Operating wind park study: Better understanding of wind turbine direction deviation

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Abstract

The impact of the wake in terms of wind speed deficit was studied under many aspects by the wind industry but is less documented regarding wind direction bias.

The analysis relies on a case study conducted on a Wind Park located west part of France, with a supervision meteorological mast following IEC61400-12-1 conditions. It is used as a trusted external reference of direction. To perform the analysis, the comparison was done between the supervision met mast wind direction and the directional data from the turbine (wind direction / nacelle direction), only for the waked-free sector of the mast.

The objectives are:
- Monitor the direction deviation of the wind turbines on this Wind Park,
- Analyse the impact of external wind conditions: vertical wind shear and turbulence intensity at the mast,
- Understand the behaviour of the wind turbines in such conditions.

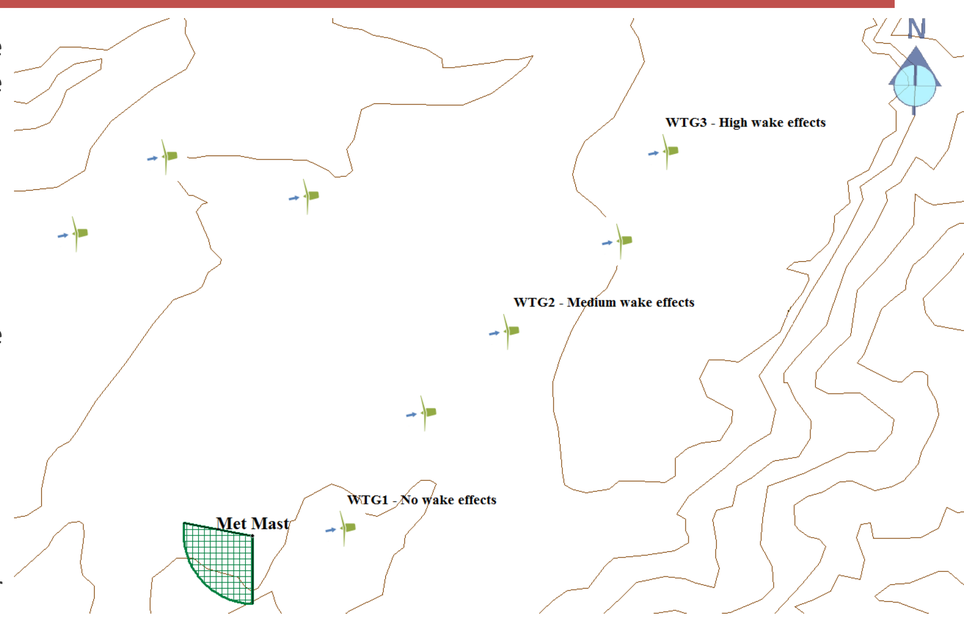
Methodology

The directional deviation (referred hereafter as “deviation”) is defined by the difference between the nacelle direction and the wind direction measured by the mast. A directional analysis using the met mast as reference is conducted on the wake-free sector of the mast i.e. [180° ; 280°].

The methodology is based on the following step :
- Calculation of the deviation
- Plot deviation vs direction (median of the deviation per direction bin of 1°)
- Compare the evolution of the deviation in the wake-impacted sectors of each turbine
- Study the influence of parameters such as wind shear and turbulence intensity on the direction deviation. The whole operational conditions are covered and analysed.

Three turbines are selected in such a way that in the free sector of the met mast:
- WTG 1 is not impacted by wake, serves as reference for the analysis,
- WTG 2 is impacted by the wake of two WTGs
- WTG 3 is impacted by the wake of four WTGs

The graph on the right is presenting the site with the selected turbines and the met mast with the directional wind sector emphasized for the analysis.

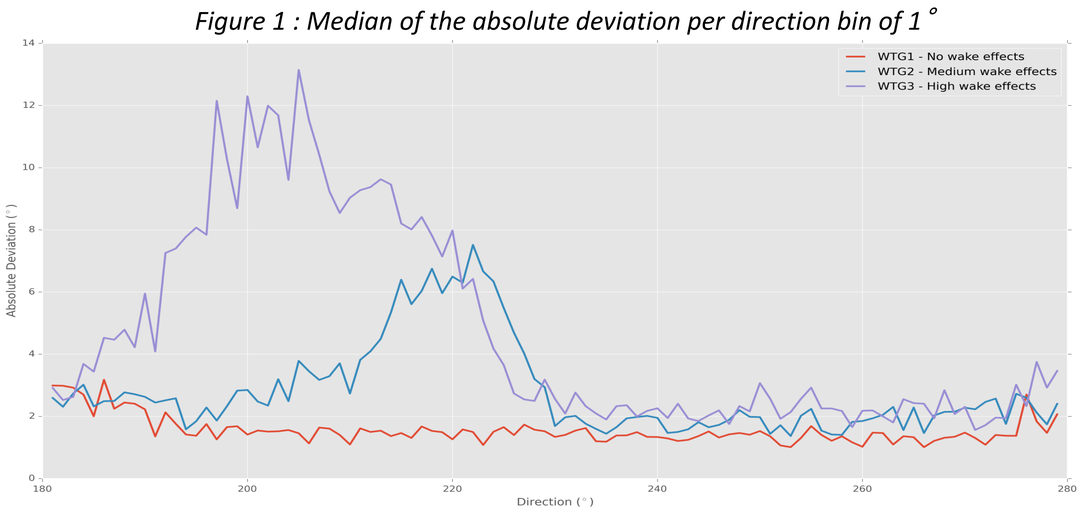


Results

The deviation between reference met mast direction and nacelle direction is plotted against several key parameters external to the turbine :

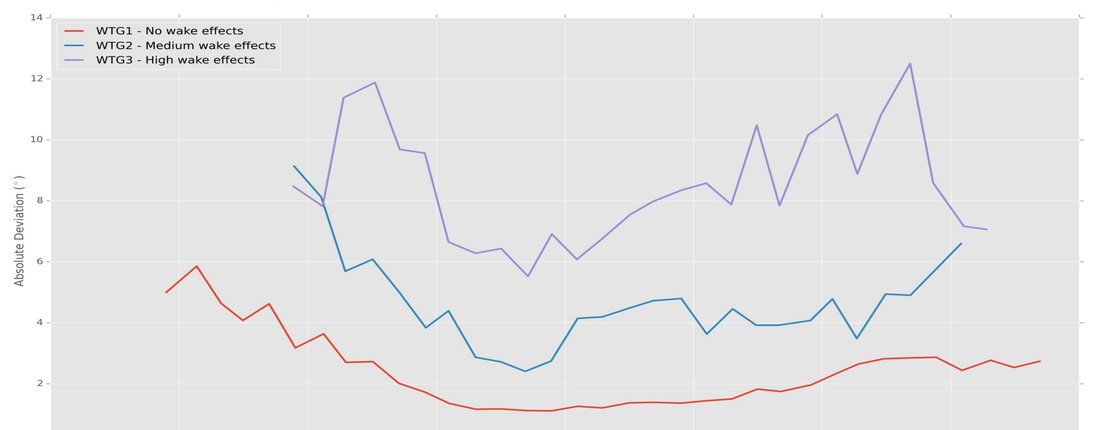
1. Wake created by upwind turbines: the median of absolute directional deviation over the wake free sector of the met mast is plotted in figure 1:
   - The non wake-impacted WTG1 shows little direction deviation (red curve).
   - Deviation spikes appear in the wake impacted sectors for the two wake impacted WTG2 – WTG3.
   - The intensity of the deviation increases with the intensity of the wake.

Figure 1 : Median of the absolute deviation per direction bin of 1 °



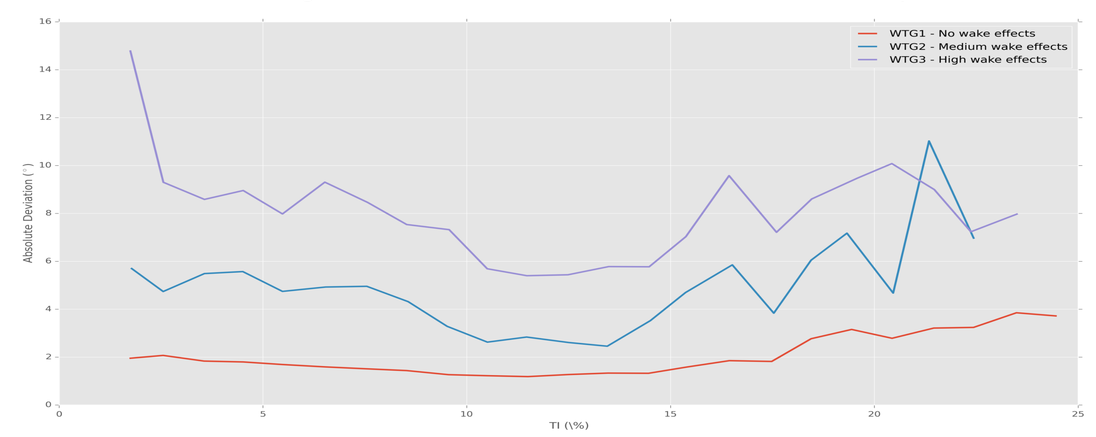
2. The vertical shear is calculated based on wind speed at 100m and 80m. The considered wind shear ranges from negative values to 0.3 and covers values outside the boundaries of the wind turbine model
   - The WTG1 deviation remains lower whatever the shear
   - The behaviour of direction deviation evolves in a parabolic fashion with the shear
     - The deviation increases for low or negative shear
     - The deviation increases for high shear
     - For the three WTGs, the minimal deviation occurs at 10° .

Figure 2 : Absolute deviation versus shear



3. The ambient turbulence intensity is calculated by the top anemometer of the met mast. In free sector, the turbulence does not take into account the wake.
   - WTG1 deviation remains lower whatever the shear
   - Direction deviation increase for both low and high site turbulence.
   - WTG2 and WTG3 display increased direction deviation for low and high wake.
     - For WTG3, the direction deviation is higher at low TI
     - For WTG2, the direction deviation is higher at high TI
   - A minimum of direction deviation occurs around 12% TI, a sharp increase occurs for a site turbulence of 15%.

Figure 3 : Absolute deviation versus turbulence intensity



Conclusions

Precise monitoring of a Wind Park is essential for efficient operation and underperformance detection. This study gives a better understanding of the turbines behaviour in terms of direction, so that an incorrect performance pattern can be identified with more accuracy.
It provides a wider overview of the wake impact on the turbine behaviour.
- Direction deviation induced by shear effects, as well as turbulence effects, are amplified by the wake.
- Turbines located in a wake impacted sector have a higher deviation than the others.

This could have an impact on important parameters for the park health and good monitoring : loads and vibrations on the turbines, production efficiency, accuracy , accuracy of directional data, etc.