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Interactive comment on "Wind tunnel study on power and loads optimization of two yaw-controlled model wind turbines" *by* Jan Bartl et al.

Anonymous Referee #1

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The paper 'Wind tunnel study on power and loads optimization of two yaw-controlled model wind turbines' presents interesting wind tunnel measurements of power output and yaw-moments for a two wind turbine setup, and for different intentional yaw angles, turbine spacings, and inflow conditions. The paper presents three main parametric studies. The first experiment studies the effect of yawing the upstream turbine on the power and unsteady loading of both turbines. The second experiment investigates how loading and power change for the downstream turbine, when it is moved laterally compared to the upstream turbine, and for two different yaw angles of the upstream turbine. The third experiment confirms that yaw-moments on a turbine with partial wake overlap can be mitigated by intentionally yawing in the opposite direction, and interestingly, that

this also results in a small power increase. The paper provides a clear view on how yawing and partial wake overlap can influence the yaw-moments and power output, for both the upstream and downstream turbine. This is important information for wind farm optimization and control studies. Overall, the paper is structured well, but some parts of the text can be written more clearly or improved grammatically. The reviewer has only minor comments about the scientific context.

Main comments:

- In this paper, the yaw-moment is measured as a main component for unsteady turbine loading. It would help motivate the research if the authors explain in the introduction why the yaw-moment is an important quantity.

- Figures 2,6 and 10 are confusing because they show a measured velocity plane, but the text mentions that these results should only be considered as an illustration, and are not accurate. What is the reason for this? It should be mentioned that these measurements were performed with only turbine 1. It seems indeed useful to illustrate the expected wake impact for certain turbine placements. However, it is very confusing to show measurements that are not accurate. Furthermore, if these measurements are not reliable, they cannot be used in the text to explain certain observations, see P12L1. Therefore I suggest to either provide accurate wake measurements, for instance based on the previous publication, or to draw an illustration/sketch of the expected wake and turbine placement.

- The Discussion section is too much of a repetition, and does not provide many new analyses. For example, P17L15-P18L21, do not provide any new information or observations. Therefore, the discussions seems unnecessary and more like a long conclusion. The reviewer suggests to move the few extra thoughts and references in the discussion to the corresponding parts in the main text.

- The reviewer appreciates that the control of the turbines is described clearly. The downstream turbine is controlled to its optimal performance tip-speed-ratio, for each

situations. However, the upstream turbine is controlled by keeping the tip-speed-ratio constant, even when yawed. When a turbine is yawed, it seems that the incoming velocity projected perpendicular to the rotor, decreases with the cosine of the yaw angle. By keeping the tip-speed-ratio constant to the reference velocity, one can thus expect that the yawed turbine actually operates at a relative higher tip-speed-ratio (compared to the perpendicular incoming velocity). Does this result in a less optimal performance? Because, this could mean that for a two turbine setup, with the first turbine yawed, even more optimal situations are possible with a higher aggregate power. It would be helpful if the authors discuss this in the text.

Minor comments:

- As there is no optimization in this study, it seems that the title can be made more clear by for example: 'Wind tunnel measurements of power output and yaw-moments for two yaw-controlled model wind turbines'

- Figures should be numbered according to their order of reference in the text. (figure 2 is the first to be referenced in the text)

- P4L14: In this section, it is in general not clear to which location the distances x/D refer. Is this compared to the beginning of the wind tunnel test-section? Where is the turbine located compared to the beginning of the test section?

- P17L17: '..,but can mostly by subscribed to lower average kinetic energy levels in wakes for turbines exposed to low inflow turbulence' âĂŤ> This sentence doesn't provide any new information. Do the authors mean that wakes are more severe or recover more slowly when the ambient turbulence levels are lower? It is also better not to describe a wake as a kinetic energy sink, but rather as a region with low kinetic energy.

- P19L10: '.. rather asymmetrical': It could be helpful to mention other studies in the literature that also observed an asymmetrical behavior and wake deflection from yawing.

- P8L21: "Obviously, the optimum downstream turbine T2's operating point shifts to higher tip speed ratios, the more kinetic energy is available in the wake." This is not obvious to the reviewer. Maybe the authors can elaborate on the reason for this?

- P8L21: Wake recovery is not directly measured in this study. Therefore, it seems more correct to say: 'these results indicate a faster wake recovery..' + cite papers that have shown that wakes recover more quickly when turbulence levels are higher.

Technical corrections: In general, the text contains many sentences that can be written more clearly. The authors should revision the text and make it generally more easy to read. For example active vs passive voice, comma placement, and typos. See some suggestions below.

Abstract:

- 'wake overlap' instead of 'wake overlap situations'

- "For partial wake overlap the concept of downstream turbine yawing for yaw moment mitigation is examined for different lateral offset positions" âĂŤ> consider splitting up this sentence to make it more easy to read.

- 'Opposed downstream turbine yawing" is not clear in the abstract. It may be more clear to say something like: "the measurements show that for a turbine with partial wake overlap, the power can be increased and the yaw moment decreased, by yawing it intentionally 10 degrees in the opposite direction."?

Main text:

- P4L12 'low turbulence' instead of 'very low'

- P4L22: keep model number as 1 part "T20W-N/2-Nm"

- Table 1: it would be helpful to indicate that yaw angles are considered from -40 to 40 in steps of 10 degrees.

- P2L 32: ‘dedicated full-scale”, what is meant with dedicated?

- P2L33: “They found an independent yaw alignment for the purpose of individual power increase of downstream turbines..” is not clear.

- P3L8: This is a long and complicated sentence.

- P7L13: The term ‘power recovery’ is not clear.

- P9L7: fix ’.., blockage-increase freestream velocity levels of u/uref = 1.10 lift the downstream turbine’s power to these levels.’

- P10L11: fix ‘have seen not to be’

- P12L13: ‘other have’ is ‘other halve’?

- P14L19: fix: ‘The downstream turbine is exposed to a strong shear flow in the partial wake situation, mitigating yaw moment by actively yawing opposed to that shear’

- P15L4: ‘deemed’: ‘expected’ may be better?

- P15L6: remove ‘obviously’

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