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Analysis of Wind Energy Potential in Using Weibull Distribution in Bukhara Region, Uzbekistan

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ABSTRACT: This article assesses the wind speed data and wind energy potential in the Bukhara region of Uzbekistan, in the south-western region. In recent years, research has been done to assess wind energy potential worldwide. The speed and direction of the wind measured at a height of 10 m were analyzed by the Weibull probability distribution function. Based on the Weibull probability distribution function, wind speed, wind power density and wind energy density values were investigated. To determine the direction of wind flow (wind rose), a graph in Matlab environment was constructed. The wind potential at different elevations was determined and analyzed. The results of the researches are given in tables and charts

KEYWORDS: Wind speed data, Weibull distribution, scale factor, shape factor, wind energy, wind rose.

I. INTRODUCTION

Today, the adverse effect on the environment has been adversely affected by the advances in the use of energy for human development. Currently, the use of natural fuels around the world amounts to about 12 billion tonnes of oil per year, approximately 2 tonnes per person. Excess greenhouse gas emissions due to the inclusion of renewable energy sources have led to climate change. This, in turn, has greatly increased the use of renewable energy sources. The use of renewable energy sources like solar, wind, biomass, geothermal and water energy is rapidly developing. Because of the low cost of electricity generated on renewable energy sources, there is almost no environmental impact, such projects are becoming more and more widely available, they are investing heavily in investment and prospective development and research.

The most promising project is the use of wind energy in renewable energy sources. China, United States and Germany are leaders in the use of wind energy. According to the Global wind energy concul (GWEC), 35% of the total energy produced from wind aggregates in the world is in China, 17% in the United States and 10% in Germany. The wind energy from 2001 to 2017 is presented in the graph below [1].

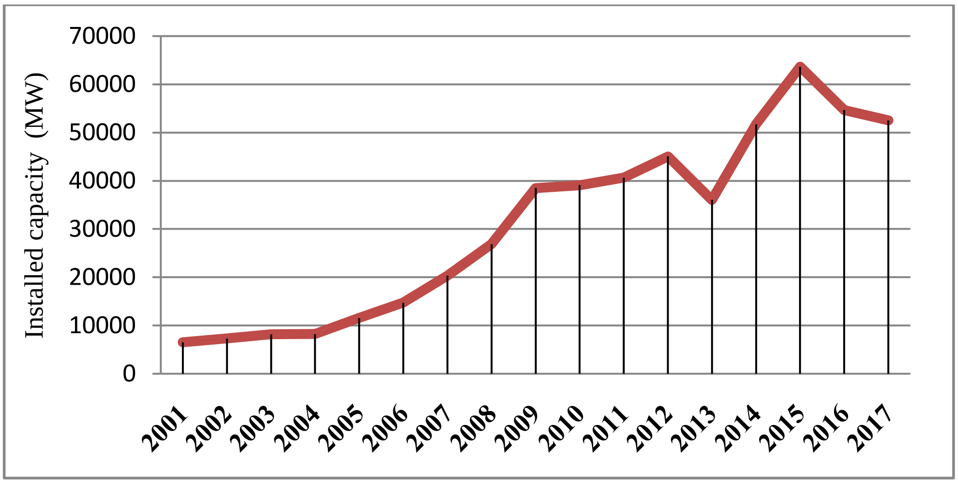

Fig.1.Global annual inctalled wind capacity2001–2017

Asia is the world's leading provider of wind energy. Produced wind energy in Asian countries in 2017 is 42%, European countries 28%, North and South America 18%, Africa and the rest of the world 12% [1].

In collaboration with German company Intec-COPA, GEONET and Uzbekenerego, research on wind energy potential and wind maps was conducted in Uzbekistan. Based on the results of the research, the wind potential has a capacity of 520 GW per year. This will generate approximately 1.7 trillion kWh of electricity annually [2].

Bukhara region is located in the south of $39{,}770^0$ and western $64{,}480^0$, its total area is 39,400 km2. The region basically consists of 75% of steppe and deserts. Research on wind potential in Bukhara region is under way. Based on the data from the meteorological station in the region, we determine the potential of wind energy in the region using the Weibull probability distribution function.

Weibull probability distribution functionis used by many researchers in different research studies because it has more precision. To achieve these goals, we determine the potential for wind energy at different altitudes by extrapolating the Weibull parameters using the two-parameters Weibull probability distribution function.

II. LITERATURE REVIEW

Today, many scientists have been carrying out numerous research projects related to the potential and properties of wind power. Let's take a closer look at the research on wind potential in the world.

A. Allouhi, O. Zamzoum and others evaluated the potential for wind energy in the coastal areas of Morocco using special forces and energy values using the Weibull and Reyleigh probability distribution function. According to this, in July, according to coastal areas, the specific strength of 50 m is 542 w/m^2 [3].

A. Rasham discovered the annual energy potential of the wind by extruding wind speed data and annual energy potential by using the Weibull and Reyleighprobability distribution at 60, 90, 120 m high [4] in three regions of Iraq.

A. Azad, M. Rasul, T. Yusuf provide extensive information on the methods of Weibullprobability distribution. The results obtained from different methods were analyzed and compared with differences [5].

S. Ali, S. Lee, Ch.Jangwas assessed the statistical analysis of the wind characteristics in the South Korean city of Incheon, Deokjeok-do, using the Weibull and Rayleigh distribution. In this article, wind potential is analyzed in months and the results are shown in the graphs [6].

M. Dahbi, A. Benatiallah, M. Sellam, the main purpose of this paper is to analyze wind potential in Algeria and analyze wind power potential of the Algerian steppe. Using the Weibull distribution, the results of the wind power density are shown in the graphs. A simulation model has been designed to determine the specific wind turbine characteristics. The results are shown in charts and tables [7].

III. WIND SPEED ANALYSIS MODEL

To accurately assess wind potential in the area, we use the two parameters Weibull probability distribution function, which is now widely used. Here, basically, scale factor and shape factor parameters defined using several methods. These techniques include queries [5,6,7,8,9,10]:

1. Graphical method (GM);
2. Method of moments (MOM);
3. Standart deviation method (STDM);
4. Maximum likelihood method (MLM);
5. Power density method (PDM);
6. Modified maximum likelihood method (MMLM);
7. Equivalent energy method (EEM).

Taking maximum and minimum wind speeds from the meteorological station, we calculate the average daily, monthly and yearly wind speeds from the following formula [4,5].

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

Here:
$\bar{V}$ −average value of wind speed;
V_i −daily rate wind speed;
N −number of collected data.

The wind is a variable amount and, accordingly, the standard deviation of the wind is determined by the expression below.

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$$\sigma = \sqrt{\frac{1}{N-1} \cdot \sum_{i=1}^{N} (V_i - \bar{V})^2} \quad (2)$$

Here:
σ −standard deviation of wind speed.

To analyze wind data, we have to define parameter two of the Weibull probability distribution, namely, scale factor and shape factor parameters. Scale factor and shape factorare determined by the following formula:

$$k = \left(\frac{\sigma}{\bar{V}}\right)^{-1,086} \quad (3)$$

$$c = \frac{\bar{V}}{\Gamma\left(1+\frac{1}{k}\right)} \quad (4)$$

Here$c$ −thescale factor refers to the variability of the distribution function speed along the speed scale, which has the speed dimension v and$k$ −describes the shape factorof the recovery of the distribution.
Γ −gamma function.

Statistical analysis of Weibull distribution models is proven for wind research. Weibull probability distribution function is not just about descriptive statistics of the wind, but with experimental data. The variable speed of the wind can be expressed by two parameters of the parameter; Weibull probability density and cumulative distribution function are important features of the wind speeds variability. The Weibull probability density function is detailed in these publications [9,10].

$$f(V) = \frac{k}{c} \cdot \left(\frac{V}{c}\right)^{k-1} \cdot e^{-\left(\frac{V}{c}\right)^k} \quad (5)$$

$$F(V) = \int_0^{\infty} f(V)dV = 1 - e^{-\left(\frac{V}{c}\right)^k} \quad (6)$$

According to Weibull distribution, the average of wind speed andstandard deviation also can be estimated as [10].

$$\bar{V} = c\Gamma\left(1 + \frac{1}{k}\right) \quad (7)$$

$$\sigma = c\,[\Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right)]^{1/2} \quad (8)$$

At certain altitudes, the density of the air, the wind speed changes. The density of the airflow according to the height is determined as follows:

$$\rho = \rho_0 - (1{,}194 \cdot 10^{-4} \cdot H) \quad (9)$$

Here:
ρ_0 −Density of airflow in normal conditions$\rho_0 = 1{,}23 kg/m^3$;
H −The height of the wind speed measured.

The wind speed values are related at any height. As the height increases, the wind speed increases. The following formula is based on the height of the wind speed:

$$V_2 = V_1 \cdot \left(\frac{H_2}{H_1}\right)^{\alpha} \quad (10)$$

Here:
V_2 −The wind speed measured at a certain height;
V_1 −Wind speed measured at the initial level;
H_1 −Station elevation;
H_2 −Selected height;
$\propto$ −Wind shear exponent.
The wind crossover indicator is determined by the following formula:

$$\propto = [0{,}096\, log_{10}(Z_0) + 0{,}016\,(log_{10}(Z_0))^2 + 0{,}24] \quad (11)$$

Z_0 − theroughness height of terrain. In the steppe areas Z_0 =0,1 m[10].

The values of the scale factor and shape factor parameters at the specified height also vary. The determination of these parameters is made by the following expression:

$$k_{H2} = \frac{k_{H1}}{1 - 0{,}0881 \ln\left(\frac{H2}{H1}\right)} \quad (12)$$

$$c_{H2} = c_{H1}\left(\frac{H_2}{H_1}\right)^n \quad (13)$$

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$$n = [0{,}37 - 0{,}0881\ln(c_{H1})] \quad (14)$$

Knowing the average speeds of the measured wind, the specific strength and energy potential of the zone are determined by the following formula [12]:

$$P = \frac{\sum_{i=1}^{N}(\frac{1}{2})\rho \bar{V}_i^3}{N} \quad (15)$$

$$E = P \cdot T \quad (16)$$

Here:
T −time duration.

By using the Weibull probability distribution function, it is possible to estimate the potential for wind energy to obtain wind power density or wind energy density. We define these parameters by the following formula [3,4 and 11,12,13]:

$$P_w = \frac{1}{2}\rho c^3 \Gamma(1 + \frac{3}{k}) (17)$$

$$E_w = \frac{1}{2}\rho c^3 \Gamma(1 + \frac{3}{k}) \cdot T (18)$$

IV.RESULTS AND DISCUSSION

In this study, wind speed data and wind energy potential analysis were examined in Bukhara region. The mean values of the wind speed measured at 10 m in 1 day and 30 mps were calculated and analyzed. The Weibull distribution determined the standard deviation, wind power density and wind energy density values by using the empirical method to determine the scale factor and shape factor parameters. Wind power densityandwind energy density values at different levels were determined by extrusion. Figure 2 shows the average wind speed in months of year 2016. The average wind speed is 3.404 m / s. Figure 3 illustrated of the wind direction (wind rose) in the Matlab environment. The wind direction is mainly from the north. Table 1 lists the estimated parameters and the approximate parameters for the Weibull distribution. Accordingly, the shape factor is k = 2.98 and scale factor is c = 3.75 m/s. Figure 4 shows the Weibull distribution function, probability density function and the cumulative distribution function. Figure 5 shows the wind power density values of the 10 m high wind speed using the Weibull division function in months. The largest wind power density isin June 93.18 w/m^2. The average annual wind power density is 40.98 w/m^2. Figure 6 shows the wind energy density values in the segment of months. The highest value is in June, i.e. 67.09 kwh / m2. The annual wind energy density value is 359.56 kwh/m^2. Figure 7 shows the linear speed of the wind speed. Accordingly, the average wind speed was 3.404 m/s in 10 m and 4.4 m/s in 50 m and 4.9 m/s at 100 m. Figures 8 and 9 show wind power density and wind energy density values of different height winds. Accordingly, the wind power density and wind energy density height of 100 m were 164.79 w/m^2, 1443.59 kWh/m^2.

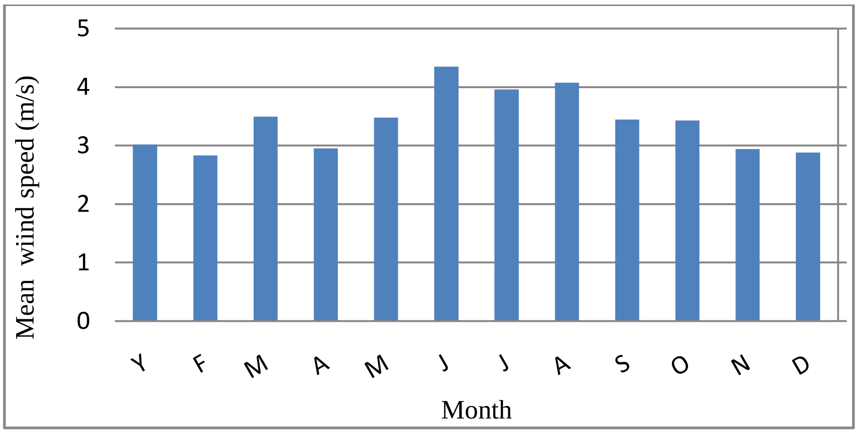

Fig.2. Monthly variation of mean wind speed in Bukhara region, Uzbekistan.

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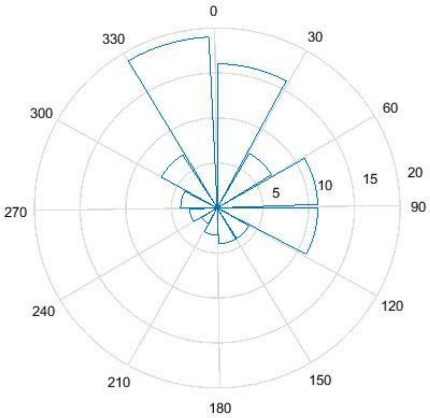
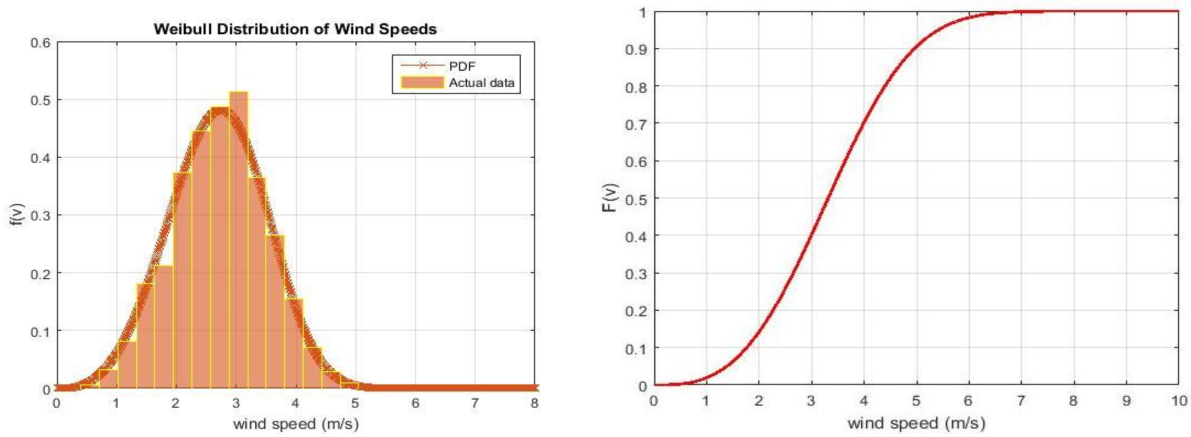


Fig.3. Wind rose

Year	Month	Parameters of measured quantities				Estimated Parameters by Weibull Distribution				
		$\bar{V}$ m/s	σ m/s	P w/m^2	E Wh/m^2	k (-)	c m/s	σ_w m/s	P_w w/m^2	E_w kwh/m^2
2016	**Jan.**	3.018	1.079	23.690	17.625	3.056	3.380	1.069	33.476	24.909
	Feb.	2.833	1.951	42.163	29.345	1.499	3.137	1.916	56.981	39.659
	Mar.	3.494	1.297	38.614	28.729	2.933	3.917	1.299	37.235	27.740
	Apr.	2.954	0.898	19.941	14.358	3.646	3.27	0.889	20.149	14.507
	May.	3.476	1.005	32.090	23.875	3.847	3.845	0.999	32.372	24.085
	Jun.	4.350	2.226	100.229	72.165	2.070	4.91	2.21	93.18	67.09
	Jul.	3.959	1.236	49.049	36.493	3.540	4.394	1.23	49.357	36.722
	Aug.	4.077	1.225	53.010	39.439	3.691	4.515	1.219	52.868	39.334
	Sep.	3.444	1.405	37.242	26.814	2.649	3.874	1.394	37.9	27.288
	Oct.	3.429	1.219	34.952	25.165	2.373	3.318	1.228	34.545	25.701
	Nov.	2.940	1.327	26.493	19.075	2.373	3.318	1.327	25.61	19.054
	Dec.	2.879	0.792	18.012	13.401	4.063	3.178	0.795	18.1	13.47
	Annual Average	3.404	1.305	39.62	346.48	2.98	3.75	1.29	40.98	359.56

Table.1. Measured and Weibull estimated parameters of Bukhara at station elevation.



(a) (b)

Fig.4. Distribution function of Weibull and frequency measured (a), Weibull cumulative distribution function with wind speed for selected sites at stations elevation of annual figure and scale factors (b).

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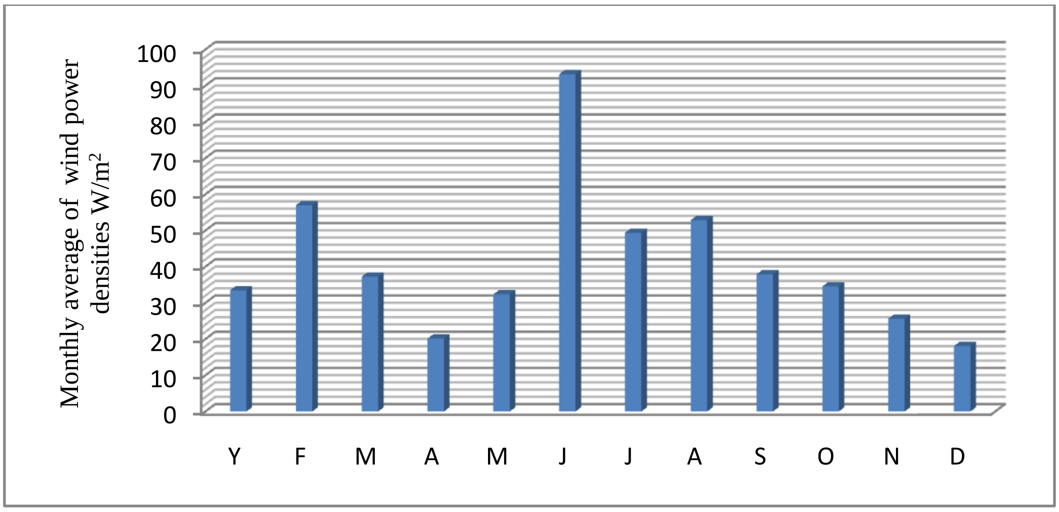

Fig.5. Monthly average for measured and Weibull estimated of wind power densities of selected sites at stations elevation.

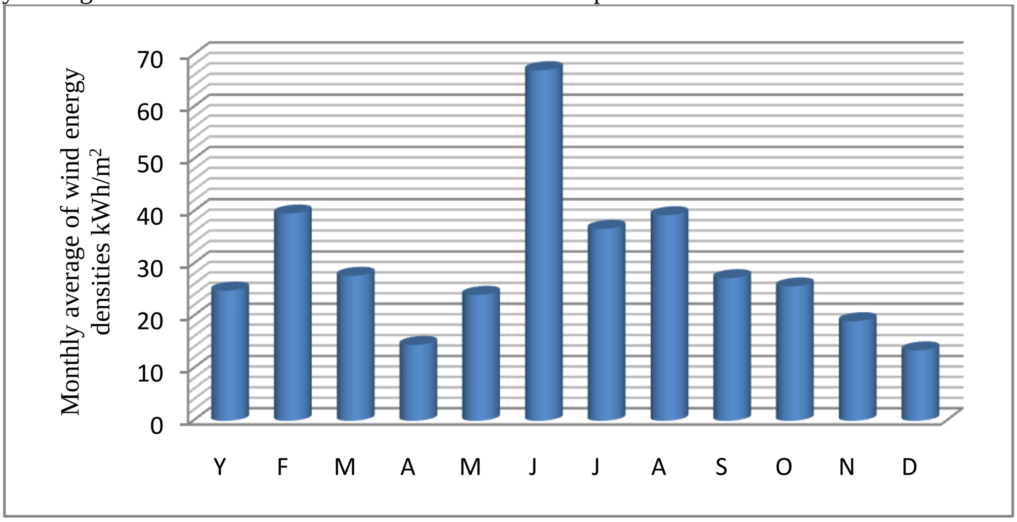

Fig.6. Monthly average for measured and Weibull estimated of wind energy densities of selected sites at stations elevation.

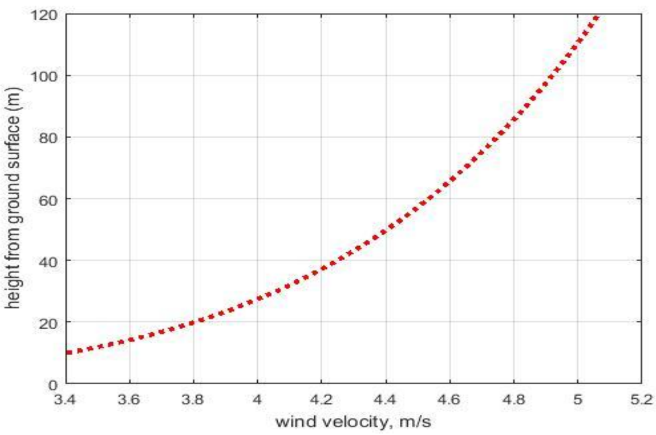

Fig.7. Wind shear of selected sites at selected heights for annual average of wind velocities.

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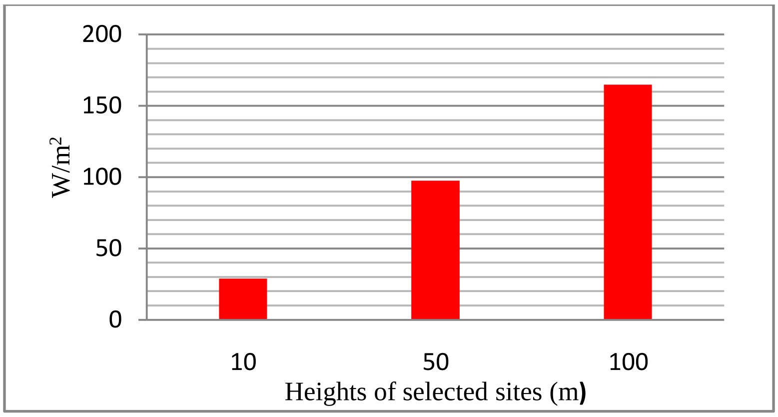

Fig.8. Annual average for measured and Weibull estimated of wind power densities of selected sites at selected heights.

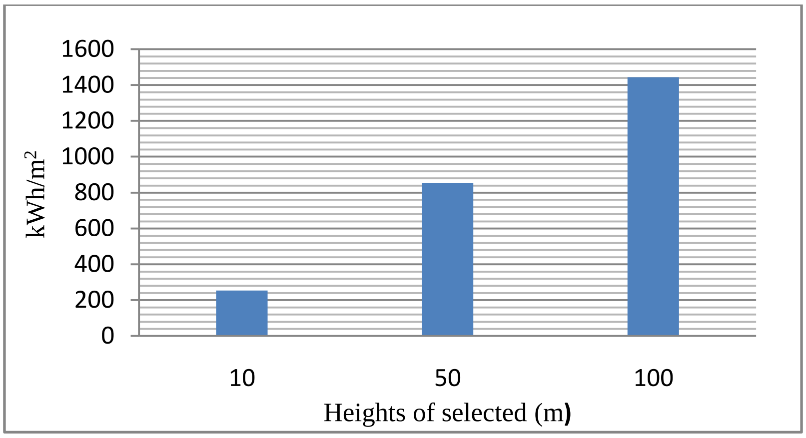

Fig.9. Annual average for measured and Weibull estimated of wind energy densities of selected sites at selected heights.

IV. CONCLUSION

The results of the research have lead to the following conclusions:

1. The maximum and minimum wind speed, wind direction data were obtained and analyzed from the meteorological station. Average speed of the measured wind is 3.404 m/s.
2. In the Matlab environment, the wind direction (wind rose) graph was constructed. The wind blows in the Bukhara region from the north.
3. Using a two-parameter Weibullprobability distribution function, yearly average shapefactor and scale factor were determined at a height of 10 m. Accordingly, k = 2.98, c = 3.75 m / s.
4. Wind power density and wind energy density values of 10 m were determined and analyzed using the Weibull probability distribution function. Accordingly, the average wind power density is 40.98 w/m^2, with an annual wind energy density of 359.56 kwh/m^2.
5. The wind potential at different heights was determined using the Weibull distribution. Accordingly, wind power density and wind energy density values of 100 m were determined by extrapolation method 164.79 w/m^2, 1443.59 kWh/m^2.
6. Analyzing the results, it is effectual to use low-powered wind turbine units in this region.

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