

ENERGY POTENTIAL PREDICTION BY NUMERICALLY GENERATED WIND FIELD ATLAS

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SUMMARY

The generation of Wind Atlas and prediction of Energy potential has been studied using the Three Dimensional CFD code **fluidyn-PANEOLE**. The code solves fluid flow over any arbitrary domain and predicts the energy distribution, power production under the specified atmospheric conditions over a highly complex terrain. The numerical approach for the estimation of wind energy potential of a prospective site is subjected to critical analysis and the thus obtained results were compared with the measured values. It was finally concluded that the prediction of wind power density by **fluidyn-PANEOLE** is in close agreement with the value quoted by the governing agencies. The annual power production from the tentatively placed turbines is also estimated.

1. INTRODUCTION

Reliable energy production is necessary for the development and survival of the societies. The rapid depletion of the conventional energy resources forced the human being to start thinking on the non-conventional energy sources to make up the global energy deficit. Wind Energy Conversion is one of the clean energy technologies, which are thought of in the past few decades to solve the energy crisis. The selection of the sites, for the establishment of the wind farms, needs meso and micro-scale analysis of the concerned area. All our efforts, in the direction of supplying the clean energy and technology to the society, have culminated in **fluidyn-PANEOLE**, which can simulate the generation of Wind Atlas and the Energy potential over a specified area numerically using a 3-D CFD code.

1.1 FORMULATION AND NUMERICAL ASPECTS OF FLUIDYN-PANACHE

PANEOLE uses Computational Fluid Dynamics tools in a finite volume based approach to solve the differential equations governing mass, momentum, and energy transfer.

A SIMPLE type pressure-momentum coupling is used for implicit treatment of acoustic terms in the momentum equations.

fluidyn-PANEOLE computes a mass consistent wind field over the domain boundaries using an interpolation technique based on Lagrangian multipliers.

Atmospheric and mechanical turbulence is treated by k-ε and k-l models.

1.2 Wind Energy model

1.2.1 Energy density

Energy density can be calculated using the following formula

$$E = \sum_i E_i = \frac{1}{2} \rho \times \frac{\sum_i f_i \times V_i^3}{\sum_i f_i} \rightarrow \text{Eq.(1)}$$

with

E : energy density in the whole domain in W/m^2

E_i : energy density for the wind speed V_i (in W/m^2)

ρ : density of air in kg/m^3

V_i : wind speed in m/s

f_i : frequency of occurrence of the wind V_i

1.2.2 Power production

Wind turbines are created in the complex terrain. Each wind turbine is associated with the power curve. Power curve is used to calculate the power production from the turbines and it is the function of velocity.

$$\text{Power} = f(\text{velocity}) \rightarrow \text{Eq. (2)}$$

2. Case Study on Wind Potential Calculation

2.1 Example: Wind power potential evaluation of a prospective windfarm in a complex terrain

2.1.1 Terrain Features

The wind power potential of a complex terrain was evaluated during this exercise. The selected area for the calculation is characterized by highly undulated terrain with dense forests. The altitude in the domain varies from a minimum of 748m at the valley to a maximum of 1180m at the hill top.

Major part of the study area is covered by thick vegetation. This vegetation cover, when exist with water bodies and open fields, is mainly responsible for the advection currents.

In order to simulate the effects of the complex topography, considerably large study domain of approximately 19.3 Km x 14 Km, centered around the locations of interest, is outlined for the study. The vertical extent of the domain was kept at 1 Km keeping in view the turbulence on the surface.

The topography is imported into *fluidyn-PANEOLE* by defining the characteristic landscape features mainly altitude contours, open fields, forests, water bodies, etc. *Fig. 1* shows the thus imported topography along with the location of tentatively placed wind turbines.

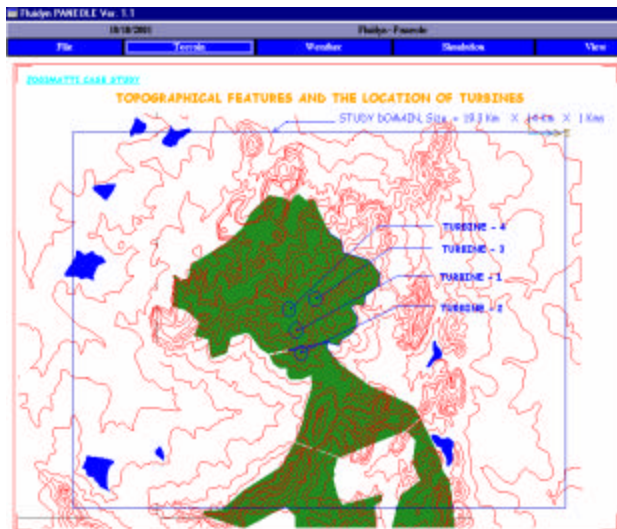


Fig. 1: Digitised topographical features and location of Turbines in the study region

2.1.2 Wind Turbine details

The annual power produced by the wind turbines placed at some tentative locations is calculated using the Eq. (2). A typical power curve is as shown in the *Fig. 2* shown below.

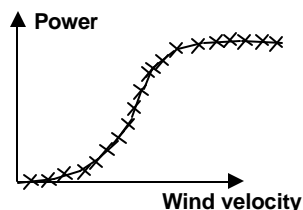


Fig.2: Typical Power Curve

The power curve values used in this study are as tabulated in *Table 1* below:

Table 1: Wind Velocity v/s Power produced

Wind Speed, m/s	Power, KW
1	0
3	4
4	20
5	46
6	85
7	142
8	218
9	312
10	429
11	527
12	609
13	673
14	719
≥ 15	750

Four wind turbines were placed at the topmost region of the domain so as to estimate the annual power production.

2.1.3 Meteorological Data

Meteorological observations from 1990 to 1992 from the nearby Met station were collected. The wind rose data was then derived from these meteorological observations and the same is used for the study. The wind data represented in the form of frequency table is as shown in the *Table 2*.

Table-2: Wind frequency table; Data used: Jan 1990 - Dec 1992; Sensor Height: 10m

Speed, m/s	N	NE	E	SE	S	SW	W	NW
2.7	176	176	176	176	176	176	176	176
3.6	109	151	194	145	51	84	182	188
4.5	149	203	268	197	69	114	247	256
5.4	184	256	326	243	85	140	305	316
6.3	67	281	565	254	60	94	533	221
7.2	71	297	597	269	63	99	563	234
8.0	72	303	611	275	64	101	576	239
8.9	10	205	757	88	10	79	1027	102
9.8	10	198	718	85	10	77	994	99
10.7	9	187	671	80	9	72	935	93
11.6	3	63	332	22	1	51	1362	33
12.5	2	53	278	18	1	43	1130	28
13.4	2	41	217	14	1	33	884	22
14.3	1	31	163	11	0	25	663	16
15.2	1	22	118	8	0	18	481	18
16.1	1	15	82	5	0	13	333	8
17.0	0	10	53	3	0	8	217	9

From the Table-2, it can be observed that the predominant wind blows from the West. The average wind speed in this direction is 10.6 m/s. Wind speed as high as 17 m/s was observed in the region.

2.1.4 Simulation and Results:

The terrain undulations as mapped by **fluidyn-PANEOLE**, and the body fitted mesh is as shown in the Fig. 3.

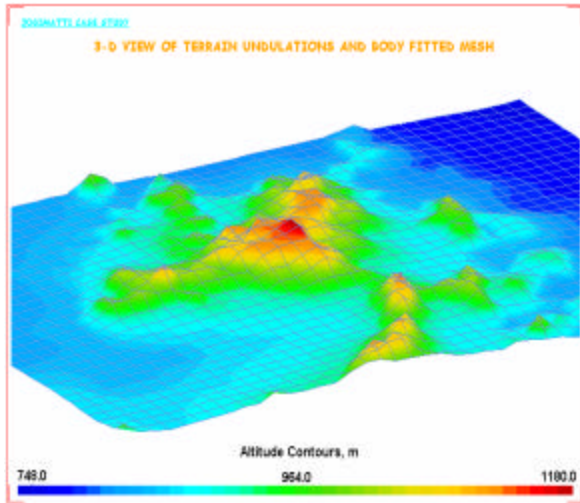


Fig. 3: Terrain undulations and the body fitted mesh

With the available terrain data and the meteorological data, the sector wise wind atlas is established by the numerical solver of **fluidyn-PANEOLE**. Thus established wind field is then made use of in computing the wind power density over the entire domain. Fig. 4 shows the wind atlas for the direction of 270° .

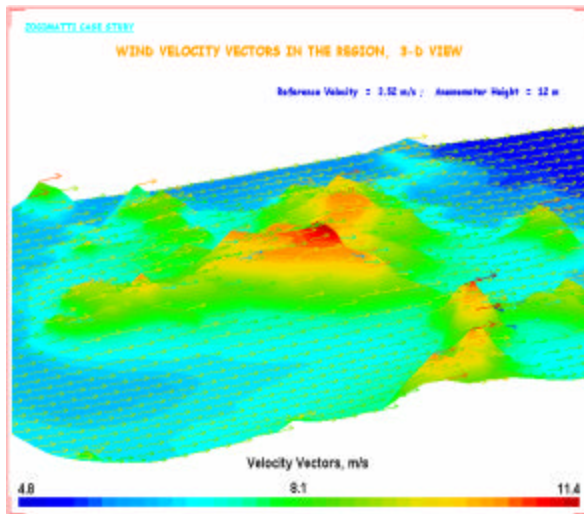


Fig.4: Windfield over the region (Wind speed: 3.52 m/s, Direction 270°)

The wind power density (WPD) is finally calculated as per Eq.(1). Fig. 5 shows the final WPD for the entire domain at the hub height of 32m. The value of WPD in the domain is found to vary from 64 W/m^2 in the valley to 518 W/m^2 at the hilltops.

The annual power production by the turbines is calculated using the Eq. (2). Fig. 6 shows the annual power production by the turbines in MW-Hr / Year.

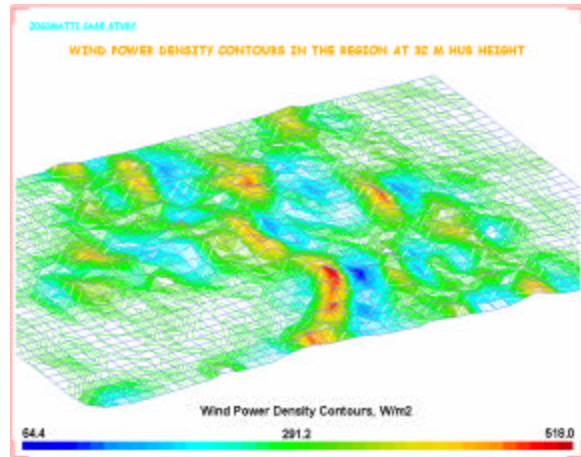


Fig.5: Wind Power Density (WPD) over the region

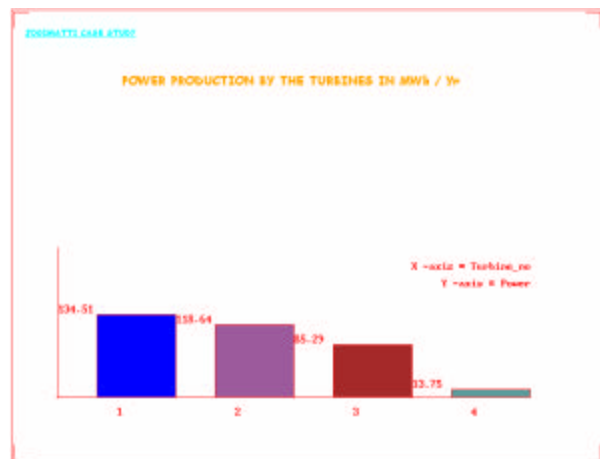


Fig.6: Power produced by the Turbines, in MW-Hr. / Yr.

Table 3 shows the comparison of the WPD computed with the measured value at a predetermined location. It can be observed that the predicted value at the reference height of 20 m differs from the measured value by only -2.01% . An error of $+8.86$ was observed for the WPD values at 30 m reference height.

Table-3: Comparison of predicted WPD against the measured value

Measurement Height, m	WPD, KW/m ²		% Error
	Measured	Predicted	
20	497	487	-2.01
30	553	602	+8.86

3. Conclusion

In the present paper it is shown that the wind power potential in a complex terrain can be meticulously evaluated by the CFD based model, with the help of the numerically established Wind Atlas using **fluidyn-PANEOLÉ**. The results demonstrated on wind power potential are closer to the on site measurements[16].

4. References

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