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Wind Energy Science Discussion

Date: January 16, 2024
Subject: WES-2023-137 Final Response

Dear Referees,

We would like to thank you for having reviewed our manuscript and for the valuable feedback. Your suggestions focused our attention on aspects we didn’t consider in the first version of the article, and we believe this will improve the quality and impact of this work.

We tried to improve article following your suggestions and we hope to have addressed most of your concerns, otherwise we would be happy to continue the discussion. Below, you can find our response (AC) to your comments (RC).

On behalf of all Authors,
yours sincerely,

Alessandro Fontanella

Attached documents:

- Response to Anonymous Referee #1
- Response to Rad Haghi (Referee #2)

Response to Anonymous Referee #1

Dear Referee,

Thank you for taking the time to review our manuscript and for the valuable comments you made.

General comments

RC1.1	In line 41: one of the paper goal is a sensitivity analysis. However, the results is randomly presented and the parameters of the sensitivity analysis are unclear. For example: the control strategy was only checked once at steady state but not in respect with the other parameters. Also the turbine rating and platform topology. There was no clear structure of the analysis and in some cases only the results of the 15MW with the VoltrunUS platform was shown.
AC1.1	We agree with you that talking of a sensitivity analysis is inappropriate. Literally, a sensitivity analysis studies how uncertainty in a model output is related to uncertainty in the model inputs. This is usually done testing the model under a range of alternative inputs. Off course, it is not the goal of our work. We rephrased the goal at line 41 saying that in the article "we study the effect of floating wind turbine characteristics (control strategy, turbine rating, platform typology) and met-ocean conditions (wave spectrum, wind-wave directionality) on the generated power". We also agree it is useful to show results for all four FOWTs, thus we added them where they were omitted.

RC1.2	In Line 43, the third main contributions of this work is that it defines a methodology to study the response. However, this was not clear through the paper. There was no clear method with an objective, input and output.
AC1.2	The method of the analyses presented in the article is discussed in Sect. 2 where we define the inputs, i.e., the environmental conditions, the simulation tools, and the parameters of our interests, mainly the wind turbine power production. That said, the third contribution of the article was not clear since it refers to the use of clustering to introduce the sea conditions in a multi-physics simulation. Therefore, we rephrased the sentence at line 44 to make it more explicit.

RC1.3	The result section needs to be restructured. 1) A suggestion would be to have 4 sections representing each of the four defined multifidelity models. Then in each section perform the simulations of each of the four FOTWs and have a clear comparison at the end. 2) Another option would be to define a set of analysis parameters at the beginning of the section. Then do the analysis for each of the FOWTs then have a final section to compare.
AC1.3	The idea behind the article is to show that wave-driven platform motions can increase the average power output of a floating wind turbine when this is modelled under very simplistic assumptions, but this does not occur in more realistic conditions. For example, this is mentioned at line 39: "we use multi-fidelity models of increasing complexity to clarify how physics of the energy conversion process taking place in floating wind turbines is influenced by platform

	motion and waves"; or in the Conclusions at line 470: "To understand how waves and platform dynamics impact the power production of a floating wind turbine […] We used four simulation models of increasing complexity that gradually move from simple analytical calculations to a non-linear aero-servo-hydro-elastic model reproducing a realistic scenario with stochastic wind and waves in the Mediterranean Sea". In our mind, the results section is adherent to this objective: first it presents results of the simulations with prescribed platform motion, then it shows the outcomes of simulations with regular waves, and finally the results of simulations with stochastic wind and waves, these being generated in two ways. Before results of the four simulation scenarios, we discuss the effects of platform static tilt and wind properties (vertical shear and turbulence intensity) because we believe they are important to understand the rest of the results. Coming to your suggestion, this is what we did to improve the structure of the Results section: - We added a brief introduction at the beginning of the section mentioning the key parameters we analyse. - In all sub-sections we present the results of the four floating wind turbines. - At the end of each subsection there is a short conclusion paragraph that summarizes the main findings.

RC1.4	The way that authors presented the results is not clear and very hard to follow with long. paragraphs and complex Figures. Clear Figures and statements will help the readers to understand the results.
AC1.4	We improved the Figures and description of results addressing the Specific comments received by the two Referees.

Specific comments

RC1.5	Line 9: performance is a general word, and structural loads are part of the performance. I believe you mean sacrificing the power?
AC1.5	Correct, we changed performance with power.

RC1.6	Line 21: energy point of view
AC1.6	Checked.

RC1.7	Line 39-45: Please have a look at the contributions and make sure they are clearly presented in the paper.
AC1.7	We rephrased the contributions to make them adherent to the article content.

RC1.8	In equation 3: There is a different variation for pitch angle that is introduced later on in the text. I suggest you introduce it here and add the "h" parameter. (line 303)
AC1.8	The parameter h is now introduced before Eq. 3 that is now consistent with the text at line 345.

RC1.9	In line 92: please state the DOFs considered. "different directions" is vague
AC1.9	We listed the DOFs considered in the analysis.

RC1.10	Line 104: To the best of my knowledge OpenFAST doesn't have a prescribed motion option. How as this included? If you have created a version is it open-access?
AC1.10	There are several options to prescribe motions in the latest version of OpenFAST. We briefly explained the method we used at line 120. Moreover, we uploaded all the OpenFAST model we used for simulations in a Zenodo database that is mentioned in the Data availability section of the article.

RC1.11	Line 119: what does MPRO stand for?
AC1.11	MPRO stands for Motion Power-response Operator. To simplify the notation and make it easier to understand results, we removed the notion of MPRO function from the article and we use "average generated power".

RC1.12	Line 132: what does WPRO stand for?
AC1.12	WPRO stands for Wave Power-response Operator. To simplify the notation and make it easier to understand results, we removed the notion of WPRO function from the article and we use "average generated power".

RC1.13	Why use the peak shaving and the nacelle velocity and not a baseline controller? Can you please clarify the motive behind this decision. It is clear from the steady state analysis that these options have a large effect especially around rated. But the effect they have in stochastic wind and wave is not clarified.
AC1.13	The peak shaving and nacelle velocity feedback of ROSCO are meant to improve the operation of floating wind turbines. We added this text in Sect. 2.2: "We expect that these control strategies will be used in future floating wind turbines. The peak shaving is increasingly important for large FOWTs because it lessens the restoring requirements of the floating platform (Renan dos Santos et al. (2022)). Traditionally, the instability issues of FOWT controllers have been solved with detuning, i.e., reducing their bandwidth below the platform pitch natural frequency (van der Veen et al. (2012)). As the FOWT size increases, the platform natural frequencies decrease leading to slower controllers when applying detuning. This is avoided with nacelle velocity feedback that improves power quality while reducing structural loads (Fleming et al. (2019), Vanelli et al. (2022))." The same control strategy has been used in all four floating wind turbines to have a common ground for comparisons. It is instead outside the scope of this work to investigate the effect on the dynamic response to stochastic wind and waves of using or not peak shaving and nacelle velocity feedback.

RC1.14	Line 184: Which version of ROSCO was used? How was the model tuned
AC1.14	We used the version 2.8.0. The controllers settings we adopted are those of the reference OpenFAST models of the four floating wind turbines and no further tuning was done in this study. We included this information in the section about the wind turbine controller.

RC1.15	Line 288: How many seeds were used for the assessment of the affect of the turbulence intensity?
AC1.15	We simulated every stochastic wind case for 3 hours to reach statistical convergence of wind properties. Every 3-hours wind field was generated from one seed.

RC1.16	Line 310: I agree that the other DOFs cannot lead to an increase in power production, but these motion occur and can lead to a decrease in power production. Were they locked during the simulations?
AC1.16	In Harm-M simulations, motion is prescribed along one motion direction and the others are locked (see Sect. 2.1.1). Variations in generated power due to harmonic motion in the sway, heave, roll, and yaw directions are very small and negligible compared to variations due to surge or pitch motion. As an example, with a mean wind speed of 9 m/s, the variations in average power due to sway, heave, roll, and yaw motion are between -0.3% and +0.4%.

RC1.17	Section 3.4: A list of the regular wave heights and periods used in this section should be added to the appendix. Or the method used to choose steady waves should be mentioned.
AC1.17	The values of wave height are 0.5 m 10m. 15 m, 2.0 m. 25 m. 3.0 m: the values of wave frequency are 0.05 Hz, 0.10 Hz, 0.15 Hz, 0.20 Hz, 0.25 Hz, 0.30 Hz. These values are representative of the wave conditions at the sea site of reference. We preferred to add the values of wave height and wave frequency in Sect. 2.1.2. where we describe simulations with regular waves.

RC1.18	Figure 11: The color bar for the 5MW spar is different than the rest of the Figure. Please unify the color bar for easier comparison.
AC1.18	We followed your suggestions, and we use the same colormap for the four floating wind turbines. Since the increment of generated power for the 5 MW spar is above 2%, which is the upper limit for the other three floating wind turbines, we added labels on the contour lines of the 5 MW spar to indicate the increment when the colormap is saturated.

RC1.19	Line 347: An example of when the sensitivity analysis is inconsistent is the wind wave directionality study, where only one case was considered for platform topology and turbine size. Same comment for sections 3.5.1, and 3.5.2.
AC1.19	We added results for the other three wind turbines.

RC1.20	Figure 13 caption says with steady wind and still water, which graph is steady water? I found it hard to follow the legend in this Figure.
AC1.20	You are right. We changed the legend and caption to make them coherent and clearer.

RC1.21	Line 376 and 377: Please rephrase and clarify the sentence. I did not understand what you mean in this paragraph.
AC1.21	We have rephrased the sentence.

RC1.22	Figure 14: Please use different colors to show each result.
AC1.22	We think the information provided by Fig. 14 was not very useful and we preferred to remove it.

RC1.23	Figure 15: which wind and wave directions were used in the Coupled-C model shown in this Figure? Please use different colors to show each result.
AC1.23	In response to this comment and another request from Referee 2 we added a new figure (Fig. 14) where results are shown with different colours to highlight the effect of wind-wave misalignment.

RC1.24	Line 408: This statement looks contradictory to the findings introduced in line 306 with prescribed pitch motion. Is this true? Please clarify.
AC1.24	This comment refers to the platform *static* tilt whose effect is shown in Sect. 3.1. The text at line 306 is about the effects of *dynamic* platform pitching.

RC1.25	Line 434: What do you mean by AEP algorithm? Can you please show the method used to calculate AEP?
AC1.25	The AEP calculation algorithm is explained in Appendix C. We corrected the title of the appendix that was wrong in the article draft.

RC1.26	Line 454: Point 3 in the conclusion I believe was only shown for the 15MW on the semisub. This was not proven true for the rest of the FOWTs cases.
AC1.26	We agree it is important to show this conclusion is valid for all FOWTs, thus we added the results that were missing in Sect. 3.2.

RC1.27	Line 456 "the first finding, we have shown the wind turbine controller action makes power gains due to wave-driven motion possible only in below-rated winds speeds." I do not believe the controller actions and their effect on power gain were discussed in sections 3.1 or 3.3. Is this correct? Can you please clarify this sentence?
AC1.27	We are referring to the fact that in high winds power cannot increase above its rated value because it is saturated by wind turbine controller. We rephrased the sentence to make it clearer.

Response to Rad Haghi (Referee #2)

Dear Rad,

We would like to thank you for the time spent revising our article and for your feedback. Below you have our answers to your comments.

General comments

RC2.1	The paper structure needs to be improved. It is hard to follow the paper as it has long paragraphs. Using bullet points and tables can improve the manuscript.
AC2.1	You provided in the review attachment as well as Referee 1's comments. As you suggested we used a bullet point list to present the models in Sect. 2.1 and we introduced the table summarizing the modelling approaches of the four simulation scenarios.

RC2.2	In the introduction section, the main contribution, the authors mentioned sensitivity analysis, but it is not clear in the manuscript as it is distributed in the results section. I think it is better to have its section in the results.
AC2.2	This comment is not clear. However, also Referee 1 noticed that it is inappropriate to say that we have done a sensitivity analysis. We rephrased the sentence at line 42 saying we studied the effect of floating wind turbine characteristics and sea conditions on the generated power.

RC2.3	The methodology section starts with extracting equations 3 and 4, but it is not clear how they contribute to the manuscript. Also, it is unclear how they contributed to the results, as all the results seem to be based on OpenFAST simulations.
AC2.3	The analytical model presented at the beginning of the Methodology section explains why it is legit to expect an increment in the average power output of a floating wind turbine due to the platform movements. We believe this is important to provide a physical explanation to the results of the more complex OpenFAST models. Eq. 3-4 are recalled in Sect. 3.3 when discussing the results of Harm-M simulations.

RC2.4	The results section is confusing and needs restructuring. Also, more wind-wave misalignment cases can strengthen the manuscript for the Coupled-S case, as Figure 14 only presents two wind-wave misalignments.
AC2.4	We restructured the results section addressing the comments you provided in the review attachment as well as Referee 1's comments. The old Fig. 14 tried to analyse the FOWT response in two operating conditions that are peculiar because they have the same wind speed, very similar waves, and different wind-wave misalignment angles. Unfortunately, there aren't other conditions sharing these properties. One option would have been to create on purpose more conditions with the constant wind-wave characteristics and variable directionality however this would have been very similar to the analysis done with Harm-W simulations. Moreover, it was difficult to understand results of Fig. 14 and generalize conclusions to other conditions. For these reasons, we

	preferred to remove the old Fig. 14 and add a new figure analysing the variation of power due to stochastic wind and waves of different directionality.

Detailed comments

RC2.5	Make this bullet points. It makes it easier to follow. Providing a table that summarizes the models is helpful.
AC2.5	We followed your suggestion transforming the text in a bullet point list. Moreover, we also added a table summarizing the modeling approaches in the 4 simulation scenarios.

RC2.6	Either use alpha for platform mounting orientation or wind shear. It can be confusing for the reader.
AC2.6	You are correct, we used alpha for wind shear and phi for the platform mounting orientation.

RC2.7	These need references.
AC2.7	We provided references were appropriate.

RC2.8	Interesting assumption!
AC2.8	We don't know if we interpret your comment correctly, but we added a sentence to explain why we used the steady wind assumption. "This assumption is unrealistic but enables us to discern more clearly the effect of platform motions on the generated power."

RC2.9	What MPRO stands for?
AC2.9	MPRO stands for Motion Power-response Operator. To simplify the notation and make it easier to understand results, we removed the notion of MPRO function from the article and we use "average generated power".

RC2.10	What WPRO stands for?
AC2.10	WPRO stands for Wave Power-response Operator. To simplify the notation and make it easier to understand results, we removed the notion of WPRO function from the article and we use "average generated power".

RC2.11	Here it is not clear if you are sticking to no-shear wind model, or not. Please clarify.
AC2.11	We clarified the wind has vertical shear.

RC2.12	Months
AC2.12	Checked.

RC2.13	Why did you decide to go for alpha=0.14? If there is reference, please provide.
AC2.13	At line 266 we added a reference to support this choice.

RC2.14	Maybe a bit of introduction to the section?
AC2.14	We added an introduction that presents how results are structured in the following subsections.

RC2.15	How did it effect the natural frequencies of your structure?
AC2.15	Due to this change, the first fore-aft natural frequency is 0.57 Hz instead of 0.5 Hz of the original tower. We added this sentence in the description of the WindCrete floating wind turbine.

RC2.16	I suggest to present the delta in the percentage instead of kW. That is easier for the reader to interpret.
AC2.16	We followed your suggestion and we updated all figures accordingly.

RC2.17	In Eq 8, the shear component is not introduced. Please correct that.
AC2.17	Checked.

RC2.18	As a reader, I am a bit confused here. In section 2.1.1 you mentioned there is no shear, but here if the pitch effecting the wind speed at the upper portion of the rotor does it mean you have taken into account wind shear here?
AC2.18	The wind is unsheared but the apparent wind speed due to platform pitching is not uniform across the rotor disk but it is proportional to the distance from the pitch rotation point.

RC2.19	How did you calculate this?
AC2.19	The parameter Vr,avg is computed by averaging the local relative velocity at the blade sections used in the aerodynamic model of OpenFAST. In the revised text, this is said at line 432.

RC2.20	why 6mps wind speed? Why not higher or lower?
AC2.20	We think the information provided by the old Fig. 14 was not very useful nor easy to interpret and we preferred to remove it. The reasons for 6 m/s were: 1) this is a below rated operating condition where, theoretically, the average power output can be increased by waves; 2) this is the only condition in the Coupled-C load cases where we have the same wave with two different misalignments.

RC2.21	I guess this should be coupled-S
AC2.21	True, checked.

RC2.22	I would like to see more analysis on the cases with wind wave misalignment for Coupled-S case. Similar plots to Figure 11 and 12 is necessary for the readers to understand the changes in power with respect to different parameters.
AC2.22	We agree it is interesting to show more clearly the effect of waves misalignment. Thus, we added Fig. 14 where we show how the average generated power varies with turbulent wind only, with turbulent wind and irregular waves aligned to the platform, and with turbulent wind and misaligned irregular waves.

RC2.23	In reality, How feasible are these large and high frequency motions for a floating wind platform?
AC2.23	“These [motions] are difficult to achieve because wind and wave forcing generally occurs at low frequencies and because large movements can only be achieved through resonance excitation of the platform modes, which would result in high structural loads.” We included this sentence in the Conclusions at line 550.

RC2.24	I would like to see the simulation inputs and outputs in the data availability. That help readers to reproduce the data. The links here should be in the bibliography.
AC2.24	We followed your suggestion, we created a Zenodo database with all the models and simulation outputs. The database link is provided in the Data availability section whereas links to the OpenFAST models we used as a reference for our study reported in Sect. 2.2 together with the description of the 4 floating wind turbines.