WIND ENERGY POTENTIAL IN GARMYAN ZONE

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Abstract

The wind data for four locations in Garmyan zone were used to calculate the average wind speed and the potential of wind energy in some location of Garmyan zone. The locations are [Kirkuk(1981- 1990), Kalar (2003), Khanaqin (1988- 1997), and Touz (1991-2000)]. Monthly and annual wind speed, power and energy density at 10 meters and 50 meters above ground level calculated. The results are all shown in both tabulated and graphical forms. The mean monthly power exponent factor (α_p) of the power law model also found. A full statistical analysis has been carried out for Kalar station which involved monthly and annual values of shape and scale parameters of Weibull distribution, the average speed frequency, Weibull distribution, speed distribution, and their cumulative duration in hours. It can be seen that the wind it is not suitable for electricity generation, but it is suitable for the applications in agriculture

الخلاصة

جمعت بيانات سرعة الرياح المسجلة فى اربعة محطات أنوائية ضمن منطقة (كرميان). وهذه الناطق هي مدينة كركوك (1981-1990)، كلا ر(2003)، خانقين (1988-1997) و كذلك طوزخورماتو (1991-2000). تم استنباط البيانات عند ارتفاع 2م فوق سطح الارض للحصول على سرعة الرياح عند ارتفاع 10 م و 50م فوق سطح الارض و ذلك باستخدام معادلات الاستنباط الاحصائية معترفة بها عالميا. تم استخراج المعدلات الشهرية و السنوية لقيم السرعة والطاقة الكامنة للرياح ووضحت النتائج على شكل جداول و رسوم بيانية يسهل الرجوع اليها،ولقد تم ايجاد المعدل الشهري لعامل القدرة الاس α_pوفقا لنموذج قانون القدرة الاسي، تم ايضا دراسة التوزيع التكرارى لسرع الرياح و المعروفة بدالة توزيع وايبل. و أوضحت النتائج بان هذه الدالة تتطابق مع البيانات المسجلة فى محطات أنواء منطقة (كرميان) بشكل جيد. و كذلك تم استخراج معاملى دالة توزيع وايبل K و c باستخدام طريقة المربعات الصغرى و رتبت النتائج على شكل جداول وكذلك تم حساب القيم السنوية لكثافة قدرة الرياح لجميع المناطق قيد الدراسة على ارتفاع 10م و 50م فوق سطح الارض. من

خلال النتائج و البيانات التي تمت التوصل اليها استنتجنا ان الرياح فى هذه المناطق غير مناسبة لتوليد الطاقة الكهربائية ولكنها مناسبة لاستغلالها في تنمية الحقول الزراعية.

1. INTRODUCTION

Garmyan is one important zone for Kurdistan region-Iraq and its known to be rich in fuels namely oil and natural gas. In addition to these fuels. Other energy resources are available such as renewable energy. Also the wind energy and solar energy are available in this zone, whereas energy produced by wind power and solar is neglected.

Wind energy is the kinetic energy associated with the movement of atmospheric air (wind). The wind is a free, clean, and inexhaustible energy source. It has been used for hundreds of years for sailing, grinding grain, and for irrigation. Wind energy systems convert this kinetic energy to more useful forms of power. Wind energy systems for irrigation and milling have been in use since ancient times and since the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas. Wind energy is now a low cost generation technology, and it is likely to provide 10 % of the world's electricity by the year 2020 [1,2].

In this papers, different wind zones in Garmayan are described and the wind energy potential available in different parts. Four meteorological were selected, namely (Kirkuk, Kalar, Khanaqin, and Touz). The selection of the stations is based on the reliability and the completeness of one year hourly/ daily wind speed data. The readings were recorded by the standard anemographs installed at height 10m above the ground level. The stations are of two types, manual and automatic stations. The manual stations uses classic anemograph and these are (Kirkuk, Khanaqin, and Touz). The automatic stations use digital instruments with sensors receiving pulses in a very short period of time, accumulating them and storing in the microprocessors specially designed for this purpose, and this kalar meteorological station.

Table (1): shows the physical feature and locations of the meteorological stations within Garmyan zone used in this work[3].

Table (1): Geographical data for the selected stations[3].

Station	Latitude, $^{\circ}N$		Longitude, $^{\circ}E$		Altitude, ft
	Deg.	Min.	Deg.	Min.	
Kirkuk	35	28	44	24	1123
Kalar	34	36	45	18	705
Khanaqin	34	21	45	22	600
Touz	34	52	44	38	723

2. MATHEMATICAL ANALYSIS

In this work different statistical analysis were described in the form of graphs for Kalar town. Similar analyses were carried out for the rest of the locations but not necessarily shown in the text.

2.1 HEIGHT EXTRAPOLATIONS

In most of the meteorological stations, generally, wind velocity is recorded at 2m and 10m standard level above the ground. As the wind velocity increases with height due to the reduction of friction with the surface, it is customary to extrapolate the wind velocity as much height as possible to avoid the effect of the surface roughness [4,5,6]. The most important and widely used model is the power law model developed by Mikhail and Justus (1988) [4,6].As follow:

$$\frac{V_h}{V_a} = \left(\frac{Z_h}{Z_a}\right)^{\alpha_p} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where Z_a is the anemometer height, Z_h is a common hub height. And the exponent α_p, characterizes the amount of wind shear and is a function of the surface roughness and terrain features up wind of the measuring site. It is considered to be variable with the measured wind speed v_a and the anemometer height according to the relationship [5]

$$\alpha_p = a + b \ln(V_a) \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where the coefficients a and b are given by [4]

$$a = 0.37/[1-0.0881 \ln(V_a/10)] \ldots\ldots\ldots(3)$$

$$b = -0.881/[1-0.0881 \ln(Z_a/10)] \ldots\ldots(4)$$

Kalar automatic station gives wind speed at two different levels (2 and 10 meters above the ground) for one complete year (2003). The recorded data in this station are highly reliable, since the station is fully automatic without any interference of human being. Therefore, these data are used in determining the exponent by using equation (2) and then generalized the results for the other locations due to the similarity of the ground. It carried out the calculations for each hour in each month, and then the results were accumulated and converted into monthly means. The calculated monthly values of (α_p) obtained are presented in Table (2). It can be seen that these values range from 0.37-0.42, with annual mean value of 0.395.

2.2 WIND SPEED DISTRIBUTION

Wind average or mean wind speed or resultant wind is the most commonly used indicator of wind production potential, it is defined as[6,7]:

$$\overline{V} = \frac{1}{N} \sum_{i=1}^{N} V_i \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Where N is the sample size, and V_i is the wind speed recorded for the i^{th} observation [7].The monthly mean wind speed at 10m and 50m elevation extrapolated and estimated by using equation(1).The wind speeds were extrapolated using annual mean value of α_p= 0.395. The results are represented in Tables(3 and 4). They are also presented in graphical forms in Figures (1 and 2).

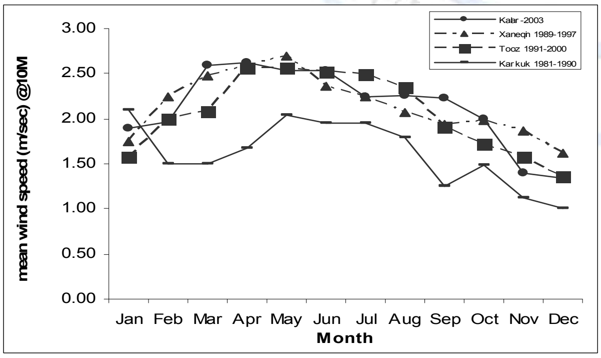

Fig.(1): The average wind speeds at the four locations, at 10m height.

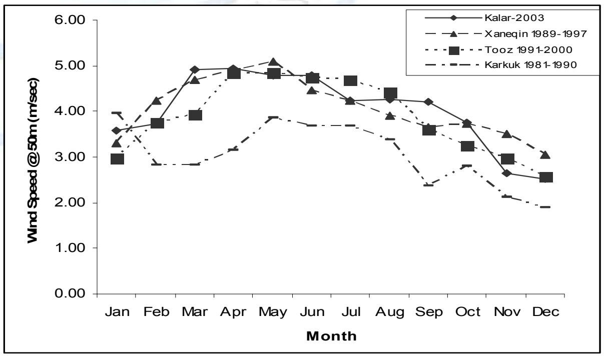

Fig.(2): The average wind speeds at the four locations, at 50m height.

Table (2): Monthly mean values of α_p

Month	α_p
Jan	0.38
Feb	0.38
Mar	0.37
Apr	0.42
May	0.41
Jun	0.42
Jul	0.39
Aug	0.40
Sep	0.40
Oct	0.39
Nov	0.38
Dec	0.40
Average	0.395

A typical frequency curve for the year 2003 in Kalar is shown in figure(3), while the wind speed frequency curve is in histogram form and the duration curve for Kalar(2003) is shown in figure(4).

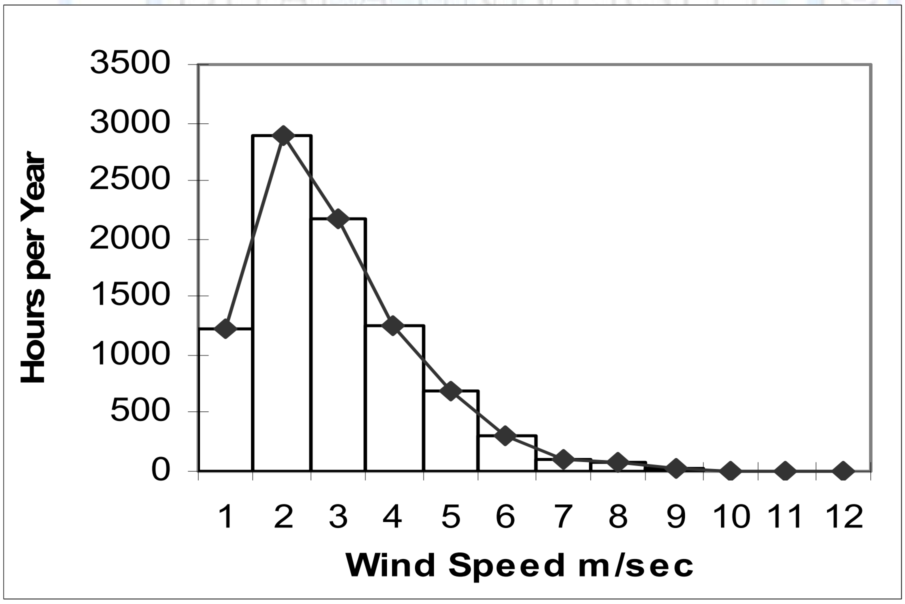

Fig.(3): Wind speed frequency data at Kalar, 2003.

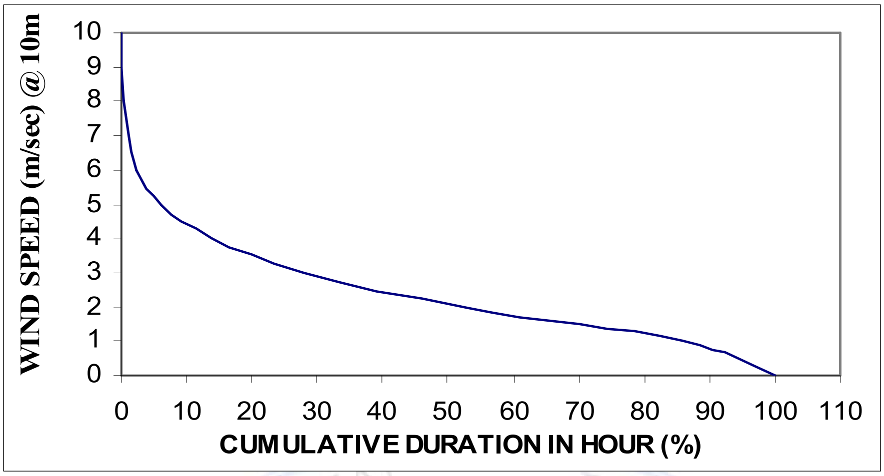

Fig.(4): The duration distribution curve for Kalar.

Statistical analysis can be used to determine the wind energy potential of a given site and to estimate the wind energy output at this site. The developments of the statistics of wind data for resource estimation are available in several text books and papers [8,9]. If extrapolation of measured data from one height to another is required, the knowledge of the probability distribution of wind speed, P(v) will be important for estimating wind energy in a specific location[8,10]. In this case there are distinct advantages in the use of analytical representation for the probability distribution of speed. For wind speeds many researchers have fitted the Weibull distribution for their application of wind speed data and they found that Weibull model is a useful tool for wind power analysis [8].The Weibull distribution is characterized by two parameters: the shape parameter K (dimensionless) and scale parameter C (m/s).

The cumulative distribution function (C.D.F.) is[10]:

$$F(v)=\int v.f(v).dv \quad \ldots\ldots\ldots\ldots(6)$$

But the probability density function (P.D.F.) is[10]:

$$f_{(V)} = \left(\frac{k}{c}\right)\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \ldots\ldots(7)$$

Where v is wind speed. Substitute eq.(7) into eq.(6), after integration, we find :

$$F(v) = 1 - \exp\left[-\left(\frac{V}{c}\right)^{K}\right] \ldots\ldots\ldots\ldots(8)$$

$$\therefore 1 - F(v) = \exp\left[-\left(\frac{V}{c}\right)^{K}\right] \ldots\ldots\ldots\ldots(9)$$

Taking the logarithm of both sides of eq.(9), we find :

$$\ln(1 - F(V) = -(\frac{V}{c})^K$$

$$\text{Or } -\ln(1 - F(V) = (\frac{V}{c})^K \quad ....(10)$$

Taking again the logarithm of both sides of eq.(10), we find

$$\ln[-\ln(1 - F(V)) = k\ln V - k\ln c \quad ....(11)$$

It can be seen that the above eq.(11) is in the form of equation of a straight line, that is

$$y = ax + b \quad ....(12)$$

Where x and y are variables, (a) is the slope and (b) is the intercept of the straight line with y- axis. Comparing equation (11) with equation (12), we find $y = \ln[-\ln(1 - F(V))]$

and

$$x = \ln v \quad ....(13)$$

And a=K, b= - K lnc

Using the least square method, a straight line can be fitted to the observed data of wind speed. In order to apply Weibull distribution, first must be calculated the values of the shape parameter K, and scale parameter C. Therefore, using equations (12, and 13), and the least square method. The results of calculations carried out are shown in Table (5) and Figures (5). In order to obtain the parameters k and C, straight lines are fitted to the above data. It is worth to remind here that, k is the slope of the straight line, while (-klnc) is the intercept on the vertical axis. Table (5) represents an example of the calculations for the month of April-2003, while Figure(5) shows plot of ln[-ln(1-F(v))] against lnv of April in Kalar as example. The rest of calculations and graphs are not shown here, since it makes the paper very long and tedious.

Table(5): Result for the log method for Kalar (April,2003)

V	f (frequency)	F(v) %	ln(V)	ln(-ln(1-F(v))
2	0.266667	0.2666667	0.6931472	1.1706833
3	0.5	0.7666667	1.0986123	0.3752033
4	0.1	0.8666667	1.3862944	0.7005711
5	0.066667	0.9333333	1.6094379	0.9962289
6	0.033333	0.9666667	1.7917595	1.2241275
7	0.033333	1	1.9459101	

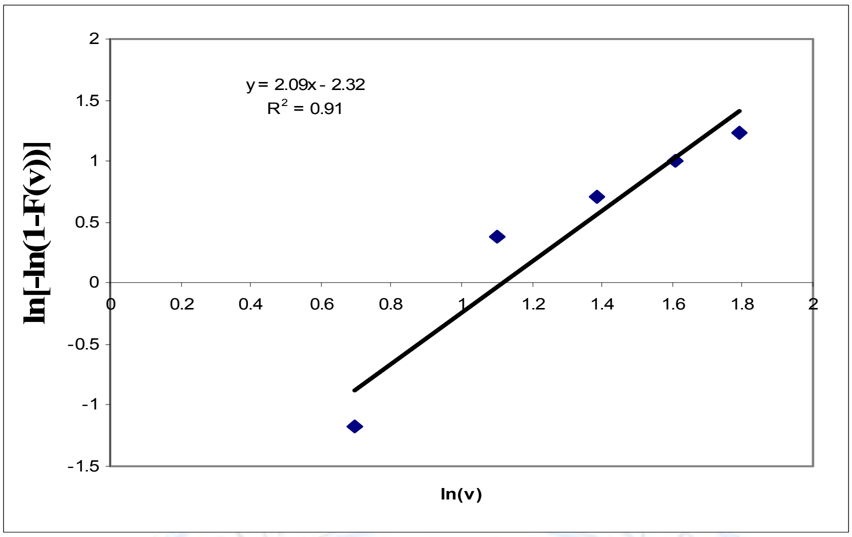

Fig.(5):ln[-ln(1-F(v))] versus ln(v) for Kalar station, of April, 2003.

The values of the parameters determined in this way are shown in both tabulated and graphical forms in the Table (6), and Figure (6).It is seen here that the values of k ranges from 1.64 to 3.23, while the values of C are ranged from 1.5m /sec to 3.02m/sec.

Table(6): Monthly value of K and C parameters for Kalar,2003.

Month	K	C m/sec
Jan	2.23	1.92
Feb	3.23	2.57
Mar	1.82	2.69
Apr	2.1	3.02
May	2.5	2.32
Jun	2.58	2.59
Jul	2.45	1.85
Aug	2.51	1.85
Sep	2.56	1.86
Oct	2.4	1.97
Nov	2.38	2.02
Dec	1.64	1.50
Average	2.37	2.18

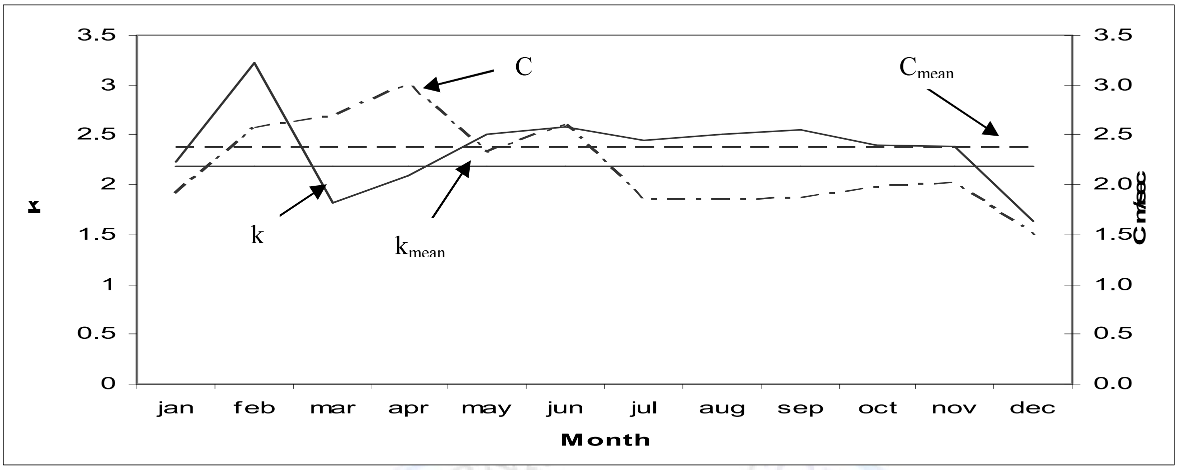

Fig.(6): Monthly value of K andC parameter of Kalar, 2003.

Figure(7) shown the Weibull distribution curve of April for Kalar station by using the value of K, C and equation(7). The Weibull distribution can also be drawn for yearly averages. Determining the annual average of K=2.37 and C=2.18m/sec, the annual Weibull distribution is drawn and shown in figure (8). Figure (8) compares annual values of the measured with theoretical frequency distribution of winds, calculated from Weibull density function with typical frequency curve of the year 2003 for Kalar station. Excellent fit and agreement is obtained between measured and calculated values.

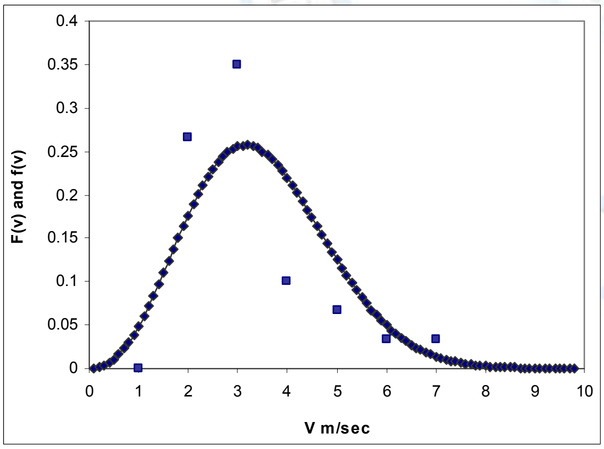

Fig.(7): Weibull distribution for Kalar in April, 2003.

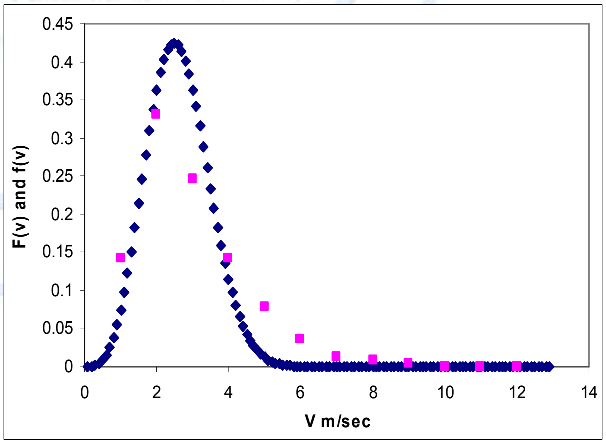

Fig.(8): Weibull distribution for Kalar for the year 2003, K=2.37 and C=2.18m/sec.

3. WIND POWER DINSITY

The power in the wind is the flux of the kinetic energy passing through the vertical cross-sectional area of the rotor disk of wind energy conversion system [10,11]. The wind power equal[11]:

$$P_W = \frac{1}{2}\rho A V^3 \quad ....(14)$$

Where ρ is air density, defined as the mass of a given sample of air, divided by that sample's volume. The overall mean air density is equal to (1.225 kg/m^3). A is cross-sectional area (the rotor swept area). And V is mean wind speed[10]. The mean wind power density equal to[11,12]:

$$\overline{P_W} = \frac{1}{2}\rho(\overline{V})^3 \quad ....(15)$$

However, for historical reason, Rayleigh has added the shape parameter K to equation(15) as a correction factor, which made equation(15) give veritable integral result for wind power density, to become as follow[12,13]:

$$\overline{p}_W = \frac{1}{2}\rho K \overline{V}^3 \quad ....(16)$$

Mean wind power density (power/unite area) for all four stations can be calculated by using equation (16) . Tables (7 and 8), shows the results of the calculations for all the stations at 10m and 50m. Accordingly, the stations can be classified into two groups: the first group with high power density and these are Kalar, Khanaqin, and Touz, with monthly average wind power for this group range from 3.49 W/m^2 to 28.57 W/m^2 at 10m and from 23.52W/m^2 to 175.81W/m^2 at 50m. The second group with low powers is Kirkuk, the monthly average wind powers for that group range from 1.45 W/m^2 to 13.25 W/m^2 at 10m and from 9.78 W/m^2 to 89.24 W/m^2 at 50m. To find monthly mean wind energy density at 10m, and 50 heights (wind power per month per unit area) the results shown in Tables (7 and 8) must be multiplied by the number of hours in each month. Tables (9 and 10) shows the results of the calculation that is monthly mean wind energy density for all the four stations. While table (11) shows the annual mean wind power density, and energy for all the stations at 10m and 50m, respectively.

Table(3): Monthly Mean Wind Speed (m/sec) for the four locations at 10m.

Location\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Kirkuk	2.09	1.5	1.5	1.67	2.04	1.95	1.95	1.79	1.25	1.48	1.12	1	1.51
Kalar	1.89	1.97	2.6	2.62	2.54	2.53	2.25	2.26	2.3	2	1.4	1.34	2.01
Khanaqin	1.75	2.24	2.48	2.59	2.7	2.36	2.24	2.07	1.94	1.98	1.86	1.62	2.01
Touz	1.58	1.99	2.09	2.56	2.56	2.51	2.49	2.34	1.91	1.72	1.58	1.36	1.99

Table(4): Monthly Mean Wind Speed (m/sec) for the four locations at 50m.

Location\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Kirkuk	3.95	2.83	2.83	3.15	3.85	3.68	3.68	3.38	2.36	2.79	2.12	1.89	2.84
Kalar	3.57	3.72	4.91	4.95	4.80	4.78	4.25	4.27	4.34	3.78	2.64	2.53	3.80
Khanaqin	3.30	4.23	4.68	4.89	5.10	4.46	4.23	3.91	3.66	3.74	3.51	3.06	3.80
Touz	2.98	3.76	3.95	4.83	4.83	4.74	4.70	4.42	3.61	3.25	2.98	2.57	3.75

Table(7): Monthly Mean Wind Power Density (W/m^2) for the four locations at 10m.

Location\ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Kirkuk	13.25	4.90	4.90	6.76	12.32	10.76	10.76	8.33	2.84	4.71	2.04	1.45	4.96
Kalar	9.80	11.10	25.51	26.11	23.79	23.51	16.53	16.76	17.66	11.61	3.98	3.49	11.81
Khanaqin	7.78	16.32	22.14	25.22	28.57	19.08	16.32	12.88	10.60	11.27	9.34	6.17	11.79
Touz	5.73	11.44	13.25	24.35	24.35	22.95	22.41	18.60	10.11	7.39	5.73	3.65	11.39

Table(8): Monthly Mean Wind Power Density (W/m^2) for the four locations at 50m.

Location\ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Kirkuk	89.24	32.99	32.99	45.53	82.99	72.48	72.48	56.07	19.09	31.69	13.73	9.78	33.37
Kalar	66.00	74.74	171.81	175.81	160.19	158.31	111.35	112.84	118.94	78.20	26.82	23.52	79.55
Khanaqin	52.39	109.87	149.10	169.84	192.41	128.49	109.87	86.71	71.37	75.88	62.90	41.56	79.38
Touz	38.56	77.04	89.24	164.00	164.00	154.58	150.91	125.25	68.11	49.74	38.56	24.59	76.70

Table(9): Monthly Mean Wind Energy Density ($kWh/month/m^2$) for the four locations at 10m.

Location\ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Kirkuk	9.86	3.29	3.65	4.87	9.17	7.75	8.01	6.19	2.04	3.50	1.47	1.08	5.07
Kalar	7.29	7.46	18.98	18.80	17.70	16.93	12.30	12.47	12.72	8.64	2.87	2.60	11.56
Khanaqin	5.79	10.96	16.47	18.16	21.26	13.74	12.14	9.58	7.63	8.38	6.73	4.59	11.29
Touz	4.26	7.69	9.86	17.54	18.12	16.53	16.67	13.84	7.28	5.50	4.12	2.72	10.34

Table(10): Monthly Mean Wind Energy Density ($kWh/month/m^2$) for the four locations at 50m.

Location\ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.
Kirkuk	66.40	22.17	24.55	32.78	61.74	52.19	53.93	41.71	13.75	23.58	9.89	7.27	34.16
Kalar	49.10	50.22	127.83	126.58	119.18	113.98	82.84	83.95	85.63	58.18	19.31	17.50	77.86
Khanaqin	38.98	73.83	110.93	122.28	143.15	92.51	81.74	64.51	51.39	56.45	45.29	30.92	76.00
Touz	28.69	51.77	66.40	118.08	122.02	111.30	112.28	93.19	49.04	37.01	27.76	18.29	69.65

Table(11): Annual Mean Wind Speed, Power, and Energy Density at Garmyan Zone.

Location	V (m/sec) at 10m	V (m/sec) at 50m	Power density (W/m^2) at 10m	Power density (W/m^2) at 50m	Energy density ($kWh/year/m^2$) at 10m	Energy density ($kWh/year/m^2$) at 10m
Kirkuk	1.51	2.84	4.96	33.37	43.41	292.32
Kalar	2.01	3.80	11.81	79.55	103.48	696.87
Khanaqin	2.01	3.80	11.79	79.38	103.26	695.39
Touz	1.99	3.75	11.39	76.70	99.78	671.93

4. CONCLUSIONS

According to these results, the Garmyan zone has good wind resource, especially in three stations (Kalar, Khanaqin, and Touz). These three stations are with values of annual mean wind speed ≥ 2m/s at 10m, and ≥ 3.75 m/s at 50m. The Kirkuk location has low annual mean wind speed; it is equal to 1.51 m/s at 10m, and 2.84 m/s at 50m. The annual wind power densities estimated from wind speeds at 10 meters height are 4.96, 11.81, 11.29, and 11.39 W/m^2 for Kirkuk, Kalar, Khanaqin, and Touz, respectively, while the corresponding values of wind power densities from winds at 50 meters height are 33.37, 79.55, 79.38, and 76.70 W/m^2,respectively. The annual wind energy densities are 43.41 for Kirkuk, 103.44 for Kalar, 103.28 for Khanaqin, and 99.78 KW/year/m^2 for Touz at 10m, and 292.32, 696.87, 695.39, and 671.93 KW/year/m^2 at 50m height, respectively (see table(11)). In general the results show that the wind powers in this zone are relatively small for electricity generation but it is suitable for the applications in agriculture. And it is suitable for water pumping from shallow (30m) and deep (100m) wells using windmills, especially in spring and summer because the higher wind speed recorded and the rain is a little.

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