Wake Model Description

for the

Optimization Only Case Study

IEA Task 37 on System Engineering in Wind Energy

This is an explanatory enclosure for the IEA37 Wind Farm Layout Optimization Case Studies.

AEP Algorithm

For the Optimization Only Case Study, the enclosed Python file `iea37-aepcalc.py` is what will be used to evaluate your reported `.yaml` optimal turbine locations. If you desire to implement the algorithm in another programming language, a step description is provided below. Please esure your implementation computes the same AEP value for each of the example layouts (`iea37-exXX.yaml`) also enclosed.

1. Read the following input from `.yaml` files:
   - Turbine (x,y) locations.
   - Turbine attributes (cut-in\cut-out\rated wind speed\rated power).
   - Wind directional bins (16 in this Case Study).
   - Wind frequency at each binned direction.
   - Wind speed at each direction (invariant at 9.8 m/s for these Case Studies).
2. Calculate the power produced from each turbine at each direction:
   (a) Rotate turbine locations\frame of reference so freestream follows the $+x$ direction
   (b) Iterating through each turbine in the field:
      - Apply the B. Gaussian wake Eq. (1) between each pair of turbines.
      - Use Eq. (3) to calculate the effective wind speed at each turbine.
      - Use eff. wind speed and power curve to calculate power from each turbine.
3. Use calculated power from every direction to compute AEP:
   - For each binned direction, sum power from all turbines for farm's total power generated.
   - For each binned direction, multiply farm power by wind frequency probability.
   - Sum power/probability predictions for all wind directions.
   - Multiply the sum by hours in a year (365·24), for AEP.

Wake Model Equations

The wake model for the Optimization Only Case Study is a simplified version of Bastankhah's Gaussian wake model [?]. The governing equations for the velocity deficit in a waked region are:

$$\frac{\Delta U}{U_\infty} = \left(1 - \sqrt{1 - \frac{C_T}{8\sigma_y^2/D^2}}\right)\exp\left(-0.5\left(\frac{y}{\sigma_y}\right)^2\right) \quad (1)$$

$$\sigma_y = k_y \cdot x + \frac{D}{\sqrt{8}} \quad (2)$$

Where:

Variable	Value	Definition
$\frac{\Delta U}{U_\infty}$	-	Wake velocity deficit
C_T	$\frac{8}{9}$	Thrust coefficient
x	-	Dist. from hub generating wake to hub of interest, along freestream
y	-	Dist. from hub generating wake to hub of interest, perpendicular to freestream
D	130 m	Turbine diameter
σ_y	Eq. (2)	Standard deviation of the wake deficit
k_y	0.0324555	Variable based on a turbulence intensity of 0.075 [?, ?]

Note that if the hub of interest is upstream from the hub generating the wake ($x \leq 0$), it feels no wake effects ($\frac{\Delta U}{U_\infty} = 1$). Partial wake is not considered. Hub coordinates are used for all location calculations. For turbines placed in multiple wakes, the compound velocity deficit is calculated using the square root of the sum of the squares, depicted in Eq. (3):

$$\left(\frac{\Delta U}{U_\infty}\right)_{cmbnd} = \sqrt{\left(\frac{\Delta U}{U_\infty}\right)_1^2 + \left(\frac{\Delta U}{U_\infty}\right)_2^2 + \left(\frac{\Delta U}{U_\infty}\right)_3^2 + \dots} \quad (3)$$