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Assessment and evaluation of wind energy in some cities of Libya

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Abstract

A potential assessment of wind energy at Gharyan, Nalut, Asabah, Alraiyna cities in the western region of Libya is realized for 850 KW Siva wind turbine model. A background information about wind power and its resources was provided, including a review of available data, which are obtained from the representative meteorological stations For the chosen location, a measured long term time series of 3 hours wind data was used, and the wind data has been recalculated to represent the actual wind speed at hub height, The mean wind speed, Weibull distribution, power density function, annual energy and annual capacity factor by creating a data base using Microsoft excel program. Alraiyna has a good wind energy potential were the wind turbine (Siva 850 KW) had an annual energy output equal to 1.275861 MWh. According to the studied machine, the capacity factor was 17.14 %, and the wind resource appears to be suitable for power production.

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

الملخص

تم إجراء تقييم محتمل لطاقة الرياح في مدن غريان ونالوت والاصابعة والريااينة في المنطقة الغربية من ليبيا لنموذج توربينات الرياح Siva 850 KW. تم توفير معلومات أساسية حول طاقة الرياح ومواردها، بما في ذلك مراجعة البيانات المتاحة، والتي تم الحصول عليها من محطة الأرصاد الجوية التمثيلية. بالنسبة للموقع المختار ، تم

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استخدام سلسلة زمنية طويلة المدى من 3 ساعات من بيانات الرياح، وتمت إعادة حساب بيانات الرياح لتمثيل سرعة الرياح الفعلية عند ارتفاع المحور، وسرعة الرياح المتوسطة، وتوزيع وبيل، ودالة كثافة الطاقة، والطاقة السنوية وعامل السعة السنوي من خلال إنشاء قاعدة بيانات باستخدام الحاسوب. تمتلك الرياينة إمكانات جيدة لطاقة الرياح، حيث كان لتوربينات الرياحSiva 850 KW إنتاج سنوي للطاقة يساوي (1.275861) ميغاوات في الساعة. وفقًا للآلة المدروسة، كان عامل السعة 17.14%،ويبدو أن مصدر الرياح مناسب لإنتاج الطاقة.

1. Introduction

In the last century, the wind energy was used by human in many fields such as air conditioning in hot areas, extinguishing fires, melting raw materials and sailing ships guiding, and in the field of agriculture which include the wind energy has been used for irrigation and grain purification and etc. The nearly constantly blowing winds in the subtropical belts of the Earth are still named (trade winds) today [1].

The power of the wind has been utilised for at least 3000 years. Until the early twentieth century wind power was used to provide mechanical power to pump water or to grind grain. At the beginning of modern industrialisation, the use of the fluctuating wind energy resource was substituted by fossil fuel fired engines or the electrical grid, which provided a more consistent power source [2].

In the early 1970s, with the first oil price shock, interest in the power of the wind re-emerged. This time, however, the main focus was on wind power providing electrical energy instead of mechanical energy [3]. This way, it became possible to provide a reliable and consistent power source by using other energy technologies – via the electrical grid – as a backup.

The first wind turbines for electricity generation had already been developed at the beginning of the twentieth century. The technology was improved step by step from the early 1970s. By the end of the 1990s, wind energy has re-emerged as one of the most important sustainable energy resources. During the last decade of the twentieth century, worldwide wind capacity doubled

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approximately every three years. The cost of electricity from wind power has fallen to about one sixth of the cost in the early 1980s. And the trend seems to continue. Some experts predict that the cumulative capacity will be growing worldwide by about 25% per year until 2005 and costs will be dropping by an additional 20 to 40% during the same time period [4]. Wind energy technology itself also moved very fast in new dimensions. At the end of 1989 a 300kW wind turbine with a 30-meter rotor diameter was state of the art. Only 10 years later, 2000kW turbines with a rotor diameter of around 80 meters were available from many manufacturers. The first demonstration projects using 3MW wind turbines with a rotor diameter of 90 meter were installed before the turn of the century. Now, 5MW turbines are commercially available.

2. Historical background

The following historical overview divides the utilisation of the natural resource wind into the generation of mechanical power and the production of electricity:

2.1 Mechanical power generation

The earliest windmills recorded were vertical axis mills. These windmills can be described as simple drag devices. They have been used in the Afghan highlands to grindmgrain since the seventh century BC [5].

Persia and China were the forerunners in the manufacture of windmills according to historical documents from about a thousand years ago, which were of the horizontal axis type, then they were popular in the Middle East and in England in 1150, in France in 1180, Germany 1222 and Denmark in 1259, The windmill industry developed between the twelfth and nineteenth centuries, after which windmills were used for several other purposes, including pumping water from lakes and others, and in the year 1800 France developed about 20,000 windmills and the Netherlands used about 90% of its energy from wind energy Figure (1) shows Shape of windmills, It is worth mentioning that wind has attracted human attention since ancient times and how to benefit from it in their practical lives. Indeed, the windmill industry has been developed and promoted, but the discovery of oil has made the chances of using wind energy reduced in humans and oil is

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considered the most important source of energy generation in the world .

Fig (1) an ancient windmill in the British Isles

In the early twentieth century, American windmills appeared, which are known as the self-regulation mechanism, other than European mills, which must be extinguished or winding the blades of the wind turbine during high wind speeds, and also when the rates of industrialization in Europe increased, it led to a gradual decline in windmills, for example in the Netherlands in 1904 was energy Wind provides 11% of industrial energy, and in Germany there are more than 18,000 units was installed, this made the opportunity favorable for American windmills to enter Europe strongly during the period from 1920 to 1930, where about 600,000 units were installed, and thus the American windmills used for agricultural purposes became popular in Figure (2) shows these windmills around the world.

Fig (2) an ancient Spanish wind farm

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2.2 Present status of wind energy in Libya

Although being one of the greatest oil exporting countries Libya has identified the existence of potential renewable energy resources. Therefore, it is Libya's goal to increase the share of renewable energy sources to 10 % of the entire energy production within the near future. The motivation behind this is to significantly reduce the costs of the national electricity production.

Fig (3) Wind farm in Darnah

The electricity production is essentially based on fossil fuels in particular, natural gas that is abundant in the country. Since 2000, Libya electricity utility GECOL (General Electric Company of Libya) began seeking professional engineering experts, which would help the company to qualify the country's wind energy potential and build the first commercial wind farm to both generate electricity from an renewable energy source on economically reasonable terms and educate local engineers in understanding the requirements and interrelating subjects of wind farm development.
The geographical location of Libya has several advantages for extensive use of most of the renewable resources. In this regard, Libya has to make use of its renewable resources, such as wind solar and geothermal, not only to meet the increasing energy demand but also for environmental reasons [24].

3. Study locations

In this study the location of four chosen stations in Libya are selected Nalot, Alraiyna, Gharyan, Asabah. The locations of these sites are shown in Fig (5).

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Fig (5) Distribution of speed measurement stations over Libya [17]

The wind speed data continuously by the data logger EKO 21B in all stations. Information about these locations are given in table (1). Knowing that all the data were taken from the meteorological centre

Table (1) Physical features of the meteorological stations

station	Elevation above sea level (m)	Latitude $N°$	Longitude $E°$
Nalot	705	31 52	10 58
Garrin	715	32 10	13 01
Asabah	583	31 30	11 50
Alraiyna	724	31 37	11 14

4. Analysis of wind data

4.1 Calculation of mean wind speed

The mean wind speed and standard deviations values are calculated for available time series data for all the stations are presented in table (2).

Table (2) Mean monthly, annual wind speed (m/s) and standard deviation for whole years

Station	Months - wind speed(m/s)						
	Jan	Feb	Mar	Apr	May	Jun	Jul
Gharyan	6.88	7.03	6.88	7.57	6.93	6.28	5.38
Nalut	6.12	6.13	5.96	6.18	6.28	5.82	5.55

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Asabah	**7.97**	**8.64**	**8.03**	**11.54**	**7.64**	**9.06**	**6.78**
Alraiyna	**6.58**	**8.28**	**7.95**	**10.90**	**7.89**	**8.48**	**6.88**

Station	**Months - wind speed(m/s)**					**AM (m/s)**	**SD**
	Aug	**Sep**	**Oct**	**Nov**	**Dec**		
Gharyan	**5.66**	**5.81**	**6.35**	**6.20**	**7.13**	**6.51**	**3.68**
Nalut	**5.27**	**5.56**	**5.11**	**5.89**	**6.22**	**5.84**	**2.73**
Asabah	**7.68**	**5.99**	**8.17**	**7.40**	**7.62**	**7.92**	**5.01**
Alraiyna	**7.40**	**7.38**	**8.18**	**7.17**	**7.24**	**7.67**	**3.65**

AM: Annual mean, SD: Standard deviation

The diurnal variation of wind speed for all the stations are shown in Fig (6). It's clear form this figure that the wind speed is near constant during the night until about 8 m/s in the morning then increases strongly reaching the maximum value at 3.00 p.m. This figure also indicates that the wind speeds decrease slightly in the early morning and evening hours.

Daily wind intensity variations, which are directly related to daily temperature variations, are low in the mornings, reaching a maximum value in the afternoons and start decreasing in the evenings. It is seen from figure (6) that the hourly wind speeds vary 4.19 m/s in Nalut and 8.45 m/s in Asabah with a maximum occurrence in the afternoon.

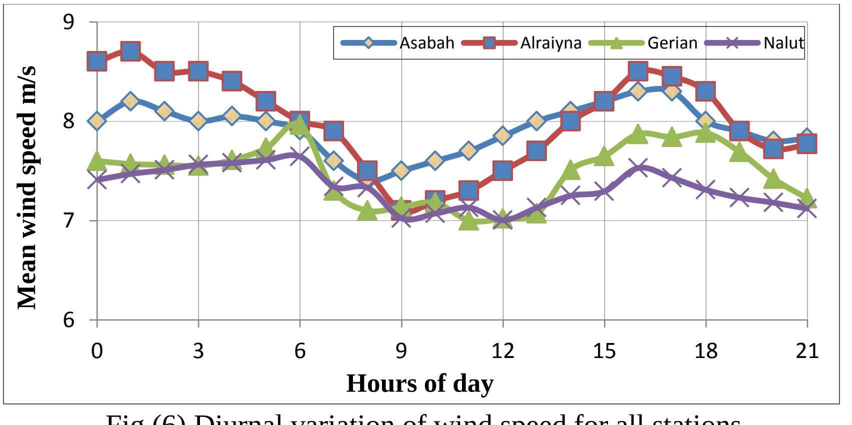

Fig (6) Diurnal variation of wind speed for all stations

Fig (7) illustrates the monthly mean wind speed for all stations.

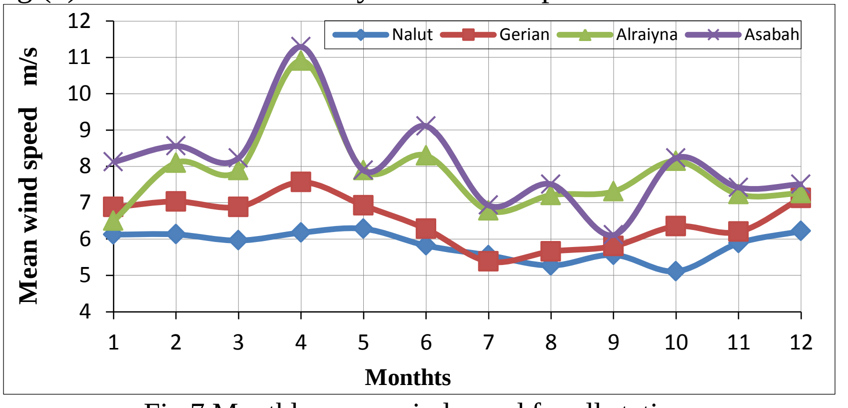

Fig 7 Monthly mean wind speed for all stations

It is clear from this figure that the wind speed for whole years has the lowest value in month of August and October and the maximum in the months of April and JUN. Also from Fig (7) the wind speed has maximum value of 11.29 m/s at Asabah and the minimum value of 5.11 m/s at Nalut.

Mean wind speed for different seasons of the year are plotted in Figs (8), (9), (10) and (11). During winter season, the wind speed level at four stations reaches high value of 6.123 m/s – 8.12 m/s, where the maximum mean wind speed occurs at Asabah during February with 8.12 m/s.

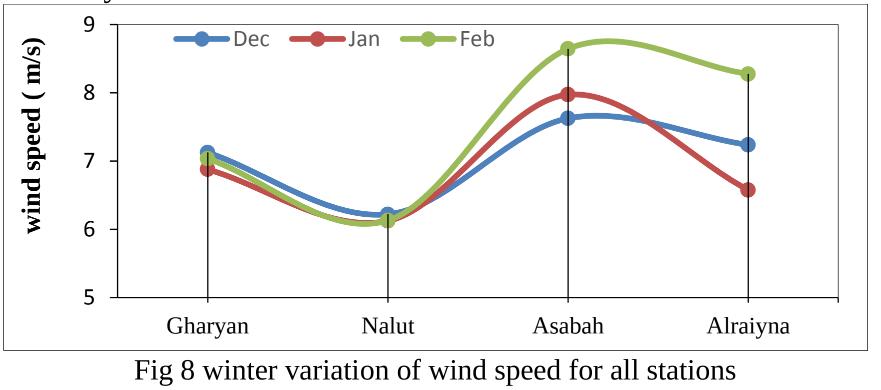

Fig 8 winter variation of wind speed for all stations

In spring season, four stations have high values of wind speed 5.9601 - 11.29 m/s, where the maximum value is recorded in Asabah with 11.29 m/s during April.

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In summer season the wind speed level reaches 9.11m/s at Asabah during Jun. For autumn season, the maximum mean wind speed is recorded as 8.23m/s at Asabah in October.

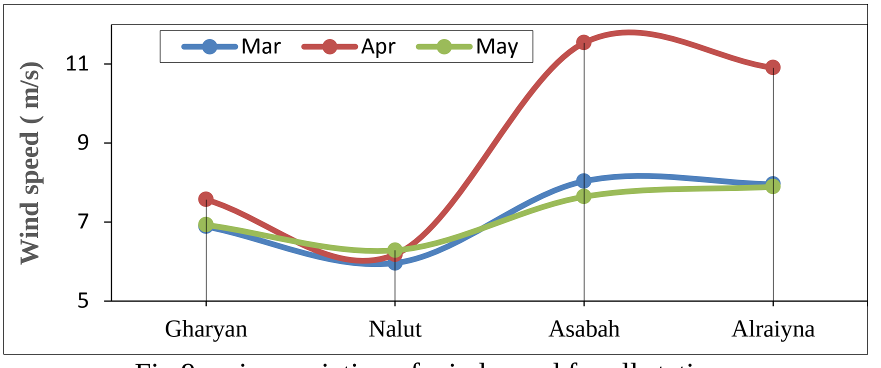

Fig 9 spring variation of wind speed for all stations

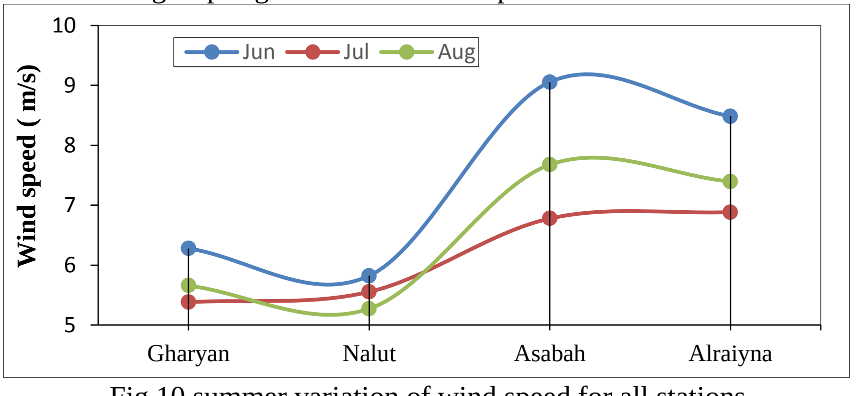

Fig 10 summer variation of wind speed for all stations

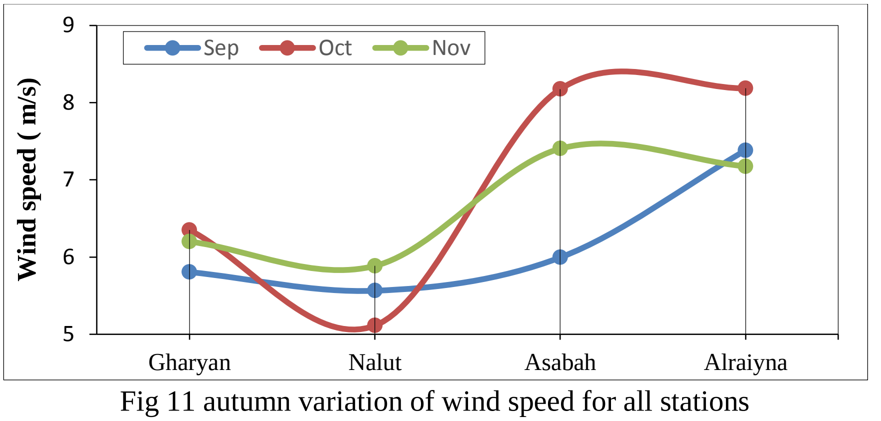

Fig 11 autumn variation of wind speed for all stations

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From Figs (8), (9), (10) and (11). The following paragraphs are concluded.

1. The highest value of mean monthly wind speed of all stations occurred during winter and spring seasons, this can be explained by the decrease the temperature during winter and spring. Such decrease causes thermal convection, so that some of momentum of the upper air, which is moving at higher velocity, is transmitted to the surface layers causing the noticed increase in the mean monthly wind speed.
2. For three seasons, we notice that Nalut has the minimum values of monthly wind speed and has the minimum value in spring.
3. The monthly wind speed for all the seasons, has the same trend.

4.2 Calculation of Weibull frequency

Determination of Weibull frequency distribution and Weibull cumulative distribution required to determine first the scale parameter "C" and the shape parameter "k". The two parameters C and k for all the stations are calculated using two methods.

The results of "C" and "k" for all stations using the first method are shown in Fig (12). The values of $ln(-ln(P(U)))$ are plotting in the y axes, and the values of lnU are plotting in the x axes. Straight line is fitted through the points, and deduction the best equation which is shown in each figure, and comparing these equations, gives the values of "C" and "k".

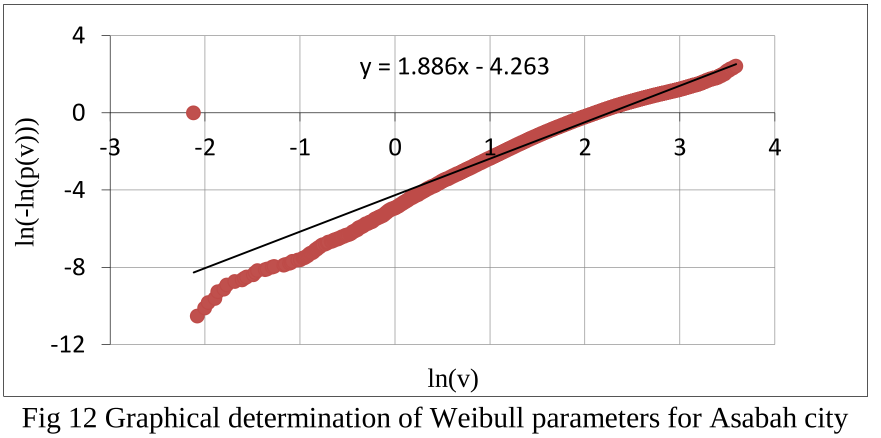

Fig 12 Graphical determination of Weibull parameters for Asabah city

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While the results of "C" and "k" using the second method are obtained using equations where the values of $\Gamma(1+1/k)$ are presented. The parameter "C" is then found by using equations. The final results of two methods are presented in table (3).

Table (3) gives the estimation of parameters "C" and "k" by two methods

station	Method 1		Method 2		Error (%)	
	C	k	C	k	C	k
Gharyan	3.9151	1.6057	6.1302	1.5506	36.135	3.4369
Nalut	4.5885	1.6406	4.3	1.733	6.287	5.331
Asabah	9.6	1.886	8.8636	1.6437	7.6705	12.846
Alraiyna	8.967	2.365	8.6688	2.2432	3.3317	5.1498

It is clear from results in table (3) that both methods give identical estimates of the parameters "C" and "k", Fig (13) shows the value of "C" and "k" parameters for both methods.

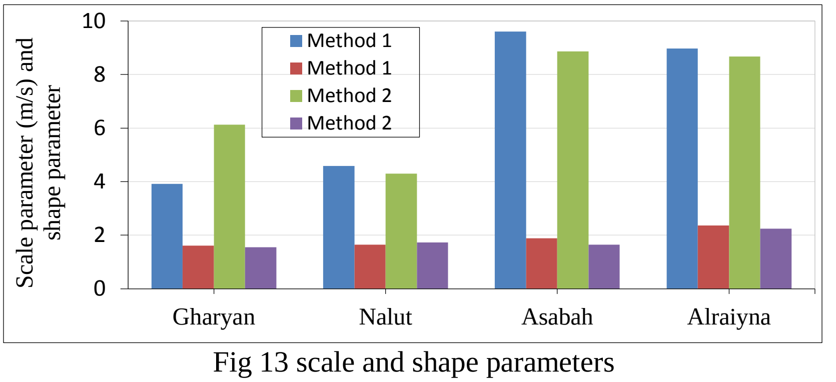

Fig 13 scale and shape parameters

Fig (14) show the histogram for the probability of wind speed which drawn by using the value of scale and shape parameter, from these histograms, it is clear that the highest wind speed of maximum frequency is 7 m/s at Asabah and ALraiyna with profitability 8.45 and 10.32% respectively, and the lowest 2 m/s at Gharyan with profitability 16.1% 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.

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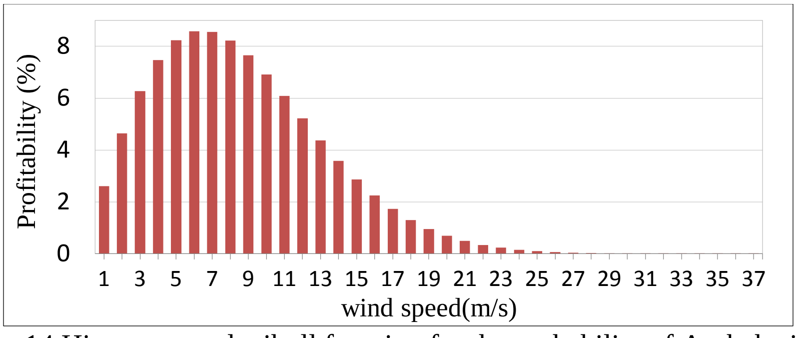

Fig 14 Histogram and wibull function for the probability of Asabah city

Fig (15) shows the value of mean wind speed and wind seed of maximum frequency for all the stations. It is clear from this figure that the highest wind speed was 7.924 m/s in Asabah and the lowest was 5.841m/s in Nalut as indicated in table (4).

Table 4 Annual mean wind speed and wind speed of maximum frequency

station	Wind speed of maximum frequency(m/s)	Annual mean wind speed(m/s)	Profitability (%)	Hours/year
Gharyan	**2**	**6.50719**	**12.82**	**1123.032**
Nalut	**3**	**5.84135**	**19.513**	**1709.339**
Asabah	**6**	**7.924**	**13.69**	**1199.244**
Alraiyna	**7**	**7.67**	**15.303**	**1340.543**

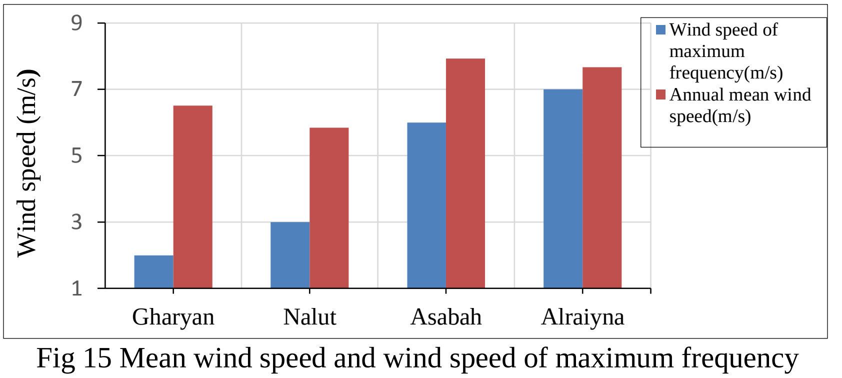

Fig 15 Mean wind speed and wind speed of maximum frequency

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Fig (16) show the Weibull cumulative distribution which gives the probability of wind speed exceeding the value of any given wind speed . And the rest of the cities the same way.

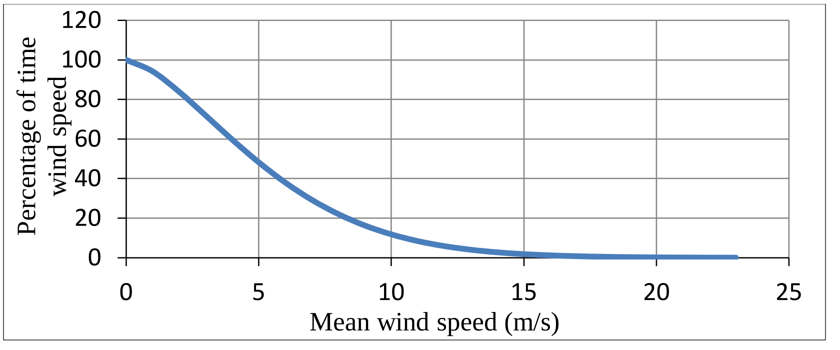

Fig 16 Cumulative Weibull distribution to Gharyan city

4.3 Calculation of power density

Table 1.5 shows the wind power density for the different stations. It's clear from this table that the maximum power density is 313.6W/m in Gharyan and the minimum is 97.456W/m in Nalut.

Table 5 Maximum power density for all stations

Station	Mean power density (W/m^2)	Maximum power density (W/m^2)
Gharyan	76.56	313.6
Nalut	57.988	97.456
Asabah	90.12	304.28
Alraiyna	81.32	276.37

4.4 Calculation of annual energy

The calculation of annual energy for each site are based on the data of Vestas (V60- 850kw) wind turbines.

The total energy output per year from the wind machines of different sizes is shown in table (17), the maximum energy of 1275861 kW is obtained from the wind turbine of capacity 850 kW at Alraiyna while the minimum value of 1008521 kW from wind machine of capacity 850kw at Nalut.

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Table 6 Annual energy values for all the stations

Station	Annual energy (kWh) for Turbine 850kW
Ggaryan	1089566
Nalut	1008521
Asabah	1228378
Alraiyna	1275861

4.5 Calculation of annual capacity factor

The energy output data is used to calculate the capacity factor of the wind machines that have rated power 850kw. The machines are similar in the values of cut-in speed and cut-out speed and the difference in the value of rated wind speed.

Table (7) shows the value of capacity factor for selected site. It is clear from table (7) that the highest capacity factor of 17.14 % in Alraiyna was obtained for the 850 kW machine, while the next highest value was found at Asabah, Gharyan is placed the third.

Table 1.7 Capacity factor values for all the stations

Station	Capacity factor (%) for turbine 850kw
Gharyan	14.632
Nalut	13.55
Asabah	16.5
Alraiyna	17.14

Conclusions

This project shows the outcome of an assessment study of wind energy in Nalot, Alraiyna, Gharyan, Asabah area. The results show the possibility of utilizing wind energy in areas selected and linking it with the general electric power grid. Another area could be used in other applications such as battery charging or pumping water. Coming to a conclusion from the study:

1. The wind data presented in this study are based on human recording, which may not be as accurate as modern equipment with automatic data loggers. In addition, wind speed values

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were recorded to the nearest knots, this may cause a cumulative error of meter per second.

2. Investigation of available wind power density (which is 313.6 W/m2) indicates Gharyan area have a good power density. This site is ideal for grid connection applications.
3. Existing data resources indicates that the mean annual wind speed of over 7.924 m/s at Asabah with theoretical capacity factor exceeding 16.5%. These values indicate that Alraiyna could generate 1.275861 MWh per year.

Recommendations

The principle recommendations are described in following paragraphs:

1. This work should be extending to study the wind energy at different locations, this will help the resources in this field.
2. Making campaigns to measure wind speed data in order to cover the majority in our country, paving the way for making a wind Atlas.
3. Making studies about the effect of entering the wind energy systems to the general electric grid.
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.
5. One or more pilot project should be implemented to demonstrate feasibility and to develop skills. A pilot project requires careful preparation and planning in order to be successful. Essential components in pilot project include the following.
   - ✓ Cost and performance data from wind turbine manufacturers.
   - ✓ Information about current electricity generation.
   - ✓ Preliminary and final project desires.
   - ✓ The final decision on pilot project implementation is dependent on site data.

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The proposed future research will improve existing knowledge on the wind energy systems and enhance their performance, so there are some of considerations rules must be taken:

1. Emphasize the importance of the ability of renewable energy in the energy balance in Libya, especially to meet the energy requirements.
2. Encourage and supporting the use of wind energy among all universities and education programs by (books, DVDs and study guides).
3. Awareness through various media is needed to rationalize energy consumption in buildings.
4. Encourage the establishment of centers for renewable energy research (especially in universities and scientific centers) that will localize and develop renewable energy technologies

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