Checking The Capabilities Of Commercial Software For Numerical Site Calibration

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Summary. Good accuracy and reasonable computing time of commercial CFD have been tested for Wind Farms energy evaluation. Very specific CFD are not useful for some applications in actual wind industry (prices, computing time, unknown input parameters). The capabilities of two commercial CFD (Meteodyn WT and Windsim) have been checked for their use in numerical site calibration, with default models parameters and without specific adaptation to the site. The models results have been compared with results using standardized site calibration procedures based on measurements according to IEC 61400-12-1 and the MEASNET Procedure. Seven sites with different orography and land cover have been considered. The deviation errors in the determination of the flow distortion factors are bellow 3% for most of the cases. Higher flow distortion factors are related with higher errors, and very complex sites show higher errors. The conclusion is that commercial CFD models can give acceptable results for numerical site calibration in not very complex terrains, even if they are used in their standard version and without additional adaptations.

Introduction

Even in short distances, orography and obstacles cause systematic differences between measured wind at met-masts and incident wind over wind turbines. For this reason, it is necessary to carry out site calibration in order to perform the correct evaluation of the performance of wind turbines. Site calibration is typically used for power curve measurement. However, this process requires the installation of meteorological masts before wind turbine generators are installed and, when dealing with an already-built wind farm case, site calibration is not possible in any this way.

This paper analyses the quality of the numeric calibration of sites performed by using commercial CFD software and it compares these results to those obtained by using met-masts measurements. For actual sites where a calibration was carried out in the past with met-mats measurements, following the standardized procedures [3], comparisons will be made between the obtained results and numeric calibration (software models) results. In order to estimate the applicability of numeric calibration, results dependence on site complexity (Slopes, RIX) have been analyzed.

It will be discussed in which extent the numerical site calibration is a valid procedure and whether its results remain within the acceptable error margins given by the met-mast measurements site calibration.

The next figure shows the process that has been carried out for each site.

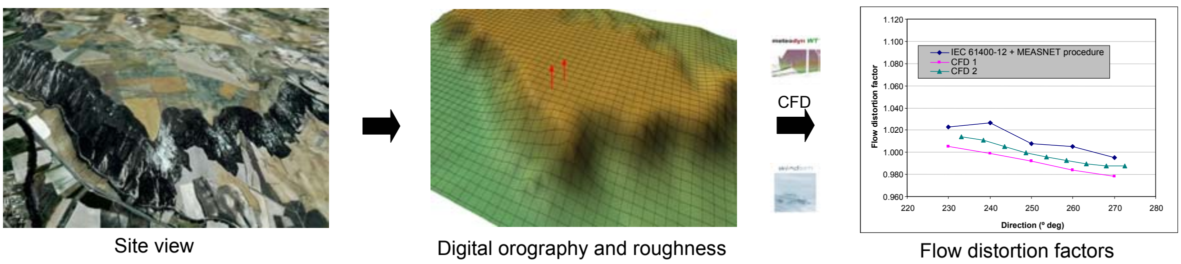

Figure 1. Diagram of the carried out process for each site.

Advances in commercial CFD software

Instead of using statistical methods (i.e. WAsP), CFD software integrates numerically the Navier-Stokes flow equations to obtain the wind characteristics in a zone. Good accuracy and reasonable computing time of commercial CFD have been tested for wind farms energy evaluation.

Commercial CFD have been considered because very specific CFD are not useful for some applications in actual wind industry because of prices, computing time and usually unknown input parameters (stability, mixing height...). The capabilities of two widely used CFD models have been checked: Windsim [1] and Meteodyn WT [2]. Is not the objective of this work to compare both models.

Work undertaken

Site selection

Seven sites have been considered, with a total of nine site calibrations performed by Barlovento according to IEC 61400-12-1 [3] and the MEASNET procedure. For every site the site calibration has been carried out for several direction 10º bins, having different orographical characteristics each. The sites vary from very complex terrain to very easy and have different land cover. There were no significant obstacles in the surroundings of the interest areas.

Site modelling

The CFD models define a grid and boundaries conditions to solve the flow equations. The inputs used for the models have the following characteristics:

- Default values for all the configurable settings (including grid settings).
In this point is important to remark that the 'parameter files' used by the models, usually contains default parameters that are not measured during measurement campaings at the sites, like stability or boundary layer depth.

- Orography and roughness: the maps considered are the typically used for energy evaluation, with altitude lines every 10 meters.

- Grid characteristics:

· Meteodyn WT:	Minimum Horizontal Resolution: 25m Minimum Vertical Resolution: 4m Horizontal Expansion coefficient: 1.1
· Windsim:	Base Resolution: 10 or 15 meters, depending on the site Grid refinement area: 1/3 of the map

More information about how each model calculates the grid and solves the flow equations can be found in [1] and [2].

Comparison between measurements and models results

For each site and direction bin, the results of the flow distortion factors calculated by the CFD models have been compared with those obtained with the standardized site calibration procedure (IEC 61400-12-1 and MEASNET procedure).

Analysis of the deviation errors dependencies

Several factors have been analyzed to establish a possible dependence between the deviation errors of the CFD models respect to the standardized site calibration. These factors are:

- The flow distortion factor.
As far from 1 the flow distortion factor is, the CFD results could be worse.

- The RIX.
The more complex the site is, the more difficulty to the CFD models to solve the equations. Rix has been calculated using WAsP model [4].

- The dRIX (difference of RIX between both met-mats).
Different RIX in reference and calibration met-mats sites could lead to different behaviour of the models.

- The slope.
The definition of slope for a site calibration has to be defined. For this paper, it has been taken as the slope of the terrain surrounding the reference met-mast in the considered direction bin.

Results

From now on, the models will be referenced as CFD 1 and CFD 2 (the election of the name has been done aleatory because the objective of the work is not to compare both models). The next Figures show a comparison between the results obtained for two very different sites, one very complex and one easy.

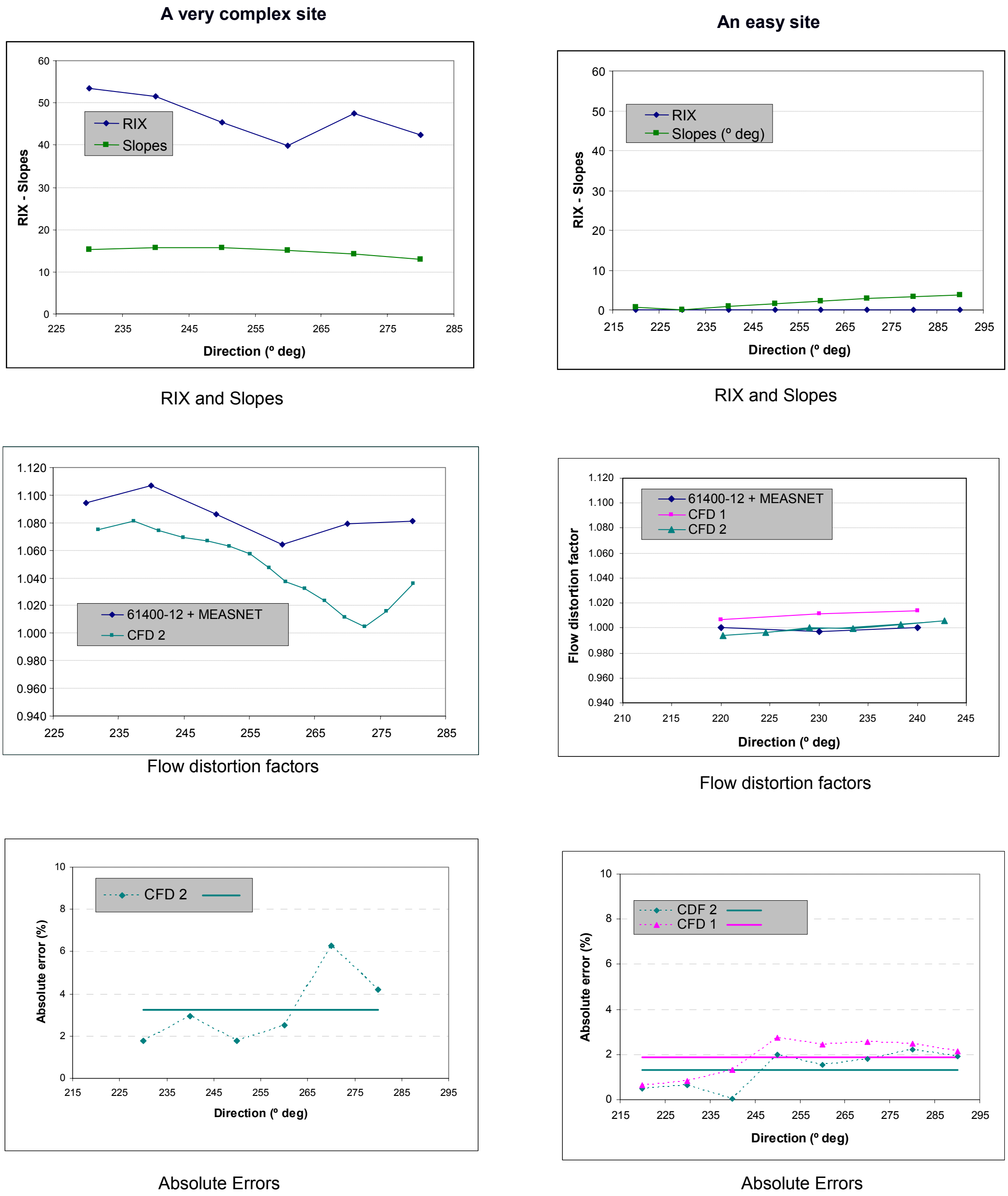

Figure 2. Comparison between a very complex and an easy site.

It has to be underlined that one of the models (CFD 1) had convergence problems with the most complex site and did not obtain valid results.

The absolute error is higher in the very complex site, but only two points (that represent two sectors 10º wide) have errors above 4%.

The next figures show the flow distortion factors obtained for all the sites and directions.

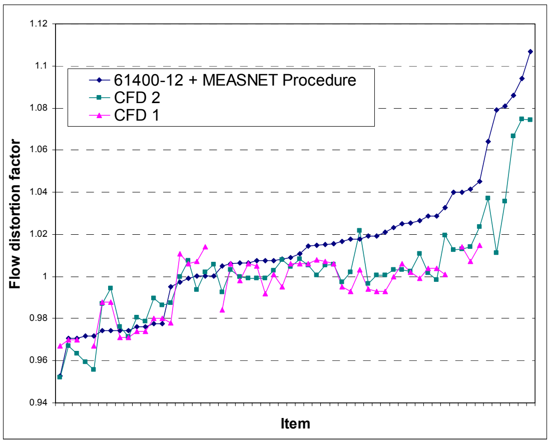

Figure 3. Results of the flow distortion factors obtained for all the sites and directions.

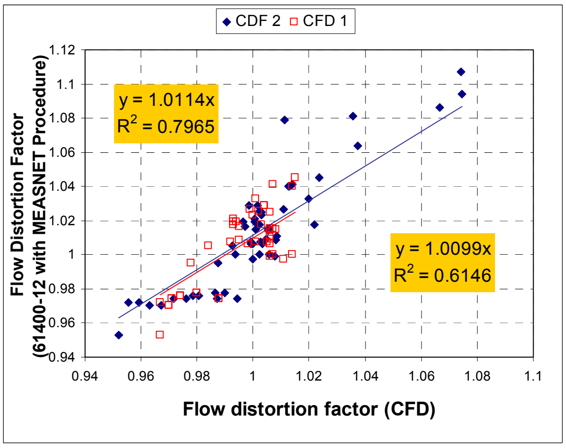

Figure 4. Correlation between flow distortion factors obtained by CFD models and the standardized procedure.

As can be observed in Figure 3 (where the items have been ordered by ascending order of the results obtained by the measurements), the two models reproduce the tendency. It can be also seen that higher factors are related with higher errors.

Figure 4 shows the correlation between the flow distortion factors obtained by CFD models and the standardized site calibration procedure. As can be observed, there is a good correlation.

The next figures shows the dependencies with RIX and slopes of the absolute deviation error between CFD 2 and the measurements.

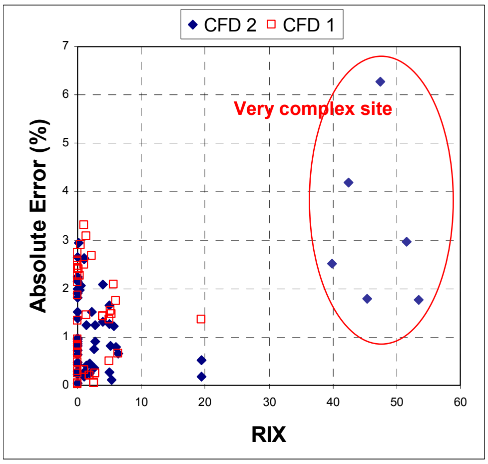

Figure 5. Deviation error dependence with RIX

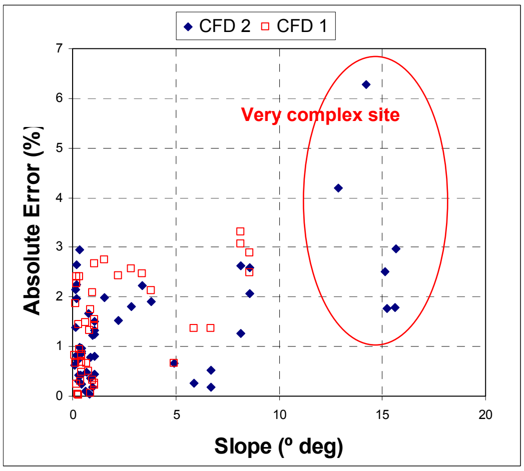

Figure 6. Deviation error dependence with Slope

As can be observed, for both models the absolute error is below 3% for most of the cases.

The points corresponding to the very complex site have been marked in the figures. They show an average error higher than the rest of the sites.

No correlation has been found between the difference of RIX and the absolute error (Figure 7). Anyhow, the dRIX of the selected sites does not cover a wide range and more research is needed.

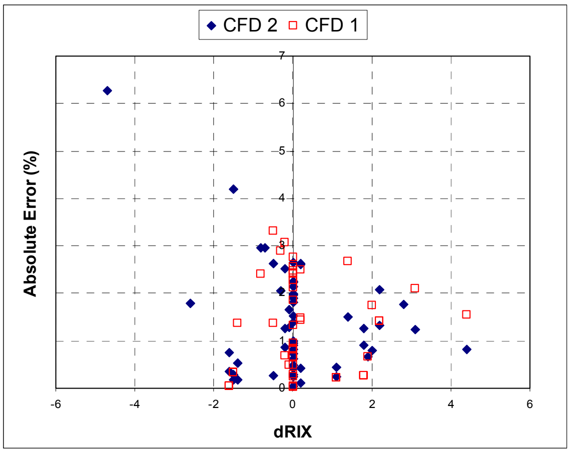

Figure 7. Absolute Error vs. dRIX

Conclusions

Commercial CFD models can give acceptable results for numerical site calibration in not very complex terrains, even if they are used in their standard version and without additional adaptations:

- Errors are below 3% for most of the cases, with default settings and no specificaly modified input parameters for the CFD models.
- Higher flow distortion factors lead to higher errors, however, only 2 points have errors higher than 4%.
- Very complex sites show higher errors. There could be convergence problems for very complex terrains.
- No dependence has been found between dRIX (difference of RIX of both metmats) and deviation errors.

Additional refinements can be carried out to get better results:

- Standardization of the definition of "slope".
  A definition of slope in needed in the standards. Today is not defined how the slope shoud be calculated: resolution of the orographic data (scale of the maps), distance between contour lines, method of adjustement of the plane to the terrain, ...
- Improvement of inputs of orography and roughness.
- Use of actual wind profiles at the reference site, not only reference height wind speed values.
  It's important to remark the influence of stability on the wind profile. The use of actual wind profiles as input to the models, could improve the results.
- Definition of additional inputs as stability and turbulence, which could be measured.
  The standard parameters (as stability) included in the parameter files of the models should be modified by actual parameters measured at the site. The parameter variations should be based always in measurements.

The use of numerical site calibration methods, based in commercial CFD models, can be a reasonable alternative in cases where standard site calibration based on measurements is not possible, as per exemple in already built wind farms. The analysis of results at different sites will permit the evaluation of the uncertainty of the method.

References

1. Windsim user's manual and help. http://www.windsim.com
2. Meteodyn WT users's manual and help. http://www.meteodyn.com
3. IEC 61400-12-1 Power performance measurements of electricity producing wind turbines, 2005.
4. WAsP user's manual. http://www.wasp.dk