INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 4, Issue 5, 2013 pp.807-814
Journal homepage: www.IJEE.IEEFoundation.org

Assessment potential wind energy in the north area of Iraq

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Abstract
Wind energy is renewable and environment friendly, which can be connected for various end-uses. A precise knowledge of wind energy regime is a pre-requisite for the efficient planning and implementation of any wind energy project. However, due to the absence of a reliable and accurate Iraq Wind Atlas, further studies on the assessment of wind energy are necessary. The main purpose of this paper is present and perform an investigation on the wind energy potential in the northern area of Iraq. Therefore, in this study, wind data collected over a period of nearly three decades at five different locations in order to figure out the wind energy potential in this region. The data from selected stations were analyzed using the two-parameter Weibull probability distribution function. The higher probability frequency wind speed at windy month (July) is found in Tuz and Tikrit stations. In Tuz the range (2.5-3.0 m/s) taken about 45% from the domain wind, In Tikrit the high ranges of wind (3.5-4.0 m/s) and (4.0-4.5m/s) form 40.9% and 36.4% of wind speed frequency, but high frequency of low wind speed is concentrated at Biji, Kirkuk and Mosul. This is reflected on The maximum expected energy output (13.5kw/h) occupied at Tikrit station. Overall The study presented here is an attempt to promote wind energy in north Iraq and to bridge the gap in order to create prospective Wind Atlas of Iraq.

Keywords: Wind energy; Wind data; Weibull distribution; Wind energy potential; Iraq.

1. Introduction
Electric energy is an important index of a country ‘s economical and technological progress, and in the wake of the oil and natural gas reserves, rising coast of this type of fuel and the negative environment impacts such as air pollution, acid rain and greenhouse effects associated with it. therefore renewable energy gained great importance, its domestic, clear, free and inexhaustible. Thus more work and effort have been made to develop this energy resource, and many studies have been completed to estimate the potential of wind and potential to generate electrical energy in different parts of the world, first of these in the United States as it dependent on statistical analysis of monthly average wind speed and the annual [1]. In other extracted values of average total wind power depending on annual wind speed and quarterly to the United States through the use of third Wallace frequency tables of wind speed [2]. In Denemark and at 1981 Peterson in [3] make convention between Weiball function and wind speed variation. While the universal analysis in 1990 show the relationship between power that results from the wind farm and the surface type [4]. In Pakistan many studies made in 2004 to study wind power in the Castile region depending on Weiball distributions and by used different diameter of (blades) of turbine and the promising region is Jivani & Pasni [5]. In Spain and specially, In 2004 Torres used in [6] model autoregressive moving average process to forecast hourly wind speed and its relationship to topographic of earth surface and tilting to the persistence and its effect on the wind power. In Iraq, many studies

performed to treat the problem of lack in the generation of electric power, one of these solutions can be done by substituting electric power station that uses oil and organic matter with electric power station uses wind farms. but where you can instill this farms, this paper takes northern area of Iraq to study possibility of install this farms. And also further knowledge about wind resource of this area, by correlating the result of qualitative studies with statistical analysis of available records. Data of this study was gathered from five sites where its analyzed in order to support the evaluation and planning of future wind energy projects in this region.

2. The theory

2.1 Probability density function

Wind speed for a given location can be characterized by several probability density functions. For wind data analysis, the Weibull and Rayleigh probability density functions are commonly used and widely adopted [7, 8]. Here, the Weibull density function is used to describe the wind speed frequency distribution. The Rayleigh distribution is a special case of the Weibull distribution. The general form of the two-parameter Weibull probability density function is mathematically expressed by [9]:

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

where *f(u)* is the probability of having a wind speed of *u* (m/s), *k* is a dimensionless shape factor, and *c* is the Weibull scale factor with units of speed (m/s), which could be related to the average wind speed, on the other hand shape factor, k, describes the distribution of the wind speeds and have condition (k>0, c>1 at u>0). The relationship between the Weibull scale factor c, Weibull shape factor k and average wind speed $\overline{X}$ is given by the following formula:

$$\overline{X} = c\Gamma\left(1+\frac{1}{k}\right) \tag{2}$$

where Γ is the usual gamma function (can be given from standard tables). The parameters *k* and *c* may be estimated by the following equation [5, 10]:

$$k = \left(\frac{S.D.}{\overline{X}}\right)^{-1.086} \tag{3}$$

where $\overline{X}$ is average wind speed, *S.D.* is Standard deviation of wind data.

$$c = \frac{\overline{X}}{\Gamma\left(1+\frac{1}{k}\right)} \tag{4}$$

2.2 Wind energy potential

At a wind speed u, the available energy per unit area perpendicular to the wind stream over given period of time t is expressed by the kinetic energy flux as [11]:

$$E_a = 0.5\rho u^3 t \tag{5}$$

where ρ is the air density (kg/m^3 is equal to 1.2kg/m^3 at 1.013bar) and E_a is the theoretical total energy available for doing work on the wind turbine. However, only a fraction of the total energy would be extracted. The maximum extractable energy from a system working at its optimum efficiency is limited by a coefficient of performance called the Betz limit (16/27 = 0.593). This capacity factor makes the extractable energy approximately 59.3 % of the theoretical energy and is given by [12]:

$$E_m = 0.2965 \rho u^3 t \tag{6}$$

3. Site measurements and data preparation

The northern area of Iraq (the area selected in this study) is considered transition zone because it located between mountain in the extreme north east and the opening plains in the south, this may be considered as the most promising locations where wind machines can be installed. The data from this region, were gathered at five sites, namely; Tikrit, Tuz, Biji, Kirkuk and Mosul; by the Iraqi Meteorological Organization and Seismology, The corresponding location of the sites investigated is shown on the map, (Figure 1). The wind data are made up as time series and frequency statistics based on observations of wind speed and wind directions recorded every hour time intervals. Approximately thirty years or less of data is available for each selected site (1981-2010). In this type of study Long period measurements are needed for a good wind energy assessment. The longer the period of collected data, the more reliable are the estimated wind potentials. However, one year data is sufficient to predict the trend of seasonal mean wind speed within an accuracy of 10 % and a confidence level of 90 % [13, 14]. Hence the data collected could be used for a preliminary analysis frequencies of a certain wind speed as well as the monthly and annual mean wind speeds, to bring out useful conclusions on the wind regime characteristics of this region. This can be done by maintained anemometer coupled to an electronic data-logger, through that all the Anemometers were mounted on a fixed height above the ground, usually 10m.

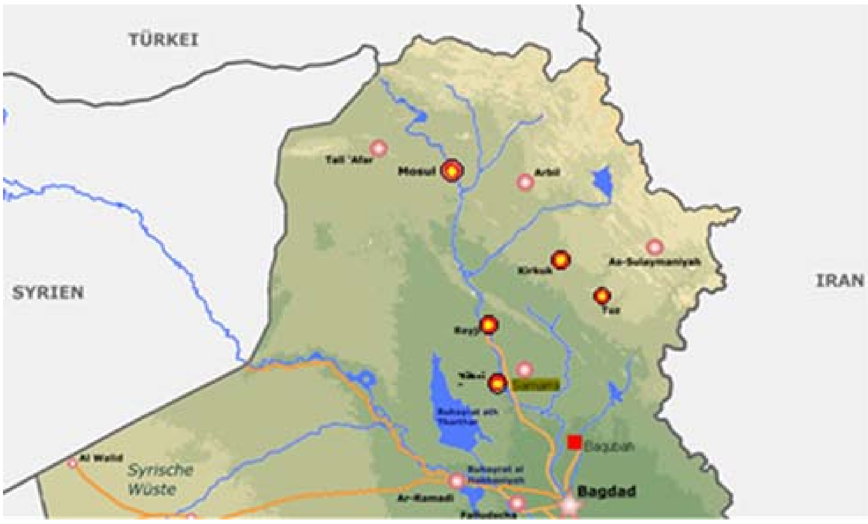

Figure 1. Map showing the location of the sites utilized for this study

4. Results and discussion

4.1 Monthly and seasonally wind speed variations

The wind at a given site usually varies frequently in direction, and its wind speed change rapidly under gusting conditions. Each data recording represents an instantaneous wind speed but Usually wind assessment is based on monthly mean wind speeds, because most of the wind system design calculations are performed on a monthly basis and that the wind has a relatively homogeneous behavior within a month, even though speed average may not reflect a reasonable estimate of wind power available at a given site. Daily and even hourly changes in speed is more difficult to analyze because of the wind's randomness. Thus we will used The monthly average wind speed distribution to displays seasonal trends in wind speed power for all sites studied. Overall climate of Iraq has been defined as sub-tropical and four distinct seasons are noticed: a hot season (June-August), cold season (December-February) and two moderate seasons (March-May), (September-November). Figure 2 illustrates the monthly and seasonal wind variation of the site (Tuz) at height 10m and at selected year 2000. The resulting seasonal pattern in wind availability is characterized by high mean wind speeds during the hot season reached 2.4m/s in July, but cold season has minimum monthly mean wind speed 1.08 m/s arises in March and November. Table 1 illustrates the monthly average wind speed at two selected months, January that represent winter months and July that represent summer months for the five stations of study, where we select the maximum recorded for every month through all period of data recorded. From the results presented we see a big variation in wind speeds through the months of year and at seasons, this is clear at stations Tikrit and Biji, see Table 1.

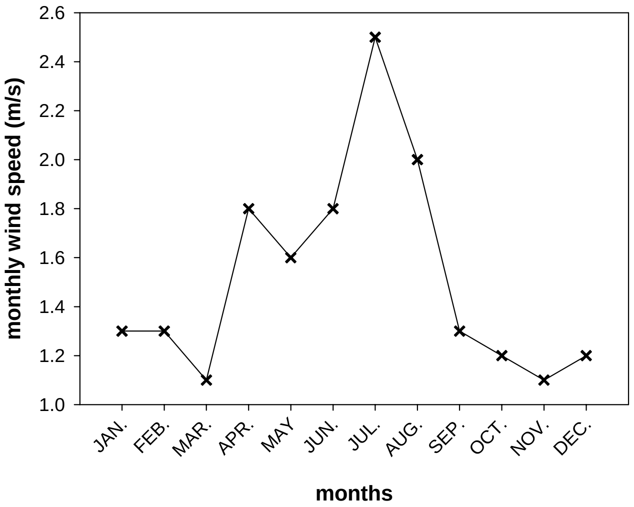

Figure 2. Variation of the monthly average wind speed at 10 m height for the site of Tuz at the year 2000

Table 1. Monthly mean wind speed variation in winter and summer in stations of study

Months	Monthly Maximum Wind Speed recorded (m/s)				
	Tikrit (1989-2010)	Tuz (1991-2010)	Biji (1980-2010)	Kirkuk (1980-2011)	Mosul (1980-2011)
Jan.	3.2	2.2	1.8	2.6	2.0
Jul.	4.9	3.2	5.3	2.8	2.5

4.2 Wind direction analysis

July gives the maximum average value of wind speed in the North zone of Iraq during any calendar year. A histogram of the wind direction measurements for the site of Tuz during this windy month is shown in Figure 3. From this figure we see that The prevailing direction of wind fall is from the north-west (NW) i.e. (315°-00) which is more than 70 % of all the time. The frequencies of wind coming from the remaining sectors are insignificant. This wind characteristic is compatible to the general climatic features of the country. Analyses of the overall wind direction frequency for July month and at all the sites are depicted in Figure 4, we notice also that the domain direction (270-30^0 deg.) form prevailing direction at all this stations, These results are important for planning wind turbine installation or in erecting wind machine to direct these machine to these predominant sectors.

4.3 Wind speed frequency distribution

The frequency distribution of wind speed is essential in evaluating the availability of wind power at any site. It also permits the selection of appropriate wind machines for exploiting the wind for such application. Histograms of frequency wind speeds and frequency simulated by weibull function equation (1) is shown in Figure 5, this figure exhibits that higher wind speed frequency is found in Tuz and Tikrit stations. In Tuz the range (2.5-3.0 m/s) taken about 45% from the domain wind, in Tikrit the high ranges of wind (3.5-4.0 m/s) and (4.0-4.5m/s) form 40.9% and 36.4% of wind speed frequency, but high frequency of low wind speed is concentrated at Biji, Kirkuk and Mosul. Comparison between the two sites confirms that the site is moderate between plains in south and mountains in north, benefits more wind presence at higher speed. Over all in these stations, there are no calms (zero wind speed) in the wind data. The monthly observed frequencies are compared with those obtained by Weibull density distribution (equation l). We notice that the monthly observed frequency is applied with fitted wind speed distribution in Mosul and Kirkuk Stations, but the prediction of mean wind speed frequency distribution in Biji, Tikrit, Tuz not match as closely that obtained from data. However The similarity of both trends illustrates the good representation offered by such a model when compared to the actual measured data.

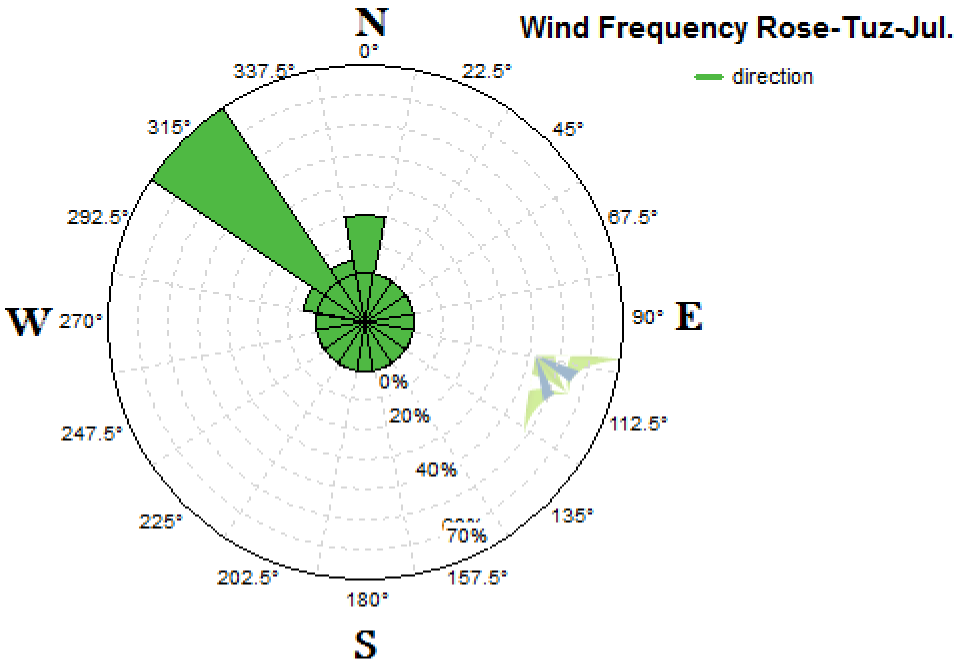

Figure 3. Wind direction frequency (wind rose) at July month for Tuz station (1991-2010)

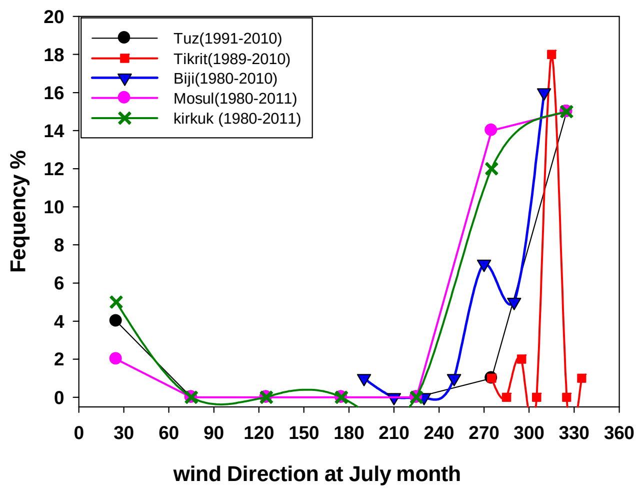

Figure 4. Overall observed wind directions frequency for 5 sites

Overall two parameters of the Weibull distribution can be easily estimated by using the wind speed data of the site. Table 2 summarizes the results of statistical properties for some sites at specified durations as well as Weibull parameters. The value of the shape factor, k, has been found to be slightly dependent on the location of station while The values of parameter scale, c, vary with the station, and are near to the average wind speed, This happens because the Weibull distribution is a reasonable fit to the recorded data [15].

By considering a typical wind machine with cut-in speed (3 m/s) and return to Figure 5 that shows domain wind speed frequency, we can draw some preliminary conclusions in terms of wind quantifies in space. For example stations Tuz, Kirkuk and Mosul would be at a standstill for about 95%, 94%, 100% and operate for about 5%, 6%, 0% of the time at partial load. Biji has about 40% of wind speed less than 3m/s and 60% over cut off, In Tikrit station all the recorded wind speed is over, see Figure 6 that show the cumulative wind speed frequency for Tikrit and Biji (other station don't state because of low wind speed frequency). In this regions wind speed is strong enough to energize a simple mechanical wind pump nearly all the time indicating the feasibility of wind powered irrigation in this region. It can also be observed that the chances of wind speed high enough for wind-electric generation can be occurring at these sites.

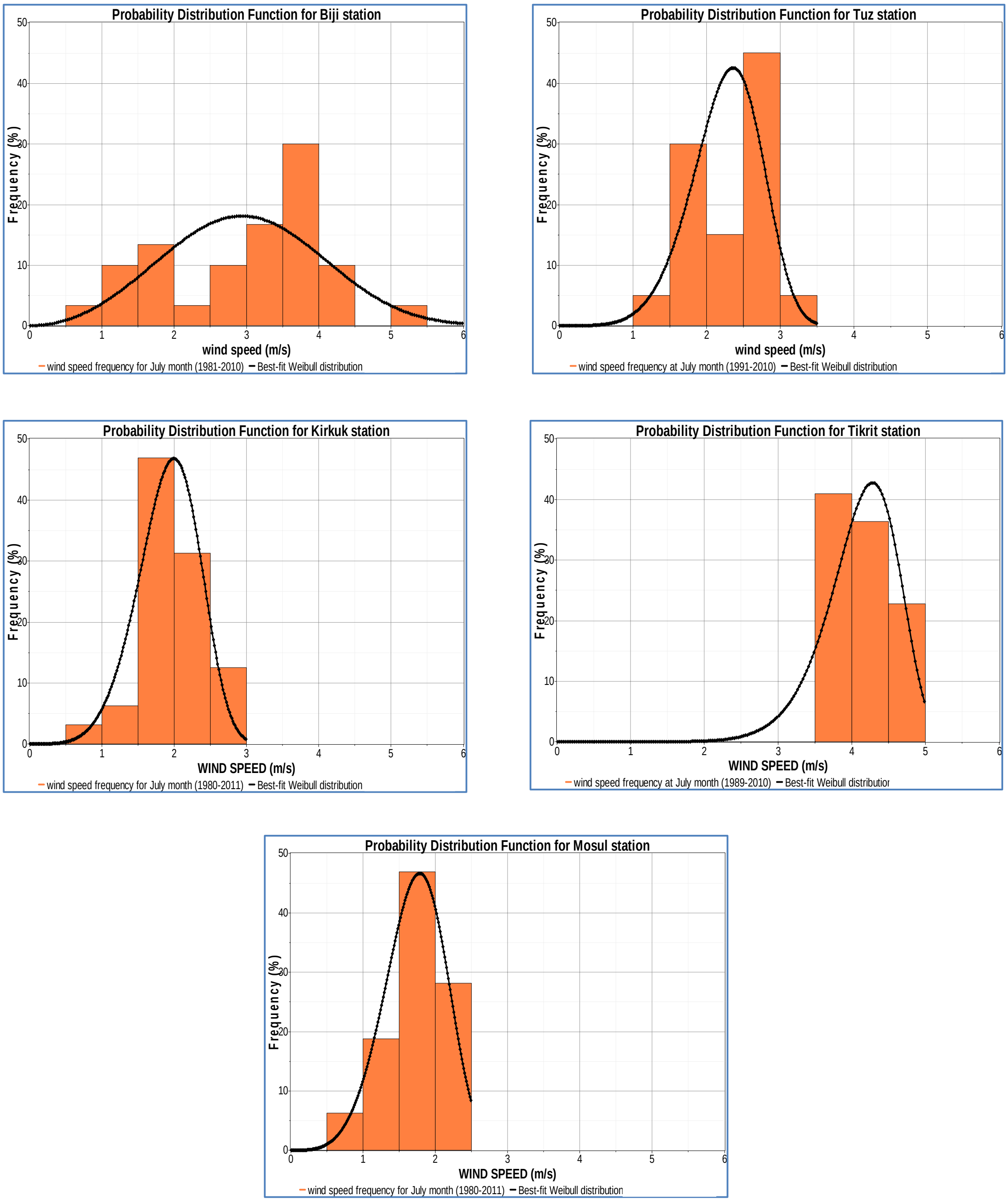

Figure 5. Histogram of the wind speed distributions simulated by Weibull function during July for the sites Biji, Tuz,Tikrit, Kirkuk, Mosul

Table 2. Annual statistical data analysis and Weibull parameters

	Biji (1980-2010)	Tikrit (1989-2010)	Tuz (1991-2010)	Kirkuk (1980-2011)	Mosul (1980-2011)
Mean	2.983	4.136	2.26	1.92	1.718
S.D.	1.107	0.354	0.398	0.299	0.333
Max	5.3	4.9	3.2	2.8	2.5
Min	0.8	3.5	1.2	0.9	0.8
Shape parameter (k)	2.934	14.411	6.5930	7.5263	5.932
Scale parameter (A)	3.343	4.2698	2.4221	2.0447	1.848

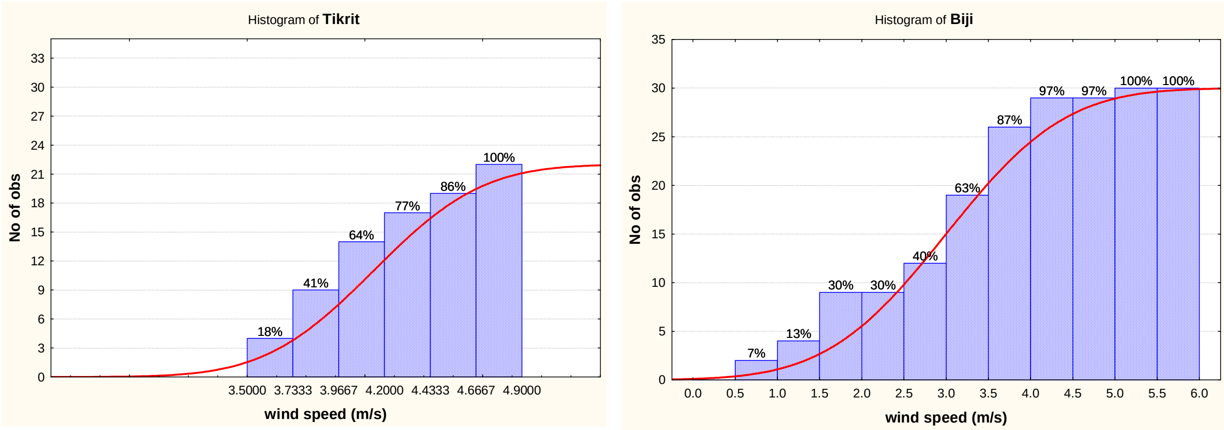

Figure 6. Cumulative wind speed frequency distribution of Biji and Tikrit stations

4.4 Energy extractable in the wind stream

The maximum fraction of the energy in the wind stream that can be extracted by a turbine rotor is given by equation 6. However wind machines are designed to operate within a certain wind speed range and it is not practical to extract all the energy from the wind stream over a given time interval. Figure 7 gives energy density produced from the wind during the month of July for Tikrit, Biji and Tuz at 10m height (we mention July month because its windy month over all time the year), wind power for other stations (Mosul and Kirkuk) is very low, thus its canceled in this figure. The maximum expected energy output is (13.5kw/h) occurs at wind speed 4.5 m/s in Tikrit station.

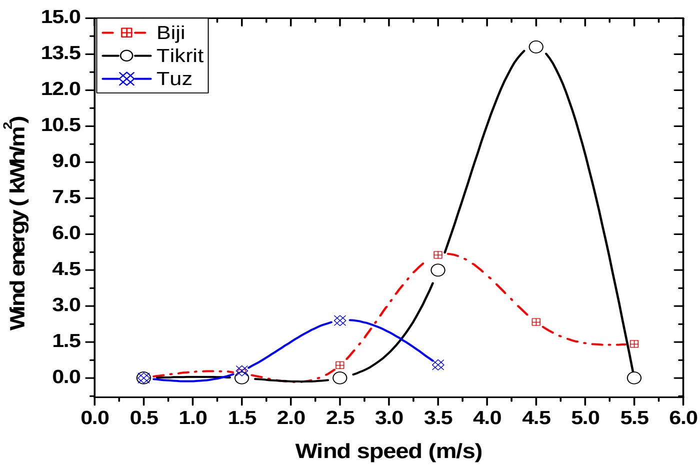

Figure 7. Maximum energy density during July for Tikrit,Biji and Tuz stations

5. Conclusion

The use of wind energy in Iraq is too limited. The main goals of this study were to identify and understand wind characteristics at northern area locations of the country and to evaluate potential for wind generation. An additional goal was an attempt to promote wind energy in Iraq and to bridge the gap in order to create prospective Iraq Wind Atlas. These goals were accomplished. On accomplishment of the study, the following observations can be drawn:

1. Overall the annual average wind speeds in northern region are moderate,this is based on data from the five locations. The highest average wind speed is recorded in july about 4.5 m/s in Tikrit station where an energy of 13.5 kWh/m^2 could be extracted.
2. The average wind speed is below the minimum speed, 5.0 m/s, needed for wind-electric generation, but wind powered water pumping applications appears to be a viable option. In addition, the demand of water for irrigation is seasonal and it is found that the windy season coincides with the dry season.
3. There is a distinct seasonal variation of the wind speed at all sites, which attains above average conditions during the summer periods, whilst dropping below average during the winter date.

4. A marked wind direction distribution is exhibited at all sites. Winds tend to blow from the sectors North-West to North-North-East with comparatively few days during which the winds blow from the remaining sectors.
5. The Weibull distribution is well suited for this particular area making it a handy tool for the calculation of parameters relevant to wind power generating systems.
6. The present work is only a preliminary study in order to estimate the wind energy potential at different locations. For a comprehensive study prior to construction and installing wind energy conversion systems, we should perform more detailed studies at each site separately.
7. More effort is needed to erect windmills for water pumping in rural areas with relative high wind potential. The result derived from this study encourages the utilization of wind energy in the region that located in north area of Iraq which included Tikrit, Biji and other sites.

Acknowledgements - The author is indebted would like to record his thanks to the meteorology of science in AL- Mustansiriyah University and to Ph.D Amani Al-Timymi for her powerful support during this paper was written.

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