Dear Reviewer

We appreciate you reading and reviewing our work. We value your insightful comments and recommendations.

The authors present a very interesting contribution on the effect of low-frequency response on the fatigue damage accumulation of offshore wind turbine foundations however, I would like the following points to be addressed before the article is considered for publication:

1) In Figure 5a it is not completely clear what data is plotted. The legend provides information only about the black, blue and red points but nothing is mentioned about the yellow curve, which is not even discussed in the text. Moreover, it would make it easier if you could use a different color for line showing the average of converged values for all sensors.

In line 198 of the article it mentions: "Figure 5. a shows the trend of the LFFD-factor over time along the circumference (four sensors) of the mono-pile under consideration (T1) for single slope S-N curves with slopes of m=3, 4, 5 shown by purple, yellow, and blue lines." But as the reviewer mentions, we added the explanation for different colors in the caption of Fig. 5 (a) as well.

In Fig. 5 (b), we kept the colors of lines blue, as it is only focusing on the m=5 results and the line for the average of sensors is coming from averaging the blue lines in Figure 5. (a).

2) In line 246 the authors observe that "the share of cycles lasting more than a day is nearly absent in both FA and SS.", which is a bit contradicting with the results shown in Figure 6. According to latter, this statement is valid only for m=3 and partly for m=4, while a considerable percentage (>10%) of those cycles is present for m=5.

Thank you for your attentive read. That is the reason we used "nearly". However, for more clarity, the body of the manuscript is changed to "the share of cycles lasting more than a day is nearly absent in both FA and SS, for m=3, and insignificant for m=4, while a considerable percentage (>10%) of those cycles is present for m=5"

3) When looking at the results of Figure 6, one can draw the following conclusion: The main contribution of the low-frequency response to fatigue is due to variations in the mean wind speed, which in turn results in variations of the thrust force. The latter is certainly correlated to a few SCADA variables (power, rpm etc.) and therefore the LFFD as well. The authors have not explored at all these insights, which could further help in estimating the LFFD using SCADA data alone. Please provide these plots of the LFFD with some metric of the wind speed variation (std, Dirichlet energy, etc.)

We appreciate the feedback of the reviewer and we share a similar concern. Indeed a study of LFFD in relation to the SCADA data would be valuable, but we think that it is not a trivial study and needs deep research with proper SCADA data.

We performed some analysis on the standard deviation of wind speed and direction, as well as cycle counting the wind speed and direction signals. None of these studies showed reasonable results as there is no linear link between the current SCADA parameters and thrust load, and standard deviation lacks information about the time sequence of cycles, therefore it is not a proper metric for quantifying the LFFD effect. Although some SCADA parameters are used to calculate the thrust force, we also need parameters that are not usually publicly available such as the thrust and power coefficients.

The scope of the current paper (and research project) is to quantify the LFFD effect based on the measured strains and to show that in some cases it can be significant. However, in light of the reviewer's questions, some additional checks have been done, which are not included in the main body of the manuscript, as it is not in the scope of the paper. We hope the reviewer agrees that the current scope of the paper is well-defined and results can be considered standalone.

4) Following up on the previous comment, the contribution of the different sources of variability should be further explored and quantified. Namely, the low-frequency response, whose cycles are smaller than a day, seems to be owed mostly to wind speed variations. On the other hand, the contributions of longer cycles is owed to both wind speed and wind directions changes. These changes can be well quantified using the available

SCADA data and related to the LFFD. These are very substantial insights that the authors should explore and provide the corresponding plots.

As the reviewer mentioned, thrust load which is linked to the wind speed, can be a parameter that might be used to have a quantification of LFFD needless of the strain measurement. In the current work, the focus was on the LFFD effect derived from the strain time series. We added in the future work that a further study can be done to see in the case of having only the SCADA, how much of the LFFD effect can be covered and how SCADA can be used to get the LFFD factor.

As to reply to the reviewer, we tried to relate the thrust force to the LFFD. For that, we made a look-up table of thrust force for different wind speeds. Since for calculating the thrust force, we needed parameters such as Ct and Cp which are turbine/blade properties and usually not publicly available, we assumed that the Mtn bending moment has a direct link with the thrust force, and we used that instead of the thrust load. So we used the mean bending moments of 10-minute bending moment signals and grouped them for small wind speed bins of size 0.1 m/s. Then in each wind speed bin, the average of all the mean Mtn values was selected and put in the look-up table. Notably, for building this table, we only used the power-generating periods. This table was used to create a thrust load signal for all the measured period. So for each 10-minute wind speed, the corresponding thrust value (Average of mean Mtn in that wind speed bin) was selected. This thrust load signal changes only with the variation in the wind speed. To have the combined effect of variation in wind speed and direction, the thrust load which is always in the direction of the wind, is projected using Eq. 1[1] to a sensor's heading (260°), which is close to the prevalent wind direction.

$$M_h = M_{tn} cos(\alpha - \beta) \qquad \text{Eq (1)}$$

Where α is a fixed heading and β is the mean yaw of each 10-minute window.

The next plots show how different the thrust load and the projected thrust load signals behave with respect to the change in the wind speed and direction.

[1] Mai, Q. A., Weijtjens, W., Devriendt, C., Morato, P. G., Rigo, P., & Sørensen, J. D. (2019). Prediction of remaining fatigue life of welded joints in wind turbine support structures considering strain measurement and a joint distribution of oceanographic data. Marine Structures, 66, 307-322.

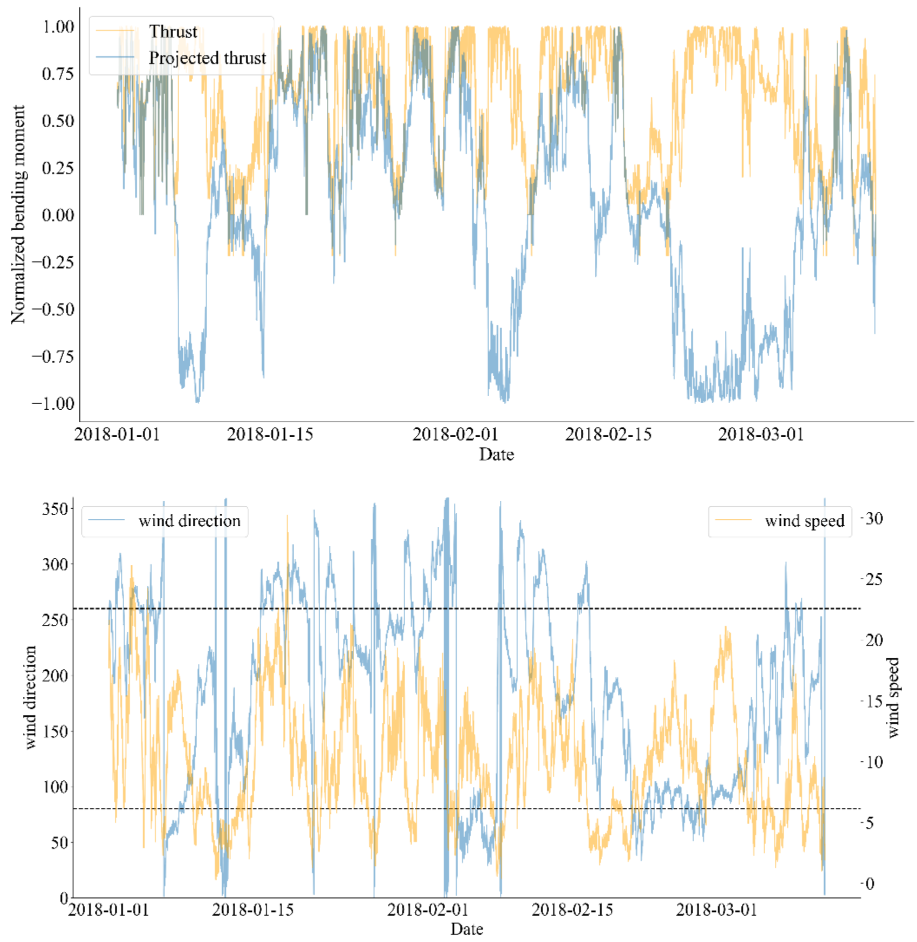

Figure 1 Different behavior of the thrust load and the projected thrust load signals for the change in the wind speed and direction. Black dashed lines are the direction of projected heading.

To see the effect of LFFD only from thrust load, we cycle counted the thrust load for different window lengths of daily, weekly, monthly, yearly, and the whole measurement which was three years. Figure 2 shows the share of full cycles of different period sizes. Because by using thrust load, we work with an average of 10-minute files, therefore, we lose the information about the cycles that happen within the 10-minute windows. So the shortest window that we can have is a daily window, as less than that gives only a few data points with not enough peaks and valleys to form a full cycle. We see that the majority of the low-frequency cycles happen within a day or a week.

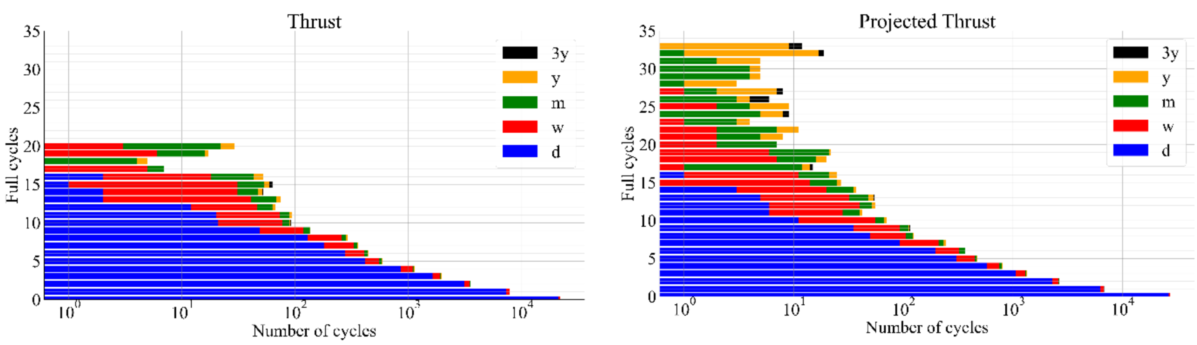

Figure 2 Low-frequency cycles forming from thrust load (wind speed) and projected thrust load (wind speed and direction) variation in different period sizes.

Figure 2 shows that when we consider the combined effect of variations in wind speed and direction (projected thrust load), longer periods such as monthly and yearly will have a large contribution. This means that some rare but very large cycles only happen when both wind speed and direction are having a concurrent effect . Based on Figure 2, we can explain what we see in Figure 6 of the article. Figure 2 shows that while wind speed variation alone (left figure), only causes almost up to week-long cycles (which we see for FA and SS in Fig 6 of the article), when we consider wind speed and direction together (right figure), cycles up to 3-year-long can appear (which we see in the sensors in Fig 6 of the article).

In light of this analysis, the main manuscript has been changed slightly in section 4.1. However, we propose to not include this analysis in the paper in full as in our opinion it does not fit with the original scope of the paper and dilutes the overall message. As mentioned there is a separate study required to accurately quantify the LFFD effect solely on SCADA data.

5) The discussion between lines 286 and 291 seems to be a bit contradictory to the findings presented in section 4.1 and the results shown in Figure 7. The sensors perpendicular to the dominant wind direction, meaning the ones closer to the SS direction, are the ones that seem to have lower LFFD factors, while the ones aligned with the dominant wind direction have higher LFFD factors.

Could you please elaborate further on the contradiction, as we did not notice any contradictions? Figure 7 demonstrates that the sensors normal to the prevalent wind direction (pink triangles) have the highest LFFD values. Also, Figure 6 shows for m=4, >30% share of low-frequency cycles for S3 and S6 (sensors in the direction of SS), while S1 and S5 which are mainly in FA direction have a 30% share of low-frequency cycles. So the results of this plot confirm the discussion in lines 286-291.

If this part of the article is confusing ("We observed that among the sensors normal and parallel to the dominant wind direction, the differences in base damage ("T") are larger than the differences in the added LFFD damage. Therefore, the LFFD-factor of sensors parallel to the wind is lower than the sensors normal to the wind."), we should emphasize that the differences in base damage are not included in the paper due to confidentiality. So Figure 6 in the article does not show this difference as the damages are normalized to their maximum value.

6) The existence of data from different turbines should be used to validate the insights from points 3) and 4) by exploring the data patterns between LFFD and SCADA for all four turbines (T1-T4).

As we mentioned earlier, finding a method to consider LFFD solely based on the SCADA needs a profound study and is out of the scope of this article. In addition, the environmental conditions of the four studied turbines are very similar as they are from two closeby farms, therefore, if we calculate LFFD from SCADA only, then the LFFD results would be very similar. For the study of LFFD based on SCADA, data should be collected from sites with very different environmental conditions to be able to have a reliable and verified methodology.

We would also like to mention that T1 and T2-T3-T4 are from two different wind farms with different turbine types and dimensions. Drawing a conclusion on the impact of SCADA conditions on LFFD between these sites would not be advisable due to their different size. A study for the turbines T2-T3-T4 is possible, but as mentioned they were subjected to near identical conditions. Alternatively one could look at a study over different years. But as mentioned we would like to keep the current discussion focused on the observations from the strain measurements.

7) A proofread would help improve the language in some parts of the manuscript.

Proofreading is conducted to enhance the quality of the article's English language.

We appreciate the respected reviewer's thoughtful remarks, and we hope our responses are acceptable.