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The Wind Energy Potential in Gujarat – A Case Study

Patel Vishwanath K[1], Dr.A.N.Mathur[2]
[1,2]*Department of Mechanical Engineering, Mewar University Chittorgarh, Rajasthan, India*

Abstract: *In Wind energy, Wind Speed plays important roles for power generation, So the Analysis of wind speed is necessity of this study. The statistical Analysis of Wind Characteristics and wind energy potential in this study ,using a monthly and yearly average wind speed data. The wind energy potential of several locations in Gujarat is received by compiling data from Agricultural Universities of Gujarat and its Agricultural science centre(krishi vigyan Kendra). The locations are Amreli, Rajkot, Junagadh, SKNagar, Anand, Godhara, Vadodara,Navsari for the period of five years(2009-2013).The wind speed is recorded at daily and for this purpose it is extraploted at 50 meter height above the ground level .Monthly and annual wind speed, power and energy is calculated. The results are all shown in graphical forms. The calculated shape and scale parameter of these locations with the help of Weibull distribution. Weibull Probability density function(PDF) and Weibull Cumulative density function(CDF) are also calculated.*

Keywords: *Energy Potential, Extraploted, wind energy, weibull distribution*

I. Introduction

Gujarat is a important state of India for power generation from Renewable energies like Solar, Wind, Biogas, Tidal etc.The possibility of power generation from Renewable energy in Gujarat is higher than other state in India. Gujarat has a long coastal area around 1600kms,so it is the most suitable for wind energy. There is also great wind energy potential in Saurashtra and Kutch region of Gujarat has to make of its renewable resources, such as solar, wind and biogas, not only for power generation, but also for environmental reasons.

Some studies have reported that the wind speed is large at coastal area. Gujarat has a unique geographic location with the wind speed for generation of electricity locally as well as grid connected. Due to all these characteristics, Gujarat is a ideal for generating energy from the wind.

In present study, daily wind speed data were measured for the year 2009 to 2013 by the Agricultural Universities of Gujarat and its Agricultural science centre(krishi vigyan Kendra).

The aim of the present study is to analyze wind speed data at selected locations of Amreli,Rajkot, Junagadh, SKNagar, Anand, Godhara, Vadodara and Navsari in Gujarat due to the importance of statistical analysis of wind speed data and to predict the power density in this area.

II. Study Area

Gujarat is a state in the western part of India. Geographically, Gujarat has the following coordinates: 20° 6' N to 24° 42' N (north latitude) and 68° 10'E to 74° 28'E (east longitude). The boundaries of Gujarat are surrounded by the Arabian Sea in the West, Arabian Sea as well as the Pakistani province of Sindh to the west. Rajasthan in the North East, Madhya Pradesh in the East and Maharashtra in the South East. It shares a common border with Pakistan on the Northern side. It has an area of 196,204 km^2 with a coastline of 1,600 km with the longest coast line 1600 km .(Govt. of Gujarat, 2014). The population of Gujarat State was 60,383,628 according to the 2011 census data. Gujarat is counted among the fastest growing Indian states in terms of economy. The following location are selected for the research work for wind speed and wind power density analysis. The detail coordinates are as follows.

Sir No.	Name of Location	Name of region	Latitude ^{0}N	Longitude ^{0}E	Elevation (m)
1	Amreli	Saurashtra	23.16	71.15	73
2	Junagarh	Saurashtra	21.31	70.36	55
3	Rajkot	Saurashtra	22.18	70.56	58
4	S.K.Nagar(B.K.)	North Gujarat	24.12	72.28	201
5	Anand	Central Gujarat	22.32	73.00	197
6	Godhra	Central Gujarat	23.56	69.5	29
7	Vadodara	Central Gujarat	22.00	73.16	197
8	Navsari	South Gujarat	21.07	73.4	222

The data were collected from the various agricultural Universities and its Agricultural Science centres for detail analysis.

III. Theoretical Analysis

(1)Wind Power Density

We can get theoretical power from the equation (Annual average wind speed)per unit area,

$$P(v) = 1/2\ \rho\ v^3 \quad \ldots\ldots(1)$$

Where:

ρ is the standard air density(1.225 kg/m^3)corresponding to standard condition (sea level,15^{0}C),

v is the wind speed (m/s) and

P(v) is power generation (kw/m^2)

IV. Weibull Distribution

(1)Frequency Distribution of Wind Speed:

The Weibull distribution has been found to fit a wide collection of recorded wind data**.** In this paper, the Weibull method is used. The Probability density function of the Weibull distribution is given by,

$$f = (k/c)\ (v/c)^{k-1}\exp(-(v/c)^k) \quad \ldots\ldots(2)$$

Where v is the wind speed, k is a shape parameter, and c is a scale parameter determined from the data. These parameters allow the calculation of the expected monthly and annual, wind power density per unit area in a given area. The corresponding cumulative probability function of the Weibull distribution is given by:

$$f\ (v) = 1-\exp(-(v/c)^k) \quad \ldots\ldots(3)$$

For this present work,the scale and shape parameters were estimated using standard deviation method(SDM) using Matlab software.

Determine the k and c from the following equation:

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086}, \quad c = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)}$$

where k=shape parameter ,c= scale parameter(m/s),Γ( )=Gamma Function, σ=standard deviation

(2)Wind Speed Variation with Height:

Wind speed near the ground changes with height. This requires an equation that predicts the Wind speed at one height in terms of the measured speed at another. Apply the power law ,

$$v_2/v_1=(h_2/h_1)$$

Where v_2 and v_1 are the mean wind speeds at heights h_2 and h_1,respectively.The exponent α depends on such factors as atmospheric stability and surface roughness. The value of α is 0.14 (Widely applicable for well exposed sites).

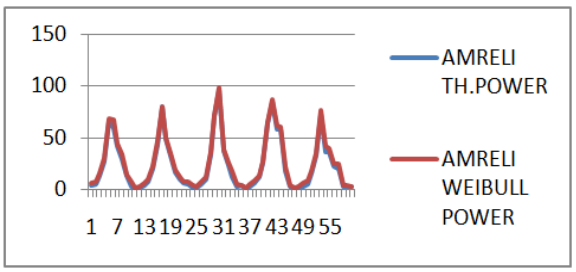
Modified theoretical equation $P(v) = 1/2\ \rho\ v^3$ and get the Weibull formula is

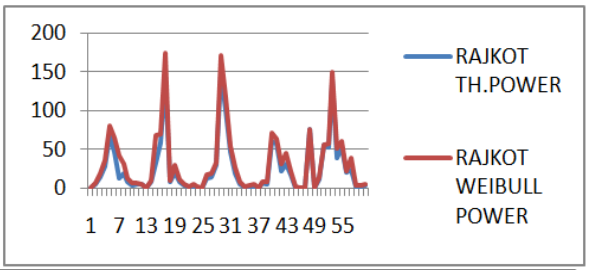
$P(v)=1/2\ \rho c^3\Gamma(1+3/K)$.The power measured by observed wind speed and apply this equations, the result is nearly of both equations.

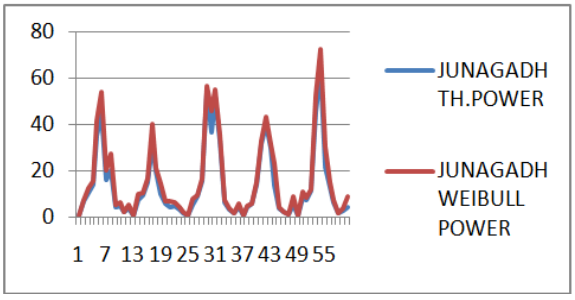
V. Graphical Representation

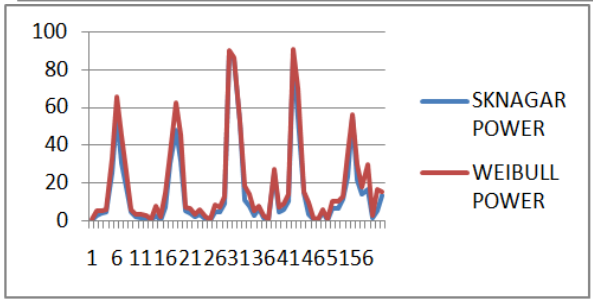
From the recorded data ,the graphical representation of selected locations are as under:

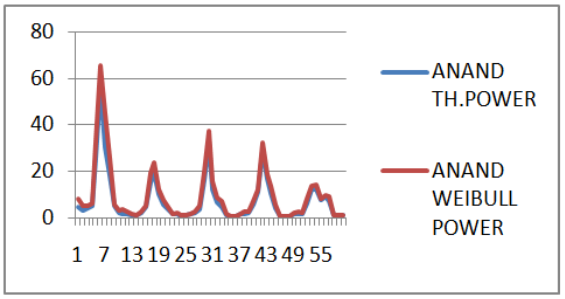
Fig. Period (Month) versys Power (Theoretical and Weibull Power)

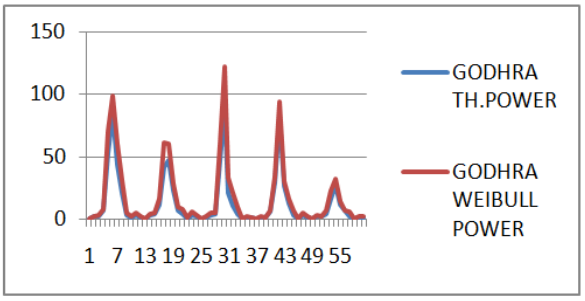


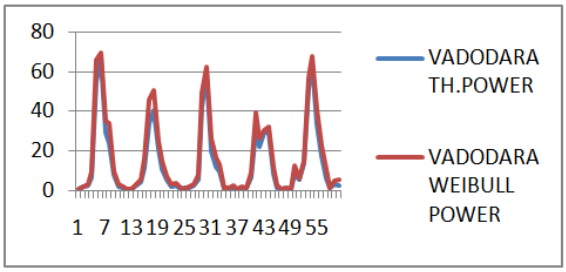


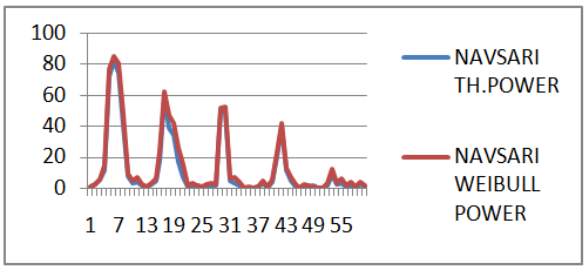












From the graphical representation the theoretical power and weibull power is nearly same, so weibull distribution is the best fit for wind energy potential.

VI. Statistical Parameter

After Statistical Analysis (correlation coefficient R^2 test) the data of selected locations are as under:

Location	**(R^2)** Correlation coefficient
Amreli	0.992095
Rajkot	0.976073
Junagadh	0.987137
SK Nagar	0.971722
Anand	0.986278
Godhra	0.987093
Vadodara	0.987348
Navsari	0.978006

VII. Conclusion

From this study, it is concluded the wind speed is low of these locations, so it is not useful for wind farm. Power generation from wind farm is not possible but it is suitable for the applications in agriculture, small scale industries, minor grid connection etc.Weibull model(Weibull distribution) is best fit for low wind speed. Analyzing the all values related power generation of wind energy, it can be noted that the chosen locations are not technically feasible for the installation of big scale of wind farm.

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