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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Ground-generation airborne wind energy design space exploration" *by* Markus Sommerfeld et al.

Anonymous Referee #2

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1 General comments

– Comment 1
In this paper, Sommerfeld et al present a good body of work combining realistic wind data with an optimal control based trajectory optimisation toolbox to explore the effects of multiple wing scale variants.
However, I would advise rephrasing the title as the content is not a "Ground-generation airborne wind energy design space exploration" but rather a comparison of scaling effects based on a reference design that is derived from previous work on the Ampyx AP2 model. The current title promises much more, and as a minimum, a design space exploration should look at more than a single configuration that is just scaled.

– Comment 2
The work presented here is a high level description of the optimisation results for the scaled variants of the AP2 reference model. However, the discussion of the results at times lack depth. The results are simply presented as optimisation results from the model as compared to an actual design/variant exploration which should try and correlate the design variations to the results. The discussions do not distinguish between model and physical/design driven artefacts.
In a few instances, hypotheses for the results obtained are given but they are not fully explored and confirmed. This should be trivial given the capabilities of the model utilised.

In its current form, this manuscript is a macro description of the results of the power optimisation toolbox utilised, and lacks the exploration and discussion of results that would elevate this to a holistic scientific publication.

2 Specific comments

– Line 59:
Please clarify what these other studies refer to.

– Line 91:
Have the results between this higher fidelity time resolved model been compared to a simpler steady state model for power prediction? Such a comparison would help motivate the use of such a non-trivial model for a "design space exploration", where it is not immediately visible what effects result from the artefacts of the optimisation algorithm choices, and what are driven directly by the physics of the design.

– Line 132:
What are the actual constraints applied to the tether speeds? Is it $v_{out} = 10m/s$?

– Line 140:
The C_L vs α curves shown depict the typical offset in lift from slats, while in the text flaps are also mentioned. Which one is it?
If the coefficients are just adjusted in a representative manner please mention that, as the change in C_D does not look like the typical change associated with slats. In fact, the C_D looks simply offset as well, which would not be the case with slats.
If this is strictly a theoretical exercise, it would be prudent to ensure that such a combination of resulting C_L, C_D, and C_m is actually possible from said high lift devices. If this has already been done (or not done), please mention it explicitly. Even simple literature references should suffice for this.

– Lines 165-170:
The actual constraints utilised for the results discussed is vital and missing. Are all the system constraints described in Section 3.6 in Table 1.? While implementation specific constraints are also helpful, as a bare minimum, system constrains should be listed clearly. Interpreting optimisation results without the specifics of the constraints can be quite futile.

– Line 202:
It is not clear why the results should not be consistent if all the studies referenced to are utilising the same model. Describe the reasoning behind expecting different results if the path constraints are the same?

– Lines 203-205:
Please add a plot with the tether forces and speeds over the cycle, to show how the expected trajectory is changed in order to satisfy the constraints? This would make things much clearer.

– Line 215:
Why is total cycle time constant across all variants explored? This seems more like an artefact of how the problem is setup/constraints placed on it, rather than something

stemming from the physics of the problem. Please clarify the reason for this constant cycle time.

– Line 216:
Kindly cite the previous investigations - again if they all utilise the same model, it should be highlighted that this could be a model based artefact.
While from these results it would seem that the cycle time has no impact on the power produced, the trickle down effect to more detail design drivers such as structural loads (as touched upon in 4.3) are highly impacted by loading frequency which would be a function of the cycle time. Hence it would be good to know if this result is something physical or just model based.

– Lines 219-222:
Some more clarity on the aerodynamic forces periodicity would be helpful here. How does it correlate to only wind speed variations for the same scale of aircraft. Similarly, how does it correlate to aircraft scale for a given wind speed? What can be said about the influence of cycle time on the periodicity? These kind of discussions are expected from such work rather than just a direct description of the results.

– Line 230:
It would be good to clarify that the power factor ratio considered (C_L^3/C_D^2) doesn't contain the tether drag. Instead, it might be prudent to use the total system's power factor that includes the tether drag when interpreting these results.

– Figure 4:
It would seem that the model always tries to maintain the same number of loops (5?). Please clarify why this might be?

This figure would be much more useful if the variant wing design shown in Appendix A1 was included in the comparison.
Results from A1 are for a different (onshore) wind profile, that makes it meaningless to try and derive any conclusions b/w the two wing variants (reference AP2 and AP2

HL). In the current form, the figure lacks clarity. Instead, a single figure showing the trajectories for multiple variants followed by a more detailed figure investigating the variations along the full trajectory would be much more interesting.

– Section 4.3:
-Line 260:
Are the forces from manoeuvre loads due to the loops also neglected in this section? Was an initial estimate made before neglecting these effects? Is this true for all scales of wings considered in this study?
Given the nature of the study (path optimisation and wing scaling), can anything be said about the significance of ignoring the loads arising directly from the path? Overall, the motivation for including this section is lacking. The results presented here are straight forward and well understood - forces and moments scale with the wing span and aerodynamic lift coefficient. Please consider dropping this section as it does not contribute any new insights.

– Line 283:
How exactly is this $\bar{P}_{rated}$ determined? Please clarify.
Is it constrained by the model? The tether forces and speeds are constrained from my understanding.

– Line 291:
Do mention effects of mass and resulting cut-in wind speed on the AEP here as well.

– Line 298:
Please motivate the depowering hypothesis for the power variations. Taking the case of $A_{wing}50$, why does the system depower already around the rated wind speed? $\bar{U}_{ref} = 10$? An additional plot of the constraint violations at such points would be very insightful.

– Line 301:
The discussion on path length is quite lacking. From figure 7, there seems to be quite some variation that is not explained.

For example, what could be the reason for increase in I_{path} for the $A_{wing}50$ variant at wind speeds above 25? Is it the result of a depowering manoeuvre? Please explain these results better.

– Line 304:
Another reason why system constraints utilised in the model should be explicitly mentioned in one place. How is the minimal turning radius defined? How does it scale with the wings aspect ratio? Is it constrained?

– Figure 7:
Please add the configuration (HL?) utilised to the legend.

Rated power plots seem to have quite some anomalies - do mention if/how the data is interpolated. For example $A_{wing}150$ seems to have data points that are not on the curve.

– Line 305:
The motivation for defining this C_p^{AWES} is missing. The swept area for AWES doesn't compare well to the swept area of traditional wind turbines.

– Line 312:
Please motivate such hypothesis with more data, it should be trivial with the model utilised here to investigate the ratio of lift force to tether drag for the design variants considered.

A figure plotting the aerodynamic forces, inertia forces and tether drag for a few wing variants considered in the study would greatly enhance the rather brusque discussion of these results.

– Line 336:
Please consider adding another data point for either configuration with a different mass scaling factor in addition to the AEP variation for the reference vs HL configuration. Figure 10 does explore this aspect to some extent, but it could be combined here for a

better discussion.

– Figure 8:
What is the reason for the HL configuration not to follow the linear increase in rated power until $U_{ref} = 10$ as the AP2 configuration? There seems to be quite some perturbations at lower wind conditions?

– Line 344:
Clarify what aspect of Figure 7 shows the infeasible solutions for lower wind speeds.

– Line 390:
Why is half the tether drag attributed to the ground station? How is the ground station affected by the tether drag?

– Line 392:
Doesn't the 6DOF model utilised here compensate for the reduction in apparent speed by increasing angle of attack to maintain the same aerodynamic force?

– Line 405:
Again, why is half the drag assigned to the ground station? The total system drag is of importance here.

– Line 411:
Please add additional data to back this hypothesis. Would this change if the cycle time changes? This seems again an artefact of the model implementation, and not a physical effect. If this is not the case, please motivate.

– Line 440:
This should include the system weight (including tether mass).

– Lines 445,455:
Some ambiguity in the nomenclature - high lift airfoil != high lift devices (as was described previously).

– Lines 460:
Would this be different if tether speeds are varied instead of being fixed? Is this fixed tether speed assumption probably the reason why the model has fixed cycle times for all the design variants considered?

3 Technical corrections

– Line 11:
Missing space

– Line 427:
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