Answer to reviews: Integer programming for optimal yaw control of wind farms

We would like to thank both reviewers for their reports (after the major revision). As report 1 did not include suggestions for revision, the following refers to the minor comments of report 2. We revised the manuscript carefully to accommodate as many suggestions and requests. Please see below for our detailed replies.

Answers to minor comments of report 2

- 1. "Acronyms: Please capitalise definitions of SQP (line 79) & LIDAR (line 184)."—done (now in lines 79 and 186). Following this, we also capitalized the definitions of the acronyms in lines 28 and 29, i.e., "Wind Farm Yaw Problem", "Integer Program", and "Covering Approach" (in accordance with comment 8).

- 2. "Line 6: Suggest replacing "like" with "including" or "such as""—We replaced "like" by "such as" in line 6. With this in mind, we also replaced "like" by "including" in line 636.

- 3. "Abstract / Section 1.1: "yaw control" can mean the turbine-level control of yawing turbines to face the incoming wind, so the farm-wide version should be referred to as "wake steering" or "farm-level yaw control""—We decided to replace it by "farm-level yaw control" (Abstract lines 6 and 8; Sect. 1.1 lines 71, 73, and 79; Sect. 1.2 line 108; Sect. 4 Fig. 8; Sect. 5 lines 632 and 635).

  To avoid taking up more space, we got rid of the unnecessary word "increasing" in the term "scales well with increasing farm width" (Abstract line 9) and slightly reformulated the paragraph "In general, it depends on ..." (begin at line 68).

- 4. "Line 86: This paragraph is very long..."—broken at "This idea..." (as proposed), see line 87.

- 5. "Line 101: The start of this sentence..."—re-worded, but deviating from the proposal ("In this approach, called the serial-refine method...") in order to emphasize the connection to the Boolean approach (line 101): "The so-called serial-refine method, see Fleming et al. (2022), is based on the Boolean approach, whereby each turbine is run through twice (in a serial and a refine pass), which allows several yaw offsets."

- 6. "Line 188: There is a missing word..."—We fixed the typo by replacing "this transient phase in the but the effects" with "this transient phase but the effects" (line 190).

- 7. "Line 270: The phrase "without guaranteeing it" in respect to the wind threshold is confusing to the reader. If the (trapezoidal) shape demonstrated here is a suitable template for the scenarios in this paper and is believed to be useable for a range of wind conditions with negligible instances of deficit exceeding the threshold due to e.g. turbulence, then this should be stated. Otherwise it is not clear why a threshold is mentioned if not to be strictly applied."—To avoid confusion, we revised the manuscript in two places.

  First, in Sect. 1.2.1 we essentially refer to Sect. 2.2.1 for the details to avoid the threshold confusion (line 152): "Further, we accept small model inaccuracies by disregarding wake influence if the wake-induced wind speed reduction (relative to the free stream) at the downstream turbine is small, see Sect. 2.2.1 for details."

  Second, we carefully reworked the description of the simple trapezoidal construction in the first paragraph of Sect. 2.2.1 (starting with: "Moreover, we remind the reader that one assumption is to accept small model inaccuracies..." at line 269): in short, the threshold is applied, but only to the wind speeds at the so-called observation points. Meanwhile, we can also refer to an experiment in Sect. 4 that successfully compares our covering approach with full enumeration and finally supports the suitability of the chosen template.

- 8. "Line 290: ... to write out "Covering Approach" in full here."—done (line 292).

- 9. "Line 296/297: It seems that the empty section configuration has been counted, would it ever be used?"—Yes, imagine a 4×2 farm as in Fig. 5 (b) but with deactivated WTs 1 to 3, and 6; then covering section S_2 would need the empty section configuration; for reasons of space, we do not include such an example in the manuscript.

  If the question referred to the required number of simulations: there, it is not counted, see Sect. 2.2.4: "We derive the exact worst-case number of simulations needed ... for all possible section configurations ... that are non-empty...". However, because of your question we added a missing "non-empty" in Sect. 2.2.3: "Then we can assume without loss of generality that ... inside a non-empty section configuration ..." (line 323).

- 10. "Line 342: The number of non-empty configurations also includes the configuration with all turbines; also, this formula does not seem to have been used in the line 357 calculations?"—Yes, this is true; line 357 (now 359 and 360) does not include the complete section configuration; the computations there are for reasons of comparison: they are an adaption of the basic approach, i.e., full enumeration of the farm (and not of the upstream section), where the downstream-most ones run greedily and we include the possibility

to deactivate any turbine (as described in the lines above line 357, now 359).

Finally, we added a short explanation in the manuscript (line 359): instead of "... combinations (for 3×2)" we now write "... combinations (for 3×2, where three WTs have the choice between n_Γ yaw offsets and deactivation and the downstream-most WTs can be on or off)".

- 11. "Table 2 Caption: ..."—removed duplicate word "offset".
- 12. "Footnote on page 16: I think a mean % change would suffice rather than the individual numbers."—Yes, this makes it easier to understand: we realized it in terms of mean % and range in %.
- 13. "Line 445/446: Switching tenses within sentence "we introduce other conditions (and used""—we replaced "(and used fixed values)" by "(and fixed values that we use)" (line 449).
- 14. "Line 449: It is not clear what setting turbine parameters "time-dependent" means, please add a bit more description."—we reformulated "can be set time-dependent." to "can be modified at any time during the simulation." (line 452).
- 15. "Line 474: Please remove capitalisation: "of WinFaST: the ""—done (line 477)
- 16. "Line 520: The sentence seems to repeat itself."—Yes, in some way. We moved the words "sophisticated static" before "Gauss-Curl-Hybrid" and shortened the sentence in question to "as WinFaST generates a wind field and uses *dynamic* turbine and wake models." (line 522).
- 17. "Lines 541-543: This could be worded more diplomatically. E.g. by acknowledging that while serial-refine has been faster than CA+IP in the examples in the paper (assuming this is always the case), the CA+IP approach may have advantages in larger wind farms or broad ranges of wind conditions."—Thank you for the diplomatic wording suggestion. In the meantime, we have added examples where "our CA always results in the same total power outputs as the full enumeration, whereas in three cases the SR method results in slightly lower ones ...", see the reworked paragraph starting with "For the mentioned CA comparison..." in line 525.

  In this context, Table 4 has been extended by parts α) to γ). Further, in the meantime, the run times in Table 4 a) and c) were reduced (by utilizing parallelization, which is not mentioned in the manuscript). In addition, we corrected typos in b) (SR method): it takes advantage of the finer yaw offset discretization, which is discussed in the reworked paragraph mentioned above.
- 18. "Line 551: Suggest taking the final sentence out of brackets and re-wording e.g. "For reference, the baseline tower and pitch activity values are..."—done (it reads much better), line 557 now.
- 19. "Line 580: "on the order of""—done, line 586.
- 20. "Table 6 / Line 580: ..."—changed "y" to "yr" to represent years.
- 21. "Lines 597-600: Sentence is very long, suggest splitting."—split done: instead of "Further, we observe that ..., which is likely ...", it is now "Further, we observe ... This is likely ...". (line 604)
- 22. "Line 624: Suggest re-word e.g. "which makes use of repeating patterns to cover the wind farm""—We replaced "...covering approach, which exploits that the farm can be covered by patterns based on a smaller, precomputable so-called upstream section,..." by "covering approach, which makes use of repeating patterns (based on the so-called upstream section) to cover the wind farm" (line 630).
- 23. "Line 636: Suggest re-word "e.g., able to use FLORIS""—The sentence in question was moved and completely rewritten (line 637): "We demonstrated this by a comparison with full enumeration, for which we interchanged the simulation on which our superordinate model is based to FLORIS software (that does not utilize dynamic models for wakes and turbines)."
- 24. "Lines 637 & 639: Unclear on what the "associated farms" are?"—We replaced it by "several farms" and summarized the last two sentences in the conclusion to one (line 643): "Finally, solving the WFYP for several farms by our CA for a variety of wind directions and speeds should be helpful to recognize structures whose exploitation reduces the computational effort in precomputation or simplifies the WFYP itself."

Further changes

- We introduced the acronym "*Serial-Refine* (SR) method" in line 516.
- We have chosen slightly smaller image sections in Figures 7 to 9 (for reasons of space).
- We updated the Zenodo data set (rerun of series 0 case 1 part c) and new part γ)).