

Review of Querat et al.

*Effect of inflow turbulence on the wake replenishment
mechanisms of twin rotor vertical axis wind turbine*

October 2026

1 Summary

This manuscript investigates the effects of inflow turbulence on the wake recovery of a twin-rotor vertical-axis wind turbine. A scaled model of the twin-rotor is installed in a water flume, where the turbine is exposed to two different grid-generated inflow turbulence levels. The wake flow is scanned in a grid using a three-component Laser Doppler Velocimetry (LDV) probe at four downstream distances. The velocity measurements are used to estimate the terms in the momentum budget of the Navier Stokes equations, separating advective mean flow transport associated and turbulent transport. Furthermore, the paper reports a comparison of LDV processing methods with particle image velocimetry (PIV) measurements, while specifics of the experimental PIV setup are not presented. In both inflow cases, the authors identified vertical advection by the mean flow as the main contributor to streamwise momentum transport. The turbulent transport was increased in the high-turbulence case, but remained smaller than the contribution from mean-flow transport. Their explanation is that added turbulence enhances vertical transport of cross-stream momentum, helping establish downward vertical velocity earlier in the wake. That earlier vertical motion strengthens vertical advection, which in turn contributes to faster wake recovery.

The study describes and experimental approach to identify wake recovery for a novel twin-rotor vertical axis turbine. At this stage is not yet well organised and still needs a significant amount of language editing. Beyond these technical shortcomings, some choices in the experimental setup are not well justified. My main concern is that both the temporal and spatial resolution of the wake measurements might not be sufficient to draw the conclusions made about the main wake recovery mechanisms. These seem at this stage rather uncertain, a deeper analysis of uncertainty would help to trust the results. Furthermore, measurements with higher resolution (PIV?) would also make the presented results more trustworthy.

2 Specific comments

The twin rotor turbine concept presented in the article is novel, however, some choices made in the experimental setup are not well justified. These are my main points which the authors should address and justify better:

- **Twin turbine setup:** While the twin turbine setup of two two-stage vertical axis rotors is very interesting, there are some points that need to be clarified in the manuscript:
 - (1) **Single rotor reference case:** Could it be a strategy to analyse the wake recovery mechanisms of one single vertical axis rotor as a reference case first? It is difficult to distinguish to which degree the recovery mechanisms presented for the twin rotor are influenced by rotor-rotor interactions or if they are inherent for a single rotor as well.
 - (2) **Rotational direction:** It is stated that the turbine is a *inner downwind configuration*, which is not completely clear to me what that means. Also, are the two rotors co- or counter-rotating? I consider this important information when it comes to the symmetry of the wake flow and as a justification of measuring only one half of the wake.
 - (3) **Rotor synchronization:** It is stated in the text that the two rotors *are not angularly synchronized*. In table 1 an *angular offset* of 90 deg is mentioned. Does that refer to the two stages of the rotors, or an angular offset between the two rotors? Moreover, I would guess that the synchronization/angular offset of the two rotors does potentially influence the wake recovery. If a twin rotor setup is first analysed this parameter should be investigated (or for a reference case defined to a fixed value).
- **Wake measurements - Temporal resolution:** The manuscript states that the coincidence data rate for multi-component LDV measurements was approximately 1 Hz. Given the manuscripts incoming flow speed and turbine's rotational speed, the blade passing frequency and blade-vortex shedding dynamics should occur at frequencies above 10 Hz.

While a 1 Hz effective sampling rate can yield accurate mean velocity statistics ($\overline{u}, \overline{v}, \overline{w}$) if the acquisition window is sufficiently long, estimating second-order turbulent moments ($\overline{u'v'}, \overline{u'w'}$) and their spatial derivatives requires statistical convergence. Non-equispaced LDV arrival times combined with low coincidence rates can bias turbulent shear stress measurements toward higher-velocity bursts. Please include error bounds or confidence intervals (e.g., via bootstrapping) on the estimated Reynolds stress gradients ($\partial \overline{u'v'}/\partial y$) to demonstrate that statistical uncertainty does not overshadow the physical transport terms.
- **Wake measurements - Spatial resolution:** Wake measurements were performed at downstream distances of 2D, 4D, 6D and 10D. The authors present a momentum budget analysis across the turbine wake based on a 13×13 mea-

surement grid ($\Delta y = \Delta z = 0.05 \text{ m} = D/6$). While this spatial resolution may be sufficient to capture macro-scale velocity recovery in the far wake, it appears inadequate for accurately resolving spatial derivatives in the shear layers of the near-wake.

Near-wake shear layers typically have a thickness on the order of $0.05D$ to $0.1D$. With only 6 grid points across the entire rotor diameter, the discretization provides at most 1–2 points across the steep gradient region. Discrete spatial differentiation (e.g., central differencing) on such a coarse grid will introduce significant spatial smearing and truncation errors, leading to an underestimation of both mean advection gradients ($-v\partial U/\partial y$, $-w\partial U/\partial z$) and turbulent transport derivatives ($\partial \overline{u'v'}/\partial y$, $\partial \overline{u'w'}/\partial z$).

If finer spatial measurement grid data are not available (see next comment on PIV), consider restricting the full budget quantification to regions where spatial gradients are well-resolved (e.g., far-wake regions where profiles approximate smooth Gaussian shapes) and explicitly acknowledge the truncation errors near the rotor.

- **Particle Image Velocimetry (PIV) measurements:** As both the temporal and spatial resolution of the LDV measurements might be low, I wonder if PIV measurements with a higher spatial (and maybe also temporal?) resolution would not have been a better dataset for the presented analysis. On page 9, it is mentioned that PIV measurements have been carried out under the same experimental setup. Results of the comparison are then presented in Appendix B, which would be nice to have in the main body of the paper. However, any details about the experimental setup of the PIV measurements are lacking. It would be nice to have at least some information about the resolutions and a justification why the LDV data were chosen for the analysis over the PIV data.

3 Technical corrections

As mentioned in the summary, the manuscript contains informal language (“don’t/it’s/its”) and should undergo a general language revision. Here are some technical corrections I found on a first glance, but there are many more that I probably overlooked:

- **Line 40:** *Unfortunately, ... didn’t lead to a faster wake recovery. Unfortunately* is judgemental and not fitting here. Also, *didn’t* is informal language.
- **Line 144:** wich
- **Line 181:** compares
- **Figure 10** *Mean vertical transport* instead of *turbulent kinetic energy*
- **Figures C1 - C6:** On all these plots, the left hand side (low turbulence case) and right hand side (high turbulence case) look exactly the same to me. Could it be that the same figure was inserted twice?