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# *Interactive comment on* "A Validation and Code-to-Code Verification of FAST for a Megawatt-ScaleWind Turbine with Aeroelastically Tailored Blades" *by* Srinivas Guntur et al.

**Srinivas Guntur et al.**

srinivaskguntur@gmail.com

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Dear Reviewer 2,

Thank you for your time and valuable comments on our manuscript. Here are our responses to your comments.

Comment: "I don't quite understand the distinction between tables 2 and 3. How can the agreement of the different codes with experiments be better or worse in the time domain and frequency domain " Response: The intention behind making two tables was to be able to distinguish between analysis in the time domain (Table 2), which



ranks the results in the mean and the standard deviation of the time series of various quantities, and analysis in the frequency domain (Table 3), which ranks the turbine operating modes. The title of Table 2 will be changed to

"The tools FAST (BD), FAST (ED), and BHawC ranked according to how well their results compare to the experimental measurements in the mean and standard deviation for each QOI. . . ",

and that of Table 3 to

"The tools FAST (BD), FAST (ED), and BHawC ranked according to how well their PSD results compare to the experimental measurements . . .",

in order to avoid any confusion.

Comment: "An explanation of why the rated rotor speed in the FAST simulations deviates slightly from the experimental data and the BHawC results." Response: This slight difference is most likely the result of the controller (a DLL in a black-box form) that was obtained from Siemens to carry out the FAST simulations. It is assumed (with reasonable confidence) that this difference doesn't have a significant effect on the conclusions of this paper.

Comment: "If possible some rough details on the BHawC aerodynamic model" Response: A description of BHawC and a reference have been added (see below).

Comment: A discussion on the tower side-side bending moments (+ comments on Figure 10). Response: The emphasis in the paper is to identify the correct frequency of this mode (which is a function of the dynamic system modelled in FAST, which includes the combined dynamics of blade elements, hub, nacelle, generator, and the tower), and whether or not the frequency is being damped out is most likely related to the controller. The difference seen in the tower side-side moments seem to be related to the latter. Since the paper is focussed on the modelling ability of FAST (along with our inability to change the controller settings), we focussed on it being the correct freq. This has been highlighted in text thus: “Plots c and e in Figure 21 show a difference in the peak amplitude at peak B. This reflects the difference in the standard deviation seen in Figure 10 between FAST and the measurements. As seen, the frequency of this mode is accurately captured by FAST. This mode seems to be less-damped than in BHawC or the measurements, which may be related to the tuning of the DLL controller.”

Comment: What is the difference between aeroelastic tailoring and bend-twist coupling? Response: The two terms imply a similar technology, although bend-twist-coupling is a subset of aeroelastic tailoring. This sentence has been changed to the following to avoid confusion: “Additionally, these blades are flexible and aeroelastically tailored, incorporating bend-twist coupling.”

Comment: Suggestion to change ‘simplicity’ to brevity’ Response: Done

Comment: Page 9., Line 21. “due to weight” Response: Added.

Comment: Is it possible to include pitch angles also? Response: Unfortunately, pitch-power and pitch-speed curves are deemed confidential and cannot be published.

Comment: Is the main difference here (Figure 3d) due to torsion? Response: Blade torsion was not investigated in this paper (due to the lack of blade-twist data), but that is very much possible. However, we see significant differences between ElastoDyn and BeamDyn in terms of the tip deflections (e.g., Figure 4d), and so it may be caused by blade bending and also torsion.

Comment: Change “all” to “most of the QOIs” in Conclusions Response: Done.

– Description of BHawC:

BHawC is an aeroelastic simulation tool used to study the dynamic response of wind turbines. The model consists of substructures for foundation, tower, nacelle, drivetrain, gearbox, hub, and blades. The structure is modelled primarily with finite beam elements and the aerodynamics is modelled using blade element momentum theory. The code is coupled to a controller identical to that on the real turbine.



The structural model of BHawC employs a co-rotational beam formulation, which is a combined multibody and linear finite-element representation allowing for geometric nonlinearities through a series of multiple bodies, each composed of a linear finite element. The BHawC model of the SWT-2.3-108 blade used in the current study was initially curved in space and discretized into 16 linear elements. In other parts of the turbine where bearings are present, special elements are introduced and the drivetrain consists purely of torsional elements.

The aerodynamic force in BHawC is calculated at a given number of points on the blades, in this case 63, positioned independently of the structural nodes. Blade element momentum theory is applied to determine the tangential and axial induced velocities at these aerodynamic calculation points, and Prandtl’s tip loss correction as well as a correction for thrust at high induction values are implemented. The blade-element implementation in BHawC also allows for unsteady and skewed inflow. The aerodynamic force is based on 3D-corrected coefficients for stationary airfoil data, and a Beddoes-Leishman type model for unsteady/dynamic events. In addition, BHawC contains a model for tower shadow, and it also calculates the aerodynamic forces on the nacelle and tower. For further details on BHawC , see [1].

[1] Skjoldan, Peter Fisker. “Aeroelastic modal dynamics of wind turbines including anisotropic effects.” PhD Thesis, Risø-PhD-66(EN), March 2011. http://orbit.dtu.dk/fedora/objects/orbit:85866/datastreams/file_5509069/content

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Sincerely, Srinivas Guntur.

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