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Interactive comment

Interactive comment on "Actuator Cylinder Theory for Multiple Vertical Axis Wind Turbines" *by* A. Ning

Anonymous Referee #2

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General comments

The paper presents an extension of the Actuator Cylinder (AC) flow model for a single VAWT to model the interaction of more VAWT′s placed in the vicinity of each other. The model extension is carried out along the lines of the model approach of a single turbine by deriving additional influence coefficients correlating induction from loading on the different turbines. In the end the induction at an azimuth position of a turbine rotor can be written as a sum of the induction from the turbine itself plus induction from the neighboring turbines. Different approaches are presented for accelerating the computations e.g. by utilizing symmetry conditions in the derived influence coefficients. In order to extend the linear model′s application to higher thrust loading an almost similar approach is used as presented by Madsen (2013), however now applied on the flow field from the individual turbines.

Numerical results are shown for the interaction of two turbines with a separation up to 6D and for co-rotation and counter-rotation of the two turbines, respectively. The overall result from the numerical study is that for two co-rotating turbines the combined power is almost equal to the sum of the power from each of the turbines. However, for the counter-rotating set-up the so-called “counter-up” configuration where the blades at their closest position are rotating against the wind gives an increase in power of about 1% for a lateral separation of the turbines of one radius. The achieved results are also briefly commented on in relation to recently published higher fidelity model results (RANS CFD) with the overall comments that this show “mixed results”.

The authors also mentions the limitations of the model which in particular are found in the wake region where the linear, inviscid model computes a nonexpanding wake that does not decay or spread.

As the use of the VAWT turbines have shown a renewed interest during the last 5-10 years and not least for floating off-shore applications the overall subject of the paper is of considerable interest as models for design of VAWT′s and optimization of VAWT farm layout are needed. Due to the model limitations in its present form as mentioned by the authors (a corrected linear version of the model) future work on computing the flow field for a full nonlinear AC model e.g. by CFD would be of big value.

Specific comments:

P5 l23 and P6 l7: It is mentioned both places that the wake terms could be omitted and instead one could apply a momentum deficit factor from some other VAWT wake model. This should be elaborated a little bit more. For example if such wake model can be integrated to yield a continuous transition from the wake flow and to flow outside the wake as computed here with the AC model ?

P12 l7: It is mentioned that the notation corresponds to assume that blade sweep is accomplished through shearing rather than rotation of the blade section. As rotation of the blade sections might be the way that sweep is introduced the force equation for that case could also be shown.

P13 l4: It is mentioned that “Madsen notes that this linear solution produces good trends for the induced velocities, but is off in magnitude”. This should be modified and expanded to say that the linear solution is off in magnitude for high loading but fits well for low loading measured by the thrust coefficient.

P18 l2: Please explain what “Julia” is ?

P18 l5: The investigation has been carried out for spacing down to 1R. However, it could be interesting to go to even closer spacing as this is relevant for at least one floating VAWT concept which has two rotors on the same floater and where the spacing seems to be less than 1R. http://www.nenuphar-wind.com/en/15-the-nenuphar-solution.html

Page 19: For the interpretation of the contour results in Fig. 15 it would be very helpful to show the rotation direction on the plots by an arrow.

P23, l15: The presented data from The Caltech Field Laboratory for Optimized Wind Energy show that the Counter Down configuration shows a benefit compared with the isolated turbine and thus opposite to the present results. As it can be seen that these turbines have a much lower Cp it could have been interesting to see what the present modelling would show for a turbine configuration matching the low Cp shown in Figure 22. This could be done by adjusting mainly the profile drag coefficient. It might be that a considerable higher airfoil drag coefficient would have a major influence on what is the most optimal configuration. However, as the paper already has a considerable length it is probably not good to propose any extensions.

Page 24: In the conclusions it seems that in particular the mid part from line 16 to line 27 is not really conclusions from already presented material in the paper but new discussions of other research results from literature. This should be moved to the main body of the paper.

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