PO.086c

Wind Farms Production under Wake Conditions

Bruno Pinto[1,2], Jérôme Imbert[1], Dominique Legendre[2]
1 - SEREEMA, Montpellier, France
2 - Institut de Mécanique des Fluides de Toulouse, Toulouse, France

Introduction

Wind farms are characterized by interferences due to wake effects between the wind turbines resulting in power losses in the farm production. The global power loss of the farm varies with multiples parameters, such as the relative position of the wind turbines, their spacing, the terrain and the atmospheric turbulence amongst others. Quantifying the power losses is therefore of great importance to the understanding of the wind turbines production under wake effects.

The processing and analysis of existing data can improve the comprehension of the operation of already installed farms as well as the new developments in wind energy. Three different single lined wind farms (Farm1, Farm2 and Farm3) were used as test cases for the wake power losses analysis courtesy of EDF Energies Nouvelles.

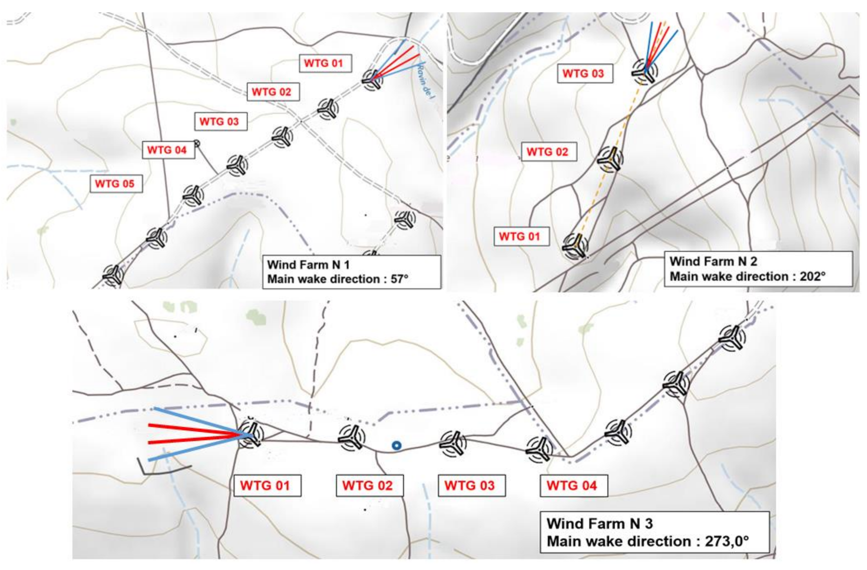

Figure 1: Geographical positioning and turbine placement of the 3 studied wind farms. 10º width between the red arrows and 30º width between the blue arrows

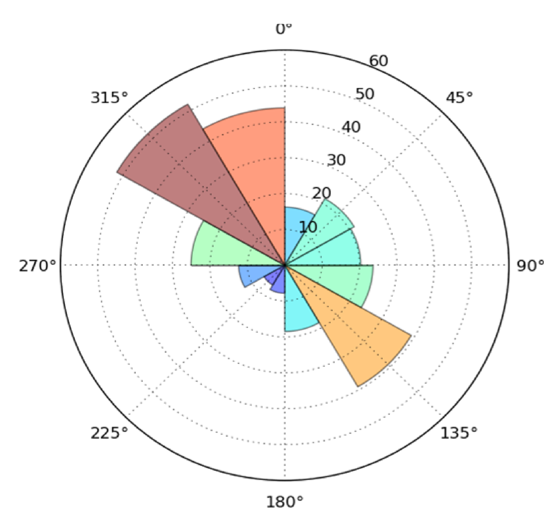

Figure 2: Load Factor at wind farm Farm1 2010-2014 obtained from SEREEMA's data analysis program

Methods

The analysis was based on 10 minutes averages SCADA data for the power of each turbine, the wind speed and direction that correspond to the entire period of January 2010 to December 2013 for wind farm Farm1 and to April 2014 for Farm2 and Farm3.

The data was then selected using a data analysis program that was specially developed for wind turbine performance analysis using SCADA data. In our study, we have selected the data of interest for the wake effects analysis. They correspond to the record data for the wind sector centered on the turbine alignment (Fig. 1). Different wind sectors widths were considered as well as several peculiar wind speeds 6, 8 and 10 m/s +/- 0.5 m/s.

The power deficit can be characterized by introducing the wind farm efficiency E_W by comparing the averaged power produced by the farm to the maximum power observed in the farm P_{max} as:

$$E_W = \frac{\sum_{k=1}^{N} P_k}{N\, P_{max}}$$

where P_k is the power of turbine k and N is the number of wind turbines on the cluster. Here E_W is calculated for specific wind sectors.

A different approach to quantity the power losses consists in the normalization of the wind turbines on the cluster production by the production of the head turbine. This approach permits the analysis of the evolution of the power losses in the cluster. Both approaches were studied for the 3 wind farms.

Results

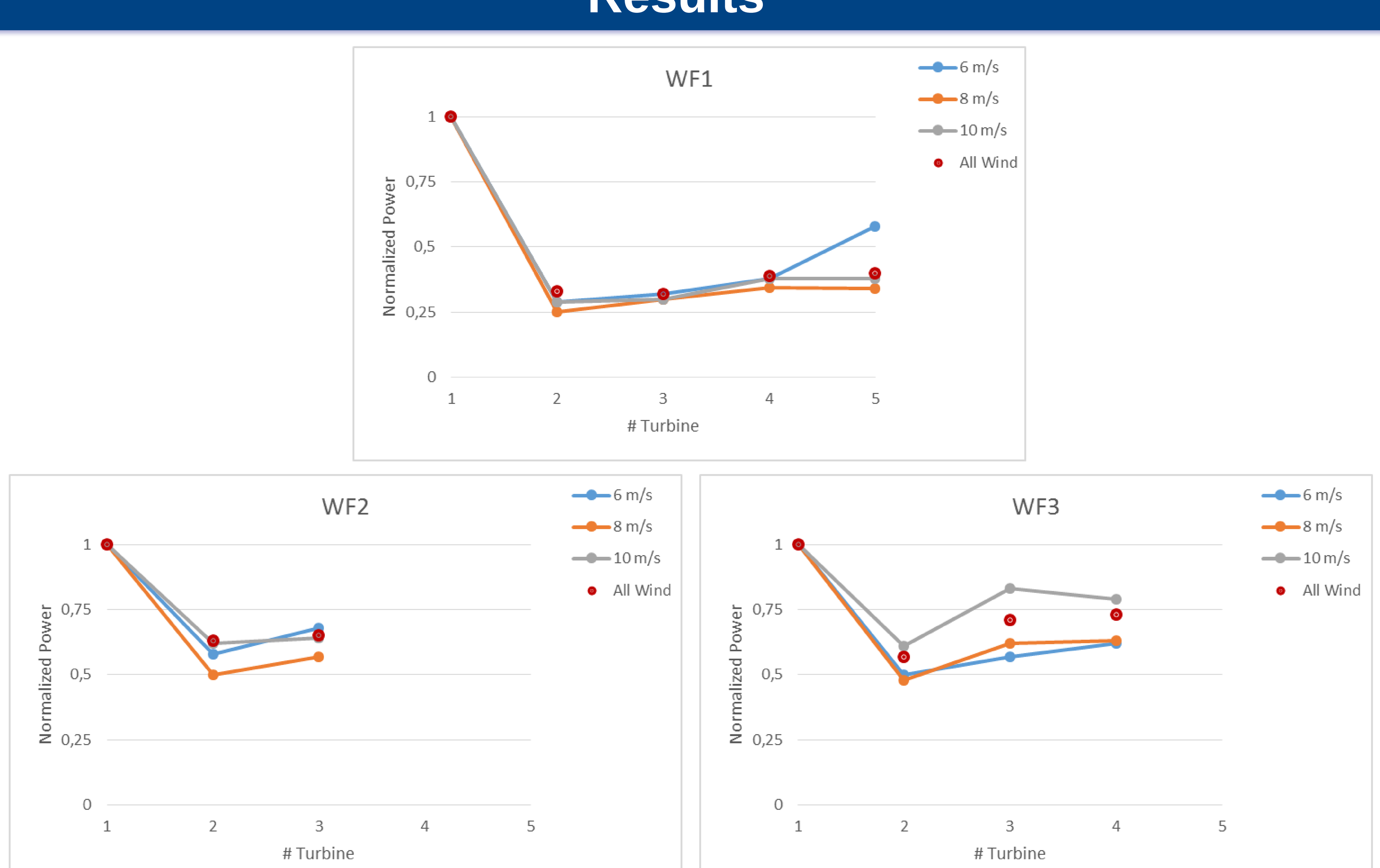

Figure 3: Normalized power on the wind turbine cluster of the wind farm Farm1 (top), Farm2 (bottom left) and Farm 3 (bottom right) for the wind speeds of 6, 8 and 10 m/s +/- 0.5 m/s and for all wind speeds taken into account. The wind sector analyzed corresponds to the turbine alignment +/- 5º.

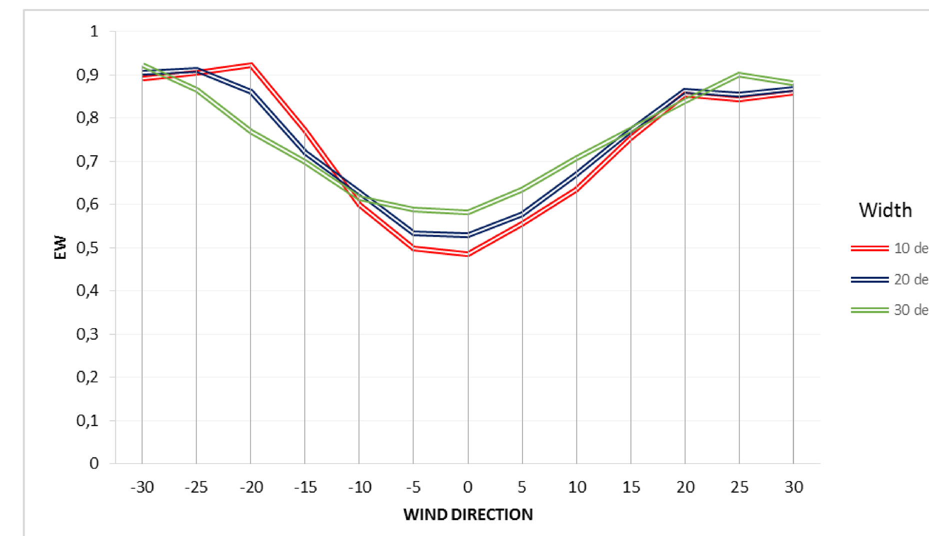

Figure 4: Evolution of the wind farm "wake efficiency" E_W for Farm1 as a function of the wind direction. The angle is 0 when the wind direction is aligned with the farm alignment.

ETA	All Winds	6 m/s	8 m/s	10 m/s
Farm1	0,50	0,51	0,44	0,47
Farm2	0,75	0,76	0,70	0,74
Farm3	0,75	0,68	0,69	0,82

Table 1: Values of the wind farm "wake efficiency" E_W for the 3 wind farms at wind turbine alignment with a wind sector width of 10º. The results are presented for the wind speeds 6, 8 and 10 m/s +/- 0.5 m/s and for all wind speeds taken into account.

The evolution of the normalized power (Fig.3) shows that the difference in power production is mainly observed between the head turbine and the second turbine and then the power of the successive turbines is almost constant.

On the other hand, the wind farm efficiency evolution (Fig.4) allows the detection of the wind directions impacted by wake effects: turbine alignment +/- 20º for the case of Farm1. In addition, Table 1 shows that Farm1 is the most impacted by wake power losses and that the wind speeds of 8 +/- 0.5 m/s correspond to lower efficiency values.

We show that the power losses are controlled by the power loss between the first and the second turbine and they reach a maximum for a wind sector width of 10º centered with the turbine alignment and for wind speeds of 8 m/s.

The influence of the non-dimensional wind turbine spacing, is presented in Fig. 5. For the presented results the power difference tends to stabilize for a spacing comprised between 3 and 4 diameters, as a critical spacing seems to exist under which the power losses tend to largely increase.

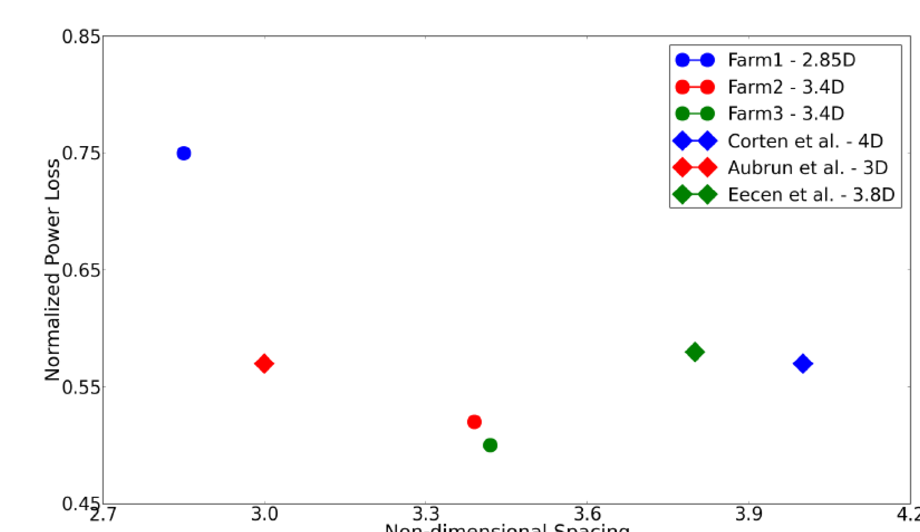

Figure 5: Evolution of the Normalized Power Losses of the second wind turbine on the cluster with the non-dimensional spacing of the wind turbines. Our results are compared to those found on the literature: [1], [2] and [3].

Fig. 6 reports the normalized power for a particular event: Farm1 has experienced long periods of time where one of the wind turbines (the 4th in the cluster) was stopped. Selecting the data corresponding to those conditions, a direct comparison can be made between the normal condition and the case of a stopped wind turbine.

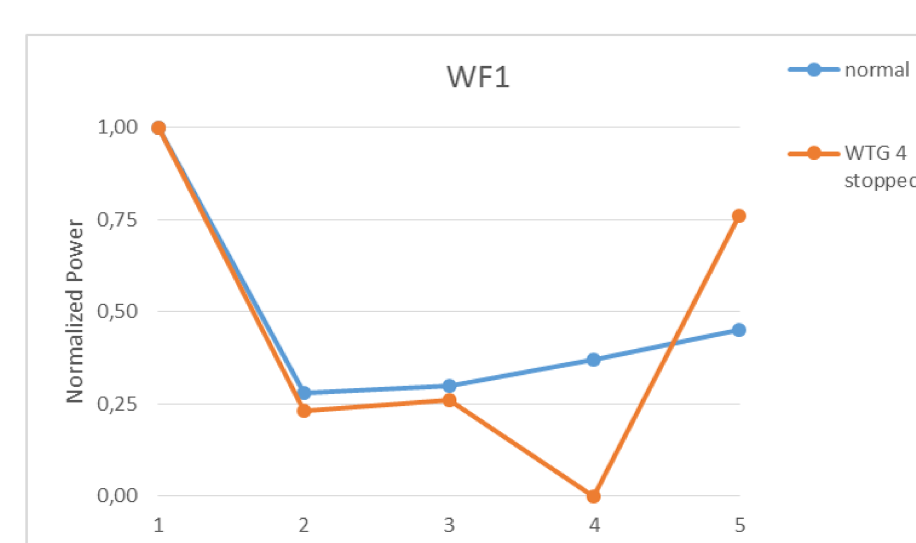

Figure 6: Comparison of the normalized power of the cases: (1) all working wind turbines and (2) 4th wind turbine at a stop.

The downstream turbine of the stopped one is able to recover 30% of the normalized power production when compared to the normal case.

The overall production of the wind farm does not increase in this case, nonetheless a potential gain in production seems attainable with an optimized control of the wind farm.

Conclusion and Further Work

Our work presents the quantification of wind farm power losses due to wind turbine wake effects for 3 wind farms. The influence of the wind sector, wind speed and turbine spacing were analyzed. Our approach was then applied to data where a wind turbine was stopped and a recovery in production was observed on the downstream turbine. Our future goals are to better understand the influence of each parameter using SCADA data in order to identify conditions where gains in production are attainable.

References

1. S.Aubrun, Ph. Devinant and G. Espana; Physical modelling of the far wake wind turbines. Application to wind turbine interactions. EWEC 2007, Milan, 2007
2. G.P. Corten, P. Schaak and T. Hegberg. Velocity profiles measured above a scaled wind farm. EuropeanWind Energy Conference, London, 2004.
3. P.J. Eecen, S.A.M. Barhost, H. Braam, A.P.W.M. Curvers, H. Korterink, L.A.H. Machielse, R.J.Nijdam, L.W.M.M. Rademakers, J.P. Verhoef, P.A. van derWerff, E.J.Werkhoven and D.H. van Dok. Measurements at the ECN wind turbine test location Wieringermeer. EWEC, Athens, 2006.
4. G.Espana. *Etude expérimentale du sillage lointain des éoliennes axe horizontal au moyen d'une modélisation simplifie en couche limite atmosphérique*. Ecole doctorale sciences et technologie, Orleans. 2009
5. A.C. Pillait, Dr. J. Chick and V. de Laleu; Modelling Wind Turbine Wakes at Middlegrund Wind Farm. EWEA, Barcelona, Spain, 2014.

EWEA 2015 – Paris – 17-20 November 2015