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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Wind tunnel experiments on wind turbine wakes in yaw: Redefining the wake width" *by* Jannik Schottler et al.

Anonymous Referee #3

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General comments

The article describes wind turbine experiments on two different model wind turbines. The results include velocity measurements on a plane, 6 rotor diameters (6D) behind the rotor, with transversal and vertical extent 2D. For each model turbine, the load cases include yaw angles of 0 and +-30deg, at a tip speed ratio of 6. The different rotor diameters and chosen test conditions lead to a ratio of about two for wind tunnel blockage and tip Reynolds number, and thrust coefficients of 0.97 and 0.87 respectively. The results are presented on the measurement plane in terms of mean velocity deficit, Turbulent Kinetic Energy (TKE) and a shape parameter describing the shape of the probability density function for velocity increments. Methods for identifying the wake center and thereby the skew angles, and wake shapes are presented. The result

include the shape parameter showing the maximum non-Gaussians behavior well outside of what we normally regard as the wake in terms of velocity deficit and TKE, and non-circular wake shapes resulting from the yaw errors.

The paper is interesting, clear, well written and easy to read. The quality of the measurements, data analysis and presentation appears to be high. The analysis provides a novel view on the wake shape and extent. The results are relevant to wind farm design, including current topics such as wake steering through manipulation of wind turbine yaw. The impact may be a broader view on what is the wake width, and strategies for wake steering, although further quantification on the impact on wind turbine loads should be carried out.

Specific comments

The anonymous referee #2 has commented on the high induction factors and the choice of position of measurement plane, the different TI, Ct and blockage ratios for the two turbines tested, and the possible impact on the measured wake velocities.

I understand that the wake effects are more easily studied at high induction factors, relatively close to the rotor, but I also share ref #2's curiosity about how this relates to real wind farms. I suggest a section showing the Ct vs. wind speed curve for a large modern wind turbine, and a few sentences about typical wind turbine spacings in recently built wind farms (along and across the main wind direction).

The anonymous referee #1 main comment is on the impact of inflow velocity increments on the loads for a wind turbine. I would like to add a few comments on this topic.

Figure 5 shows the mean velocity deficit at 6D behind the rotor. As expected, the wake (in terms of velocity deficit) has expanded somewhat, but at y/D and z/D of 1, we have more or less free stream conditions. Figure 6 shows the influence of the rotor in terms of TKE. Again we see that the wake has expanded, but at y/D and z/D of 1, we are almost at free-stream. Figure 7 is intriguing. Although the wake in terms of mean velocity deficit and TKE is hardly present at y/D and z/D of 1, the shape parameter here shows a strong signal, close to the maximum value across the measurement plane.

My main comment is that the shape parameter can be high, but the velocity fluctuations may be too small to affect the loads. I therefore appreciate that the authors in the following figures try to present the results in different ways, but in my opinion, some more figures should be added here.

In figure 8, the probability density functions at the two points are normalized in different ways to be compared with the same Gauss distribution. What is the ratio of velocity increment standard deviations at the two positions? How would a plot look if the results were normalized in the same manner?

In figure 9, the velocity increments at the two positions are again normalized with different standard deviations. I would like to see the corresponding plots also normalized with the standard deviation at D/2.

I suggest also time series and PSD plots of longitudinal velocity fluctuations at D/2 and D, and for the free stream, all normalized in the same manner. Maybe it is better to show a comparison at D and free stream separately.

Technical corrections

Caption of Table 1, pg. 3: Is the effective velocity during turbine operation the relative wind speed with respect to the rotor tip? The blade tip of the ForWind turbine looks like it has a rounded shape. Where is the tip chord defined?

2.3, page 6: Please mention if measurements support the assumption about vertical vs transversal fluctuations. I assume you mean <wˆ2> vs. <vˆ2>

Caption, Figure 3: Consider adding something like: For the NTNU turbine, the wind tunnel walls are located at z/D = +-3.03 and y/D = +-2.02. For the ForWind turbine, the wind tunnel walls are located at z/D = +- 4.67 and y/D = +- 3.12

Caption, Figure 11, pg. 12: Bottom row.

Caption, Figure 13: The red marks show the approximation of the respective parameter's radial extension based on $\mu\pm$1 u and $\mu\pm$2 u as described in Section 3.1. But I see only two red lines, is it at one or two sigma?

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