Evaluation of CFD wind flow computations at Andhra Lake wind farm (India)

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Abstract

The Andhra Lake wind farm is located on a very sharp terrain, where 117 out of 142 turbines fail to conform to the “complex” terrain characterization according to the 61400-1 Ed3 standard. The reference meteorological data come from a long measurement campaign with five met masts with a maximal height of 50 m/57 m. A complete assessment study including the estimation of the Long Term Annual Energy Output (LTAEO), load conditions and turbine suitability has been performed by means of the CFD software Meteodyn WT.

This paper presents an evaluation of the software’s performance based on cross-comparisons between met masts results. It gives an approach on uncertainty values in non standard conditions: very sharp reliefs, very large domain and large distances between the masts.

Objectives

This study is devoted to evaluate uncertainties due to wind flow modeling in such complex sites. Both horizontal and vertical extrapolations were analyzed in terms of standard error by cross-comparisons between met masts. Topography data and available wind data have been validated and completed.

The Andhra Lake wind farm covers an area of about 25 km x 18 km. The elevation data are obtained from the ASTER GDEM data base with a horizontal spatial resolution of 50 m. Cliffs description close to wind turbines and met masts is improved using iso-altitude lines data with a vertical resolution of 5 m provided by CLP India. Roughness maps have been created by considering photographs on the site, Google Earth visualizations and on-site observations.

Methods

Long measurement periods were available for the following periods: 2005-2012 (2 masts), 2008-2011 (1 mast) and 2009-2011 (2 masts). Non-valid values due to the wake effect of the mast itself and of wind turbines have been removed. Meteodyn WT solves the steady isotherm uncompressible averaged Navier Stokes equations. The non linear Reynolds stress tensor is modeled by one equation closure scheme dedicated to atmospheric boundary layer. The turbulent length scale is computed at the beginning of the calculation according to a model based on Yamada and Arritt [1]. Wind flow simulations on the site have been computed with a directional step of 10 deg. The horizontal and vertical spatial resolution of the computation grid is 20 m and 4 m respectively. The computational domain area has been extended to a zone of 40 km x 40 km in order to minimize boundary effects. All these constraints lead to a very large computational grid of about 60 Million cells.

The spatial extrapolation analysis is accomplished by comparing the mean wind speed obtained by the wind modeling (wind extrapolation from a met mast to another) with the measured wind speed at each met mast.

The cross comparison has been performed as follow: mean wind speed at masts 3027, 3037, 3038 and 3045 is deduced from measured wind at mast 3018. And, reciprocally, mean wind speed at mast 3018, is deduced from measured wind at mast 3027, 3028, 3038, 3045.

Results

Computation time to converge (60 Million cells grid):
- 1 direction (1 processor) = 8 h
- 36 directions (8 processors) = 72 h

Wind speed coefficient at 75 m height for wind direction 270 deg (West)

Wind direction rose at mast 3038 (57 m height)

The standard error based on 8 cross-comparisons of wind speed is 5.2%. It must be noted that the distances between met masts are very large (going from 5.2 km to 13.5 km) while the spatial extrapolation between met masts and turbines is 5.5 km at most.

Additionally, turbulence intensity has been analyzed. The correlation coefficient for all directions is 0.83. The model slightly over estimates turbulence with a bias of 0.012 for easterly winds and 0.015 for westerly winds. The standard deviation of the error is 0.012 for easterly winds and of 0.017 for westerly ones.

Conclusions

CFD computations have been applied to a complex site and the performance of the software has been validated. Both wind speed and turbulence evaluation have an acceptable margin of error.

Regardless the long distances between met masts, errors are not very high. Lower errors in extrapolation to wind turbines are expected, as distances between met masts and wind turbines are 5.5 km at most.

References