Wind Resource Assessment and Wind Power Potential for the City of Khaf, Iran

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Abstract- Development of renewable energies is a major issue in today's society. One of the best renewable energies is wind energy and wind turbines used to harness wind energy. In this study, wind speed data for 10 m, 30 m and 40 m heights for the city of Khaf in Razavi Khorasan province is measured. Wind power generation has been analyzed by wind speed and wind direction data. We used Weibull distribution function for determining the wind power energy and density. Yearly and monthly mean Weibull parameters, *k* and *c* have been calculated. Yearly parameters were k=1.659 and c=11.156. In order to utilize wind energy, Vestas V80 2MW is considered for installing in this location. The simulation and calculation have been done by WindPower software.

Keywords- Wind potential; Weibull distribution; Razavi Khorasan; Wind rose.

1. Introduction

Electricity supply is one of the most important human concerns, so the people are always looking for clean and unlimited energy that they have been fully successful in recent centuries and have found a way to use of energy of the sun (construction of the first solar cell in 1883) [1] and wind energy (invention of first wind turbines with application of generating electricity in 1887) [2].

Wind is one of the symbols of the sun’s energy and it is the moving air and continuously a small fraction of solar radiation that reaches from outside of the atmosphere, it converted to the wind energy. Heating of the earth and its atmosphere are unequal due to convection currents (displacement) and also the relative motion of the atmosphere than earth, can produce wind.

Declining of oil and gas reserves in the world has become a serious problem, therefore the investment in new energy is much more widespread than in the past. Construction and development of new energies in countries like Spain and USA, have the strong support of the government and investors, while in Iran unfortunately only a small fraction of the budget is devoted to this topic and investment is very poor. According to the Ministry of Energy [3] in 2004, there is no investment in the field of construction of 60 MW wind farm and investors only for building and development of a wind power station of Manjil have shown interesting that maybe one of the reasons for the lack of proper investment in Iran, is the lack of sufficient awareness the wind potential of various regions of Iran. Islamic Republic of Iran is located in the western part of the plateau and in the south-west of Asia. Iran is facing a large climate variability. Northern areas of Iran have a mild climate and considerable rainfall, especially in the western areas of the province of Gilan. The climate of the western areas of Iran in the cold seasons is cold and humid and in warm season is dry and mild. In the south, temperatures and humidity is high, very hot summers and mild winters are characteristic of the climate in this area and daily changes of temperature is less sensitive. Eastern and south-eastern areas have desert climate with considerable changes of temperature during the day. To produce electricity from wind resources, the wind reliable information about wind potential of the region is essential for the construction of wind power plants. In Iran, windy areas are suitable for extending of the usage of wind turbines. The installed wind power capacity in Iran is shown in Table 1 [3].

The installed capacity of wind power plants of Iran from the year of 2003 until now has been growing, and it increases from 47580 kilowatts in the year of 2005 reaches to 109000 kilowatts in the year of 2011 [3]. World association of wind energy has a strategy that wind energy will provide about of 10% of world consumption energy in the year of 2020 [6]. Iran is considered as one of the richest countries of the world in terms of various sources of energy, because it has the extensive resources of fossil and non-renewable fuel such as oil and gas, on the other hand it has much potential of renewable energies like wind. Iran with talented windy areas and located in the air flow path, has the appropriate platform for expanding of utilization of wind turbines to electricity production and injection to the network. Several factors cause the development of wind power industry that among which may be mentioned to government subsidies and tax encourages, improved technology, increasing the price of fossil fuels and attention of investors to reduce carbon dioxide [4]. Currently, China (44,720 MWh per year), USA (40,180 MWh per year) and Germany (27,250 MWh per year), are the largest producer of wind power in the world and Iran is ranked 38th in the world with production of 130 megawatt hours per year [5]. Although, Iran isn't a poor country in terms of fossil fuels, but it should be considered that excessive consumption of these fuels creates air pollution and global warming; so in this correlation, renewable energies are important, while supplying a part of electricity needed by wind power seems to be necessary.

Table 1. Wind Power Station Capacity for Iran

Location	**Installed capacity and number**	**Type of Turbine**
Manjil (Gilan)	(8100 kW) 27	300 kW
Manjil (Gilan)	(1000 kW) 2	500 kW
Manjil (Gilan)	(9900 kW) 18	550 kW
Manjil (Gilan)	(600 kW) 1	600 kW
Manjil (Gilan)	(46200 kW) 70	660 kW
Manjil (Gilan)	(5940 kW) 9	660 kW
Binalood (Khorasan)	(28380 kW) 43	660 kW
Zabol (Sistan)	(660 kW) 1	660 kW
Babakuh (Shiraz)	(660 kW) 1	660 kW
Awn ibn Ali (Tabriz)	(1980 kW) 3	660 kW
Sarein (Ardebil)	(660 kW) 1	660 kW
Isfahan (Isfahan)	(660 kW) 1	660 kW
Mahshahr (Khuzestan)	(660 kW) 1	660 kW
Khaf (Razavi Khorasan)	(1.5 MW) 1	1.5 MW
Khaf (Razavi Khorasan)	(2.5 MW) \1	2.5 MW
Total capacity in MW	109.4 MW	-

It should be tried to wind machines have the lower main cost (the construction cost of the rotor, tower, etc.) and it must be installed in locations where they have significant wind and the machine is set to operate at a certain wind speed. Preparing of the machine for working in all wind speed, is more expensive. A typical wind machines primarily used to avoid the use of other fuels during the wind blowing and it is also used along with other energy production devices.

The purpose of writing this paper is to investigate the wind potential of the province of Razavi Khorasan, Khaf city, to the installation of wind turbines and calculation of the needed cost and benefits from the investment.

2. The Geographical Location of Khaf

The studied region in this analysis is the province of Razavi Khorasan. The Razavi Khorasan province is located in the north-west of Iran and it is the fourth largest province of Iran. The Razavi Khorasan province is located between 34° to 38° north latitude and 56° to 62° east longitude. The Razavi Khorasan province is located in the east of Iran and with an area of approximately 117,769 square kilometres is the fourth largest province of Iran and it is included about 7% of the total area of Iran. The Razavi Khorasan province in terms of climate classification is located in semi-arid climate. This province in terms of rainfall and humidity is a moderate rainfall area. Khaf city is one of the cities in the Razavi Khorasan province and its center is Khaf town that is located in 250 kilometres south-west of Mashhad. This city is located in the east border strip of Iran [7-8].

Fig. 1. The geographical location of Khaf

3. Study of Wind Speed

We should consider that used turbines in Iran typically have a height of 30 meters of the surface, so wind speed is determined by data in this height [2]. To calculate the average wind speed at the height of 30 meters above ground level, data related to wind speed in one year is used for Khaf (relevant numbers were recorded every 10 minutes) [9]. Because changes in the speed affect on activity process and wind turbine production, "Mode" and "Median" are calculated for better analysis.

We studied data related to the city of Khaf. The numbers of data for Khaf City are about 63000 data that example of 4 pieces of data in term of meter per second with the date and time are shown in Table 2:

Table 2. Sample Wind Speed Data in Khaf

08/07/2007 13:40	09/17/2007 09:20	09/27/2007 01:50	01/01/2008 00:00
12.2 m/s	8.7 m/s	5.9 m/s	0.5 m/s

To analyse of data, Excel software is used. After entering and analysing the relevant data, the following characteristics are obtained:

Table 3. Calculated Wind Data

Height	40m	30m	10m
Mean Speed	10.45 m/s	10.038 m/s	8.82 m/s
Max Speed	31.2 m/s	33.1 m/s	30.3 m/s
Median	10.8 m/s	10.1 m/s	8.8 m/s

The average wind speed (30m) in Khaf city is equal to 10.038 m/s and it is an acceptable speed.

Median of data is about 10.1 m/s and the Max speed is about 33.1 m/s. These three data show that wind change is appropriate in a period of time, and this area in terms of wind speed is desirable. The scatter plot of speed data at the height of 40 meters, is shown in Fig.2:

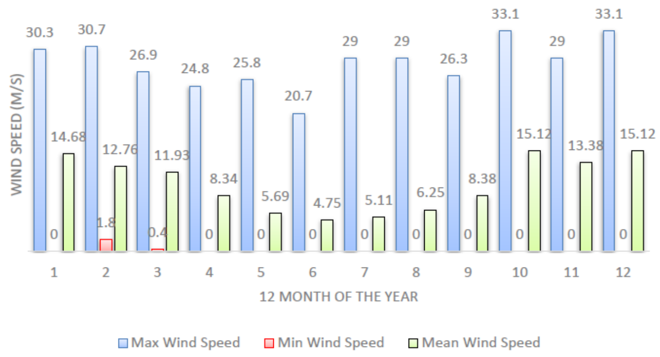

Fig. 2. The scatter plot of speed data at the height of 40 m

the typical cut-in speed for wind turbines is equal to 3-4 m/s, so speeds less than 3.5 m/s are usually would be problematic if they be continuously on the whole period [10].

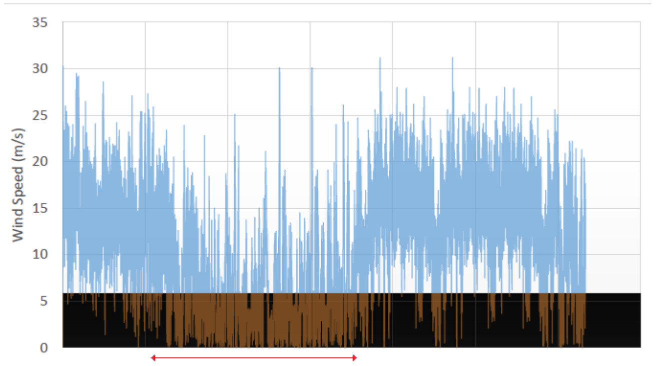

Fig. 3. Wind Speed per time

In the scatter plot, the data with speeds less than 6 meters per second are shown in red. Among the total 63363 data related to wind speed, 15719 data are related to speeds of less than 6 m/s. It should be noted that in a relatively continuous time range in a few months, we will see the possibility problem in turbine performance.

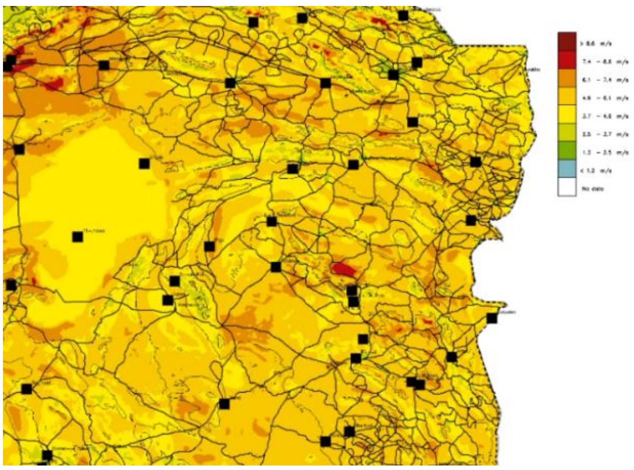

Fig. 4. The wind speed map at the height of 40 meters for Razavi Khorasan [9]

Due to a better position of Khaf region in terms of wind speed than the Khaf city and with reference to the data of Meteorological Organization, average wind speed in Khaf city is considered about 10 meters per second, which is significant speed. But for the installation of wind turbines in a region, also other parameters must be considered that can be noted to the direction of wind and its changes. So it is necessary to determine the average wind direction in this location.

4. Study of Wind Direction

Large and modern turbines are generally controlled by measuring wind direction from wind vane. Turbines that use this technology also work against the wind while in conventional turbines; wind blowing direction on its blades must be from face [2]. In any case, the determination of the direction of the prevailing winds of the interest location is essential and one of the main characteristics of wind potential of a region, is the curve of wind direction of its area. To investigate the wind direction, we visited the data and information related to Iran Renewable Energy Organization for Khaf [9].

Star chart for showing of abundance relative direction and wind speeds in a station for a certain time period called “Wind Rose”. With this method, we can get an overview of the regional wind conditions. Wind rose is a diagram that shows the temporal distribution of wind direction for a location. For example, wind rose for the first three months of year, is shown in Fig.5:

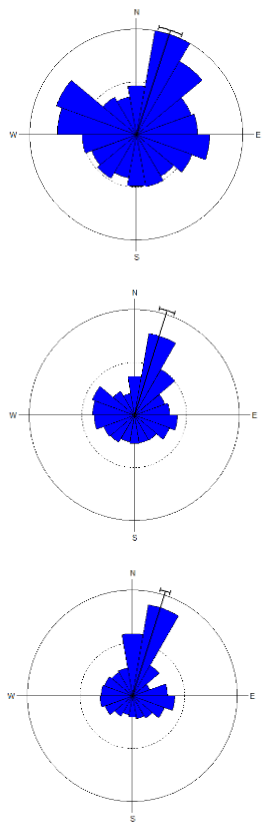

Fig. 5. The mean wind direction for the first 3 months of the year in Khaf

To drawing of analysis diagrams of wind rose of location, ORIANA software is used [11] and by entering data, we can achieve to wind rose diagram related to Khaf.

Wind rose diagram of Khaf city with configuration of confidence intervals 95% and rotation clockwise is drawn in Fig.6:

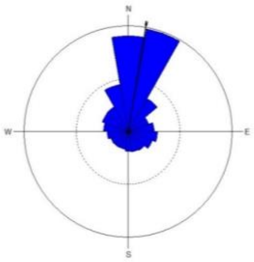

Fig. 6. Rose diagram for Khaf

According to this approximate diagram of wind direction, we can install wind turbines in appropriate direction that is between north wind of 360˚and northeast wind 45˚.

5. Calculating the Power of the Wind Turbine

Generally for calculation of the power of wind turbines in standard conditions (regardless of temperature, altitude and weather conditions), the simple physical relations is used [12].

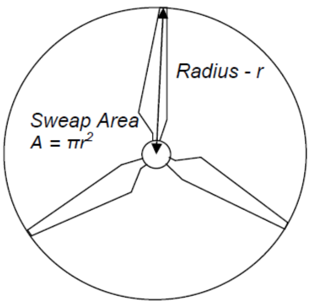

Fig. 7. Three blade turbine schematics

The work done on any object is equal to the entering force at travelled distance [12]:

$$W = F.X \tag{1}$$

According to Newton's law:

$$F = m.a \tag{2}$$

Then, according to equation (1-2):

$$W = m.a.X \tag{3}$$

The third law of motion states where U is the initial velocity.

$$U^2 + 2aX = V^2 \tag{4}$$

If we consider the initial velocity equal to zero:

$$a = \frac{V^2}{2X} \tag{5}$$

From equation (3), (5) for a mass having kinetic energy, we will have:

$$W = \frac{1}{2} m V^2 \tag{6}$$

Power is equal to derive a work that the turbine is done:

$$P = \frac{dW}{dt} = \frac{1}{2}\frac{dm}{dt} V^2 \tag{7}$$

Also we have:

$$\frac{dm}{dt} = \rho A \frac{dx}{dt} \tag{8}$$

For equation (8) rather than derived of distance, we can put velocity. From combination two equations (7), (8), the following relative relation is obtained:

$$P = \frac{1}{2} K \rho A V^3 \tag{9}$$

In equation (9), the value of K is the coefficient that is calculated by a method with the German scientist named Albert Benz, this coefficient indicates that no turbine efficiency is greater than 0.593 [13]. So we put the maximum value of this coefficient equal to C_{Pmax}=0.59. The value of this coefficient for turbines, depending on its type and structure is different and its usual range is between 0.30 and 0.45.

In this study, we used the standard deviation method to compute Weibull parameters.

To calculate the coefficient of cumulative and frequency distribution of Weibull, first it is necessary to calculate its first parameter that is *k* shape.

Using this method *k* and *c* are calculated respectively as [14]:

$$k = \left(\frac{\sigma}{\upsilon}\right)^{-1.086} \tag{10}$$

$$c = \frac{\upsilon}{\Gamma\left(1+\frac{1}{k}\right)} \tag{11}$$

$$\Gamma(x) = \int_0^\infty exp(-u) u^{x-1} dx \tag{12}$$

In order to calculate the mean wind speed, *v*, and standard deviation of wind speed, *σ*, equation (13), (14) can be used

$$\upsilon = \frac{1}{n}\sum_{i=1}^{n} \upsilon_i \tag{13}$$

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\upsilon_i - \upsilon)^2} \tag{14}$$

In terms of Weibull distribution function, υ and σ can be obtained as follows [14]:

$$\upsilon = \int_0^\infty \upsilon f_w(\upsilon) d\upsilon = c\ \Gamma\left(1 + \frac{1}{k}\right) \tag{15}$$

$$\sigma = \sqrt{c^2 [\Gamma(1 + 2/k) - \Gamma(1 + 1/k)^2]} \tag{16}$$

According to equation (9) we can calculate the wind power per unit area:

$$P = \frac{1}{2}\rho \upsilon^3 \tag{17}$$

Based on the probability density function of Weibull by combining of relations, we can calculate the wind power according to equation (18):

$$\frac{P}{A} = \frac{1}{2}\rho \int_0^\infty \upsilon^3 f(\upsilon) d\upsilon = \frac{1}{2}\rho c^3 \Gamma(1 + \frac{3}{k}) \tag{18}$$

Parameter of ρ is the air density at sea level and at a temperature of 15 ° C and a pressure of 1 atmosphere.

To estimate of corrected value ρ in a month, equation (19) is used:

$$\rho = \frac{\bar{P}}{R_d \bar{T}} \tag{19}$$

The parameter of $\bar{T}$ is average of air temperature in a month in Kelvin, the parameter of $\bar{P}$ is the average monthly value of air pressure and R_d is the gas constant. The climate of Khaf is considered dry climate, so we put the value of R_d equal to 287 J/kg°k that is for dry air.

Table 4. The Wind Speed Parameters for Khaf

Months	σ	v	k	c
Jan	4.281	6.007	1.428	6.621
Feb	4.283	5.533	1.301	5.997
Mar	4.588	5.437	1.21	5.801
Apr	5.035	6.265	1.294	6.797
May	5.576	10.696	1.951	12.004
Jun	3.953	15.632	4.536	17.075
Jul	4.919	12.886	2.845	14.408
Aug	3.934	15.638	4.561	17.078
Sep	4.145	14.893	3.955	16.427
Oct	4.505	12.379	2.99	13.81
Nov	5.087	10.576	2.162	11.893
Dec	4.893	8.565	1.733	9.562
All	5.882	10.038	1.659	11.156

The wind energy density can be calculated by equation (20), T is a desired duration:

$$\frac{E}{A} = \frac{1}{2}\rho c^3 \Gamma\left(\frac{k+3}{k}\right) T \tag{20}$$

The histogram of the wind velocity for the station is shown in Fig.8. From Fig.8, it is clear that the speed U= 5.5 m/s has the maximum probability (7.8%). The Weibull cumulative distribution is shown in Fig.9 which gives the probability of the wind speed exceeding the value of any given wind speed (U).

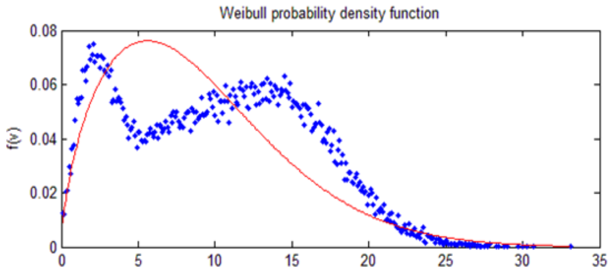

Fig. 8. Weibull probability density (30m)

The cumulative distribution graph is useful for estimation of the time for which wind is within a certain velocity interval. The wind speed at 30 m heights is greater than 4 m/s for most of the time in the year. The wind speed limit is 4 m/s and it is important, because it is the cut-in speed for many wind turbines. The cut-out speed of wind turbines is between 20 and 25 m/s. In this graph we can see that the cut-out wind speed exceeds 25 m/s in some periods at this location [15].

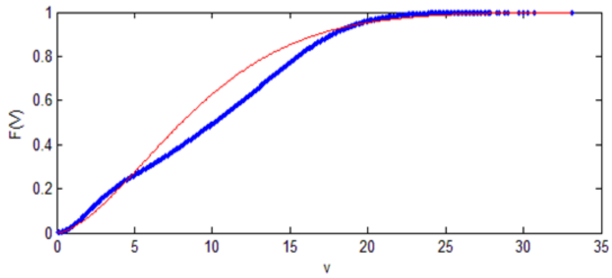

Fig. 9. Cumulative Weibull probability density function (30m)

Calculating and determining of annual energy production for a wind turbine is one of the important steps in any project. The parameters of wind turbine totally depend on height and wind speed. To determine the performance quality of the wind turbine of selected model, the Vestas V80 2mW is considered as the studied turbine. The related analysis is done using the WindPower software [16-17].

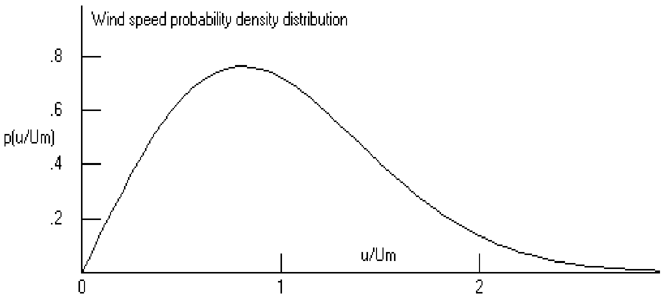

Fig. 10. Wind speed probability density distribution

This is a widely used turbine rated for IEC-1 sites - that is the windiest sites with a mean wind speed of up to 10 m/s. The power curve here is for the noisiest offshore version (106.4dBA) which has slightly higher peak efficiencies (i.e. power coefficients) than the onshore versions and these extend over a wider range of speeds.

Also the output power of the turbine or annual power generation with respect to the average speed is estimated by the software:

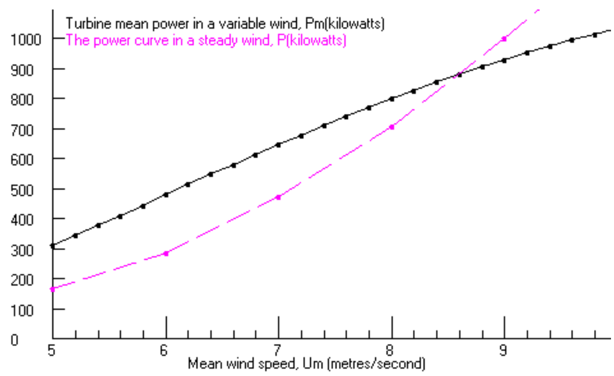

Fig. 11. Turbine mean power per mean wind speed

Table 5 shows the amount of annual power generation for a desired turbine (Vestas V80). From Fig.11, it is clear that with increasing the average speed, also the amount of annual output power is increased:

Table 5. Annual Output Power per Wind Speed

U_m (m/s)	Annual kWh	U_m (m/s)	Annual kWh
5.0	2,734,119	7.6	6,504,304
5.2	3,021,925	7.8	6,765,582
5.4	3,315,033	8.0	7,019,170
5.6	3,611,082	8.2	7,264,639
5.8	3,910,777	8.4	7.501,621
6.0	4,210,496	8.6	7,729,799
6.2	4,509,696	8.8	7,948,910
6.4	4,807,207	9.0	8,158,744
6.6	5,101,971	9.2	8,359,136
6.8	5,393,033	9.4	8,549,969
7.0	5,679,531	9.6	8,731,170
7.2	5,960,693	9.8	8,902,708
7.4	6,235,824	10.0	9,064,590

Annual energy production and capacity coefficient for desired turbine that is Vestas V80 model in terms of wind speed, is shown in Fig.12. According to the average wind speed of the location that was estimated about 10 meters per second, the amount of coefficient C_p is calculated equal to 31.54%.

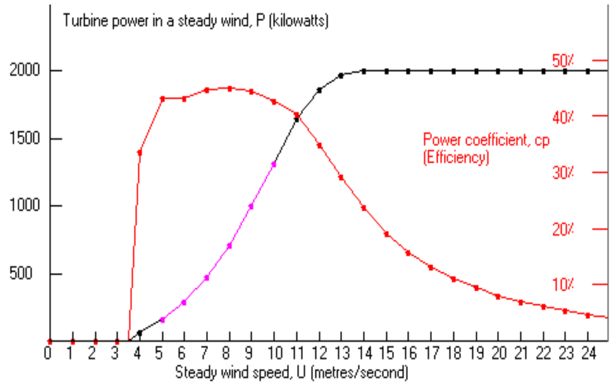

Fig. 12. Power coefficient per steady wind speed

6. The Effect of Dust on the Performance and Turbine Power

According to experiments that have been performed, existence of dust affects on the performance of wind turbines and it also depends on the type and condition of roughness of blades [18]. According to the costs and investments that are made to develop wind turbines, it is important that the presence of dust in this region would be much reduced turbine efficiency.

Change in turbine efficiency in dust condition is dependent on the moment output power of turbine and with the changing of turbine power is changed and is not fixed. Another factor that affects on the rate of power change, is the design of turbine blades [18]. Whatever blades are smooth and aerodynamic efficiency decreases is less. Another influential factor is the number of turbine blades. 3-blade turbine is the best case used.

For example, in Fig.13, diagram of the power curve of turbine of Nordtank 300 kW has been investigated in different condition of dust in different size of particles:

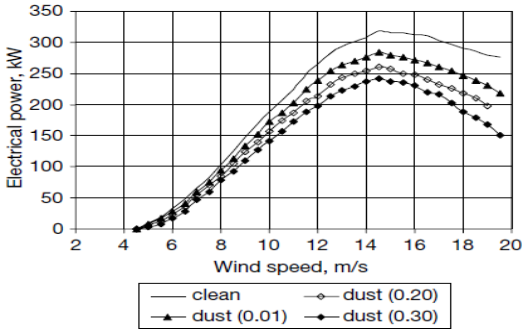

Figure 13. Dust effect on power curve diagram [18]

Dominant winds of the region from early March to late October have the highest speed. Based on the obtained results of done investigations in the desert area of Iran, this wind can move tiny particles of soil, with size less than 400 microns to a distance over than 7 km. In Fig.13, the output power of a turbine 300 kW in four different climatic conditions is plotted. Due to the dust in Khaf city [19] have high relatively concentration and is continuous in half of the year, should be consider the diagram of Dust (0.2). If we consider the average of speed about 10 m/s, the output power in smooth air is about 185 kW and in dusty air is about 155 kW that is equal to speed of 9.1 m /s in normal condition. But since the average of very high speed and acceptable of wind in Khaf city, despite this reduction of power in turbine and still output power of installed turbines has a high percentage and it is suitable for the investment. It should be noted that with the installation of these wind turbines on the farm can be somewhat reduced the amount of dust.

The results in Fig.13 show that, the losses of output power increase by increasing the wind speed in dusty conditions. When the blade surface roughness increased, the power curves variability increased. So, in Khaf city with big dust particles and high wind speed, we should clean dust from blade surface during in several months to decrease the reduction of output power.

With these results, the power curve of Vestas 2MW turbine is shown in Fig.14 with considering dusty conditions:

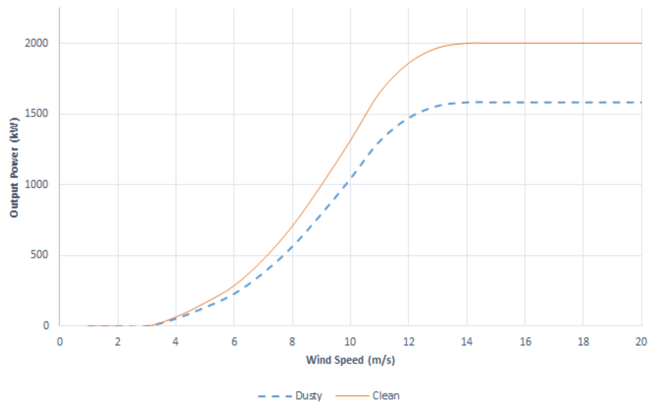

Fig. 14. Power curve of Vestas 2MW turbine in dusty condition

7. Cost Estimation and Economic

The usual cost of a 1 MW of turbine capacity is about 1 million dollars [20] that of course with respect to the purchase of domestically manufactured turbines, this amount can be reduced. Each turbine is including the cost of installation, launch and also annual service charge. Service charge depends on the type and size of the turbine and it is between 1% and 3% of the total cost of turbine. It includes a full check of the turbine and also necessary repairs [14, 17].

Razavi Khorasan region has the electric stations with appropriate capacity, and produced electricity by turbines can be exported to neighbouring countries such as Afghanistan and Turkmenistan. Exported electricity price is dependent on the capacity of the generation power of the turbine; in previous years, the price of exported electricity to Afghanistan was lower to help the country's development and it was about 4-5 cents/kWh. But these prices for Turkmenistan were higher and were changes in the range of 8-12 cents/kWh and they were lower than real world prices [21]. Tariff for renewable energies (like wind turbine) in Iran is about 0.13$/kWh [22]. Table 6 shows the price of any kWh produced in England by penny units [17]:

Table 6. Rate Turbine Manufactured Power in UK by penny/kWh

Energy Source	Scale	Tariff (p/kWh)	
-	-	< 30/9/14	> 1/10/14
Wind	>100 - 500kW	14.82	13.34
Wind	>500kW - 1.5MW	8.04	7.24
Wind	>1.5MW - 5MW	3.41	3.07

The average lifetime for a turbine is about 20 years, with the fixed cost of installation and annual service charge, we can estimate the price of kWh [17]:

$$\text{Cost per kWh} = \frac{\text{Turbine and Other fixed costs} + (\text{Annual recurrent costs} \times \text{Lifetime})}{365 \times 24 \times \text{Lifetime}(\text{years}) \times P_m\,(U_m)} \qquad (21)$$

In equation (21), the amount of P_m (U_m) is the average power generated by the turbine in the average speed of U_m. Usually generated power with speed less than 6 m/s cannot be considered beneficial. Fig.15 indicates the estimate of the price of 1 kWh in Iran for a turbine of Vestas 2MW with considering the coefficient of average velocity (Mean Speed = 0.58). This diagram has been drawn by the WindPower software:

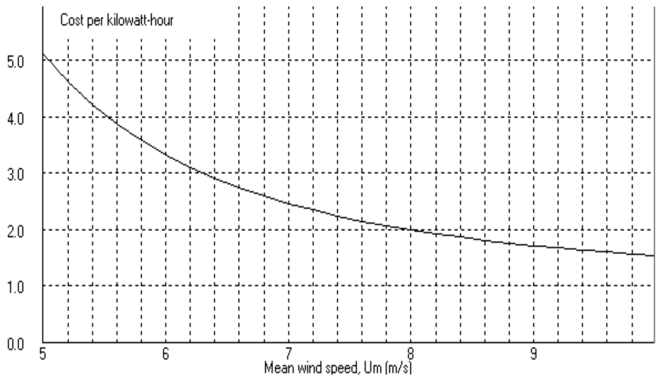

Fig. 15. Cost per kWh for mean wind speeds

According to Fig.14, the price of one kWh in speed of 10 m/s is about 1.54 cents. Due to the high capacity of 2 MW turbine and cost about 13 cents for kWh, it will be a good investment. Any turbine will produce the amount of output power annual average that the selling price of this power is dependent on the speed of the blades. By considering that the installation and launch cost are paid only at the beginning of the project and the remaining is an insignificant cost of service, any turbine after an approximate duration can supply installation and launch cost and becomes to a source benefit.

To estimate the payback time (the time of return on investment), equation (22) can be used. In this relation also the return time depends on the speed of the turbine [17]:

$$\text{Return time} = \frac{\text{Turbine and Other fixed costs}}{365 \times 24 \times P_m(U_m) \times T_{ref} \times \left[1 - \dfrac{\text{Annual recurrent Costs}}{365 \times 24 \times P_m(U_m) \times T_{ref}}\right]} \qquad (22)$$

In equation (22), T_{ref} is the sale reference price per 1 kWh that according to capacity of 2MW turbines, we considered it about 13 cents.

In the power generation from renewable energies in Iran, the tax has not been considered. Iran government gives this good option for Investment and developing of renewable source. So we considered the initial investment amount for turbines of 2 MW, about 2 million dollars. In Khaf city, the selected turbine can produce 9,528,011 kWh annual energy output. It should be noted that we have a fixed cost and an annual cost, so we must consider it. It is logical to assign 1–3% of the system cost for yearly repair and maintenance [14, 17]. Therefore the equation of yearly cost of operation for the turbine is presented [22]:

$$\text{Yearly Cost} = \frac{C_I}{n}\left[1 + m\left(\frac{(1+I)^n - 1}{I(1+I)^n}\right)\right] \qquad (23)$$

In equation (23), n is the useful life of the wind turbine (20 years), C_I is the initial investment of the project (2million$), m is percent of annual operation and maintenance costs from total cost (3%), I is the interest rate (21% for Iran [22]).

From equation (23), we can find yearly cost about 114000$ or 9500$ monthly.

8. Conclusion

Due to a high average wind speed in Khaf city and also the existence of suitable area for installation of wind turbines, this location is ideal for wind power generation and even with existence dust particles and their adverse effects on the performance of wind turbines, Khaf city can be one of the main options for investment in electrical industry. With development of wind power in Razavi Khorasan province, it can be minimized the reducing the power that is created by exports to the neighbouring countries and also in the storage of diesel fuel be a big step. Average wind speed in the location has been estimated about 10 m/s. With calculation and estimation of the parameters k and c in Weibull method, the efficiency of electricity annually generation can be determined. Annual parameter value of k for Khaf is in the range of 1.210 to 4.536. Also the parameter value of c in this method is between values of 5.997 and 17.078. Direction of wind is specified by the diagram of wind rose for Khaf city that is between north wind of 360˚ and northeast wind of 45˚. In this paper, intended turbine is a turbine of Vestas V80

2MW that parameters and values related to it, are calculated by a factor of 0.58. In the investigation and estimation of project cost, the amount of monthly benefit of 9500 dollars for this project has been estimated.

NOMENCLATURE

The notation used throughout this paper is reproduced below for quick reference:

v	Moment speed
k	Shape parameter for Weibull function
c	Scale parameter for Weibull function
σ	Standard deviation of wind speed
ρ	Air density
T	Average monthly air temperature in Kelvin
P	The average monthly air pressure in Pascal
R_d	Gas constant for dry air

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