European Wind Energy Conference 2009

Micro-scale effects over an operational wind farm: CFD wind shear study

Antonio Angulo, Pep Moreno, David Madueño
ALSTOM Ecotècnia

Abstract summary

Two turbines of an operational wind farm had some problems and stopped, apparently when wind was blowing from a nearby hill. A CFD study using WindSim software was performed in order to reproduce the wind flow around the turbines and to find non-linear effects caused by the hill.

The most remarkable effect found was a very high wind shear profile at hub height in the affected turbines compared with the not affected nearest ones. Large wind shear could be the reason of structural vibration problem that stopped the turbines.The results of the research allowed then for a implementation of a start-stop strategy of the turbine control that avoided the accidental stops.

Objectives

The purpose of this work was to find why, during westerly wind episodes (with hub-height speed above 10m/s), two specifc turbines (T20 & T21) experienced structural vibrations large enough for their control to react stopping them.

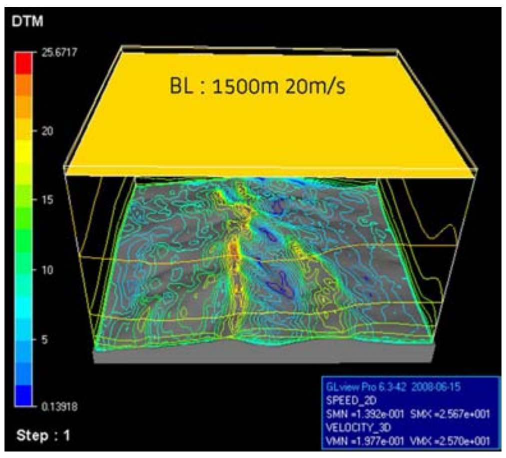
View of the hill from T20. The top of the hill is 415m away from T20 and 60m higher.

General view of affected turbines (T20 and T21, in red) and neighbouring turbines included in the study (T28 and T22).

At a first glance, after discarding wakes from surrounding wind turbines, we suspected of a re-circulation problem caused by a nearby, abrupt, higher hill located 430m west from the two affected turbines.

In order to recreate micro-scale effects, WindSim software, (PHOENIX solver) CFD simulation of the affected area was performed.

Methods



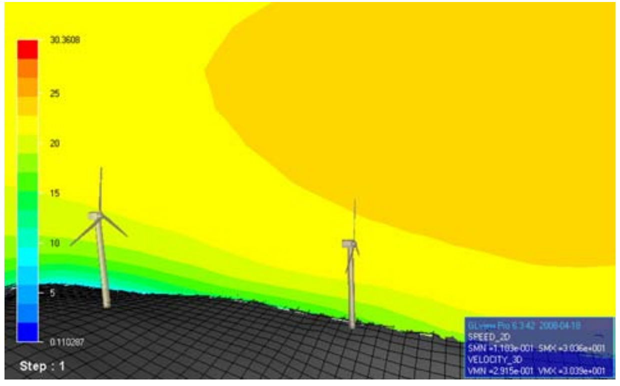
Workspace for CFD simulation. The speed displayed is not scaled with the wind farm measured data.

We performed the CFD in a workspace with a 9x12km topography and a grid with a minimum cell spacing of 11.9m. The upper boundary layer was set to fixed pressure.

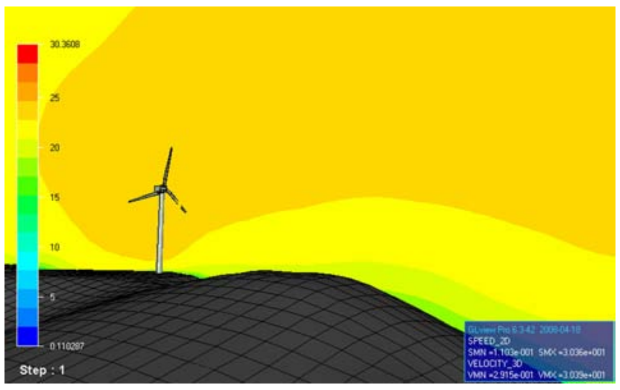
An extended iterative process was necessary to achieve the convergence for west wind directions. Our attention focussed in 270 and 250deg.

Results

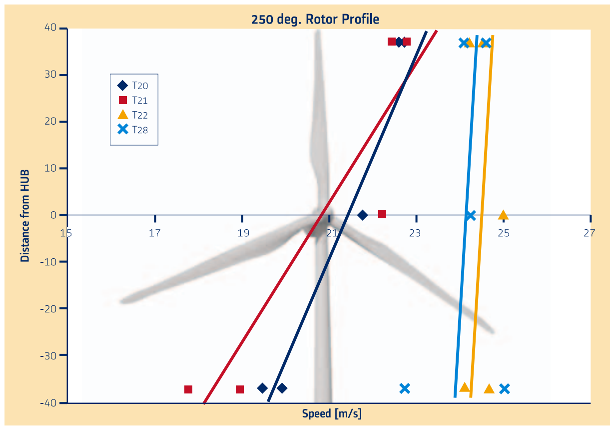
Although no recirculation was found at the lee side of the hill, a very high wind shear was detected at the two affected wind turbines positions in contrast with the much flatter profile found at the neighbouring turbines (see T28 for example).



2Dspeed cut-plane orthogonal to 250deg in T21 position.



2Dspeed cut-plane orthogonal to 250deg in T28 position.



Speed profile at hub height. Lines are only indications.

The error reported from the turbine control is usually associated to very different loads over the blades. That load gradient spreads to the nacelle and are detected as a structural vibration error. A large wind shear could perfectly be the source of such load differences.

Conclusions

Most wind farm projects are designed using industry-standard linear flow models. However, on complex terrain, wind behaviour often gives unpleasant surprises creating difficulties for the operation of the turbines.

In the studied case, the application of CFD Windsim model allowed the detection of a zone of unexpectedly high wind shear which, apparently, was the reason of the stop of the machines due to structural vibrations.

With the aid of the simulation, the range of conflictive wind directions (all from the lee side of a nearby hill) was estimated allowing a narrow definition of an start-stop strategy of the turbines control that avoids the accidental stop of the machines.

References

1. Moreno J., Gravdahl A.R. & Romero M.(2003). Wind Flow over Complex Terrain: Application of Linear and CFD Models.EWEC Proceedings, 16-19 June 2003, Madrid.
2. Calbó J., Pozo M., Moreno J. & Gravdhal A.R. (2006). Micro-scale effects over the wind: Modelling flow around buildings with Windsim-Phoenics. EWEC Proceedings, 27 Feb. – 2 March 2006, Athens.

ALSTOM ecotècnia