# Shell.ai Hackathon for Sustainable and Affordable Energy

Windfarm Layout Optimisation Challenge

## Wake Effect Modeling

Wake effect in a wind turbine layout can be described as the inter-turbine interference, due to which a turbine downstream of some upstream turbine may experience deficit in wind. This depends on: *(a)* whether the downstream turbine is inside the wake region of the upstream turbine, and *(b)* how far is the downstream turbine located from the upstream turbine.

**PARK Model.** There are several ways through which, it is possible to model the wake effect among wind turbines. We have used the classical Jensen model, also known as PARK model here. The Jensen wake model is the most popular model in this area due to its high simplicity and practicality and is also the standard implementation in the wind resource assessment of many commercial softwares .

According to the PARK model, the equation for deficit due to a wake inducing upstream turbine is given by:

$$\frac{\Delta V}{V_\infty} = \begin{cases} (1-\sqrt{1-C_T})\left(\frac{D}{D+2k_w x}\right)^2 & \text{, if} \quad x > 0 \quad \text{and} \quad y \leq (D+2k_w x)/2 \\ 0 & \text{, otherwise} \end{cases} \tag{1}$$

, where the description of the variables above in the equation is provided is provided below.

| | |
|---|---|
| $\Delta V$ | - Reduction in wind speed at a downstream distance $x$. |
| $V_\infty$ | - Unhindered free stream wind speed in m/s. |
| $C_T$ | - Thrust coeffecient. Is estimated based on the value of $V_\infty$ |
| $D$ | - Wake inducing turbine rotor diameter in meters. |
| $k_w$ | - Wake decay constant. Typically has value 0.05 for offshore cases |
| $x$ | - Distance of target location from wake generating turbine, along free stream |
| $y$ | - Distance of target location from wake generating turbine, perpendicular to free stream |

A diagrammatic representation of wake expansion and deficit as described by the PARK model is shown in Figure 1.

> *Note that we do not take partial wakes into consideration and ignore the wake effect if the turbine center of a target turbine is not falling inside the wake region of a wake generating turbine.*

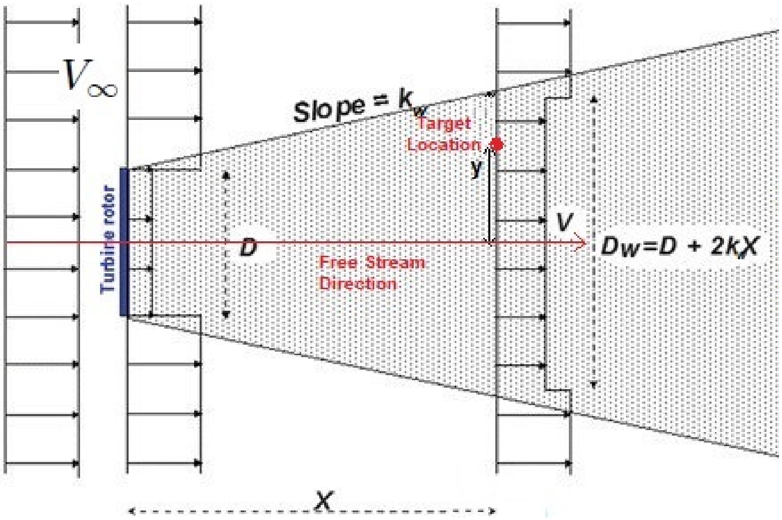


Figure 1: Wake expansion and deficit as modeled by the PARK model of N.O. Jensen. Image reference provided in the main problem statement document.


Figure 2: Turbines experiencing multiple wakes. As an example, turbine 3 is experiencing wake effects from both turbine 1 and 2. Image reference provided in the main problem statement document.

### Wake Combination.

In a wind farm, it usually happens that a single turbine may be experiencing wake effects from multiple turbines (Figure 2). In such cases, we first independently calculate the deficit due to wake effect from each contributing upstream turbine on a target downstream turbine (using Eq. (1)) and then the total deficit suffered by this target turbine is calculated by using the square root of the sum of squares of the deficit from each upstream turbine:

$$\left(\frac{\Delta V}{V_\infty}\right)_{\text{total}} = \sqrt{\sum_{i=1}^{n}\left(\frac{\Delta V}{V_\infty}\right)_i^2} \tag{2}$$

, where $n$ is total number of wake causing upstream turbines and $\left(\frac{\Delta V}{V_\infty}\right)_i$ is the individual deficit due to $i^{th}$ turbine among $n$.