Wind Energ. Sci. Discuss.,
https://doi.org/10.5194/wes-2019-35-AC1, 2019

eawe european academy of wind energy
Open Access WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Design and Analysis of a Wake Steering Controller with Wind Direction Variability" *by* Eric Simley et al.

Eric Simley et al.

eric.simley@nrel.gov

Received and published: 20 December 2019

Thank you for your comments on the manuscript and for your interest in the topic. We plan to wait until all of the reviewers have provided comments before revising the manuscript and will respond again regarding the revisions. But in the meantime, we'd like to reply to your comments because it has been a while since you shared them with us.

1) A good paper with some interesting theoretical treatment of directional uncertainty.

We appreciate your interest.

2) I only have one criticism, in the way the performance improvements are quantified, for example on page 17 line 22, where an improvement of 128% seems dramatic, but

is actually only an increase in a change in wake losses. Those changes in wake losses are themselves small, around 1% to 3%, representing an even smaller change in actual energy production. Given the many other uncertainties, not least in the underlying wake model itself, these small changes could easily be 'lost in the noise' in real life. Tables 1 and 2 only report the actual changes, which is not so misleading, so I don't think the dramatic percentage changes in differences should be reported in the text either. Better still would be to report the percentage change in power prodution, rather than the percentage change in the wake losses, even if the numbers won't look as dramatic.

Author response: This is a good point, and we agree that statements like "an improvement of 128%" can be misleading, especially because the change in actual energy produced is small. We will update the presentation of the gain in energy capture in the revised draft, focusing on the absolute percent change in energy or wake losses recovered. The reasons we decided to present the improvements in terms of percentage of wake losses recovered are:

a) this resolves the issue of deciding which sector of wind directions to include when calculating the baseline energy and energy with wake steering. Otherwise the percentage change in energy would depend on which wind directions are included, which is a somewhat arbitrary choice.

b) the percentage change in energy capture with wake steering is relatively small for this two-turbine scenario, when considering the entire sector of wind directions. Because the main objective of wake steering is to improve energy capture when applied to an entire wind farm, we feel the improvement in energy gain for a two-turbine example is not as relevant as wake losses recovered. We expect the metric of percentage of wake losses recovered to be more consistent for different wind farm sizes and layouts (although it will still vary) and thus more meaningful. We think presenting both the percentage change in energy and the percentage of wake losses recovered will make sense.

3) Another comment is about the use of wake steering in one direction only. The justification is that yawing in the other direction increases certain loads. However there are many reasons why it may still be worth steering in both directions (there is as yet no consensus on this point): - not all loads increase; some will decrease, and they may be more important loads, depending on the turbine design drivers. - even if loads increase on the yawing (upstream) turbines, this may be compensated by decreases in the same loads when the wind direction changes so that the turbine benefits from wake steering at other turbines. - the increased loading may not happen if the turbine uses individual pitch control. It would therefore be interesting in future to extend the analysis to include bi-directional yawing. This introduces additional practical difficulties because of the sudden rever- sal in desired yaw offset as the wind direction passes the turbine alignment direction. However, to study this properly, non-Gaussian direction changes, driven by synoptic weather patterns for example, may become important.

Author response: Another motivation for considering only positive yaw misalignments is that positive yaw misalignments have been shown to increase power at the downstream turbine more than negative offsets through high fidelity modeling (e.g., the following references).

Archer, C. L. and Vasel-Be-Hagh, A.: Wake steering via yaw control in multi-turbine wind farms: Recommendations based on large-eddy simulation, Sustainable Energy Technologies and Assessments, 33, 34–43, doi:10.1016/j.seta.2019.03.002, 2019.

Fleming, P., Annoni, J., Churchfield, M., Martinez-Tossas, L. A., Gruchalla, K., Lawson, M., and Moriarty, P.: A simulation study demonstrating the importance of large-scale trailing vortices in wake steering, Wind Energy Science, 3, 243–255, doi:10.5194/wes-3-243-2018, 2018.

However, that is a good point that a concensus has not been reached on which directions of yaw offsets should be used, especially when considering the load benefits on downstream turbines. Research suggests that some loads might increase regardless

of the sign of the misalignment while others decrease regardless of the sign. One motivation from a loads perspective for using positive offsets alone comes from the indication that blade root bending moment loads will be reduced for positive offsets but will increase for negative offsets, as shown in:

Damiani, R., Dana, S., Annoni, J., Fleming, P., Roadman, J., van Dam, J., and Dykes, K.: Assessment of wind turbine component loads under yaw-offset conditions, Wind Energy Science, 3, 173–189, doi:10.5194/wes-3-173-2018, 2018.

The blade load trends combined with the higher power gains with positive offsets and the added complexity when switching between large positive and negative misalignments motivated us to consider only positive misalignments. Furthermore, only positive offsets are used in several recent wake steering field experiments, and we intended for the results of this study to aid in the analysis of field experiments.

Considering the points you raise, we will explain why we are focusing on positive offsets, but discuss how implementing both directions could be beneficial and that this is still an open area of research.

Interactive comment on Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2019-35, 2019.