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# Evaluation of Wind Data Reliability by Using Logarithmic and Power Laws: A case study in Southern Iraq

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# Evaluation of Wind Data Reliability by Using Logarithmic and Power Laws: A case study in Southern Iraq

## Abstract

In this study, two sites were investigated in the southern region of Iraq: Ali AL-Gharbi and AL-Salman in Mesan and AL-Muthana provinces, respectively. A theoretical extrapolation between wind speed and height was carried out for both locations each month using the Logarithmic Law. Power Law was also applied to achieve calculations of wind shear coefficient (α) by using the actual data collected from the meteorological mast installed in each site at three levels of 10 m, 30 m, and 50 m, at an interval of ten minutes. To compare the effects of each law, two laws are employed.

## Keywords

Logarithmic law, Power-law, Wind data, Wind shear coefficient, Met mast

## 1. Introduction

Usually, fossil fuel is used to generate electricity; the world can replace this fuel with renewable energy. Wind energy can reduce the demand for fossil fuel when it is used successfully [1]. Wind energy is sustainable and available naturally, while fossil fuel can be depleted someday.

There is much research on wind energy calculations in Iraq and the world [2]. Some of them have used extrapolation laws to calculate wind speeds at specific altitudes, such as the turbine hub heights and within different models [3–5]. On a log-based WA$^{S}$P model to calculate wind speeds at different altitudes [6], whereas in others, the law of power was used for wind calculations [7]. Real data has been used from the erected met masts for wind energy purposes and for different cities of Iraq. Determining the wind speed precisely is an important factor in wind energy calculations since the wind power density is proportional to the wind speed cube [8,9]. In this research, two legal survey sites have been studied in southern Iraq to know the accuracy of the real data recorded when compared to theoretical calculations. The prediction of the wind speed at different heights is very necessary to know the available speed at a specific site, as well as achieving site assessment for this site to determine the values of wind speed and direction. Wind speed can be affected by the height above the ground level. Generally, wind speed increases as the height above the ground increases [10] because there is no friction at higher altitudes. Friction with ground and obstacles causes turbulence in the wind flow, which slows down the wind speed [11], while the laminar flow of the wind is very important to get the highest records of wind speed.

## 2. Methodology

More than one formula can be applied to calculate wind speed at any height; they are suitable from 10 m to about 100 m in altitude. One of these formulas is called "Logarithmic Law," which is used to estimate the wind speed ($V_z$) at any corresponding height (z) as in equation (1) [12,13]:

$$V_z = V_{10}\left[\ln\left(\frac{z}{z_0}\right) \Big/ \ln\left(\frac{z_{10}}{z_0}\right)\right] \quad (1)$$

where $V_{10}$ is the wind speed at height $z_{10}$, which is 10 m, $z_o$ is the surface roughness length that can be chosen according to the landscape [14]. Another formula that has been found to relate height and wind speed is called "Power Law," as in equation (2) [15,16]:

$$V_2 = V_1\left(\frac{Z_2}{Z_1}\right)^{\alpha} \quad (2)$$

where $V_1$ is the wind speed at the height $Z_1$, $V_2$ is the wind speed at the height $Z_2$, $\alpha$ is the wind shear coefficient or friction coefficient, which is used to estimate the wind speed at higher elevations, generally, ($\alpha$) increases with roughness length $z_o$ [17]. Generally, a power law is applied to relate wind speeds at different heights to a reference wind speed at a reference height close to the ground [18]. Practically, the Sonic Detection and Ranging (SODAR) can be used to estimate the values of wind speed at various elevations, but its measurement accuracy cannot match that of cup anemometers because it depends on the clarity of the air and its instantaneous density. It is possible to the existence of dust or water vapor in the air, which is causing attenuation in signals as well as the electronics problems. This problem may be solved by using a high acoustical power as possible [19–21]. It is a fact that atmospheric stability and ground topography play an important role in shaping wind-speed profiles against altitudes [22,23]. Many researchers have been studying the wind speed characteristics and use the available data to compare wind speed data, site terrains, and comparison between the Logarithmic and Power Laws and their improvement [24–26].

After calculating the wind speed at hub height, it is possible to install suitable wind turbines or wind farm there, the data which used to achieve the assessment must be at least for one year. To achieve a good wind energy assessment, long-term measurements are needed [27]. The longer the period of collected data, the more reliable are the estimated wind potentials [28]. When the actual data (which is logged in a met mast at any site) is applied in the Logarithm Law, it must give a similar behavior of the data, which is calculated theoretically to be sure that this data is right. Generally, the relation of wind speed versus elevation is almost direct proportional [29].

Installing a meteorological mast (met mast) is very necessary to get the actual data at different heights, which can be lattice or tubular types. It is possible to use these two types of masts in a study to obtain data to use it in different calculations [30]. The logged data in the mast must be recorded every 10 min to ensure the accuracy of the calculations [31]. Depending on the

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necessity of the study, the measurement equipment was mounted at different levels upon the met mast according to a global standard [32], including NRG 40C anemometers and NRG 200P dog vanes type. Anemometers are mounted at the levels of 10 m, 30 m, and 50 m on a lattice meteorological mast of 50 m height. The data have been recorded using (Stylitis - 101 data logger).

The comparison between estimated data and actual data will prove the reliability of actual data. Usually, actual data gives the real behavior of the wind in any studied site, and its reliability leads to more accuracy of site assessment. The reliable data of wind speed and direction, as well as some other requirements, must exist to have a perfect choice to install a wind farm on a specific site [26]. The monthly average wind speed can be determined by Eq. (3) [33]:

$$\overline{V}=\frac{1}{n}\sum_{i=1}^{n}V_i \tag{3}$$

where n is the number of recorded wind data, $V_i$ is the wind speed. Logarithmic Law has been applied for the wind speeds at 10 m height for twelve months along the year (2016). The actual wind speed (average) for the levels 10 m, 30 m, and 50 m have been drawn as a function of height. Each figure has two curves, calculated and actual data, to compare their behavior. The monthly average of actual wind speed of the levels 10 m and 50 m are applied in the Power Law to calculate the wind shear coefficient ($\alpha$) for both sites.

### *2.1. Region of study*

Two locations have been selected in this study; the first one is the site of AL-Reem Natural Reserve in Ali AL-Gharbi town, which is about 300 km southeast of Baghdad, with coordinates of E: 4648.470 N: 32 34.981. The second location is the Al-Salman site, which is about 500 km south of Baghdad, with coordinates of E: 44 34.382 N: 30 34.248. In both locations, there is a met mast installed to record wind speed data. Fig. 1 shows the location of each studied site. The vertical raw refers to the Ali Al-Gharbi site, while the horizontal one refers to the Al-Salman site.


Fig. 1. The locations of the studied sites.

## 3. Results and discussions

### *3.1. Wind speed versus height*

Fig. 2 shows the relation between height and wind speed at altitudes 10 m, 30 m, and 50 m for the first six months of 2016 in the Ali AL-Gharbi site. While Fig. 3 shows the same relation for the second six months of 2016. Also, Fig. 4 represents the same relation at the AL-Salman site for the first six months of the same year, while Fig. 5 shows the same relation for the second six months of 2016 for the AL-Salman site.

It is important to note that the value of wind speed at 10 m is the same in each of the theoretical calculations and the actual data, while there is some difference between them in both 30 m and 50 m in height.

Each of the figures above includes the theoretical calculation of wind speed values (red curve) obtained by applying the Logarithmic Law, by using the average wind speed at 10 m as a reference and $z_o$ equal to (0.03 m). These figures include the actual values of average wind speed (black curve), too.

Both curves have almost the same trend, but the actual data have higher values than theoretical calculations. It is very easy to observe these results in the previous figures. When it just the minimum and maximum values of wind speed in both sites observed.

For the maximum wind speed in the Ali Al-Gharbi site at 50 m, the actual value is 7.37 m/s in July, while the calculated value is 6.3 m/s in July, too. For the same site and the same altitude, the minimum actual value of wind speed is 4.44 m/s, while the calculated value is 3.18 m/s in November for both.

For the minimum wind speed in the Ali Al-Gharbi site at 30 m, the actual value is 6.65 m/s, while the calculated value is 5.87 m/s in November for both. For the same site and the same altitude, the minimum actual value of wind speed is 3.84 m/s while the calculated value is 2.96 m/s in November for both.

In the Al-Salman site, at 50 m, the actual wind speed is 6.68 m/s, while the calculated wind speed is 6.16 in May for both. In the same site and altitude, the minimum actual wind speed is 4.77 m/s in August, while the calculated wind speed value is 3.86 m/s in August, too.

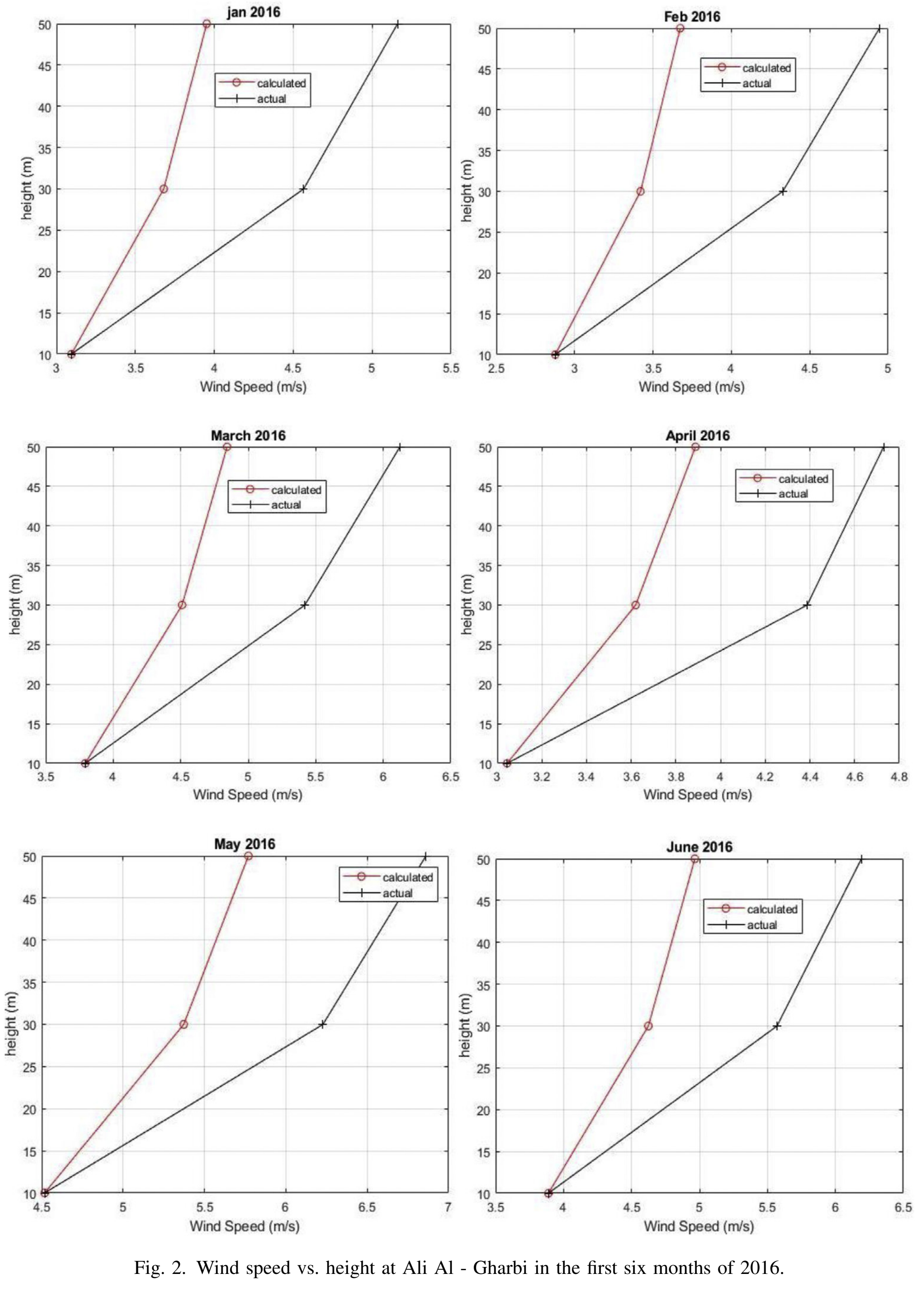


Fig. 2. Wind speed vs. height at Ali Al - Gharbi in the first six months of 2016.

In the Al-Salman site, at 30 m, the actual wind speed is 6.06 m/s, while the calculated wind speed is 5.73 in May for both. In the same site and altitude, the minimum actual wind speed is 4.22 m/s in August, while the calculated wind speed value is 3.59 m/s in August, too.

The difference occurred between the two sets because the actual wind speed data give the real and natural values that suffering some friction with the ground surface as well as the effects of air density, humidity, and atmospheric pressure. Both of the studied sites are located far away from the urban zones.

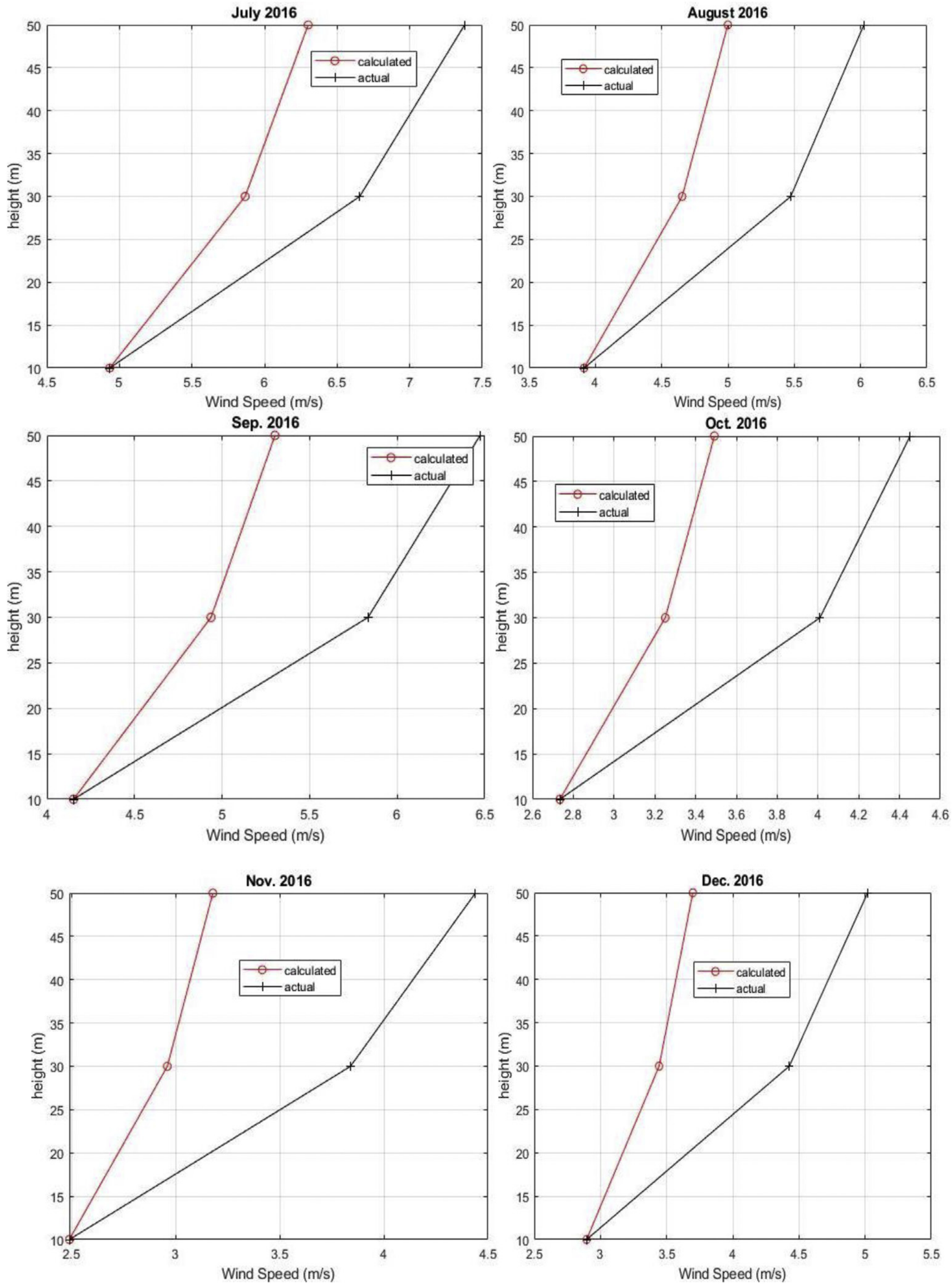


Fig. 3. Wind speed vs. height at Ali Al - Gharbi in the second six months of 2016.

Therefore, no significant pollution appears, like smoke or other harmful gas emissions, which can affect the obtained results.

On the other hand, Logarithmic Law is an empirical formula with a probability of error utilized to indicate the values of wind speed mathematically by using the extrapolation method.

### 3.2. Monthly distribution of wind speed

Figs. 6−11 show the monthly averages wind speed for the Ali AL-Gharbi and AL-Salman sites at 10 m, 30 m, and 50 m. Although they demonstrate almost the same behavior in the three various studied levels of 10 m, 30 m, and 50 m, the values found different. This

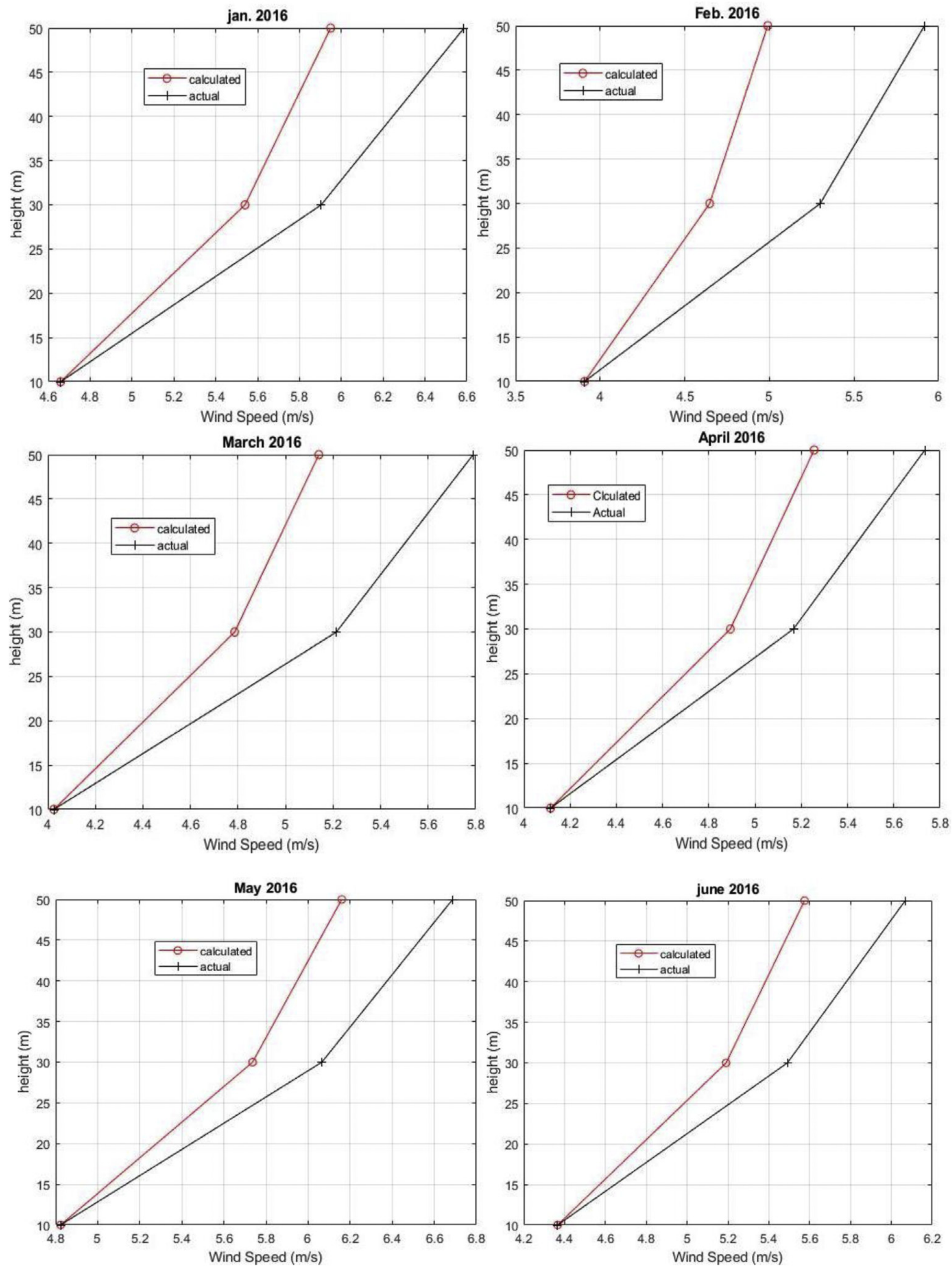


Fig. 4. Wind speed vs. height at Al - Salman in the first six months of 2016.

can depend on the ambient temperature of each month because increasing the temperature causes increasing in wind speed. The ripples in these figures may be found because of the dust rising. Sunlight can be screened because of dust rising, causing decreasing in the temperature, which leads to a decrease in the wind speed in some months. Again, the actual data of wind speed demonstrates higher values than the calculated values as mentioned previously.

### 3.3. *Calculating alpha (α)*

The average wind speed at 10 m and 50 m of equation (2) has been determined at both sites for each

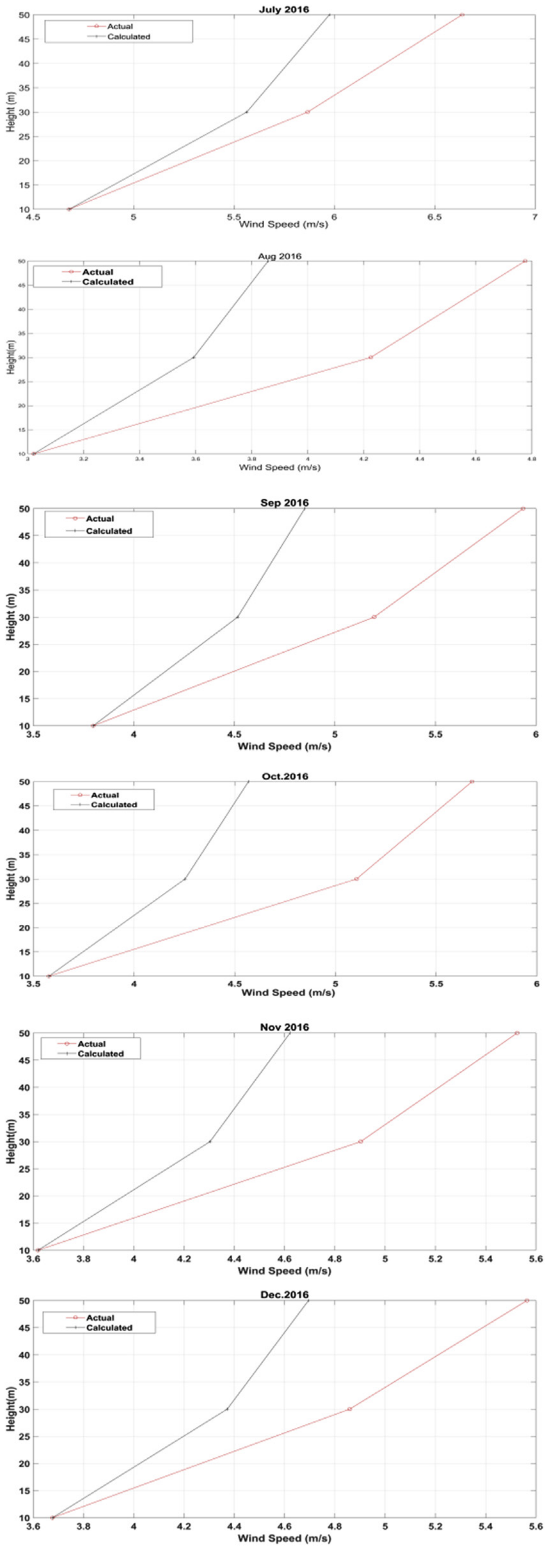


Fig. 5. Wind speed vs. height at Al - Salman in the second six months of 2016.

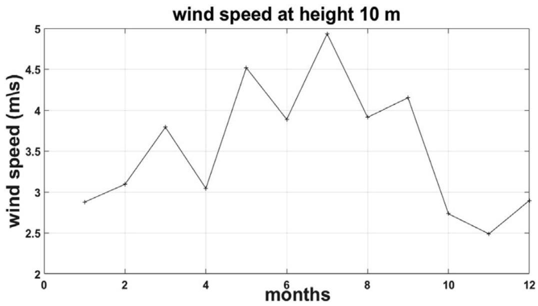


Fig. 6. Average monthly wind speed at 10 m for the Ali AL-Gharbi site.

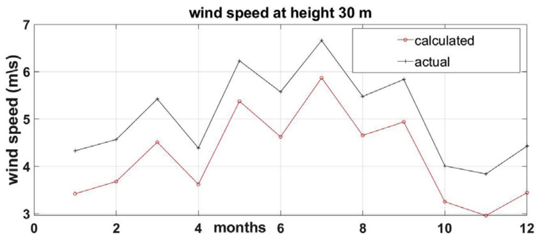


Fig. 7. Average monthly wind speed at 30 m for the Ali AL-Gharbi site.

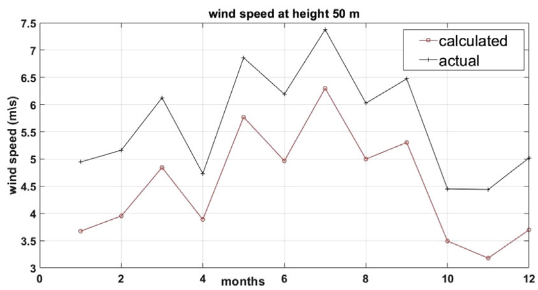


Fig. 8. Average monthly wind speed at 50 m for the Ali AL-Gharbi site.

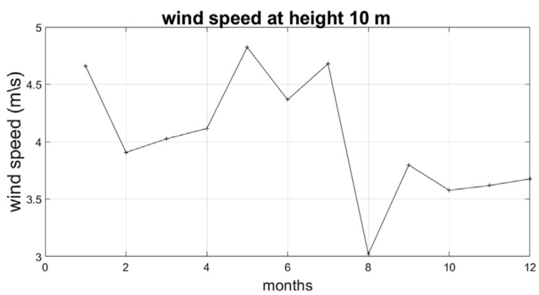


Fig. 9. Average monthly wind speed at 10 m for the AL-Salman site.

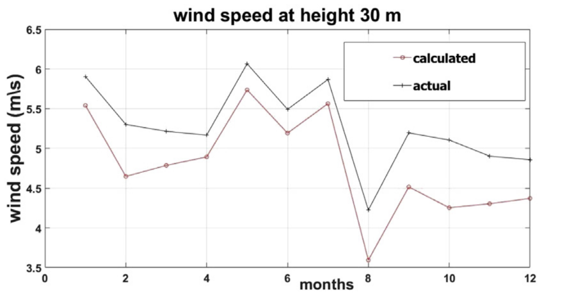


Fig. 10. Average monthly wind speed at 30 m for the AL-Salman site.

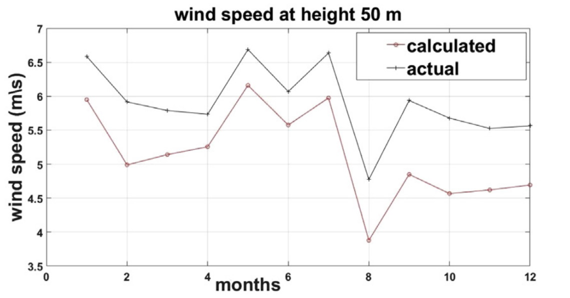


Fig. 11. Average monthly wind speed at 50 m for the AL-Salman site.

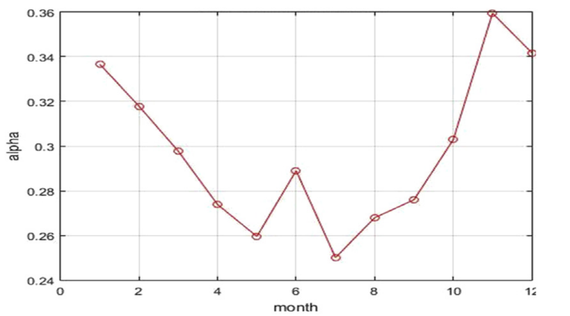


Fig. 12. Monthly values of (α) in the Ali AL-Gharbi site.

month. The monthly values of wind shear coefficient (α) in each site are illustrated in Figs. 12 and 13 for Ali AL-Gharbi and AL-Salman, respectively. The annual average value of (α) in Ali AL-Gharbi is (0.29) while its annual average value in the AL-Salman site is (0.24). The greater values of wind speed in summer mean that a slight effect on terrains. Therefore, (α) decreases to the minimum values during this season, as shown in Figs. 12 and 13. The peak, which is formed in June, in Fig. 12 may be configured due to dust rising. Dust rising acts to screen sunlight. Therefore, the wind speed is decreased due to the reduction of temperature.

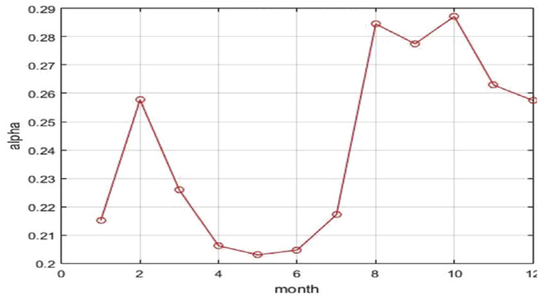


Fig. 13. Monthly values of (α) in the AL-Salman site.

## 4. Conclusion

The relation between theoretical calculations and actual data shows that the actual data demonstrate the same behavior as theoretical calculations. The exactness of the actual details, which means the credit of this data, can be considered. The real data values are higher than those of theoretical calculations; this comes from the empirical formulation of the Logarithmic Law. Actual data gives the real behavior of the wind in any studied site, and its reliability leads to more accuracy of site assessment. The reliable data of wind speed and direction, as well as some other requirements, must exist to have a perfect choice to install a wind farm on a specific site.

Wind speed depends on the air temperature or depends on the season, in other words. In Ali AL-Gharbi, the wind has a peak value in July, while in the AL-Salman, at the altitudes observed, the greatest value is in May. In both sites analyzed, alpha (α) is measured monthly. Ali's AL-Gharbi value is (0.29) and in AL-Salman is (0.24). In the future, it is possible to take the improvement of the Logarithmic Law and power-law into account to obtain results that more close to actual data.

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