METEODYN_WT: SITE ASSESMENT ON COMPLEX TERRAIN

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ABSTRACT

Complex terrain is not only a challenge for energy yield evaluation but also an issue for load evaluation and site certification of wind turbines. This last issue is not easily investigable as only few sites are adequately instrumented to conduct a full validation of the different wind components. In this paper, comparisons of different wind-flow model, in-site measurements, and standard approach are presented. The main features investigated are up flow angle, turbulence intensity, and extreme wind speed. Results points out the improvement that can be derived by taking advantage of the latest advances in CFD for wind resource assessment and draw up new methodology for site assessment on complex terrain. Results are given for the present test cases and are not supposed to represent the standard accuracy of the different models or methods.

INTRODUCTION

As a wind turbine manufacturer, GAMESA is deeply involved in improving the methods to evaluate wind flow characteristics and especially those involved in the lifetime of a wind turbine. Some of the most relevant parameters regarding fatigues and turbine performances are the up-flow angle, wind shear and the turbulence intensity. Hence GAMESA hold some met masts accurately instrumented with 3D Sonic Anemometers at two or three different measurement heights. Thank to these met mast data GAMESA has been able to measure, for the concerned projects, directional up flow angle properties as well as turbulence intensity.

These measurements are compared with results obtained by different CFD approach, Linearized model and empirical formulae.

Classical methods consist in deriving those parameters from slope, height above ground or roughness. This takes additional time on a project and can lead to strong uncertainties on a complex terrain. Thank to recent CFD models as Meteodyn WT, wind flow calculation gives these information by resolving the full Navier stokes equations for momentum and mass. Many papers have already tested the performance of CFD on evaluating wind speed and production. Here, the paper focus on other important information regarding the wind flow properties and benefits from “a manufacturer point of view”.

UPFLOW ANGLE

Upflow angle has a crucial impact on the life time of a wind turbine on a complex terrain. Following the IEC 61400-1 Ed3 this wind parameter has to be computed for any cases where the upflow angle may exceed 8°. It is defined as the inclination of the flow at hub height compared to an horizontal plane.

Different approaches to compute this angle are investigated here and compared with site measurements. Fig 2. points out the terrain slope on the masts surroundings.

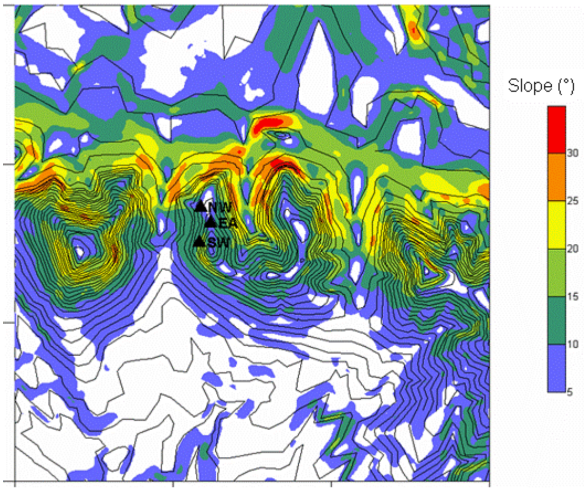

Figure 2: Slope around met masts.

Measurements have been conducted at 43m above the ground during 6 months on both masts with 27260 pairs of validated data. It has to be pointed out that roughness is almost constant and very low around the area.

Results at figure 3 points out the conservative approach given by the IEC 61400-1 Ed 3 recommendation. In this standard, it is said that in absence of upflow site data and where the terrain is complex, it shall be assumed that the flow is always parallel to the fitted plane within a distance of 5 times the hub height from the wind turbine .In order to better compare the results vs measurements, the fitted planes have been made by directional sectors.

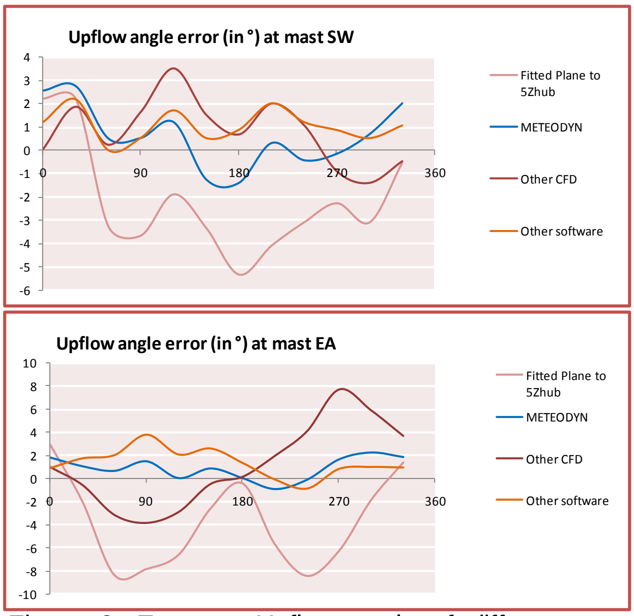

Figure 3: Error on Upflow angle of different models by sector

Meteodyn WT gives here consistent results compared to measurements.

A more in deep analysis of the upflow angle shows that its values is not constant whether the wind is strong or not. As many wind flow parameters, it is not surprising to find that the upflow angle is dependent to the thermal stratification of the atmosphere. Indeed, On a general basis, percentage of time under stable stratification is much more significant under low wind speed situation. This is quite well represented by figure 4 where we can observe a decrease of positive upflow angle under low wind speed situations, and an increase of negative upflow angle under the same situation. This matches Meteodyn WT simulation results under different stratification classes.

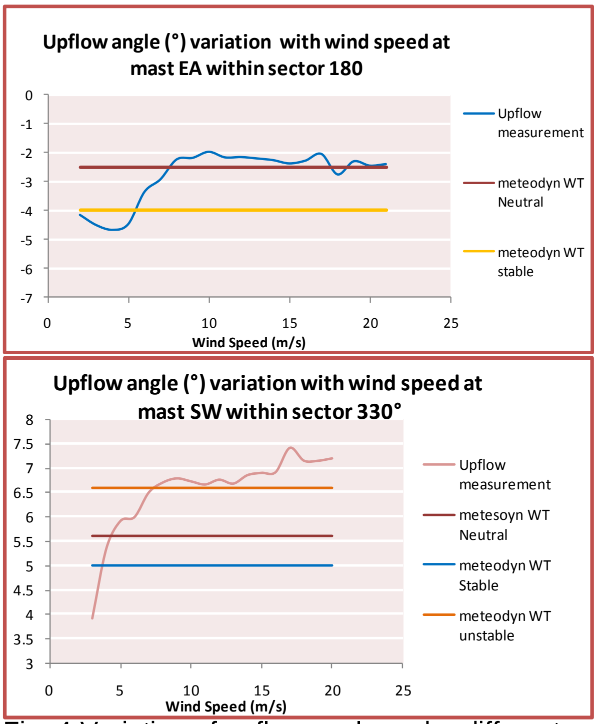

Fig. 4 Variation of upflow angle under different thermal stratification

Obviously, low wind speeds do not lead to the same loads than high wind speeds, but if we combine higher wind shear (usually the case at low wind speed) and negative upflow angle (which might be also associated to slightly higher turbulence places), this can definitively have an impact on a wind turbine life time.

The horizontal standard deviation of the wind direction is currently under examination in order to quantify the thermal stability impact on the test site regarding upflow angle and turbulence.

TURBULENCE INTENSITY

In the IEC61400-1 edition 3, the representative turbulence intensity standard deviation, σ_1 , is given by:

$$\sigma_1 = I_{ref} * (0.75 * V_{hub} + 5.6)$$

Where Iref represents the mean turbulence intensity for a 15m/s wind.

For high wind velocity, the atmospheric boundary layer is most of the time driven under a neutral thermal stratification. This might enable any CFD model to adequately represent the boundary layer condition as the atmospheric stratification is not fluctuating through the time. Hence, Iref might be calculated with CFD modelling approach. For this study, Iref values have been calculated by sectors. Results obtained on site 1 are presented in figure 5.

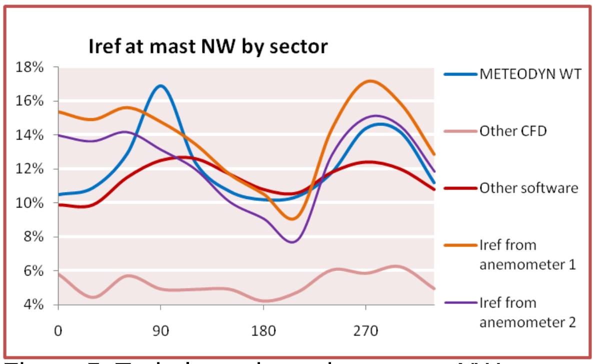

Figure 5: Turbulence intensity at mast NW

Any microscale modelling approach is limited by the fact that meso-turbulence could not be taken into account through the inlet conditions of the model. A specificity of these meso-turbulences is that they've got a large length scale.

To take into account these site specific conditions, a new method is presented here. It consists in calibrating the meteodyn WT results on turbulences thanks to on-site turbulence measurements by directions assuming that the modelling error is due to these mesoscale turbulences and that these turbulences have the same impact through the site. Results presented figure 6 looks to be promising.

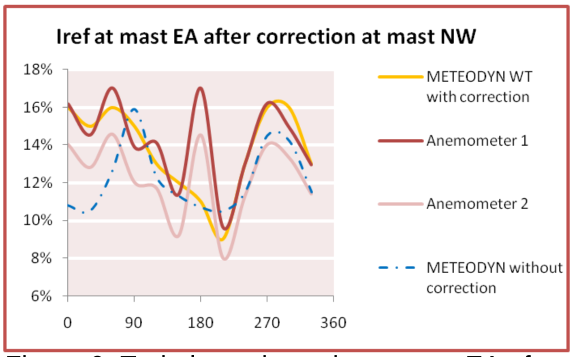

Figure 6: Turbulence intensity at mast EA after Calibration

Indeed, mean Iref looks to be accurately represented on the three available masts as pointed out on table 1:

Iref (%)	Mast EA	Mast SW	Mast NW
meteodyn WT without correction	15.2%	15.8%	15.3%
meteodyn WT corrected at mast NW	13.7%	14.2%	13.7%
Anemometer 1	14.2%	14.6%	14.0%
Anemometer 2	12.3%	12.6%	12.0%

Table 1: Iref modelled by meteodyn WT compared with measurements

EXTREME WIND SPEED

Reference wind speed (Vref) is defined as the extreme wind speed that might occur at each wind turbine location within a period of 50 years. This event may come from a wide range of directions, as a storm is not monodirectional, and might not come from a sector defined as the more energetic of a wind rose.

From this definition it looks obvious to take the worst directional sector (regarding Speed-up factor) to extrapolate to the wind turbine positions the Vref obtained from measurements. Nevertheless a site climatology study shows that usually, storms took place from a defined sector of the wind rose. Then, to extrapolate Vref from the met mast to each wind turbine location by applying the highest directional speed up factor should be conservative.

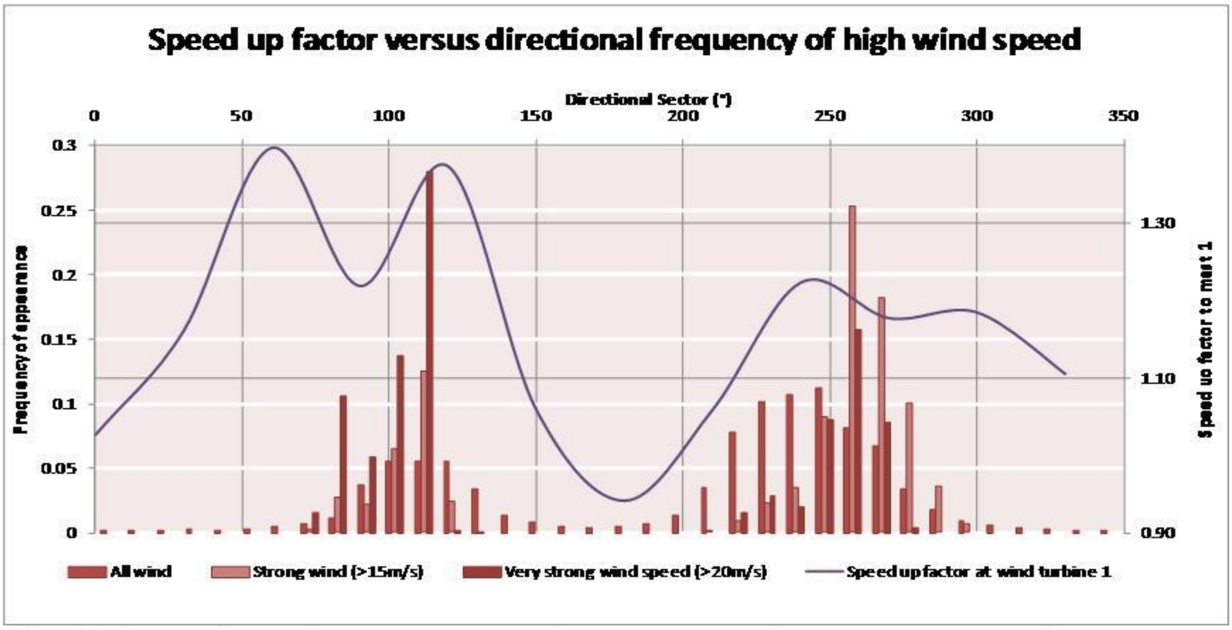

Figure 7: Speed-up factor versus frequency of appearance of strong wind event

Figure 7 points out the different speed-up factors that might be taken into account to extrapolate a measured extreme value at a mast location to a wind turbine location on a real case. The figure also draws the frequencies of appearance of strong wind event by sector. In this case, the more likely sector in which the Vref might happen is not corresponding to the sector with the highest speed-up. So far, Meteodyn WT, which applies the EUROCODE NV95, will tend to be very conservative in its results concerning Vref. In this case, Meteodyn WT gives a 45m/s Vref. If a directional analysis of the Meteodyn WT results is conducted a value of 36m/s is obtained. This is close to values obtained applying other methods. At a second mast of this site, the results given by Meteodyn WT is really close to the results obtained by measurements.

CONCLUSION

Site assessment is of crucial importance for any wind farm project as it will enable to verify if the expected wind turbine will bear the loads to which it will be confronted during its lifetime. As the terrain became more complex, its became harder to evaluate the different wind properties relevant for the site assessment.

New tools are available to assess some of the crucial parameters as upflow angle, turbulence or extreme wind speed. On the presented test cases some of these tools are investigated and results are encouraging.

Classical methods consist in deriving upflow angle from slope and height above ground and looks to have quite a conservative approach. Results appear to be improved by advanced wind flow models.

Regarding extreme wind speed, the Meteodyn WT approach is quite conservative. A directional analyses of the “extreme wind events” must be conducted and applied to the directional results given by Meteodyn WT. This might be implemented in a next version of the software.

Regarding turbulence, the results shown that Meteodyn WT turbulence values are quite similar to the Iref values according to IEC61400-1 Ed3. Confidence on turbulence extrapolation is quite high especially whether a turbulence calibration has been made.