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Wind Analysis for Power Generation in the South of Iraq

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ABSTRACT

The spectrum of the wind speed is expressed as the total wind speed that results from events split up into space, time, or both. It is the relationship shown between the energy or magnitude of any given parameter versus the frequency. In this study, the spectra of the wind speed at the Al-Reem site in Iraq were presented. Since the goal of the current research is to analyze wind speed and direction using the Fast-Fourier-Transform, experimental measurements for the wind speed and wind direction were taken every ten minutes for a year, from December 2014 to December 2015 at heights (10, 30, 50 m). Based on the performance of the Fast-Fourier-Transform, the peak with the highest spectral density, measured at 226,236.282 m/s at the frequency of 2 Hz, was found to be at a height of 50 m throughout the night, while the peak with the lowest height level. The spectral density was 115,863.7 m/s at a frequency of 2 Hz, at a height of (10 m) all into the night. Winds coming from the west and northwest were the most common direction in the region. In the morning, the wind was blowing faster than at night.

INTRODUCTION

The utilization of wind energy has received significant attention worldwide as a clean and renewable source of power generation. In the context of Iraq, especially the southern region, understanding wind speed characteristics is crucial for the effective deployment of wind energy conversion systems. The wind speed parameter (WS) fluctuates greatly. Using the power spectrum to explain the variable nature of wind speed is one of the most preferred approaches. Researchers, particularly those conducting wind energy evaluation studies, can greatly benefit from knowing the wind speed range (Ahmed et al. 2021). Al-Jiboori (2010) conducted a study to analyze the slow response observations for the Baghdad area and concluded that the values of the wind speed within the urban canopy are small at low levels and increase upwards.

Accurate analysis of WS in power generation systems in southern Iraq faces challenges such as the need for statistical analysis to determine wind energy potential (Jabbar 2021), the importance of selecting ideal locations and appropriate wind turbines based on estimated power and cost (Al-Rufaee et al. 2020), and the requirements for theoretical extrapolation between wind speed and height using logarithmic law and power law to calculate wind shear coefficients (Bashaer et al. 2019). Solutions include utilizing the Weibull distribution functions for statistical analysis of wind speed measurements (Mohammed et al. 2020). In 2018, Al-Jiboori et al. (2018) presented research regarding the selection of related low heights for the operation of a wind turbine in Baghdad, and the results showed that 75% of the wind at the site is not promising for wind harvesting due to the tall building and trees in the site (Al-Jiboori et al. 2018). In 2019 it is following a research paper showed that the height of 78 m at Mustansiriyah University in Baghdad is the best height level for wind turbine generation (Hadad et al. 2019). Developing software tools (such as MATLAB) based wind energy analysis tools for in-depth wind energy analysis, turbine selection, and implementing wind energy systems in ideal locations (such as Alhay in southern Iraq) to provide sufficient electricity for cities. In 2022, Mahmoud et al. (2022) and Mishaal et al. (2020) conducted a study and concluded that the wind profile gives better results at night time.

When it comes to studying wind evaluation, the spectroscopy method is very important and effective.

The spectrum of any variable consists primarily of the total wind speed resulting from events divided in time or space or as a combination of both (Abbas et al. 2019, Hadi et al. 2020). The research was conducted to identify wind energy in the Al-Reem and Al-Shehabi regions in southern Iraq through the Iraqi Zero Map Project, which identified the Al-Reem region as a suitable area for wind energy generation (Resen 2015). In addition, Abbas et al. 2019 conducted a thorough analysis of the WS parameter in the Ali Al-Gharbi area to demonstrate the WS spectrum and concluded that WS at the Ali Al-Gharbi location has specified that it is a favorable site for utilizing wind power generation (Abbas et al. 2019). Resen (2015) studied the region and used the WAsP model to map and analyze wind and climate. To better understand the characteristics of the wind speed in this region, this study aims to conduct a comprehensive analysis of wind speed data in the southern region of Iraq, to evaluate the characteristics of the wind spectrum for the Al-Reem region in the Maysan district of southern Iraq for the period from December 2014 to December 2015. It would make a significant contribution to our knowledge of the characteristics of the wind speed in this region.

STUDY AREA

The topography of the research area is the primary determinant of the wind assessment study. The site is situated in the Maysan Governorate. Al-Reem region is located approximately 238 kilometers away from the Iraqi capital, Baghdad, with coordinates approximately 32.27° North 46.41° East, and at an altitude of 14 m. Fig. 1 depicts the location of the chosen Al-Reem site in the southern region of Iraq. This region experiences hot desert climates (Köppen climate classification BWh-hot desert climate), characterized by hot, dry, and cool summers, just above 40°C. Winters are wet, and rainfall is greater during the winter months, averaging 177 mm annually. The area was formerly covered by marshes, which supported a variety

Table 1: Features for the researched region (Abbas et al. 2019).

Height [meter]	Daily WS [m.s^{-1}]	Standard deviation	Median	Minimum [m.sec^{-1}]	Maximum [m.sec^{-1}]
10-m	3.771	03.141	3.271	0.351	17.03
30-m	5.41	03.49	4.93	0.382	19.69
50-m	06.14	03.79	5.51	0.331	20.61

Fig. 1: Location of the chosen site (www.google earth.com).

of livelihoods. At present, the terrain consists of about 25% land and more than 50% desert. The Tigris River passes through Maysan, providing moisture to the marshes. Table 1 provides a summary of wind characteristics in this region (Resen 2015, Maysan Governorate 2024).

MATERIALS AND METHODS

A meteorological tower in Al Reem provided wind speed data, which was examined at three different altitudes (10, 30, and 50 meters) over a year. The data was reorganized and analyzed using the Origin 9.0 software to find the peak of the power spectrum. The programs Original 9.0 and Sigma Plot were used to examine the data. The meteorological mast, set up and operated by the Ministry of Science and Technology in Iraq, provided the data.

The Weibull Distribution

It is a statistical technique that can be used to determine a location's wind energy potential and evaluate the wind energy available there. Many probability functions can be employed to determine the statistical distribution of wind speed (WS) and are suitable for wind computations. With an appropriate level of accuracy, the Weibull distribution is considered the most accurate among other procedures. One benefit of this approach is that it can be used to quickly ascertain the average wind energy density for a given site (Mohammed et al. 2020). Equation (1) can be used to calculate the probability density function for wind speed (Mishaal et al. 2020, Resen 2015):

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^{k}\right]$$

$$\text{with} \quad k > 0,\ v > 0,\ c > 1 \qquad \ldots(1)$$

The Weibull scale parameter is represented by (c), the dimensionless Weibull shape parameter is known as (k), the recorded wind speed probability is denoted by f (v), and the wind speed is (v). The wind potential in the research area is described by the Weibull shape parameter (k) and the Weibull scale parameter (c). In simple terms, the scale parameter (c) is employed for the site consideration to show how much wind is blowing there, while the shape parameter (k) represents the peak of the wind speed (WS) distribution. (Abbas et al. 2019)

The Wind Rose

In wind assessment studies, determining the prevailing wind speed direction is crucial because it clarifies how local topography affects the wind. Using a plot known as a wind rose, which is a 360-degree cycle divided into a, 8,16, or 32 sectors, we can plot wind frequencies over a period of time by the direction of the wind, with color sets showing ranges of the WS. This graphical tool is very useful and used in many wind studies because it may depict the wind's direction and speed at any altitude and any specific location. Table 1 illustrates how the wind speed is adjusted at heights of 10, 30, and 50 meters (Bashaer et al. 2019).

The Constructed Spectrum of Wind

Although the wind spectrum is thought to be complex, there is a form similarity when utilizing different wind speed data sets. The spectral analysis process discounts the wind energy distribution for every frequency by converting the time series of wind speed data into the wind spectrum. This is a transformation from the time domain to the frequency domain and is more accurately implemented using a mathematical tool known as the Fast-Fourier-Transform (FFT). The spectral analysis procedure is based on the theory that the wind parameter could be formulated as a constant, Gaussian random process (Abbas et al. 2019). Normally, the wind spectrum appears as a continuous curve that connects the discrete points produced by Fourier analysis (Mahmood et al. 2022).

RESULTS AND DISCUSSION

Data from the meteorological mast at the specific site, with instruments in place for at least a year for non-stop wind measurements on-site, is essential for any wind assessment to calculate and interpret wind speed. In 2015, data were collected at a height of 10 meters using a cup anemometer. The data must be sorted before any analysis can begin. To do this, a daily ten-minute dataset was normalized to average morning and night hours as well as three different height levels (10, 30, 50 m). Next, we started performing the spectrum analysis using FFT.

Wind Speed's Statistical Analysis

Data were averaged daily so that they could be processed. Then, each day was split into two sets, that is, the morning and night hours. Following that, we began the statistical analysis of the data sets, and the results are shown in Table 2 with the statistical parameters that were reached.

Table 2 shows that the highest WS was at 50 m because, at these heights, the effect of surface roughness is eliminated. The lowest daily WS was at 10 m height level for both morning and night hours. The estimated value of the average daily WS for the morning hours was 5.6 m.sec^{-1} at 50 m, while the average daily wind speed for the night hours was 6.1 m.s^{-1} at 50 m. The values of the night hours are higher than those in the morning.

Results of Weibull Distribution

The Weibull probability function has been used to estimate the frequency distributions of WS, and it is clear from the table summary and graphical result that the Weibull distribution closely matches the actual distribution data. For each height, the values of the shape parameter (k) of the Weibull function and the scale parameter (c) were determined and are shown in Table 3. According to Fig. 2, 3, and 4, the average wind speed in the Reem had the highest probability of repeating at (4.8) $m.s^{-1}$ at 30 m. At night, the lowest is 2.1 $m.s^{-1}$ at 10 pm.

Table 2: Wind speed's statistical measures.

Height [m]	WS [$m.s^{-1}$]	Maximum [$m.s^{-1}$]	Minimum [$m.s^{-1}$]	The range	The median	Standard deviation	The Skewness	Kurtosis	Confidence level (95%)
Day-hours									
10	4.26847	13.85986	0.0075	13.852	3.86	2.771	0.9985	0.583	0.284
30	5.17	16.0018	0.01	15.9	4.75	3.07	0.99	0.60	0.31
50	5.600	17.01194	0.014	16.99	5.148	3.235	0.984	0.582	0.332
Night-hours									
10	3.215	10.09528	0.42	9.668	2.761	1.968	1.17	1.071	0.202
30	5.181	12.425	0.444	11.98	4.895	2.318	0.632	0.247	0.238
50	6.1348	13.945	0.351	13.593	5.840	2.7	0.451	0.108	0.277

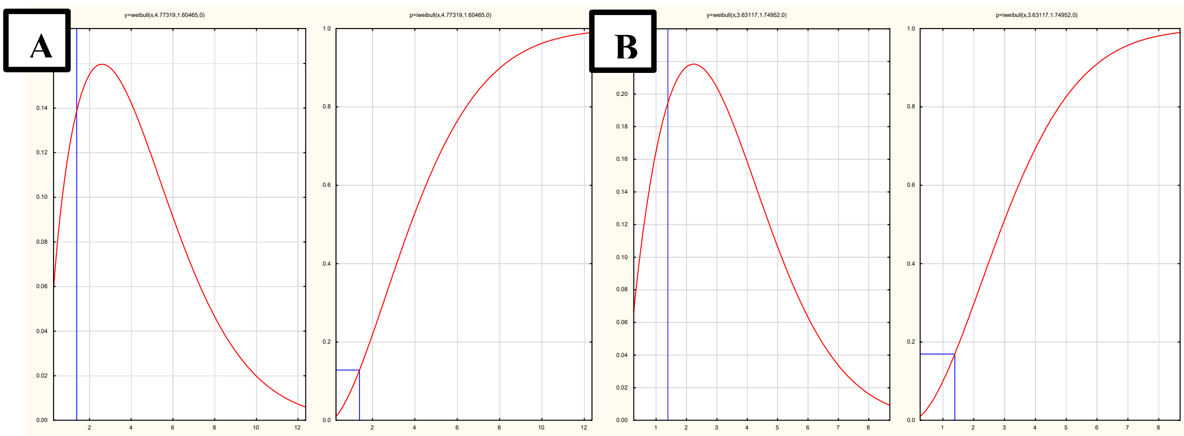

Fig. 2: The Weibull distribution for WS at 10 m throughout (A -morning time, B -night time).

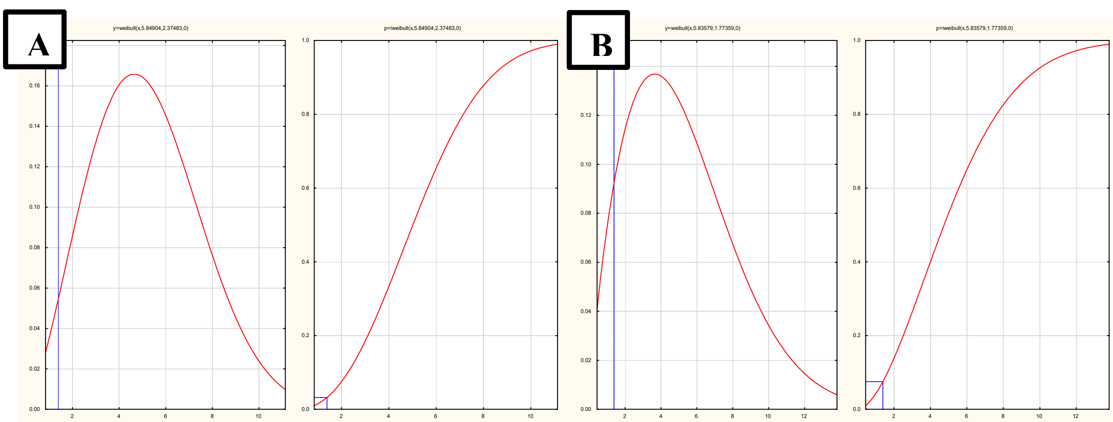

Fig. 3: The Weibull distribution for WS at 30 m throughout (A -morning time , B -night time).

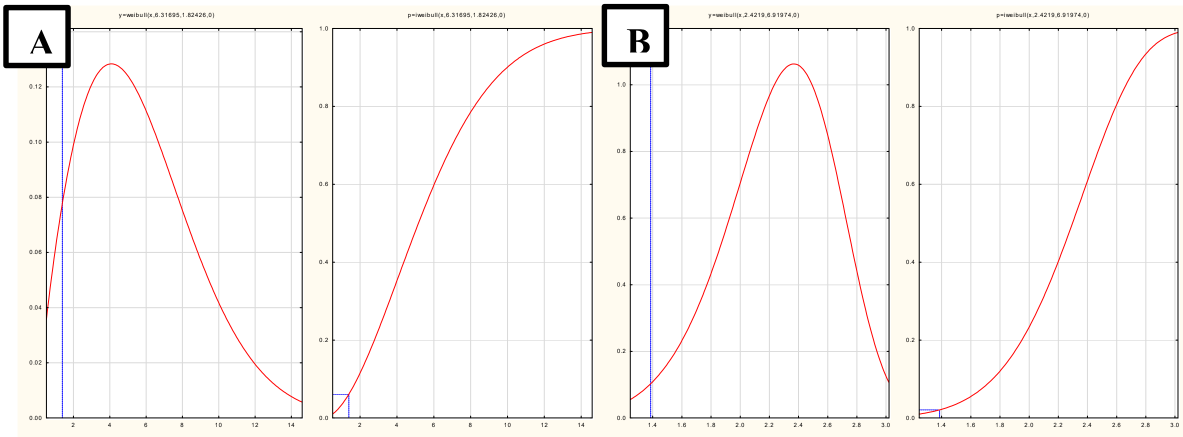

Fig. 4: The Weibull distribution for WS at 50 m throughout (A -morning time, B -night time).

Table 3: The Weibull both scale parameter and shape parameters.

The morning hours		
level (m)	The scale parameter	The shape parameter
10	4.81	1.60
30	5.93	1.82
50	6.41	1.82
The night hours		
10	3.62	1.74
30	5.92	2.37
50	7.0	2.42

The Wind Rose Analysis

Data for wind rose diagrams, which show the wind speed trend at the three chosen elevation levels as well as in the morning and at night, were collected at 10-minute intervals. Table 4 shows this as follows: For a height of 10 m, the maximum mean WS was in the 280°-300° sector with a value of 17.3 $m.s^{-1}$, and the lowest mean speed was in the 200°-220° sector with a value of 1.8 $m.s^{-1}$. Likewise, for the 30 m range, the lowest mean wind speed in the 200°–220° sector was 1.7 $m.s^{-1}$, and the maximum mean WS, measured was 17.3 $m.s^{-1}$, between 280° and 300°. The maximum mean WS recorded at 50 m was 25.3 m/s in the 300°-320° direction, and the minimum was 1.7 $m.s^{-1}$ in the 200°-220° direction. Winds at the site were mostly blowing from the northwest, specifically from the west, northwest, and northwest (NW-NW), but winds were also blowing from the southwest, west, and southwest (SW-SW).

Time Series Construction of Wind Speed Data

To show the general trend in wind speed, a daily time series was generated. Based on the results, it is found to be about (6.1 m/sec) represents the average WS at 50 m throughout the night, while the value (3.2 $m.sec^{-1}$) represents the average WS at 10 m throughout the night.

Wind Power Density Spectrum

The Fast Fourier Transform (FFT) was used to quickly and efficiently construct the wind spectrum of the time series of the measured data. Through a series of calculations, the wind speed spectrum for the Al Reem site was obtained at

Table 4: Wind speed and its direction for the selected area at three levels.

Direction sector [°]	Mean value of WS at 10 m	Mean value of WS at 30 m	Mean value of WS at 50 m
0 – 20.	3.44854	3.39466	3.06943
20 – 40.	2.67685	3.49858	2.47671
40 – 60.	2.97321	4.56277	2.57871
60 – 80.	3.6506	4.11631	3.20414
80 – 100.	3.74682	4.91302	4.89762
100 – 120.	6.04072	7.34932	7.99207
120 – 140.	6.99523	5.17859	5.86752
140 – 160.	4.71673	3.37926	3.70064
160 – 180.	3.22531	2.32276	2.44592
180 – 200.	2.32469	1.94173	1.93018
200 – 220.	1.89362	1.75314	1.71465
220 – 240.	1.8609	2.23424	1.81857
240 – 260.	2.15534	2.79617	2.20345
260 – 280.	3.22916	5.63082	3.70834
280 – 300.	8.42699	17.37357	12.44131
300 – 320.	24.68825	19.36725	25.3387
320 – 340.	13.02248	6.41598	10.38026
340 – 360.	4.81872	3.71219	4.15095
Calm WS value	0.1058	0.05966	0.08083

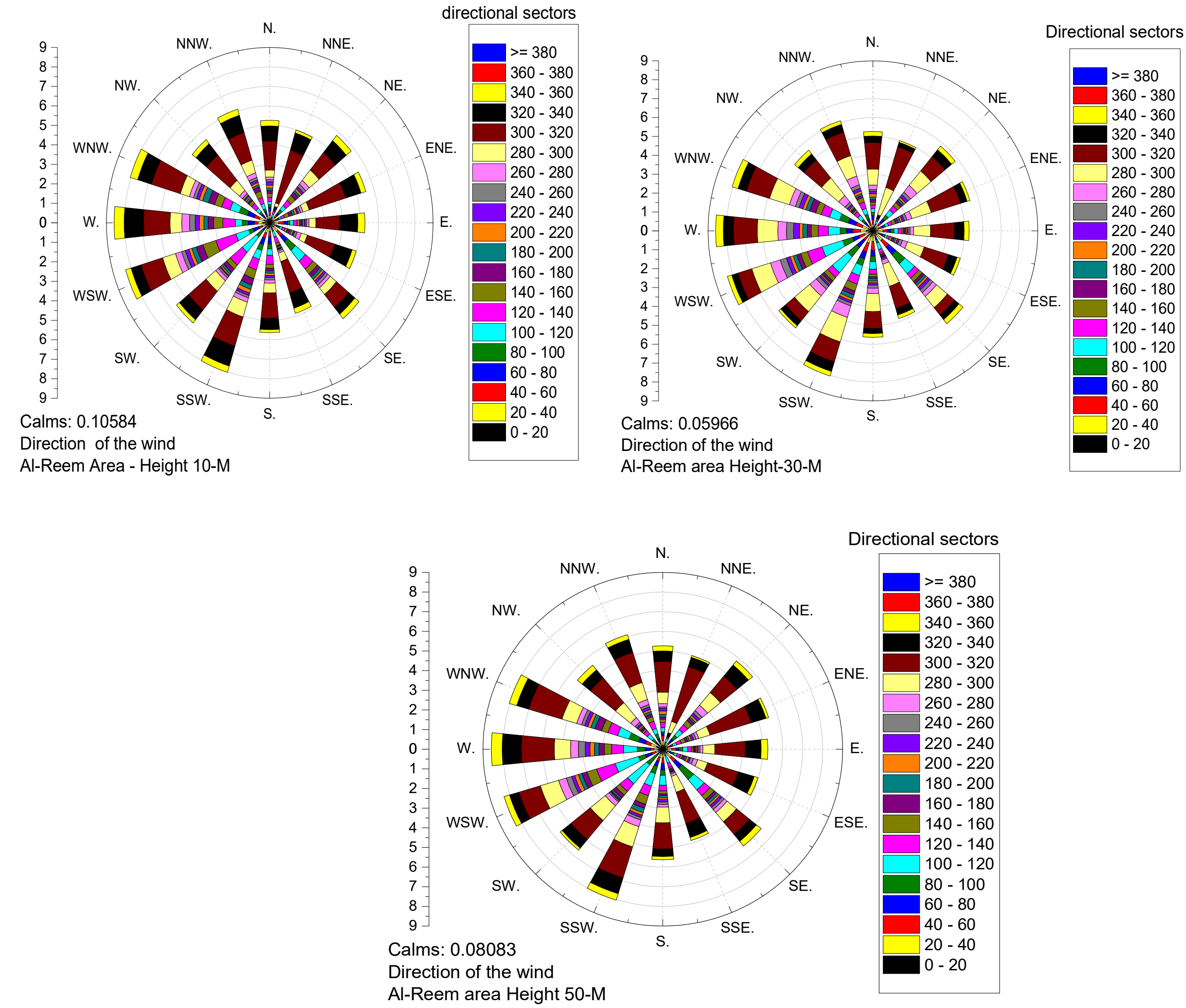

Fig. 5: The wind rose plots for the heights of (10, 30, and 50 m).

three different height levels (10, 30, and 50 m) during the day and night. The spectrum calculation process consists of several basic steps: finalizing the time series, obtaining daily mean WS data from the 10-minute data, and running the fast Fourier transform. Then, the data is filtered and smoothed. The highest spectral density was recorded in the Al-Reem region at 226,236.282 $m.s^{-1}$ at a frequency of 2 Hz at 50 m during the night, while the lowest spectral density was recorded at 115,863.7 $m.s^{-1}$ at a frequency of 2 Hz at 10 m. m rise during the same period. These results are clear from the peaks in Fig. 7.

CONCLUSIONS

To determine the shape of the WS spectrum at the Al-Reem region, wind measurements were analyzed at heights of 10, 30, and 50 m above the ground. The results can be summarized as follows:

1. Compared to night, morning hours yield higher wind speed data. During the morning hours of the research year, the average standard deviation and maximum wind speed at a height of 50 meters were calculated as 3.235 $m.s^{-1}$ and 5.60011 $m.s^{-1}$, respectively.
2. There is a strong correlation between the data obtained from actual observations and the Weibull distribution function at heights of (10, 30, 50 m).
3. The plots for the wind rose disclosed that the WNW and the NNW are the predominant wind directions.

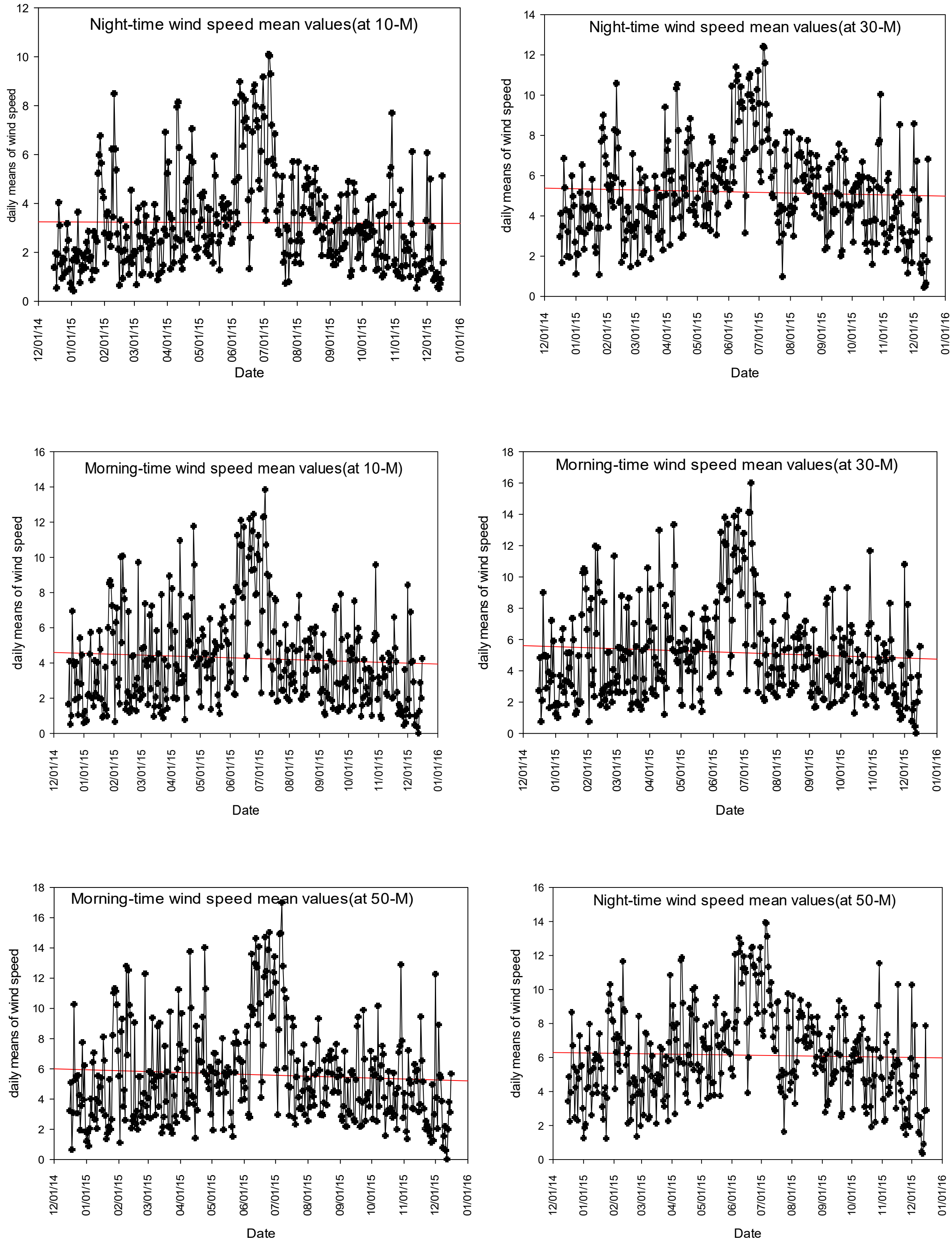

Fig. 6: The time series for both day and night at 10, 30 and 50 m.

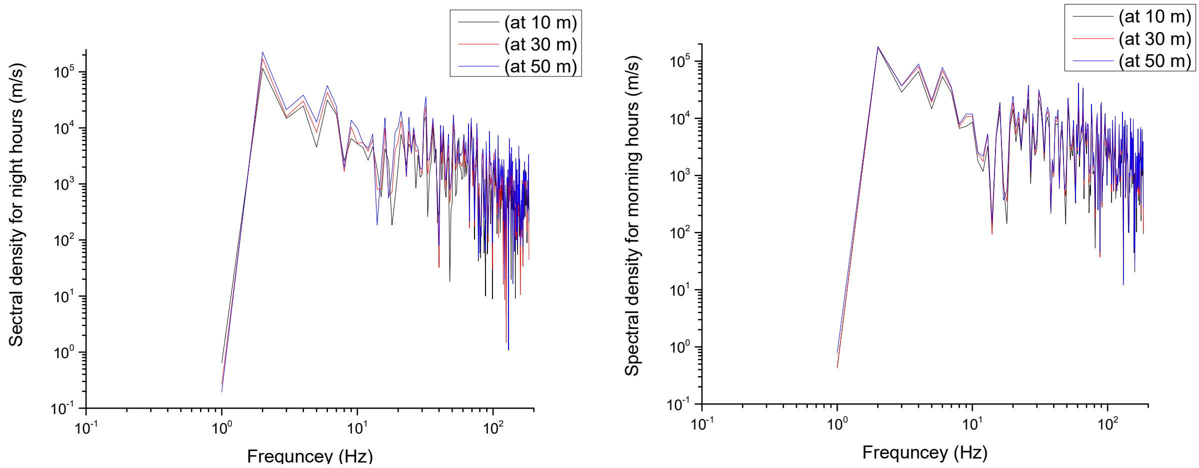

Fig. 7: The spectrum of wind speed at (10, 30, 50 m) during morning hours and night hours.

4. For the heights of 10, 30, and 50 m, the spectral peaks for Al-Reem during the day exhibit a better agreement than those during the night.
5. According to this analysis of the wind speed data at the Al-Reem region, there is a good chance that wind power presents a great way of generating clean power.

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