Wind Energ. Sci. Discuss.,
https://doi.org/10.5194/wes-2016-58-AC2, 2017

Interactive comment on "Wind farms providing secondary frequency regulation: Evaluating the performance of model-based receding horizon control" *by* Carl R. Shapiro et al.

Carl R. Shapiro et al.

cshapir5@jhu.edu

Received and published: 10 July 2017

We thank the referee for their careful reading of the manuscript. We have included detailed responses to each of the referee remarks/questions below, where the referee comments are in bold face.

The paper presents interesting results regarding the ability of wind farms to provide secondary frequency regulation while minimizing the amount of energy not produced. Some points that would improve, in my opinion, the paper:

1. The presented wind farm control approach is likely to be computationally too

expensive for the use in real wind farms. It would be useful to also discuss how the control approach could be applied to real wind farms.

In the implementation used in this paper, the optimization step takes ∼60 seconds on a single processor. While this is 6 times larger than the advancement time of 10 s, several refinements can bring the optimization time to a fraction of the advancement time (allowing real time control). We discuss these refinements in a recent American Control Conference paper, and we will include this discussion at the end of Section 3.1.

2. The introduction could be shortened by moving some of the content to a methodology chapter.

Thank you for this suggestion. We will either move page 3, lines 5–21 to section 5 or add an additional section between sections 4 and 5 discussing the PJM signals (this would include page 3, lines 5–21, and Figure 4 and the related analysis in section 5)

3. Switching chapter 2 and 3 would improve the flow of the paper.

We think section 3 requires information from section 2 to be fully coherent and will therefore keep the current organization.

4. The use of thrust coefficient as input to a wind turbine controller is not realistic.

We agree using the thrust coefficient as control input is a significant simplification. However, we discuss the future work needed to move toward more realistic controls in the last paragraph of the conclusion (page 18, line 15). To help with this discussion, we will add a sentence about the relationship between the thrust coefficient and blade pitch/generator torque on page 7, line 8 .

5. Please provide more details regarding the rated power of the wind turbines, their rated wind speed and the mean wind speed considered in the simulations.

The actuator disk model used to represent the wind turbines in LES assumes an idealized wind turbine operating in region 2 (always operating below the rated wind speed and power). Based on the maximum observed wind speed in the simulations, we will report the effective rated wind speed and power corresponding to this assumption. These will be provided along with the mean effective wind speeds in Table 2. We will also add rotor diameter, hub height, and representative mean and maximum wind speeds to the caption of Figure 3.

6. Please mention the frequency of the control with regards to the discussion on p. 13 line 13ff

Control actions are applied every 10 seconds (the receding horizon advancement time). To clarify, we will add the advancement and horizon times to page 12, line 15 and mention on page 13, line 13 that the time length discussed is several times the advancement time.

7. Instead of showing the performance of the static model-based controller for all cases it would be useful to focus on a single cases and include figures on rotor effective wind speed at a column of turbines.

We believe it is useful to show all of the comparison cases to highlight consistent trends in the results. Since the inflow is different between the different cases, we can get a better sense of the overall performance by looking at a variety of cases. We propose adding an additional figure to show more details of row power, rotor effective wind speed, and thrust coefficient for a single simulation case.

8. The impact of the paper would be improved by a comparison of the performance of the controllers to a standard PI(D) control approach.

We agree that a comparison to other control designs, particularly those of Aho et al. (2013) and van Wingerden et al. (In press), would be of interest. However, a standard for farm level frequency regulation has yet to be reached and PI(D) control techniques for frequency regulation are still being developed (see van Wingerden et al.). We think

this comparison would be well covered by a collaborative effort among the community, but it is outside the scope of the present paper. In this paper, we compare the performance of the dynamic and static model-based control designs and demonstrate that controllers based on static wake models have difficulties providing frequency regulation similar to approaches that do not consider wake effects at all (see Fleming et al., 2016).

9. In chapter 7 please use a quantitative assessment of the controller instead of qualitative statements. It is mentioned that the controller reduces turbulence driven power fluctuations. It would be necessary to justify this state by comparing the controller against a PI(D) control approach.

In Figure 8 of section 7 we provide a quantitative analysis of the controller using PJM's performance scores. To justify the statement about reduced turbulence driven power fluctuations, we will compare on page 13, line 24 the variance of the pre-control power about the baseline power P_{base} to the wind farm power during the controlled period about the reference signal. A comparison to other control approaches, such as PI(D), is outside the scope of this paper.

10. Please also include the total available wind farm power in the figures. This would also facilitate the discussion on page 16 line 8ff.

We will add the uncontrolled power production, i.e. the power the farm would have produced without the controller, to Figure 7. This is the best comparison to help in the discussion on page 16 line 8 because "total available wind farm power" is difficult to clearly define.

Interactive comment on Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2016-58, 2017.