Wind Energ. Sci. Discuss.,
https://doi.org/10.5194/wes-2019-70-RC2, 2019

WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Is the Blade Element Momentum Theory overestimating Wind Turbine Loads? – A Comparison with a Lifting Line Free Vortex Wake Method" *by* Sebastian Perez-Becker et al.

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Received and published: 30 December 2019

The paper performs a thorough comparison between two lifting line models: the BEM model of AeroDyn, and the free-wake model of QBlade. The paper presents results from steady state and turbulent simulations, looking at damage equivalent loads and extremes. The results and approach are presented in a clear way, the analyses are precise and discussed in details. I congratulate the authors for the work put in this paper, there is potential for a great paper.

I have the following general comments: - Dynamic wake/inflow model: It is true that the Dynamic wake model of OpenFAST is not documented, but I'm afraid this model cannot be discarded for the fatigue analyses. The study would not be fair without it... I'm aware that this will require more time and might entirely change the results and analyses, but I'm afraid that discarding this model makes the study less valuable. The model acts as a filter, which filters high frequencies out and introduces a phase shift in the signal. Without it, the BEM code uses quasi-steady induction factors, with a high and unrealistic frequency content. The DBEMT model of OpenFAST is an implementation of the dynamic wake model of Oye (presented in the report of Snel and Shepers of the book of Martin Hansen). Please consider including the DBEMT model and updating the results of the paper. I'd be happy to assist you if you need further help or documentation. I would recommend using a different time constant for each mean wind speed.

- Aerodynamic differences. As you mention, the elastic and servo parts are the same for both models, the only thing affecting the results are differences of the aerodynamic model. The paper follows a nice scientific approach, yet it seems that there is a gap between the stiff and steady simulations, and the elastic unsteady simulations. It would be valuable to investigate the key aerodynamic differences between the models, using stiff unsteady simulations (e.g. performing a sweep at different yaw angles, studying response to wind steps, or looking at azimuthal variations of inductions similar to fig 13). If possible, these results could be compared to CFD, measurements, or, other BEM implementations. Such results could then be used to interpret the results of the full aero-servo-elastic simulations. This again would require more work, but I think it would be valuable to focus on this first, and maybe present the fatigue analyses in a separate paper... Even if you chose to stay with the current structure, I think it is important if it is stressed that the differences are between two specific implementations, the BEM from OpenFAST and the free vortex wake from QBlade. In light of this, I would think you might want to revise the title to highlight that the results are specific to these two implementations, unfortunately, the title would be less catchy..

- Length of the paper: Despite the careful and valuable analyses and discussions, I believe the paper could be considerably reduced in length. Here are some ideas to reduce the length: The literature review and presentation of the models can be significantly reduced. The results of section 5 are a bit repetitive. You may consider presenting one of the plot for one sensor, and then simply focus on the key conclusions that you drew for the other sensors (maybe summarizing them in a table). You are thorough in your analyses, and I believe the reader will trust your conclusions without having to see the plots. Also, I would think you can remove some text that describe the figures, and move more rapidly to their discussions. The reader might get lost in such a level of details, and I would advise to focus more on the story and key conclusions of the paper.

I enclose some specific comments below. I hope that addressing these general and specific comments will improve the quality of the paper. Clearly a lot of work has been done, and I would be happy to review a revised version of the manuscript. Good luck for the work,

Emmanuel Branlard

p1 l1: "state of the art" might not be appropriate -> "common" maybe (CFD would be state of the art)

p1 l3: BEM does not only simplify the rotor-aero (also wake and inflow). To some extent the rotor aero are the same for BEM and FVW

p1 l19: the "wake memory" effect need to be included for this study, otherwise the results won't be fair

p3: very nice literature review, but quite long, maybe a page could be removed.

p5 l13: "yawed-inflow condition" -> or "yawed and tilted conditions"

p5 l24: the dynamic wake model is the model of {\O}ye

p5: the model description could be condensed to a smaller list with references to shorten the paper.

p6: Can you detail the core model you are using? In particular, please mention how you determine the core size of the bound and wake vorticity? How are these parameters determined as function of the discretization?

p8 l3: "in the rotor plane": It can be argued that the main issue comes from the fact that the annuli are assumed to be independent, not so much that the momentum balance was determined in a plane.

p8 l9: ElastoDyn does not rely solely on Euler-Bernoulli beam theory, it also includes corrections to account for geometric non-linearities.

p10 l1: Feel free to contact me if you want ore information on the DBEMT model. I believe this model needs to be used for the current study.

p10 l14: It would be valuable to present aerodynamic performances of the FVW&BEM at exactly the same operating conditions (RPM/Pitch) instead of using the controller. Presenting radial distribution of axial and tangential inductions along the span at different operating point will reveal the aerodynamic differences between the two models. The inductions are the main variables of lifting-line codes (such as BEM and LLFVW).

p11 tab2: You may consider using "steady" instead of "constant"

p11 l20: "Purely aerodynamic calculations" -> you could replace by "CFD" or something similar maybe?

p13 tab3: The fact that only DLC1.2 is used might indeed make the comparison of the ultimate load difficult, you can consider using a gust case. This would avoid the some of the discussions of section 6 related to the different responses of the two models, where maxima occur at different simulations.

p13 l16: Though I like the extra information on the plot, you can maybe mention that 6 points are likely not statistically significant.

p17 l5: How do your results compare to other studies?

p19 l17: The main effect there is the small amplitudes of the inductions, not the pitch angle. Probably what is meant here is that the angle of attack is mainly composed by the rotational speed and the undisturbed wind, since the inductions are small, and hence the rotor performances are not strongly affected by the aerodynamic model.

p20 l7: Both the BEM implementation from OpenFAST and vortex code have limitations in yawed inflow. For the vortex code, the "wake is going up" in skewed inflow (I discuss this in a paper entitled "Aeroelastic large eddy simulations using vortex methods: unfrozen turbulent and sheared inflow"). On the other hand the limitations of the OpenFAST BEM code are more inherent the implementation choices (coordinate systems used for the axial and tangential inductions, and choice of determination of the wake skew angle), these choices are made differently in different codes. You may want to mention this somewhere in the paper. This is why in my general comments I mention that the observations made are specific to the implementations, and it would be highly valuable to present some "stiff" simulations comparing some key aerodynamic components of the models (against, CFD, measurements, or other BEM codes).

p22 l1-4: How did you determine the time constant for DBEMT here? This might need to be adapted since it does not filter the high frequencies enough.

p23 l12: Is wake memory actually included in Fig 10d? I might have missed it. Or is the figure reference wrong maybe?

p27 l2: "have a mean value of 0" -> "have been adjusted to a mean value of 0", maybe?

p27 l15: DBEMT will also introduce a phase shift, maybe similar to the LLFVW code, or not..

p27 l24: "In last section" -> "In the previous section", or, "In section ..."

p30 l21-29: The comparison of the two simulation might be too difficult (or "anecdotic") since the wind turbine is indeed a highly non-linear system, and both aerodynamic models are behaving quite differently here. I would recommend using a more deterministic case like a gust for the study. Figures 14-15 are still interesting and valuable.

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