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Advances in Applied Science Research, 2013, 4(3):220-225

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ISSN: 0976-8610
CODEN (USA): AASRFC

Wind energy potential of Ban village

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ABSTRACT

An evaluation of wind energy resource was undertaken to determine the suitability of wind energy development in the areas of wind pump and electricity generation technologies in Ban village, Plateau state, Nigeria. Ten year hourly wind speed data measured at 10 m height was collected from the meteorological unit of Jos airport, which was used to determine the mean monthly wind speed, annual wind speed and the wind speed distribution. Wind Energy Resource Analysis (WERA) software was also used to determine the Weibull distribution factors, energy density, most frequent wind speed and the wind velocity contributing to maximum energy using the raw wind speed data collected. This study indicates that Ban village has a mean annual wind speed of 4.84 m/s, (which is about twice the value of the minimum wind speed required for wind pump application), the Weibull shape factor of about 2 and the Weibull scale factor of over 4 m/s which are indicators of high wind energy potential. This information will be helpful to government and any organisation to make an informed decision regarding investment in wind energy technology in Ban village.

Keywords: Weibull factors, WERA software, Wind energy, Wind speed.

INTRODUCTION

Wind is air in motion caused by the rotation of the earth and the uneven heating of the earth by the sun. Wind energy can be used for many processes, such as generating electricity and pumping water. Wind energy is stochastic. However, it is clean, renewable and environmentally benign. It has the advantage of being harnessed on a local basis for applications in rural areas and remote areas.

Supplementing our energy base with clean and renewable sources of energy such as the wind, especially in rural areas has become imperative due to the present energy crisis and growing environmental consciousness.

Knowledge of the mean, monthly and annual wind speeds, wind speed distribution and Weibull distribution factors are essential pre requisites for predicting the energy potential of a location[1]. Thus, this study investigates the potential for wind energy development in Ban village using the Wind Energy Resource Analysis (WERA) software to determine the suitability of the village for wind energy technology development and utilization.

Ban is a village in Plateau State, Nigeria. It is about 2 km away from Jos airport. It is located at an altitude of 1200 m above sea level between longitudes 8^0 53’ E and 8^0 54’ E and between latitude 9^0 39’ N and latitude 9^0 40’ N. It has an average annual rainfall of 1,400 mm, which lasts between 6-7 months [2].It has the lowest temperature record of 15^0C between December and January and the highest record of 32^0 C in March. The dry season is dominated by the north-easterly wind between October and April and the wet season is dominated by the south-westerly moist tropical maritime wind between May and September [2]. The natural vegetation of Ban village is close to Guinea Savannah. The vegetation is characterized by shrubs and grass with few scattered trees planted by the people in the village.
Energy available in the wind is basically the kinetic energy of large masses of air moving over the earth’s surface.

The wind turbine converts this kinetic energy to mechanical or electrical forms, depending onthe end use.

Research works have shown that Weibull and Rayleigh distributions can be used to describe the wind speed variations in a regime with an acceptable accuracy level [3]. In Weibull distribution, the variations in wind velocity are characterized by two functions:

(i) The probability density function and (ii) The cumulative distribution function. The probability density function $f(V)$ indicates the fraction of time (or probability) for which the wind is at a given velocity, V. It is given [4] as:

$$f(V) = \frac{k}{c}(\frac{V}{c})^{k-1} e^{-(\frac{V}{c})^k} \quad (1)$$

Here, *k* is the Weibull shape factor and *c* is the scale factor.

The shape factor *k* shows that the variation of the hourly mean wind speed around the annual mean is small while the scale factor *c* shows how high the annual mean is or how windy a location is.

The cumulative distribution function of the velocity $F(V)$ gives us the fraction of time (or probability) that the wind velocity is equal or lower than *V*. Thus the cumulative distribution $F(V)$ is the integral of the probability density function. Thus, average wind velocity of a regime, following the Weibull distribution is given in [4] as:

$$F(V) = 1 - e^{-(\frac{V}{c})^k} \quad (2)$$

Where, V in m/s is the velocity of the site.

The peak of the probability density curve indicates the most frequent wind velocity in the regime. The cumulative distribution function can be used for estimating the time for which wind is within a certain velocity interval.

The reliability of Weibull distribution in wind regime analysis depends on the accuracy in estimating k and c. For the precise calculation of k and c, adequate wind data, collected over shorter time intervals are essential [4]. In many cases, such information may not be readily available. Under such situations, a simplified case is derived by approximating k as 2 in the Weibull model. This is known as the Rayleigh distribution.

The Wind Energy Resource Analysis (WERA**)** programme was developed by Prof. Sathyajith Mathew of the Kerala Agricultural University (KAU) and Kelappaji College of Agricultural Engineering and Technology, India. The programme is based on the Weilbull statistical models[4].WERA can be used for:

- Analysing the wind energy potential at a given site.
- Estimating the performance of a Wind Energy Conversion System (WECS) at the site.

Present version of WERA has three modules, namely, site, wind turbine and wind pump. The site and wind turbine modules have provision to perform the analysis on the basis of either Weibull or Rayleigh distribution or using raw wind speed data from site. Wind pumping systems with positive displacement piston pump and rotor-dynamic pump are also considered in the wind pump module.

MATERIALS AND METHODS

Wind data measurements over a period of ten years are required to obtain an accurate assessment of the wind regime of an area[5]. According to literature, when there are no remarkable changes in terrain, wind speed can be applied as far as 25 km [3]. Thus, the wind speed data was collected from the Jos airport which is about 2 km away from Ban village for the analysis. The average monthly wind speed for ten years and the frequency distribution of the wind velocity were determined from the ten year hourly wind speed raw data collected from the airport.

Analysing the wind speed raw data obtained from the airport using WERA software gives the changes of the Weibull shape factor, k, Weibull scale factor c, wind energy density, E_D, wind energy intensity, E_I, the most frequent velocity, $V_{F\ \max}$, and the velocity contributing to the maximum energy, $V_{E\ \max}$, over the months of the year.

RESULTS AND DISCUSSION

Table.3.1: Ten year monthly average wind speed in m/s for Ban village

Year\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	4.52	4.40	4.80	5.44	5.50	5.26	4.78	4.12	3.48	3.73	3.65	3.98
2003	4.27	4.59	4.30	5.52	5.10	4.87	5.01	4.30	3.62	3.62	4.98	5.14
2004	4.48	4.42	4.98	5.38	5.02	5.06	4.55	4.27	3.85	3.35	3.58	4.51
2005	5.13	4.95	5.28	5.46	5.74	5.15	4.61	4.30	3.75	3.53	3.24	3.39
2006	5.34	4.70	5.56	5.38	5.29	5.03	4.93	4.51	4.25	3.35	3.22	3.62
2007	5.50	4.57	5.63	5.60	5.75	5.37	5.00	4.98	4.50	3.79	3.53	3.45
2008	5.47	4.78	5.53	5.50	5.63	5.33	5.22	5.02	4.44	3.97	3.85	3.80
2009	5.77	5.27	5.60	5.63	5.68	5.42	5.40	5.27	4.52	4.47	4.24	4.28
2010	6.50	5.96	5.71	5.51	5.47	5.42	5.28	5.18	4.93	4.52	4.39	4.23
2011	7.60	5.52	5.59	5.14	5.32	5.11	5.28	5.18	5.00	4.52	4.47	3.84
Average wind speed	6.00	4.92	5.30	5.46	5.45	5.20	5.01	4.71	4.20	3.89	3.90	4.02

Table.3.2: Wind velocity distribution of Ban village

Wind speed interval (m/s)	Frequency distribution of site wind speed (Hr)
0-1	71
1-2	164
2-3	571
3-4	654
4-5	1921
5-6	1358
6-7	893
7-8	1526
8-9	742
9-10	549
10-11	268
11-12	33
12-13	10
Total	8760

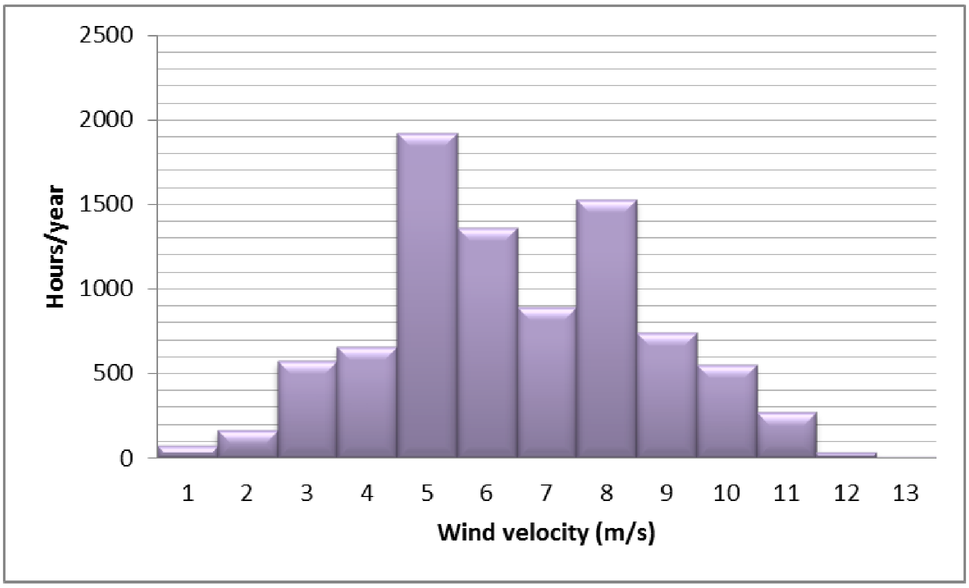

Figure 3.1: Probability distribution of yearly wind velocity of Ban village

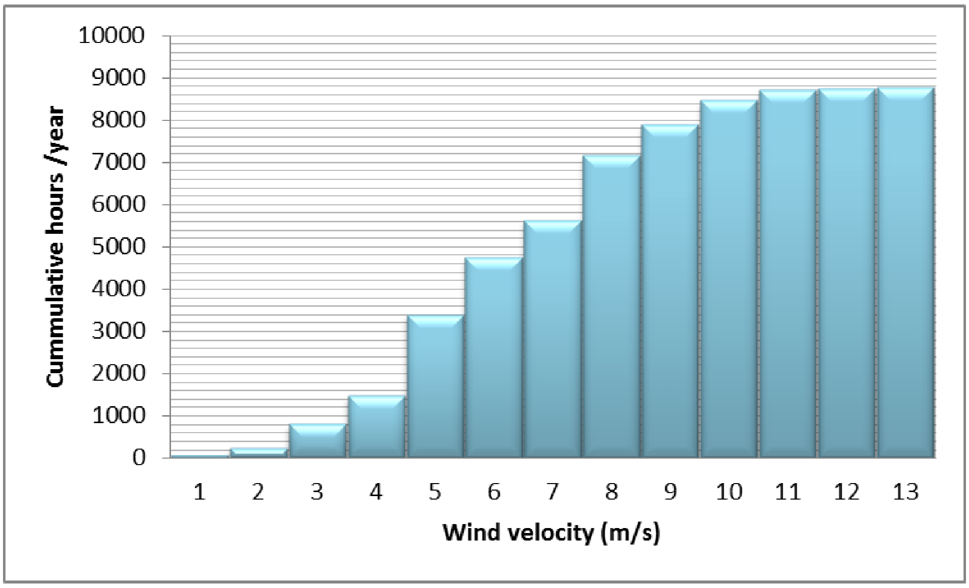

Figure 3.2: Cumulative distribution of wind velocity of Ban village

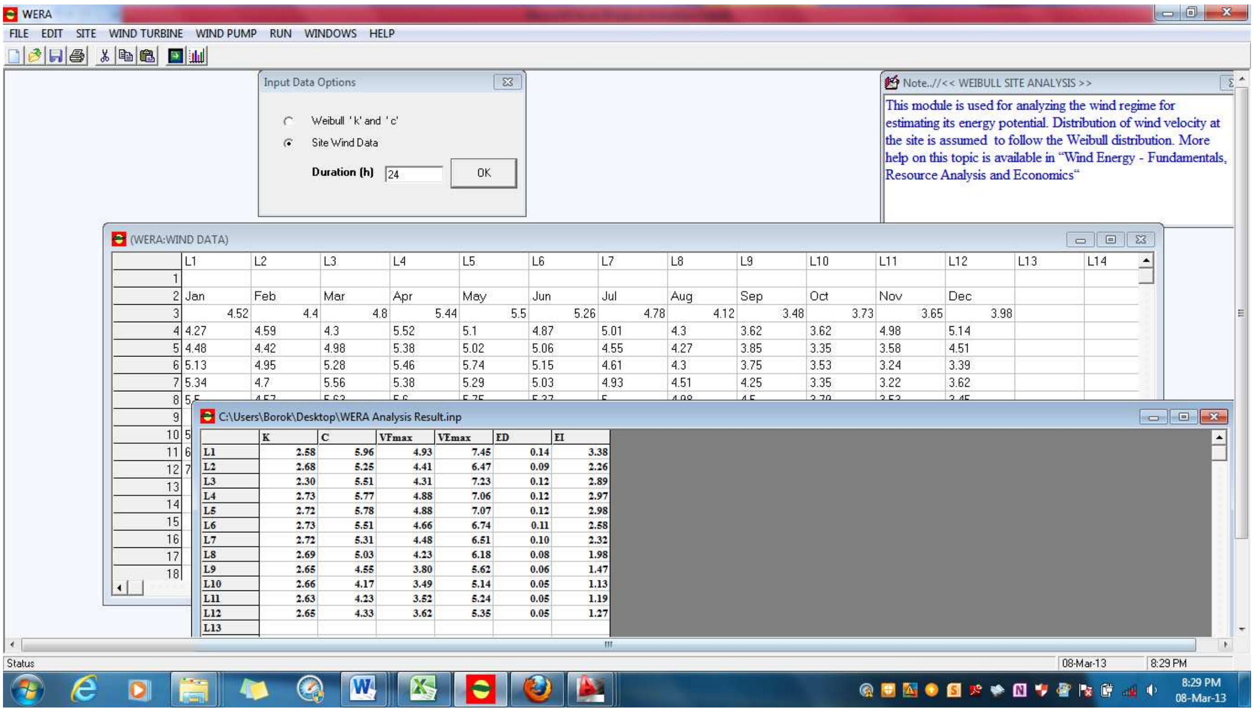

Figure 3.3 WERA software windows displaying analysed results of wind speed data of Ban village

Table 3.3: Results of Wind speed data analysis of Ban village using WERA software

3.2

	Shape factor *k*	Scale factor *c*	E_D (kW/m^2)	E_I (kW/m^2/day)	$V_{F\,max}$ (m/s)	$V_{E\,max}$ (m/s)
Jan	2.58	5.96	0.14	3.38	4.93	7.45
Feb	2.68	5.25	0.09	2.26	4.41	6.47
Mar	2.1	5.51	0.12	2.89	4.31	7.23
Apr	2.73	5.77	0.12	2.97	4.88	7.06
May	2.72	5.78	0.12	2.98	4.88	7.07
Jun	2.73	5.51	0.11	2.58	4.66	6.74
Jul	2.72	5.31	0.1	2.32	4.48	6.51
Aug	2.69	5.03	0.08	1.98	4.23	6.18
Sep	2.65	4.55	0.06	1.47	3.8	5.62
Oct	2.66	4.17	0.05	1.13	3.49	5.14
Nov	2.63	4.23	0.05	1.19	3.52	5.24
Dec	2.65	4.33	0.05	1.27	3.62	5.35

DISCUSSION

Table 3.1 is the average monthly wind speed of Ban village, determined from the ten year hourly wind speed raw data collected from the airport. The lowest average monthly wind speed is calculated to be 3.89 m/s which fall in the month of October, which shows that Ban village has high energy potential for water pumping since a minimum wind speed of 2.5 m/s is enough for siting wind pump[6].

Similarly, table 3.2 is the wind speed distribution of Ban village from which the probability and cumulative distribution of the yearly wind velocity of Ban village were produced as shown in figures 3.1 and 3.2 respectively, which follow the Weibull distribution curves. The frequency distribution gives the information on the number of hours for which the velocity is within a specific range and is used to determine the energy output of a windmill by multiplying the number of hours in each interval with the power output that the windmill supplies at that wind speed interval [7].

Table 3.3 is the result of wind speed data analysis of Ban village using WERA software. The result shows that the Weilbull shape factor k, for all the months of the year is above 2 and the scale factor c, is above 4 m/s. With the Weibull scale factor above 4 throughout the months of the year shows that wind speed variation is minimal, thus, this will guaranty the availability of windpump installed in the village. The variation of the hourly mean speed around the annual mean is small as the shape factor k is above 2. Similarly, with an average Weibull shape factor of 2.4, throughout the year, k can be approximated to 2 which is a simplified case of Weibull model known as Rayleigh distribution. This implies that Rayleigh distribution model for analysing wind speed is applicable for Ban village as this analysis is simpler.

A Wind Energy Conversion System (WECS) operates at its maximum efficiency at its design wind speed, V_d . Hence, it is advantageous that V_d and the velocity contributing to maximum energy, $V_{E\max}$ (as determined by the WERA software analysis) are made as close as possible if not constrained by other factors [4].

CONCLUSION

The wind energy potential in Ban village, in Heipang, Plateau State, Nigeria has been evaluated from the wind speed collected from the meteorological unit of Jos airport using WERA programme. The study shows that wind energy potential in Ban village is high and it could be used to generate electricity or pump water from boreholes to the community. Existing data resources indicate that the lowest mean monthly wind speed is 3.89 m/s which falls in October and the annual wind speed of over 4.84m/s. The Weibull shape factor *k* and the Weibull scale factor *c* are above 2 and 4 respectively which are indicators of high wind energy potential. With Weibull scale factor of about 2, implies that Rayleigh distribution model for analysing wind speed is applicable for Ban village as this analysis is simpler.

Acknowledgement
The authors would like to appreciate the meteorological unit of Jos airport and the Department of Mechanical Engineering, Ahmadu Bello University, Zaria for making this study possible.

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