The Estimation of The Weibull Parameters and Specific Wind Energy for The Sumawaha City in Iraq.

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Abstract

In the present study, the results of recorded observations for the wind speed at heights of 10 meter in the Sumawah site at the southern region of Iraq are presented in the form of tables, bar charts and graphs. The annual and monthly wind speeds and wind density are investigated. A statistical analyses based on the Weibull function were involved to determine the potential of wind energy for the location under study. The annual and monthly values for the shape and scale parameters were calculated from the available data. The results shows that the Weibull function gives a good fit to the recorded data and shows that this location have a moderate amount of wind power for power generation.

Keywords: Renewable energy, Weibull functions, Wind Turbine, Duration.

الخلاصة

تم في هذا البحث عرض سرع الريح ألمسجله على ارتفاع (١٠) متر من سطح الأرض لمدينه السماوه في جنوب العراق على شكل جداول ومنحنيات.تم حساب متوسط سرع الريح الشهرية والسنوية. كذلك تم دراسة سرع الريح إحصائيا بموجب داله ويبل الإحصائية لتحديد واستخراج قدره الرياح للمنطقة المختارة.أيضا تم حساب قيم معامل ويبل ألشهريه والسنوية من المعلومات المتوفرة. أظهرت نتائج البحث أن داله ويبل تعطي ملائمه جيده للبيانات المسجله وأظهرت كذلك ان هذا الموقع يمتلك كميه معتدله من قوه الريح التي يمكن استخدامها لتوليد الطاقة.

الكلمات المفتاحية: الطاقة المتجددة، وظائف بيل، توربينات الرياح، مدة

LIST OF SYMBOLS:

Symbols	Definition
C	Scale factor, Operation cost
f(v)	Probability function
F(v)	Cumulative distribution function
H,h	Height
i	Inflation rate.
K	Shape factor
n	Life time of the machine.
P	Power
PVC	Present Value Cost
r	Discount rate.
S	Scrap value.
T	Duration
V	Wind speed
x	Exponent factor.
Γ	Gamma function

Introduction

In order to meet the uncertainty in supply of oil since the mid-1970, utilization of energy from renewable such as wind has gained considerable momentum and is being widely used for displacement of oil-produced energy, and eventually to minimize atmospheric degradation. The historical evidence indicate that the wind has been useful energy resource in times of need for pumping water, grinding grains and electricity generation. Literature indicates that wind is being free, non-depletable,site-dependent,environment-friendly,promising,and non-polluting energy.

The assessment of wind energy conservation systems (WECS) as available energy source requires an evaluation of the statistical characteristics of the wind, in particular, wind speed and its duration. For this reason, several efforts have been made to construct an adequate statistical model for describing the wind speed frequency distribution which can be used as adequate tool in analyzing wind speed data for wind energy purposes. Most attention has been focused on the Weibull function since this gives a good fit to measured data [Hennessey 1977, Wetink 1976]. Most authors applied this distribution for the data of different locations around the world and do a comparison with other distributions such as Plank, Rayleigh and the gamma distribution, they concluded that the Weibull distribution rendered best fit to the recorded data[Hennessey 1977,Wetink 1976,Justs 1976,Peterson1981]. The aim of the present study is to analyze wind speed distribution at Sumawaha site in the southern part of Iraq that is due to the important of statistical analysis of wind data to predict the power density in this area and the areas around it. The scope of windmill in Iraq will help the oil in meeting the increase in the demand of energy as a result of the raped increase of economic growth.

Wind Data

The Sumawah site is at the center of the Sumawah governor, located at the southern part of Iraq at 31◦.18' N and 45◦.19' E and its height above sea level is 11.4 meter (The location of the selected location on the map of Iraq is shown in Fig.(1)).Climatic conditions dictate the availability and magnitude of wind energy at a site as its very much a desert environment .Two distinct seasons are noticed in this region; a very hot season (May to October) and a cold season (Nov. to April).Monthly mean temperatures reach to close 40^{o}Cfor hot months .The mean temperature will drop about 20^{o}C for cold months.

The decision of using the WECS in any location depend on the answers of many questions, how much wind is available? Is it likely to have suitable winds in the suitable time and place, and if so, what is the cost of getting unit energy from theses winds which have different directions?. However determining the parameters for the annual wind speed distribution will help in determining the overall wind energy potential for any site. The monthly parameter are useful for estimating the size of the WECS for application such as in water-pumping for irrigation where the energy requirement varies greatly from time to time. Wind speeds data recorded by the Iraqi Meteorological Organization were used for estimating the values of the Weibull parameters. These data are sampled every three hours at(10)meter above ground level, the quality of the data varies from time to time and assumed to be fair. The wind speed near the ground changes with height, this requires an equation that predicts wind speed at any height in terms of the measured speed at another height. The most common expression for the variation of wind speed with height is the power law having the following form [Mahyoub 2006]

$$[\frac{V_i}{V_h}] = [\frac{H_i}{H_h}]^x \qquad (1)$$

Where V_h (m/s) is the actual wind speed recorded at height H_h (m) and V_i (m/s) is the wind speed recorded at height H_i. The exponent (x) depend on the surface roughness and atmospheric stability, it can be calculated from the following equation [Mikhail 1981]

$$x = \frac{0.37 - 0.008(\ln V_h)}{1 - 0.088(\frac{H_h}{10})} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The Weibull distribution and related quantities:

The Weibull distribution is a two parameters function. The probability function *f(v)* and the cumulative distribution *F(v)* which is given by the following equations[Stevens 1979]:

$$f(v) = \left(\frac{K}{C}\right)\left(\frac{v}{C}\right)^{K-1} \cdot e^{-\left(\frac{v}{C}\right)^K} \quad \ldots\ldots\ldots\ldots (3) \quad v > 0$$

$$F(v) = 1 - e^{-\left(\frac{v}{C}\right)^K} \quad \ldots\ldots\ldots\ldots\ldots (4) \quad K > 0,\ v > 0,\ C > 0$$

(K) and (C) are the parameters which characterize the Weibull distribution. The mean of the distribution ,i.e. the mean velocity (V_m), is equal to[Stevens 1979]:

$$Vm = C\,\Gamma\left(\frac{1}{K} + 1\right) \ldots\ldots\ldots\ldots\ldots (5)$$

Where Γ is the gamma function. The average theoretical available power(p), in the wind stream moving at speed(v) is calculated per unit area as follows [Wei *et al*., 2006]

$$P = \frac{1}{2} d.v_m{}^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where (d) is the mean air density considered at a height of (10) m of the, the value of 1.225 kg/m^3 is used in the present work[IMO 2006].

The wind power density is calculated from the following equation[Yaseen 1996]

$$P = 0.615 \sum V_i^3 * T_i^3 \ldots\ldots\ldots\ldots\ldots (7)$$

V_i is the midpoint wind speed for the (ith) interval and T_i is the corresponding duration of the wind in that interval. However this available power cannot be totally extracted by any wind energy conversion system, while the Betz equation which is expressed below gives the maximum attainable power from an optimum system[Yaseen 1996]:

$$Pm = 0.363\, V^3 \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The energy pattern factor method for the estimation of shape and scale parameters:

There are more than six methods for estimating the shape and scale parameters of the Weibull distribution analytically, but there is no significant difference between the results of different methods .In this study the energy pattern factor method was used as follows[Stevens 1979]:

$$\text{Ke} = \frac{\text{Total amount of energy available in the wind}}{\text{Energy calculated by cubing the mean wind speed}} \ldots\ldots\ldots (9)$$

Then

$$K_e = \frac{\Gamma(1+\frac{3}{K})}{\Gamma^3(1+\frac{1}{K})} \ldots\ldots\ldots (10)$$

Also

$$K_e = \frac{\frac{1}{n}\sum_{i=1}^{n} V_i^3}{[\frac{1}{n}\sum_{i=1}^{n} V_i]^3} \ldots\ldots\ldots (11)$$

By substituting this value in Equation(10) ,(*K*) can be easily determined, while the scale parameter(*C*) is estimated by using equation (5) by using the value of V_m which is directly calculated from the recorded data.

Results and Discussion:

Wind speed data for Sumawaha site in Iraq, measured and recorded for one year at Iraqi meteorological station were examined. The main results obtained from the present study can be summarized as follows.

Fig (2) shows the hourly wind speed variation for different months throughout the year. Visual inspection of the figure show that the daily peak value of the wind speed occurs between 10-15 o'clock.

Fig (3), shows the velocity duration curve for the site, which shows that the number of hours greater than 4m/s is 5329hr, the percentage of the annual wind speed below 4m/s which does not contribute to produce energy from wind is about 39%.The energy generation from wind is justified mostly in the times between the speed is greater than 4m/s. Fig (4)shows the annual duration of the available wind power based on the velocity duration curve . The annual average of the wind power is determined to be 70W/m^{2}refering to the annual mean wind speed of 4.5m/s.

The annual average of the max attainable power were calculated to be (931)W/m^2.The monthly average wind speed and wind power density distribution are shown in Figs.(5)and(6)respectively. In general the distributions for both the average speed and the average power density shows that a maximum value of the wind speed and power occurs in June month while the lowest value occurs in September month, that for the year under inspection. The change in wind speed is proportional to the cubic power of wind speed shown in Fig.(6).The variation of wind speeds were described using the Weibull distribution .The method of energy pattern factor was used to evaluate the monthly and annual Weibull parameters(*K* and *C*) for the selected site. Table (3) and Fig.(7) shows these values. It is clear that these values were vary over a considerable range. In general the values of (*C*) are low during the months of December, January and March) and high during the months of (June, July and August).The scale factor varies between 2.7 to 3.9 while the shape factor ranges from 1.2 to 2. Fig(8) shows a comparison between the measured speed data recorded at the station with the distribution of the Weibull function, also Fig.(9) shows the wind power density calculated from the measured data and that calculated according to the parameters of the Weibull distribution. Both figures shows that Weibull model is fit the measured recorded data. The Weibull distribution is a powerful aid in wind energy analyses. As the output of any WECS doesn't appear to be very sensitive to the value of the shape parameter, the Weibull model can be used effectively as long as the value of the average wind speed is reasonably well-known.

Probably the desired application of wind energy in Iraq is the generation of electricity. Examination of the obtained results shows a moderate wind speed, so the WECS must be chosen to be able to start at low speed and have the ability to increase the starting torque.The wind speed distribution allow to determine the amount of power a wind turbine will make at a certain speed. A power curve shown in Fig.(10) for a wind turbine with a blade diameter of (7.5)m, The cut in speed is (4)m/s[Gipe 2004].At wind speeds lower than this, no power will be generated, at 20m/s the power output begins to drop. This is due that the wind turbine turning out of the wind to avoid over speed damage. Performance could be extended to higher speeds, but performance and lower speeds would suffer.The selected machine design is the best overall solution since the majority of time is spent at lower wind speeds [Elhadidy 2007].

Putting the wind speeds and wind machine power curve together gives us an estimated power output. The annual energy production for the wind machine was calculated and found to be 35889.7kwh.The details of the results are listed in Table (2). An estimation of the cost of (1)kWh produced by the selected machine was done using the present value and the unit energy cost method presented by the following equation[Yaseen 1996] :

$$PVC = I + C\left[\frac{1+i}{r-i}\right]\left[1-\left(\frac{1+i}{1+r}\right)^{n}\right] - S\left[\frac{1+i}{1+r}\right]^{n} \quad ....(12)$$

Substituting the values given in Table (4) in equation (12) the present value of the costs, *PVC*, becomes(43448.7$). Dividing this value by the total, *kWh*, produced during the life time of the wind machine (35889.7kWh/year) give the present value of the cost to be (0.065 $) or (77) Iraq dinar per kWh. This value is seem to be not very much expensive since it is very close to the price of the supplied electricity by the local electricity authority using steam turbines. It's found that installing the wind machine at height of (20)m and (30)m that will reduce this value to(40) and (34)I.D/kWh corresponding to (66237) and (77673)kWh generated power respectively, calculated using equations (1)and(2).This latest price is seem to be more economical although the cost of both the installing and the maintenances at these heights will be more.

Conclusion:

A statistical study for a site in the southern region in Iraq named Al-Sumawaha is done. The study involved the wind speed distribution and the amount of energy available from the wind speed from measured and recorded data at (10)m above ground level for a period of one year. The results shows that a moderate prospects for wind energy utilization as the wind speed is not high enough to support the wind power generation. The Weibull function have been applied to the measured probability distribution on a monthly basis and it was found that this distribution is fit the measured data for the year under study. According to the wind analysis and to the natural condition of the site, a small wind turbine for electricity generation is suggested to operate at the location at a height of (10)m. It was found that the feasibility of generating electricity from the wind have a moderate economical effect comparing with the price of the local produced electricity.

Table(1):The wind speed duration for the location under study.

V(m/s)	MONTH												TOTAL
	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	
0-1	0	3	0	0	0	3	0	21	42	33	30	36	168
1-2	162	114	81	66	87	18	207	69	147	129	132	117	1329
2-3	162	75	189	201	156	204	96	195	159	183	144	183	1947
3-4	123	93	114	174	207	177	189	174	156	129	111	93	1740
4-5	111	78	129	96	99	87	114	108	84	108	102	90	1206
5-6	81	87	78	33	66	75	24	63	42	63	87	96	795
6-7	54	54	57	33	24	48	33	30	30	33	39	45	480
7-8	24	78	42	48	39	42	33	39	30	30	30	45	480
8-9	15	30	33	30	30	30	27	21	15	18	21	15	285
9-10	0	21	12	12	12	9	12	6	9	6	9	9	117
10-11	3	12	3	6	3	9	6	9	0	0	3	3	57
11-12	3	6	0	9	6	6	0	6	3	3	0	3	45
12-13	3	15	0	6	3	6	0	0	0	3	3	0	39
13-14	3	0	3	0	3	0	0	3	3	3	3	0	21

Table(2):Wind speed frequency distribution and annual energy production.

V(m/s)	Duration (hr)	Relative Duration	Power density	V<VU	V>VU	Cumulative fraction of time	Power at speed	Annual energy output(kWh/year)
1	168	0.0192	0.0014	168	8592	0.0192	0	0
2	1329	0.1518	0.3151	1497	7263	0.170	0	0
3	1947	0.2222	2.1352	3444	5316	0.393	0	0
4	1740	0.1987	5.2393	5184	3576	0.591	1.8	3132
5	1206	0.1377	7.7169	6390	2370	0.729	3.2	3859.2
6	795	0.0910	9.3112	7185	1575	0.8202	5.7	4531.5
7	480	0.0548	9.2554	7665	1095	0.875	8	4840
8	480	0.0548	14.218	8145	615	0.929	11	5280
9	285	0.0326	12.312	8430	330	0.9263	14.5	4132.5
10	117	0.0134	7.0656	8547	213	0.9756	21	2457
11	57	0.0066	4.6988	8604	156	0.982	24	1368
12	45	0.0051	4.7702	8649	111	0.987	32	1440
13	39	0.0043	5.165	8688	72	0.991	37	1443
14	21	0.0022	3.3289	8709	51	0.994	44	924
15	18	0.0020	3.7498	8727	33	0.996	47	846
16	15	0.0016	3.6643	8742	18	0.997	50	750
17	9	0.0010	2.7265	8751	9	0.999	49.5	445.5
18	9	0.0010	3.296	8760	0	1.0	49	441
Total	8760	1						35889.7

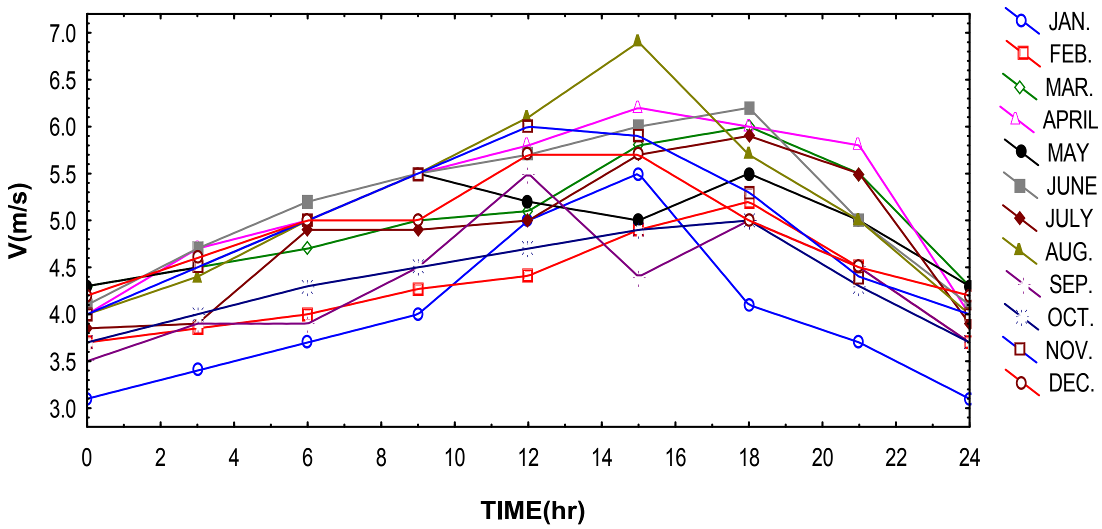
Table(3):The monthly and annual values of Weibull parameters (*K*) and (*C*).

MONTH	*K*	*C*
JAN.	1.3	2. 8
FEB.	1.2	3.4
MARCH	1.2	2.9
APRIL	1.5	3.4
MAY	1.3	3.1
JUNE	1.8	3.9
JULY	2	3.3
AUG.	1.6	3.5
SEP.	1.5	2.8
OCT.	1.3	2.7
NOV.	1.4	3.1
DEC.	1.3	2.8
ANNUAL	1.5	3.0

Table(4):Summary of the cost analysis data.

Item	U.S.$
Wind m/c cost	30000
Civil work cost	10000
Investment	40000
Operating cost	375
Scrap value(10% of the investment	4000
Discount rate	8%
Inflation rate	6%
Life time of the machine(year)	20
PVC (Calculated from eq.12)	43448.7
Total kWh produced / year(Table 2)	35889.7
Present cost	1.21
Present cost during the life time of the m/c.	0.065

Fig(1): Map of Iraq showing the location under study.



Fig(2):Hourly variation of the mean wind speed.

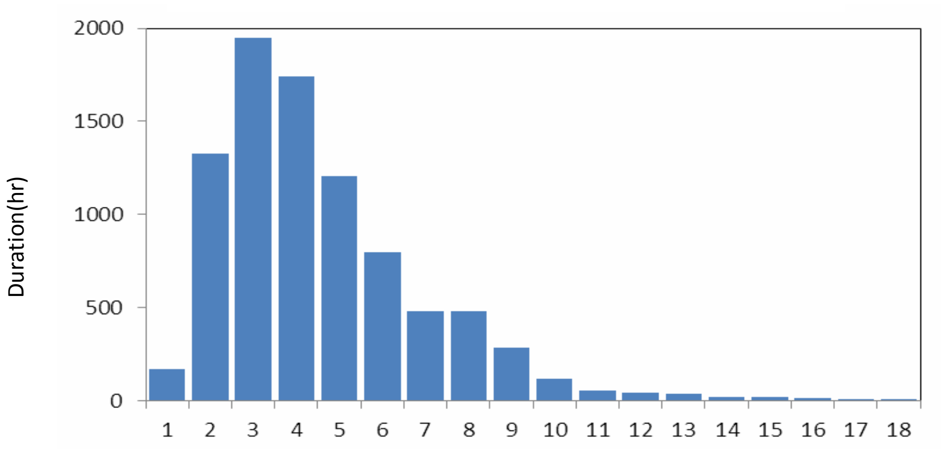
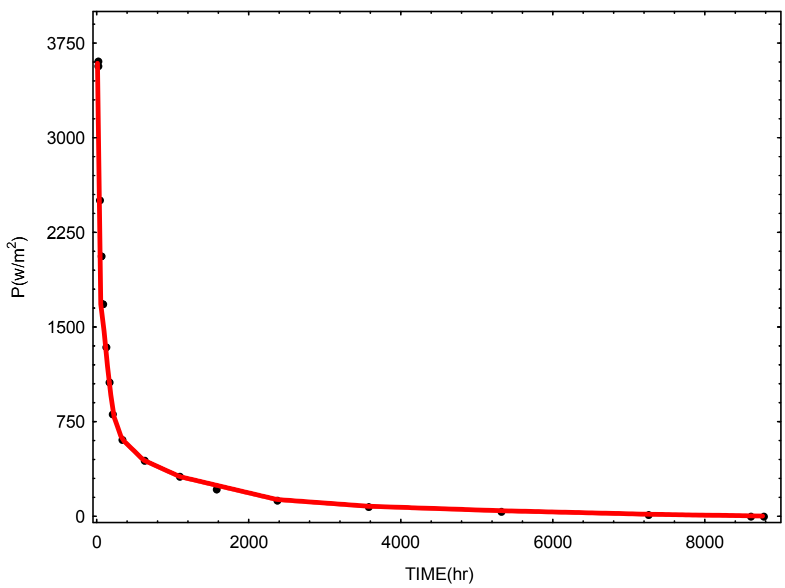
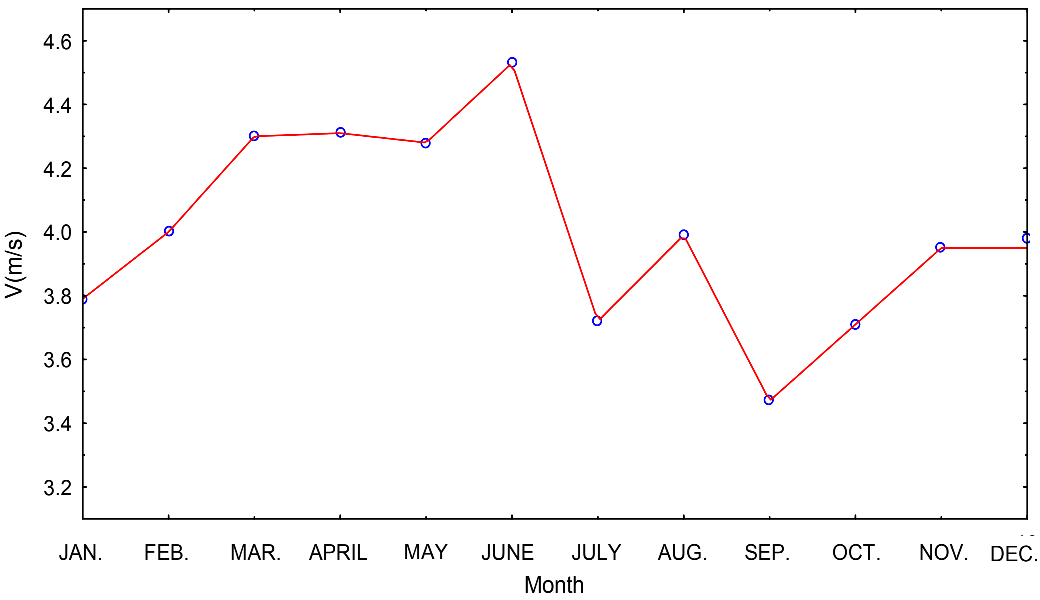


Fig.(3): The velocity duration curve for the city of Sumawaha.

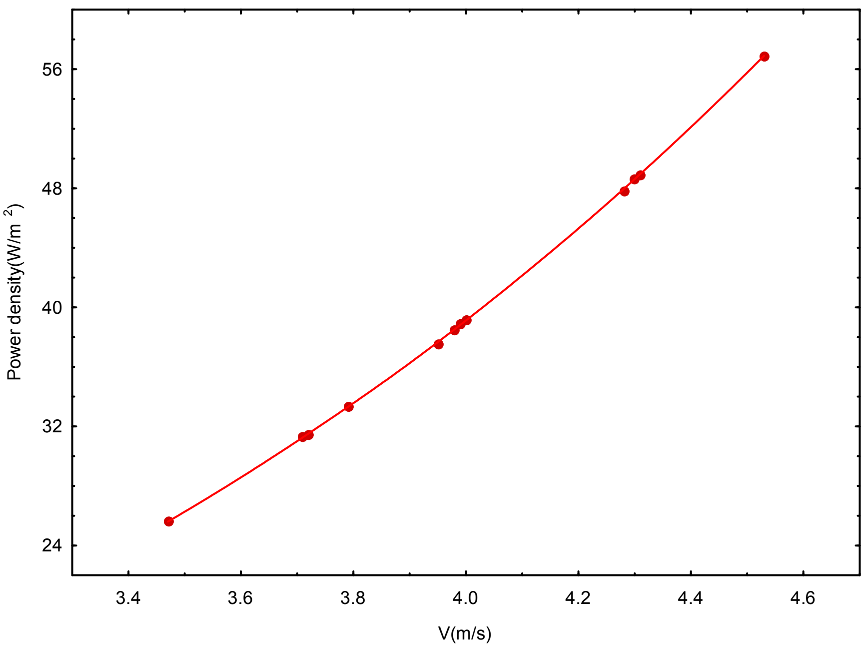
V(m/s)



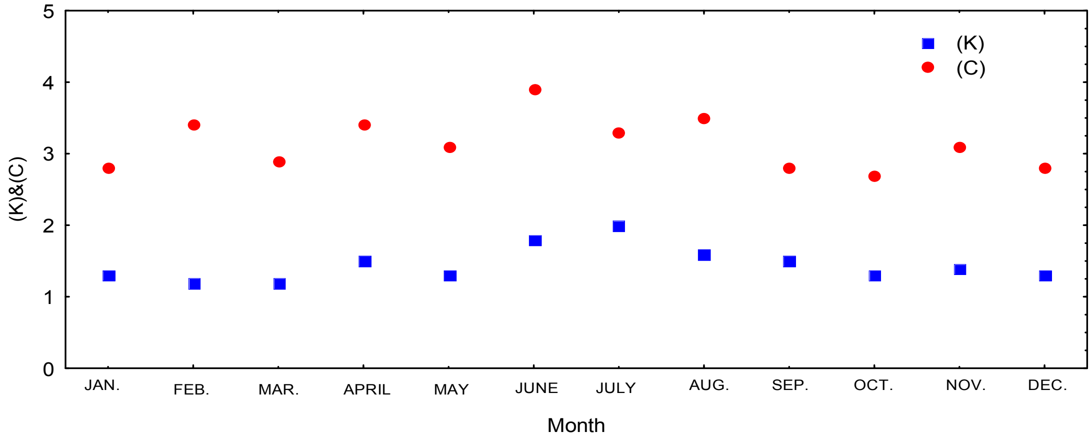
Fig(4): The annual duration of the available wind power.



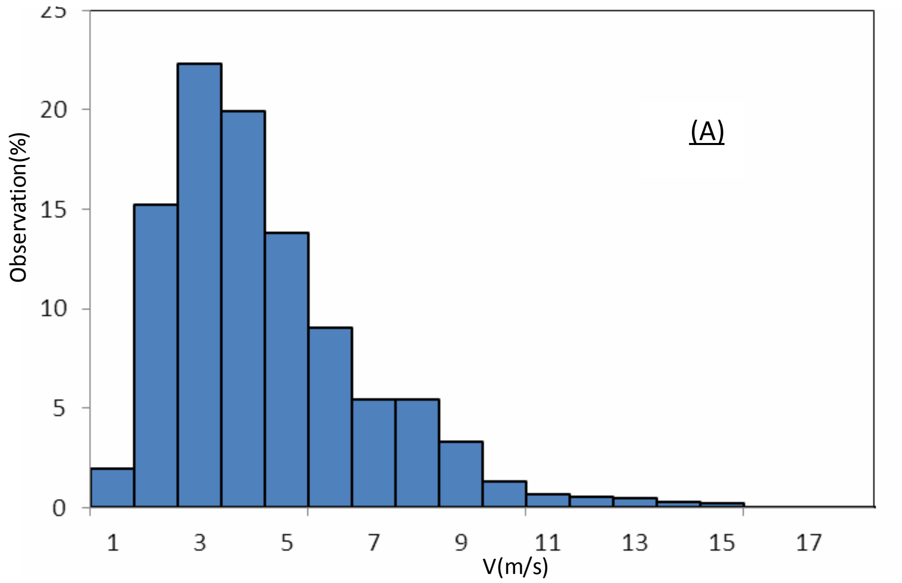
Fig(5): Monthly variation of the mean wind speed.

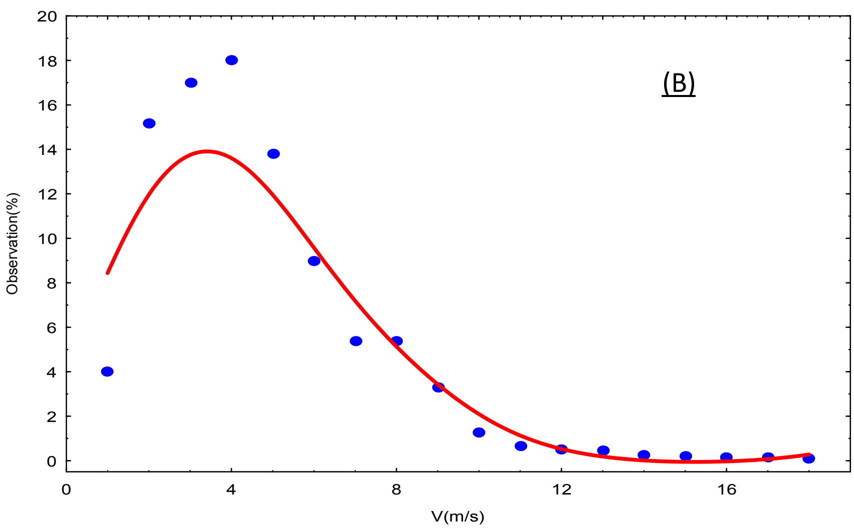


Fig(6): Wind power density against average wind speed.

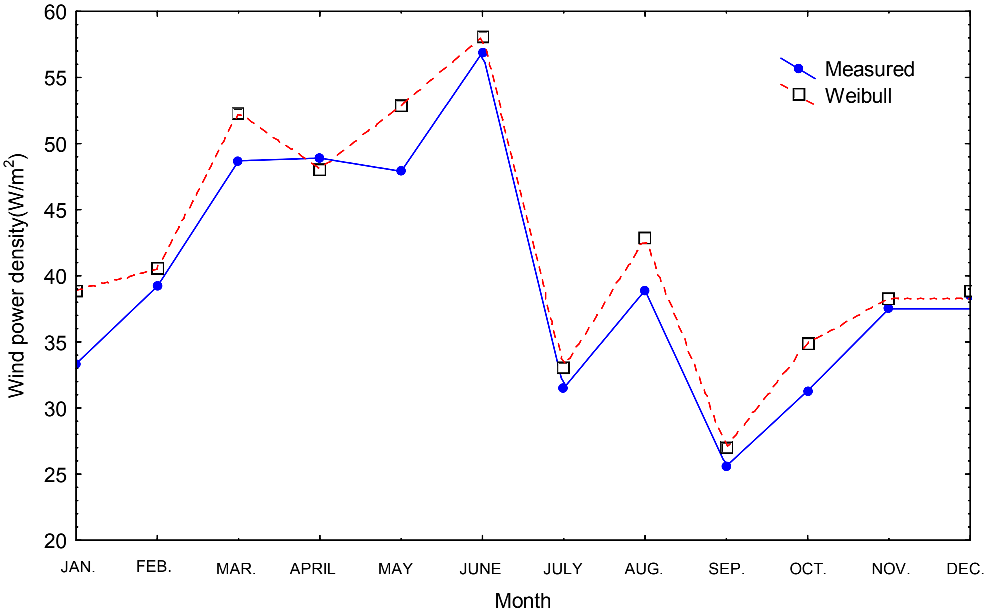


Fig(7): The Monthly values of Weibull function parameters,(*K*) and (*C*)

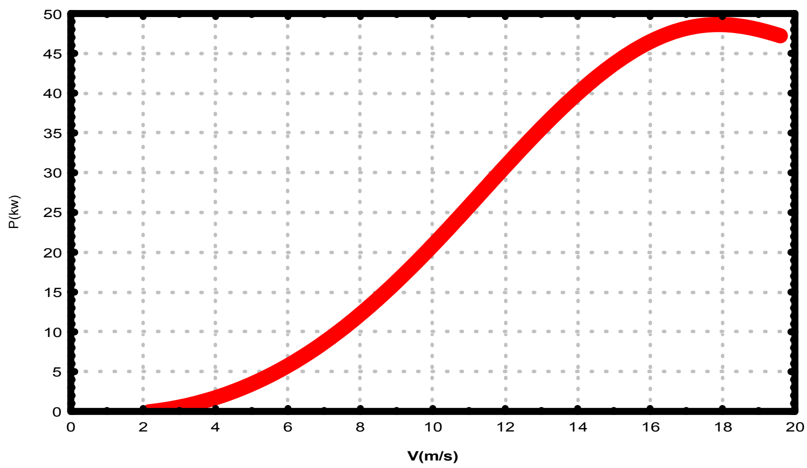




Fig(8): Wind speed comparison between the wind speed data measured at the location (A) and the Weibull function(B).



Fig(9): wind power density calculated from the recorded data and according to the Weibull distribution



Fig(10): Power duration curve for the wind machine[Gipe 2004].

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