Estimating potential wind power as a source of electrical power generation in Al-shihabi area, Iraq

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Abstract
Al shihabi is one of the highly potential areas when it comes to energy generated by wind, wind energy is the new source of energy that's environment friendly and low in cost non-depletion easy to harnessed by different users. A general understanding of wind behavior is necessary for the accurate planning and implementation of any wind energy projects, but due to the lack of information of wind power at these area further studies of wind is very important. The goal of this paper is to conduct an investigation on the wind energy potentials of Al-shihabi area in south of Wassit. For this reason the wind data was collected for one year from Dec 2014 to Dec 2015 in the time interval of 10 minutes at heights of 10, 30 and 50 meters then the data were analyzed using the Weibull probability distribution function and the wind rose and for the spectral analyzes the Fast Fourier Transform was performed. With the annual mean wind speed of (6.84) m/sec at 50 m to be used in wind energy generation as shown in the spectral analysis that the peak was (185912.078 m/sec/12 hour) at the frequency of (2 Hz) at the 50 m height throughout the night time but the lowest was (95161.3369 m/sec/12 hour) at the frequency of (2 Hz) at the 10 m height throughout the night time. The wind speed during morning hours were higher than that at the night time. While the governing wind direction at the area was from west-north west and the north-north west.

Keywords- wind energy generation; Wind energy spectrum; Fourier series; Weibull distribution.

تقدير طاقة الرياح المحتملة كمصدر لتوليد الطاقة الكهربائية في منطقة الشهابي، العراق

المستخلص الشهابي تعتبر احدى اكثر المناطق الواعدة عندما يتعلق الأمر بالطاقة المولدة من الرياح ، وطاقة الرياح هي المصدر الجديد للطاقة التي تكون صديقة للبيئة ومنخفضة التكلفة كذلك غير قابلة للنفاذ وسهلة الاستخدام من قبل مختلف المستخدمين. إن الفهم العام لسلوك الرياح ضروري من اجل التخطيط والتنفيذ الدقيق لأية مشاريع تخص طاقة الرياح ، ولكن بسبب نقص المعلومات عن طاقة الرياح في هذه المنطقة يعد إجراء المزيد من الدراسات حول الرياح أمراً بالغ الأهمية. الهدف من هذا البحث هو إجراء دراسة حول إمكانيات طاقة الرياح في منطقة الشهابي في جنوب محافظة واسط. ولهذا السبب ، تم جمع بيانات الرياح لمدة عام واحد من ديسمبر ٢٠١٤ إلى ديسمبر ٢٠١٥ في الفترة الزمنية لكل ١٠ دقائق على ارتفاعات ١٠ و ٣٠ و ٥٠ متر ، ثم تم تحليل البيانات باستخدام دالة ويبل لتوزيع احتمالية ووردة الرياح وايضآ التحليل الطيفي حيث تم استخدام تحويلات فورير السريعة. كانت قيمة المتوسط السنوي لسرعة الرياح (٦,٨٤) م / ثانية على ارتفاع ٥٠ م والممكن استخدامها في توليد طاقة الرياح كما هو اثبت في التحليل الطيفي فإن الذروة كانت (١٨٥٩١٢,٠٧٨ م / ثانية / ١٢ ساعة) عند تردد (٢ هرتز) عند ارتفاع ٥٠ م في فترة الليل ولكن أقلها كان (٩٥١٦١,٣٣٦٩ م / ثانية / ١٢ ساعة) عند تردد (٢ هرتز) عند ارتفاع ١٠ أمتار خلال ساعات الليل. كانت سرعة الرياح خلال ساعات الصباح أعلى منها خلال ساعات الليل. بينما كان اتجاه الرياح المسيطر في المنطقة من الغرب –الشمال الغربي وايضآ الشمال–الشمال الغربي.

الكلمات المفتاحية – توليد طاقة الرياح: طيف طاقة الرياح : سلسلة فورير : توزيع ويبل.

Introduction

Energy derives from various sources and is created in great amounts to satisfy the increasing demand which is done by the improvement of large scale power projects. In the beginning, many power projects used water or coal to produced power, both of which were assets that were available in abundance. Most lately, in second part of the twentieth century, improvement was concentrated on nuclear power, [1]. Well, it is well-known that coal and oil reserves are being depleted as an outcome of vast intake demands, and also create a harmful effect on the atmosphere. Additionally, the world depletion of

these types of resources is happening quicker than they can be replenished so, as a consequence, is not a sustainable conduct, [2].

And for that reason the search of new altered types of energy production technologies had to be established. Lately, the world's turn into the green energy such as solar photovoltaic, wind, tidal, biomass and hydro which is replenishing in a fast rate to meet the growing world's demand of power, [2].

The implement of a zero map project has been performed in Iraq which categorized the area of Al shihabi as a favorable area for wind energy production and In 2007 Mohammed [3] definite the selected area as a good location for wind power production, The objective of the present paper is to examine the wind characteristics for Al shihabi area in south of Wassit Governorate on the south of Iraq for the time period of Dec 2014 till Dec 2015, which would be an significant impact to the understanding of the general behavior of the wind speed in this area so it can be used in power generation.

Materials and methods

Using wind data for the speed and direction for one year for three various height levels (10, 30, 50 m) were analyzed which was gathered from meteorological mast located in Al-shihabi area, then the data were processed and then Weibull distribution was initiated also the FFT was performed to identify the energy spectrum and detect the peaks of the spectrum .

Area of study: The area is located in Wassit Governorate at a coordinate of 32.51°N 45.82°E 22 M above sea area is about 172.1 Km from Baghdad (the capital of Iraq); Figure. 1 shows the location of chosen site of Al shihabi in south of Wassit. This area is passed across by the Tigris River, beside a ribbon of irrigated farmland runs, producing a dry desert landscape to the north east. The area has a dry, desert climate, characterized by temperatures certainly higher than 40°C in summer. Rainfall is infrequent and concentrated in the winter months and a flat topography of a few roughness. [4]

The geographical site gives the wind the chance to reach a high values since it's an open area with no obstacles and table (1) give some characteristics features for Al-Shihabi area .[4]

Table 1. Characteristics for the study area [3].

Height (m)	Ū (m/s)	S.D.	Median	Min.(m/s)	Max.(m/s)
10	4.60	3.10	4.12	0.34	**17.53**
30	6.13	3.41	5.90	0.38	**19.52**
50	6.84	3.81	6.50	0.39	**24.50**

Fig. 1. Location of studied area in Iraq.[6]

The Weibull distribution: To characterize the wind speed at a specific site there are many probability density functions one of them is the Weibull probability density function that's generally used to define the wind speed frequency distribution. The Weibull distribution is the best of the other approaches, since it has an acceptable precision level. The advantage of this technique is the clear and fast definition of the average wind density at a specified location [6].The wind speed probability density function can be expressed as eq.1 [7]:

$$F(x) = \frac{k}{A}\frac{(x-g)^{(k-1)}}{A}.\exp\left[-\left(\frac{(x-g}{A}\right)\right]^{K} \quad (1)$$

Where F(x) is the probability (W/m^2) of calculated wind speed v , The Weibull shape (A) , scale (k) and location (g) parameters, used to refer to the wind potential of the site under examination.

The wind direction: Describing the governing direction of wind speed is critical in wind valuation studies because it's clarifies the influence of the geographical features for the region on the wind.

As it can be understood from table 1, for wind speed at height of (10, 30, 50 m) alongside the wind direction which is linked to it. [8]

The wind spectrum: The spectral analysis of wind speed is explained on theory since the wind speed can be modeled as a stationary and Gaussian stochastic process, that's who it can give the wind power distribution for each frequency by changing the time series to a wind spectrum, this is principally a transformation procedure from the time-domain for the wind data employed to the frequency-domain of the same data points, which can be executed acceptably by using the Fast Fourier Transform (FFT). [9] As the output of this process a wind speed data points that's being multiplied and plotted with respect to frequency, the plotted graph demonstrates the energy of wind components at each frequency.[10] [11]

Results and discussion

For the analysis of wind speed at Al-shihabi area in south of Wassit during (Dec 2014 till Dec 2015) on intervals of ten minutes at (10, 30, 50 m) height for both morning hours and night hours the data was regained from a metrological mast (met mast) with sensors sited at least one year for around-the-clock wind measurements at the site. The ten minutes data had to be rearranged in daily basis for morning hours and night hours and at the indicated height levels (10, 30, 50 m)

Then it was statistically analyzed and the Weibull distribution was constructed and a scheme of the wind rose is completed, after this the process of the spectral analysis by using the Fast Fourier Transform (FFT) has been initiated.

The statistical analysis: In order to create a whole picture of the wind speed at the selected site the data has to be statically studied and the result listed in table 2.

The Average wind speed: The highest value for the daily mean wind speed for morning hours was estimated as 6.40127 m/s at 50 m while the highest mean daily wind speed for the night hours was 7.02418 m/s at 50 m. Its evidence from observing table 2 that the highest wind speed was at 50 m and that's because in height levels like this the effect of the surface roughness is

no longer exist, while the lowest daily wind speed was at the 10 m height levels where the roughness has a great effect on reducing the wind speed since the area has a flat topography and a dry desert climate with high temperatures and low rainfall, Now let's consider the effect of the solar heating since the sun has an important effect on the wind speed and the mean wind speed for the morning hours was 5.015 m/s and it was for the night time 4.843 m/s it's clear that the morning hours has higher values than the night hours.

Table 2.statistical parameter for wind speed data

Morning hours								
Height (m)	**Ū (m/s)**	**Max & Min**	**Range**	**Median**	**Standard deviation**	**Skewness**	**Kurtosis**	**Confidence level (95%)**
10	**5.11242**	**14.51569 & 0.66305**	**13.852**	**4.539**	**2.99**	**0.841**	**0.148**	**0.307**
30	**6.07019**	**16.42069 & 0.8443**	**15.576**	**5.573**	**3.273**	**0.815**	**0.11**	**0.336**
50	**6.40127**	**17.25791 & 0.67**	**16.587**	**5.78**	**3.465**	**0.773**	**0.014**	**0.356**
Night hours								
10	**4.16404**	**10.87069 & 1.11819**	**9.752**	**3.793**	**1.912**	**1.078**	**1.053**	**0.196**
30	**6.1427**	**13.1168 & 1.17333**	**11.943**	**5.85**	**2.239**	**0.541**	**0.169**	**0.23**
50	**7.02418**	**14.54164 & 0.71875**	**13.823**	**6.785**	**2.715**	**0.303**	**– 0.256**	**0.279**

The Weibull distribution results: The Weibull probability function has been achieved and table 3 summarized the results which can indicate that the Weibull distribution fits real distribution data in good terms. The shape parameter (*k*) and the scale parameter (*c*) of the Weibull function were computed for every height level and listed in table 3.

Table 3.the Weibull K and A parameters

Morning hours		
Height (m)	**Scale parameter -A (m/s)**	**Shape parameter-A**
10	**5.772**	**1.808**
30	**6.874**	**1.975**
50	**7.245**	**1.962**
Night hours		
10	**4.714**	**2.314**
30	**6.886**	**2.935**
50	**7.890**	**2.797**

The wind rose: to construct a wind rose plot has been made in order to show the direction of the wind speed at each height levels and for both morning and night hours. As it can be learn from table 4, for wind speed at height of 10 m vs. the direction that the highest wind speed was at the sector of 280° - 300° with the value of 28.39342 m/s and the lowest was at 200° - 220° with the value of 1.30328 m/s while for the 30 m the maximum wind speed was in 280° - 300° with a value of 28.37496 m/s, and the lowest wind speed is in 180° -200° with a value of 1.47496 m/s. however at 50 m the highest wind speed was 28.66478 m/s at the direction of 300° - 320° and the lowest was 1.27005 m/s at 200° -220°. The governing wind direction at this location was at the North West precisely at the west-north west and the north-north west (WNW and NNW) while the modest wind direction was at the South West and the west-south west (SW and WSW).

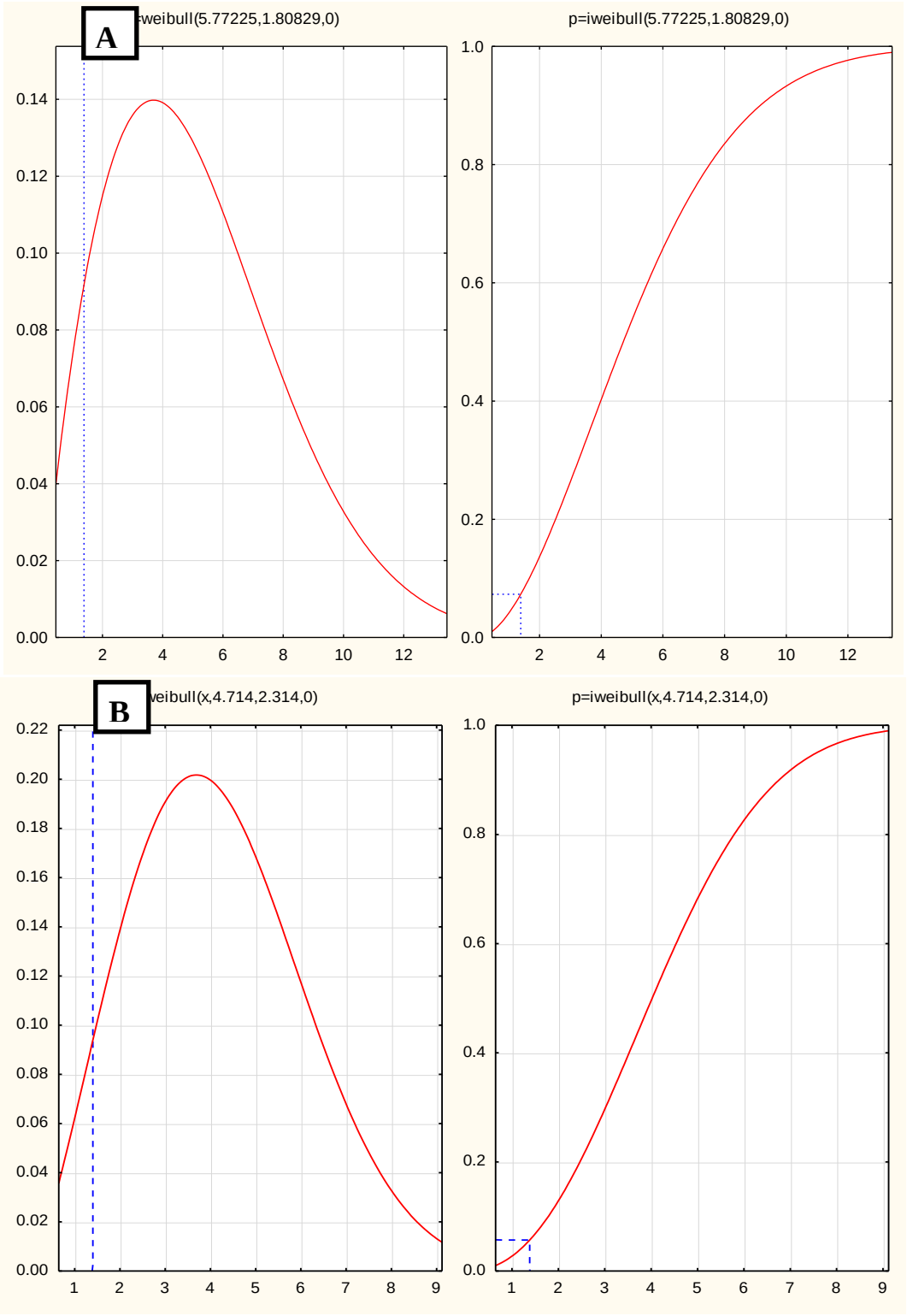

Fig. 2. Weibull distribution at 10 m during (A) morning (B) night.

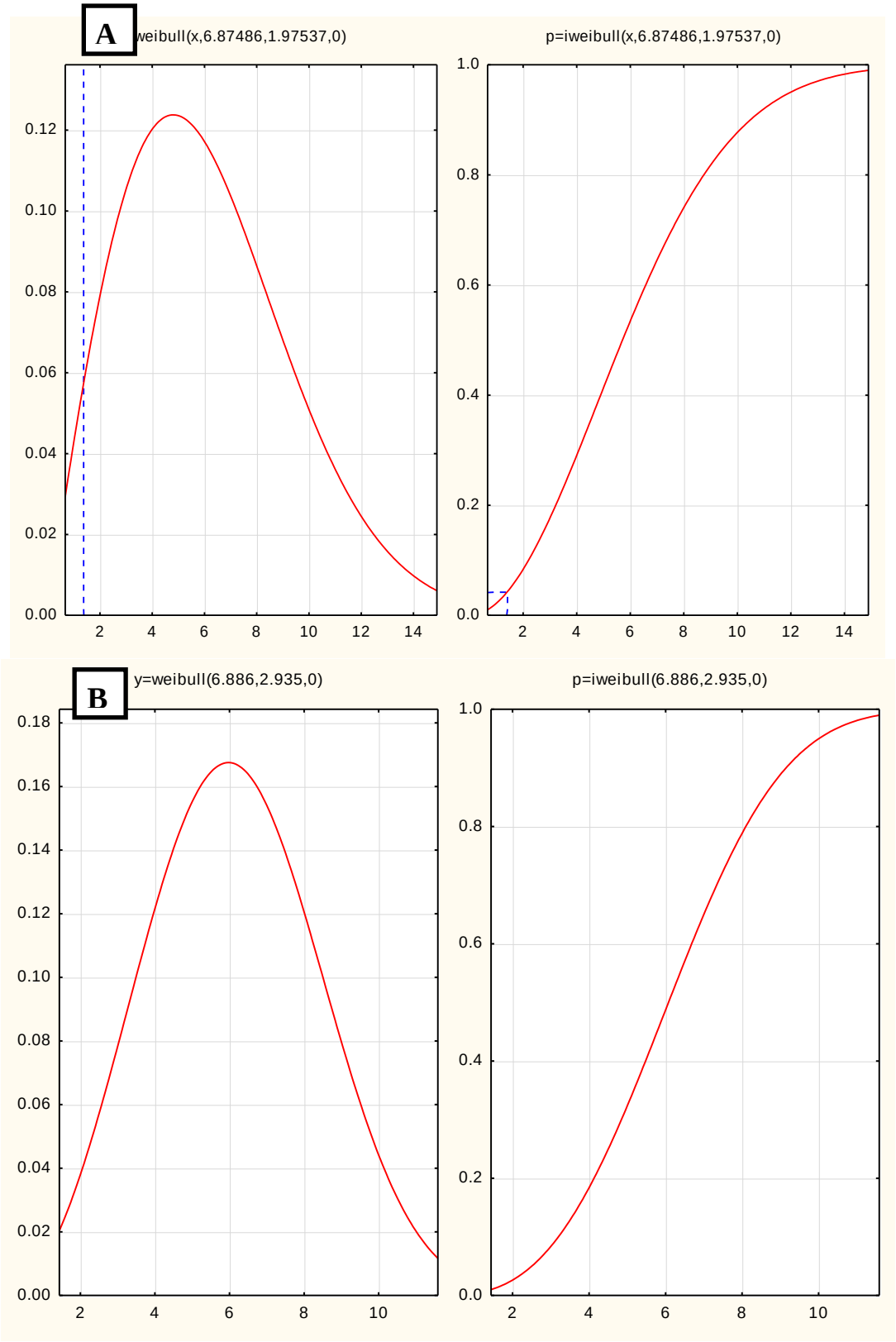

Fig. 3. Weibull distribution at 30 m during (A) morning (B) night.

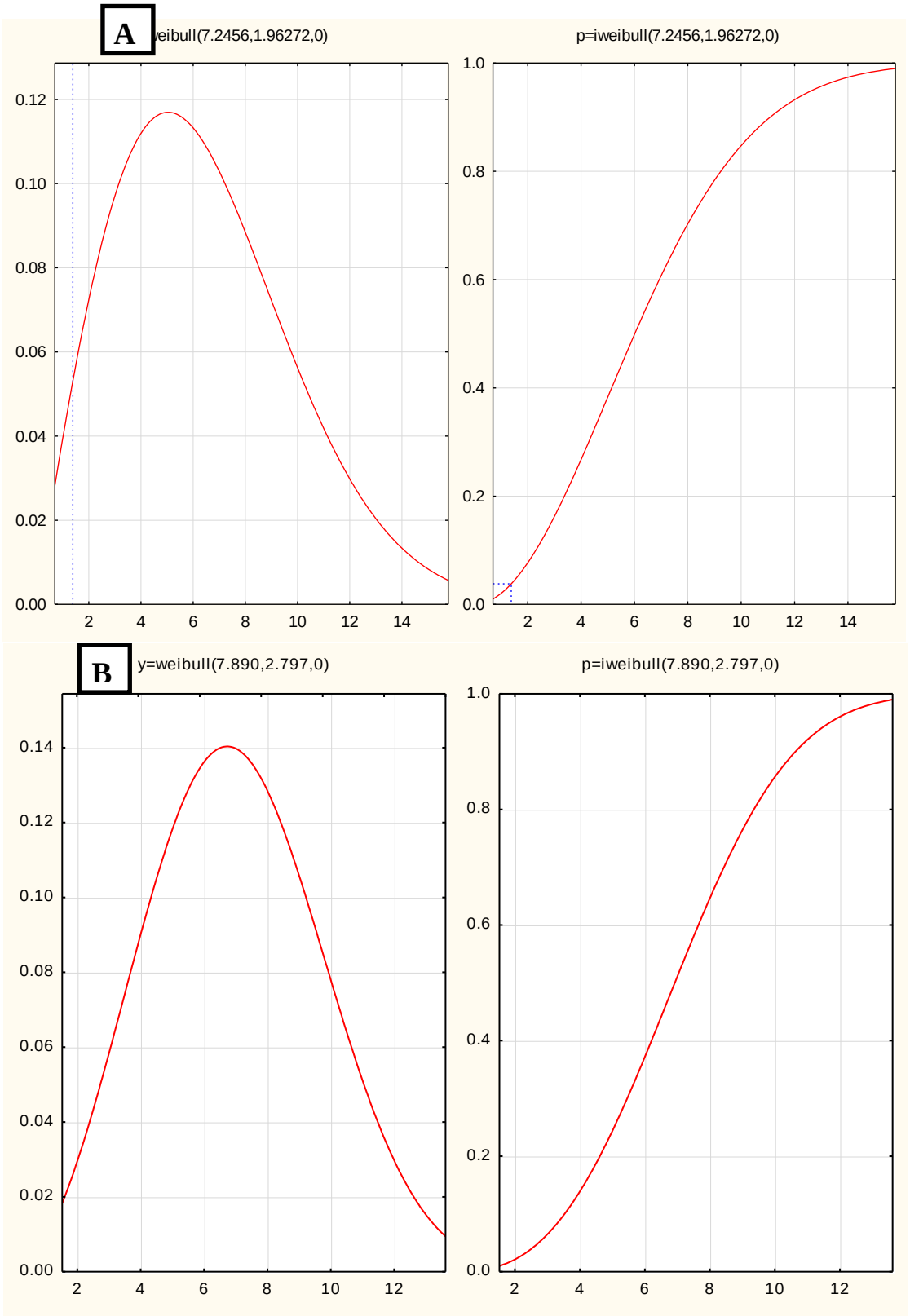

Fig. 4. Weibull distribution at 50 m during (A) morning (B) night

Table 4. Wind direction & wind speed at 10 m .

Direction Sector (°)	Mean wind speed (m/s)	Calm
0 - 20	2.71548	0.05907
20 - 40	1.86447	
40 - 60	2.06937	
60 - 80	2.38689	
80 - 100	4.73685	
100 - 120	8.19073	
120 - 140	5.47341	
140 - 160	2.99607	
160 - 180	1.76109	
180 - 200	1.43804	
200 - 220	1.30328	
220 - 240	1.63556	
240 - 260	2.36658	
260 - 280	6.79699	
280 - 300	28.39342	
300 - 320	17.49275	
320 - 340	5.18359	
340 - 360	3.13636	
360 - 380	0	
>= 380	0	

Table 5. Wind direction & wind speed at 30 m .

Direction Sector (°)	Mean wind speed (m/s)	Calm
0 - 20	3.16221	0.09968
20 - 40	2.72101	
40 - 60	2.18752	
60 - 80	2.61025	
80 - 100	5.68201	
100 - 120	6.73423	
120 - 140	4.06306	
140 - 160	2.42196	
160 - 180	1.49342	
180 - 200	1.47496	
200 - 220	1.49157	

220 - 240	2.12845	
240 - 260	4.03352	
260 - 280	15.46584	
280 - 300	28.37496	
300 - 320	9.57708	
320 - 340	3.55172	
340 - 360	2.72655	
360 - 380	0	
>= 380	0	

Table 6. Wind direction & wind speed at 50 m .

Direction Sector (°)	Mean wind speed (m/s)	Calm
0 - 20	3.05329	0.0443
20 - 40	1.98076	
40 - 60	1.57834	
60 - 80	2.09891	
80 - 100	4.07783	
100 - 120	7.98028	
120 - 140	6.57547	
140 - 160	3.47972	
160 - 180	2.04168	
180 - 200	1.42696	
200 - 220	1.27005	
220 - 240	1.3162	
240 - 260	1.82385	
260 - 280	3.50926	
280 - 300	15.72428	
300 - 320	28.66478	
320 - 340	9.48847	
340 - 360	3.86554	
360 - 380	0	
>= 380	0	

The time series: The daily time series was plotted to examine the general trend in wind speed and from the result it was established that the value 7.024189 m/sec indicates the highest value at 50 m during the night time

though 4.164042 m/sec represent the lowest value at 10 m during the night time.

The Spectrum: For the calculation of the wind spectrum (or the power spectral density [PSD] of the wind speed), the Fast Fourier Transform (FFT) was used for the time series of the collected data points and by means of some mathematical manipulations the power spectrum of wind speed was constructed for Al-shihabi during the day time and night time at the three selected height levels (10, 30 and 50 m).

Examining the peaks shows that the highest spectral density for Al-shihabi region was 185912.078 m/sec/12 hour at the frequency of (2 Hz) on the 50 m height level in the night time but the lowest was 95161.3369 m/sec/12 hour at the frequency of (2 Hz) at the 10 m height during the night time.

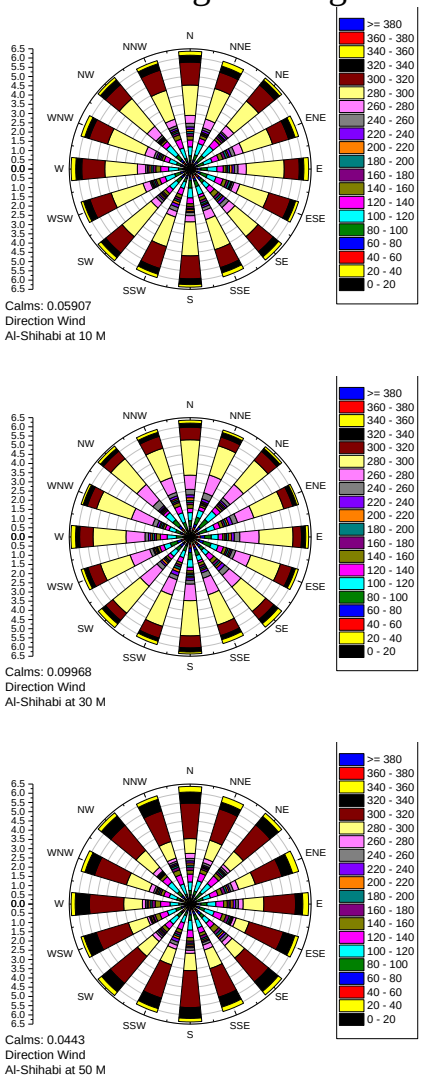

Fig. 5. The Wind rose at 10, 30 and 50 m

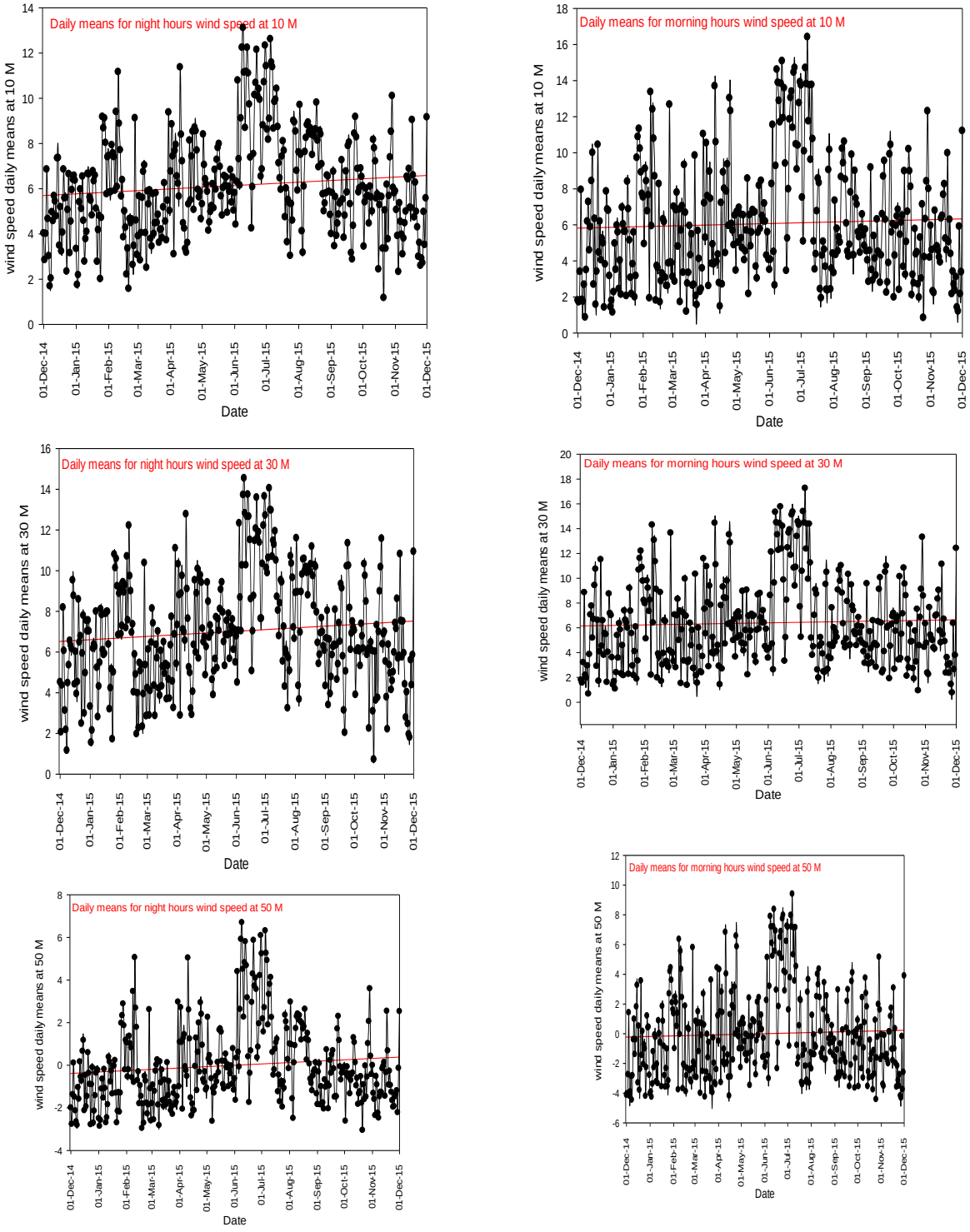

Fig. 6. The time series for both morning & night at 10, 30 & 50 m

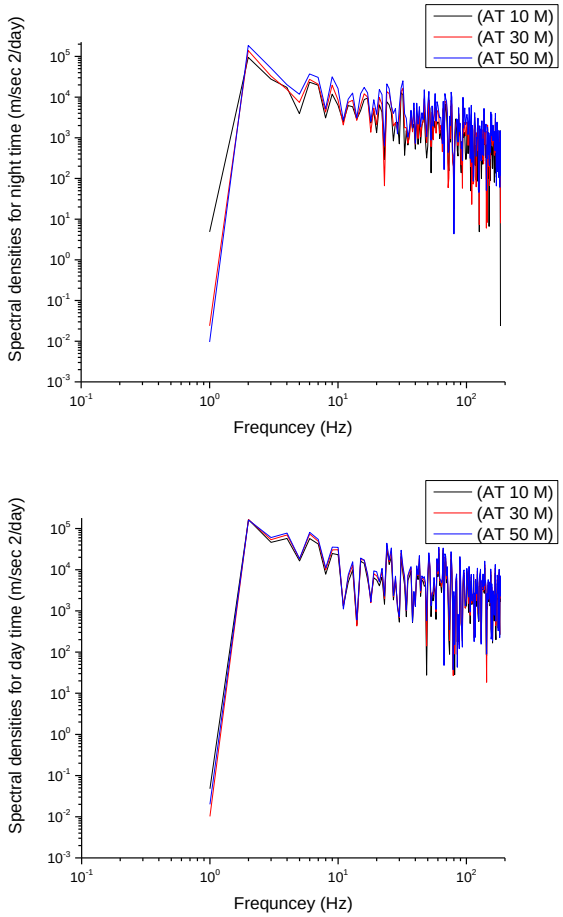

Fig. 7. The wind spectrum at 10, 30 & 50 m for night hours & morning hours

Conclusions

The examining of wind data at 10 m, 30 m and 50 m heights was accomplished in order to describe the wind potentials in Al-shihabi area, the results can be determined in:

1. In the morning hours the wind speed has a higher value that at night times with values of 6.40127 m/s at 50 m height and the slandard deviation value was 3.465.
2. The Weibull distribution function at 10 m, 30 m and 50 m heights shows a good agreement with the data gathered from the actual measurements.
3. The wind rose shown that, the prevailing wind directions are from west-north west and the north-north west.
4. The spectral density peaks for Al-shihabi indicate a better agreement for day time than the night time for the heights of (10, 30 and 50 m).

5. This study of wind data at Al-shihabi location has point out that it comes to be a respectably potential for production of wind power assessment.
6. Energy is crucial to the social and economic growth that's the reason we need to seek other energy sources. The result derived from this study encourages the employment of wind energy on Al-shihabi area.

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