Offshore and onshore ground-generation airborne wind energy power curve characterization - Referee Comment

Mark Schelbergen[1]

[1]Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands

Correspondence: Mark Schelbergen (m.schelbergen@tudelft.nl)

1 General comments

The first part of the paper up to section 3 was a pleasure to read: clear structure and good language. The goals of these sections are clear and it was clear how these contribute to the bigger picture: summarizing the WRF results (section 3) and obtaining a wind resource model from it (section 4). On the other hand, from section 5 it's not clear how the presented material will be used. The reader can be helped a lot if the story line/different analyses are introduced early in the paper, preferably using a diagram. Only while reading section 5 it becomes more clear how the material in section 4 is used. Still a lot of details are missing for the reader to be able to reproduce the presented results. I find it unsatisfying that there is no justification/discussion on the degree of simplifications needed to map the high-fidelity model output to wind statistics and power curve as single argument functions (height-range-averaged wind speed). I would expect that the accuracy benefits of the relatively high fidelity (and computational costly) models in the first computational steps, cancel out when the author simplifies them before calculating AEP. Why not use a more detailed numerical integration that regards the detailed information of the clustering output/power optimizations.

I understand that the goal is to get a simple characterization of the power output/AEP similar to that of a WT. However, how much is this worth when you loose precious details in the process given that you went through all the effort of setting up the suggested high-fidelity tool chain?

Writing: The paper still contains numerous typos. It could benefit from a better structure and more precise writing. Citing and referring to figures is done inconsistently and not in line with WES standards. Also referring to figures/sections that are presented later on in the paper is distracting. Minimize inconclusive language, e.g.: "which could indicate that these are more realistic estimates" (p27, l493), however more results might be required to give definite statements.

We have different understanding of how to use "However" (pointing out a contradiction) and "Non-trivial" (not unimportant).

Figures, tables, and equations: Figures are placed in the appendix, while they are covered in the body of the paper.

2 Specific comments

Section 2 misses a discussion on why WRF data is used. It is clear that WRF can provide an accurate basis for getting to a wind resource model. However, this study only considers 1 year of simulation data, which is far too little for giving a good representation of the wind climate and thus for AEP calculations. Typically 30 years of data is needed for this purpose. The need for correcting WRF using lidar is stated in the introduction. However, it is not clear if this is done for this study. Also it is not justified why going through all the effot of doing WRF simulations should be an integral part of the methodology. There are a few wind atlases available that cover a wide area (including the investigated sites) for a much longer period, which might be a better source for the wind data? In conclusion, what would the added value be compared to alternative approaches such as that of Malz and Schelbergen?

Section 4 could gain a lot of clarity by more clear structuring. First introducing the system models. Therefore a clear distinction between the dynamic model and OCP should be made. At the moment they are presented as one. The QSS model is a very simplistic. I would suggest also including the reel-in in the model, similar to what is done by Luchsinger. The current model does not give a good estimation for a pumping mode system. It's not clear why the upscaling model is needed. I don't see results for multiple system sizes in the section 5. I only found some plots in the appendices. The contribution to the paper of including a scaled up system is unclear in the current format. Split up 4.3 in the dynamic model and OCP and add 4.5, 4.6, and 4.8 to the latter as these are part of the OCP formulation/solving it. Split section 4.7 up in the wind profile model and wind resources model. Add the polynomial description of the wind profiles. After reading this section, I did not have a good understanding of how the p5/p50/p95 cluster profiles are used. I would argue that this is the most important part of the paper and therefore the approach taken there should be presented unambiguously. E.g., I'm puzzled by the last sentences - do you sum up 10 min energy production of every WRF data point, or do you integrate the product of power curve and probability function? Also you "interpolate within each cluster linearly between p5,p50 and p95" - do you do this to get the power output of every 10 min data point? Why do you use 3 points? Isn't 3 points very little? It would help me if you would try visualize this process, or at least add some equations. Finish the section with an overview of what analyses are performed to get to the results in section 5 in e.g. a table. Clearly state which combination of system/wind models are analyzed.

Section 5.1 and 5.2 nicely introduce the OCP results. However it is not clear how the results of the remaining sections are obtained. This could be improved, by improving section 4. Don't mix methodology and results too much, e.g. equation 10 would nicely fit in section 4. Also, it would also help to take the reader a bit more by the hand when introducing the results. I had to go back and forth between section 4.7 and 5.3 to get a taste of what's been done, however I couldn't figure it out completely. Some open questions:

- which profiles are presented in fig 11?
- which of the data points represent p5/50/95 profiles in fig 12?
- how do you get to the dashed curve in fig 13a/b? a curve fit of some kind? - describe how
- how do you come up with the relation between Uref(z operating) and U(z W=100 m)? - provide it in a plot

- how exactly is the log profile used? - I suppose you also use it in the OCP?
- how do you get the input for constructing the QSS curve?
- how do you calculate the AEP distribution exactly?

If I understand correctly, you did is doing some kind of curve fit to the markers in fig 13a to get an expression as a function of a height-range-averaged wind speed. What kind of curve fit do you use? How sensitive is the AEP to the type of curve fit? By doing the fitting, you loose precious information about how the power output relates to the wind profile that you acquired with the computational costly optimizations. Also by expressing the probability function of the wind resource as a single argument function (solely a function of height-range-averaged wind speed) you loose much information that was acquired with a lot of computation effort by the WRF and clustering. I think a more detailed numerical integration would be in place here instead of going through all this effort of detailed system/wind modelling to end up with simplistic models for power output and wind statistics. However, I might have misinterpreted the methodology used here (see comments section 4). Also, since the relation between Uref(z operating) and U(z W=100 m) is non-linear, you'll get a differently shaped power curve/probability distribution and thus AEP, depending on which of the two properties you use to express these functions. This tells me that this approach is mathematically unsound. I would say more proof is needed to justify your methodology.

Does the approach suggested in eq 10 act as a benchmark for the other AEP calculations? W.r.t. which property do you integrate? If I understand correctly, it comes down to sampling 3 points per cluster (p5/p50/p95) to quantify the power output within this cluster. Why just 3? I would suggest you use a sampling technique that picks a higher number of samples. Only 3 does not give a trustworthy benchmark.