Analysis and estimation of wind energy data for some regions in Libya

[1]Husein Ahmed Ali Issah
[2]Yassen Abdallh
[3]Ali Shommaki
[4] Tariq R. Aboalhol
[a]hussienbnissa@gmail.com
[b]yaseen.76.2015@gmail.com
[c]shommakiali@gmail.com
[d]tr2003a@gmail

[1,2]The High institute of Petroleum Tech and Professions | Tripoli
[3,4]The Libyan Higher Technical Centre for Training & Production

Abstract

This project will study the wind energy and wind assessment in some selected sites such as Asabah, Tarhunah, Alheira, Ghutalriah, and Msalath, this project will first provide background information about wind power and its resource, including a review of available data, which are obtained from the Renewable energies. For each location, long term time series of 10-minutes measured wind data will be used; the wind data has been recalculated to represent the actual wind speed at hub height. The mean wind speed, the Weibull distribution, power density function, annual energy and annual capacity factor will be calculated for each site.

Tarhunah has the maximum annual energy and capacity factor while Ghut-alriah has the minimum annual energy and capacity factor. Existing data resources indicates that the mean annual wind speed of over 7.67 m/s in Tarhunah with theoretical capacity factor exceeding 44.13522 %. These values indicate that Tarhunah could generate an annual energy 1275861 kWh. Knowing that Excel and SPSS were used in the calculations and drawing conclusions.

Keywords: wind assessment; annual energy; wind power; wind energy; Weibull distribution.

الملخص

يدرس هذا المشروع تقييم طاقة الرياح في بعض المواقع المختارة مثل الاصابعة وترهونة والهيرة وغوط الريح ومسلاتة، وسيوفر هذا المشروع أولاً معلومات أساسية حول طاقة الرياح ومواردها، بما في ذلك مراجعة البيانات المتاحة، والتي تم الحصول عليها من مركز الطاقات المتجددة لكل موقع، وسيتم استخدام فترات زمنية طويلة من بيانات الرياح المقاسة لمدة 10 دقائق، وتم إعادة حساب بيانات الرياح لتمثيل سرعة الرياح الفعلية عند ارتفاع المحور وكذلك تم حساب متوسط سرعة الرياح وتوزيع وايبول ودالة كثافة الطاقة والطاقة السنوية وعامل السعة السنوية لكل موقع.

من النتائج تبين ان ترهونة لديها الحد الأقصى لعامل الطاقة والسعة السنوي بينما غوط الريح لديها الحد الأدنى لعامل الطاقة والسعة السنوي، مع العلم انه تم استخدام برنامج الاكسل SPSS في الحسابات واستخلاص النتائج.

تشير مصادر البيانات الحالية إلى أن متوسط سرعة الرياح السنوية أكثر من 7.67 م / ث (في ترهونة مع عامل قدرة نظري يتجاوز 44.13522٪. تشير هذه القيم إلى أن ترهونة يمكن أن تولد طاقة سنوية 1275861 كيلوواط ساعة.

Introduction

Solar energy is the indirect source of wind energy, where about 1-2% of the sunlight reaching the earth is converted into wind energy. From the earth to the upper layers of the atmosphere, a difference in pressure occurs, and thus the air atoms move from places of high pressure to places of low pressure [1].

The wind speed increases with the height above the ground due to the frictional drag of the ground vegetation and buildings. It is clear that any plans to harness the wind must take into account these variables. This paper outlines physical phenomena that are related to the characteristics of the wind for the selected areas (**Asabah, Tarhunah, Alheira, Ghutalriah, and Msalath**). Since conducting a series of wind energy assessment studies leads to an assessment of the economics of wind energy and therefore the cost of developing wind energy depends sensitively on the nature of the wind resource.

A wind energy assessment is an integrated analysis of the potential wind energy resources of a particular area. Such an assessment begins with an understanding of the general wind patterns of the area, and progresses to the collection and analysis of wind data. Wind assessment may also involve a monitoring program and, at the most advanced stages, computer simulations of wind flow to determine wind turbine micro-sitting. In this research, the Weibull distribution method was used for wind calculations using Excel to extract results and graphics [2].

Wind Assessment

To conduct a wind energy assessment for the selected sites, wind data is first collected, such as wind speed and direction, and wind data is recorded with special devices at wind monitoring stations for a period of no less than a whole year to reach real results [1]. The data is in reliable and reliable records. In this research, wind data was obtained from the local meteorological station for each region [3].

Study Areas

In this study the location of five chosen stations in Libya are selected **Tarhunah**, **Msalath**, **Asabah**, **Alheira**, and **Ghutalriah**. The locations of these sites are shown in Fig (1).

http://www.doi.org/10.62341/hayt2728

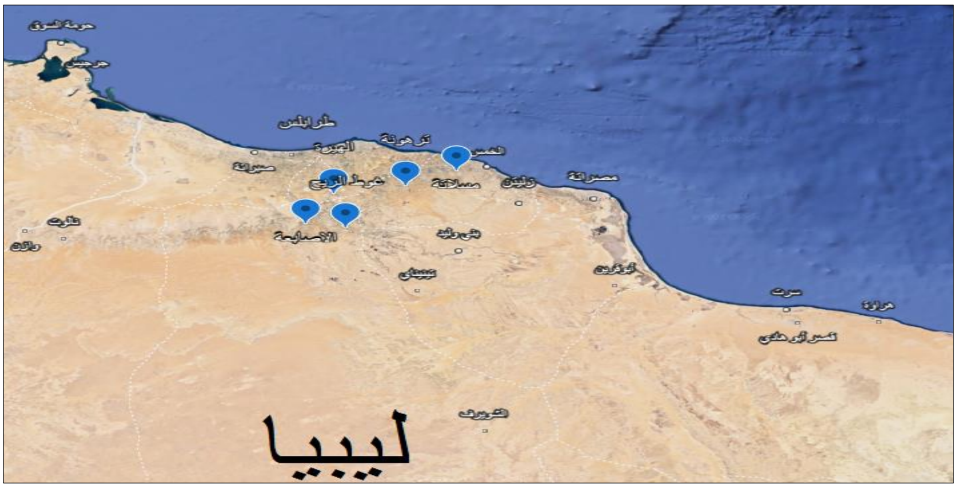

Fig (1) Distribution of meteorological stations over Libya [4]

Analysis of Wind Data

In this project, wind speed data at a time every hour as a series for all measuring stations were 3nalysed statistically. Usually the data is arranged in the form of wind speed time series in the form of distribution of frequencies because they are more suitable for statistical analysis. Has been translated the available time-series data in the form of distribution of frequencies. Data recorded wind speed at an altitude of 40 m, continuously by the data logger EKO 21B in all stations. The average wind speed data recorded continuously over periods of 10 minutes and gives a top speed of smaller speed during a 10-minute average was discernible in this project. Wind speed can be calculated for these period from the following equation [5] [6] [7] [8] [9] [10] [11]:

$$U_m = \frac{1}{M}\sum_{j=1}^{M} U_j \qquad (1)$$

Where:
U_m: mean wind speed.

U_j: wind speed.

The diurnal variation of wind speed for all the stations are shown in Fig (2) It's clear form this figure that the wind speeds is near constant during the night until about 08.00 pm then increases strongly reaching the maximum value at 1.00 in the morning. This figure also insdicates that the wind speed decrease slightly in the midday.

http://www.doi.org/10.62341/hayt2728

Daily wind intensity variations, which are directly to daily temperature variations, are low in the midday, reaching a maximum value in the mornings and start to increase in the afternoon. Also, that the hourly wind speeds vary (5.38 m/s) at Ghutalriah and (7.84 m/s) at Asabah with a maximum occurrence in the afternoon.

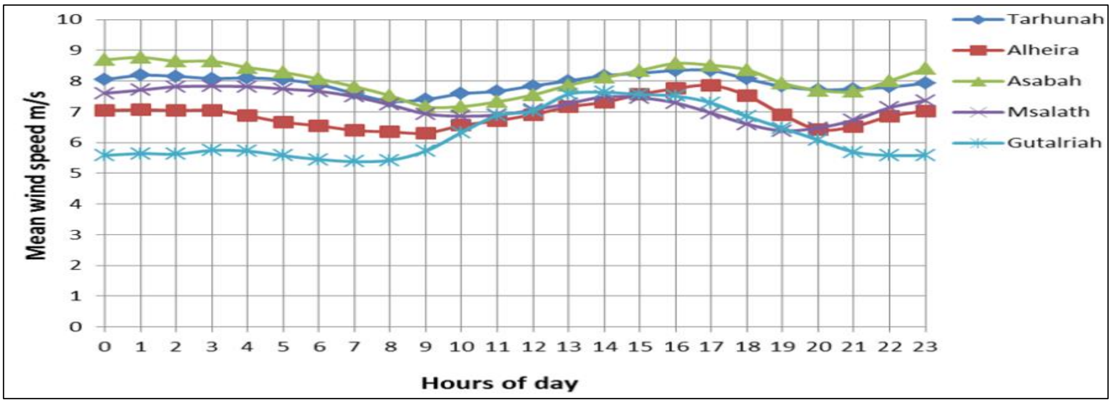

Fig (2) Diurnal variation of wind speed for all stations

Fig (3) illustrates the monthly mean wind speed for all stations. Where the wind speed for whole years has lowest value in August and September and the maximum value in April and May. Also the wind speed has maximum value of (11.53 m/s) at Asabah and the minimum value of (4.45 m/s) at Ghutalriah.

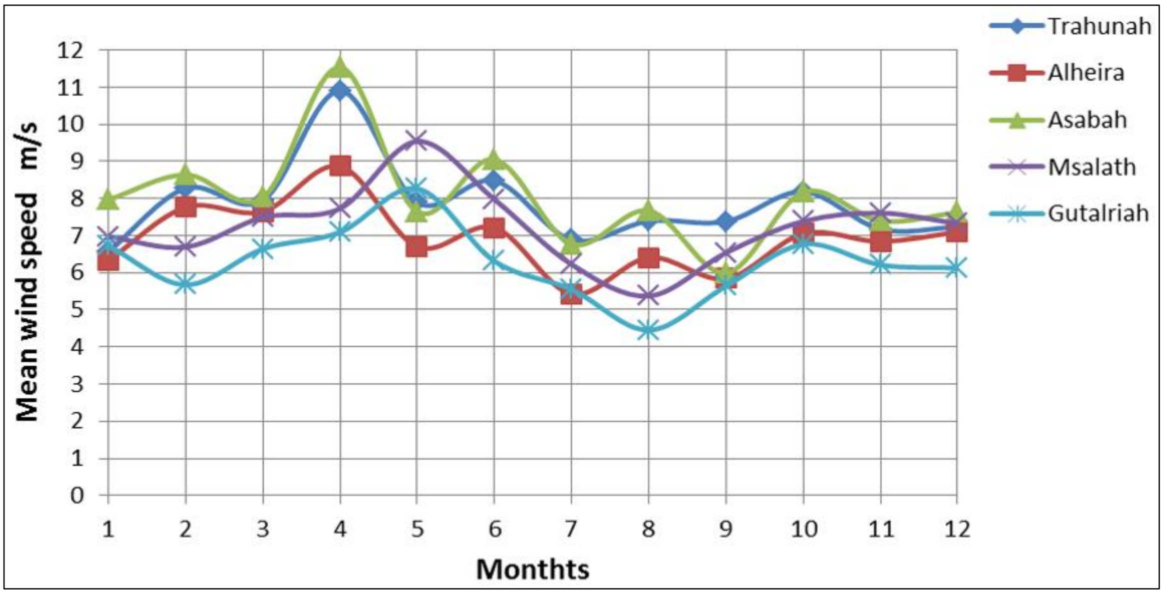

Fig (3) Monthly mean whind speed for all station

During winter season, figure (4) illustrates the wind speed level at three stations Tarhunah, Alheira and Asabah reaching high value of (8.27 m/s) – (8.64 m/s) at a height of 40 meters above the ground level, where the maximum mean wind speed occurs at Asabah during February with (8.64 m/s).

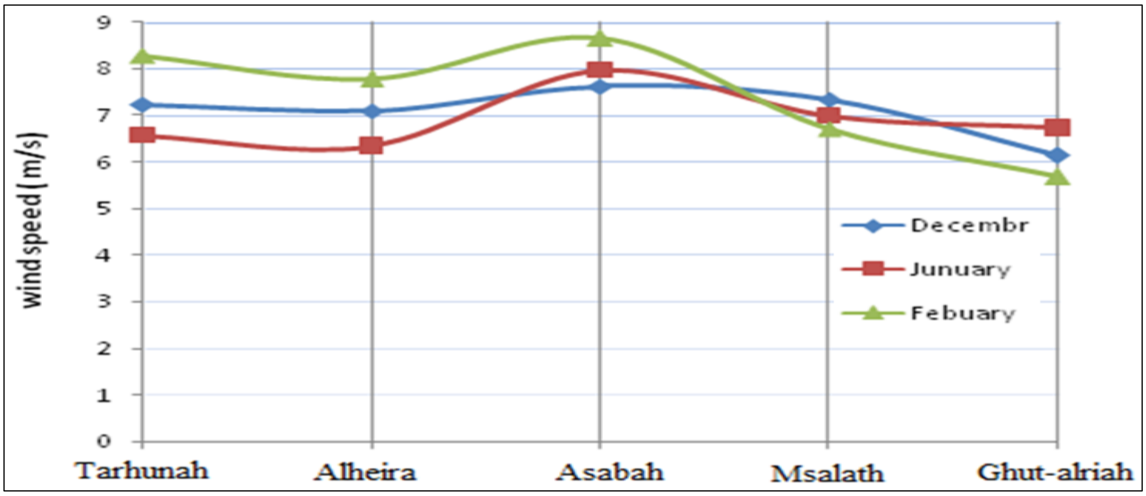

Fig (4) Winter vairation of whind speed for all station

Fig (5) shows the variation of the wind speed of spring for the different stations. It is clear that the maximum wind speed was recorded at Asabah station which is (11.535 m/s) during April while the lowest value was recorded at Alheira station with (6.86 m/s) during May.

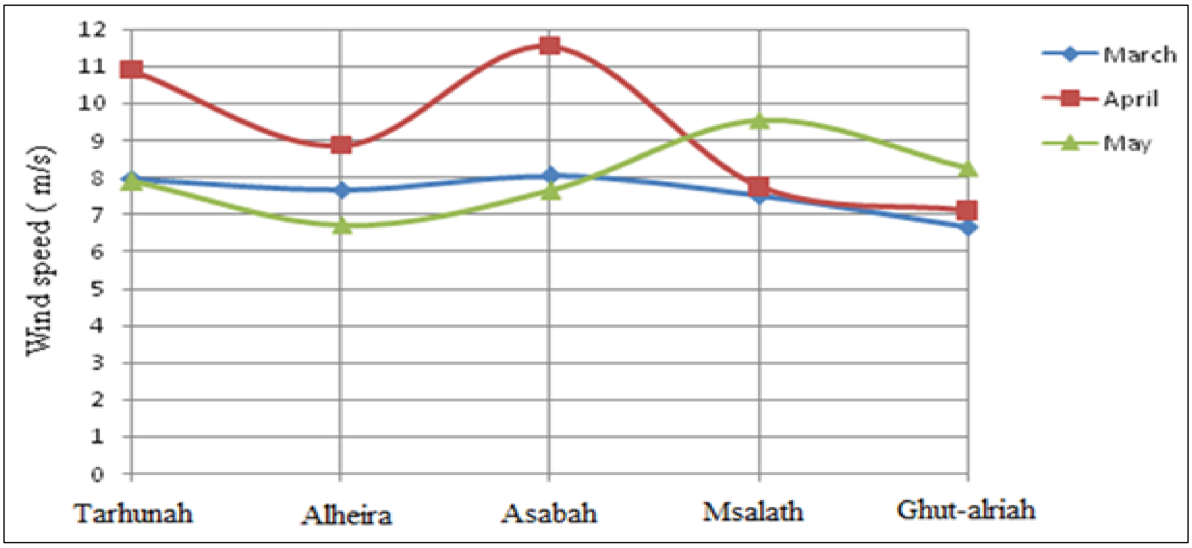

Fig (5) Spring vairation of whind speed for all station

http://www.doi.org/10.62341/hayt2728

In the summer season Fig (6) demonstrates that the wind speed level reaches (9.055 m/s) at Asabah during Jun.

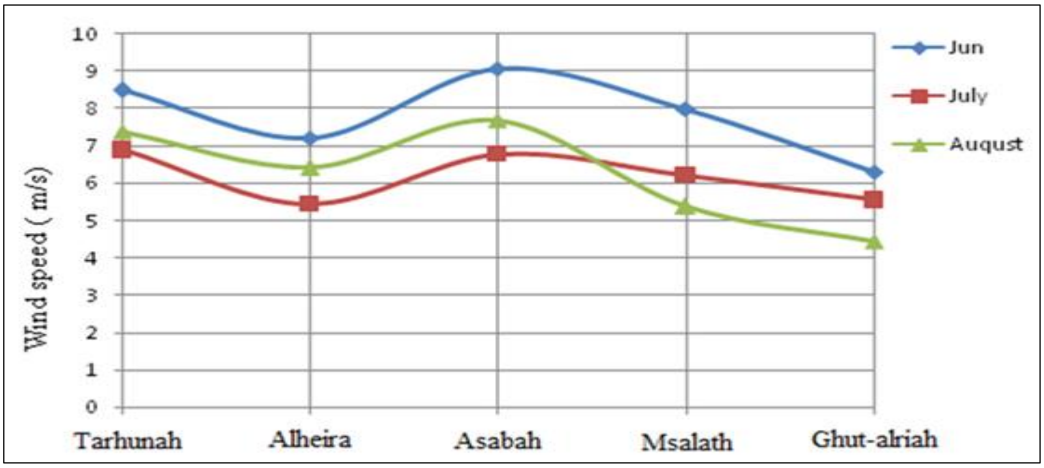

Fig (6) Summer vairation of whind speed for all station

While in autumn season as shown in Fig (7), the maximum mean wind speed is recorded as (8.17 m/s) in Asabah in October.

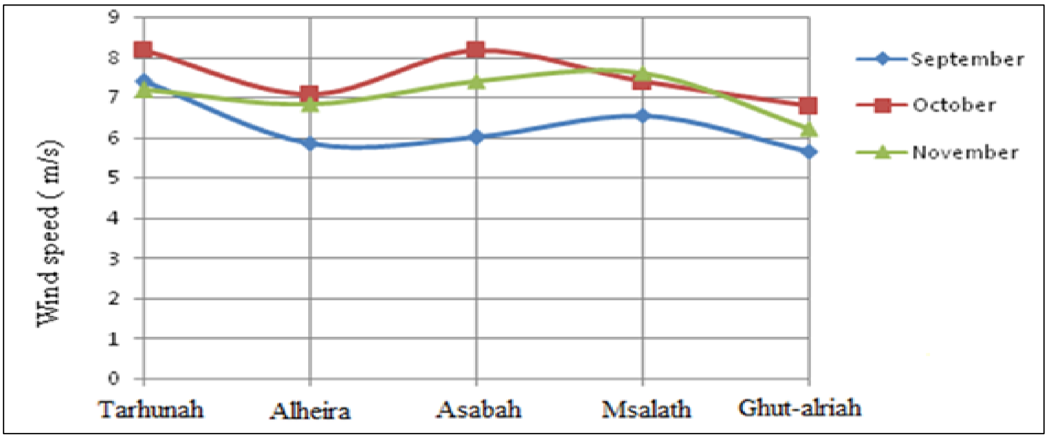

Fig (7) Autum vairation of whind speed for all station

Weibull distribution

Wind speed distribution can typically be described in terms of the Weibull distribution. The Weibull probability density function requires knowledge of two parameters a shape parameter k or factor and a scale parameter C. Both of these parameters are function of average mean wind speed U and standard deviation.

The probability density function of Weibull distribution is given by:

http://www.doi.org/10.62341/hayt2728

$$P(U) = \frac{k}{C}\left(\frac{U}{C}\right)^{k-1} exp^{-(U/C)^k} \quad (2)$$

The corresponding cumulative probability function of Weibull distribution is given as:

$$P(U) = 1 - exp^{-(U/C)^k} \quad (3)$$

Where P(U)is the probability of observing wind speed U, k is the dimension less Weibull shape parameter and c is the Weibull scale parameter, which has reference value in the unite of wind speed. To estimate the Weibull parameters k and *C*. Will be calculated k and C in tow method, the common method for determining *k* and *C* is graphical method.

1. **Graphical Method**

We took the city of Tarhuna as an example and the calculations were done on all the selected sites, as shown Fig (8).

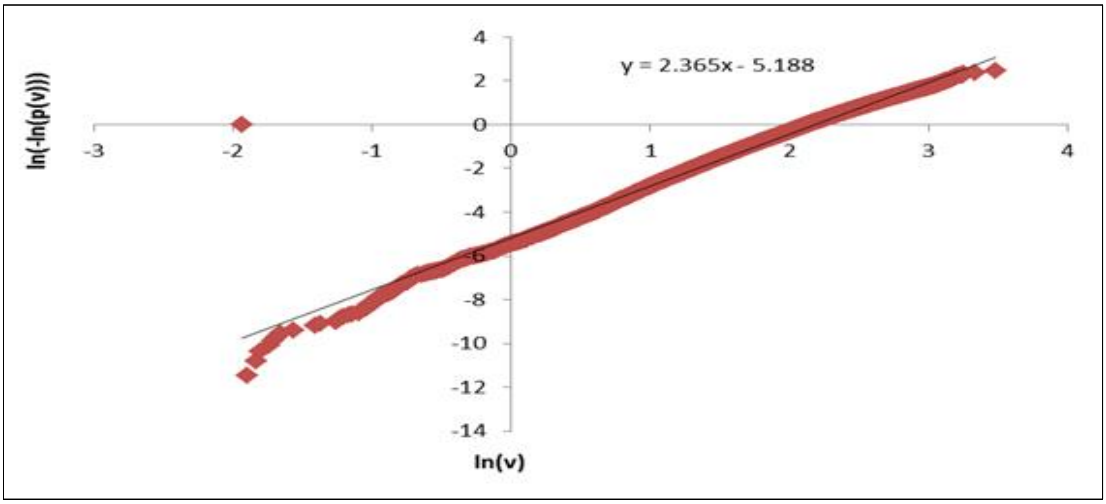

Fig (8) Graphical determination of Weibull parameters for Tarhunah city

2. **Method two**

In this method k and C are calculated based on the mean wind speed and standard deviation as the following:

$$k = \left(\frac{\sigma_u}{\overline{U}}\right)^{-1.086} \quad (4) \qquad C = \frac{\overline{U}}{\Gamma\left(1 + \frac{1}{k}\right)} \quad (5)$$

It is clear from results in table (1) that both methods give identical estimates of the parameters C and k, Fig (9) shows the value of C and k parameters for both methods.

http://www.doi.org/10.62341/hayt2728

Table (1) gives the estimation of parameters C and k by two methods

station	Method 1		Method 2		Error (%)	
	C	k	C	k	C	k
Asabah	9.6	1.886	8.863625	1.643743	7.670519	12.84591
Alheira	8.025	1.938	7.62014	1.81546	5.045	6.3222
Ghutalriah	7.382	2.01	7.189966	1.912	2.601379	4.899245
Tarhunah	8.967	2.365	8.668824	2.243208	3.331738	5.149772
Msalath	8.25	2.479	7.949367	2.333865	3.644037	5.854594

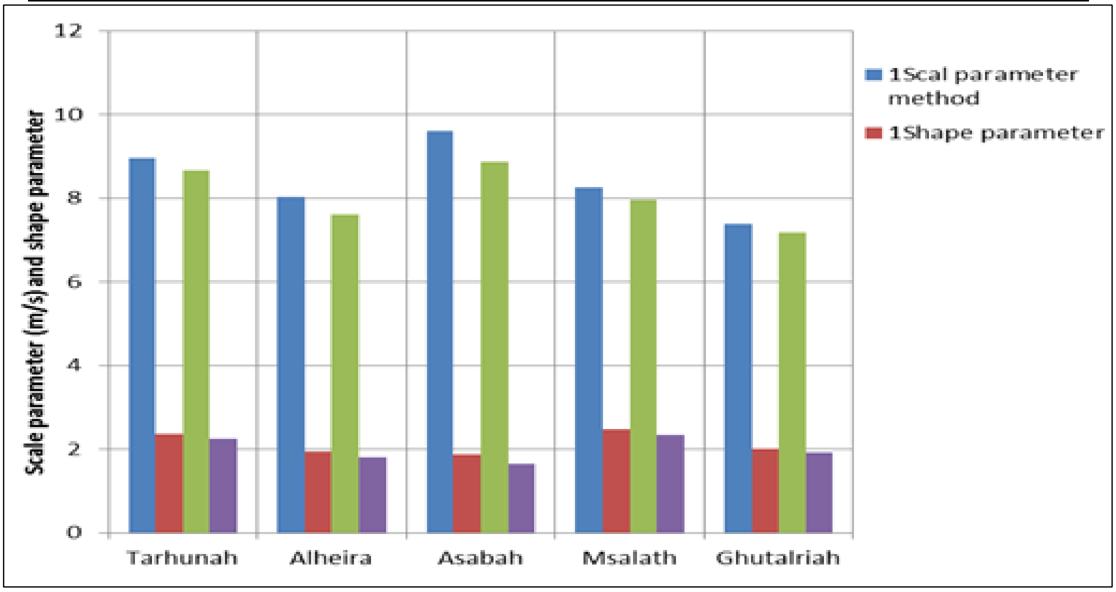

Fig (9) Scale and shape paramaters

Fig (9) show the histogram for the probablity of wind speed which drawn by using the value of scale and shape parameter, from these histograms, it is clear that the wind speed of maximum frequency is (7 m/s) at Tarhunah and Msalath with profitability of (10.792%) and (12.1141%) respectively, while at Ghutalriah the wind speed of value (5m/s) has the maximum ferquency with profitability of (11.63%) and the annual mean wind speed can be estimated from the histogram of probability of wind speed by take summation of multiply each wind speed in its profitability.

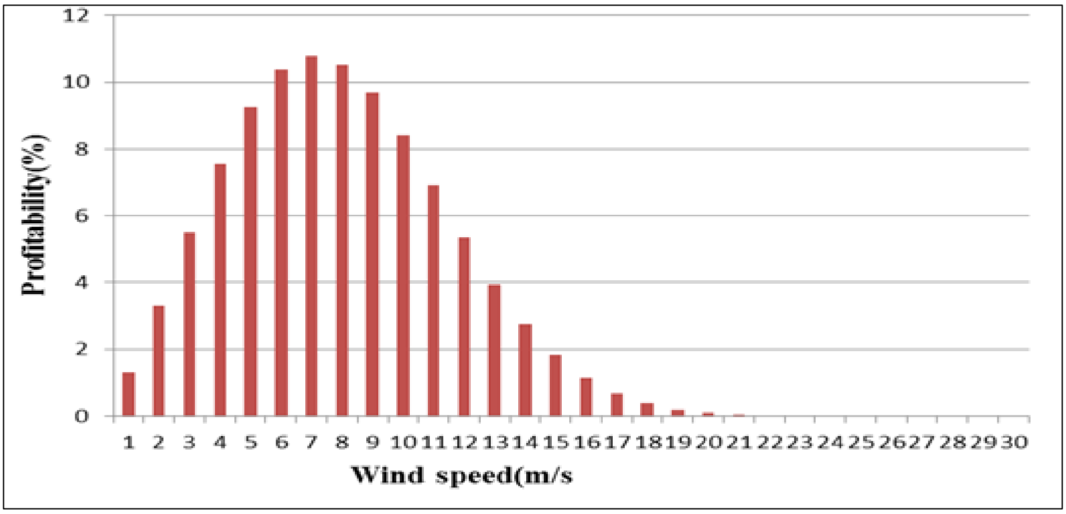

Fig (9) Histogram and Weibull function for the probability of Tarhunah city

From the Fig (10), we notice that there is a convergence between the mean wind speed and wind speed of maximum frequency, especially in the city of Maslatah.

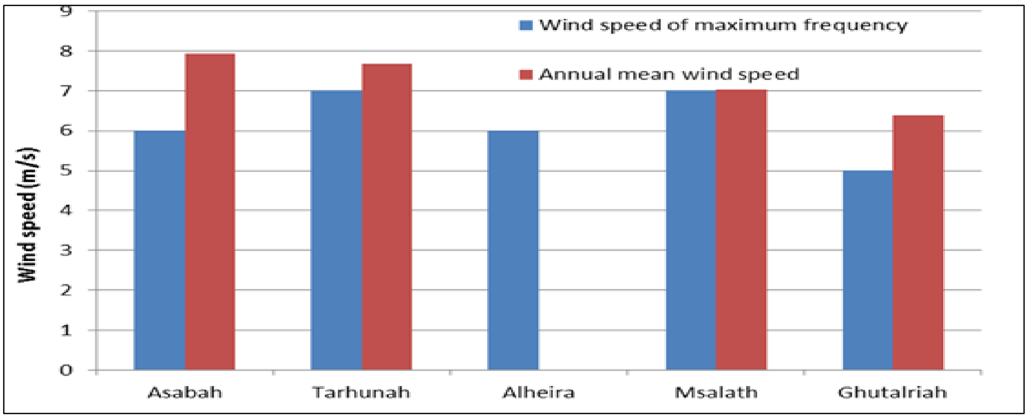

Fig (10) Mean wind speed and wind speed maximum frequency

This Fig (11) shows the Weibull cumulative distribution which gives the probability of wind speed exceeding the value of any given wind speed (all the results of stations are calculated at 40 meter height and details of calculations. The highest power density was in the city of Asabah as shown Fig (12).

http://www.doi.org/10.62341/hayt2728

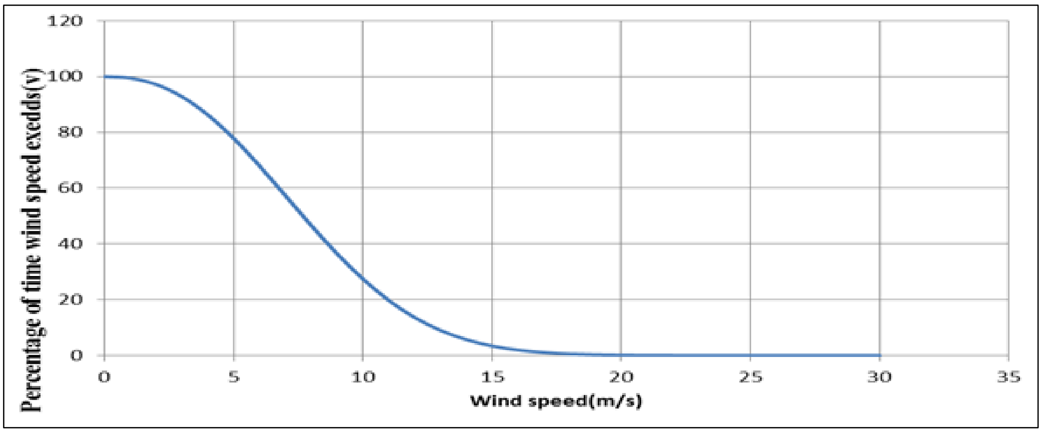

Fig (11) Cumulative Weibull distribution for Tarhunah city

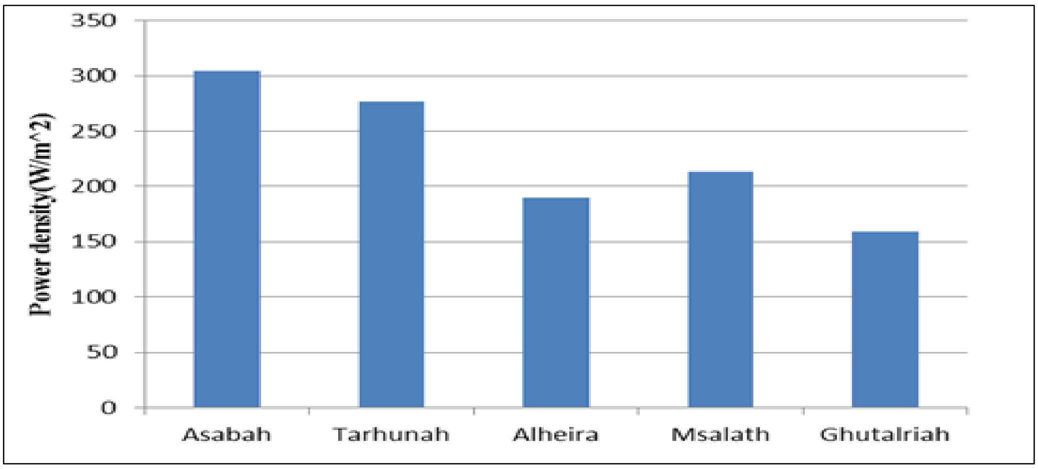

Fig (12) Power density for all stations

The calculations of annual energy for each site are based on the data of Enercon E-33 (330KW) wind turbines using the equation below:

$$Energy = \sum_{i=1}^{i=n} H(i).P(i) \qquad (6)$$

The annual energy for all stations is shown in the Fig (13). The maximum energy of 1275861 $kW\ h$ is obtained from the wind turbine of capacity 330 kW at Tarhunah. And the Fig (14) shown the highest capacity factor of 44.13522 % in Tarhunah was obtained for the 330 kW machine.

http://www.doi.org/10.62341/hayt2728

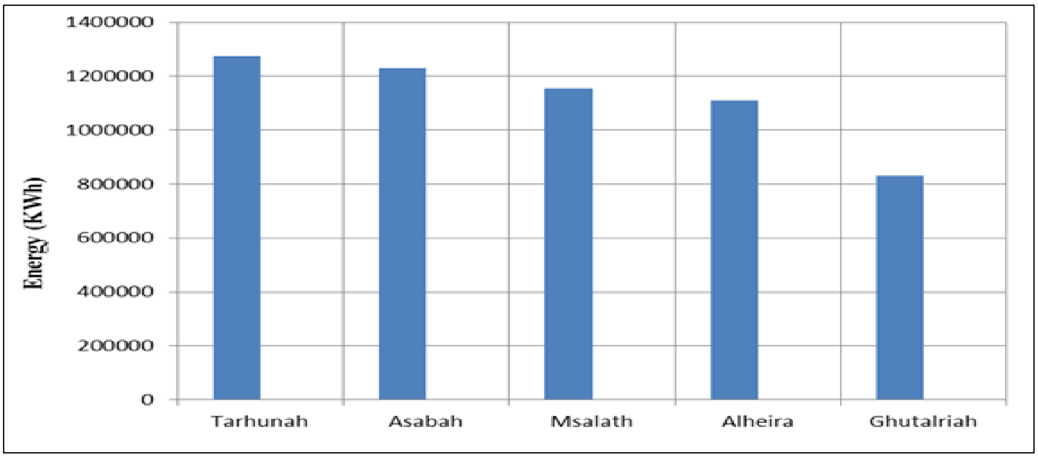

Fig (13) Annual energy by using Enercon E-33 (330kW) wind turbines

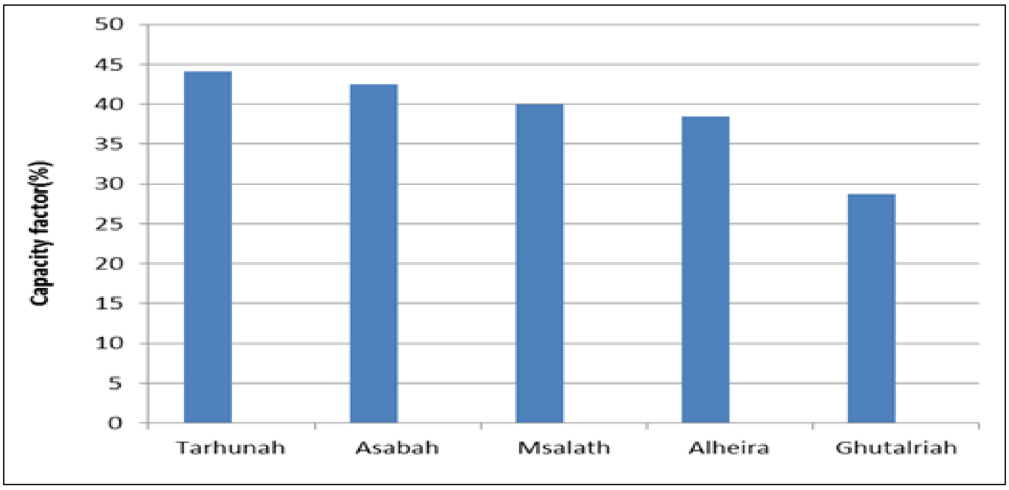

Fig (14) Capacity factor values for all the stations

Conclusion

This study indicates that the wind power varies from location to another hence we should install the proper wind turbine in the right suitable zone. All monitoring data that this study represents the latest global measurement techniques, and can therefore be relied upon in any Execution of this study practically, Investigation of available wind energy density at the height of 40m indicates that all stations have a good power density and can be linked with the public network The results indicate that Tarhunah has the maximum annual energy and capacity factor while Ghut-alriah has the minimum annual energy and capacity factor, existing data resources indicates that the mean annual wind speed of over 7.67 m/s in Tarhunah with theoretical capacity factor exceeding 44.13522 %. These values indicate that Tarhunah could generate an annual energy 1275861 kWh.

http://www.doi.org/10.62341/hayt2728

Recommendations for Future Work

1. This work should be extend to study the wind energy at different locations, this will help the resources in this field.
2. Take advantages of previous studies and this study to build the wind Atlas of Libya.
3. Studying the effect of the geographic distribution of the wind power stations on the actual power of the wind energy.
4. The whole area of the country should be examined to detect the fields proper for the establishment of wind turbine farms, and public initiatives should start establishing wind energy farms in the selected areas.

References

[1] D. C. a. T. D. K. ANASTASIOS BALOUKTSIS, "A NOMOGRAM METHOD FOR ESTIMATING THE ENERGY PRODUCED BY WIND TURBINE GENERATORS," Pergamon, vol. 72, no. 3, pp. 251 - 259, 2002 .

[2] T. L. S. Ackermann, "An overview of wind energy-status 2002," Pergamon, vol. 6 , pp. 67 - 128, 2002 .

[3] K. P. A. K. Sathyajith Mathew, "Analysis of wind regimes for energy estimation," Pergamon, vol. 25, pp. 381 - 399, 2002 .

[4] "google map," 2022. [Online]. Available: https://www.google.com/search?q=map+of+libya&oq=map&aqs=chrome.2.69i57j0i512l4j46i512j0i512l4.7557j0j15&sourceid=chrome&ie=UTF-8.

[5] M. H. Albuhairi, "ASSESSMENT AND ANALYSIS OF WIND POWER DENSITY IN TAIZ- REPUBLIC OF YEMEN," AUCES, vol. 9 No. 2, pp. 13 - 20, 2006 .

[6] G. Li, "Feasibility of large scale o€shore wind power for Hong Kong Ð a preliminary study," Pergamon, vol. 21, pp. 387 - 402, 2000 .

[7] J. M. a. A. R. J.F. Manwell, wind energy explained, U.S.A: John Wiley, 2002 .

[8] S. Mathew, Wind Energy Fundamentals, Resource Analysis and Economics, Malapuram, Kerala India: Springer, 2006 .

[9] D. K. S. a. N. V. J. T. V. RAMACHANDRA, "WIND ENERGY POTENTIAL ASSESSMENT IN UTTARA KANNADA DISTRICT OF KARNATAKA, INDIA," Pergamon, vol. 10, no. 4, pp. 585 - 611, 1997 .

[10] E.-A. F. A. S. S. S. Rehman, "Wind power resource assessment for Rafha, Saudi Arabia," ELSEVIER, vol. 11, p. 937 – 950, 2007 .

[11] S. P. a. M. M. M. JAMIL, "WIND POWER STATISTICS AND AN EVALUATION OF WIND ENERGY DENSITY," Pergamon, vol. 6, no. 5, pp. 623 - 628, 1995.