تقييم وتقدير طاقة الرياح في ليبيا

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ملخص البحث :

تقييم طاقة الرياح هو تحليل متكامل لموارد طاقة الرياح المحتملة في منطقة محددة. يبدأ هذا التقييم بفهم أنماط الرياح العامة ثم تجميع وتحليل البيانات المتعلقة بالرياح. تعتبر طاقة الرياح شكلا غير مباشر من الطاقة الشمسية بما أن حوالي 1-2% من الإشعاع الشمسي الذي يصل الأرض يتحول إلى طاقة في الرياح. تتكون الرياح من التسخين غير المتساوي لأجزاء مختلفة من سطح الأرض والذي ينتج عنه كميات من الهواء البارد الكثيف ليحل محل الهواء الدافئ الخفيف.بعض من طاقة الشمس يتم امتصاصها مباشرة في الهواء بينما يمتص سطح الأرض معظم الطاقة الناتجة من الرياح ليتم نقلها للهواء.

تزداد سرعة الرياح مع الارتفاع فوق سطح الأرض بسبب السحب الاحتكاكي للأرض و النباتات والمباني. وهكذا يبدو من الضروري أخذ هذه المتغيرات في الاعتبار في أي خطة أو برامج للاستفادة من الرياح

يتطلب أي تقييم مفصل للجدوى الاقتصادية لطاقة الرياح مجموعة من الدراسات التي تتعلق بتقييم الرياح وذلك لان تكلفة تطوير طاقة الرياح تعتمد على طبيعة مصادر الرياح.

وقد تشمل عملية التقييم إنشاء آلية رصد أو الاعتماد على برنامج المحاكاة بالحاسوب لتدفق الرياح لتحديد توربينات الرياح.

تأتي هذه الورقة كتكملة لدراسة المنطقة الأولى والثانية. تعتبر عملية تقدير مواصفات الرياح الخطوة الأولى المهمة في تقييم إي مشروع لطاقة الرياح بناءً على معلومات متعلقة بمظاهر تطبيق وتشغيل المشروع كافة. عليه من الضروري الحصول على فهم تام للريح لاختيار التوربينات الريحيه المناسبة لمنطقه. محدده و لتقدير أدائه.

كما أنه من المهم التعرف على المعلومات الآتية : متوسط سرعة الريح, الاتجاهات, التغيرات اليوميه والفصلية, و السنوية والتغيرات الناتجة عن الارتفاع. هذه المعلومات مقتصرة عن مكان تجميعها ومن الممكن فقط تحديدها بدقة تامة من خلال ذات المكان وخلال مده طويلة

تهتم هذه الدراسة بطاقة الريح وتقييمها في مناطق بوزريق, تازربو, إجخرة و مراوا. تقدم هذه الورقة معلومات تتعلق بخلفية طاقة الريح . تعتمد الدراسة على مراجعة البيانات التي تم التحصل عليها من محطات الأرصاد الجوية.

في كل موقع تم استخدام سلسلة طويلة المدى تقاس كل 3 ساعات . تم إعادة حساب هذه البيانات لتمثل سرعة الريح الحقيقية في أعلى محور الارتفاع متوسط سرعة الرياح وتوزيع ويبول , الطاقة السنوية والقدرة السنوية في كل موقع..تم احتساب هذه المعايير :

تشير نتائج هذه الدراسة لوجود طاقة الرياح في بعض المناطق في ليبيا وأكثرها منطقة مراوا

Prediction of Wind Energy Potential in Libya

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Abstract—

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 energy is an indirect form of solar energy. Between 1-2% of the solar radiation that reaches the Earth is converted into energy in the wind. Winds result from an unequal heating of different parts of the Earth's surface, causing cooler dense air to circulate to replace warmer, lighter air. While some of the sun's energy is absorbed directly into the air, most of the energy in the wind is first absorbed by the surface of the Earth and then transferred to the air by convection.

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.

Because the cost of wind energy development depends sensitively on the nature of the wind resource, any detailed evaluation of wind energy economics requires a series of wind assessment studies.. 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. This paper is considered as an extension to the study of the first zone and the second zone. Estimation of wind characteristics is considered as the first essential step to evaluate a wind energy project based on information about all aspects of the implementation and operation of the project. It's therefore necessary to have detailed knowledge of the wind to select the suitable wind turbine for a certain zone and also to estimate its performance accurately. Various parameters need to be known of the wind, including the mean wind speed, directional data, variations about the mean in the short term (gusts), daily, seasonal and annual variations, and variations with height. These parameters are highly site specific and can only be determined with sufficient accuracy by measurements at a particular site over a sufficiently long period.

This study focuses on the wind energy and wind assessment in some selected sites such as Bozraig, Tazirbo, Jkhirra, and Mrawa. This paper first provides background information about wind power and its resource, including a review of available data, which are obtained from the representative meteorological stations. For each location, long term time series of 3-hourly measured wind data were used; the wind data has been recalculated to represent the actual wind speed at hub height. The mean wind speed, the Weibull distribution, annual energy and annual capacity factor are calculated for each site. The annual energy and annual capacity factor calculation are based on

specification of wind turbine known as Vestas (V60- 850kw), This study indicates that wind energy is available in some sites in Libya, and Mrawa has the maximum power, annual energy and capacity factor.

Keywords—shape parameter; scale parameter; annual capacity factor; cumulative Weibull distribution

I. ANTRODUCTION

Global population is increasing day by day. The population growth is more rapid in developing countries than the industrialized nations. As a result of this population growth and developmental activities, the energy demand is also increasing. Growing energy demand and environmental consciousness have re-evoked human interest in wind energy. As a result, wind is the fastest growing energy source in the world today.

Energy is one of the crucial inputs for socio-economic development. The rate at which energy is being consumed by a nation often reflects the level of prosperity that it could achieve. The global energy demand is met from a variety of sources. Fossil fuels consisting of coal, oil, and natural gas, but unfortunately, these fossil fuels are finite resources and will be completely exhausted one day or the other, hence, while our energy demand is increasing day by day, the available resources are depleting. This will definitely lead us to the much discussed energy crisis. However, the crisis may not be an imminent reality as the time scale may prolong due to discoveries of new resources. Here comes the significance of sustainable energy sources like wind. The quantum of energy, associated with the wind is enormous. With today's technology, wind is an environment friendly and economically viable source of energy which can be tapped in a commercial scale. The most critical factor influencing the power developed by a wind energy conversion system is the wind velocity. Due to the cubic relationship between velocity and power, even a small variation in the wind speed may result in significant change in power. The Speed and direction of wind at a location vary randomly with time. Apart from the daily and seasonal variations, the wind pattern may change from year to year, even to the extent of 15 to 35 per cent. Hence, the behavior of the wind at a prospective site should be properly analyzed and understood. This paper outlines physical phenomena that are related to the characteristics of the wind for the selected areas as Bozraig, Tazirbo, Jkhirra, and Mrawa. Knowing that the cost of wind energy development depends sensitively on the nature of the wind resource, hence any detailed evaluation of wind energy economics requires a series of wind assessment studies. 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

ii. WIND ASSESSMENT

After the region has been selected for assessment, it is necessary to collect the wind data(wind speed and direction). A complete wind resource assessment involves a dense network of anemometers (wind monitoring stations) recording continuous wind data for at least one year. Since such wind monitoring efforts are time consuming and costly, wind researchers often obtain data sets that have been previously recorded. Several sources may be helpful in obtaining existing meteorological databases. For example, climatologically stations, and airports are likely to maintain reliable records. If possible, existing data sets should be supplemented with spot measurements. When choosing sites to examine for potential wind development, the researcher should focus on areas likely to have enhanced wind speeds. In this paper data were recorded at height 30 meters continuously by a cup generator anemometer for all stations of each area. Samples of this data which represents the mean monthly wind speed for 0ne year (2012) are as shown in tables 1.

Station	Jan	Feb	Mar	Apr	May	Jun
Bozraig	5.99	6.87	7.79	6.98	7.98	7.12
Tazirbo	6.5	6.85	8.04	7.2	7.61	7.32
Jkhirra	5.76	6.98	7.67	7.67	7.66	6.67
Mrawa	6.65	7.12	7.94	7.43	7.67	7.98

TABLE1. MEAN MONTHLY WIND SPEED(METER/SEC)

III. Analysis of wind regimes

The next step in the wind resource assessment is to analyze the wind data set to determine patterns in the magnitude, duration and direction of the wind. The Mean wind speed (V_m) is the most commonly used indicator of wind production potential where defined as

$$V_m = \frac{1}{N}\sum_{i=1}^{N} V_i$$

Where N is the sample size, and V_i is the wind speed recorded for the i^{th} observation.

Where the sample size is large, it is useful to group the wind speed data into intervals to create a histogram of the wind speed distribution.

The wind speed at the surface is zero due to the friction between the air and the surface of the ground. The wind speed increases with height most rapidly near the ground, increasing

Station	Jul	Aug	Sep	Oct	Nov	Dec
Bozraig	6.76	5.69	5.43	5.74	5.57	6.77
Tazirbo	6.78	6.23	5.79	6.34	6.52	6.86
Jkhirra	6.74	6.21	5.67	5.89	6.10	6.91
Mrawa	7.95	7.49	7.53	7.12	6.74	7.91

$$\frac{V(z)}{V(10)} = \frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{10}{z_0}\right)}$$

(3)

less rapidly with greater height. At a height about 2 km above the ground the change in the wind speed becomes zero. The vertical variation of the wind speed, the wind speed profile, can be expressed by different functions. Two of more common

functions which have been developed to describe the change in mean wind speed with height are based on experiments and are given below.

- **Power exponent function**

$$V(z) = V_R\left(\frac{z}{z_r}\right)^{\beta}$$

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Where Z is the height above ground level, V_R is the wind speed at the reference height Z_r above ground level, V(z) is the wind speed at height z, and □ is an exponent which depends on the roughness of the terrain. A typical value of □ might be 0.1

- Logarithmic function

Where V(10) is the wind speed at 10 m above ground level and z_0 is the roughness length. The parameters □ and z_0 for different types of terrain are shown in Table 2.

TABLE 2 ROUHJNESS OF DIFFERENT TERRIANS.

Type of terrain	Roughness class	z_o (m)	β
WATER AREAS	0	0.001	0.01
Open country, few surface features	1	0.12	0.12
Farmland with buildings and hedges	2	0.05	0.16
Farmland with many trees, forests, villages	3	0.3	0.28

Both functions can be used for calculation of the mean wind velocity at a certain height, if the mean wind velocity is known at the reference height. In this study we used the power exponent function during the calculation and choose the value for β which equal 0.12.

IV. WIND STATISTICS

Studies show that a wind speed distribution can typically be described in terms of the Weibull distribution. The equation of the non-cumulative Weibull distribution is:

$$p(\mathrm{V}) = \frac{k}{C}\left(\frac{\mathrm{V}}{C}\right)^{k-1} \exp\left\{-\left(\frac{\mathrm{V}}{C}\right)^{k}\right\} \qquad (4)$$

While the cumulative Weibull distribution is:

$$P(\mathrm{V}) = \exp\left\{-\left(\frac{\mathrm{V}}{C}\right)^{k}\right\} \qquad (5)$$

Where k is the shape parameter and C is the scale parameter. Finding a best fit Weibull distribution is a convenient way to approximate a continuous wind speed distribution from the discrete observed values. In addition, this method is also useful in that the wind regime of an area can then be described using only the two Weibull parameters, k and C.

The parameters C and k for the Weibull frequency distribution can be found by plotting ln V against ln(-ln(P(V)), where ln is the logarithm to base e, and fitting a straight line to the points. The slope of the line is equal to k and C is equal to exp(ln V), or V, where ln(-ln(P(V)) is zero. This technique is based on taking logarithms of cumulative Weibull distribution twice

IV. ANNUAL ENERGY AND CAPACITY FACTOR

The calculation of the annual energy yield of a wind turbine is of fundamental importance in the evaluation of any project.

The long-term wind speed distribution is combined with the power curve of the turbine to give the energy generated at each wind speed and hence the total energy generated throughout the year. It is usual to perform the calculation using 1m/s wind speed bins as this gives acceptable accuracy. The annual energy expressed mathematically as

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

Where H(i) is the number of hours in wind speed bin i and P(i) is the power output at that wind speed.

Another measure is the load or capacity factor, defined as the ratio of the actual energy generated in a time period to the energy produced if the wind turbine had run at its rated power over that period. For example,

$$\text{Annual load factor} = \frac{\text{energy per year (kWh)}}{\text{rated power (kW)} \times 8760} \qquad (7)$$

There are several similar measures of power plant performance. To avoid confusion when comparing the performance of wind plant, the precise definitions of availability or load factor should be clearly understood.

VI. RESULTS AND DISCUSSION

To determine the Weibull frequency distribution, and the Weibull cumulative distribution, it is necessary to determine first the scale parameter (C), and the shape parameter (k). Fig. 1 show the technique that used to determine these parameters for Mrawa city (as a sample), the values of scale parameter is C = 9.34 m/s. While the slope of straight line is the value of shape parameter which is k = 3.23, and the values of these parameters for the other areas are indicated in Fig.3.

Table 4 show the value for the probability of wind speed which drawn by using the values of scale and shape parameters with equation 4, from this histogram its clear that the wind speed that has maximum frequency is 7.1 m/s in Bozraig (Profitability =13.78%), 8.0 m/s in Tazirbo (Profitability = 13.53%), 7.0 m/s in Jkhirra (Profitability = 13.66%)and 8.2 m/s in Mrawa (Profitability = 12.54%). The annual mean wind speed can be estimated from the histogram of the probability of wind speed by take a summation of multiply each wind speed in its profitability, the mean wind speed is 7.2 m/s in Mrawa, while Fig.4, show the values of mean wind speed and the wind speed of maximum frequency for the other areas. Figs. 2, show the Weibull cumulative distribution for Mrawa city which gives the probability of the wind speed exceeding the value of any given wind speed, (all the results calculated at 30 meter height)

The calculations of the annual energy and capacity factor for each site are based on the data of Ventis v 60 wind turbine, which has a rotor diameter of 60 meters and a rated power of 850 kW. Fig. 5 shows the annual energy for each city, and the maximum annual energy is 2187.34 MWh in Mrawa, while the minimum one is 1434.12 MWh in Bozraig, from these values it seems that this type of wind turbines is proper in some areas like Mrawa.. The final results of calculations are summarized in table 3 and table 4.

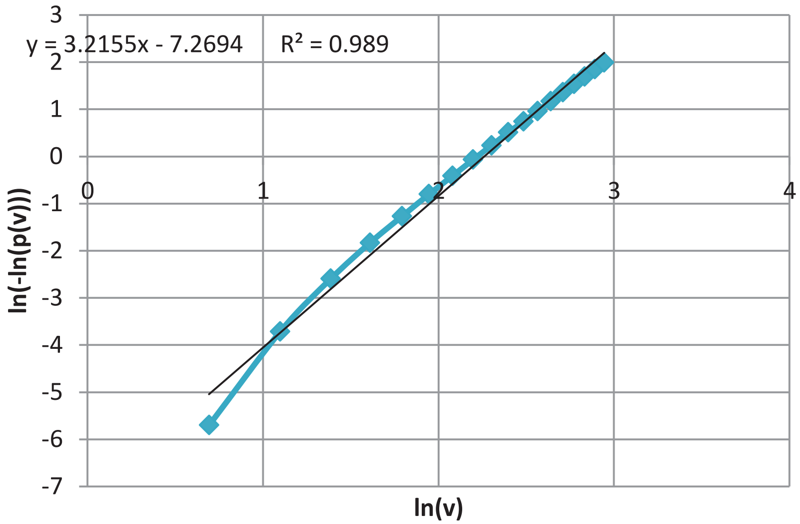

Fig1: Weibull parameters for Mrawa city

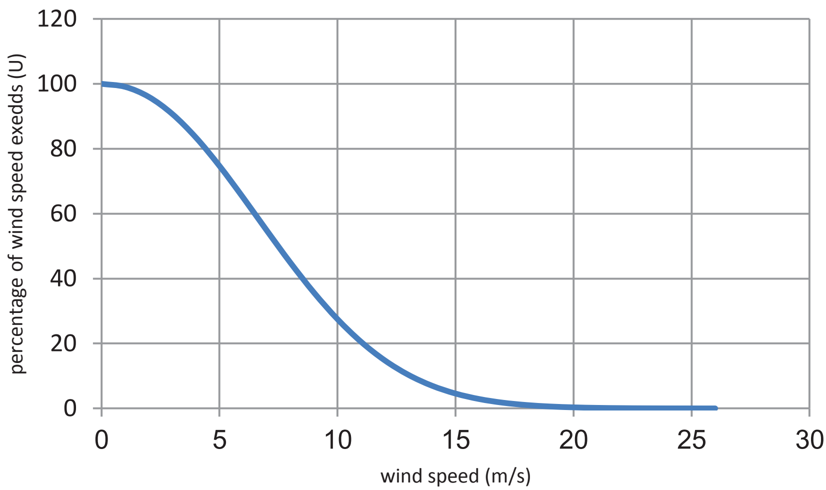

Fig2: Cumulative Weibull distribution for Mrawa city

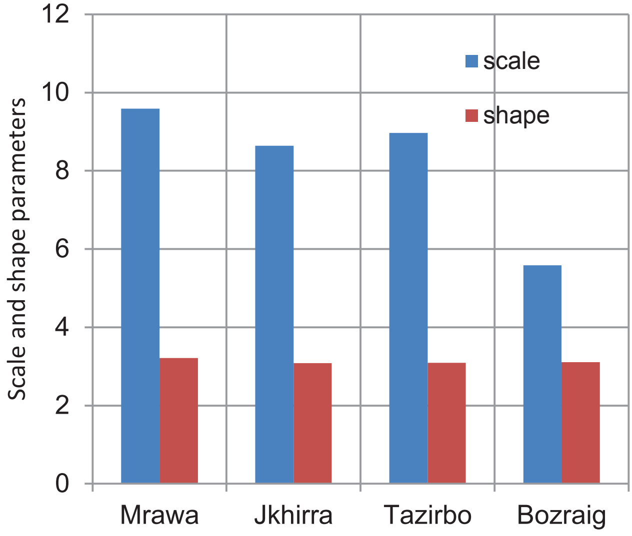

Fig3: Shape and scale parameters

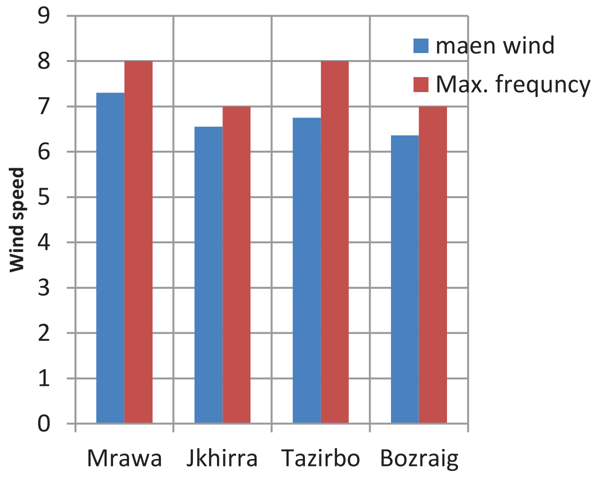

Fig. 4. Mean wind speed and wind speed of max-frequency

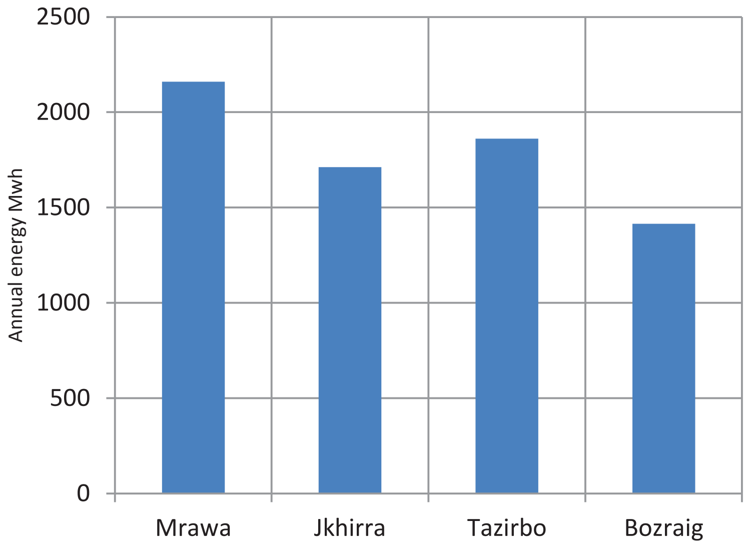

Fig5: Annual energy –based on V60-850 Kw

TABLE 3. RESULTS OF THE AREAS UNDER STUDY

City	Wind speed of max. frequency	Annual energy Mwh	Annual capacity factor (%)
Bozraiq	7.1	1434.12	19.30
Tazirbo	7.98	1877.5	26.01
jkhirra	7.1	1743.58	24.15
Mrawa	7.99	2187.34	30.02

TABLE4. PERFORMANCE OF THE AREAS UNDER STUDY

City	Scale parameter C (m/s)	Shape parameter K	Probability (%)	Annual mean wind speed
Bozraiq	5.5835	3.1199	13.78	6.3
Tazirbo	8.9768	3.0912	135.3	6.7
jkhirra	8.6479	3.0828	13.66	6.5
Mrawa	9.3410	3.23	12.54	7.2

VII. CONCLUSION AND RECOMENDATIONS

1-The results of this paper indicates the possibility of utilizing wind energy in electricity generation for some selected areas and linking it with the general electric power grid as in cases of Mrawa, Tazirbo and Jkhirra, while the Bozraig could be used in other applications such as battery charging or pumping water.

2- Mrawa has the maximum annual energy and capacity factor while Bozraig has the minimum annual energy and capacity factor.

3-Existing data resources indicates that the mean annual wind speed of 7.2 m/s at Mrawa with theoretical capacity factor exceeding 30.02 %. These values indicate that Mrawa could generate 2187.34 kWh.

4- More modern wind measuring equipments and an advanced soft wares should be available to increase the accuracy of the work.

5- Making campaigns to measure wind speed data in order to cover the majority in our country, paving the way for making a wind Atlas.

6-Making studies about the effect of entering the wind energy systems to the general electric grid

7-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.

7- The Universities and the scientific centers of North Africa countries should work together as one team in the field of renewable energy, this will reduce the cost and save the time required.

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