Authors' response: Assessing lidar-assisted feedforward and multivariable feedback controls for large floating wind turbines

Feng Guo* and David Schlipf

13.06.2023

First of all, we would like to sincerely express our appreciations to the associate editor for her interest in our manuscript and for taking her valuable time to carefully read our manuscript. Without a doubt, the associate editor's comments were really helpful in raising the calibre of our manuscript. We thoroughly read and thought about each and every suggestion, and we updated our work.

Please find below our response to the associate editor's comments. The editor's comments are repeated in black text, our response should be given in blue text, and if necessary, the corresponding corrections are provided in red text.

Response to comments of the Associate Editor

Methodological points

(1) Could you please provide an explanation on why the load cases have been selected to have a 600 s duration referring to the IEC onshore standard taking into account this is a floating wind turbine? We have put the wrong reference there. According to IEC 61400-3-2-2019 (Section 7.5.6), which is build upon the Section 7.5.6 of IEC 61400-3-1-2019, 10min simulations are suggested for most of the DLCs regarding the design of an offshore turbine. We have corrected the reference in the revision.

(2) Section 5.1, from L350. Could you please clarify why the selection of optimal parameters is performed under nonlinear simulations with a specific implementation of the gain scheduling (mean wind speed) but the controller assessment is made with a different implementation (blade pitch angle)? This would represent a shortcoming from the methodological point of view, and would call into question the tuning process and, more particularly, its optimality. I'd strongly advise that the parameters selection and the controller assessment are performed in a coherent way with the same control implementation, taking into account that this seems to have an effect. Otherwise, it is very difficult to draw clear and solid conclusions from the results. Thanks a lot for your comments and suggestions. We have now updated the gain scheduling methods to use the mean wind speed for both MVFB and LACPF+MVFB controls. The whole manuscript is updated according to the new simulation results. With these updates, the results shown in Figure 7 is now in accordance with that shown in Figure 10. We also deleted some text in Section 1 that are no longer necessary after the updates.

Other comments

1. Introduction, L56. Could you please further emphasize the differences between your work and previous works in the optimization of parameters of multivariable feedback controller with nonlinear aeroelastic simulations vs Zalkind et al.(2022), for instance? Also, in that paragraph, it would be interesting to better highlight which is the novelty and main contributions of the manuscript, since it remains a bit unclear: the controller structure? The parameter optimization process? Any controller implementation aspect? Any other aspects in the control design process? Thanks for your comments. We have explained a bit more how Zalkind et al.(2022) find the optimal parameters in Lin 55 and highlighted that we did not use any optimization solver but used the simple brute force optimization approach in Lin 58. From Lin 61 to 64, we added the highlights of this work: The main contributions of this work include (a) guidance towards the baseline design of lidar-assisted feedforward controllers for floating turbines; (b) comparisons of the optimal controller

tuning parameters between the MVFB and the LACPF+MVFB controllers; and (c) assessment of the performance of the two controllers using realistic offshore turbulence characteristics.

2. Please be aware that Table 1 exceeds the page limits.
Thanks for the your reminder. This table will be reduced in size when we compile it with the "final" option. This problem will be solved in the typeset procedure.

3. In section 3, it would be nice to separate the explanations about the ROSCO baseline controller and the modifications introduced with the multivariable feedback controller in section 3.1. For instance, the sentence at L151 would better fit when reference is made to ROSCO, not after commenting the modifications introduced by the authors.
Thanks for your comments. We have rewritten this section to cite ROSCO first and then explain our modifications.

4. Figure1, please include the reference to Task 37 GitHub repository in the caption
Thanks for the your comments. We have added the reference.

5. References. Please complete the references with works not belonging to the authors or their research groups. E.g. application of LACPF to floating turbines in the introduction.
Thanks for the your suggestion. We have added a review paper in the introduction that lists almost all studies related to LAC applications for offshore turbines.

6. It would be nice in Figure 3 to better highlight (e.g. with a different color in the blocks) the additional part that the LACPF part adds to the MVFB controller scheme. Thanks for the your suggestion. We have highlighted the LACPF block in the revision.

7. Figure 3 – caption, "the real-time pitch angle" sounds a bit strange. Something like "measured blade pitch angle" would be clearer. Thanks for the your suggestion. We have updated this point in the revision.

8. L161, instead of "the speed control reference", maybe "the generator speed control reference" would be clearer. Thanks for the your suggestion. We have updated this point in the revision.

9. L178, for the sake of clarity, could you please specify explicitly to which coupled frequencies do you make reference with "the motion is much more significant in the coupled-frequency ranges for floating turbines"? Thanks for the your suggestion. We have pointed out that it is the natural frequency of the platform pitch fore-aft mode in the revision.

10. Please include the explanation of the complex frequency from equation (4) in equation (2) as it is the first time it appears. Thanks for the your suggestion. We have now put the explanation after equation (2).

11. Equation (7) -> It could be a bit misleading to use the same Greek letter in this equation as the one used for the blade pitch angle. Thanks for the your suggestion. We have modified θ_{pitch} to θ_{actuator}.

12. Figure 7, Figure 9 – caption: Could you please specify what do you exactly mean by "Only parts of the mean wind speed conditions are shown"? Maybe the sentence could be rephrased to make it clearer. Thanks for the your suggestion. We have modified the sentence to Only four representative mean wind speed conditions are shown.

13. Figure 9 – caption. For the sake of caption completeness, could you please specify the type of load case used in the simulation? Thanks for the your suggestion. We have specified that it is based on DLC 1.2 in the revision.

14. L319 – Do you have any hypothesis on why the case of 14 m/s presents an increase in tower load and platform motion in Figure 9?
authorresponseThanks for the your suggestion. We have added explanations to Lin 339 in the revision as When the floating feedback gain is too aggressive ($>$ 25 s), the control performance reduces, which might be caused by the fact that the fore-aft motion is more sensitive to the blade pitch changes at this operating point..

15. Figure 9 – according to the figure, MVFB decreases loads more than LACPF+MVFB. Maybe this should be commented in the discussion. Thanks for pointing this out. Actually, the results here are relative to the case with $k_{\text{p,float}}$ =0 s. In (a) to (d), the results are relative to the MVFB control with $k_{\text{p,float}}$ =0 s. In (e) to (h), the results are relative to the LACPF+MVFB control with $k_{\text{p,float}}$ =0 s. Therefore, the results are not comparable vertically. We have rewritten the caption to make it more clear.

16. L316, L323 -> Please make clear reference to the figure you are discussing (Figure 9). Thanks for the your suggestion. We have added the reference (Figure 9) in the revision.

17. L345. Please specify in the text that the figure and discussion refers to DLC 1.3 cases, not only in the figure caption. Thanks for the your suggestion. We have specified that these results are obtained from DLC 1.3 in the revision.

18. L357, the statement "which should be further improved by more advanced algorithms such as model predictive control (MPC)". Should it be strictly improved by MPC? The statement seems to be a strong conclusion which cannot be directly

derived from the results and their discussion, specially taking into account that the selection of parameters is performed with a different implementation of the gain scheduling than the one used for the controller assessment. I'd advise to present this comment as a future work of interest for the authors rather than as a conclusion from the work performed. Thanks for the your suggestion. We have deleted thses sentences because this overspeed problem does not present with the updated gain scheduling method (depends on the mean wind speed).

19. Figure 11 and L365. Since the cases with mean wind speeds higher than 12 m/s are not executed for stability 1 and 3, I'd advise not to plot any point for those speeds and stabilities since they could be misleading. Or is it really a typo and you meant 20 m/s in L365? Thanks for your careful review. Indeed, it is a typo and it should be 20 m/s not 12 m/s. We have corrected this in the revision.

20. Figure 11 – For the sake of caption completeness, please indicate which DLC cases are shown in the figure.Thanks for the your suggestion. We have specified that it is based on DLC 1.2 in the revision.

21. When making reference to the obtained life extension in section 5.2, abstract and conclusions, a disclaimer should be introduced saying that this is based on the assumption that the fatigue life of the turbine is fully based on the DLC1.2 cases. Thanks for the your suggestion. We have added the explanations in the parts you mentioned. abstract: The two optimally tuned control strategies are then assessed using design load cases 1.2 specified by the IEC-61400 standard. Compared to the baseline multivariable feedback controller, the one with optimal tuning significantly reduced the tower damage equivalent load, leading to a lifetime extension of 19.7 years with the assumption that the lifetime fatigue is only caused by design load cases 1.2. Section 5.2: Here, it is assumed that the lifetime fatigue loads are only resulted from the DLC 1.2. Note that the EL and relative change are... Conclusion: In terms of the fatigue load resulted from DLC 1.2, the most significant improvement from re-tuning the feedback loops with MVFB control is the extension of the tower lifetimes by 19.7 years.

22. L438: The sentence "However, a more detailed assessment can be further improved by more complicated modeling of the pitch actuator damage" sounds a bit strange. Do you mean rather a more complete modeling? Thanks for the your suggestion. We have used "a more complete modeling" now.

Language aspects and typos

1. L18, please correct the unfinished sentence "Under the same wind speed conditions" Thanks for the your comments. This is a sentence we forgot to delete as it has been rewritten as follows "At the same wind speed, the rotor swept-area of the turbine increases quadratically when the rotor radius increases, and the aerodynamic thrust on the rotor increases accordingly.". We have now deleted it.

2. L55, please correct “to improving” Thanks for the your comments. This has been corrected to ”to improve”.

3. Footnote 2: space between value and unit Thanks for the your comments. This has been corrected.

4. L165: openloop -> open loop Thanks for the your comments. This has been corrected.

5. L165: missing “and” in the sentence “both the blade pitch angles generator torque are kept” Thanks for the your comments. This has been corrected.

6. L318: As $k_{\mathrm{p,float}}$ “increases” Thanks for the your comments. This has been corrected.

7. Figure 10 caption: interesting instead of interested? Thanks for the your comments. We now use ”key variables”.

8. L429: space in between “%of” Thanks for the your comments. This has been corrected.