Authors' Note to the Associate Editor and Reviewers

Title: Sensitivity of Uncertainty in Wind Characteristics and Wind Turbine Properties on Wind Turbine Extreme and Fatigue Loads

Ref. No: wes-2019-2

The authors thank the reviewers for their thorough assessment, comments, and insights. Revised text in the manuscript is highlighted in red.

Reviewer's comments are shown in blue. Authors' responses are shown in black.

The date of Reference number 2 ("Assessment of extreme design loads for modern wind turbines using the probabilistic approach," DTU Wind Energy (DTU Wind Energy PhD; No. 0048(EN)) should be 2015 and not 2018.
A. This has been corrected in the reference itself and any mention of the reference throughout the paper.

Early in the paper, the authors should consider explaining their logic for choosing to use the Elementary Effects sensitivity approach instead of other approaches. As far as I am concerned EE sensitivity type of analysis is mainly used for initial assessments of input parameters, when you have large number of input parameters and it only provides information in the qualitative sense: indicates influential vs non-influential input, and hints to higher order effects caused by nonlinear or interactive relationship between parameters. You briefly explain this in section 3.1, but maybe you should consider summarizing the logic in your intro.
A. We have added some new information to the introduction based on this advice.

Page 2, Lines 4-6: I don't fully agree. Say we have a long and slender blade. You use ElastoDyn for the to define the blade dynamics via 1-2 assumed flap and 1-edge modes. This means that all your structural dynamics are effectively filtered through those three modes. A complex combination of wind speed, turbulence, shear, veer and yaw error might -in reality- result in a bend-twist coupling that will increase the loads or, unintuitively, reduce the loads (because the twist results in lower angles of attack). You will never be able to capture such a phenomena with a simpler model resulting in erroneous conclusions on your sensitivity analysis.
A. It has been shown in many studies that ElastoDyn is sufficiently accurate for loads analysis of the NREL 5 MW turbine blade. This has been shown via code-to-code comparisons to BeamDyn, MSC.ADAMS, HAWC2, Bladed, etc.

Page 2, Lines 13-14: What do you see the downfall of your sensitivity analysis if correlations and joint distributions of input parameters are not taken into account? See for instance slides 22 and 23 in http://www.gdr-mascotnum.fr/media/mascot12caniou.pdf
A. Correlations and joint distributions of the parameters were not considered since developing this relationship for so many parameters would be difficult or impossible. In addition, the correlation could be very different for different wind sites. The impact of not considering the correlation was limited by choosing parameters that were fairly independent of one another, when possible, and by binning the results by wind speed.

On the same topic, since you use ranges, you might easily fall into an erroneous case where high wind speeds and large shear exponents (alfa>1) combine ... but I could see from Table 3 that you chose your ranges and combinations carefully (you also make this clear on lines 4.8, page 10).
A. The authors agree and correlations on inflow parameters were minimized by binning the results by mean wind speed.

Page 3, Lines 23-24: could you please explain the reason for choosing the vector sum of the components of the bending moments? Imagine bending moment Mx is an order of magnitude larger than bending moment My. Under some combination of the input, we observe that My exhibit large variations (x2 or x3) whereas Mx doesn't. However, given that Mx is an order of magnitude larger than My, the large fluctuations of My will not be really reflected in the vector sum. Consequently, the sensitivity analysis will not reflect the real effects of the input any longer.
A. It is common practice in axisymmetric structure responses (blade root, drivetrain, tower) to only consider the vector magnitude of the bending moments in ultimate loads analysis.

Page 10, lines 4-6: I actually propose you compare the sensitivity analysis performed on the same set of input assuming they are independent and then assuming joint distributions (where possible).
A. It would not be possible to make an 18-dimensional joint probability distribution. The purpose of this study is to take a very large set of input parameters and identify the parameters that most contribute to turbine response sensitivity. As such, including 18-dimensional joint distributions is not possible and was not considered for the present study. However, it would be beneficial to include joint probability distributions in future studies that include fewer parameters.

Despite my previous comment, your results in Figures 3 & 4 and your summary on page 18, conform to results found by investigators/researchers. So, I don't think you have introduced flagrant errors using the approach proposed in this article.
A. Agreed.

Section 4.2.2.4 Steady Airfoil Aerodynamics - Abdallah et al. proposed the initial probabilistic model. You made some nice modifications and contributions. I propose we make both models available to the public (open source, open access), in order for further future improvements be made by others.
A. The authors agree that this would be beneficial to the research community.

Figure 13 shows samples of perturbed Cl and Cd curves. I notice that the Cl perturbations for positive angles of attack are shown but not for the negative angles of attack. Does this mean that the model does not handle Cl perturbations for negative angles of attack? If not it should, especially that you consider ultimate loads and large yaw errors.
A. Analysis was intentionally limited to only consider normal range of operation. As such, the Cl perturbations were limited to the range between the beginning of the linear Cl region and 90°. The beginning of the linear region is found to begin as low as $\alpha = -13°$.

It is not clear if you maintain the correlations of Cl and Cd curves along the span of the blade?
A. The perturbations are made at the blade tip and root and interpolated to the airfoil data between these extremes.

Control properties, Table 10 - -20 to 20 degrees is a fairly large range for standard yaw error for a turbine in normal operation and connected to the grid, which might explain why this parameter ends up being so significant as shown in Figure 13, 14, and Table 11. Unless the underlying assumption is that this range implicitly includes the effect of rapid directional change of the wind. In principle a controller should be able to detect such large yaw errors (say over a 30-60 second averaging windows) and perform the necessary safety procedure (whatever that might be).
A. This is the value found in the literature and seems reasonable given the authors' discussions with experts.

Figure 13 has the grid on, Figure 14 has the grid off.
A. This has been fixed.

Page 25, Line 13: "Ultimate turbine loads are most sensitive to yaw error (theta) and lift (Cl) distribution" I would say "Both Ultimate and fatigue loads are..."
A. As fatigue loads are not most sensitive to the lift distribution, this adjusted statement would be incorrect.

Page 27, Lines 3-17: very good discussion. Useful information here that needs to be carried out to future investigations!
A. Agreed.

Page 35, Line 8-10: very good discussion. Useful information here that needs to be carried out to future investigations!
A. Agreed.