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WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "A control-oriented dynamic wind farm model: WFSim" *by* Sjoerd Boersma et al.

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Dear Referee #1,

We thank you for your feedback. Please find our responses to your questions below.

(1) The author's don't mention power increasing wind farm control. Is that deliberate, in that is model is being designed specifically for electrical grid service provision?

Answer: The presented wind farm model can potentially be used in/for controllers providing grid facilities as demonstrated in

Vali, M., Petrovic, V., Boersma, S., van Wingerden, J. W., Pao, L.Y. and Kühn, M.: Model Predictive Active Power Control of Waked Wind Farms, American Control Conference, 2018 (under review).

, but also controllers providing power maximization. In fact, in both:

Vali, M., van Wingerden, J. W., Boersma, S., Petrovic, V., and Kühn, M.: A predictive control framework for optimal energy extraction of wind farms, Journal of Physics: Conference Series, 2016.

Vali, M., Petrovic, V., Boersma, S., van Wingerden, J. W., and Kühn, M.: Adjoint based model predictive control of wind farms: Beyond the quasi steady-state power maximization, International Federation of Automatic Control, 2017.

the objective is to maximize the power production of the farm. In the revised version of this paper, we will emphasise the fact that this model can potentially also be used for power optimization.

While the above results are promising, they are obtained with controllers using the same wind farm model (WFSim) as to which the found control signals are applied (called the simulation model). In other words, perfect system knowledge is assumed. Similarly, in

Munters, W. and Meyers, J.: An optimal control framework for dynamic induction control of wind farms and their interaction with the atmospheric boundary layer. Phil. Trans. R. Soc. A 375: 20160100.

the authors illustrate the potential of power maximization using a LES based wind farm model as the simulation model and as model in the controller. While a LES based model is relatively accurate, it is also computationally complex and therefore not suitable for online control.

At the moment, we are investigating if a combination of the above results can give satisfying controller performance. More precisely, the model in the controller should be WFSim (due to its computational efficiency) and the simulation model should be a LES based wind farm model.

(2) Do I understand correctly that for the PALM and SOWFA comparisons, identical Ct time series are played through the turbine models, effectively open loop?

Answer: a) The control signals applied in the PALM and SOWFA case are not equivalent. b) The CT' series applied to PALM and WFSim are exactly equivalent. c) The CT' series applied to WFSim are not exactly equivalent as applied in SOWFA since the latter does not allow for such a control input. We used equation 24 to estimate CT' (this is applied in WFSim) from SOWFA data.

(3) Is there no online estimation being applied?

Answer: There is no online estimation applied in this work. However, the presented model can be used for online estimation (see citations in next answer).

(4) Is the assumption that if such estimation, made possible by the model structure, remove any remaining error?

Answer: In the following work:

Doekemeijer, B. M., van Wingerden, J. W., Boersma, S., and Pao, L. Y.: Enhanced Kalman filtering for a 2D CFD NS wind farm flow model, Journal of Physics: Conference Series, 2016.

Doekemeijer, B. M., Boersma, S., van Wingerden, J. W., and Pao, L. Y.: Ensemble Kalman filtering for wind field estimation in wind farms, American Control Conference, 2017.

we illustrate that the model can be used for online estimation and we illustrate that the estimation of wind farm dynamics will be improved by using an estimator (Ensemble Kalman filter in this case).

The purpose of the WindFarmSimulator model is not to capture all the flow and turbine dynamics that LES models typically capture. Rather, the objective is to capture the dominant spatial and temporal dynamics inside the wind farm to allow reliable forecasting of each turbine's power generation in a time efficient manner. This in turn enables wind farm control algorithms to, e.g., consistently track a desired power reference signal by predicting the effect of turbine control policies on the surrounding wind turbines. In the bigger picture, we propose a closed-loop control solution in which the WFSim model is calibrated in real-time to model discrepancies and to the current atmospheric conditions inside the wind farm. This calibrated model is then used for forecasting and for determining a control policy. The proposed closed-loop control framework is displayed in Fig. 1 in the paper.

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