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Interactive comment on "From wake steering to flow control" *by* Paul Fleming et al.

Anonymous Referee #1

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The paper "From wake steering to flow control" by Fleming et al. is generally well-structured and yaw-based wake deflection is a topic of high interest. Three different wind farms are simulated in both the LES model SOWFA and the engineering wake model FLORIS. The results show that the baseline cases agree well, while the application of yaw-based wake deflection at the front-most turbine introduces a deviation between the models. This deviation increases after the second turbine in a row. The authors relate the difference between the models to the cross-stream component of the flow, that is not included in the FLORIS model. Specifically, they observe two counter-rotating vortices in the wake flow of the yawed turbine, that are regarded to influence the wakes of downwind turbines. In an LES of a larger wind farm they observe that the power output of a simultaneous control of all turbine rows differs from the power addition of individually controlled turbine rows. They conclude in claiming that a new concept of flow control could make use of the observed effects.

Technically the analysis of the simulation studies is good, the chosen visualizations mostly allow to detect the differences between the two models.

Unfortunately, the very short description of the models makes it difficult to fully believe the argumentation of the authors.

The authors might overstate the influence of the observed vortices on the difference between LES-model and engineering model. An analysis or discussion of other potential sources, e.g. wake superposition, turbine model, flow entrainment, is missing.

Title and abstract of the paper are promising more than the paper actually delivers, as no new concept of flow control is developed or presented, but is only suggested.

These major aspects need to be addressed before we can recommend it for further publication in the Wind Energy Science journal.

Specific Comments:

1. Title and abstract: Please relate the title and abstract more to the content of the paper. Also, the term "new physics" should be replaced by a more specific term.

2. P01. L26: Since the focus of study is on the interaction of multiple wakes, it is necessary to briefly introduce how multiple wakes are modeled in FLORIS and what is missing. A more detailed description of FLORIS would fit better into section 2.

3. P04. L09: Besides a mean wind speed of 8 m/s (hub height?) no further information on the inflow condition are given. Similar to past studies? To what extent? This part should be improved by adding further inflow characteristics (e.g. inflow profiles, TI, . . .)

4. P05. L08: In the paper of Fleming 2015 this has only been investigated for the specific case that the upstream turbine is yawed and the downstream turbine has no lateral offset. Can you conclude that there are no cases where a negative yaw offset would be beneficial?

5. P07. L03: "there does not appear to be any deflection" -> Due the colorbar it is

impossible to see any details of the flow structure. It indeed looks like no deflection of the wake took place. But what is YOUR definition of wake? Could some wake tracking be applied in order to make a reliable and clearer statements?

6. P10. Figure 7: It seems that the employed FLORIS model only considers the wake deficit for modeling multiple wakes and does not consider the superpositions of deflected wakes by upwind turbines. Since FLORIS benefits from the generic AD model, it might be good to be evaluated with a LES model with the non-rotating AD model as well. Moreover, conducting such observations provides a clear view on the physics of the counter-rotating vortices.

7. P10. L10: Please also discuss the other potential sources for the deviations between FLORIS and SOWFA. While the baseline cases indeed show a good agreement, wake superposition is a potential source of error, e.g. wake superposition, turbine model, flow entrainment, especially for half-wake conditions (see e.g. Machefaux, "Multiple wakes", 2015 or Trabucchi et al., "3-D shear-layer model for the simulation of multiple wind turbine wakes: description and first assessment", 2017), which is essentially what is happening when the wake of the upwind turbine is deflected.

8. How could the FLORIS model be potentially improved? Or which further analysis are required before such recommendations could be substantiated?

Technical Corrections:

9. P01. L10: The first part should include a few more literature references. The literature review on engineering models is limited just like the one about the interaction of multiple wake. Furthermore, there have been early wake deflection studies in the wind tunnel which might be worth mentioning.

10. P01. L13: "Early work in wake steering . . ." This sentence somehow suggests that first investigations of wake steering were performed using computational fluid dynamics. In the years before, however, multiple investigations were carried out in the wind

tunnel. Please consider rephrasing this part.

11. P01. L22: "The model is shown to predict the behavior of wake steering and . . .". If the model does predict the behavior of wake steering why do we need other models? What are the weaknesses of the model? Consider adding further details or rephrase the statement.

12. P02. L16: Typo: "to changing a the deficit"

13. P03. L01: The 1st and 2nd objectives of the paper seem similar. They might be combined or rephrased.

14. P03. L05: Some brief description of the FLORIS model, especially the handling of multiple wakes and the assumed natural wake deflection, may help a reader for following the comparative studies.

15. P03. L03 and L19: The 3rd objective is not addressed enough through the paper. The described approach of a hypothetical wind turbine downstream (in section 3) is introduced for reducing computational efforts of the simulation studies. It might be also good to discuss the benefits of this method for wind farm control research.

16. P03. L06: "models of wind farms" -> wind farm models?

17. P03. L06: Who developed the two models? References

18. P03. L16: It seems that the actuator disc with rotation is used in the SOWFA simulations. It should be clarified.

19. P03. L18: ".Churchfield et al." Reference Typo

20. P03. L20: " the two models have been used" -> FLORIS and SOWFA? There is no real separation between Chapter 2 "Models" and Chapter 3 "Method". This seems rather unusual.

21. P03. L20: In the 1st paragraph, some references for past research would be

beneficial.

22. P03. L27: “(see Fig 1.)” Typo, unnecessary space before “see”.

23. P03. L28: Why averaging the flow for 1600s? What is the reason for this specific amount of time?

24. P03. L29: “by an additional hypothetical at some point” Typo, “turbine” missing?

25. Figure 1: Colorbar?

26. Figure 1: Without a grid or ticks the use of the tick labels is limited

27. Figure 1: View from above down at the plants?

28. Figure 1: Consider including a sketch to define positive and negative yaw offsets (CWW, CW)

29. P04. L01: How do you determine the averaged flow?

30. P04. L04: Reference for FAST

31. P04. L12: “this method has shown to be comparable to an actuator line model in predicting power” -> To what extent?

32. P05. L03: “+/- 25âŮę” The degree sign does not show up right in the reviewed draft. Please verify if this is a typo.

33. P04. L04: Please consider adding the coordinate system to Figure 1

34. P05. L07: “For example, in Fleming . . .” Please consider rephrasing this sentence due to its complex structure.

35. P04. L27: Please distinguish between the approach of the current paper and the approach of the prior studies in the previous paragraph.

36. P05. L12: “However, this natural deflection in non-yawed conditions is not observed in simulations without the Coriolis effect . . .” -> add reference

37. Figure 3: It should be clearly stated whether the wake flow is looked at from upstream or downstream

38. Figure 3: The color scheme should be avoided since information is lost when printed in greyscale.

39. Figure 3: Why are the limits of the colorbar -2 m/s to 2 m/s. Are there any positive values at all?

40. Figure 3: Grid lines or ticks should be added

41. Figure 3 and Figure 4: Merging both figures would certainly make it easier for the reader to compare the impact of a positive and negative yaw misalignment on the shape of the wake.

42. Figures 3,4,8,13: Please add a reference scale for the arrows to be able to see the magnitude of the vortices.

43. P06. 03: “cut-through slices of the flow at a distance downstream of the turbine.” -> flow = longitudinal velocity component?, vertical slice?

44. P06. 08: The analysis was performed with a AD model of the turbine. The results look like the rotation of the rotor is included. Often this is not the case if an AD implementation is used. Therefore, this should be clearly stated when the model is introduced whether the rotation of the rotor is included or not. In case it is not included it should be commented on: To what extent could the results differ in a model that takes rotation into account? Is the use of “only” an AD model justified for this type of investigation.

45. Figure 4: Same comments as for Figure 3

46. P07. L02: “Visual inspection indicates some discrepancies . . .” -> In the following sentence an example about a similarity is given. Consider rephrasing.

47. Figure 5: Caption: “showing good agreement . . .” -> Consider moving the analysis

to the main text.

48. Figure 5: yaxis labeling for right column missing

49. P09. L02: Mention the method used for obtaining the wake center

50. P09. L07: “Under positively . . .” Should it be positively offset?

51. P09. L07: “Under positively . . .” Should it be “7D and more” instead of 5D? No results are shown for distances greater than 5D and smaller than 7D.

52. P09. L07: What about negatively yawed conditions?

53. Figure 6: Same comments as for Figure 1 (greyscale of colorbar, ticks, grid, . . .)

54. Figure 7: Same comments as for Figure 1 (greyscale of colorbar, ticks, grid, . . .), add “at hub height” in the caption

55. Figure 8: Same comments as for Figure 3

56. Figure 8: Caption “visualization of FLORIS 2D”, add SOWFA

57. Figure 8: YLabel: Everything is stated in “D”. Here no explanation is given, the D is missing and X is introduced. Compare labeling with Figure 13

58. Figure 9: Same comments as for Figure 5

59. Figure 9: Caption: “Power of a hypothetical behind” -> Word missing “turbine”

60. P13. L02: “. . . three-turbine cases, A . . .” Typo

61. P13. L02: “A final case simulates a tightly spaced wind farm is used to further explore . . .” -> Grammar?

62. P13. L02: Please provide the averaging time of the SOWFA simulations

63. P13 L17: The statement “we can compare the result of summing the effects of . . .” is not clear enough. It might be reformulated better.

64. P14 L3: Please specify that Fig.13 corresponds to “YawAll” scenario. Moreover, a bar graph helps to evaluate the results.

65. P15. L03: Is there a specific reason for choosing 3.5D?

66. P16. L14: Are you not influencing the wake generation and due to this the characteristics of the downstream flow. Therefore, the focus is still on controlling the wakes, because they are your tool to influence the entire flow.

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