Response to the Reviewer's comments - review 1

Investigation into Instantaneous Centre of Rotation for Enhanced Design of Floating Offshore Wind Turbines.

Dear Reviewer,

The authors would like to express their gratitude to the Reviewer for the thorough review and constructive comments. Please find our response with an indication and details of the modifications made below.

Comment 1 "(...) it does not seem appropriate to 'optimise' a design using this parameter. It doesn't seem possible to clearly identify the most advantageous (=optimal) ICR position, as it is very dependent on the floater concept and the response parameters you want to optimise."

Response 1 Thank you for your comment. You are correct that the ICR is not a parameter that can be directly used to optimise the floating offshore wind turbine (FOWT) design in a strict sense. The optimal position of the ICR does not directly correlate to the "best" design. However, it serves as a useful metric, and adjusting its location (or, statistics of it) can lead to significant improvements in multiple response parameters. Shifting the ICR towards a particular location may not necessarily minimise loads, but it will help reduce them. The ideal location of the ICR (or its statistics) is indeed concept-specific, as demonstrated in the paper. This varies between different substructure concepts, such as spar and semi-submersible, due to differences in the relative importance of external loads and stability mechanisms. The methodology is intended to assist in the early-stage design of FOWTs, providing additional insights into system behaviour and is meant to be applied only within the context of a specific floating substructure concept. It should not be used to choose between different concepts, but rather to adjust design parameters (e.g., column diameter, mooring line length) within a single concept.

Modification 1 A statement clarifying the use of ICR in design context was added to the Conclusion section: "Importantly, the study showed that the ICR should not be treated as an independent design variable. It can only be adjusted by modifying other design variables that also impact the loads, through mechanisms different from the ICR itself, and in some cases, may even counteract its effects. Because of these complexities, relying solely on the ICR to guide the design is insufficient. Instead, the ICR is useful for understanding one of the mechanisms that affect the global response and loads experienced by FOWTs".

Comment 2 "The correlations between the design parameters, the centre of rotation and the response parameters are not very clear, they seem to depend strongly on the floater concept and configuration. This means that the correlations presented in the paper probably cannot be generalised or applied to another floater design. They would have to be recalculated for each design, which is likely to be a time-consuming task. The practical application of this aspect of the study may therefore be limited. I suggest to acknowledge this limitations of the study related to practical application explicitly in the Conclusions section of the manuscript. This would help to prevent any "unwise" application by less experienced engineers. See also specific comment below".

Response 2 That is correct, the ICR trends and correlations with the design features and responses of interest strongly depend on the floating system concept and configuration and cannot be generalised to all FOWT types. This methodology is intended to aid improvements of a single-class FOWT, and not to compare the designs of various classes.

Modification 2 While the Conclusions section already summarises the findings for each floating concept separately, we have added a statement to clarify this point further: "To inform practical design applications, we explored which design variables could be adjusted to influence ICR statistics and how these statistics affected key responses, **for each substructure type separately**". Additionally, we changed the last sentence of the Introduction section to reflect that the methodology and not the specific findings is the main added value of this work: "The **methods proposed by this paper** can be applied in a practical design scenario, as will be demonstrated in Sect. 6".

Comment 3 "(...) plotting the ICR over different wave periods could be a useful figure, together with the motion RAOs and other hydrodynamic parameters".

Response 3 Thank you for this suggestion. The study of the ICR versus wave frequency and amplitude was conducted in a previously published work:

Patryniak, K., Collu, M., and Coraddu, A.: Rigid body dynamic response of a floating offshore wind turbine to waves: Identification of the instantaneous centre of rotation through analytical and numerical analyses, Renewable Energy, 218, 2023.

We acknowledge that studying the ICR in relation to motion response RAOs and load parameters would be very interesting. We consider this to be a significant extension of the current study, and we have recommended it for further investigation in the Future Work section.

Comment 4 "Line 151-154: Change of underwater geometry is (together with the mooring system design parameters) the main design variable for a FOWT (not considering the WTG design). So, excluding the change of hydrodynamic loading on the structure seems to be a serious limitation".

Response 4 Following the feedback received, we studied in more detail the impact of the hydrostatic stiffness and potential hydrodynamic coefficients on the ICR and responses of the semisubmersible designs range considered in this study. This analysis showed a significant impact, as indicated by the reviewers. Therefore, we updated the numerical model to update the hydrostatic stiffness matrix and potential coefficients for each semisubmersible platform design based on the Boundary Element Method solution. Additionally, we introduced re-ballasting to keep the draft of different platforms the same. Sections 4–6 with now present the updated results. Thank you for highlighting this important point.

Modification 4 Changes were made to numerical results in figures, tables and text of Sections 4–6. In particular, the new results changed the shape of the second case study and its conclusions, which necessitated changes in the Conclusion section. In particular:

- Identifying a single ICR metric to shift to improve all responses of interest was no longer possible,
- Identifying a clear design direction was not possible, therefore we proposed the use of "influence factors", as explained in the updated draft.
- We summarised the limitations of the methodology that became more apparent after the updated analysis.

Please refer to the updated draft for all modifications.

Comment 5 "Line 166-167: FOWT are designed to a large extend for ultimate limit strength (ULS) and fatigue limit strength (FLS). The proposed averaging process seems to be targeted at "representative" FLS responses. However, ULS responses (maximum responses within all conditions) would be averaged by this process and thus largely underestimated".

Response 5 In this work, the authors decided to average the results out between a set of FLS conditions, with some ULS-like conditions (maximum thrust conditions around rated wind speed) contributing to the average significantly (please refer to Table 1). However, the methodology presented in the paper can be adapted to account for another set of loading conditions, depending on the design scenario. As noticed, the results and conclusions are only valid within these conditions.

Comment 6 "Line 167-168: Are the same seeds used for each design variant? If not results between design variants would not be comparable with each other".

Response 6 Yes, all results were obtained with the same random seed.

Modification 6 We added a clear statement of the above in Section 2.3 Dynamic simulations: "Each simulation is run for 1 hour (excluding the initial transient phase) with a single random seed **(the same seed in all simulations)**.

Comment 7 "Figure 17: Why do the original design values show different ICR values? Shouldn't all original design values share the same ICR value? The original design values should all represent the same original design configuration and thus have same result values".

Response 7 Thank you for noticing this, that is correct. The results were generated by systematic variations of the variables between the minimum and maximum values and the original design values were not always part of the design matrix; the markers corresponding to the original designs were mislocated.

Modification 7 We have now added the results of the original design and marked the correct original design values in Figures 19 and 20 (note that these are also updated in response to other comments).

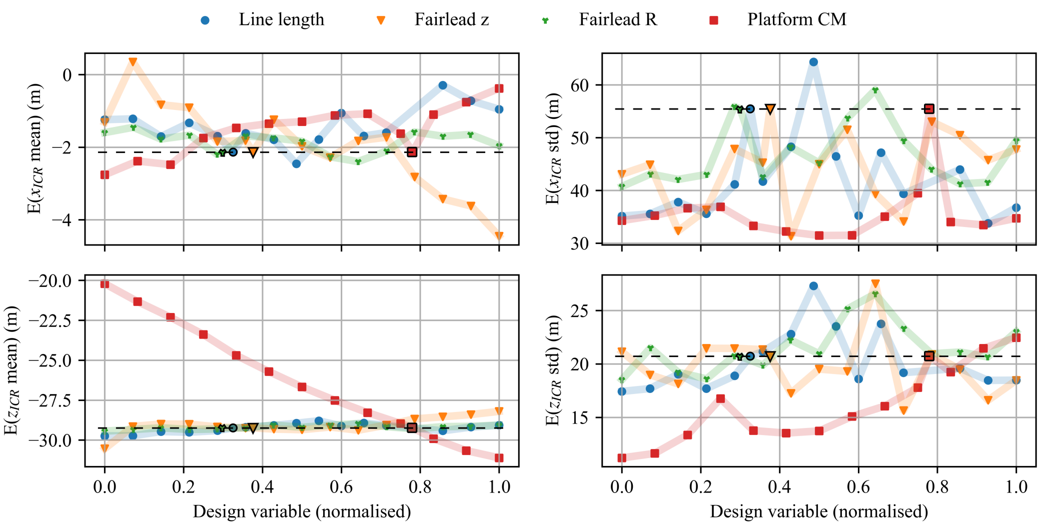


Figure 1: ICR statistics for different one-at-a-time design variable perturbations for a spar FOWT. Original design values marked with black outline.

Comment 8 "Table 10. (FAIRTEN2 mean Value 10983.62): This seems to be a very high mean/static tension especially, considering that usually the dynamic tension is the governing mooring line maximum load."

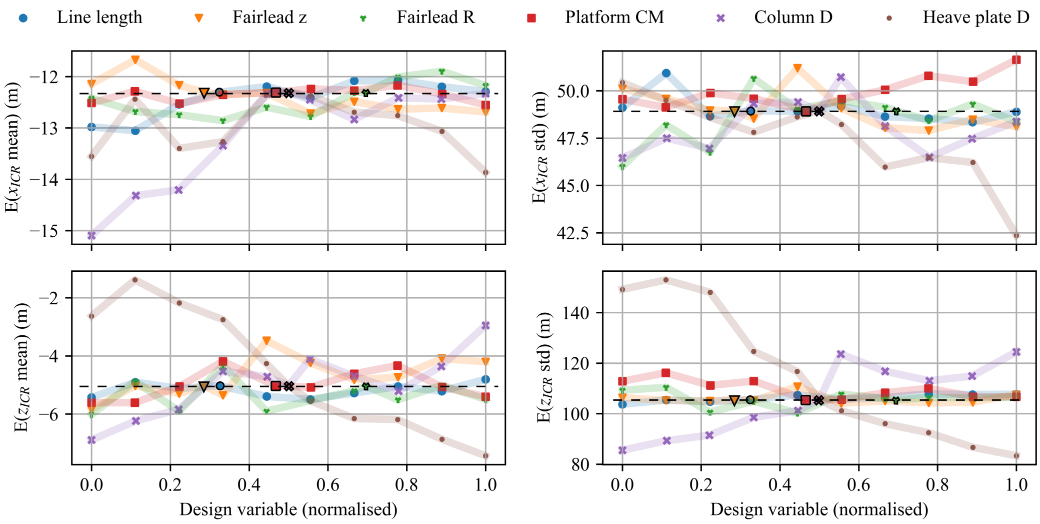


Figure 2: ICR statistics for different one-at-a-time design variable perturbations for a semisubmersible FOWT. Original design values marked with black outline.

Response 8 The high value of mean tension results from an unusual combination of a very low fairlead radius and short mooring lines, leading to very tight lines. Even though this configuration is beyond the usual design choices, it is included in the full factorial study, as each of the fairlead radius and line length values could be good values in combination with other, less extreme design parameters.

The semisubmersible results were re-computed as per Comment 4 of Reviewer 1 and Comment 5 of Reviewer 2. The updated Section 5 now uses a design matrix where the fairlead height is not varied and the tension values are less extreme.

Modification 8 No change has been made to the numerical data of Table 10. However, the order of columns in the table was changed, as it was noticed that the original table presented results related to each of the concepts under the wrong headings (”Spar”, ”Semisubmersible”). Additionally, the values were updated as per other comments.

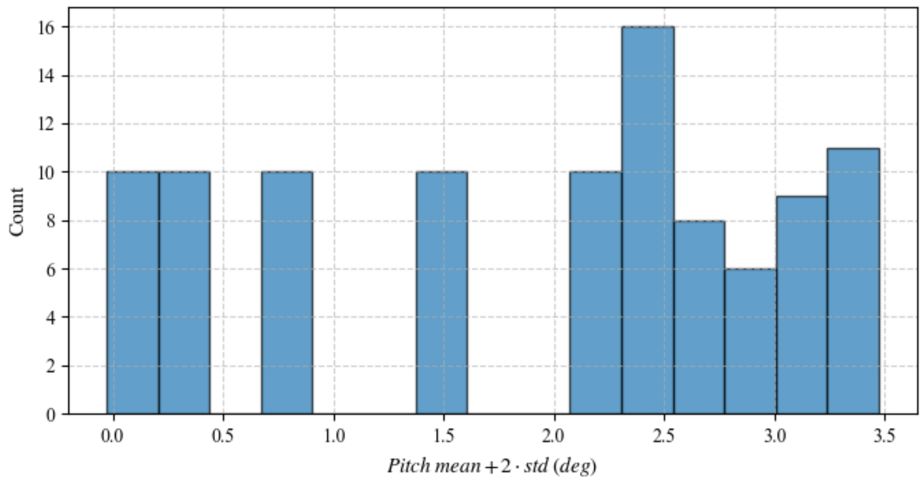
Comment 9 ”Table 11. (Platform zCM adjusted value -100.00): The vertical CM of a SPAR is usually already as low as technically possible. Thus, reducing the CM without any major changes to geometry seems unlikely. Then, if geometry would change, hydrodynamic loading would change and the correlations might be different”.

Response 9 Thank you for this practical observation. We believe that the OC3 Hywind spar is likely not an optimised design, being one of the first FOWT designs out there, therefore there should be some room for higher draft design variations, subject to port facilities and other practical constraints. However, we do agree that additional changes would be necessary to accommodate the change of the centre of gravity. Since a spar is primarily ballast-stabilised, we believe that increasing the draft of the structure would not significantly affect the motion response and structural loads, the shift of the centre of mass being the dominant effect.

Modification 9 We added a note clarifying this point in section 6.1 Spar sizing design case study: ”Implementing such adjustments may necessitate additional design modifications—for example, lowering the centre of mass could require a deeper draft structure. While some consideration has been given to the practicality of these design variations, their overall feasibility is not guaranteed".

Comment 10 "Table 13. (Offset column d, mean Re-vol. value 8.38): Offset column has a major impact on hydrostatic stiffness and restoring. Reducing the parameter by this extend is would probably result in insufficient floating stability thus large tilt during power production and even risk of capsizing/downflooding".

Response 10 We double-checked the maximum pitch angle from the simulations of the different variants of the semisubmersible, as presented in the figure below. All designs had sufficient stability in all conditions considered (including that of maximum thrust).



Once again, we would like to thank the reviewer for the thorough review of the article and extremely useful feedback. We believe that this helped to make the paper better, and we greatly appreciate your time spent reviewing it and the useful input you shared.