Dear Pieter Gebraad

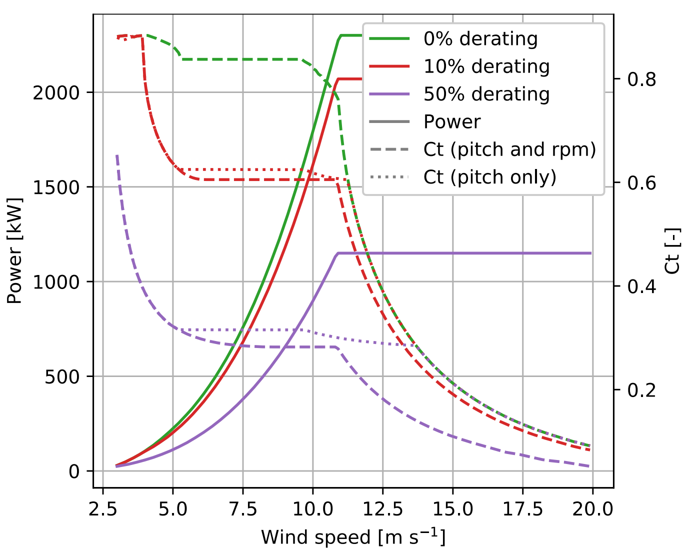
Thank you for your interest in our study and for your comments.

We are not intentionally concluding that wake deflection is of smaller importance compared to wind turbine derating/axial induction based control:

We are referring to Deshmukh and Allison (2017) who obtains 0.9% increase in AEP for wake deflection, 6.6% for wake expansion and propagation (axial induction control) and 17.7% when combining the two strategies.

We are referring to Andersen (2019) who based on his two-turbine investigation finds that for a given reduction of the upstream WT thrust, the yaw wake deflection strategy is penalized more severely than the derating strategy measured in terms of aggregated power production of the two turbines analyzed in the study case. We will rephrase the sentence “The same conclusion was reached by Andersen (2019)” as this is not the case.

We are, however, arguing that axial induction control should not be rejected insignificant based on studies that uses either pitch regulation or rotor-speed regulation isolated, as a combination of pitch and rotor-speed regulation in most cases results in more power for the same level of thrust.
The plot below shows the thrust curves obtained with combined pitch and rotor-speed regulation (dashed lines) and with pitch regulation only (dotted lines). It is clearly seen that the combined pitch and rotor-speed regulation results in lower thrust for the same power production.



It is correct that slide 13 in Andersen (2019) does not show significant power gains for derating. According to the author, however, the derating strategy applied in this study is based on pitch regulation only. We therefore believe that this study do not reveal the full potential of derating.

It is also correct that Fuga, as well as all other models, are not able to capture all aspects of wake flow and WT interaction. In this case, however, simplifications of the flow field modeling is inescapable. It is simply not realistic to do wind farm layout and control optimization using a full non-linear LES coupled to meso-scale models for correct flow boundary conditions. Therefore, the question is how to simplify in the most adequate way. An alternative, widely used, simplification is to describe the wind-farm flow field by superposition of engineering/empirical single wake models. However, we consider the present direct solution to the wake affected wind farm flow field as an innovative, valid and competitive alternative to the traditional single-wake-based approach as it provides a consistent solution to the full set of linearized Navier-Stokes equations and thus avoids the challenging inconsistent merging of engineering single wakes into a wind farm flow field.

The mentioned recent paper (Effects of axial induction control on wind farm energy production-A field test, van der Hoek, 2019) is indeed interesting, and we will refer to it in our manuscript. Their FarmFlow simulations shows an increase of 5.6 %, which we consider in the same order of magnitude as our 8%. The numbers are, however, not directly comparable due to different turbine spacing, wind speed distributions, inclusion/exclusion of above-rated wind speeds and derating strategies (van der Hoek (2019) derates using pitch regulation only).

In the numerical study by van der Hoek (2019) as well as ours, the inflow field is assumed homogenous, stationary and well known. Furthermore, controller-technical and practical details such as tower exclusion zones and smooth transition between regions not are considered. In the field test by van der Hoek (2019), for instance, the derating is applied via a two-level pitch offset as the optimal pitch setting was too complicated to implement in the controller.
The power increase of 3.3% seen in the field test is therefore, in our opinion, surprisingly high compared to the simulation results. In any case, it confirms that the potential of axial induction control is worth to investigate.