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Wind Speed Model for Anantapur District, Western Andhra Pradesh, India

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Abstract— The main objective of the present study is to analyse statistically the wind data obtained in western part of Andhra Pradesh State, India. The wind speed at heights of 10 m and 25 m above ground level were measured. In this study, exponential regression surface model were performed for estimation of wind speed and power over Anantapur District, Western Andhra Pradesh, India in spatially at different extrapolated elevations and to identify potential wind locations. This attempt was made by the Geostatistical method using in-situ data by the conventional methods for 30 stations. Spatial estimation of wind speed and power has been carried using Kriging method of exponential variogram at different extrapolated elevations up to 55m. It was observed that wind speed and power were increased with increase of altitude for all the stations exponentially. Using this Kriging analysis we identified new wind potential locations for different elevations for generating wind energy.

Keywords— Spatial Interpolation; Wind Speed; Power; Western Andhra Pradesh

I. INTRODUCTION

Among various non-conventional energy sources wind energy offers the greatest realizable potential. Assessment of any site from the point of view of wind energy potential is an essential and primary exercise in any wind power generation program. Improper siting of wind mills or wind farms often results in considerable loss of revenue and manpower. In a study made in 1994 [1] it has been shown that only about 40% of installed wind mills in India were located in areas having sufficient wind speed for movement of the wind mills. Studies relating to wind energy in India have been made by a number of authors mostly utilizing the wind data base from the India Meteorological Department [2, 3, and 4].

The present study made to know the spatial interpolation of wind pattern for wind potential assessment. Numerical studies provides an objective method for interpolation or extrapolated of wind data and also estimates the effects of terrain, surface roughness, stability of atmosphere and distance from the land of the station on air flow mechanism. Several studies have been reported for wind speed prediction using statistical and empirical techniques [5, 6 and 7]. Different types of numerical models depends on the type of application, area under consideration, topography of the terrain, type and density of the available observations for the input of the model are available in various spaces in different dimensions.

The comparisons of interpolation methods for temperature and precipitation, [8, 9,10,11,12 and 13] few research efforts have been directed towards comparing the effectiveness of different spatial interpolators in estimating wind speed. In this work an attempt has been made to study the wind speed distribution and wind power patterns in vertically and spatially using measured and extrapolated wind data, and from this calculated the power output in order to assess the wind potential sites for harnessing the wind power and also compared the estimated wind speed with measured wind speed for validation.

II. BASIC PRINCIPLES AND ANALYSIS OF WIND TURBINE POWER PRODUCTION

Analysis of estimated wind energy has been done with spatial variations at different elevations using the measured wind speed for 30 stations for different years as shown in the Figure 1 (Table I).The method of calculation of wind energy is show in the equation (1), where ρ is the density of air (kg/m³), A is the area swept by the turbine (m), V is the velocity of wind (m/s) and Cp is the coefficient of power which can be taken to a maximum value of 0.593 as per Betz' law [14]. Extrapolation of wind speed has been done using $1/7^{th}$ power law as shown in the equation (2).

$$P \text{ (available O/P)} = \tfrac{1}{2} \times \rho \times A \times V^3 \times Cp \qquad (1)$$

$$\left(\frac{V_2}{V_1}\right) = \left(\frac{H_2}{H_1}\right)^{\alpha} \qquad (2)$$

Where V_1 is the velocity of wind at known point and V_2 is the velocity at which the wind speed has to be measured, H_1 is the known wind speed height and H_2 is the calculated wind speed height and the exponent α is a dynamic value that is dependent upon the stability of the atmosphere. The wind shear exponent may be taken as constant for a given height in a given height range, but a different α should be chosen depending on the height range over which the power law is applied, but in general α can be taken as 0.144 [15, 16 and 17].

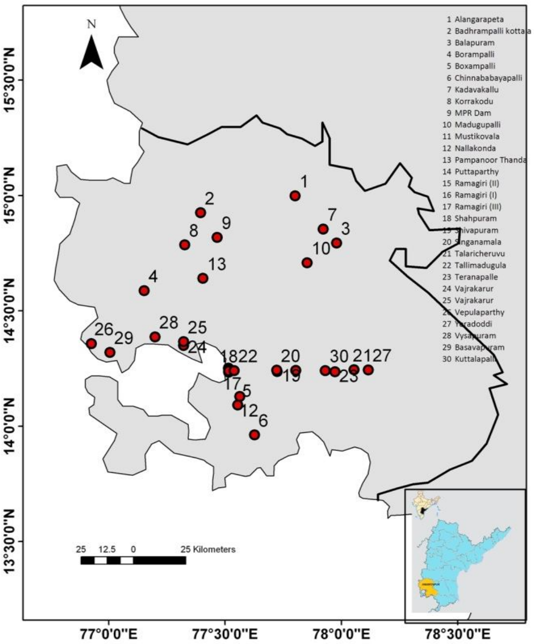

Fig.1 Wind monitoring stations in Anantapur District

TABLE 1 DETAILS OF WIND SPEED LOCATIONS IN ANANTAPUR DISTRICT AT AN ELEVATION OF 25M, ANDHRA PRADESH

Station Id	Station Name	Data period	Longitude	Latitude	Elevation (MASL)	Mean Wind speed (m/s)
1	Alangarapeta	2000-2002	77.80	14.99	360	5.85
2	Badhrampalli kottala	1994-1998	77.39	14.96	433	5.92
3	Balapuram	1999-2000	77.98	14.79	290	4.47
4	Borampalli	1998-2000	77.15	14.58	550	5.45
5	Boxampalli	1994-1997	77.55	14.09	639	4.7
6	Chinnababayapalli	1998-2000	77.63	13.96	762	5.14
7	Kadavakallu	2001-2010	77.92	14.85	368	6.14
8	Korrakodu	2000-2002	77.32	14.78	460	5.19
9	MPR Dam	1988-1993	77.47	14.81	404	5.53
10	Madugupalli	1998-2000	77.85	14.70	440	5.19
11	Mustikovala	1992-2001	77.51	14.25	570	5.61
12	Nallakonda	1994-1998	77.56	14.12	735	6.33
13	Pampanoor Thanda	1994-1997	77.40	14.64	490	5.44
14	Puttaparthy	1993-1996	77.80	14.24	542	4.92
15	Ramagiri (II)	2001-2005	77.52	14.23	567	5.88
16	Ramagiri (I)	1988-1993	77.52	14.23	573	5.42
17	Ramagiri (III)	1991-1995	77.51	14.24	550	5.39
18	Shahpuram	1997-1999	77.51	14.24	605	4.81
19	Shivapuram	1997-1998	77.72	14.23	295	3.9
20	Singanamala	1992-1998	77.72	14.24	425	6.61
21	Talaricheruvu	1997-1999	78.05	14.24	360	5.03
22	Tallimadugula	1994-1998	77.54	14.24	555	6.17
23	Teranapalle	1997-1998	77.97	14.23	245	4.14
24	Vajrakarur	1997-2000	77.32	14.34	512	5.3
25	Vajrakarur	1999-2001	77.32	14.36	511	5.41
26	Vepulaparthy	2000-2002	76.92	14.35	515	4.83
27	Yeradoddi	1992-1995	78.11	14.24	521	4.39
28	Vysapuram	2011	77.19	14.39	479	7
29	Basavapuram	2011	77.00	14.32	587	5.84
30	Kuttalapalli	2011	77.92	14.24	697	6.68

The friction coefficient α has been calculated from the help of the wind data available for the same station at different heights for the Anantapur district, Andhra Pradesh. Depending on the terrain conditions these friction coefficients α will change as shown in the Table II. The standard values of α has been given by Fernandez, 2008; Masters, 2004; Patel, 2006 [18, 19 and 20]. So we have compared our calculated α values with the standard values and we have approached closely to the results. Thus we have used α value for extrapolating the wind data to different elevations for the state of Andhra Pradesh in the power law equation (2).

TABLE II

FRICTION COEFFICIENT α FOR A VARIETY OF LANDSCAPES

S No	Landscape type	Friction coefficient α	Calculated Friction coefficient α
1	Lakes, ocean and smooth hard ground	0.10	0.103
2	Grasslands (ground level)	0.15	0.153
3	Tall crops, hedges and shrubs	0.20	0.231
4	(Fernandez, 2008; Masters, 2004; Patel, 2006)		Calculated α values for Anantapur District, Andhra Pradesh

Kriging (Krige, 1966) is a stochastic technique similar to IDW, in that it uses a linear combination of weights at known points to estimate the value at an unknown point. In contrast with deterministic methods, kriging provides a solution to the problem of estimation of the surface by taking account of the spatial correlation. The spatial correlation between the measurement points can be quantified by means of the semi-variance function:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(s_i) - Z(S_i + h)]^2 \qquad (3)$$

Where N(h) is the number of pairs of measurement points with distance h apart. The semi-variance can be a function of both distance and direction, and so it can account for direction-dependent variability (anisotropic spatial pattern). A parametric function is used to model the semi-variance for different values of h [21]. Within various variogram models, the exponential model is the most widely used and often preferred when the nugget variance is important and there is a clear range and sill effect [22, 23]. In this study, the exponential model was used to determine the weights for the nearby supporting data to compute the interpolated values.

Estimation of wind speed and power at different levels such as 10, 25, 35, 45 and 55 m height has been carried out using the exponential regression analysis for Anantapur District, Western Andhra Pradesh
Mean Annual wind data were extrapolated up to 55 MAGL at different levels from 10, 25, 35, 45 m and mean values of wind speed and power were estimated.

III. RESULTS AND DISCUSSION

Estimated mean annual wind speed distribution patterns using the Kriging analysis, based upon exponential variogram of wind speed extrapolation up to 55 m for 30 stations, are shown in Figure 2. The wind speed increases gradually with increase of altitude. Wind varies from 3.6 to 6.2 m/s at 10m, 4 to 7 m/s at 25m, 4.2 to 7.4 m/s at 35 m, 5.4 to 9.4 at 45 m/s and 5.6 to 9.8 m/s at 55 m height in Anantapur district

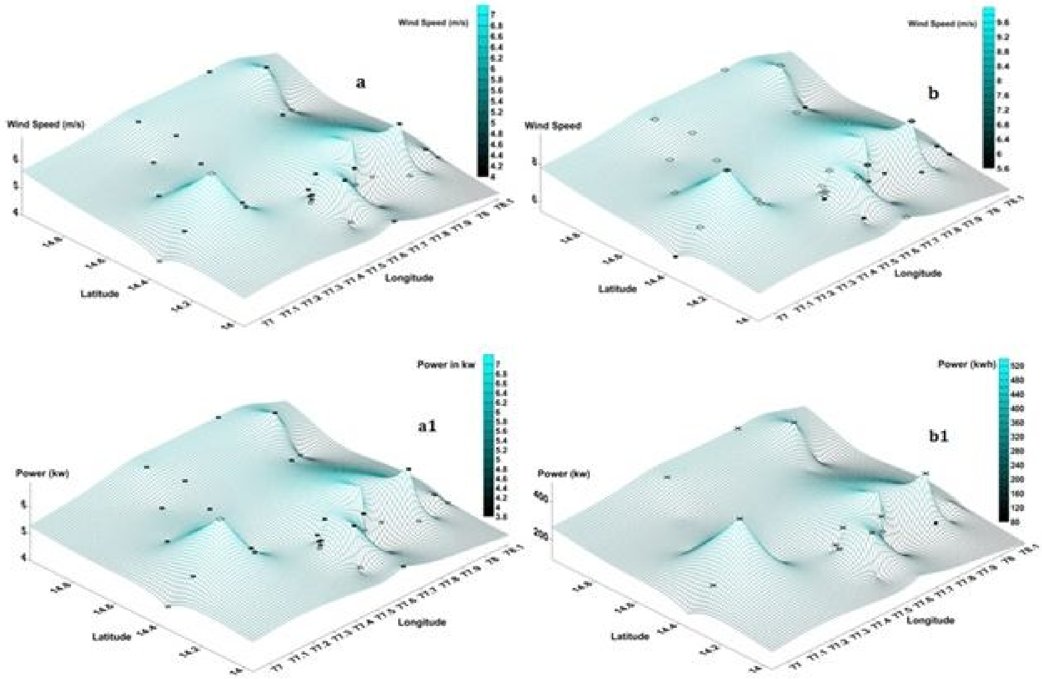

Fig. 2 Spatial estimation of wind speed (a, b) and Power (a1, b1) at a height of 25 and 55m

The contour map of wind speed and power distribution patterns of different altitudes such as 10, 25, 35, 45 and 55m as shown in Figure 3 and Figure 4. Low power (< 4 KW) was observed at 10 m height and high power 540 KW was observed at a height 55 m for district of Anantapur for the year 2000. New site locations of high wind power for different elevations as shown in Table 3. From the Table III, we observed almost 18 new potential locations for different elevations in which Gandlavandlapalle, Palthur and Havaliga at 55m and Chinnapolamada and Nittur at 45m give the more power than the exciting stations. Thus by developing the wind generations in these stations, the power increases as the increase of elevations.

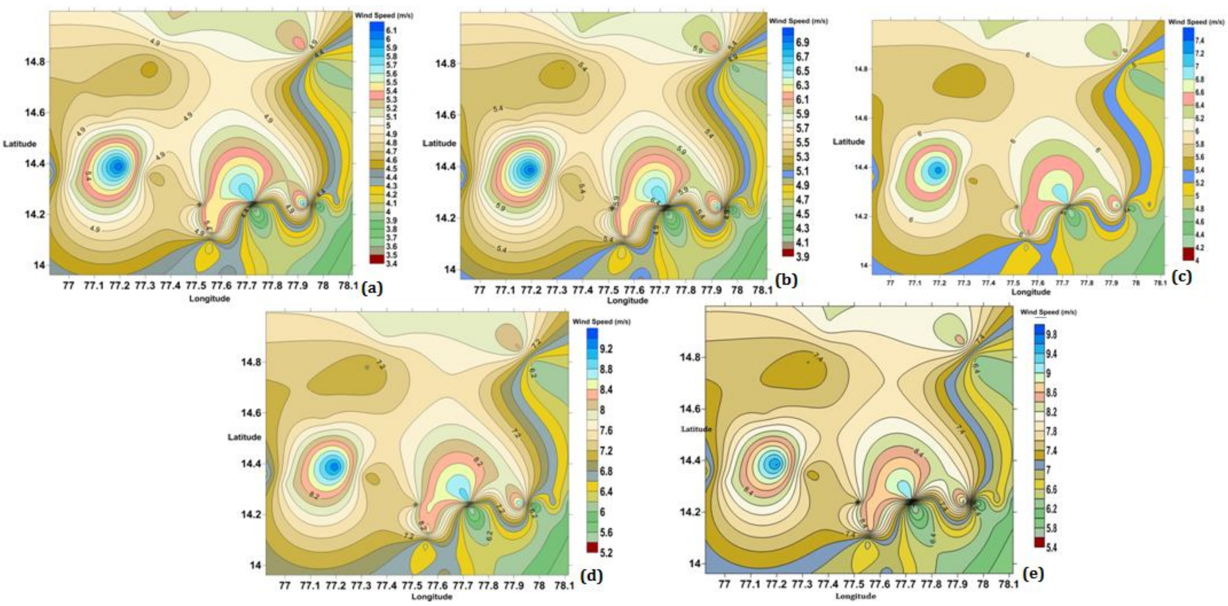

Fig. 3 Contour maps of wind speed distribution patterns at different elevations of (a) 10 m, (b) 25 m, (c) 35m, (d) 45 m, and (e) 55 m.

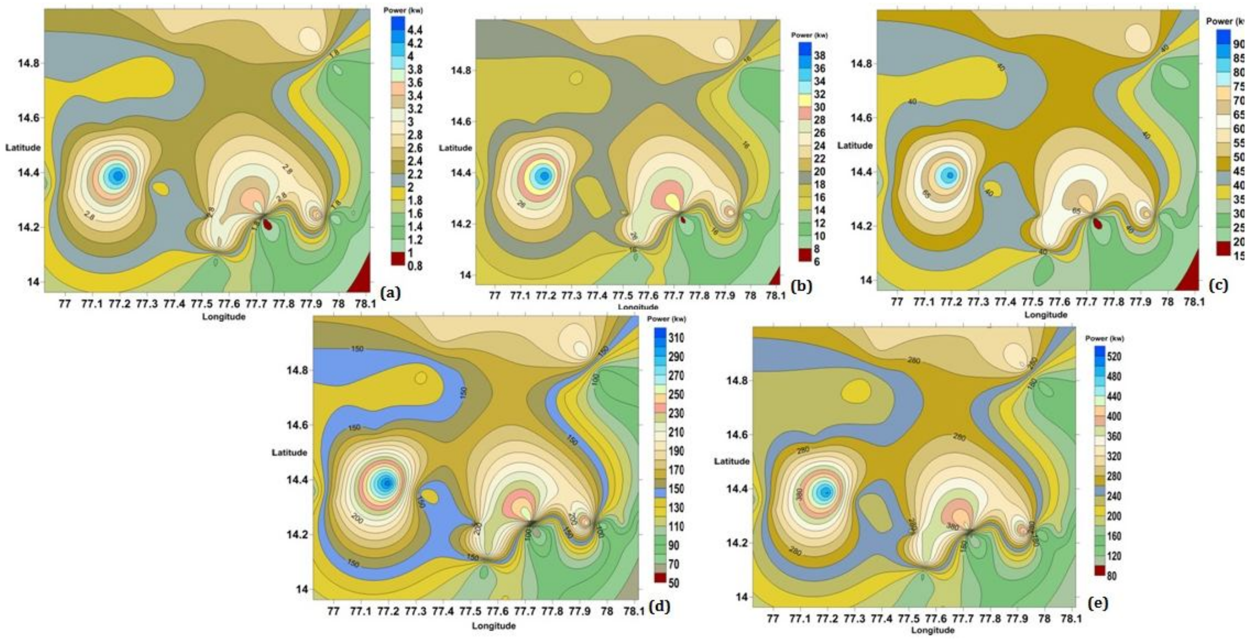

Fig. 4 Contour maps of power distribution patterns at different elevations of (a) 10 m, (b) 25 m, (c) 35m, (d) 45 m and (e) 55 m.

TABLE III NEW POTENTIAL LOCATIONS USING THE ESTIMATED WIND AND POWER FOR ANANTAPUR DISTRICT

Wind speed at 10 m height					
New Location	Lat	Long	Wind Speed (m/s)	Elevation MASL	Power Kw
Edulapalli	14°28’	77˚59’	5.75	1061	3.67
Wind speed at 25 m height					
Yerragudi	14°42’	77°09’	6.32	1591	28.07
Komatikuntla	14° 45’	78° 01’	6.02	871	24.26
Marthadu	14° 24’	77° 92’	6.5	1084	30.54
Wind speed at 35 m height					
Batwanapalli	14° 24’	77 °11’	6.5	1864	61.30
Kaverisamudram	14° 58’	78°00’	6.01	819	48.46
Chukkalur	14° 56’	77° 59’	6.39	790	58.24
Velidandla	14° 33’	78° 03’	6.26	922	54.76
Wind speed at 45 m height					
Karethimmanahalli	13° 59’	76° 59’	6.88	2040	121.75
Bommanahal	15° 00’	76° 58’	7.51	1485	158.35
Nittur	15° 02’	77° 56’	7.87	890	182.23
Chinnapolamada	14° 54’	77° 58’	8.04	794	194.30
Achutapuram	14° 41’	78° 82’	7.00	822	128.23
Wind speed (m/s) at 55 m height					
Gandlavandlapalle	14° 24’	77° 59’	8.5	1129	345.81
Havaligi	15° 00’	77° 06’	7.8	1442	267.22
Palthur	14° 58’	77° 08’	8.1	1472	299.25
Bollanagudam	14° 59’	77° 03’	7.5	1459	237.56
Pavagada	14° 06’	77° 15’	7.32	2165	220.86

We have compared the estimated wind speed with measured wind speed for different height levels 10, 25, 35, 45 and 55 m to validate the exponential regression model. Strong correlation (R^2=0.99) was observed at height of 55 m between the estimated wind speed derived from regression model and measured wind speed (Figure 5). The Correlations between the estimated and measured wind speeds at different heights as shown in the Table IV.

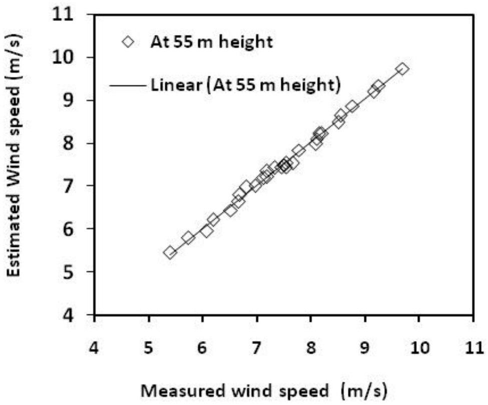

Fig. 5 Comparision of estimated wind speed using the model and measured wind speed

TABLE IV COMPARISON OF ESTIMATED WIND SPEED USING THE MODEL AND MEASURED WIND SPEED FOR DIFFERENT ELEVATIONS

Height (m)	Regression Equation	R^2
10	Y = 1.044 X + 0.058	0.86
25	Y= 0.970 X+ 0.355	0.86
35	Y = 1.038 X - 0.093	0.97
45	Y= 0.986 X+ 0.134	0.98
55	Y = 1.009 X- 0.039	0.99

IV. CONCLUSIONS

Annual wind speed and power was estimated using the Kriging, a method of exponential model for different elevations over Anantapur district, Andhra Pradesh. Spatial distribution of wind speed and power patterns was observed and also identified new wind potential locations for generation of wind energy. Gandlavandlapalle, Palthur and Havaligi at 55m and Chinnapolamada and Nittur at 45m were observed more power. Thus by developing the wind energy generations in these stations increases the power generation. Strong correlation was observed between the estimated and measured wind speed.

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