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Evaluation Efficiency of Wind Turbines for Barjisiah (South of Iraq) Wind Plant

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Abstract
The main objective of the paper is to study the possibility of erecting 2 MW wind turbine in the south of Iraq (Barjisiah site) by utilizing WAsP model. Wind potential and output predicted the power of WT at a supposed site was calculated. The results for proposed WT showed the WT has a weak performance due to its high capacity and low potential of wind speeds at this site. So, the WT will provide power for a limited time during the year due to its operating at the zone under the rated wind speed.

Keywords: Weibull, WAsP, power density, Barjisiah.

تقييم كفاءة توربينات الرياح لمحطة الرياح في البرجسية (جنوب العراق)

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الخلاصة
الهدف الرئيسي من البحث هو دراسة امكانية نصب توربين رياح قدرة 2 ميكا واط في جنوب العراق(موقع البرجسية) باستخدام موديل WAsP . مكمن الرياح والقدرة المخمنه للتوربين حسبت عند الموقع المقترح. نتائج التوربين المقترح بينت ضعف اداء التوربين نتيجة الى سعته العالية وضعف مكمن سرع الرياح عند ذلك الموقع. لذلك، فان توربين الرياح سيزود طاقة لفترة محدودة من السنة بسبب عمله في نطاق تحت معدلات سرعة الرياح .

Introduction

As of late, wind energy has turned out to be a standout amongst the most efficient sustainable power source innovation. Wind energy has been most pervasively used to create electric power due to non- contaminating to the earth and the preservation of non-renewable energy source assets. Many studies were introduced for assessing and predicting the possibility of erecting wind turbines in Iraq by utilize Wind Atlas and Application Program (WAsP). WAsP is the most-commonly used modeling software for predicting wind climates and power productions from wind turbines. This model based on the wind atlas methodology; it calculates a "wind atlas" or "regional wind climate" based on measured wind data. The regional wind climate represents the raw wind data as a wind climate over an ideal terrain (perfectly flat with uniform surface roughness) –to remove local terrain effects. This process can be reversed to determine the wind climate at another site using the wind atlas [1, 2].

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The energy created from the WT relies upon the wind site attributes and the WT parameters. The appraised speed is the most vital to WT plan. In the event that the estimated speed is picked too low to use lower wind speeds, much energy will be lost in the higher wind speed. Despite what might be expected, if the evaluated speed is too high, the turbine from time to time works at its appraised limit and furthermore will lose excessive energy in bringing down breeze speed. This implies the appraised speeds must be chosen with the end goal that the turbine yields higher energy. [3]. The aim of this study is to calculate the wind potential at Barjisiah site and identify the possibility of installing WT to be used at the location by calculating Weibull parameters in order to reduce uncertainties related to the wind energy output and power density (PD) to estimate the electrical energy from WT.

2. Methodology

The wind variety for a normal site is typically depicted utilizing a Weibull distribution function. Wind speed can be expected to have the two-parameter Weibull distribution; in any case, three parameters Weibull distribution fits the wind speed data in a refined way than the two-parameter form [4].

The Weibull distribution is depicted by two variables; the shape (K) & the scale (A) parameter. Wind speed cumulative distribution function (U) is given by equation 1:

$$F(U)=1-e^{[(-U/A)]} \text{ ----------- (1)}$$

equation 2 gives the probability density function (PDF)

$$f(U)=dF/dU=\frac{K}{A}\left(\frac{U}{A}\right)^{K-1}e^{\left[-\left(\frac{U}{A}\right)\right]^{K}} \text{ -----------(2)}$$

The Weibull variables k & A are related to the mean wind speed ($\overline{U}$) and the associated standard deviation (σ) by the following equations

$$A=\frac{U}{\Gamma\left(1+\left(\frac{1}{K}\right)\right)} \text{ -----------(3)}$$

$$\sigma=A\sqrt{\Gamma\left(1+\frac{1}{K}\right)}+\Gamma^{2}\left(1+\frac{1}{K}\right) \text{ -----------(4)}$$

Where Γ is the Gamma function. If the values of ($\overline{U}$) and (σ) of the wind speed for a given site are known, c and **A** can be explained using equations (5, 6) **[3].**

The Wind Power Density (WPD)

The wind power is defined as a flood flow (flux) of wind power through unit area perpendicular to the direction of the wind, it is used to assess the electrical potential which is resulting from the turbine blades and it can be calculated from the equation below-

$$P=0.5\sigma\upsilon^{3}\Pi r^{2} \text{ -----------(5)}$$

The best wind capacity is the density of wind capacity WPD, because it will give a clear picture of how to distribute wind speed on average (mean) and this quantity can be estimated in practice by using (Weibull Distribution) which it depends on the two parameters (c) scale and (k) shape parameters [6]

$$WPD=\frac{1}{2}\rho A^{3}\Gamma\left(\frac{1+3}{K}\right) \text{ -----------(6)}$$

The power created by WT shifts with the wind that strikes the rotor. It is a regular practice to utilize the wind speed at hub height as a kind of perspective for the powerful reaction of the WT. The power created as a function of the wind speed at hub height is customarily called the power curve. At the point when the wind speed is not as much as the cut-in wind speed, the turbine won't have the capacity to deliver provide power. At the point when the wind speed surpasses the cut-in speed, the power yield P (u) increments with increasing wind speed to a more extreme value, the rated power; from there on the yield is practically steady. At wind speeds higher than the cut-out speed the WT is halted to anticipate structural failures.

The amount of electricity produced by a wind turbine depends on three factors: Wind speed, Wind turbine availability and the way wind turbines are arranged, by using the equation (7)

$$Amp = power / volts \qquad \text{-----(7)}$$

Study Area

The study area is of Barjisiah located in the south of Iraq at longitude (47.06) and latitude (30.29). As shown in Figure-1 Which lies adjacent the Kuwaiti-Iraqi border and is characterized by the presence of large green areas beside of a number of oil fields leading to increased concentration of CO_2 **[7].**

Figure 1-Location of study area.

Results and Discussions

We obtained the data of hourly wind speed for the (3) years from the Ministry of Agriculture in Iraq at high 10 m. Data from Barjisiah station are retrieved and analyzed using the WAsP climate analysis tool to produce the observed wind climate (OWC). All sector statistics are shown in Table-1.

Table 1-All sector statistics

	Weibull-A	Weibull-k	Mean speed	Power density
Source data	-	-	4.01 m/s	109 W/m^2
Fitted	4.4 m/s	1.44	3.96 m/s	110 W/m^2
Emergent	-	-	3.98 m/s	110 W/m^2
Combined	4.4 m/s	1.46	3.98 m/s	110 W/m^2

The observed wind climate was calculated at (10) m for metrological data, as shown in Table-2.

Table 2-Observed wind climate

Sector		Wind climate				power
No.	Angle [$_o$]	Frequency [%]	Weibull-A[m/s]	Weibull-k	Mean speed [m/s]	Power density [W/m^2]
1	0	3.9	4	1.57	3.58	72
2	30	2.4	3	1.25	2.83	51
3	60	2.1	2.3	1.16	2.2	28
4	90	3.2	3	1.24	2.83	52
5	120	7.9	4.8	1.54	4.27	125

6	150	4.7	3.8	1.26	3.53	99
7	180	2.9	2.2	1.14	2.11	26
8	210	2.7	1.9	0.92	1.97	35
9	240	5.9	2.5	1.30	2.26	25
10	270	23	3.8	1.52	3.45	67
11	300	28.6	5.7	1.77	5.06	173
12	330	12.8	5.7	1.83	5.03	164
All					3.98	110
Source data					4.01	109

Also, the wind rose and histogram for the site was calculated and shown in Figure-2.

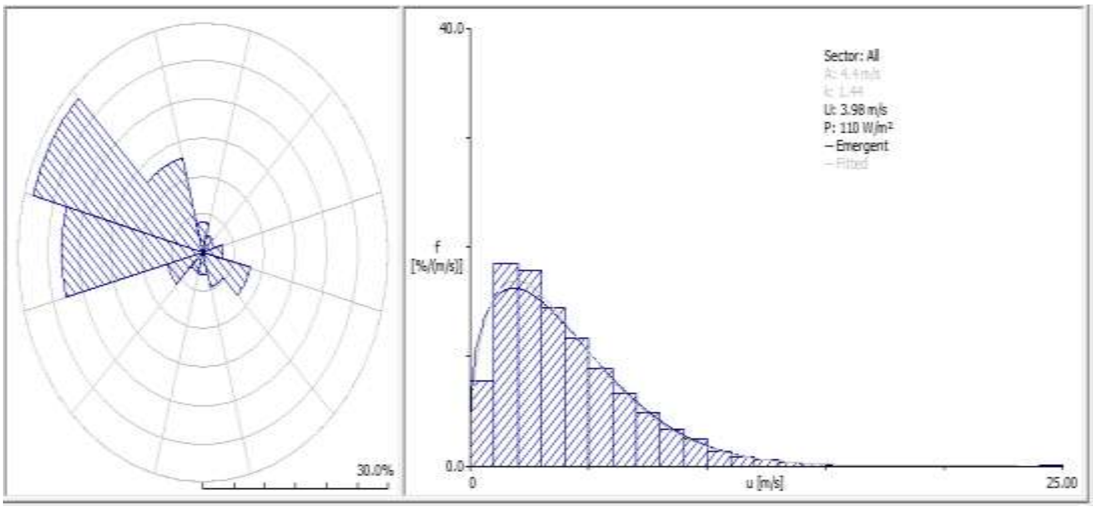

Figure 2-(left) Wind Rose, (right) Histogram.

Time variation of the time period is shown in Figure-3.

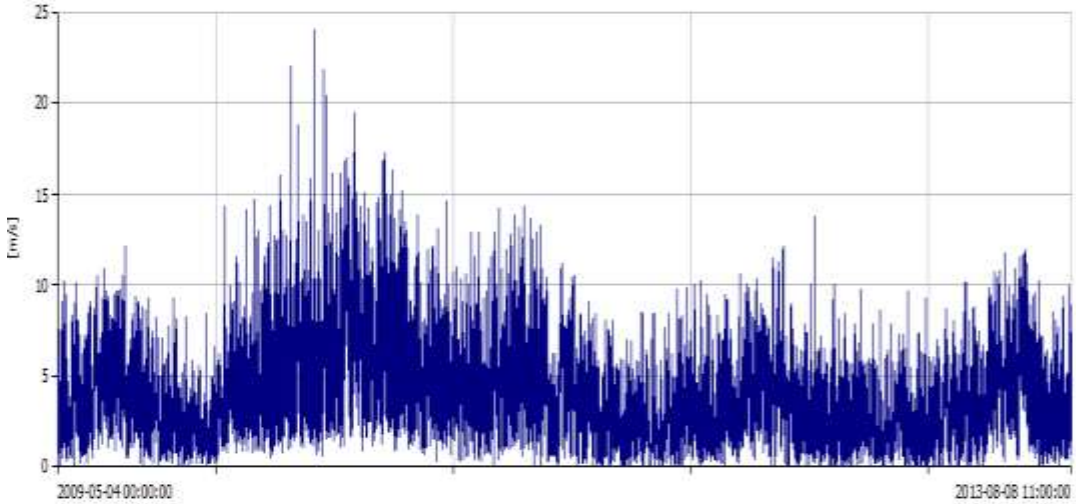

Figure 3-Time variation

In addition, the vector map of the site was drawn to determine the elevation (topography) and roughness of this site as shown in Figure-4.

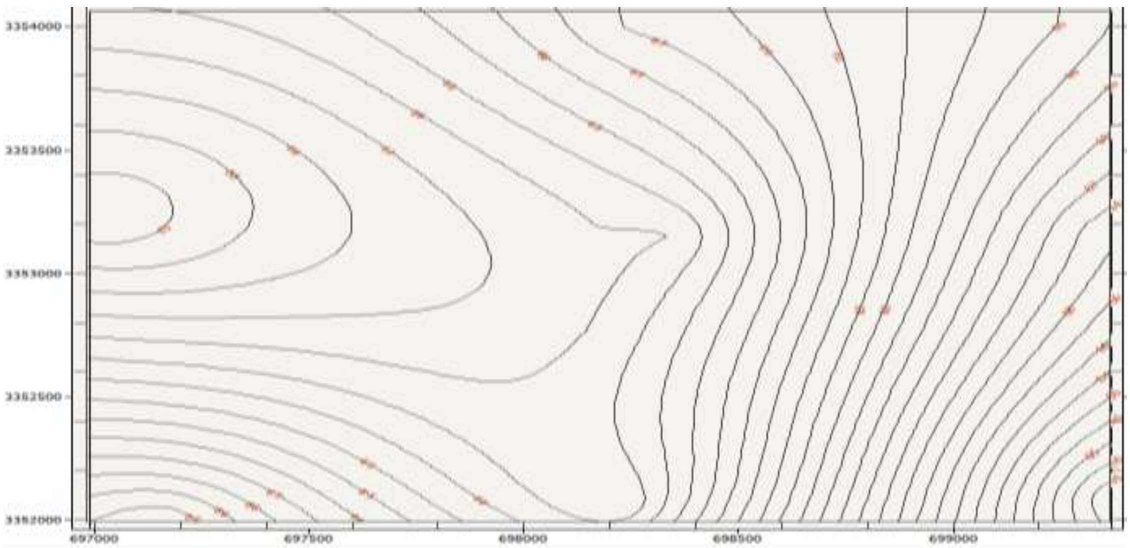

Figure 4-vector map of site.

WAsP was utilized the total energy content of the wind's mean that has ascertained from the Metrological data when it makes a generalized wind climate for the investigation region. So, wind atlas (regional wind climate) for the site was calculated at four different heights and five different roughnesses, as shown in Table-3.

Table 3-Site wind atlas

Height (m)	Parameter	Roughness Length (m)				
		0	0.03	0.10	**0.40**	**1.50**
10	A [m/s]	5.1	3.7	3.2	2.5	1.7
	k	1.63	1.46	1.46	1.48	1.50
	U [m/s]	4.53	3.32	2.90	2.30	1.55
	PD [W/m²]	138	63	42	21	6
25	A [m/s]	5.6	4.4	4.0	3.4	2.6
	k	1.67	1.56	1.55	1.56	1.57
	U [m/s]	4.96	3.97	3.58	3.03	2.34
	PD [W/m²]	175	98	72	44	20
50	A [m/s]	6.0	5.1	4.7	4.1	3.4
	k	1.71	1.72	1.69	1.68	1.67
	U [m/s]	5.33	4.59	4.19	3.66	3.00
	PD [W/m²]	211	134	104	70	39
100	A [m/s]	6.5	6.1	5.6	5.0	4.2
	k	1.67	1.82	1.83	1.87	1.86
	U [m/s]	5.78	5.42	4.98	4.42	3.77
	PD [W/m²]	277	206	159	109	68

The WAsP combines the topographic effects and the regional wind climate at the turbine site (the adopted turbine type in this project was Suzlon S-950 KW of hub height (65 m) to produce wind resource grid map for the study area. Table-4 shows the specifications of the wind turbine.

Table 4-specifications of wind turbine

Nominal Power	950 kW
Rotor Diameter	64 m
Cut-in wind speed	3 m/s
Cut-out wind speed	25 m/s
Rated wind speed	11 m/s
Voltage	690 V
Grid Frequency	50 Hz

Hub Height	65m
Swept area	3.218 m^2
Number of blades	3

The 255 sites for each sector were calculated (starting with (0-360) sector and maps for wind power densities were drawn as shown in Figure-5.

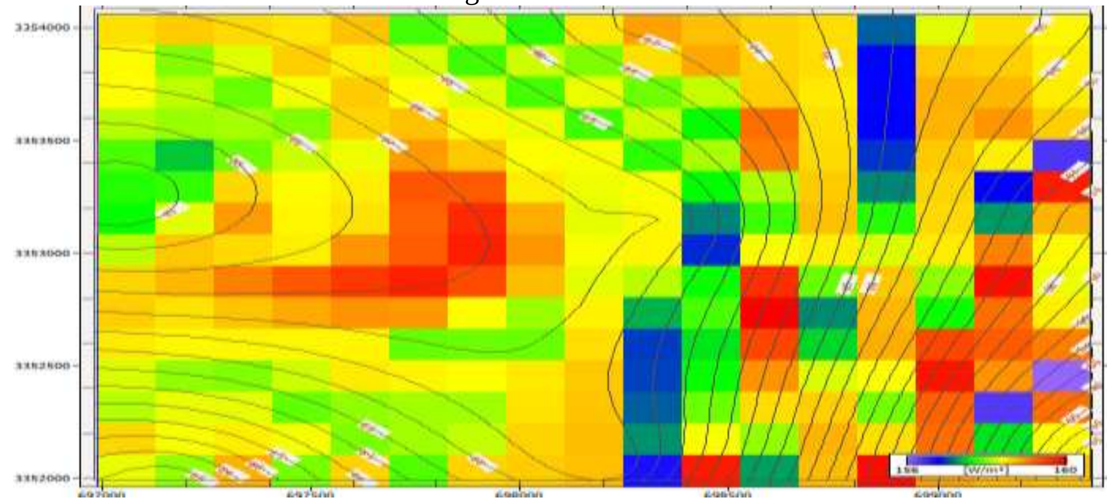

Figure 5-wind power density map for all sectors.

The maps of wind power density at hub height (65) meter above ground level (m.a.g.l) for area (696990,3351962) -(699370,3354062) with resolution (140) m was drawn from all sector as shown in wind rose and the high potential regions were determined (red color refers to the high potential region), also lower potential regions were displayed in blue color.

Conclusion

As the previous calculations**,** the wind power density was (160) w/m^2 and the mean wind speed for all sectors were (4.91) m/s at hub height. The Weibull shape parameter was (1.76) and scale parameter was (5.5) m/s. This shows a good measure of the fit of the Weibull distribution to the given data. The cut-in wind speed of the Suzlon turbine is 3 m/s, and the rated wind speed is 11 m/s. The mean speed at the site is higher than the cut-in speed of the turbine. Capacity factor for a wind turbine on this site is (22%). This site classified as (class-1), this indicates that the turbine is producing power in a minority of the time. The outcomes prompt the conclusion that, however introducing large- scale wind turbines isn't practical for the considered area.

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