Graphical and Energy Pattern Factor Methods for Determination of the Weibull Parameters for Ali Algharbie Station, South East of Iraq

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ABSTRACT

The hourly mean wind speed data for Ali Algharbie station locations in south east of Iraq are collected and analyzed over a period of 1 year. The Data are fitted to the Weibull distribution function which is considered as the infrastructure to form a wind atlas for any country obtaining the Weibull distribution is necessary to determine the shape (*k*) and scale(*c*) parameters. There are several methods that can be used to determine these parameters. This paper presents the comparison between two methods, Graphical method and the new method is called Energy Pattern Factor (*EPF*) method. It is found that the highest value of the shape (*k*) and scale (*c*) in Jun. at the two methods and the lowest value in Oct. at the two methods and this corresponds with the highest (8.597m/s) and lowest (3.265m/s) value of hourly mean wind speed in these months. So the new method shows good agreement compared with the result of the Graphical method therefore, we recommend using this method to calculate the Weibull distribution parameters.

Keywords: Weibull Distribution,mean wind speed, Graphical Method, Energy Pattern Factor method (*EPF*).

استخدام طريقة التمثيل البياني وطريقة عامل نمط الطاقة لحساب معاملات توزيع ويبل لمحطة علي الغربي جنوب شرق العراق

الخلاصة

في هذا البحث تم تحليل البيانات الساعية لسرعة الرياح لمحطة علي الغربي جنوب شرق العراق ولمدة سنة واحدة(2001) ولغرض تطبيق توزيع ويبل الذي يعتبر البنية الاساسية لتكوين اطلس الرياح لاي بلد، يجب حساب معاملات توزيع ويبل وهما معلمة الشكل ومعلمة القياس ،توجدعدة طرق لحساب المعلمات .في هذا البحث تم استخدام طريقتين وهي طريقة التمثيل البياني وطريقة جديدة تدعى عامل نمط الطاقة(*EPF*)والمقارنة بينهما ولقد وجد ان اعلى قيم

لمعلمتي الشكل والقياس في شهر حزيران ولكلا الطريقتين واقل قيمة للمعلمات في شهر تشرين الاول ولكلا الطريقتين وهذا يتوافق مع أعلى (8.597m/s) وأدنى (3.265m/s) قيمة لمعدل السرعة الساعية في هذه الأشهر. وبالتالي فإن الطريقة الجديدة تعطي نتائج تتوافق مع طريقة التمثيل البياني لذلك نوصي باستخدام هذه الطريقة لحساب معلمات توزيع ويبل.

INTRODUCTION

The current demand for energy is increasing day by day due to various reasons such as increasing population, the aspiration for improved living standards and general economic and industrial growth. In the wake of the increasing world energy crisis, which mostly affected the least developed countries, the interest in renewable energy resources has been increased considerably. The renewable energy resources include solar, wind, wave,hydroelectric, geothermal and biomass. The use of wind energy can significantly reduce the combustion of fossil fuel and the consequent emission of carbon dioxide besides, utilization of wind energy has been growing rapidly in the whole world due to environmental pollution, consumption of the limited fossil fuels and global warming.

FREQUENCY DISTRIBUTION OF WIND SPEED

The wind speed probability density distributions and their functional forms represent the major aspects in wind related literature. The probability distributions most commonly used are those of Weibull and Rayleigh [1]. The Weibull distribution has been found to fit a wide collection of recorded wind data. The variations in wind velocity are characterized by the two functions; the probability density function and the cumulative distribution function [2] [3] .Obtaining the Weibull density distribution is necessary to determine the shape (k) and scale(c) parameters, the common methods for determining k and c are: graphical, standard deviation, moment, maximum likelihood and energy pattern factor methods [4]

In this research we applied the two methods, Graphical which is one of the most reliable ways to get real results close to the observed, and a new method called energy pattern factor method (*EPF*).The concept of this method is useful in calculating the available energy in the wind along with the knowledge of the annual or monthly wind speed. It is also useful in choosing a location with limited wind data, because long-term data from neighboring sites can be correlated with one-site short-term measurements.

1. Graphical method is another way to determine the k and c from Weibull distribution[5,6]. We transform the cumulative distribution function into a linear form, adopting logarithmic scales. The expression for the cumulative distribution of wind velocity can be rewritten as

$$1 - F(v) = e^{-(v/c)^k} \qquad \ldots\ldots (1)$$

Considering the logarithm twice, we get

$$ln\{-ln[1 - F(v)]\} = kln(v) - klnc \qquad \ldots. (2)$$

Where $F(v)$ the probability density function, k the shape parameter, c the scale parameter. By Plotting different values of *ln[-ln(1-F(v)]* vs. *ln (v)* ,a straight line is fitted to the points . The slope of line is, k and the intercept on the *ln[-ln(1-F(v)]* axis is $-klnc$. The scale parameter-

$$c = e^{\left(-\frac{y-intercept}{k}\right)} \qquad \ldots.. (3)$$

2. Energy pattern factor (*EPF*) or Cube Factor is the ratio between the total power available in the wind and the power corresponding to the cube of the mean wind speed [5].

$$EPF = \frac{Total\ amount\ of\ wind\ power\ available\ in\ the\ wind}{Power\ calculated\ by\ cubing\ the\ mean\ wind\ speed} \quad \text{.....} \quad (4)$$

Realizing that the power density of the wind [W/m^2] is given by

$$\frac{P(v)}{A} = \frac{1}{2}\rho v^3 \quad \text{....} \quad (5)$$

Where *P(v)* wind power (w),A area(m^2),ρ air density (kg/m^3),*v* wind speed(m/s).Then the total amount of energy available in the wind in a period *T* (J/m^2) is equal to

$$\frac{E}{A} = T\int_0^{\alpha} \frac{1}{2}\rho v^3 f(v)dv \quad \text{.....} \quad (6)$$

Where *E* Available energy (wh/m^2),*T* total time (hour),*f(V)* Provability density function, whereas the energy is calculated by cubing the mean wind speed is equal to

$$\frac{E}{A} = \frac{1}{2}\rho v^3 T \quad \text{.....} \quad (7)$$

Using Weibull provability density function *F(v)* in (6) results,

$$EPF = \frac{\frac{1}{N}\sum_{n-1}^{N} v_n^3}{\left(\frac{1}{N}\sum_{n-1}^{N} v_n\right)^3} \quad .....(8)$$

where N Total number of hours[7]
Once the energy pattern factor for a regime is found from the wind data, an approximate solution for k is[4]:

$$k = 3.957\ EPF^{-0.89\,8} \quad ....(9)$$

STUDY AREA AND DATA COLLECTION

In this research ,data of hourly wind speed of one year (during 2001) wasobtained from the Iraqi Meteorological Organization and Seismology for Ali Algharbie station , the geographic location of the site is latitude 32° 27′ 12.01″ N and longitude, 46° 40′ 53.07″ E.Ali Algharbie is located at south east of Iraq to the north-east of the city of Amarah, it is about 27 km away from the Iraqi- Iranian border where the Iranian mountain range along the eastern side of the district, specifically Hamrin and Bashtko mountains, also it is in the middle between Baghdad and Basrah, as shown in figure (1). Table (1) shows some descriptive statistics properties for the station such as the account of the events(N), hourly yearly mean wind speed $\overline{v}$(m/s),standard deviation($S.D.$), median, coefficient of variation($C.V.$), minimum and maximum wind speed. The time series of hourly wind speed and direction of the wind are shown in figure (2).

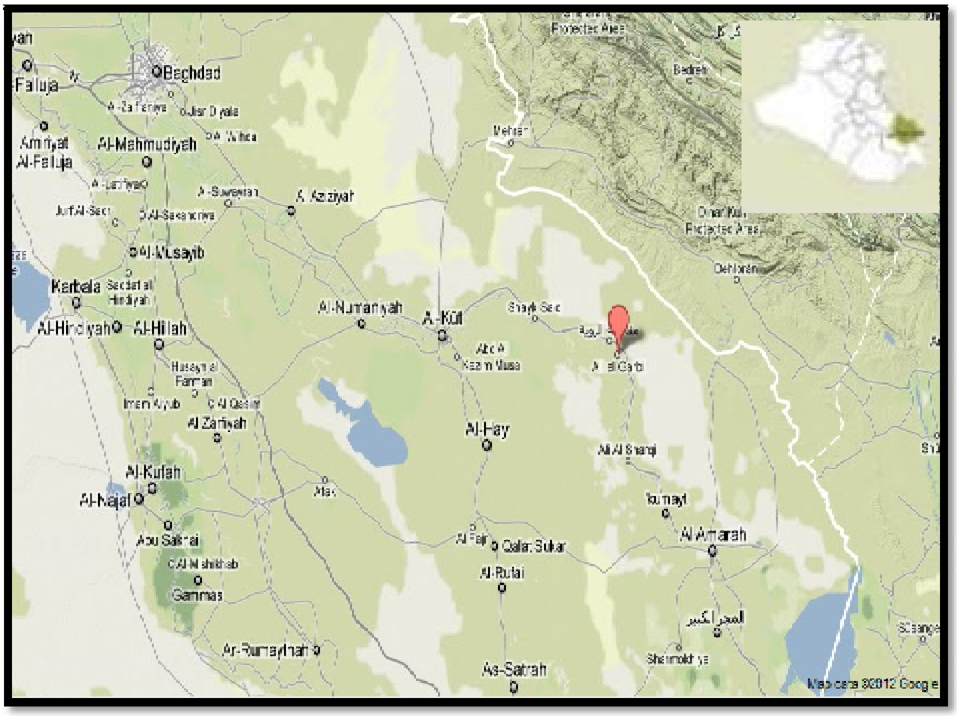
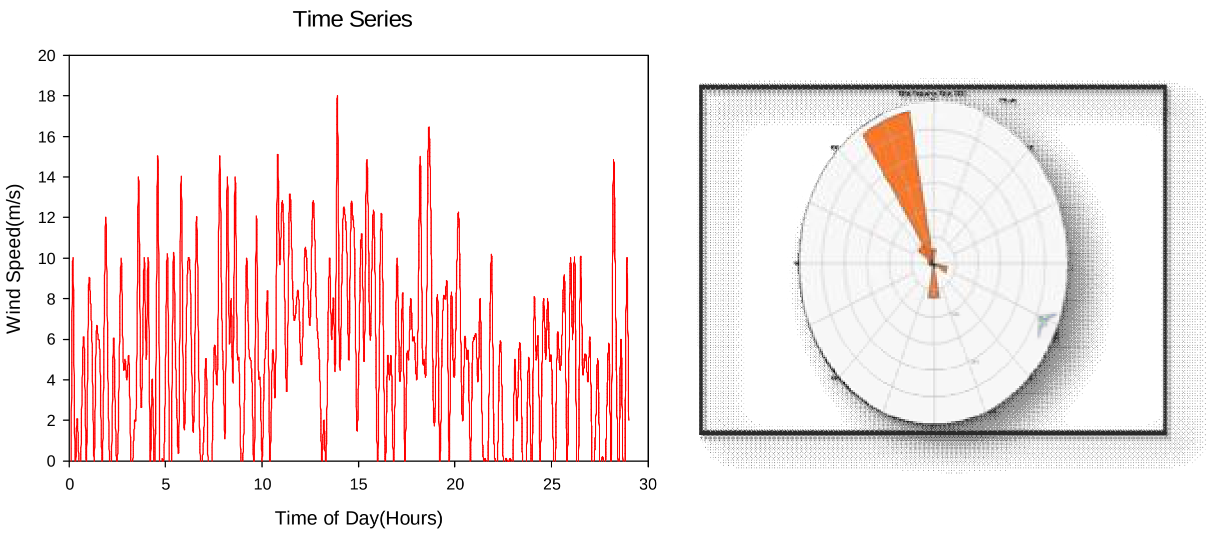


Figure (1): Map of the study area (Ali Algharbie).



igure (2): Time series and the wind rose hourly wind speed for Ali Algharbie Station.

Table (1): The descriptive statistics for hourly yearly wind speed for Ali Algharbie Station.

Statistics	Value
N	2911
$\bar{v}$	4.99
S.D.	4.19
Med.	5.00
C.V.	17.58
Min. wind speed	0.0
Max. wind speed	20

RESULTS AND DISCUSSION

Estimation of the Weibull Parameters

This section deals with two methods of extracting the Weibull parameter *k* and *c* from a given set of data.

1.Graphical method

In this method, at first percentage of cumulative distribution have been calculated then these are plotted for corresponding wind speed as shown in table (2) and by plotting different values of $ln[ln(1/(1-F(v))]$ on *Y*-axis vs $ln(v)$ on *X*-axis a straight line is fitted to the points as shown in figure.(3) the slope of the line is *k* and the intercept on the $ln[ln(1/(1-F(v))]$ axis is $[- k \ln c]$ compared with equation (2), we can find out the values of *k* and *c*.

Table (2): Frequency distribution of hourly wind speed for Ali Algharbie Station.

Interval	Failure Freq.	Cum. Freq.	*F(v)*	*ln(v)*	*ln (ln1/1-F(v))*
0.00000<=x<2.00000	773	773	0.2655	0.6931	-1.1758
2.00000<=x<4.00000	269	1042	0.3580	1.3862	-0.8138
4.00000<=x<6.00000	750	1792	0.6158	1.7917	-0.0443
6.00000<=x<8.00000	262	2054	0.7058	2.0794	0.2017
8.00000<=x<10.0000	315	2369	0.8141	2.3025	0.5203
10.0000<=x<12.0000	290	2659	0.9138	2.4849	0.8965
12.0000<=x<14.0000	142	2801	0.9626	2.6390	1.1896
14.0000<=x<16.0000	83	2884	0.9911	2.7725	1.5521
16.0000<=x<18.0000	8	2892	0.9939	2.8903	1.6291
18.0000<=x<20.0000	9	2901	0.9970	2.9957	1.7594
20.0000<=x<22.0000	8	2909	0.9997	3.0910	2.0933

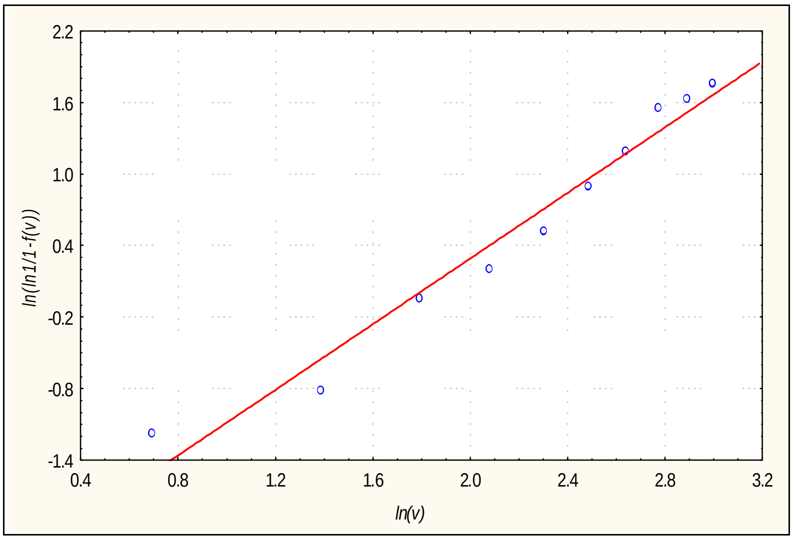


Figure (3): Graphical Method for estimating Weibull parameters

k and c using hourly wind speed data of Ali Algharbie Station.

The resulting equation for the plot ($y = -2.532+1.419x$) then k=1.419,c=5.955m/s. In the same way we calculated Weibull parameters k and c for each month and the hourly monthly mean wind speed, standard deviation, the goodness of fit of the Weibull distribution to the frequency distributions of the observed data is assessed by the correlation coefficient (R^2) as shown in table (3).

Table (3): Weibull parameters k and c, hourly monthly mean wind speed, standard deviation and correlation coefficient for each month for Ali Algharbie station.

Month	k	$c(m/s)$	$\bar{v}(m/s)$	S.D.	R^2
Jan.	1.170	3.914	3.748	3.332	0.9638
Feb.	1.204	5.518	5.186	4.326	0.9590
Mar.	1.213	5.372	5.039	4.174	0.9779
Apr.	1.238	6.792	6.340	5.151	0.9700
May	1.467	7.960	7.206	4.994	0.9414
Jun.	1.742	9.650	8.597	5.091	0.9075
Jul.	1.480	8.760	7.921	5.445	0.9490
Aug.	1.524	7.302	6.580	4.403	0.9742
Sep.	1.616	6.585	5.899	3.740	0.9608
Oct.	1.030	3.305	3.265	3.171	0.9595
Nov	1.197	4.317	4.063	3.409	0.9608
Dec.	1.742	3.418	4.102	5.61	0.9563

2. Energy Pattern Factor (EPF) method

To calculate the Weibull parameters k and c using Energy Pattern Factor method we need to determine the mean wind speed $\bar{v}(\mathrm{m/s})$ and the cub mean $\overline{(v(\mathrm{m/s}))^3}$ for each month and by using equations (8) and (9) we get the result shown in Table (4).

Table (4): Weibull parameters *k* and *c*, for each month at Ali Algharbie Station using *EPF* method.

Month	$\overline{v}$ m/s	$\overline{v}$(m/(s))^3	$\overline{v}^3$ m/s	*EPF*	*K*	(m/s) *c*
Jan.	3.748	52.65	161.17	3.06	1.44	4.13
Feb.	5.186	139.47	378.99	2.71	1.61	5.78
Mar.	5.039	127.94	318.09	2.48	1.75	5.65
Apr.	6.340	254.84	545.66	2.14	1.99	7.15
May	7.206	374.18	648.54	1.73	2.41	8.12
Jun.	8.597	635.39	869.27	1.36	3.00	9.62
Jul.	7.921	496.98	811.79	1.63	2.55	8.92
Aug.	6.580	284.89	594.37	2.08	2.04	7.42
Sep.	5.899	205.27	416.18	2.02	2.10	6.66
Oct.	3.265	34.805	134.26	3.85	1.17	3.45
Nov.	4.063	67.07	183.45	2.73	1.60	4.53
Dec.	4.102	69.02	246.11	3.56	1.26	4.41

Weibull distribution parameters shape (*k*) and scale (*c*) are calculated by two methods. It is found that the highest value of shape (*k*) in June in the two methods and it's about (1.742) in Graphical method and (3.00)in (*EPF*)method and the lowest value also in the same month in the two methods in Oct. and it's about (1.030,1.17) respectively while the highest value of scale (*c*) in Jun. in the two methods and it's about(9.650,9.62 m/s) respectively and the lowest value at Oct. in the two methods and it's about (3.305m/s) ,9.62m/s)respectively, and this corresponds with the highest(8.597m/s) and lowest(3.265m/s) value of hourly mean wind speed in these months.

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