# Authors' response to reviewer 1

We thank the reviewer for the valuable comments and suggestions, which we consider very important and help us to sharpen and improve the manuscript. Here are our responses written in green to each comment.

The authors response is shown in green.

## General comments:

It is suggested to shorten the paper to focusing on the main results only as in the current form it is hard to follow and read.

Thank you for your suggestion. We realised that the paper is long while writing it and we actually kept it as short as we can and we even decided not to add some sections to avoid making it longer. We believe removing any of the current sections takes away from the goal of the paper and its structure. The paper mainly aims on showing three main points:

- The results of the relocating FWF layout design using steady state wake models (Gaussian wake model in FLORIS) and static tools for mooring systems (using MoorPy). This can only be done through a quick introduction of the method and the results obtained at each step. Showing only the final results when using steady state tools will add ambiguity to the paper, and makes it dependent on our previous work and cannot be read as a standalone paper.
- The dynamic results of the same relocating FWF using OpenFAST and FAST.Farm.
- The comparison between the steady state results and the dynamic results.

Removing any of the sections of the paper will take away from the paper's integrity and our ability to fully present these three points. However, we decreased the level of details in section 2.3, and made it shorter.

It is suggested to change the writing style from the first to the third person

Thank you for your comment. We know there is a debate on what writing style to use. However, it was suggested for us by the internal editor at NREL to use first person, so we prefer to keep using it in this work.

The power gain increase achieved by the authors is insignificant, so it is hard to justify the application of the proposed mooring system design to industry

The energy gain of the new design should be compared to the losses in the baseline layout design and not as an absolute value. A system with small losses will have small gain after optimization, while a system with higher losses should have higher gain. This was missing in the paper but now we added tables 3 and 4 to show it, which we will mention also later in the response.

Moreover, the paper is presenting a preliminary design method and more work needs to be done before proposing this method as mature for industrial application (For example, we do not consider the cable design in this work) to include large lateral displacements of the FOWT. We are also aware that the energy gain will even decrease more when the full wind rose is applied as no gain will be produced form the above rated wind speeds, and less gain will be produced for lower wind speeds.

The paper introduces a method to integrate the mooring system design as part of the FOWT's design. The paper shows that these movements are capable of affecting the AEP of the wind farm. Therefore, we do not think that the gain presented in this work is insignificant and we will go through this in detail while discussing the last comment to avoid redundancy.

## Technical comments:

Line 30, the statement "... provides stiffness in surge, sway, and yaw degrees of freedom" is only valid for slack-mooring and is not valid for TLPs

Thank you. We updated the text as shown below:

"For a FOWT, the mooring system is responsible for station-keeping, as the catenary mooring system provides stiffness in surge, sway, and yaw degrees of freedom (DoFs)."

Line 110, the authors demonstrate a gain of 6.1% at 10 m/s, it would be good to know the power gain using the entire wind probability at a particular deployment location

Thank you for your comment. We believe calculating the full wind rose energy gain lies out of the scope of this paper for the following reasons:

- The goal of the paper is to verify the results of steady states models to the dynamic models. Therefore showing the maximum targeted gain for a full wind rose is out of scope of this work and was presented in our work in [1].
- The wind rose used is a theoretical wind rose created within IEA Task 37. Therefore, we cannot apply any wind rose for a location of deployment as this means we need to redesign the FWF and the mooring system for this new wind rose.

We updated now the text in section 2.2 as follows: "The energy gain achieved in through this paper only considers a constant wind speed of 10 m/s, and not the full wind spectrum. As shown in our work in [1], when all wind speeds are considered the energy gain was reduced by 40% to 30% of the gain calculated at 10 m/s. The calculation of the full wind rose energy gain is out of scope of this paper because we instead focus on the comparison of the steady state and dynamic models."

Figure 8 and 9 - use the power of 10 to show Frequency of the FOWT, and the chosen color-scheme does not demonstrate the variation in frequency range

Thank you for your suggestion. We updated the Figures to show the frequency as a power of 10 as suggested. We have also changed the color-scheme as suggested.

Figure 11 is mentioned first on page 6 while it appears on page 14

Yes, this is true. We preferred to show this Figure as a comparison rather than splitting it into three figures. We believe this allows the reader to compare the results at different stages of the process easier. However, we removed the early mention of Figure 11.

Section 3.2 - the authors refer to the natural frequency of FOWT but not clear which DOF

Thank you for the clarification. We used x-axis and y-axis in Figures 8 and 9. We will update the text to include that these are for surge and sway DoFs. We updated the captions of the figures and line 224 is now updated as follows:

"The figures show the value of the natural frequencies in the $x$-axis and $y$-axis directions (surge and sway DoFs respectively)."

Figure 8 and line 230 - the authors state that the natural frequency does not change with the wind speed and wind direction while in reality it is. It has been shown in https://asmedigitalcollection.asme.org/OMAE/proceedings-abstract/OMAE2023/86908/1167328 that the natural frequency in surge changes with wave and wind directions

Thank you for the clarification. This is true, as we indicated in Figures 8 and 9, the stiffness is changing with wind speed and direction. In line 230 we say that for the baseline mooring system design the stiffness is almost constant for all wind speeds and all wind directions in comparison to the new less stiff mooring systems which have bigger changes with wind speed and direction. We understand that our explanation for this was unclear and confusing and updated the text as shown below:

"In Fig. 8, the natural frequency of the baseline design shows only small changes as the wind speed and wind direction change. This means that for all wind excitations and for all positions inside the watch circle, the natural frequency is changing within a small range as shown in Fig. 8. This is because the stiffness of the baseline design is linear and almost constant for all wind speeds and wind directions."

Line 265 - the choice of the sea state parameters should be explained

Thank you for pointing this out. We updated the text as shown below:

"The significant wave height for all simulations was equal to 2 m, and the wave period was equal to 6 s. We used these values for the sea states as they are the operational values used during the Activefloat design as indicated in [2]."

Line 275 - the gain of 1.4% might be within the modelling error and is insignificant

Thank you for this comment. We have added context to explain why the 1.4% gain is significant.

- The 1.4% is a small value when we do not consider the value of the wake losses. However as shown in Table 4 newly added to the text the new design leads to decreasing the wake losses from -6.08% to -4.73%. This decrease is equivalent to a decrease of wake losses by 22%. The gain in our work is only 1.4% because we used the optimized wind farm layout OWFL as a baseline for comparison. We decided to do this instead of using a gridded shape layout to truly show the benefit of relocating the FOWT. Starting with a gridded shape layout would lead to a much higher gain value as the gridded layout has higher losses. We are currently working on a paper showing that for wind farm layouts that are gridded shaped similar to the Horns Rev I wind farm, this method has a much higher potential as any small relocation will significantly increase the power. Tables 3 and 4 are now added to the text to show the wake losses of each layout.

- There is a big uncertainty from the wake model implemented within FAST.Farm as we discuss in the paper. However, FAST.Farm currently underestimates the wake losses for a FWF. As we discussed in the paper the work done in [3], compared the FAST.Farm results to MIRAS-HAWC2 results. The results show that FAST.Farm over estimates the vertical deflection of the wakes due to the pitching of the FOWT. This overestimation decreases the wake losses predicted by FAST.Farm and this is explained in section 3.4. Therefore, the uncertainty in the wake model decreases the

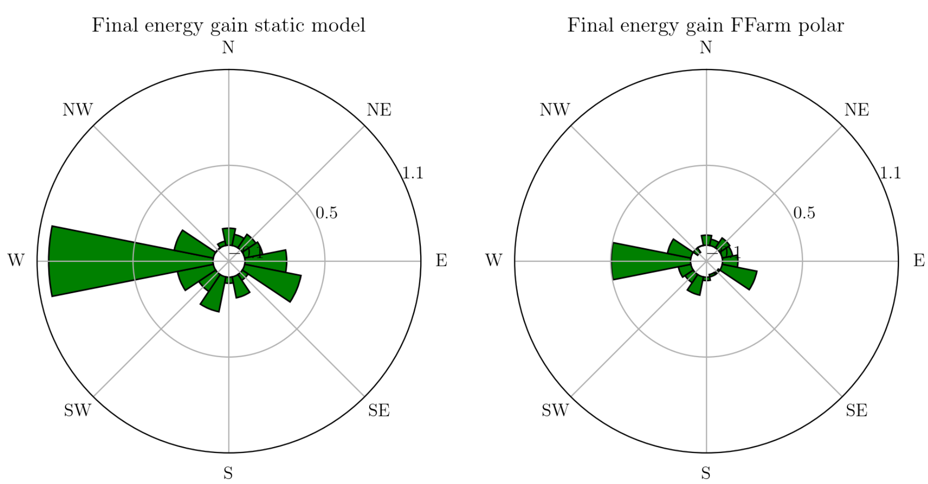


Figure 1: Final energy gain in FLORIS on the left and in FAST.Farm on the right

energy gain due to relocating the FOWTs and does not increase it.

- In Figure 11, that we zoom in and introduce again here, the final gain expected from the static model and the gain from FAST.Farm follow the same pattern. If the gain was due to numerical uncertainty the gain distribution over the wind directions will be random and would not agree with the predictions of the static model. This is explained in the paper in section 3.4 in line 290. The text is now updated as follows: "The energy gain distribution per wind direction in the FAST.Farm model follows the same trend as the gain distribution for the MoorPy-FLORIS results. This shows that the energy gain achieved by the OWFL when coupled to the OWFL, is not numerical as it is not random but follows our expectations from the steady state model."
- In section 3.3 we showed that the lateral movements of the FOWTs and OpenFAST match each other. This minimizes the probability of the gain being a numerical modelling error.

# References


[1] Mohammad Youssef Mahfouz and Po Wen Cheng. A passively self-adjusting floating wind farm layout to increase the annual energy production. *Wind Energy*, 26(3):251–265, 2023.

[2] Mohammad Youssef Mahfouz, Mohammad Salari, Fernando Vigara, Sergio Hernandez, Climent Molins, Pau Trubat, Henrik Bredmose, and Antonio Pegalajar-Jurado. D1.3. Public design and FAST models of the two 15MW floater-turbine concepts, December 2020. This deliverable is a draft version, and still under revision by the EC.

[3] Néstor Ramos-García, Sergio González-horcas, Antonio Pegalajar-jurado, Ozan Gözcü, Henrik Bredmose, Umut Özinan, Mohammad Youssef Mahfouz, Alessandro Fontanella, Alan Facchinetti, and Marco Belloli. D1 . 5 : Methods for nonlinear wave forcing and wakes. Technical Report March 2022, 2023.