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WIND ENERGY SCIENCE DISCUSSIONS

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Interactive comment

Interactive comment on "Control-oriented Linear Dynamic Wind Farm Flow and Operation Model" *by* Jonas Kazda and Nicolaos Antonio Cutululis

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Authors' response

We would like to thank the reviewer for the comments and his/her time spent with the review. Please find our response below. The attached paper includes revisions for Anonymous Reviewer #2 and Anonymous Reviewer #3 with changes highlighted in yellow and green, respectively.

Apart from the technical questions in previous reviews, which are all relevant and cannot be disregarded too quickly, perhaps it is good to better place this paper in existing work, by extending the introduction and trying to address the following:

Authors' response

We thank the reviewer for the comment. We would be grateful if the reviewer could please view our response to the previous reviews, where the other reviewers' comments are discussed thoroughly, including additions to the paper.

As regards the placement of this work in literature, we have added details to the introduction according to the suggestions of the reviewer, as discussed in the following.

- Specifically, what is new about the given approach of using the Kalman filter? Kalman filters have been used by Doekemeijer (https://doi.org/10.1088/1742-6596/753/5/052015), and Gebraad (PhD thesis), and both works also show the reduction in prediction error. Maybe it can be argued that these previous works are even stronger, because they use high-fidelity LES simulations to compare to. Also, even earlier work in Soleihmanzadeh's PhD thesis (Paper D) is worth comparing to, because it uses a linear model, with H2 control (i.e., implicitly, some filtering of output measurements (eq 8.43) to estimate the state).

Authors' response

The novelty of this work is the use of a dynamic, linear, engineering model-based approach to model the dynamics of wind farm operation and wind farm flow. Furthermore, the application of the Kalman filter to such type of modelling approach is novel. As for the other approaches, which are cited by the reviewer, the Kalman filter is used to improve the accuracy of the model predictions.

- What is the importance of including dynamics? You could discuss the importance of transport delays in wake dynamics in large wind farms. Can you point out some specific issues?

Authors' response

General guidelines for control-oriented modelling suggest to include dynamics in the model that are of time scale and magnitude relevant to the control problem. An application area of the Dynamic Flow Predictor is its use in active power control of wind farms. The time scales of reference signals used in active power control are of similar magnitude as transport delays in wake dynamics of large wind farms. In accordance with the modelling guidelines, these dynamics are thus included in the Dynamic Flow Predictor. The phenomenon is addressed in the introduction with reference to the work of Shapiro et al. (2018). The following statement is added to the introduction in order to enlarge upon the topic.

The dynamics included in the investigated dynamic flow model [by Shapiro et al. (2018)] are transport delays in wake dynamics. The time scale of these dynamics are of similar magnitude as the time scale of certain type total power reference signals used in wind farm control. Shapiro et al. (2018) argue that the use of a dynamic flow model is therefore more beneficial.

- Is it necessary or desirable to go to linear control? Does it not simplify too much? These points have to be clarified in the introduction of the paper, to motivate its relevance.

Authors' response

The computational requirements of many nonlinear models motivate the use of linear models for wind farm control. For example, running the optimization in nonlinear

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Discussion paper

model predictive wind farm control is currently in the order of minutes. In order to allow for "real-time" wind farm control, less computationally expensive approaches are necessary, such as linear model predictive control. Linear model predictive control, however, requires a linear model, such as the Dynamic Flow Predictor presented in this work. The attached, revised paper discusses the topic in more detail in the introduction.
As regards the fidelity of the model, we believe that the results presented in this work show the validity of the modelling approach used in the Dynamic Flow Predictor. The Dynamic Flow Predictor estimates wind speed dynamics of the higher fidelity model SimWindFarm with a normalised root-mean square error of only 0.6% to 3.5%. The following statement is added to the conclusion in this regard.
The Dynamic Flow Predictor can thus capture the dynamics of wind farm flow modelled by the higher fidelity model SimWindFarm.

Please also note the supplement to this comment:
https://www.wind-energ-sci-discuss.net/wes-2018-29/wes-2018-29-AC3-supplement.pdf

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