UNCERTAINITY ANALYSES OF WIND POWER PREDICTION BY LINEAR MODEL AND CFD TECHNIQUES

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1. Introduction

The European wind energy sector launched the European Wind Energy Technology Platform (TPWind) in 2006.

TPWind's tasks are to identify and prioritize areas for increased innovation, and new and existing research and development tasks.

TPWind proposed an ambitious long-term '3% vision' of uncertainties.

This paper deals with uncertainty analyses of wind power prediction in wind community by commonly used industrial standard of linear model (WAsP), and improved nonlinear CFD techniques (WindSim) at complex terrain.

We are confirmed that 3% uncertainty can be reached using CFD techniques in the area of wind power performance assessment.

2. Wind Energy Resource Assessment

2.1. Linear Model - WAsP

Basic Characteristics:

- Meteorology Model
- Vertical logarithmic wind speed profile corrected by:
  - Roughness Model
  - Obstacles Model
  - Atmosphere Conditions Model

- Horizontal correction is based on:
  - Terrain Elevation Model (Bessel-Zooming model, solving linear form of perturbation wind velocity equations)

Misleading:

- Great uncertainty in complex terrain with slope greater then 17 degrees – air flow separation.

- Turbulence is NOT included.

2. Wind Energy Resource Assessment

2.2. CFD Model - WindSim

Basic Characteristics:

- **Fluid Flow, Heat and Mass Transfer Model**
- **Numerical solution of Reynolds Averaged Navier-Stokes equation, coupled with:**
  - **Continuity equation**
  - **Energy equation**
  - **Two-equations turbulence dissipative models**
- **Atmosphere stability is included.**

Misleading:

- **Boundary conditions specification.**
- **Solution Convergence.**
- **User with at least 3-5 years of experience working in this field with a thorough background in Fluid Dynamics, Turbulence Modelling, Mechanical Engineering and Information Technologies.**

3. Case Study: Wind Farm “DOBRICH”

3.1. Numerical Prediction - Data

A summary of the data which was required for this purpose includes:

- **High quality height contour data (10m contour data was used for 14km x 15km domain size).**
- **Site photographs and additional site information for building site roughness models.**
- **Detailed information on the measurement mast used, including calibration certificates for calibrated instrumentation and mast installation reports.**
- **10 minute averages for the wind speed at 10m, 30m and 50m above ground level (a.g.l.), standard deviation of the wind speeds (from which turbulence could be calculated), wind direction at 30m and 50m a.g.l., air temperature, relative humidity and atmospheric pressure at 10m a.g.l.**

3. Case Study: Wind Farm “DOBRICH”

3.1. Numerical Prediction – Boundary Conditions

Boundary conditions of inlet velocity is setting sector by sector, that is highly preferable in order to reach desired accuracy compared to measured values at mast (e.g. less than 3%).

This is iterative process consuming more CPU time than usual, but the desired accuracy can be reached.

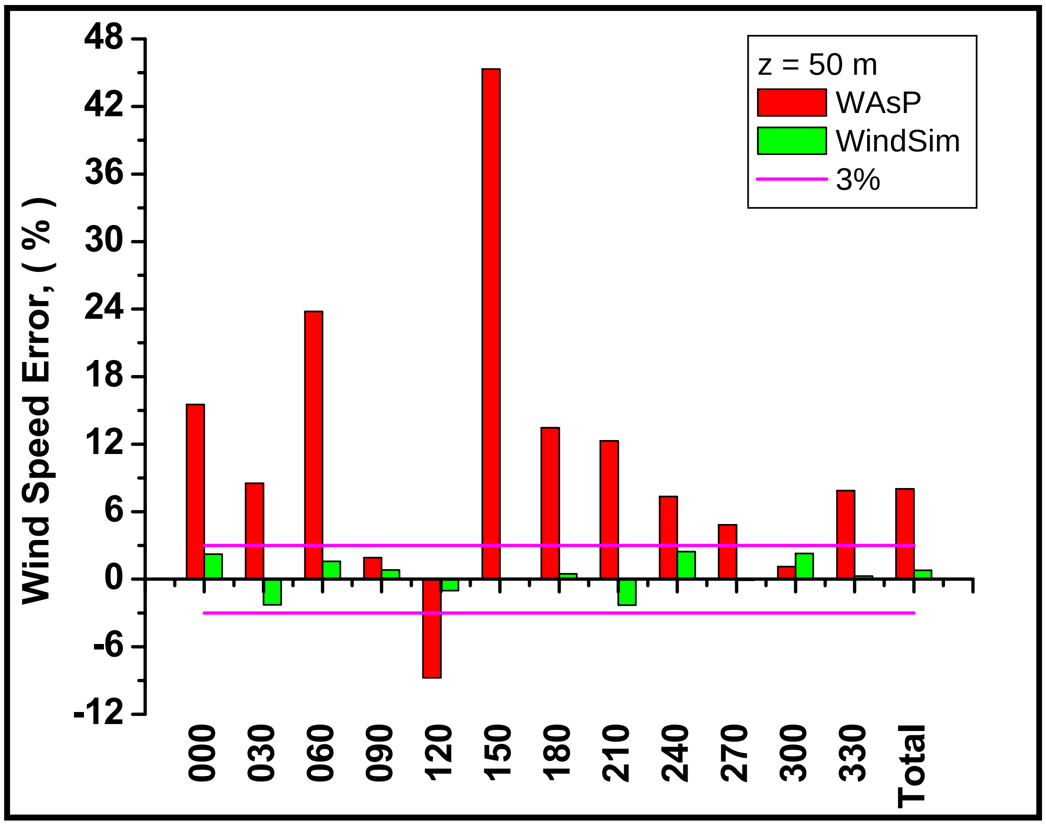
Boundary Conditions at z = 500 (m) : U_{500} (m/s)												
Direction:	0	30	60	90	120	150	180	210	240	270	300	330
1st Iteration	4.820	5.324	5.214	6.952	8.389	4.173	5.395	5.721	5.906	5.652	4.978	5.518
2nd Iteration	5.173	6.084	5.520	7.520	9.163	5.256	7.542	6.542	6.869	5.945	5.245	6.306
3rd Iteration	5.382	6.431	5.520	7.965	9.473	5.864	9.060	6.916	7.324	5.945	5.245	6.306
4th Iteration	5.382	6.650	5.520	7.965	9.597	6.204	10.140	6.916	7.324	5.945	5.245	6.306
5th Iteration	5.382	6.650	5.520	7.965	9.597	6.607	12.515	6.916	7.779	5.945	5.245	6.306

3. Case Study: Wind Farm “DOBRICH”

3.2. Validation – Uncertainty Analysis

Concerning validation phase, the focus has been dedicated to comparison of measured and predicted results on measurement site.

Predicted wind speed errors at 50m a.g.l.

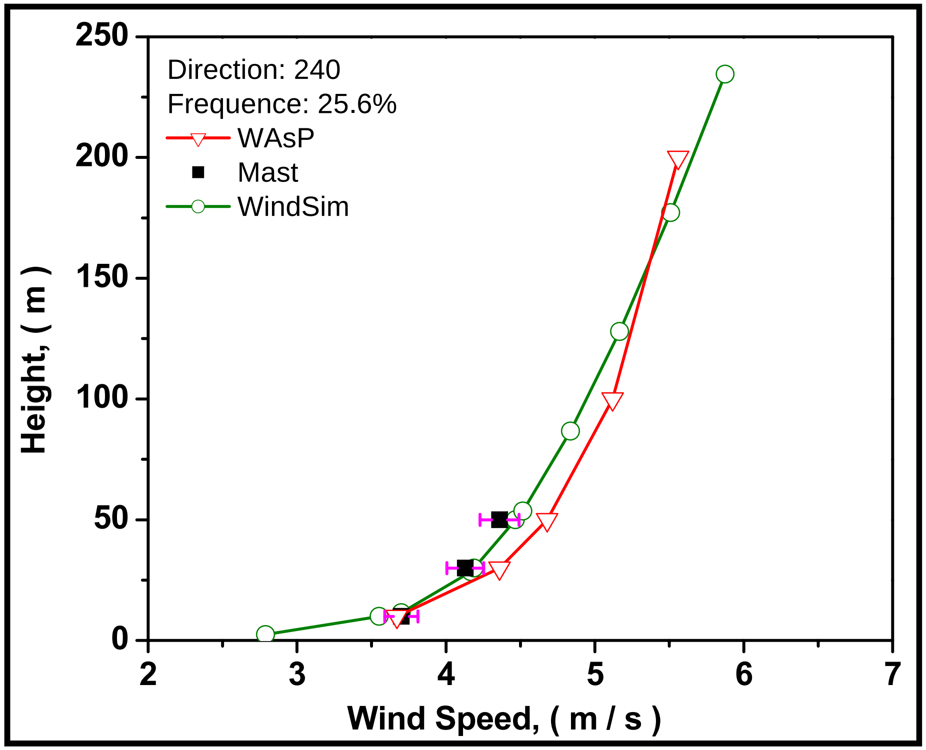


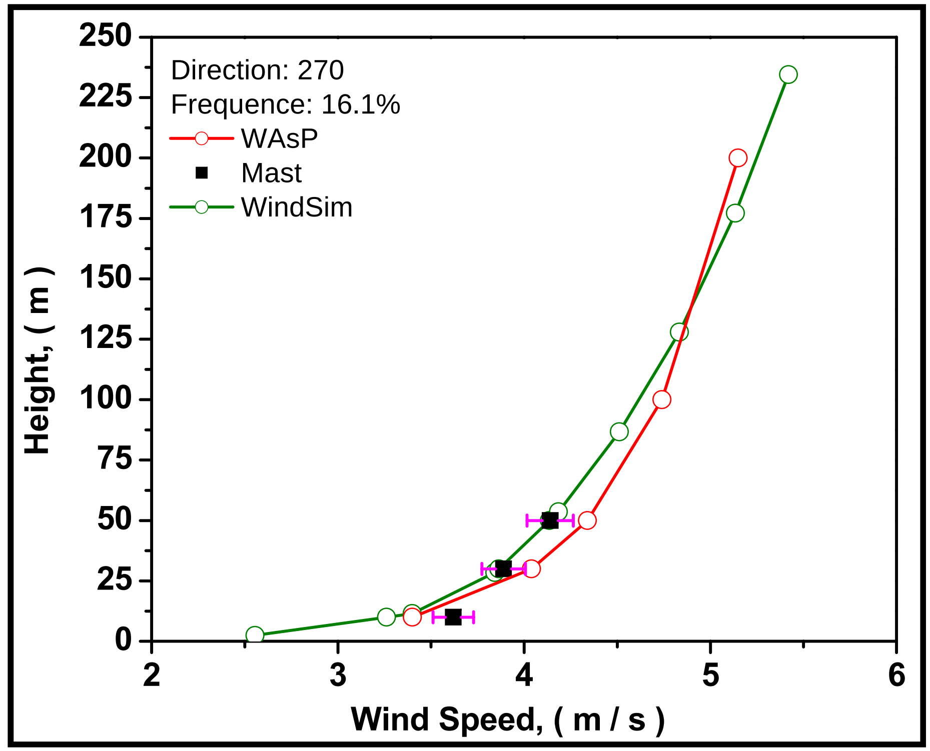
Calculated Hit-Rates

Dir.	f (%)	WAsP			WindSim		
		z = 10m	z = 30m	z = 50m	z = 10m	z = 30m	z = 50m
000	3.00	0	0	0	0	1	1
030	3.10	0	0	0	0	1	1
060	6.90	0	0	0	0	1	1
090	19.60	1	1	0	0	1	1
120	5.00	0	0	0	1	1	1
150	1.20	0	0	0	1	1	1
180	1.70	1	0	0	0	1	1
210	7.80	1	0	0	0	1	1
240	25.60	1	0	0	0	1	1
270	16.10	0	0	0	0	1	1
300	4.90	0	1	1	0	1	1
330	5.10	1	0	0	0	1	1
Hit-Rate by heights		0.598	0.245	0.049	0.062	1.000	1.000
Total Hit-Rate		0.297			0.687		

4. Result Presentation and Discussion

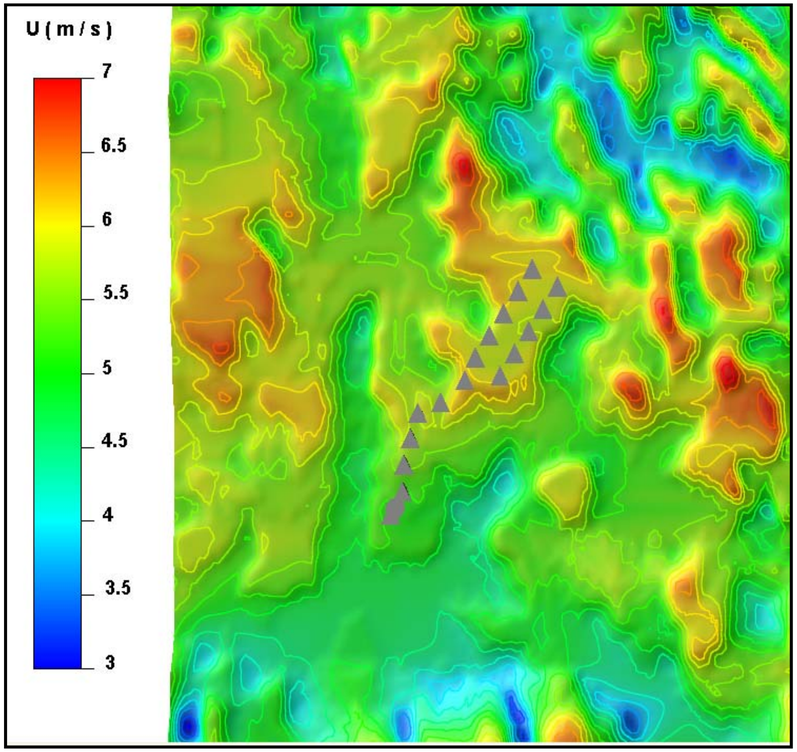
4.1. Vertical Wind Velocity Profiles

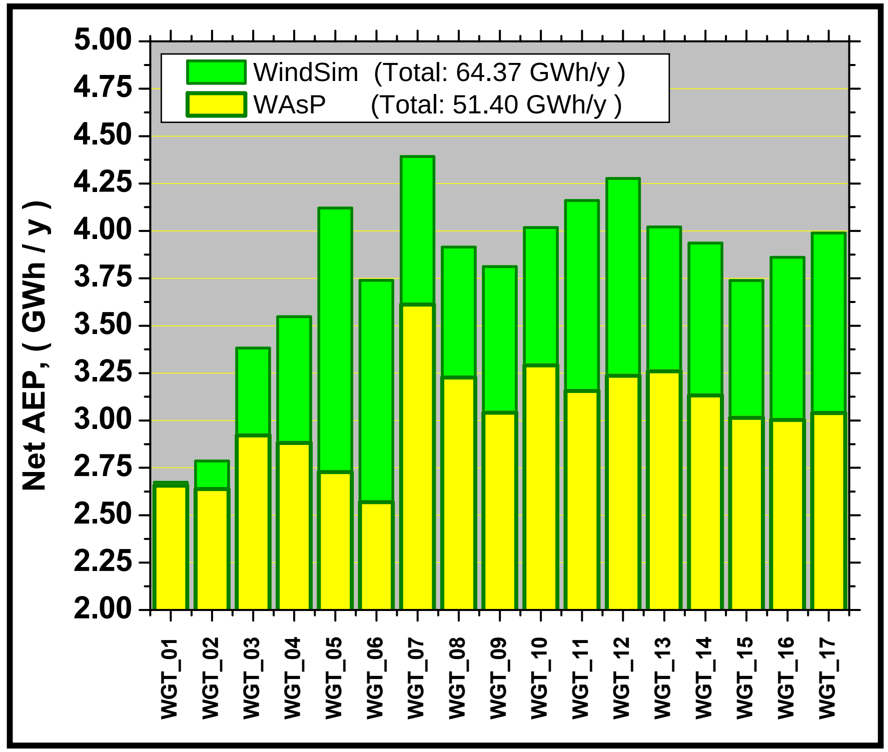




4. Result Presentation and Discussion

4.2. Annual Electricity Production – Wind Farm





4. Result Presentation and Discussion

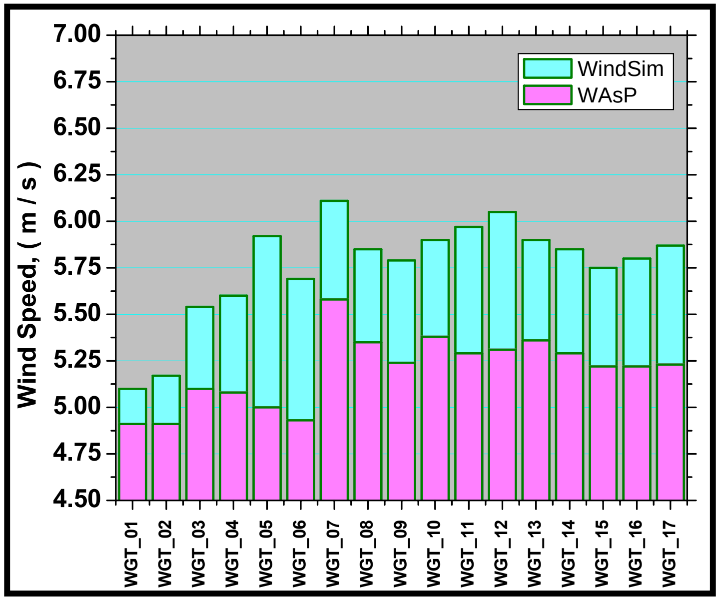
4.2. Annual Electricity Production – Wind Turbine No 5

Predicted wind speed of WGT's at 98m a.g.l.

WindSim Calculation ENERCON E82, H = 98 m		
WGT	wind speed	Net AEP
	(m/s)	(GWh/y)
WGT_01	5.10	2.6737
WGT_02	5.17	2.7860
WGT_03	5.54	3.3816
WGT_04	5.60	3.5473
WGT_05	5.92	4.1202
WGT_06	5.69	3.7391
WGT_07	6.11	4.3925
WGT_08	5.85	3.9152
WGT_09	5.79	3.8118
WGT_10	5.90	4.0169
WGT_11	5.97	4.1606
WGT_12	6.05	4.2768
WGT_13	5.90	4.0217
WGT_14	5.85	3.9355
WGT_15	5.75	3.7379
WGT_16	5.80	3.8609
WGT_17	5.87	3.9884
All		64.3661
Capacity Factor (%) =		21.61

WAsP Calculation ENERCON E82, H = 98 m		
WGT	wind speed	Net AEP
	(m/s)	(GWh/y)
WGT_01	4.91	2.6560
WGT_02	4.91	2.6380
WGT_03	5.10	2.9210
WGT_04	5.08	2.8810
WGT_05	5.00	2.7280
WGT_06	4.93	2.5690
WGT_07	5.58	3.6120
WGT_08	5.35	3.2270
WGT_09	5.24	3.0410
WGT_10	5.38	3.2910
WGT_11	5.29	3.1560
WGT_12	5.31	3.2360
WGT_13	5.36	3.2600
WGT_14	5.29	3.1320
WGT_15	5.22	3.0140
WGT_16	5.22	3.0030
WGT_17	5.23	3.0390
All		51.4040
Capacity Factor (%) =		17.26

DIFERENCE (WAsP - WindSim) ENERCON E82, H = 98 m		
WGT	wind speed	Net AEP
	(m/s)	(GWh/y)
WGT_01	-0.19	-0.0177
WGT_02	-0.26	-0.1480
WGT_03	-0.44	-0.4606
WGT_04	-0.52	-0.6663
WGT_05	-0.92	-1.3922
WGT_06	-0.76	-1.1701
WGT_07	-0.53	-0.7805
WGT_08	-0.50	-0.6882
WGT_09	-0.55	-0.7708
WGT_10	-0.52	-0.7259
WGT_11	-0.68	-1.0046
WGT_12	-0.74	-1.0408
WGT_13	-0.54	-0.7617
WGT_14	-0.56	-0.8035
WGT_15	-0.53	-0.7239
WGT_16	-0.58	-0.8579
WGT_17	-0.64	-0.9494
All		-12.9621
Diference =		-20.14%



5. Summary

1. This paper is dealing with uncertainty analyses of wind power prediction by two of the most frequently used software packages based on linear model (WAsP) and full RANS conservation equations model knowing as CFD simulation (WindSim).
2. The analyses are performed by comparison with high quality of measurement data.
3. Besides of comparison analyses, the primarily task of this work is to confirm the hypotheses that is possible to reach TPwind vision of 3% uncertainty.
4. In this study, it is shown that is possible at validation phase by iterative specifications of inlet boundary conditions compeering measurement data with predicted ones.
5. Obviously, TPwind vision of 3% uncertainty is concerned to the final net annual electricity production, but this kind of analyses is only possible when the wind farm is built. Nevertheless, this is the first step of uncertainty analyses and it is the most important.
6. Also, it is shown that somewhere can occurred contradictory results of validation process and with the basis task of optimal wind-farm layout design. Therefore, any user who is pretended to analyze wind flow phenomena must be very experienced with criticism of any obtained results.