated, the explanations and interpretations of the differences across cases are sometimes difficult to follow. The interpretation of the results is present but could be strengthened and expanded in some sections to better guide the reader and to more clearly highlight the physical mechanisms behind the observed wake behavior.

In addition, the terminology is not fully consistent throughout the manuscript, which at times leads to confusion. A more uniform and clearly defined terminology would improve readability and clarity.

Another aspect that could further enhance the relevance of the study is a stronger connection to real-world applications. While this is inherently challenging for wind tunnel studies with scaled turbine models, additional discussion on how the findings relate to full-scale applications and real world flows would be beneficial.

Overall, the manuscript presents high-quality experimental work and a valuable dataset. I believe that the paper can be published after minor revisions, provided that the authors improve the clarity and consistency of the presentation.

Specific comments (and Authors response in blue)

p. 2 – l.57: It would be interesting to share how often you calibrated the devices and accounted for humidity, temperature and pressure.

> Good point, added in the document. Calibrations were performed at the beginning and at the end of every measurement day

p. 3 – l.63: What is the reference turbine for the MoWiTO 0.6 on which you match the CP. This sounds quite surprising to me, as to my knowledge, it is very hard to match the CP of a full-scale

machine if you use low-Reynolds airfoils. Wouldn't it be more interesting to talk about the CT in the case of a wake study?

> There is no specific reference turbine, as to the dimensions of the model (0.6m diameter). However the initial design goal for the turbine was to have a functioning model turbine with a collective pitch mechanism and torque control, maximizing the c_p. But indeed, in this case the thrust coefficient is way more relevant, and should be used instead. This can be matched to full scale very well.

p. 3 – l.64: Was the turbine controlled by collective pitch during the measurements? If so, why did you use region 3 and not region 2 for the wake measurements? What influence did the varying pitch angle have on the wake measurements? In the next sentence, you talk about turbulent inflow, but later about laminar inflow; this is a bit confusing to me.

> Thanks for pointing that out, the sentence is formulated a bit misleading. During the laminar measurements, the pitch, and hence c_T was kept constant. However, it needs to be mentioned that the rotational speed and the torque were not fixed at a specific operational point. This allows the PID control to adjust the operational parameters for the local wind speed changes caused by the second rotor and the yaw misalignments.
> The pitch was not controlled and the turbines operated independently in the partial load region at maximum c_P.

p. 3 – Figure 1 Right: How is the mount optimized aerodynamically? You can also refer in the text about it. Here it would also help to provide distances between the measurement probes. The distances in flow direction are clear from Figure 2, but not the lateral distances.

> The mount of the HW is aerodynamically optimized pointing into the wind. Through the streamlined shape of the black mounts, the total blockage of the hotwire-array can be reduced. The lateral measurement distances were chosen to be higher towards the outside of the dual rotor wake, and a higher spatial resolution was used for the center wake, i.e. the interaction area. This is shown in figure 2.

Fiugre1/Figure2: Please provide a coordinate system in at least one of the two figures.

> Indeed that is a good comment and was added in both figures for better understanding.

p.4 – 75: How did you achieve laminar inflow and how high was the corresponding inflow TI?

> The wind tunnel Oldenburg can be operated without active or passive grid and offers a very laminar inflow in this configuration with a TI of 0.1-0.3% background turbulence. Neunaber2020.

p.5 – 95 this sounds like a repetition of your last sentence from the introduction. Just in your introduction turbulent kinetic energy is $\langle u'^2 \rangle$ and here TKE. You have to be consistent.

> Consistency is very important, hence we have adjusted alle terms in the paper correctly and consistently.

P.5 – 106: What is the difference between the reference inflow wind speed u0 and the reference wind speed (U_{ref})? Is U0 the same as the laminar inflow velocity from p.4? Later in Figure 11 you also have U_{Inflow}.

> Indeed, it is u_0 for both U_{Ref} and U_{Inflow}. We eliminated the according inconsistencies.

Figure 5: What is the use of this figure? The right plot is already shown on the same page in Figure 4. The only difference is that "yaw" is missing in the title. This is very confusing. Also the colorbar is missing

> True, the right plot was already shown previously, however we still think it is most relevant to show the wakes of both turbines, yawed at the same angle, to show the impact of the

rotational sense to the wake. We adjusted the figure caption to make this better understandable. As you might notice, we have also added more plots of the single rotor wakes and a schematic figure to explain and "prove" the concepts of wake rotation, the relevance of the tower wake and the relevance of rotational direction. This was one of the main comments of the other review and increases the clarity and understanding of the presented document.

Chapter 3.1. and 3.2. You qualitative comments like: "it appears that the wake width is not increasing as strong" or "a much wider wake" could you use a more quantitative measures, determining the wake width and the deflection? This would help to strengthen what you are describing in the contour plots.

Very good point and we went through the document to improve clarity and quality of the text as well as better understanding.

P8 – l. 178. You use the term 7 a, but in no of the contour plots you defined an a) or b). you can only use this if this numbers are also in the plot.

All plots were adjusted and numberings/letters for individual subplots added.

P.10. – l. 204: What are center wake fields?

The term is truly misleading and the paragraph was rephrased for a better understanding.

Figure 10: For me, it is very hard to differentiate between dark and lighter green and thus identify 0 on the colormap. It could help to choose a colormap with a clear different color at 0.

The new colormap ranges from blue (negative wake recovery = wake buildup) over white (neutral) to red (positive wake recovery), which improves the plot a lot.

All contour plots: The fonts have to be the same size for all the plots. Some of your colorbars have different font sizes and are differently in size. "Downstream positon [D] is quite big, consider making it not as prominent. A good approximation is to have the text in the figure around the same size as in the text. Do you need the full explanation with the formula at the colorbar, you already explained it in equations 1-3. If you have it use at least the same terminology <u> or UMess. The a) b) c) and d) are not visible in the plots. Try to locate them outside the plots, or use a background or other color to make them visible. Also be consistent, use them in all contour plots also in 3.1 and not only in 3.2

All plots were reworked addressing the mentioned good points on font size, colorbar annotations, numbering/indentification of individual (sub)plots and general readability.

P.12 – l. 263: "The reference case (black dashed line) shows the relative wind in the wake of a dual rotor with 0° yaw of the single turbines" What is the relative wind here?

Apparently it was not clear enough at this stage that U_{Rel}, the relative windspeed introduced in equation 4 and 5, is a measure to compare the available windspeed across the dual rotor area to downstream positions, allowing us to see whether or not the introduced yaw has a positive effect on the wake recovery.

p.13 – l. 275: "of more than 0.75." This sounds strange you could use of URel=0.75 to make clear what it is.

Addressed.

Here it could also be nice to discuss what this means for the turbine performance. You talk about faster recovery, which is good for downstream turbines. But what are the losses on the upstream turbine in case you introduce a yaw?

For the maximum yaw of ±20°, losses are 12.6% ±1.6% as measured by our model turbines. We have included a paragraph on this and its meaning for full-scale turbines.

Conclusions: Here I would be nice to see what configuration would be recommended for a real application. This is always hard for experiments in clean lab flows, but at least in the conclusions it would be nice to elaborate a bit on how the results would change in a more realistic non-uniform turbulent flow.

> We have included that feedback in the conclusions, although we intended to be careful when drawing to far reaching conclusions that we cannot prove at this point.

Technical corrections/comments

p.4. – Caption Figure 2: Two dots at the end of the sentence. -Checked

p.11. – 245: rates -Checked

p.13. – 268: lines -Checked