

## **Assessment of Wind speed for Electricity Generation in Technical Institute / Mosul**

### **تقييم سرعة الرياح لتوليد الطاقة الكهربائية في المعهد التقني / الموصل**

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#### **Abstract**

The present research deals with the assessment of wind speed for electricity generation in Technical Institute / Mosul for laboratory usage. A wind mill was designed and fabricated to carry out the experimental work, it was positioned on a tower of 30 meter height above sea level, and the wind speed was measured and recorded by Anemometer device every 20 seconds and then were averaged over 10 minute. The 10 minute average wind speed data were then averaged over one hour. All the wind speed data were measured and recorded close the wind mill apparatus.

The Weibull Probability Density Function for wind potential was calculated from the mean wind speed data and the Weibull scale factor  $c$  was calculated.

Experimented results showed that the relationship between the average wind speed  $\bar{V}$  and the scale factor  $c$  was  $c = 1.495 \bar{V}$ .

The measured and calculated wind speed data were also averaged over each eight hours period for each day of the whole month in March, and the experimental results revealed an average wind speed of 6.2 m/s which was available for large parts of the day.

The results also showed that there are certain periods in which the wind speed are useful for converting their power to an electricity for laboratory usage.

It was also concluded that there is an enough number of hours in which the wind speed of a high potential power are available and enough for running the wind mill.

The results obtained for the wind speed measured by Anemometer device and the Weibull Probability Density Function showed a best fitting between wind speed measured in the present study and the wind speed distribution for Weibull Probability Density Function which indicate that there is an efficiency and enough wind speed on the top of the workshop in Technical Institute / Mosul for the generation of electricity which can run the devices and the instruments for laboratory usage.

**Key Words:** Wind speed, Wind mill, Weibull scale factor, Weibull Probability Density Function, renewable energy.

#### **الخلاصة**

يهدف البحث الحالي تقييم سرعة وشدة الرياح في توليد الطاقة الكهربائية في المعهد التقني / الموصل للاستفادة منها في الاستخدامات المخبرية. تم تصميم وتصنيع طاحونة هوائية (Wind mill) لتنفيذ الاختبارات العملية وثبتت على برج (tower) يرتفع بمقدار 30 متر عن مستوى سطح البحر.

تم قياس وتسجيل سرعة الرياح لفترات زمنية وتم حساب المعدل لكل 10 دقائق ثم سجلت معدل سرعة الرياح (wind speed) لكل ساعة وذلك في الموقع المثبت عليه جهاز الطاحونة الهوائية. تم حساب دالة احتمالية ويبل لكثافة الرياح (Weibull Probability Density Function) من متوسط سرعة الرياح التي تم قياسها ثم حسب معامل ويبل للقياس،  $c$  (Weibull scale factor).

أظهرت التجارب العملية بان العلاقة بين معدل سرعة الرياح  $\bar{V}$  (Average wind speed) ومعامل ويبل للقياس  $c$  هي:

$$c = 1.495 \bar{V}$$

حسب أيضاً معدل سرعة الرياح التي تم قياسها لكل ثمانية ساعات فترة زمنية ولكل يوم وخلال شهر اذار. أظهرت النتائج العملية بأن معدل شدة سرعة الرياح الناتجة كانت 6.2 m/s وتبين بأن هذه المعدلات من سرعة الرياح متوفرة في فترات زمنية كبيرة من اليوم.

تبين أيضاً من خلال النتائج وجود فترات زمنية ولساعات عديدة أثناء النهار تكون فيها سرعة الرياح (wind potential)

مفيدة وبالإمكان استخدامها لتدوير مراوح الطاحونة الهوائية (wind mill fans) وتحويلها إلى طاقة كهربائية (Electrical power) لغرض الاستفادة منها في تشغيل الأجهزة المختبرية. كما تبين أيضاً من نتائج سرعة الرياح (wind speeds) التي تم قياسها بواسطة جهاز الانيموميتر (Anemometer device) ودالة احتمالية كثافة ويبل (weibull Probability Density Function) وجود تطابق كبير بين سرعة الرياح التي تم قياسها في البحث الحالي مع دالة احتمالية كثافة ويبل وهذا يبين بأن الطاقة الناتجة من سرعة الرياح كافية في الموقع المثبت عليه الطاحونة الهوائية لبناية الورش في المعهد التقني / الموصل والتي يمكن الاستفادة منها لتوليد الطاقة الكهربائية والتي تقوم بدورها في تشغيل الأجهزة وأدوات القياس الموجودة في تلك الورش.

**الكلمات الدالة :** سرعة الرياح، الطاحونة الهوائية، معامل ويبل للقياس، احتمالية كثافة ويبل، الطاقة المتجددة.

## **Introduction**

The European Countries especially Germany and Denmark have directed their efforts for the generation of electricity on both land and sea from wind energy, by building wind electrical power generation plants. 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 winds are more economical and non pollutants.

Special efforts have been directed by the Germany for the investment in a renewable energies (Wind, water and Solar) for electricity generation [1].

The National Energy Agency expected that the energy required in a year 2020 will reach to (327)GW. This means that a (16)GW will be added per year, and the Ministry of a Renewable energy in India expected that a (90)GW of electricity can be generated from the different types of Renewable energy in the country, and about (48.5)GW of electricity can be generated by wind potential.[2]

The total electrical power that have been produced by wind potential in year 2006 was (74.223)MW which equal to (1%) of the electricity used in the world.

The potential of wind energy can be considered as a renewable safe energy and it does not cause any pollution to the environment as a result it reduces the consumption of the fuel.[3]

The electricity that have been generated by the wind fields in the United States in the year 2007 was nearly 17 MW to fulfill the requirements of industry [4].

The required average wind speed for the turning on the turbine is ( 5.36 m/s) .

The major constituents of the wind mill systems are a rotary fans which are hold on the top of a tower, and a generator for converting the wind potential to electrical power.

The dynamic forces produced by the striking of air on the surface area of the fans lead to the rotation of these fans, as a result an electrical power is generated.[5]

The quantity of electrical power depend on both the wind speed tricking the rotating fans, the diameter of fans and the surface area of each fan, and for that reasons the turbines employed for electrical power generation that have been used for the running plants and for lighting are build up on the top of towers. This is because the wind speed increases with the height above earth level.

The weibull function was discussed for representation of the wind speed frequency distribution. The methods were presented for the estimation of the two Weibull parameter (Scale factor C and shape factor K) from wind statistics, and the recently proposed method based on the "square - root - normal" was compared with mean wind speed as input statistics.[6] The Weibull distribution was shown to give smaller root - mean - square errors than the square - root - normal distribution when fitting actual distributions of observed wind speed.

The method for estimating the actual expected power for a wind - powered generator from a given observed speed distribution was described and applied to estimate the potential output for different locations in the continental U.S.A contour map of generator capacity factor values (fraction of the rated output realizable) was obtained for wind - powered generator systems with a cut - in speed of (3.6) m/s for a unit with hypothetical values for the (1)MW class (Cut-in speed, 6.7 m/s; rated speed, 13.4 m/s). Results indicate that in the central U.S and in certain areas of the New England coast at a height of 61m, over 60% of the rated output power could be obtained on an annual

average. In these areas capacity factors of over 20% could be obtained with 1 MW system.[ The wind energy potential of the region Iskenderun (36° 35' N; 36° 10' E) located on the Mediterranean coast of Turkey was statistically analyzed for 1 - year measured hourly time - series wind speed data, and the probability density distributions were derived. Two probability density functions were fitted to the measured probability distributions on monthly basis and the energy potential of the location was studied based on the Weibull and the Rayleigh models.[8]

Three methods were presented for the calculation of the parameters of the Weibull wind speed distribution for wind energy analysis, those methods are: the maximum likelihood method, the proposed modified maximum likelihood method, and the commonly used graphical method.[9] The maximum likelihood method was recommended for use with time series wind data, and the modified maximum likelihood method was recommended for use with wind data in frequency distribution format which has been adopted in the present study.

The present investigation deals with the study of wind potential energy for electricity generation in Technical Institute / Mosul for laboratories usage.

### **Theory of wind power:**

The kinetic energy E of a wind can be expressed by the product of wind mass and the square velocity (V) divided by two.[10, 11]

$$\text{i.e. kinetic energy, } E = \frac{1}{2} m V^2 \quad \dots\dots\dots (1)$$

$$\begin{aligned} \text{The mass (m) of a wind passing perpendicular through unit area A at time (t) is} \\ m = A V t \rho \quad \dots\dots\dots (2) \end{aligned}$$

Hence

$$\text{Kinetic Energy, } E = \frac{1}{2} A V^3 t \rho \quad \dots\dots\dots (3)$$

The energy of a wind for a unit time t can be expressed as:

$$P = \frac{E}{t} \quad \dots\dots\dots (4)$$

Hence

$$P = \frac{1}{2} \rho A V^3 \quad \dots\dots\dots (5)$$

Where  $\rho$  represents the density of air

Equation (6) shows that the wind energy of a fluid (wind) passing through unit area (A) is mainly depends upon its density and velocity.

### **Experimental work**

The current study has been carried out for the assessment of the wind energy resources for the cooling and air conditioning work shops and laboratory usage of Technical Institute / Mosul. A wind mill was designed and fabricated to carry out the experimental work. It consists of two galvanized iron propeller blades of 2.4 mm diameter which rotates by wind energy around a rotor. The rotor was connected to the main shaft. The wind mill was mounted on a tower 30 meter above sea level in 36°N Latitude in the month mach [12] to capture the most wind energy, and to take advantages of faster and less turbulent wind. Fig. 1 shows a photograph of the wind mill that have been mounted on the roof of the cooling and air conditioning work shop in Technical Institute / Mosul.



**Fig. 1 Photograph of wind mill apparatus.**

The speed of the wind was recorded by Anemometer device of 0.1 resolution close the wind mill. The wind speeds were recorded every 20 seconds and averaged over 10 minute. The 10 minutes averaged wind speed data were average over one hour period as well as at 8 hour period.

The Weibull Probability Density Function for wind potential was calculated, and adopted in the present studies.[6, 13]

as

$$f(V)_w = \frac{K}{C} \left( \frac{V}{C} \right)^{K-1} \exp \left[ - \left( \frac{V}{C} \right)^K \right] \quad \text{..... (6)}$$

Where:

$f(v)_w$  = The weibull probability density function.

$V$  = Instantaneous wind speed (m/s).

$C$  = Weibull scale factor (m/s), and

$K$  = Weibull shape factor.

The relation between the weibull scale factor and the weibull shape factor is:

$$\frac{\bar{V}}{C} = \Gamma \left( 1 + \frac{1}{K} \right) \quad \text{..... (7)}$$

and

$$\frac{\sigma}{\bar{V}} = \frac{\sqrt{\Gamma \left( 1 + \frac{2}{K} \right) - \Gamma^2 \left( 1 + \frac{1}{K} \right)}}{\Gamma \left( 1 + \frac{1}{K} \right)} \quad \text{..... (8)}$$

Where:

$\bar{V}$  = The average wind speed.

$\sigma$  = The standard deviation of the wind speed, and

$\Gamma$  = The Gama function.

The wind speeds that have been measured by Anemometer device on the roof of the cooling and air condition workshop close to the wind mill were measured and recorded and the wind speed distributions were plotted in Fig. 4 as shown in Table. 1.

The Weibull parameters were then calculated.[14]

as

$$f(v)_w = 1 - \exp \left[ - \left( \frac{V}{C} \right)^K \right] \quad \dots\dots\dots (9)$$

Equation (10) can be rewritten as:

$$1 - f(v)_w = \phi = \exp \left[ - \left( \frac{V}{C} \right)^K \right] \quad \dots\dots\dots (10)$$

Where:

$\phi$  = The Cumulative wind velocity

The Weibull parameters C and K depends on the wind speed.

Taking the natural logarithm of equation (10) twice:

$$\ln \phi = \left( - \frac{V}{C} \right)^K \quad \dots\dots\dots (11)$$

and

$$\ln (- \ln \phi) = \ln \left( \frac{V}{C} \right)^K \quad \dots\dots\dots (12)$$

$$\ln (- \ln \phi) = K(\ln V - \ln C) \quad \dots\dots\dots (13)$$

$$\ln (- \ln \phi) = K \ln V - K \ln C \quad \dots\dots\dots (14)$$

Where:

$K \ln C$  = Constant.

K = The slope of the curve.

From equation (14) the  $\ln(-\ln\phi)$  versus  $\ln V$  curve was plotted as shown in Fig. 2.

## **Results and Discussion**

The wind speed data used in the present research were recorded and calculated during the year 2011 by using a rotating fan anemometer close to the wind mill station which was positioned on the top of the workshop building in Technical Institute / Mosul in open and free obstacles space at height 30m above the ground. The wind speed were recorded every 20 seconds by using wind speed data logger ( 0 to 45 m/s measurement range and 0.085 mph at 10 second reading interval resolution) and then were average over 10 minute. The 10 minute average wind speed data were then average over one hour at the end of each hour period.

The accumulative weibull probability distribution function  $f(v)$  were calculated from the mean wind speed data  $\ln(-\ln\phi)$  &  $\ln f(v)$  have been listed in table .1.

The data presented in table .1 are plotted in Fig. 2. The Figure represents the accumulative weibull probability distribution logarithm function  $\ln f(v)$  as a function of the logarithm of the accumulative time wind speed  $\ln(-\ln\phi)$ . The curve shown in the figure reveals a straight line pattern which is best revealed in equation 15.

The slop of the curve shown in Fig. 2 was calculated and analyzed to be 0.366.

The curve shown in Fig. 2 was intercepted to the  $\ln(-\ln\phi)$  - axis. to obtain the value of  $k \ln C$  shown in equation 15, and the intersection value is -0.55.

As the value  $K=0.366$  and  $k \ln C = -0.55$  have been obtained, the weibull scale factor C was calculated by applying the following formula.

$$C = \exp - \frac{k \ln c}{K} \dots\dots\dots (16)$$

$$C = \exp \frac{-(-0.55)}{0.366} = 4.082$$

$$C = 4.082$$

The average measured monthly wind speed  $\bar{V}$  was recorded to be 2.73 m/sec, hence

$$\frac{C}{\bar{V}} = \frac{4.082}{2.73} = 1.495$$

$$C = 1.495 \bar{V}$$

The data of wind speed that have been measured and recorded were also averaged over each eight hour period for each day of the whole month of March and the concluded data are presented in Table .2 which represent the measured wind speed in March 2011 for each eight hour period and their average values  $\bar{V}$  (m/sec) on the top of the workshop building in Technical Institute / Mosul. The data presented in table .2 are plotted in Fig. 3 which represents average wind speed  $\bar{V}$  versus duration period of each eight hour.

The figure shows a fluctuations of the wind speed in which it varies between 4.3 m/s to 7.7 m/sec with average value of  $\bar{V} = 6.2$  m/sec.

The figure reveals that the wind speed 6.2 m/s is available for a large parts of the day.

The average wind speed pattern for each day of the whole month are plotted in Fig. 4.

The mean wind speed that can generate electrical power is 2.5 – 3 m/s, and in our study the mean wind speed shown to be  $\bar{V} = 2.84$ . It is best clear that there are a certain periods in which the wind potentials are useful for converting their power to an electricity for laboratory usage.

The frequency distribution data of wind speed intervals are presented in Table .3 and plotted in Fig. 5 which represents a distribution graph of the wind speed.

The region shown in Fig. 5, are the most frequent wind speed, and the Fig. best reveals that there are enough duration periods in which a high potential power of wind speed were available and occurred.

Table .4 represents the cumulative, decreasing and the percentage duration period for each interval of wind speed. The data are plotted in Fig. 6 and Fig. 7 which represent the duration and accumulative distribution histogram. The patterns of the two Figs. are best reveal that there is an enough number of hours in which the wind speed of a high potential power are available and enough for running on the wind mill, i.e. the fraction of time that a wind mill produce more high enough.

The probability distribution for each wind speed interval are tabulated in Table .5 and plotted in Fig. 8.

The graphs plotted in Fig. 8 show the wind speed frequency distribution and how for is it from the best fitting unimodal Weibull Probability Density Function [13]

Experimental results plotted in Fig. 8 for the wind speed data measured by Anemometer and the Weibull Probability Density Function [13] show a best fitting between wind speed measured by Anemometer device and wind speed distribution for Weibull Probability Density Function [13]. The minimum useful wind speed for electrical generation is 2.5 – 3 m/s which indicate that there is an efficient and enough wind speed on the top of the workshop building in Technical Institute / Mosul for the generation of electricity which can run on the devices and the instruments that have been employed by the students who in turns use those devices and Instruments for the experimental tests in the laboratories.

## **Conclusions**

In the present research, the assessment study of the wind potential energy for electricity generation in Technical Institute / Mosul lead to the following conclusions:

1. The Weibull scale factor  $C$  was calculated to be 4.082.
2. A best relationship between weibull scale factor  $C$  and average wind speed  $\bar{V}$  indicates that there is an enough wind speed of large power for electricity generation for laboratory usage.
3. There is an available wind power of average speed equal to 6.2 m/s for a large parts of the day.
4. There are a certain periods in which the wind potentials are useful for converting their power to an electricity for laboratory usage.
5. There are enough duration periods in which a high potential power of wind speed were available and occurred.
6. There are an enough number of hours in which the wind speed of a high potential power are available and enough for running on the wind mill.
7. A wind speed measured by Anemometer device and the Weibull Probability Density Function show a best fitting between wind speed measured by Anemometer device and the Weibull Probability Density Function, which is a best indicating that there is an efficient and enough wind potential power on the top of workshop building in Technical Institute / Mosul for electricity generation for laboratory usage by the student.

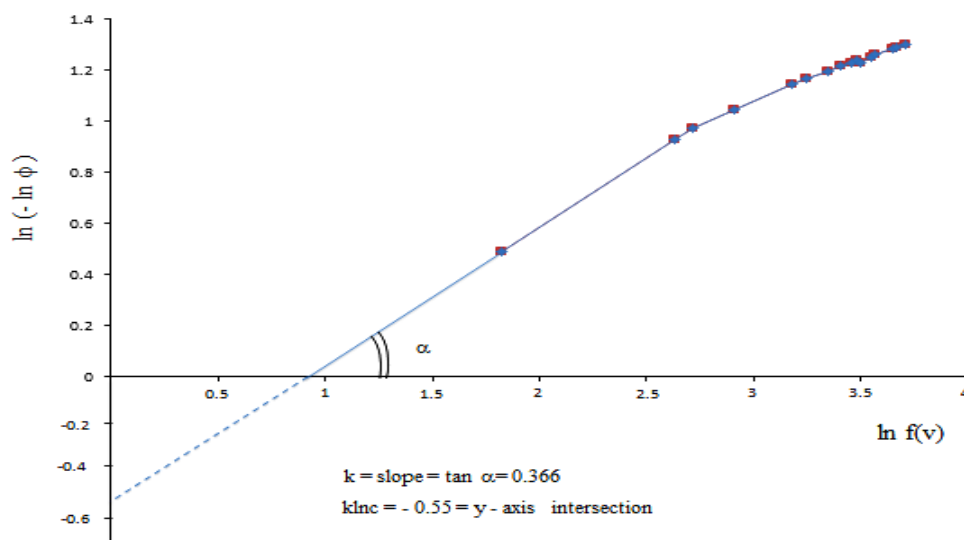
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**Table 1 The measured and calculated wind speed data in March 2011.**

<b>f(V)</b>	<b>1 – f(V) = <math>\phi</math></b>	<b>ln - <math>\phi</math></b>	<b>ln (- ln <math>\phi</math>)</b>	<b>ln f(V)</b>
6.2	-5.2	1.64	0.49	1.82
13.9	-12.9	2.55	0.93	2.63
15.2	-14.2	2.65	0.974	2.72
18.4	-17.4	2.85	1.047	2.91
24.27	-23.27	3.147	1.146	3.18
25.02	-25.02	3.218	1.168	3.25
28.52	-27.52	3.314	1.198	3.35
30.52	-29.52	3.38	1.217	3.41
31.82	-30.82	3.42	1.229	3.46
32.52	-31.52	3.45	1.238	3.48
33.32	-32.32	3.47	1.23	3.50
34.82	-33.82	3.52	1.25	3.55
35.52	-34.52	3.54	1.26	3.57
38.27	-37.27	3.618	1.285	3.65
39.37	-38.37	3.64	1.291	3.67
40.97	-39.97	3.68	1.302	3.71
44.12	-43.12	3.52	1.258	3.78

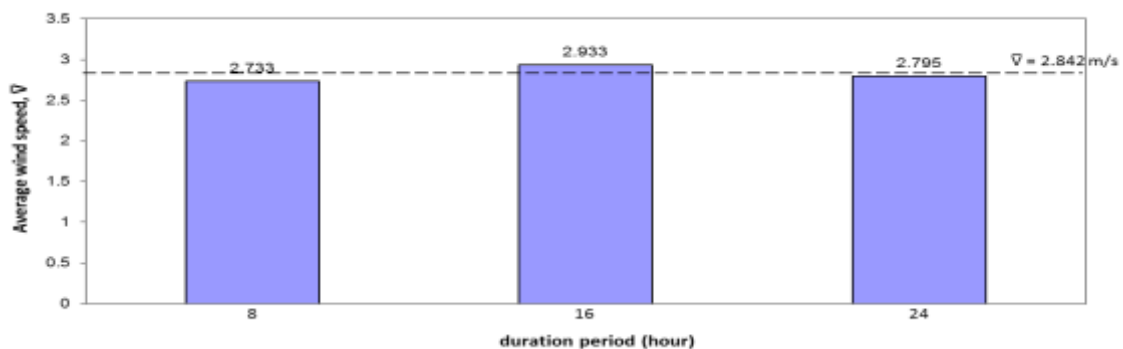


**Fig. 2  $\ln(-\ln \phi)$  as a function of  $\ln f(v)$  for Weibull parametes calculation**

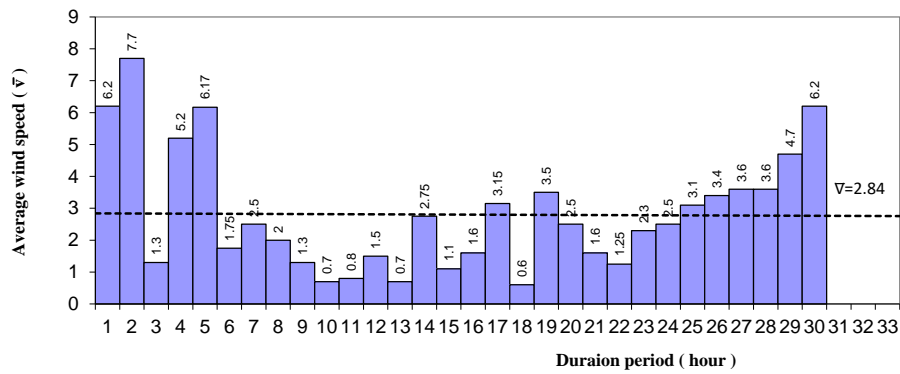


**Table 2 The average wind speed for each 8 hours in March 2011 at Technical Institute/mosul**

March, 2011	8 hour	16 hour	24 hour	Average wind speed of each day m/s
	Speed (v) m/s	Speed (v) m/s	Speed (v) m/s	
1	4.3	7.7	6.7	6.2
2	6.5	8.6	8.05	7.7
3	1.9	0.7	1.3	1.3
4	5.05	5.4	5.2	5.2
5	4.85	7.5	6.17	6.17
6	0.3	3.2	1.75	1.75
7	3.2	2.5	1.8	2.5
8	3.25	2	0.8	2
9	1.3	0.7	1.9	1.3
10	0.7	0.3	1.1	0.7
11	0.8	0.8	0.8	0.8
12	1	2	1.5	1.5
13	0	1.4	0.7	0.7
14	2.75	1.5	4	2.75
15	1.5	0.7	0.7	1.1
16	0.7	2.5	1.6	1.6
17	3.15	1.9	4.4	3.15
18	0.2	1	0.6	0.6
19	1.8	3.5	5.2	3.5
20	2.5	1.3	3	2.5
21	2.5	1.6	0.7	1.6
22	1.25	1.9	0.6	1.25
23	2	3	1.7	2.3
24	2.8	2.7	2	2.5
25	3.4	2.9	3	3.1
26	3.2	3.1	2.9	3.4
27	4.1	3.9	2.8	3.6
28	4.5	3.5	2.7	3.6
29	5.9	4.2	4.1	4.7
30	6.6	6	6.1	6.2
Average	2.733	2.933	2.795	2.842



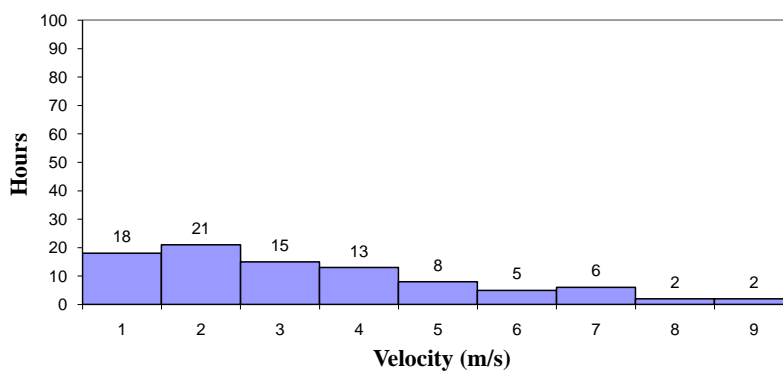
**Fig. 3 The average wind speed pattern in March 2011 at Technical Institute / Mosul**



**Fig. 4 The average wind speed pattern in March 2011 in Technical Institute / Mosul**

**Table. 3 Frequency distribution table of wind speed in March 2011 at Technical Institute / Mosu**

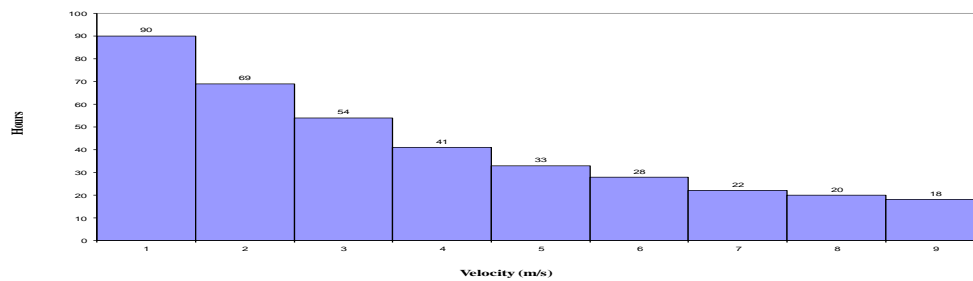
Interval V (m/s)	Frequency (hours)
0 – 0.999	18
1 – 1.999	21
2 – 2.999	15
3 – 3.999	13
4 – 4.999	8
5 – 5.999	5
6 – 6.999	6
7 – 7.999	2
8 – 8.999	2
Total	90



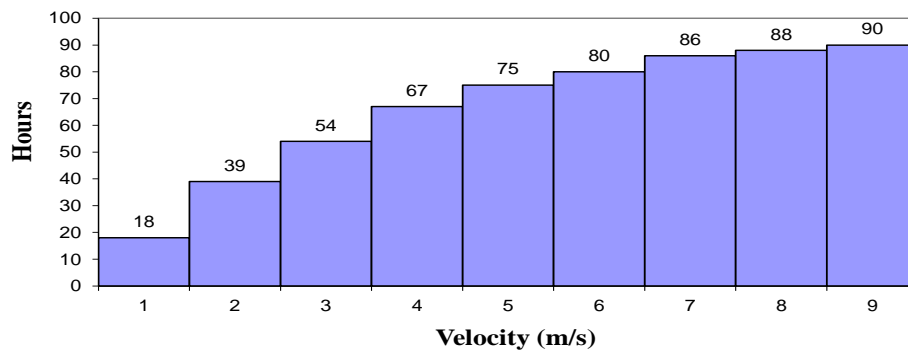
**Fig. 5 Frequency Distribution Graph of wind speed in March 2011 in Technical Institute / Mosul**

**Table 4 Frequency distribution table of wind speed in Technical Institute / Mosul in March 2011 transformed into a duration and accumulative distribution.**

Interval	Frequency	Duration $V \geq \bar{V}$	Cumulative $V \leq \bar{V}$	%
m/s	hours	hours	hours	
0 – 0.999	18	90	18	2
1 – 1.999	21	69	39	43
2 – 2.999	15	54	54	60
3 – 3.999	13	41	67	74
4 – 4.999	8	33	75	83
5 – 5.999	5	28	80	88
6 – 6.999	6	22	86	95
7 – 7.999	2	20	88	997
8 – 8.999	2	18	90	100
Total	90	375	597	



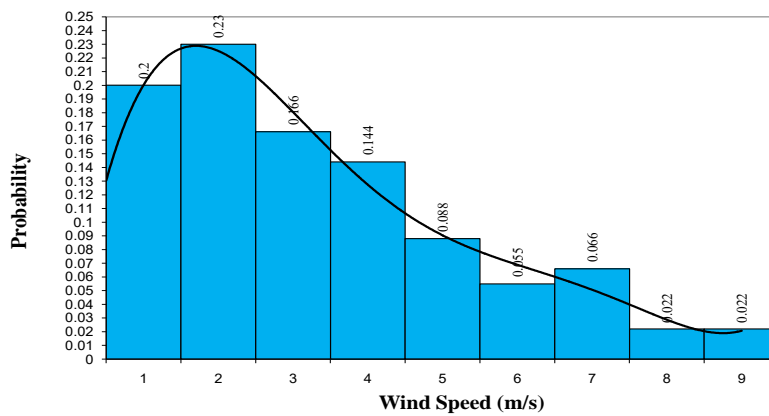
**Fig. 6 Duration Distribution Graph in March 2011.**



**Fig. 7 Cumulative Distribution Graph in March 2011  
Cumulative Distribution Graph in March 2011.**

Wind speed, V (m/s)	Probability
0 – 0.999	0.2
1 – 1.999	0.23
2 – 2.999	0.166
3 – 3.999	0.144
4 – 4.999	0.088
5 – 5.999	0.055
6 – 6.999	0.066
7 – 7.999	0.022
8 – 8.999	0.022

**Table5 Probability data of wind speed**



**Fig. 8 Wind speed distribution data in March 2011.**

■ Anemometer data  
— Weibull probability density function [12]

