VALIDITY CHECK OF NUMERICAL SITE CALIBRATION ACCORDING TO IEC 61400-12-1 ED.1 AND MEASNET PPMP V4

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ABSTRACT

According to IEC 61400-12-1 [1] and MEASNET [2] standards a site calibration (SC) has to be undertaken prior to a power performance measurement (PPM) if the terrain doesn't meet the requirements stated in Annex B of the IEC 61400-12-1 standard [1]. Under some circumstances it is allowed to evaluate the terrain influence on the flow by terms of a flow model (Numerical Site Calibration). The suitability of a CFD flow model Meteodyn WT (version 3.9.5) was evaluated for 9 sites in Spain which present different magnitude of complexity and roughness. All in-situ SC were realized by WINDTEST Ibérica S.L. according to [1] and [2]. To evaluate the suitability of the used CFD model, measured and simulated wind speed data were compared for turbine position.

OBJECTIVES

The aim of the undertaken work was to validate the CFD model Meteodyn WT and evaluate the associated errors in the context of numerical site calibration. For this purpose, evaluations with different thermal class and domain computation as well as for different terrain complexities were performed for all 9 sites.

INTRODUCTION

Power Performance Measurement is a standard measurement to determine the compliance of the measured turbine power curve with the guaranteed power curve. The setup of a PPM without SC can be observed in Figure 1.

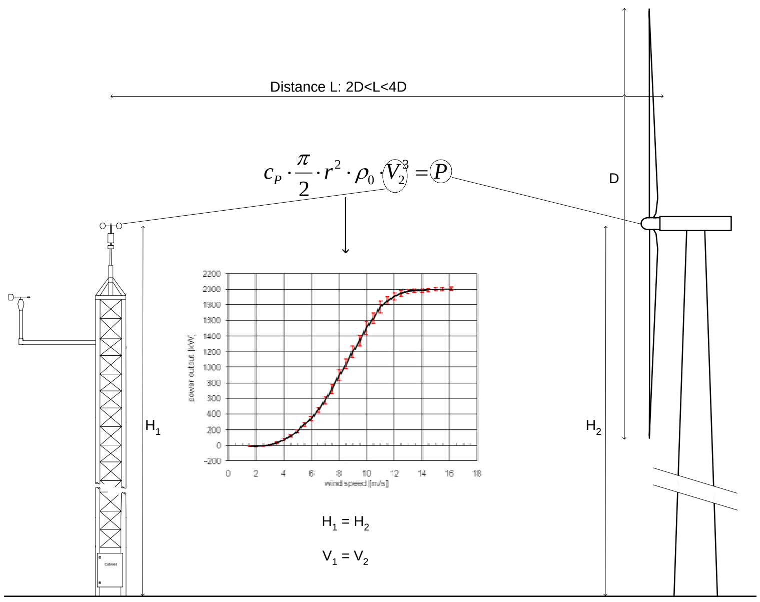


Figure 1: Power Performance Measurement Setup in flat terrain (unscaled)

According to the international standard IEC 61400-12-1 [1], a site calibration measurement has to be undertaken if the terrain where the wind turbine is erected does not meet the requirements established in Annex B [1]. To calibrate the site, a second meteorological mast has to be erected at the future turbine position to determine the sectorwise correction factors. Examples for semi-complex and complex terrains can be observed in Figure 2.

Figure 2: semi-complex (left) and complex (right) terrains

The measurement setup for such a site calibration can be observed in Figure 3. Only if the values of terrain slope are within an additional 50% of the established values a flow model can be used to determine if there is a flow distortion due to the terrain. An in-situ SC can then be avoided if the flow distortion at 10 m/s stays below 1% between both masts position. To use the flow model it is necessary to validate it for the present terrain type.

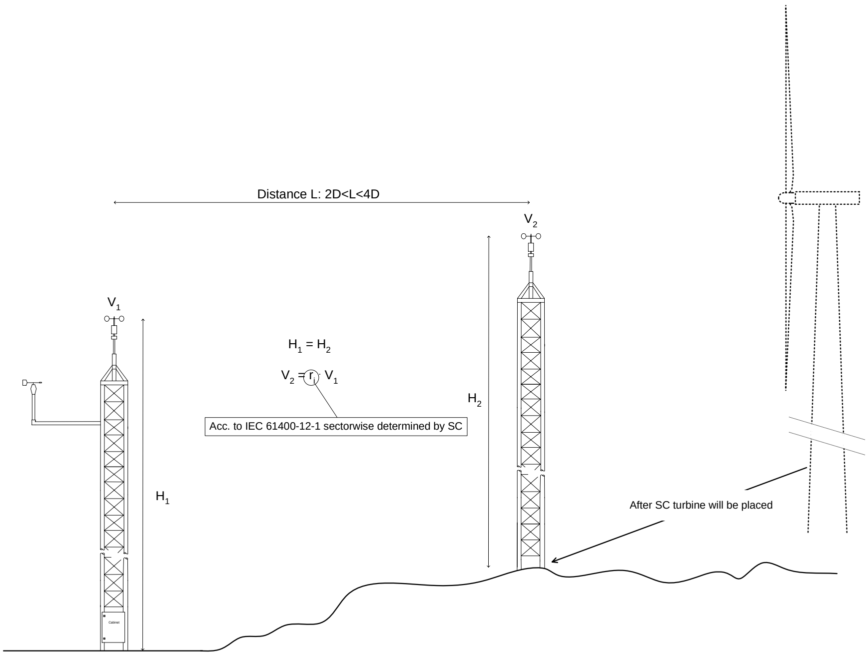


Figure 3: Site calibration setup in complex terrain (unscaled)

METHODS

The used software package Meteodyn is a CFD software, that solves the 3D RANS (Reynolds-Averaged-Navier-Stokes)-Equations numerically. To do so the following parameters have to be defined prior to calculation:

1. Minimum Horizontal Resolution (default value: 25m)
2. Minimum Vertical Resolution (default value: 4m)
3. Horizontal Expansion coefficient (default value: 1.1)
4. Vertical Expansion coefficient (default value: 1.2)
5. Orographic- and Roughness-Map radius (default value: 3000m)
6. Thermal class of the site (default value: 2)
7. Directional computation (no default value)

The parameters given from points 1 to 5 define the used grid for the computation.

The modeling of this study is characterized by:

- Orography grid of 25m resolution,
- Roughness from land cover clc00 (precision level 3).

To evaluate the suitability of the Meteodyn software package for numerical site calibration, the influence of different map radius from 750m up to 4500m as well as the influence of the thermal stability class, which has been varied to 0, 2 and 4, were investigated. In a few cases where the equations couldn’t be solved by the software due to convergence problems the minimum horizontal and vertical resolutions as well as the horizontal expansion coefficient were adjusted.

An overall of three validations were realized:

1. In some cases, the possibility to adjust the software thermal class to the measured wind profile is not possible due to the lack of a meteorological mast on site, or a lack of a low height anemometer at a significant different height or due to strong perturbation of the mast or of the mounting layout on the measured wind speed of the low height anemometer. For this reason the influence of the thermal class was evaluated on 5 different sites by varying the thermal class on 0, 2 and 4. For this evaluation the radius was fixed to the standard value (3000m).
2. The software Meteodyn offers the possibility to select different radius which has a consequence on the domain size where the computation is realized and therefore on the orography and roughness taken into account. According to Meteodyn user´s manual, the orography and roughness taken into account for the calculation are proportional to the radius value as following:

$$R_{Orog,comp} = \sqrt{2} \cdot 1.2 \cdot R_{Orog} \qquad \textit{(Equation 1)}$$

$$R_{Rough,comp} = \sqrt{2} \cdot 1.2 \cdot R_{Rough} + 2000m \qquad \textit{(Equation 2)}$$

with:

R_{Orog} : Radius parameter of orographic map (see parameter list)

$R_{Orog,comp}$: Computational Radius of orographic map

R_{Rough} : Radius parameter of roughness map (see parameter list)

$R_{Rough,comp}$: Computational Radius of roughness map

The influence of the radius was studied on the 9 sites varying from 750m to 4500m by step of 750m. These calculations were made fixing the thermal class to 2.

3. The last verification was to classify the **relative error** within RIX range for each 10º wind direction and according to wind speed bins for the 9 studied sites. Here the thermal class was fixed again to the neutral thermal class 2 and the radius to 3000m.

   For each 10 minutes wind speed on the turbine mast position, the relative error δv is defined on the turbine mast position as following:

$$\delta v = \frac{v_{simulated} - v_{measured}}{v_{measured}} \cdot 100 \qquad \text{(Equation 3)}$$

   For each 10º wind direction sector, one RIX value is calculated.

RESULTS

1. Influence of the thermal class

In order to evaluate the dispersion of the relative error with the thermal class, for each site, 3 different simulations were realized by changing the thermal class parameter for 0, 2 and 4. For each 10º wind direction, the dispersion *Δs* of the relative error is calculated as following:

$$\Delta s = s_{\max} - s_{\min} \qquad \text{(Equation 4)}$$

with:

$s_{\max}$: Maximum of relative error for thermal class 0, 2 or 4

$s_{\min}$: Minimum of relative error for thermal class 0, 2 or 4

This dispersion is then plotted against RIX and dRIX of the associated wind direction.

The RIX was calculated from the permanent mast while the dRIX is defined as the difference between the RIX of the permanent and turbine masts. The results are presented on the Figure 4.

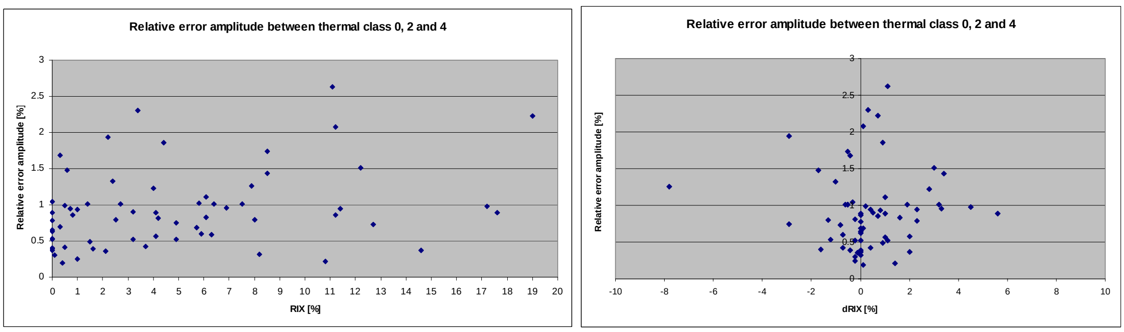


Figure 4: Dispersion of the relative error according to the RIX and dRIX

A clear correlation between the dispersion of the relative error and the RIX or dRIX was not found. The maximum relative error dispersion is below 3%.

2. Influence of the computation radius

For each site, six simulations have been realized corresponding to each radius step (from 750m to 4500m). The relative error is compared to the relative error of the previous radius in order to evaluate the variation of the relative error increasing the radius.

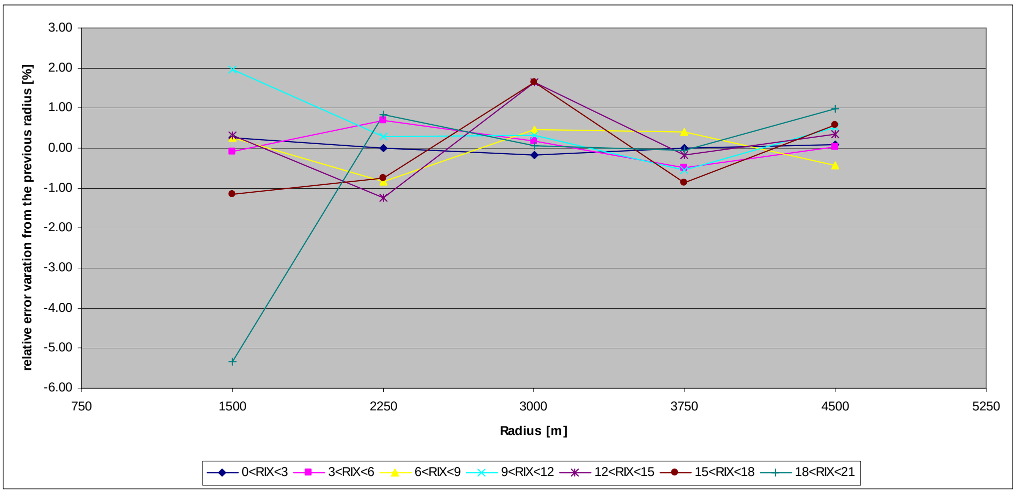
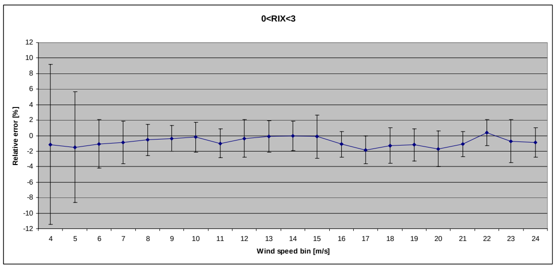


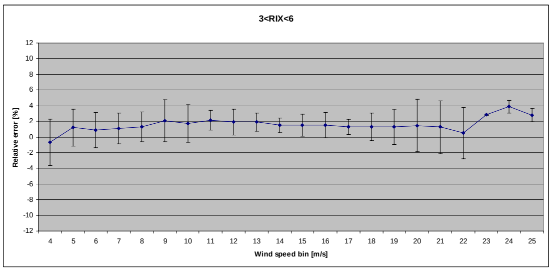
Figure 5: relative error variation from the previous radius

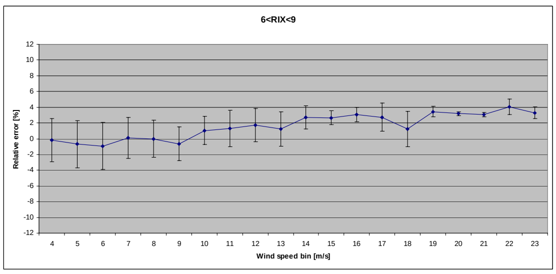
For sites with RIX between 0% to 3%, the radius does not have effect on the result. For sites with RIX inferior to 12%, the relative error stabilizes for radius above 3000m.

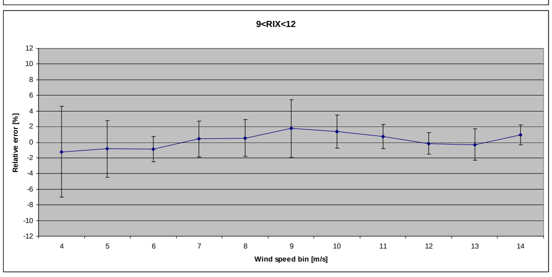
3. Classification of the relative error by range of RIX and wind speed bins

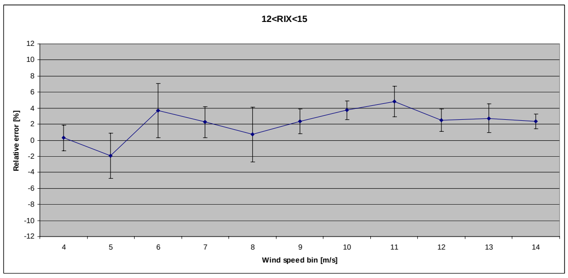
According to the previous explanations, one RIX is associated to each 10º wind direction. Additionally, inside each 10º wind direction, the relative error is classified according to wind speed bins of 1m/s. The results are presented below.

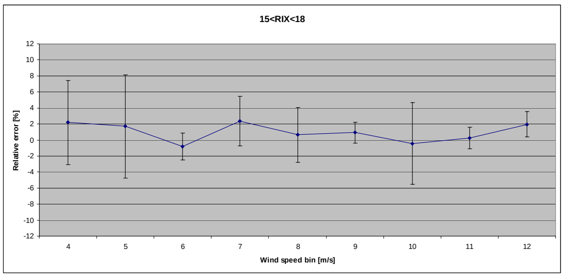












For sites with RIX<6%, the relative error is below to 2% for almost all wind speed bins with a maximum standard deviation equal to 3,3%.

The relative error increases with the terrain complexity (RIX) while the standard deviation of the relative error remains within the same limits.

CONCLUSIONS

In order to avoid the additional error due to the missing calibration of the thermal class, it is recommended to install a low height anemometer according to the IEC recommendations.

For site with RIX<12%, the radius default value (3000m) can be used.

For terrains with a RIX up to 6% CFD is suitable to perform numerical site calibration within an acceptable error range.

Thanks to the calculation of the standard deviation of the relative error for each range of RIX and wind speed bin, uncertainty can be associated on each wind speed bin.

The mean relative error and its associated standard deviation will be improved in terms of accuracy by increasing the number of sites and reducing the RIX range to 2% or 1%.

New site calibration measurements (with low height anemometer) are on study in order to calibrate the directional thermal class.

REFERENCES

1. IEC 61400-12-1 “Wind turbines - Part 12-1: Power Performance Measurement of Electricity Producing Wind Turbines”, First edition, 2005-12.

2. MEASNET: Power Performance Measurement Procedure, Version 4, November 2006