International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 4, pp: 224-230 www.ijaem.net ISSN: 2395-5252

Assesment of Wind Power and Energy Contentofatap, Bauchi Using Weighbul and Rayleigh Distribution Function

Usman, A. R[1], Sa'idu, S.[2], Sanda, S. H.[3], Lawal, A. M.[4] ,Aminu, I. M.[5]
[1,3]Mechanical Engineering Department, School of Engineering, AbubakarTatari Ali Polytechnic, Bauchi
[3]Automobile Engineering, AbubakarTafawaBalewa University, Bauchi

Date of Submission: 28-07-2020 Date of Acceptance: 12-08-2020

ABSTRACT
The objective of this research is to determine the speed of the wind of ATAP, Bauchi and to assess its potentiality as an alternative energy source using Weibull and Rayleigh distrbution.The wind speed for the period of 12 months was used analyzed using Wiebull and Rayleigh probability distribution. The average wind speed (velocity),power density pd and the energy content EC was estimated found to be 12.3375m/s,1165.323W/m^{2}and721.42Kwh/m^2/month for one year. On the basis of the annual wind speed the level of the power can be considered suitable for small wind energy conversion system to generate electricity and carry out some agricultural activities within the study area. Wind turbine can be design to suite the frequency distribution of the wind which varies on the time of the day, wind direction weather condition and the location of the turbine.

KEYWORDS: wind speed, power density and energy content

I. INTRODUCTION:

Wind is air in motion. It is a form of solar energy.The warmer air rises over the colder air causing the wind to blow. The kinetic energy of the wind blowing across the earth's surface is converted to mechanical energy using wind turbine. The generator take advantage of the wind power, long blades or rotor catches the wind and spin. A windfall converts the forces of the wind into turning forces on the rotor blades.

[1] Fossil fuel derived energy are the main courses of global warming, they are easily depleted at time when energy demand is high due to human population and partly because of the greater environmental impact. Electricity generated through the use of fossils contributes a lot to greenhouse gas (GHG), CO_2 which is equivalent into atmosphere.

[2]Power generation is essential to the development of a science and technology of any nation in the world. There has been high increase in interest in renewable energy technology steadily. Nigeria which is among the developing nations is faced with lack of electricity supply

[3]The variation in heating of the earth's surface generates atmospheric motion and kinetic energy. Factors such as surface orientation, slop, rate of reflection, absorption and transmission affect the wind energy resources. Other factors that affect wind energy resources are that they can be accelerated and decelerated. Building, bodies of water and vegetation are also additional factors. Wind is air with kinetic energy that can be transformed into useful work via wind turbine blades and a generator. Wind is an efficient source of energy. It is free and harmless and less costly.

[4] Wind has three important aspects: velocity (wind speed), density of the gas involved and energy content or wind energy. The wind energy potential is theavailable power from the kinetic energy of the movingair in wind. The kinetic energy in the wind is converted into electricity using wind turbines. Hence, wind energy is cannot be exhausted and contributes very little pollution and few green-house gases to the environment and is therefore a valuable alternative to non-renewable and depleting fossil fuel.

[5]Wind has been used by human to power and sail ships and provide ventilations to buildings or houses. Wind energy has been used as early as 17th century in Babylon for powering irrigation systems. In the 7th century it was reported that there are existence of vertical –axis wind mill which had long vertical drive shafts with rectangular blades. Materials such as wood, reed matting, cloth and limestone were used to manufacture them. This kind of windmill was used to grind corns and pump water. North-western Europe developed horizontal – axis windmills and used to grind flour the most famous are found in Netherland dated back to 1180s. During the 1800s there was a rapid increase in the development and distribution of the well-known multi-bladed turbine which was mounted on a wooden structure. These were used to pump water for irrigation cattle rearing, railroads and power locomotives and were rapidly distributed all over the world. The first modern wind turbines were built in the early 1980s, and have been subject to increasingly efficient design

[6]To calculate the maximum power that can be generated by the wind turbine Bezt law is uses which was developed by a German scientist AlbartBezt. The law states that the maximum power extracted from the wind is proportional to the product of wind speed times the drop across the rotor. If the rotor has a higher flow resistance, the pressure drop is increased, but less flow goes through the disc and more goes around it. The shows that there is maximum efficiency for the extraction of power which is 59.3%. based on this law it is common in practical to say that the turbine cannot capture more than 59.3% of the kinetic energy of the wind. There are some more than wind turbine design that approaches this potential maximum efficiency. Wind turbine are design to starting the wind speed at at around 3 to 5m/s.

[7]The shortage in electricity production causes a lot of problem to national development. Continuous raised in global warming is associated with fossil fuel derived energy sources. The bulk of the supply for electrical energy in the country has been from the National Electric Power Authority (NEPA). This expands annually in order to meet the ever increasing demand presently, that task is being performed by the Power Holding Company of Nigeria, PHCN. Energy production and consumption in Nigeria has been on the increase. Baba and Garba have reported that the prospect of wind energy it shows that the average speed of wind measured at 10metres height above the ground level for Bauchi was 4.78m/s, that of Port Harcourt was 2.56m/s and that for Akure was 0.76m/s. This showed wind turbines installation will be more preferable in Bauchi than in Port Harcourt and Akure and that the disparity in mean wind speed annually was much lower for Port Harcourt than for Bauchi suggesting that wind turbines set up in Port Harcourt would function more frequently for several years. Bauchimetropolis is located on latitude $10^{0}18`$ 57`` and longitude $9^{0}49`3``$. It was reported that the study area has good geographical location for the utilization of wind energy because of the consistent flow of wind. It was also recommended that a comprehensive study of the wind energy of site be taking in order to come up with the best location for harnessing the wind energy.

The study location AbubakarTatari Ali Polytechnic(ATAP) is situated along Jos road BauchiBauchi state. The objective of this paper is To determine the speed of the wind of ATAP, Bauchi and to assess its potentiality as an alternative energy source using Weibull and Rayleigh distribution.

II. WIND SPEED, POWER, ENERGY CONTENT, WIEBULL AND RAYLEIGH DISTRIBUTION OF THE WIND.

[6][8]Wind speed for a given location can be characterized by several probability density functions. it can be modeled as a continuous random variable in term of density function f(v) or a distribution function F(v). To estimate the wind power of a location, it is important to estimate the frequency distribution. Weibull probability distribution is commonly used to modeled wind, the Weibull distribution has two parameters which must be determined (i.e the dimensionless shape parameter “K” and the scale parameter “C” which has a unit similar to that of the wind speed m/s. The values of K and C can be adjusted to fit available data over the study period. Typically one month. For this study Rayleigh distribution has been adopted to determine the two parameters K and C, given K = 2, C is determined from the equation below and is in m/s.

$$C = \frac{2v_r}{\sqrt{\pi}}$$

The frequency distribution in m/s is given by f(v)

$$f(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)k\right]$$

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

Where v = is the wind speed in m/s
Vr = average wind speed (monthly average).*)*
Power density, pd in the wind W/m2, energy pattern factor, EPF and Energy content, EC of the wind in Wh/m2/yr, defined in the equation below serves as useful parameters for assessing wind energy for this study.

$$p.d = \frac{1}{2}\int_0^\infty f(v) V_r^3 dv$$

$$EPF = \frac{pd}{\frac{1}{2} p v_r^3}$$

EC = 8760 x pd
Where: 8760 is the number of hours in a year

Power in the wind.

[5]Wind consists of bulk movement of air from high to low pressure regions. Wind has three important aspects: velocity (wind speed), density of the gas involved and energy content or wind energy.

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The wind energy potential is the power available from the kinetic energy of the bulk of air moving in wind. The kinetic energy in the wind is converted into electricity using wind turbines. Power in the wind is equal to the energy per unit time. The energy available is the kinetic energy which is equal to 0.5mv2. m is the air mass flow rate given by m = $\rho\upsilon$ (i. e. the mass of air passing through the volume (V). vr is the free stream velocity. $\rho =$ air density equal to 1.22kg/m3.

Volume of air passing through an area A, with speed Vr in time as A.Vr.t.

Then $m = \rho Avt$

$$KE = 0.5\rho Av_r^2 t$$

Power density is given by the derivative of the kinetic energy with respect to time t.

$$pd = \frac{dk}{dt} = 0.5\rho Av_r^3$$

The Power Curve of A Wind Turbine

[6]The power curve of a wind turbine is a graph that indicates how large the electrical power output will be for the turbine at different wind speeds. Usually, wind turbines are designed to start generating at wind speeds somewhere around 3 to 5 meters per second. This is called the cut-in wind speed. The wind turbine will be programmed or designed to stop at high wind speeds in order to avoid damaging the turbine or its surroundings. This speed is called the cut-out wind speed. In Figure 3 this speed is 10, 5 m/s.

IIIEXPIREMNTATION

Wind speed measuring instrument

Wind speed data covering mainly the period of one year was measured. Average daily, weekly collection is calculated to give the monthly average wind speed from January to December of the year 2019. Instrument for measurement of data:

- Digital anemometer Am-4826C and Am-4386C.
- Thermo-digital anemometer.

METHOD OF DATA COLLECTION

Daily collection of wind speed data from the site:. Analysis of the wind speed data after these include conversion to meter –per second and calculating the average daily, weekly and monthly wind speed data of the site.

POWER IN THE WIND

Winds vary with the season, time of day, and weather events. Analysis of wind data focuses on several critical aspects of the data—average annual wind speed, frequency distribution of the wind at various speeds, turbulence, vertical wind shear, and maximum gusts. These parameters allow for estimation of available energy in the wind and the suitability of turbine technology for the site.

WIND SPEED ANALYSIS

The following table is the wind speed collected from the study location.

Table 3.1Wind
Speed in m/s For ATAP, Bauchi Of The Year 2019

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind speed m/s	12.04	11.21	12.62	10.56	13.08	12.99	12.20	13.34	12.40	11.31	12.40	13.90

Power density for Bauchi can be estimated using equation 9 below

$$p.d = 0.5\rho v_r^3$$

Where $\rho =$density of air taken as 1.221kg/m^3
At standard atmospheric pressure V_r average monthly velocity.

Table 3.2 contained the average monthly velocity $V_r$in m/s, power density in W/m^2 and the energy content in KWh/m^2/yr for the year 2019
To calculate the energy content (EC) in Kwh/m^2/Mn
Energy content EC = power density Pd×number of hours per month

Table 3.2 showing the monthly velocity, power in the wind and energy content of ATAP, Bauchi for the year 2019.

Months	V(m/s)	P.d W/m^2	hr/month	EC(kwh/m^2/mnt
January	12.04	1065.32	744	792.59
February	11.21	860.00	672	288.10
March	12.62	1227.05	744	912.93
April	10.56	718.91	720	517.62
May	13.08	1366.18	744	1016.44
June	12.99	1338.18	720	930.48
July	12.20	1108.58	744	824.78
August	13.34	1449.28	744	1078.26
September	12.40	1163.79	720	837.93
October	11.31	883.23	744	619.99
November	12.40	1163.79	744	837.93
December	13.90	1639.57	744	1219.84.

Mean of the wind speed for 12months is $V_{Avg} = \frac{148.05}{12} = 12.3375$m/s
Average power density Pd= $\frac{13983.88}{12}$ =1165.323 W/m^2
Average energy contenEc = $\frac{8657.05}{12}$ = 721.42Kwh/m^2/month

THE MODELLING OF THE WIND SPEED.

[5]Wind varies with the season, time of the day and weather conditions. Analysis of the wind speed data of a location focuses on several crucial aspect of the data. The frequency distribution of the wind at varying speed is an important factor
Understanding the wind characteristics is crucial in wind energy generation. Time is therefore been devoted to the modeling part. Weibull and Rayleigh distribution have been found to more suitable for the modeling. The Wiebull probability density function is given by;

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

The cumulative frequency is given by the equation

$$f(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)k\right]$$

The shape factor is a special case of the Rayleigh distribution, it is obtained when the shape parameter (K)= 2 (C) is given $C = \frac{2v_r}{\sqrt{\pi}}$

International Journal of Advances in Engineering and Management (IJAEM)
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Table 3.3 showing the shape factor, frequency distribution and the cumulative frequency of the wind speed of ATAP, Bauchi of the year 2019.

Months	c(m/s)	f(v)	F(v)
January	13.59	0.059	0.544
February	12.65	0.072	0.544
March	14.24	0.064	0.544
April	11.92	0.077	0.544
May	14.76	0.062	0.544
June	14.66	0.062	0.544
July	13.77	0.066	0.544
August	15.53	0.062	0.549
September	13.99	0.065	0.544
October	12.76	0.071	0.479
November	13.99	0.065	0.544
December	15.68s	0.058	0.544

IV.DISCUSSION OF RESULTS

Table 3.2 shows the result obtained of the monthly average velocity (Vm/s), the power density (pdW/m^2)and the energy content (Ec (Kwh/m^2/mnt)). The wind speed varies monthly with the highest in the December, (13.90m/s). From the calculations it was deduced that the power density is also higher in December (1639.57W/m^2) and the energy content EC is 1219.84KWh/m^2/mnt.On the basis of the annual wind speed, the power density and the energy content of site, it shows that the wind energy could be significantly harnessed in the site. Furthermore the wind energy of the site could be considered to pump water. The wind speed varies from due to time of the day, weather conditions and the location of the site it is therefore suitable to design a wind turbine to operate at different conditions and at a variable wind speed to be able to capture the maximum wind energy of the site.

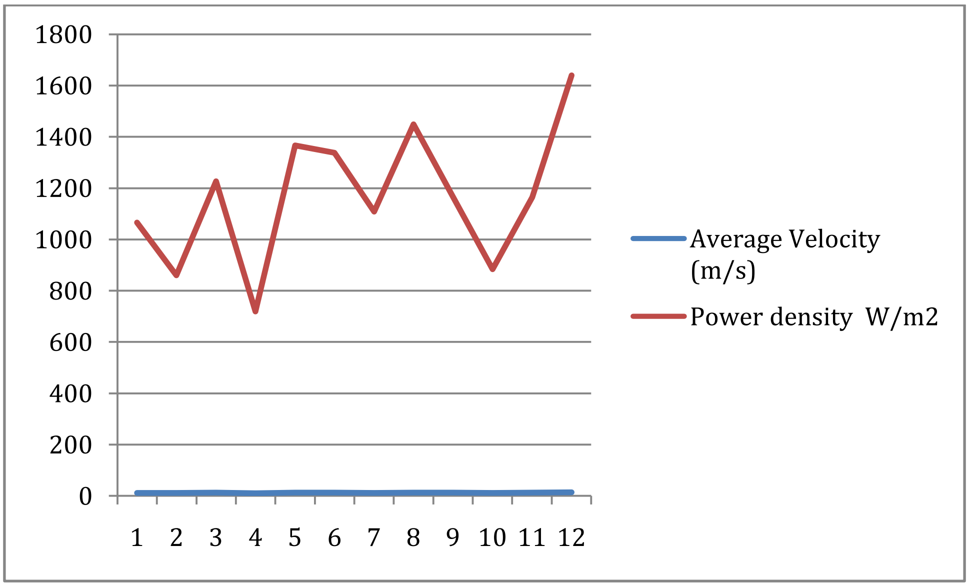


Fig 4.1Graph of power density against velocity of the wind.

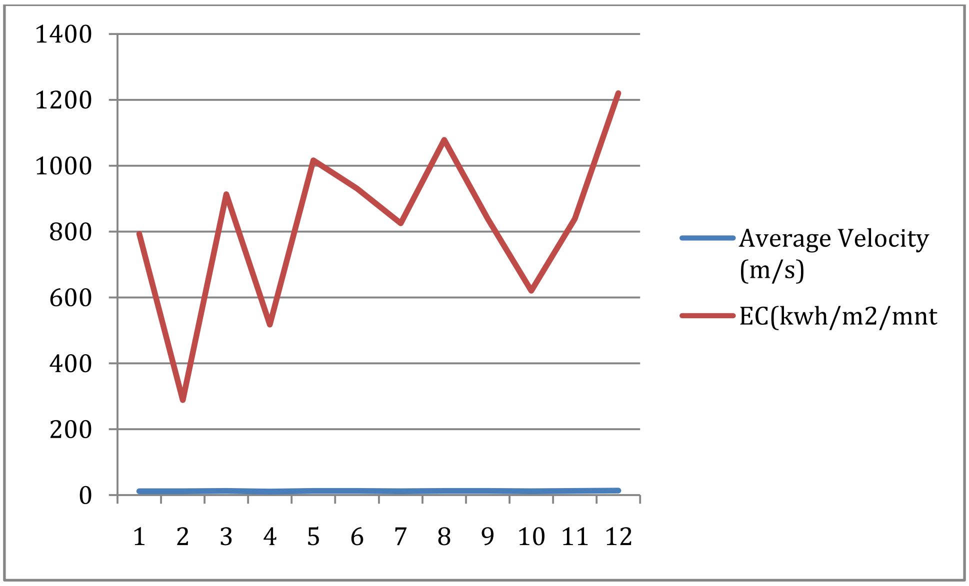
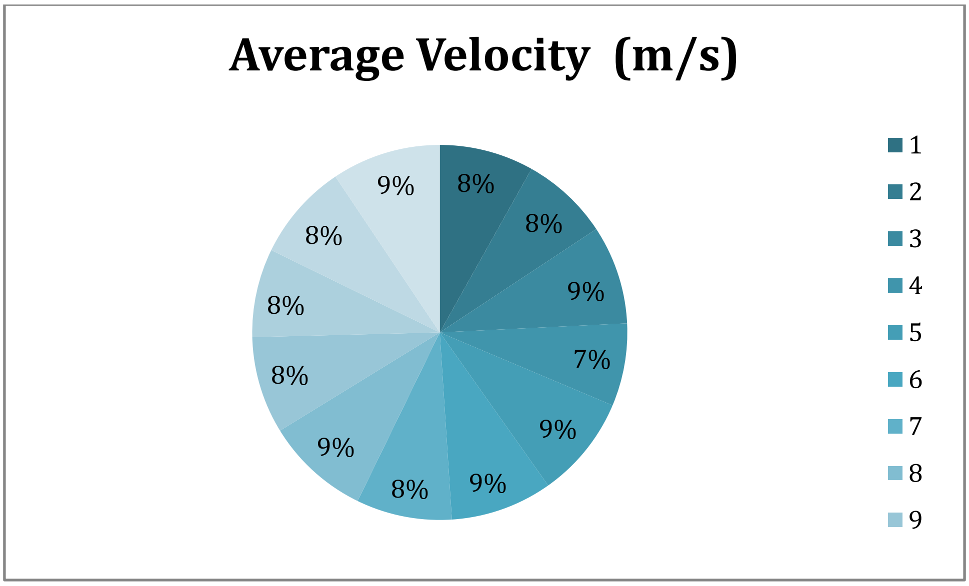


Fig 4.2 Graph of energy content against velocity of the wind.

Table4.1: Mean annual velocity, V_r(m/s) power density pd(w/m^2) and energy content, EC(kwh/m^2/yr) for the period of one year.

Mean annual velocity V_r	12.3375m/s
Mean annual power density pd	1163.323w/m^2
Mean energy content EC	721.42kwh/m^2/month.



V. CONCLUSION

In this study, a data was collected daily, the average wind speed was determined, power density, energy content of the wind speed from January to December of the year 2019 was evaluate. Weibull and Rayleigh distribution was used to determine the frequency distribution function of the win.

Analysis of the data shows that wind energy can be harnessed to generate electricity in consideration of the variation of the wind speed within the time of the day, weather and location. The wind turbine must be design to meet these requirements. The annual average wind speed was 12.3375m/s, power density 1163.323w/m^2 and the

energy content is 721.42kwh/m^2/month. Based on the analysis it was shown that more power density and energy content could be obtained in January, march, May, June, July, August, September, November and December.

Considering the prospect of wind energy within the study location ATAP, Bauchi the following recommendations were made.

a. Further study is desirable for construction of the wind turbine in order to harness the wind energy potential in the site.
b. There is need for establishment of a permanent weather station to monitor the activities.

ADVATANGES DERIVED FROM THE ABOVE RESULT

Looking at the result obtained from this study the following advantages were derived

1. Wind energy can be properly harnessed from the site. It can be used for the generation of electricity and pumping of water.
2. Further assessment can be carried out in the site because of the variation in the wind speed due to time of the day, session year and weather conditions
3. The study also reveals that in order to properly harness wind energy, the wind speed of site the need to be assessed.

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International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 02 Issue: 01 DOI: 10.35629/5252