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Assessment of Wind Speed for Electricity Generation in Makhool Mountain in Iraq

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Abstract— ***Conventional energy usage has various environments that cause global warming and this effect has forced many countries to use renewable energy resources. Despite the abundance of renewable energy resources in Iraq, the use of solar and wind energy is still in its technological and economic infancy. Makhool mountain is located in north of Iraq.***

In Iraq, the electric power generated is not enough to meet the power demand of domestic and industrial sectors. The present study deals with the assessment of wind speed for the electricity generation over Makhool mountain (Latitude 35° 7' and Longitude 43°25') in Iraq by analyzing wind speed data during the period (January 2011 –November 2013).Monthly and annual wind speed, power and energy density at 10 m and 50 m above ground level calculated. The annual mean wind speed of Makhool is obtained as 3.87 m/s at 10 m/s and 5.87 m/s at 50 m. It can be seen that the wind is suitable for electricity generation. From the result this site has a great potential for harnessing wind energy. Also, Makhool Mountain is the best site for wind energy in Iraq in comparison with the other sites.

Index Terms— ***Wind speed, Assessment, Electricity generation, Iraq.***

I. INTRODUCTION

Throughout history, people have harnessed the wind in many ways. Windmills originated in Persia during 600 A.D. The energy in the wind comes from the sun or wind energy is actually a form of solar energy, as wind is caused by heat from the sun. Wind results from the fact that the earth's equatorial regions receive more solar energy than the Polar Regions, and this sets up large scale convection currents in the atmosphere.

Due to the increase in the cost of the fuel used in traditional electricity power generation plants as well as the environmental pollution due to the smokes emitted by those fuels, the electrical power generation projects by using wind are more economical and non pollutants[1].As known, harmful emissions released from various sources such as CO, CO2, NOx and SOx have been causing negative effects on the atmosphere. Recently it has been reported by the International Energy Agency that 46% global electricity would be from renewable energy sources by 2050[2].There has been a significant increase in electrical energy demand due to the technological developments over the world. The ratio of the electric power produced via usage of renewable resources except the hydroelectricity in 2002 is only 2%. Wind energy is called to play a crucial role in the future energy supply of the European Union and of the world.

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Due to their technical and economic feasibilities, wind energy conversion systems were widely used in the electricity productions. Knowledge of the statistical properties of the wind speed is essential for predicting the energy output of a wind energy conversion system[3]. If ever the wind speed distribution in any windy site is known, the power potential and the economic feasibility belonging to the site can be easily obtained. Several papers were published, in the last three decades in Iraq and abroad, to determine wind characteristics, and electricity generation cost[4][5][6][7][8][9][10][11].

In Iraq, the electric power generated is not enough to meet the power demand of domestic and industrial sectors. Renewable energy has played an important role to meet increasing energy demand especially in the desert and rural communities. The aim of the present study is to analyze and predict the wind speed and wind power at Makhool mountain region during the period (January 2011 –November2013). The distribution of wind speed is important for the design of wind farm and knowledge of the wind speed frequency distribution is a very important factor to evaluate the wind speed potential in windy areas. This research can be considered as a base of wind energy application in this site.

II. SITE LOCATION

This region is one of the most important zone in the north of Iraq. The site is situated to the east of the main highway toward Mosul Governorate. The site contains rocky hills with wooded slopes within the Irano-Turanian and Sahara-Sindian Desert biomes and includes both the Makhool foothills that extend from the western borders of Al Fattha toward Asherkat and the steppe situated on the eastern side of the main highway linking Baiji and Asherkat. The northeastern edge of the site borderer the Tigris River and steppes that are situated in Kirkuk. This site includes an area called Al- Fattah "the Opening", which is a narrow gapping between Himreen foothill that extend from the eastern edge of Makhool Mountain. Crossing the western ridge of Makhool the habitat changes frequently between the two biomes Dry steppe and arid land is the dominant habitat of the site as viewed from the Himreen foothills on the highway road entering Kirkuk Governorate. The Baiji Oil and Gas Field Development Station, one of the largest oil and gas facilities in the northern part of Iraq is situated to the south of the site. The height of this site reaches 540 m. The location of the Makhool site on the Iraq is shown in Fig. (1).

III. MATHEMATICAL ANALYSIS

Wind speed in any region is not constant, but varies over periods of variation, seasonal variation and yearly variation. The key wind parameter is the mean hub height wind speed. This is the most significant measure of the quality of the wind resource at the site, and is the main determinant of how productive a particular wind turbine will be at the site. Wind average or mean wind speed or resultant wind is the:

$$\bar{V} = \frac{1}{N}\sum_{i=1}^{N} V_i \qquad (1)$$

Where N is the sample size, and Vi is the wind speed recorded for the observation.

Power plant sizing would, however, be crossly underestimate if it were rated at the mean energy velocity, which because of the power dependence on the cube of the wind velocity, is given by:

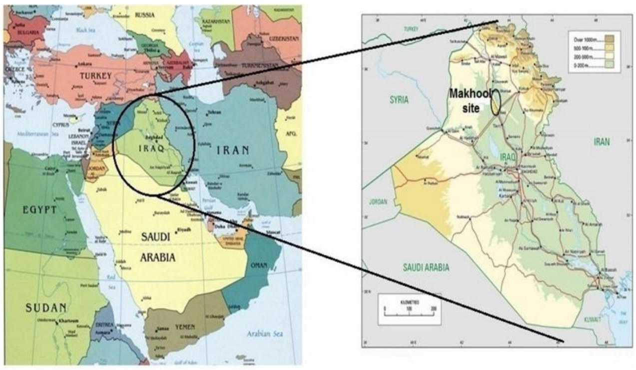

Fig. (1) Makhool location on Iraqi map

$$\bar{V}_E = \left(\frac{\sum_{i=1}^{n} V_i^3}{n} \right)^{\frac{1}{3}} \qquad (2)$$

The data produced by a wind monitoring can be analyzed by a wind rose. A wind rose is a diagram showing the temporal distribution of wind direction and azimuthally distribution of wind speed at a given location. In most of the meteorological stations, on the whole wind speed is recorded at 10 meters height above the ground. Since wind turbine hub height are typically between 30 and 50 meters, extrapolation of wind speed to the planned hub height is usually required to estimate wind potential. Many techniques and models have been established for height extrapolation of wind speed, the most important and widely used models are the power law model. Mean monthly wind speed at 50 m height is calculated using the following power model.

$$\frac{V_h}{V_a} = (\frac{Z_h}{Z_a})^{\alpha} \qquad (3)$$

Where Za is the anemometer height, Zh is a common hub height. And the exponent α characterizes the amount of wind shear and is a function of the surface roughness and terrain features up wind of the measuring site. It is considered to be variable with the measured wind speed Va and the anemometer height according to the relationship [12]:

$$\alpha = \frac{0.37 - 0.0881*\ln(V_r)}{1 - 0.0881*\ln(\frac{H_r}{10})} \qquad (4)$$

The wind speed probability density distribution and their functional forms represent the major aspects in wind related literature. The weibull distribution model has been found useful and appropriate for wind turbine performance analysis by many investigators:

$$P(V_i \succ V) = e^{-(V \succ Cr)^{K_r}} \qquad (5)$$

Where:

$P(V_i \succ V)$ = Probability that incoming wind velocity exceeds a value at reference height.

$Kr = 1.09 + 0.2V, \quad Cr = V/(\Gamma(1+(1/Kr))$

It is well known that the wind energy power is directly proportional to the cubic wind speed. The wind power (Watt) is given by the following equation:

$$P = \frac{1}{2}\rho A V^3 \qquad (6)$$

Where Hm is the site elevation in meters.

The wind power density (W/m2) was calculated using the following equation:

$$\frac{P}{A} = \frac{1}{2}\rho V^3 \qquad (7)$$

The total power of a wind stream in eq. (4) is directly proportional to its density, area, and the cube of it velocity. It will shortly be apparent that the total power discussed above cannot all be converted to mechanical power. In other, a wind power is capable of converting no more than 60 percent of the total power of a wind to useful power. The real efficiency (η) is the ratio of actual to total power, therefore the eq. (4) becomes:

$$P_{actual} = \eta \frac{1}{2}\rho A V^3 \qquad (8)$$

Where η varies between 30 and 40 percent for real turbine. Fig. (2) shows the maximum efficiency for an ideal wind power and various other wind turbines.

IV. EXPERIMENTAL FACILITIES

While determining the position of weather station installed at Makhool site, the building that hinder measurement were taken in to consideration to ensure that there were no obstacles at the around the measurement area. The site should be located where temperature and humidity are not to be influenced by heat and water sources. Nearby obstructions can affect the wind and solar radiation sensor. The World Meteorological Organization (WMO) defines open terrain as an area where the distance between the anemometer and any obstruction is at least ten times the height of the obstruction. There is a bubble level and compass on the tripod base. The tripod base should be level and the compass side faces north. The solar panel solar radiation assemblies over the front cover. In the northern hemisphere, the solar panel faces South. Solar panel latitude adjustment is to make the solar panel perpendicular to the sun's rays at noon. There are five holes arranged around the panel pivot allowing angles of 15°, 30°, 45°, 60° and 75° as measured from the horizontal. Fig.(3) shows the weather station which used in this study. This system is a remote electronic data logger which measures temperature, humidity, barometric pressure, wind speed and direction, rainfall, and solar radiation. During the data logging time interval, the wind speed and direction are averaged, the maximum wind speed captured and the solar energy calculated. All data is saved to non-volatile RAM. The Port Log communicates directly to a PC via an RS232 serial port. The logger's weatherproof housing provides sensor mounting and houses a rechargeable lead acid gel cell battery. A Solar Panel and power line charger are supplied to recharge the battery.

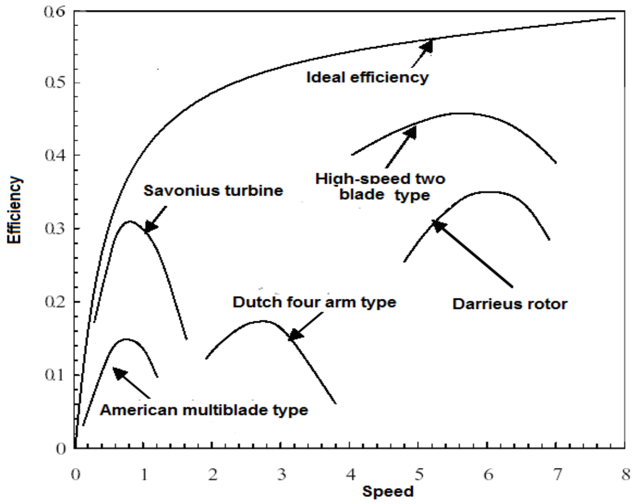

Fig. (2) Maximum efficiency for an ideal wind power and various wind turbines.

The data collection was made at an interval of every second and the hourly average values are also recorded. An uncertainty analysis was needed to prove the accuracy and reliability of the experimental data taken. As a result; the total uncertainties of the measurement are given table 1.

Table (1) The main characteristics of the elements of the weather station

Product specifications	Wind speed	Wind directions	Temperatures
Measurement range	0-67 m/s	0 – 360°	-54°C to 65°C
Accuracy	±2%	±3°	±5 °C
Resolution	0.1%	1°	-

Fig. (3) Port log weather station

V. RESULTS AND DISCUSSIONS

The average monthly wind speeds for the whole three year was shown in Fig. (4). It can be seen from the Fig.(4) that the highest average speed values occurs during March up to September and it becomes maximum during June-July-August and that the monthly value of wind speed in stations mostly exceeds 3 m/s but the monthly average values of wind speed do not exceed 5.1 m/s during the whole period. The higher average wind speed in summer months is very beneficial because the higher electricity consumption occurred in the summer months.

The mean wind speed calculated from the actually recorded data at 10 m height and the corrected values at 50 m the tower height are shown in table.(2) according to the eq.(3). It can be observed that the wind speed at 50 m height is nearly 33% higher than that of 10 m height. Wind power availability in Makhool mountain also varies on an annual basis.

Fig.(5) presented the annual average speed that would have been achieved on each year from 2011 to 2013 with a long-term average speed of 3.88 m/s. Annual average speed range from a minimum of 3.84 m/s in 2012 to a maximum of 3.91 m/s in 2013. To apply the distribution of the wind farms along the country measurements for the average wind speed in some areas must be studied to give the appropriate decision of choosing the suitable areas for this purpose. Table-3 gives the actual wind speed (m/s) in Iraqi governorates for the period of (1981-2000) [9]. Also; it is shown that the Makhool site one of the best region for used wind energy for electricity production in Iraq. In Fig.(6) hourly average wind speed in Makhool site are given for March-June-July time period. It is observed that the wind speed decreased with time until the midday, after that wind speed begin to increased toward the sunset. June has wind speed greater than 8 m/s during day time and the maximum wind speed was occurred at the 1 A.M. because of the valley and mountain wind. The wind directions in Makhool site which categorized in eight nominal scales of wind direction by a clockwise (N,NE,E,SE,S,SW,W,NW) as shown in Fig.(7), below. It can be seen that the no predominant wind direction in this site. The highest ratio was the north direction and the lowest ratio was the south west direction, but the ratio for the all direction was similar.

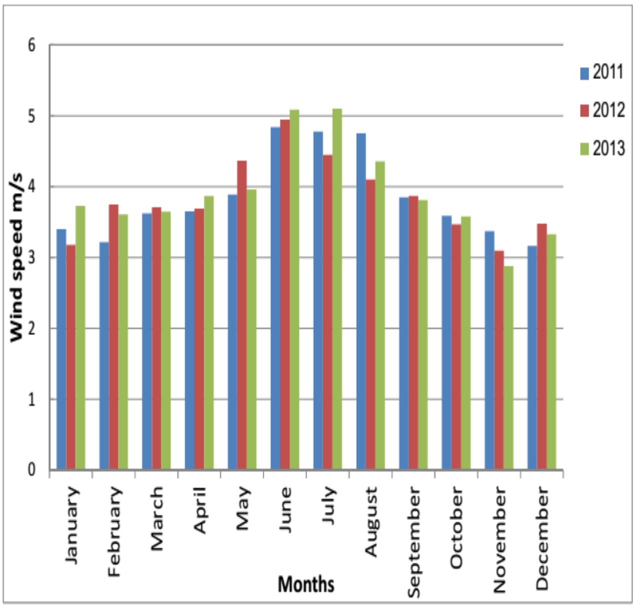

Fig. (4) Distribution of monthly average wind speed.

Table (2) Wind velocity at 50 m height at Makhool site

Month	Wind speed (m/s) at 10 m height	Wind speed (m/s) at 50 m height
January	3.44	5.14
February	3.53	5.27
March	3.66	5.47
April	3.74	5.59
May	4.07	6.09
June	4.96	7.42
July	4.78	7.14
August	4.40	6.59
September	3.84	5.75
October	3.55	5.30
November	3.12	4.66
December	3.32	4.97
Annual average	3.87	5.78

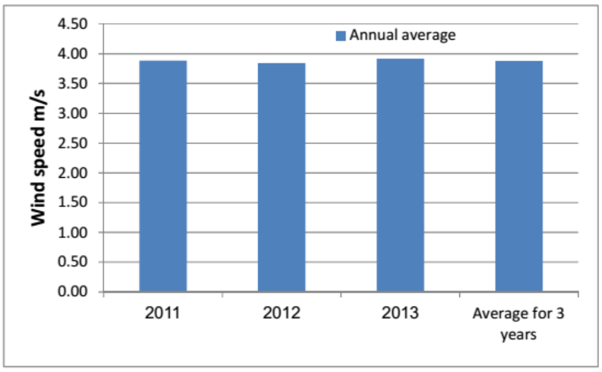

Fig.(5) Comparison of the annual average speed for 2011-2013.

Table .(3) The annual average wind speed for different Iraqi towns.

City	Annual average wind speed (m/s)
Mosul	2.2
Kirkuk	2.8
Nasria	3.9
Hilla	3.3
Baiji	2.4
Najif	2
Basrah	3.1
Rutba	3.4
Hawija	2.28
Makhool	3.88

Fig.(8) shows the typical frequency curve of wind speed for the study region. It is noticed that the speed between 3 to 3.99 m/s was the dominant speed in the Makhool site, and this speed is very benefit for electricity production. The time series of hourly wind speed are shown in Fig. (9). This figure showed that the large variation through the year but the maximum average speed was occurred in the summer months. The power in the wind is the flux of the kinetic energy passing through the vertical cross-sectional area of the rotor disk of wind energy conversion system. The wind power was calculated by using the eq.(8), where the air density ρ is calculated using the eq.(6). Table (4 and 5), show the result of calculation for power production and power density at 10 m height and 8 m diameter for wind turbine, also at 50 m and 80 m diameter for wind turbine.

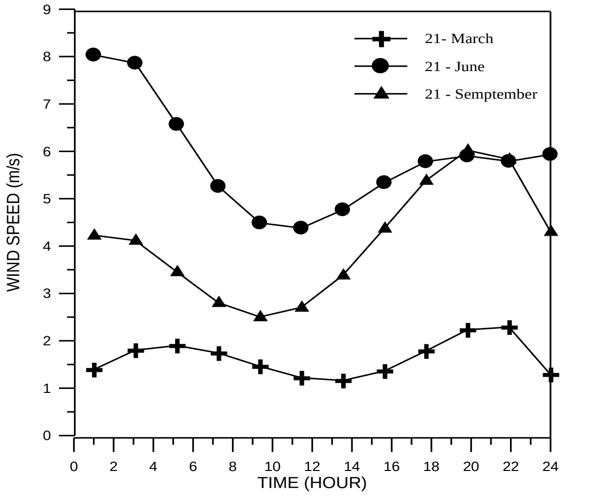

Fig.(6) Hourly average wind speed in Makhool for three days in different months.

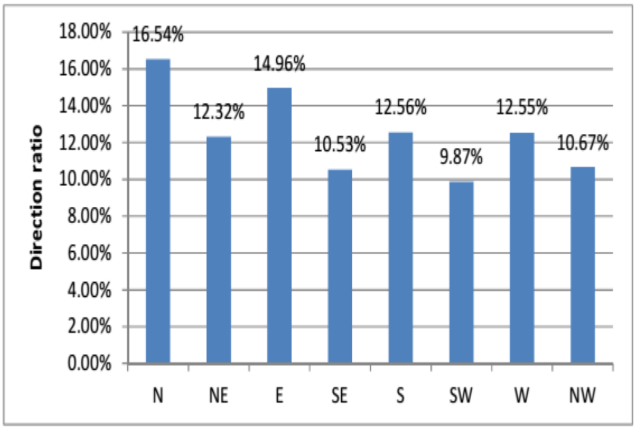

Fig.(7) . Wind direction in the Makhool mountain

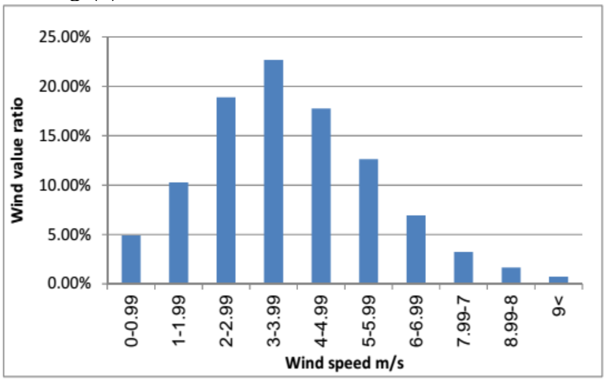

Fig. (8) Measured frequencies histogram for Makhool mountain.

Table (4) Monthly mean wind speed, Power, Power density at 10 m Height and 8 m diameter of wind turbine.

Months	Average wind speed (m/s)	Power (W)	Power density (W/m^2)
January	3.44	1245.05	24.76
February	3.53	1343.86	26.72
March	3.66	1504.88	29.93
April	3.74	1602.54	31.87
May	4.07	2074.33	41.25
June	4.96	3746.50	74.50
July	4.78	3343.27	66.49
August	4.40	2620.73	52.12
September	3.84	1741.20	34.63
October	3.55	1369.03	27.23
November	3.12	929.16	18.48
December	3.32	1126.22	22.40
Annual average	**3.87**	**1774.35**	**35.29**

Fig.(10) shows the monthly average of maximum speed. It is noticed the maximum value of monthly wind speed between 5.7 to 10.7 m/s was the dominant speed in Makhool site. Also, the maximum value of wind speed was recorded summer months (June – July - August).

Table (5) Monthly mean wind speed, Power, Power density at 50 m Height and 80 m diameter of wind turbine

Months	Average wind speed (m/s)	Power (W)	Power density (W/m^2)
January	5.14	416307.34	82.79
February	5.27	449346.41	89.36
March	5.47	503185.51	100.07
April	5.59	535842.24	106.56
May	6.09	693593.02	137.93
June	7.42	1252718.84	249.12
July	7.14	1117890.92	222.31
August	6.59	876292.82	174.26
September	5.75	582205.60	115.78
October	5.30	457763.35	91.03
November	4.66	310683.53	61.78
December	4.97	376574.41	74.89
Annual	**5.78**	**593290.86**	**117.98**

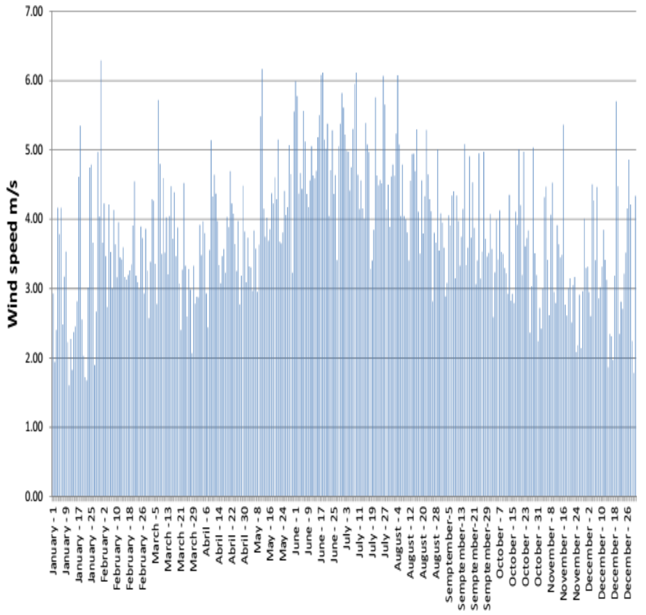

Fig. (9) Time series of daily average wind speed for three years in Makhool site

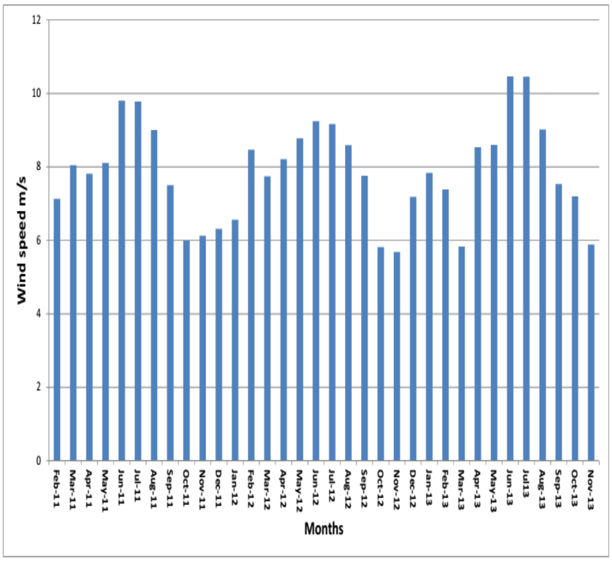

Fig.(10) The monthly average of maximum speed

VI. CONCLUSION AND SUGGESTION

In the present research, the assessment study of the wind potential energy for electricity generation in Makhool mountain leads to the following conclusions:

- The annual average wind speed at Makhool throughout the three year is 3.9 m/s and this velocity rate is agreeable.
- The direction of wind was changeable and no dominated direction in Makhool mountain.
- The production cost is 0.02 US$/kWh for wind mill whereas the conventional production cost 0.095 US$/kWh projected when the price of oil is 100 US$ per barrel. For reliable energy system, wind power production is essential
- The prospect for wind energy utilization using wind turbine technology seem good, especially in summer because the higher wind speed recorded and the rain is a little.

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