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Statistical and Spectral Analysis of Wind speed data for Wind Energy Assessment

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Abstract

Wind farms are gaining attraction as a cost effective energy solution compared to other non-conventional sources of acquiring energy. A considerable amount of research work has been carried out by researchers to locate sites where wind velocity is optimum. The continued research is on-going to optimized layout plan to place a set of wind turbines in a wind farm to be established at identified location. This paper is aimed at the computational analytics leading to optimized methodology to arrive at optimized wind mill placement architecture providing improved level of wind energy at a location of interest along with cost effectiveness of the designed wind farm implementation.

Keywords

Wind Energy, Weibull distribution, Standard Deviation.

I. Introduction

The cost effectiveness of wind farm was also an important issue in addition to the requirement site receiving optimal wind energy for development of wind farm. The under taken research work is targeted to locate sites by way of computational analysis of wind energy data in different directions and at different heights in an identified location for placement of a set of wind turbines[1]. The placement of set of turbines generates wake effect where in the wind turbine behind a turbine in the direction of wind receives less wind energy[2]. This effect continues for the turbines in succession. The wake is to be reduced at the minimum level with regard to the placement of a set of turbines in the farm. The placement architecture is optimized with regard to placement of wind turbine to achieved accumulated wake loss of all turbines together at minimum level. This needs computational analysis of data obtained with the application of Data Mining approaches to locate suitable site and modeling the placement of a set of turbines with minimum wake effect and optimum wind energy.

II. Materials and Methods

For the analysis of wind speed data there are various mathematical tools, which can simplify the characteristics of a wide range of wind speed data[3]. A large number of studies have been proposed the use of variety of standard probability distribution functions. Although many distribution functions were suggested to describe the wind speed characteristics, namely: the Pearson, the Chi-Square, the Weibull, the Rayleigh and the Johnson functions. Among several functions, the two parameter Weibull distribution is widely used function for analyzing measured wind speed data in a given location over a given time period [5,6,8]. The two parameter Weibull distribution is a special case of the generalized gamma distribution. Energy Pattern Factor method (EPF), Graphical Method (GM), Maximum Likelihood Method (MLM), Moment Method (MM) and Modified Maximum Likelihood Method (MMLM) are examined to estimate the Weibull parameters. To analyze the efficiency of the methods and to ascertain how closely the measured data follow the Weibull methods, goodness of fit tests was performed [6]. A data mining approach was applied to identify and predict status patterns of wind turbines [7]. For the analysis of wind speed data, the two parameter Weibull probability distribution function is the most suitable, accepted and recommended distribution function as it gives a better fitting and high accuracy for monthly probability density distributions of measured wind speed than any other distribution functions [8]. The Weibull probability density function is expressed as [4, 5, 10, 11]:

$$F(v) = \left(\frac{k}{c}\right)\cdot\left(\frac{v}{c}\right)^{k-1} \cdot \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (1)$$

Where f(v) is the probability of wind speed, k is shape parameter and c is the scale parameter (in m/s). The corresponding cumulative distribution function of the Weibull distribution is the integration of the probability density function [4,10] and it is given as

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (2)$$

A. *Measured mean wind speed and standard deviation*

$$v_m = \frac{1}{N}\left(\sum_{i=1}^{N} v_i\right) \quad (3)$$

$$\sigma = \left[\frac{1}{N-1}\sum_{i=1}^{N}(v_i - v_m)^2\right]^{1/2} \quad (4)$$

Where, Vm mean wind speed, m/s; standard deviation of the observed data, m/s; Vi hourly wind speed, m/s; N number of measured hourly wind speed data[6,11]. Compressed wind speed data are generated based on the Weibull wind speed distribution model [12].

The targeted work is to identify a site suitable for wind farm expecting maximum wind energy at selected location within the farm at specific height. Accurate forecasting of wind power is recognized as a major contribution for reliable large-scale wind power integration [9]. The suitability will be justified based on statistical parameters, mean, stand derivation and two parameter Weibull function.

III. COMPUTATINAL STUDIES

The suitability of an identified site is to be ascertained based on mean, standard deviation and two parameter Weibull function on data of wind speeds measured for three different locations: Diu, Bhavnagar, Valsad.

The basic steps of the evolutionary strategy algorithm are:

- Gather wind speed data, from that data find max speed and direction.
- Determine wind turbine's height and it's blade radius on base of wind speed and direction.
- Repeat until stopping criteria is satisfied (At the end of execution of these steps we will get maximum number of optimized wind mill placement design)

a. Place first wind turbine in linear plan for first row on wind direction side.

b. On the base of turbine blade radius, find weak and on that base place again other rows

The secondary data of wind speed at selected locations and a specific height of obtained and tabulated in Table1[13].

Table 1: Wind Speed Data Logged for 12 months (m/s)

Month	Diu	Bhavnagar	Valsad
Jan	4.12	2.55	3.37
`Feb	4.69	2.69	3.79
Mar	5.33	2.93	4.02
Apr	5.79	3.36	4.53
May	6.07	3.95	4.80
Jun	6.25	4.18	4.73
Jul	7.28	4.03	5.05
Aug	6.51	3.33	4.44
Sep	4.45	2.68	3.27
Oct	3.32	1.85	2.76
Nov	3.26	1.82	2.68
Dec	3.20	2.16	2.94

Diu is at Geographical location 20.7144094o N and 70.9873719o E is based at South East in Union Territory of Diu and Daman near to Arabian Sea at its South. Bhavnagar is at Geographical location 21.7644725o N and 72.1519304o E is based in State of Gujarat near to Gulf of Khambhat at its West. Valsad is at Geographical location 20.5992349o N and 72.9342451o E is based South in State of

Gujarat near to Arabian Sea at its West in figure1[14].

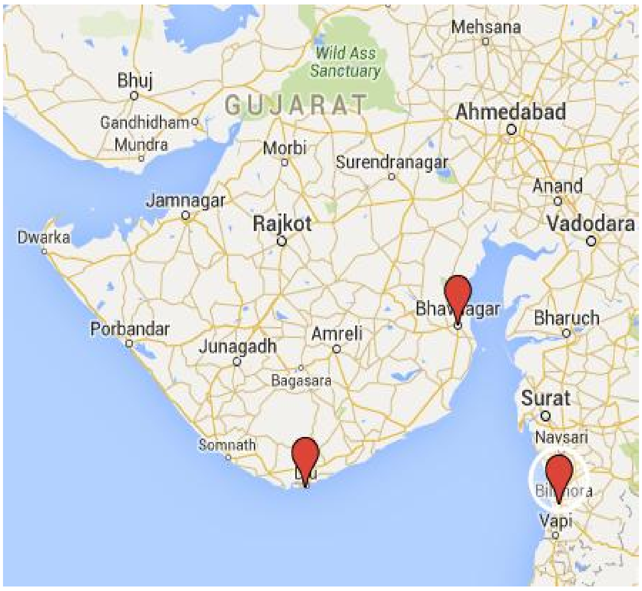

Figure 1: Map Location of selected Sites

On selected locations, wind data are measured on a meteorological observation to check if the location is a decent prospect for a wind turbine to be placed to produce maximum possible renewable energy.

IV. COMPARATIVE ANALYSIS

In the present study, the annual wind speed are derived from the available data and shown in Figure 2. Table 2 shows derived Weibull functions, Mean, Standard deviation, Variance calculation throughout the year at selected locations.

Figure-2: Annual Wind Speed

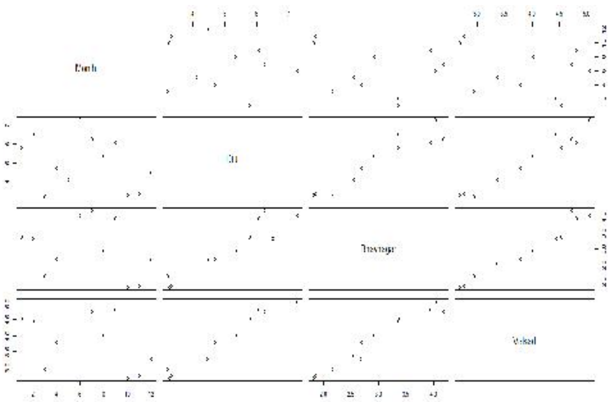

Table 2: Two parameter of Weibull Function

Location	Shape factor (K)	Scale factor C (m/s)	Standard Deviation	Mean Velocity (m/s)	Variance
Diu	4.3087825	5.5324996	1.387471	5.0225	1.925075
Bhavnagar	4.2477352	3.2626061	0.8203265	2.960833	0.6729356
Valsad	5.5741409	4.1955276	0.847944	3.865	0.7190091

In the present study the annual Two-parameter Weibull function are derived from available data and the computed results are shown in Table 2 and Figure 2, 3 & 4. It shows that Bhavnagar has lowest shape factor K, immediate scale factor C (m/s), standard deviation. Mean velocity (m/s) and variance compare to Valsad and Diu. Valsad has the most "peaked" Weibull wind distribution with the highest intermediate shape factor K with average scale factor C (m/s), standard deviation, mean velocity (m/s) and variance. Diu is the most "windy" place in the larger scale factor C (m/s) with highest standard deviation, mean velocity (m/s) and variance. An obvious calculation is that the Weibull distribution function and its two parameters are quite different for different places, so it is very important to choose a suitable site with good wind field for renewable wind energy [12].

Figure 2: Two parameter Weibull for Diu

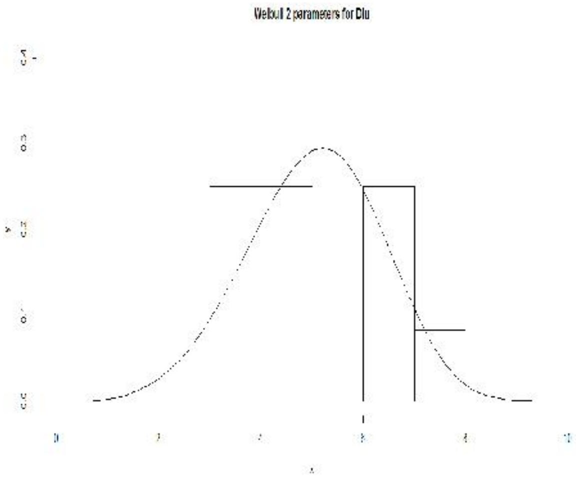

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Figure 3: Two parameter Weibull for Bhavnagar

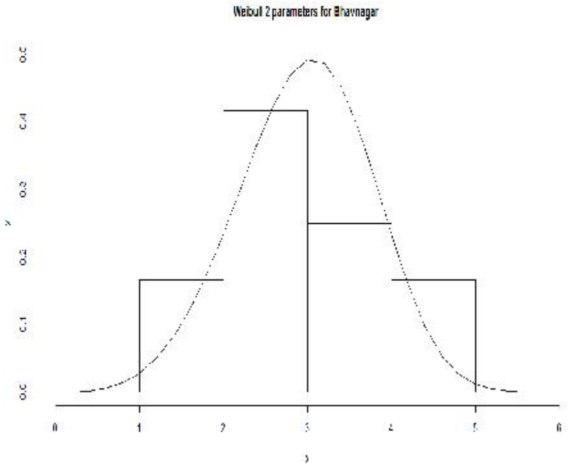
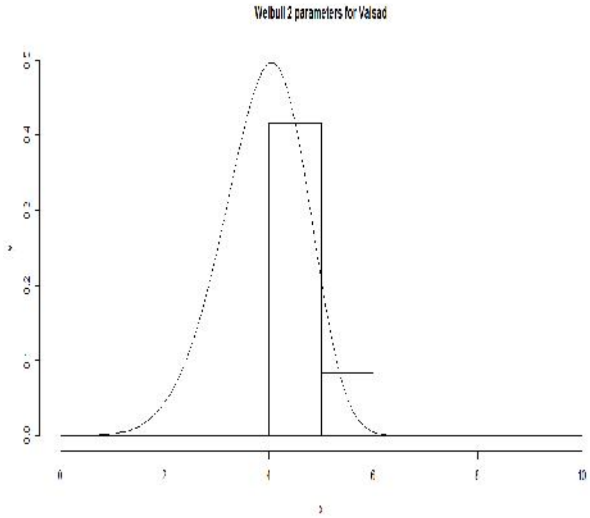


Figure 4: Two parameter Weibull for Valsad



V. CONCLUSION

This work was carried out on the data of wind speeds at the three sites that are selected based on availability of wind speed on higher side over large spans of time as monthly wind speed secondary data [6]. The observation and calculation done in this whole work are done using R. The obtained data were applied for statistical computations and two parameter Weibull function. The analysis of monthly wind speed data included the computations of Standard Deviation, Mean Velocity (m/s), Variance, and Two parameter Weibull function for the duration of 12 months. The observation and calculation analysis Diu is suitable location receiving optimum wind energy.

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