Review of *FLOWERS: An integral approach to engineering wake models* by Michael J. LoCascio et al.

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The authors propose to apply an analytical integration method for evaluating the annual energy production (AEP) of a wind farm and compare its performance against the more common numerical integration method.

The article is well written and contains novel ideas. However, I do have some major concerns with the assumptions of proposed method and the employed methodology for comparing the analytical and the traditional AEP integration methods. More detailed comments are listed below; they need to be addressed before the article can be considered for publication in Wind Energy Science.

Main comments

1. My main concern with this work is that one needs to use constant thrust and power coefficients (for all wind speeds) in order to be able to perform an analytical integration of the AEP by integrating the velocity deficits for all wind directions and wind speeds. Wind turbines do not have constant thrust and power coefficients above rated wind speed, which makes the proposed method difficult to use for wind farm layout design and optimization. The authors propose to include more realistic thrust and power coefficients in future work, but I not see how this can be done, since the current derivation of the analytical model only holds for constant thrust and power coefficients. In addition, the errors from using constant thrust and power coefficients for a wind farm layout optimization are not properly addressed because you only investigate a single below rated wind speed where the assumption is not violated significantly. Therefore, you need to add a realistic case as well (including all wind speeds, for example from 4-25 m/s) to access the errors associated to the constant thrust and power coefficients in terms of AEP.

2. The motivation of this work is to speed up an AEP calculation using an engineering wake model. The authors report a calculation time of 16700 s for a wind farm layout optimization using a numerical AEP integration within FLORIS using a wind farm of 9 wind turbines, 360 wind directions and a single wind speed. It is not clear how many different wind farm layouts are evaluated within the optimization process, but even if this was 1000 then the calculation time per layout seems to be quite long considering the small number of turbines and the use of only a single wind speed. In PyWake [2], a single AEP calculation for a larger wind farm (e.g. 80 turbines) using 360 wind directions and 22 wind speeds typically takes less than a second, so one could easily perform a wind farm layout optimization using a numerical integral. I suspect that the numerical implementation in FLORIS could be improved significantly. PyWake is an open source tool, so you could test its AEP calculation speed yourself (the script below took 0.64 s to calculate the AEP of the Horns Rev I wind farm on DTU's Sophia cluster using a single CPU):

```
import time
import numpy as np
from py_wake.examples.data.hornsrev1 import Hornsrev1Site
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```
from py_wake import NOJ
from py_wake.examples.data.hornsrev1 import wt_x, wt_y, HornsrevV80, Hornsrev1Site
wt = HornsrevV80()
site = Hornsrev1Site()
wf_model = NOJ(site, wt)
# 360 wind directions
wd = np.arange(0.0, 360.0, 1.0)
# 22 wind speeds
ws = np.arange(4.0, 26.0, 1.0)
starttime = time.time()
# Calculate AEP
sim_res = wf_model(wt_x, wt_y, wd=wd, ws=ws)
aep = float(sim_res.aep(with_wake_loss=True).sum()
endtime = time.time()
print('AEP:', aep)
print('Total time:', endtime - starttime, 'sec')
```

3. The authors mention that the analytical integration method is more smooth and therefore better suited for optimization. While this is indeed true, one could also consider a numerical integration method using the Gaussian wake model including analytical functions for all the discrete input (Weibull, wind rose, power and thrust coefficient curve), see for example [1]. (This reference also investigates how many flow cases are necessary for an AEP calculation, which you also look at, so you could cite it.)

4. Figure 5: It is interesting to see that the analytical integration works well for only a small number of Fourier modes.

5. Line 72: You definition of the wake region,

$$W(x, y) = \begin{cases} 1, & \text{if } |y| \leq kx + 1 \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

does not hold because it would imply that there is a wake region upstream (for negative values of x). So you would need to be more precise, for example:

$$W(x, y) = \begin{cases} 1, & \text{if } |y| \leq kx + 1 \text{ and } x \geq 0 \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

which applies to a wind direction of 270°.

6. Equation (1): You forgot to define the origin, I guess it is the wind turbine location. In addition, the original NOJ model use $1 + 2k$ so your wake expansion coefficient is twice as large as the standard model. I think you should mention this to avoid confusion.

7. Sections 3.1 and 3.2: A difference of 1.8% and 8% in AEP is quite a lot considering the amount of money 1% AEP represents in a large wind arm. Therefore, a wind farm developer would go for the more precise numerical method instead of the analytical method if the error is that large.

8. Section 4.1: When you compare the results of optimized AEP between FLOWERS and Jensen, do you post evaluate the AEP of the optimized layout from FLOWERS using the numerical approach? If not, then you cannot really compare the AEP values. In addition, why do you use wake added turbulence for the Jensen model and not for the FLOWERS model? Wouldn't be more fair to apply the Jensen model in the same way (so without added wake turbulence)?

9. Can you use your analytical AEP integration model if the wake superposition method is non-linear? The wake superposition model is important part of AEP calculation using engineering

wake models and one might typically want to aplly several wake superposition methods in order to get an estimate of the model uncertainty.

Minor comments

1. The title could be more clear. When I first read it I did not think of an analytic AEP integration method.

References

[1] Murcia, J. P., Réthoré, P. E., Natarajan, A., and Sørensen, J. D. How many model evaluations are required to predict the AEP of a wind power plant? *Journal of Physics: Conference Series*, 625:012030, jun 2015.

[2] Pedersen, M. M., van der Laan, P., Friis-Møller, M., Rinker, J., and Réthoré., P. DTUWindEnergy/PyWake: PyWake, 2019.