Wind Energ. Sci. Discuss.,
https://doi.org/10.5194/wes-2017-47-AC2, 2018
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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Simulation of transient gusts on the NREL5 MW wind turbine using CFD" *by* Annika Länger-Möller

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Received and published: 12 January 2018

Dear Dear Anonymous Referee #2,
thank you very much for your hints to improve the analysis of my results. I especially appreciated the recommendation of references. Furthermore I will answer your questions.
As I introduced a validation of the computation as response to Referee #1, section 2 now contains two subsections. The first one for THETA, the second to describe the simulation setup in FAST.

Overall

- RC: *The article describes a CFD approach to gust modelling for wind turbines, presenting some interesting results. As the CFD model is incompressible, any change in velocity in the domain is instantaneously influencing the full domain. As a consequence, the gust is not travelling through the domain, but the velocity is basically increasing everywhere in the domain instantaneously. The consequence of this with respect to the wake development should be discussed.*
AC: Yes. Indeed, the entire vortex-transport discussion is turning around this point. To clarify this I added the paragraph "In consequence to the infinite speed of sound in the entire flow domain, the velocity in the field changes gradually. Thus, the vortices that are shed from the blade at a given wind speed are not transported with their specific transport velocity. Contrariwise, all existing vortices experience identical changes in the transport velocity. In consequence, the geometrical distance between existing vortices remains constant." to section 5.3.

- RC: *Additionally, the assumption of infinite mass and inertia along with a non-elastic model might also have quite large effects, and should be discussed.*
AC: Yes you are right. A finite mass and inertia would reduce the rotor loading during the gust. Moreover, elastic deformation during the gust becomes important in the given test case and would destroy the symmetry in the rotor loading. These trends can be seen by switching on the according models in FAST. Nevertheless, the motivation of the paper has been to validate the resolved gust approach in THETA. In this context it is best to diminish the uncertainties by reducing the model complexity. This is done by isolating the aerodynamic effects. The discussion of results is enhanced by the information to trends for finite mass and inertia (section 5.2, 5.3). Section 1 now contains a more precise definition of the scope of the paper.

- RC: *Finally, the ABL is neglected along with any turbulence, which is also indi-*

cated by other reviewers could be much larger than the cosines gust.
AC: The cosines-gust represents the turbulence level of the atmospheric flow around wind turbines as measured by Schaffarczyk et al. (2017). A remark is added at the end of section 4.2. The ABL inflow profile can be added after the resolved-gust approach has been validated successfully. This point is clarified in the paper in section 3.1, 4.1, 4.3.

Figures

- RC: *Generally the figures are very small, and Figure 1 about the grid set-up is basically of no use and should be replaced.*
  AC: I enlarged the figure. Moreover I changed the content to represent the chord-wise distribution, span-wise distribution in the blade tip region and the meshing topology in the farfield. Please see figure 1 of my response.

- RC: *The Cp and Cf plots, Fig. 7,8,9,10, 11 and 12 are very small and not providing that much information.*
  AC: I enlarged figure 7 to 12 and summarized them into 3 figures to enable a better comparison between no tower/tower blockage. I added one exemplary figure to my response. The descriptive text in the paper changed accordingly. Please see figure 2 of my response.

- RC: *They could be exchanged with plots of radial force distributions at [0,90,180,270] degrees azimuth. Eventually, a blow-up of the Cf distribution could be included to assist the discussion about separation versus no separation.*
  AC: I added a plot of the radial distribution of rotor thrust and torque to the paper. Please refer to section Results, bullet-point 1 for further information.

- RC: *In Figure 13, the choice of blue and black color is not optimal, red would be easier to distinguish from the black.*
  AC: I changed the colouring from blue to red.

Flow solver

- RC: *The description of the flow solver setup is very sparse and should be extended. What time integration is used for the present work, and what size of time step is used.*
  AC: Eulerian Implicit time stepping scheme, global time stepping. The information is added. A time step of $0.006887052s$ is used which is equivalent to a rotor advance of $\delta\Psi = 0.5°$. The information has partly been at the end of section 2 but is expanded.

- RC: *It is stated that a second order central scheme is used, but it seems highly unrealistic that this can be done without generating wiggles for this high a Reynolds number without some artificial damping. Please explain.*
  AC: Please refer to page 3, line 13: "Pressure stabilization is used to avoid spurious oscillations caused by the collocated variable arrangement." This pressure stabilization prevents the central scheme from oscillating. No further comment is made in the paper.

- RC: *The present reviewer is well aware of the no-slip wall conditions used, but I do not understand how it differs from the viscous wall condition prescribed at the earth surface. Should it be an inviscid wall or slip conditions at the earth surface?*
  AC: It has been a typing error in page 4, line 22. The floor is a viscous wall but the top, left, and right surface of the flow domain are slip walls. I changed the word no-slip to slip in the given line.

Grid characteristics

- RC: *The description is not accurate and do not even include any description of the gridding of the tower component.*
  AC: The tower surface grid is meshed structured in a height below $5\,\mathrm{m}$ with 54 point in height and 180 points in radial direction. Above this grid, a triangulated unstructured grid is generated. The maximum edge length is $0.55\,\mathrm{m}$. As the tower surface is modelled as slip-wall, tetrahedrons are built directly on the tower surface. This information is added to section 3.2.
- RC: *Additionally, some more details about the issues related to including the nacelle in the grid should be given.*
  AC: Due to the narrow gap between rotor and nacelle a valid chimera overlap-region could not be achieved. Thus the nacelle of the NREL 5MW turbine is neglected while the tower is respected. This sentence is added to section 3.2
- RC: *The chord-wise resolution is on the coarse side; normally more than 250 cells are needed for an accurate resolution of the flow development. Are the results at all close to grid independent?*
  AC: In Länger-Möller (2017) it has been shown that with even coarser distribution in chord-wise direction, the results of THETA matched the NREL UAE phase VI perfectly. Based on this findings the mesh of the NREL 5MW turbine was generated. Moreover, the very good agreement to the NREL 5MW documentation of Jonkman et al. (2009) (section 5.1) indicate that the grid is fine enough.
- RC: *More illustrative figures showing the chord-wise and span-wise resolution should be included, along with a cut through the full grid topology.*
  AC: See section Figures, first bullet point.

Results

- RC: *Generally, the pressure distributions add very little information to the discussion, and should be replaced by span-wise force distributions.*
  AC: Thank you for the suggestion. I prepared figures of the span-wise force distribution and added them to the paper. It is also attached to my reply. In the paper, a new paragraph is added to section 5.3. Please see figure 1 of my response.
- RC: *Figure 13 on the tip vortex movement is very hard to interpret, as we do not know if the rotor is at identical azimuth positions for the different snap-shots.*
  AC: Yes, the instances were taken at identical azimuth positions. This information is added to section 5.3.
- RC: *It would maybe be more interesting to show the axial and radial location of the tip-vortex as function of vortex age at the three instances in time.*
  AC: I changed figure 14 accordingly to your suggestions and added a plot of the axial and radial location of the tip vortex as function of vortex age. Conversely, I only changed the colouring of figure 13 from blue to red. I attached the figures to give you an impression. The description of the figures changed accordingly in section 5.3. Please see figure 4 of my response.

References

- RC: *The major references to CFD for wind turbines are very recent; CFD for wind turbines track back to the late nineties which I believe should be reflected.*
  AC: I summarized the milestones in CFD for wind turbines in some additional sentences right at the beginning of section 1. I namely refer to Soerensen and Hansen (1998), Soerensen et al. (2002), Johansen et al. (2002), Bazilevs et al. (2011), Hsu et al. (2012), and Chow and van Dam (2012).

- RC: *Additionally, the author chose to refer to secondary references eg. Kessler and Löwe 2012, where the reference to Zhang et al from my point of view should be preferred. P3, L15 moving grid blocks (Zhang et al. 2007) as implemented by (Kessler and Löwe 2012).*
  AC: I followed your suggestion and additionally added a reference to Pan et al. (2002). The information is added to section 2.1.

- RC: *Another example is the reference for the usage of k-omega model for wind turbines which has been pioneered by others in the late nineties, e.g. Rotor performance prediction using a Navier-Stokes Method, Sørensen and Hansen, AIAA-98-0025.*
  AC: I never intended to state that Länger-Möller pioneered the Menter SST model for wind turbine applications. Anyway, I clarified that during the validation of THETA by Länger-Möller et al. (2017) the Menter-SST model has been the most accurate turbulence model. Thus it is used in the present study. The information will be given in section 2.1.

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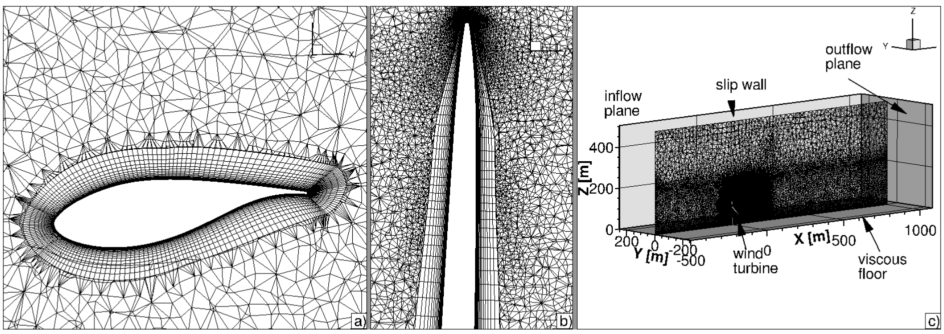

Fig. 1. Grid resolution

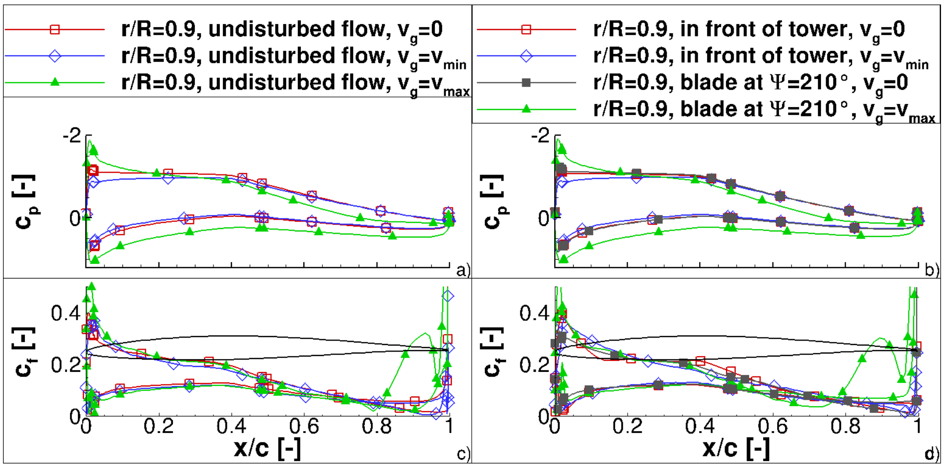

Fig. 2. pressure coefficient and friction force coefficient

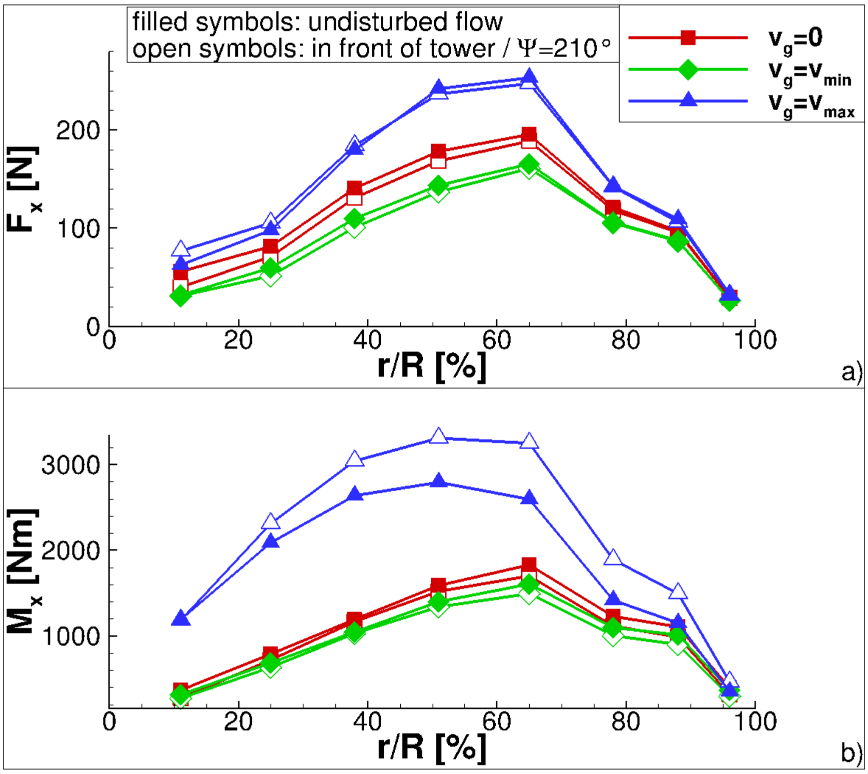

Fig. 3. radial distribution of rotor thrust and torque

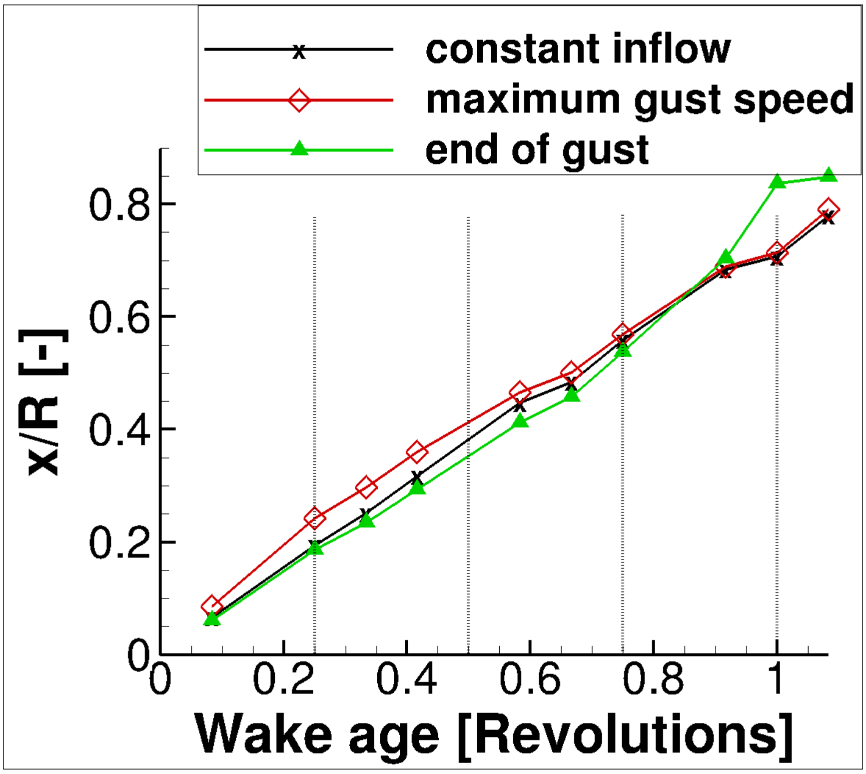

Fig. 4. vortex transport parallel to flow direction in dependency of vortex age