Response to Reviewer 2

Thank you for your time reviewing our manuscript. Your constructive comments have substantially improved the quality of our work. In the following, please find our point-to-point responses to your comments.

General comments: The manuscript presents a hybrid framework for developing a dynamic wake model that integrates first principles with machine learning (ML) techniques. The ultimate goal is to enable dynamic single-turbine wake modeling accounting for aerodynamic force oscillations. The authors leverage three sub-models to capture time-averaged wake, wake meandering, and small-scale wake turbulence. Some submodels are trained using LES data, and the results show generally good agreement with the ground truth. The work addresses an important problem in wind-energy modeling and has potential for impactful contributions. However, there are several points that need to be addressed to strengthen the manuscript.

Response: Thank you for your kind consideration of our work.

Comment 1: A primary concern is that the ML models are mostly treated as “black box”. There is no discussion or demonstration of explainability, such as feature importance or SHAP tools. Since two of the submodels rely heavily on ML and directly affect the first submodel and overall wake predictions, the lack of explainability limits the credibility and understanding of the framework. It is strongly recommended to include an assessment of how the ML predictions are derived and how dependent they are on inputs.

Response 1: we have incorporated SHAP (SHapley Additive exPlanations) analysis to transition our CNN submodels from a "black box" to a more transparent system. Specifically, we added a new paragraph and a figure (Figure 10) that provides local SHAP explanations at two physically distinct locations: the wake centerline and the shear layer (lines 373-392, page 19-20). The SHAP analysis provides local interpretability for the CNN predictions, while global explainability remains a topic for future work.

Comment 2: The manuscript lacks a comprehensive review of recent literature in data-driven wake modeling, especially regarding generalization and explainability of ML-based wake predictions. Providing a critical comparison would clarify the novelty of this work.

Response 2: The literature review has been expanded (lines 53-72, page2-3). The novelty of this work has been clarified (lines 73-80, page 3).

Comment 3: Please provide a quantified comparison of the onset of wake meandering rather than relying on qualitative assessment from the results in Figure 12.

Response 3: A quantitative comparison has been provided (Figure 14; lines 421-424, page 24).

Comment 4: Regarding Figure 14: I agree with the authors that the model struggles more in predicting the wake centerline velocity deficit than the wake center position. The model captures trends in wake centerline velocity deficit for St_f = 0.12 and 0.25 but fails for St_f =0.84 (in both wake centerline velocity deficit and position). The authors should discuss potential reasons for this discrepancy.

Response 4: Discussions on potential reasons have been added (lines 443-454 page 27).

Comment 5: The current model is developed and validated only for a single turbine. While the results are promising, it remains unclear how the approach would capture the cumulative effects of multiple interacting turbine wakes in a wind farm. This limitation should be explicitly discussed in the manuscript.

Response 5: The Reviewer raised an important concern. To address this concern, (1) we have added a test case with two turbines in an inline configuration (Appendix C), and (2) we have clarified the focus of the paper, which is on the dynamic wake model for a single wind turbine, and discussed the model development for wake overlap, merged wakes, or cumulative turbulence in arrays as future works (lines 540-558, page 33)

Comment 6: I believe there is a need to make lines 30–35 on page 2 more accurate.

Response 6: Specifics have been added in the revised text (lines 31-37, page 2).

Comment 7: Please clarify the definition of the turbine operational parameter Cop?

Response 7: Clarified. (lines 86-91, page 3).

Comment 8: Both the abstract and conclusion are highly qualitative. Including quantitative metrics on model accuracy would significantly improve the clarity and impact of the results.

Response 8: Included in both the abstract and conclusion (table 5, lines 8-11, page 1, lines 479-482, page 30).

Comment 9: Text in some sections seems repetitive, which disrupts readability. Streamlining text while keeping clarity is recommended.

Response 9: Streamlined with repetitive content removed.

Comment 10: There are a few citation issues (e.g., repeated names such as "Jensen Jensen") that should be corrected.

Response 10: Corrected.

Comment 11: Check Eq. (6): is it a complete equation or only a partial expression?

Response 11: Checked and revised to its complete form.(New Eq. (6))

Comment 12: Consider using a term other than "real" for LES predictions; "ground truth" is more accurate.

Response 12: Revised to “ground truth”.

Comment 13: Line 320, page 19, is unclear and needs clarification.

Response 13: Clarified (lines 458-465, page 27).