Reply to Reviewers
Manuscript ID WES-2024-122-R1
Title: Near wake behavior of an asymmetric wind turbine rotor

General overview

We sincerely appreciate that both reviewers acknowledged our efforts to improve the manuscript during the previous round of revision. We are also grateful for their continued engagement and thoughtful feedback in this round. In response to their comments and suggestions, we have further revised the manuscript. We believe these updates have again enhanced the clarity and robustness of our work and have adequately addressed the issues raised during the second round of review.

Reply to comments from Reviewer #1
Specific comments:
Comment #1: *In the introduction, the authors state that "The primary objectives are to provide insights into whether rotor asymmetry can serve as a viable passive strategy to accelerate wake recovery and to assess both its potential benefits and limitations." However, responding to one of my comments in Section 3, the authors say, "However, this work focuses on quantifying the effects of blade length differences on leapfrogging instability and its growth rates.". If the primary objective of this paper is to assess the viability of rotor asymmetry to accelerate wake recovery,* ***quantifying the wake recovery rate*** *or* ***wake breakdown location*** *seems to me of vital importance. I therefore maintain my initial position that the authors should seriously consider adding this analysis to the paper to strengthen their findings.*

Reply:
We thank the reviewer for this valuable perspective. While we did not introduce a specific single-value metric to quantify the wake recovery rate or the exact wake breakdown location, we believe that both aspects have already been adequately addressed in our revised manuscript from the previous round.

Regarding wake recovery rate, we refer to the disk-averaged mean streamwise velocity, $<\bar{u}>_{Disk}$, presented and discussed in Section 3.3.2. This metric provides a clear, quantitative assessment of integral wake recovery. We have demonstrated that the rotor asymmetries examined have minimal to negligible effects on $<\bar{u}>_{Disk}$ and that these effects are even more diminished with increasing inflow turbulence intensity (TI).

For the wake breakdown location, we were motivated by the reviewer's earlier comment to incorporate a visualization that more clearly depicts this phenomenon. This led us to include the phase-averaged vorticity field shown in Figure 7 of the first revised version. We are grateful for the reviewer's suggestion, which significantly improved our analysis. While we

do not provide a precise, single-value numerical definition of wake breakdown location, we believe that the contours and discussion in Figure 7 offer a sufficiently illustrative and semi-quantitative view. Specifically, we state that rotor asymmetries tend to enhance the coherence of wake structures, indicating a slight delay in wake breakdown. However, as noted in Section 3.1.2, although the two are correlated, the wake recovery rate cannot be fully explained by the wake breakdown location.

Thus, we have chosen to maintain our current approach. That is, wake breakdown is assessed through phase-averaged vorticity contours (Fig. 7), while wake recovery is quantitatively addressed via $< \bar{u} >_{Disk}$ in Section 3.3.2.

Moreover, the primary objectives stated in the "Introduction" are directly revisited in the "Conclusion and Recommendations". Specifically, "Despite the studied rotor asymmetries trigger an earlier onset of leapfrogging, their contributions to accelerating the large-scale breakdown of the helical vortex system and the subsequent wake recovery were found to be minimal." is given. We believe this sufficiently addresses the objective we proposed.

That said, we acknowledge the wording in our previous reply may have been imprecise. The sentence cited by the reviewer should have read "Precisely estimating the effects of rotor asymmetries on wake breakdown locations is not the main focus of this work, especially given that the wake recovery rates are not substantially influenced by the examined rotor asymmetries." We also should have clarified that the wake breakdown can be semi-quantitatively evaluated through the phase-averaged vorticity contours in Figure 7.

Comment #2: *Similarly, I still have concerns about the differences in findings between this manuscript and Abraham et al. (2023b). The authors give a hypothesis that might explain the differences, but do not investigate this hypothesis. I suggest that the authors consider including simulations in their manuscript that test this hypothesis. This would verify the validity of the model presented and used in the manuscript, and subsequently strengthen the findings substantially.*

Reply:
We thank the reviewer for raising this important point. After reviewing our previous revision, we agree that our earlier explanation regarding the discrepancy with Abraham et al. (2023b) was too limited, attributing the difference solely to whether the floor is included.

In the current revision, we provide a more comprehensive discussion of the potential factors contributing to the differences. These include rotor blade number, the presence of the floor, and differences in numerical frameworks. We also cite relevant literature to support our hypotheses. Please refer to the final paragraph of Section 3.3.3 for further details.

Given the range of possible contributing factors, we believe that additional simulations to isolate each would require a dedicated study beyond the scope of the current manuscript. Nevertheless, we acknowledge the merit of such investigations and suggest them as valuable directions for future research.

Reply to comments from Reviewer #2

Specific comments:

Comment #1. Page 11, line 271: unitary --> unity
Comment #2. Page 15, line 338: The contours in Fig. 9 are from a different case than the one being discussed in this paragraph. Please move this sentence or clarify.
Comment #3. Page 17, line 372: asymmetry --> asymmetric

Reply:

We thank the reviewer for their careful reading and for pointing out these issues.

Comments 1 and 3 have been addressed by correcting the noted typographical errors.

Regarding Comment 2, we agree that the reference to Figure 9 was potentially confusing. Accordingly, we have removed the sentence from its previous location. Figure 9 is now only referenced in the context where the corresponding case (Lam10D: asymmetric rotor under laminar inflow with a dense mesh) is directly discussed. Additionally, the related points previously discussed near line 338 have been relocated to the section describing Figure 9. Please refer to Section 3.1.4 for the revised discussion.