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Feasibility of installing wind turbines in Qazvin province
Case study: Jarandagh station

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Abstract
In this paper Feasibility of installing wind turbines in Jarandagh station of Qazvin province is implemented. Renewable energy organization of Iran’s 12-monthed data are used for wind energy calculations. Wind velocity at 40, 30 and 10 meter height is studied firstly. Mean wind velocity on this station at mentioned height is 7.03, 6.82, 5.96 m/s respectively. Also windrose of wind blow direction is investigated. From windrose can be seen that the dominant wind direction is between north and northeast for 30m height and is between north and northwest for 37.5m height. This difference probably is that the data reported by the Renewable energy organization of Iran has problems. Annual wind mean power at 10, 30 and 40 meters height show that maximum of wind power production is on July. Also with evaluation the annual wind average power can be seen that 40m and 30m heights for installing wind turbines are suitable.

Keywords: wind energy, Qazvin Province, Jarandagh Station, weibull distribution.

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Introduction

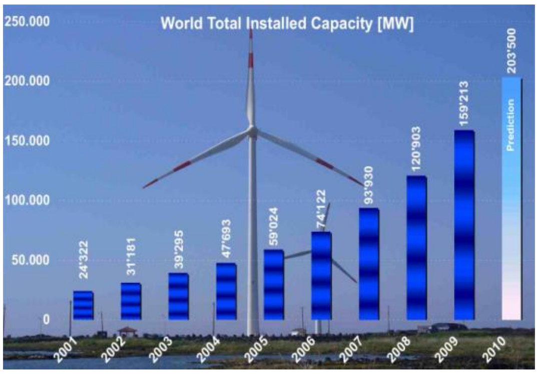
A country or region where energy production is based on imported coal or oil will become more self-sufficient by using alternatives such as wind power. Electricity produced from the wind produces no CO_2 emissions and therefore does not contribute to the greenhouse effect. Wind energy is proportionately labor intensive and thus makes many jobs. In solitary areas or areas with a weak grid, wind energy can be used for charging batteries or can be combined with a diesel engine to save fuel whenever wind is available. Moreover, wind turbines can be used for the desalination of water in littoral areas with little fresh water, for instance the Middle East [1]. the advantages of renewable energy are that it is sustainable , ubiquitous (found everywhere across the world in contrast to fossil fuels and minerals), and essentially nonpolluting. The disadvantages of renewable energy are low density and variability, which results in higher initial cost because of the need for large capture area and storage or backup power.

Word wind energy report

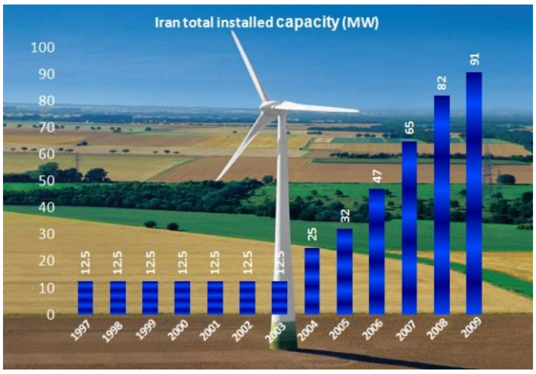
It is shown in Figure1 that worldwide capacity reached 159’213 MW, out of which 38’312 MW were added in 2009. Wind power showed a growth rate of 31.7%, the highest rate since 2001. The trend continued that wind capacity doubles every three years [2].

Wind power in Iran

Iran’s first experience in installing and using modern wind turbines dates back to 1994. Two sets of 500 kW Nordtank wind turbines were installed in Manjil and Roodbar. They produced more than 1.8 million kWh per year. These two sites are in the north of Iran, 250 km from Tehran, the capital of Iran. The average wind speed is 15 m/s for 3700 hours per year in Roodbar, and 13 m/s for 3400 hours per year in Manjil. After this successful experience, in 1996 the contract for 27 wind turbines was signed and they were installed by 1999 in Manjil, Roodbar and Harzevil [3]. Assessment of wind energy potentialin Iran has been done for some areas such as Manjil in Gilan province [4], Yazd [5] and Tehran [6] provinces; There are also studies about feasibility of offshore wind turbine installation in Iran and comparison with the world [7], future of renewable energies in Iran [8] and renewable energy issues in Middle East compared with Iran [9]; and the present study shows feasibility of wind energy potentialin another suitable province. Growth of Wind Energy in Iran was exposed in Figure2.



Figure(1) Development of World Wind Energy [2]



Figure(2) Growth of Wind Energy in Iran

Qazvin Province

The province covers 15821 km² between 48°45' to 50°50' east of Greenwich Meridian of longitude and 35°37' to 36°45' north latitude of the equator. The province is bounded on the north by Mazandaran and Gilan, on the west by Hamedan and Zanjan, on the south by Markazi and on the east by Tehran Provinces. It is in the northwest of Iran, and its capital is Qazvin. Wind Stations in the province are: Jarandagh, Papoli and Nekouei. We have studied the feasibility of using the wind in the Jarandagh station and analyzing the speed of the winds and its potentials in period of years 2009 to 2010. In figure 3 Location of Qazvin province in Iran has been brought [۹].

Figure(3) Location of Qazvin province in Iran [۹]

Analysis of wind data

Data collected over a period of 1 year, from August 2008 to July 2009 in the time interval of 10 minutes for site. The meteorological masts with 40m height were installed in suitable coordinates by power ministry.The data logger used has 3 sensors of velocity at 10m, 30m and 40m heights and also 2 sensors of directionat 30m and 37.5 m [11].

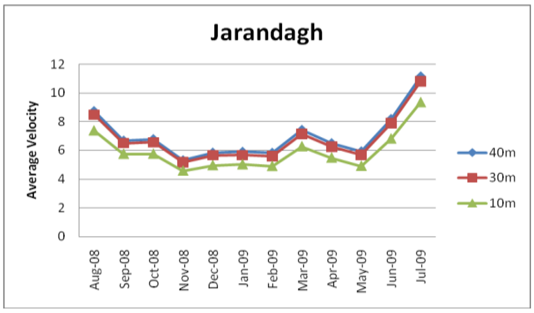
Average wind speed

In the first phase of study, as shown in Table 1, for average wind speed at 3 heights was determined.

Table(1) Wind speed at 3 heights for Jarandagh (m/s).

Site	10 m	30 m	40 m
Jarandagh	5.96	6.82	7.3

Figure 4 shows the monthly mean wind speed for 10m, 30m and 40 m of Jarandagh. From this figure is seen that average speed at 40 meter height is higher than other heights. Also at height of 40 m, average wind speed is higher in July than in other months. In addition, at heights of 30 and 40 meters results are very close.



Figure(4) Monthly average wind speed for 3 heights of Jarandagh

Wind speed distribution

Statistical analysis can be used to determine the wind energy potential of a given site and estimate the wind energy output at this site. To describe the statistical distribution of wind speed, various probability functions can be suitable for wind regimes. According to Gumbel [12], Weibull distribution is the best one, with an acceptable accuracy level. This function has the advantage of making it possible to quickly determine the average of annual production of a given wind turbine. The Weibull probability density function is given by [13]:

$$p(U)=\left(\frac{k}{c}\right)\left(\frac{U}{c}\right)^{k-1}\exp\left[-\left(\frac{U}{c}\right)^{k}\right] \qquad (1)$$

Determination of the Weibull probability density function requires a knowledgeof two parameters: *k*, shape factor and *c*, scale factor. Analytical and empirical methods are used to find k and c, such as Justus (eq. 3) and Lysen (eq. 4) formulas demonstrated in the following form [13]:

$$\sigma_u=\sqrt{\frac{\sum_{i=1}^{N}(U_i-\overline{U})^2}{N-1}} \qquad (2)$$

$$k=\left(\frac{\sigma_U}{\overline{U}}\right)^{-1.086}, \quad \frac{c}{\overline{U}}=\frac{k^{2.6674}}{0.184+0.816k^{2.73855}} \qquad (3)$$

$$\frac{c}{\overline{U}}=\left(0.568+\frac{0.433}{k}\right)^{\frac{1}{k}} \qquad (4)$$

Where σ_u and $\overline{U}$ represent the Standard deviation and mean wind speed, respectively. Standard deviation also is defined through the value of k [13]:

$$\sigma_U=\overline{U}\sqrt{\left(\frac{\Gamma(1+2/k)}{\Gamma^2(1+1/k)}-1\right)} \qquad (5)$$

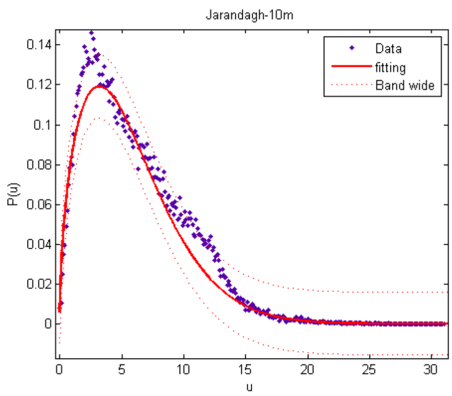
The corresponding wind data and best fits to a two parameter Weibull distribution at heights of 10m, 30m and 40m and Frequency bandwidth weibull of 10m, 30m and 40m for Jarandagh are shown in Figs. 5 to 10.

The average power, wind power density, standard deviation, energy pattern factor and cumulative density are presented in Table 2 for three heights.

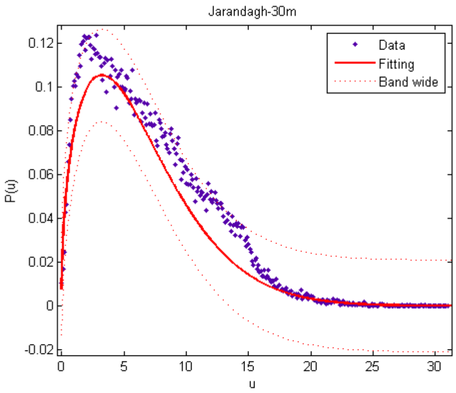
The energy pattern factor, K_e, whose application is in turbine aerodynamic design, can be defined as the total amount of power available in the wind divided by the power calculated from cubing the average wind speed is given by [13]:

$$K_e=\frac{1}{N\overline{U}^3}\sum_{i=1}^{N}U_i^{\,3}=\frac{\overline{U^3}}{(\overline{U})^3}=\frac{\Gamma(1+3/K)}{\Gamma^3(1+1/K)} \qquad (6)$$

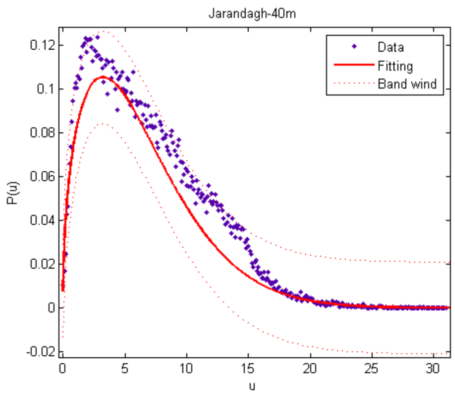
Where N is the amount of data in a year, 52559.



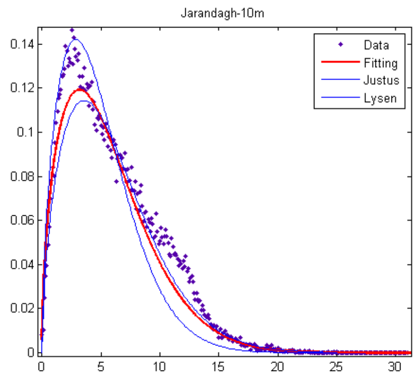
Figure(5) Frequency bandwidth at 10m



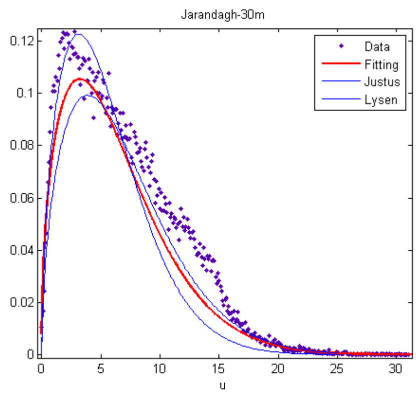
Figure(6) Frequency bandwidth at 30m



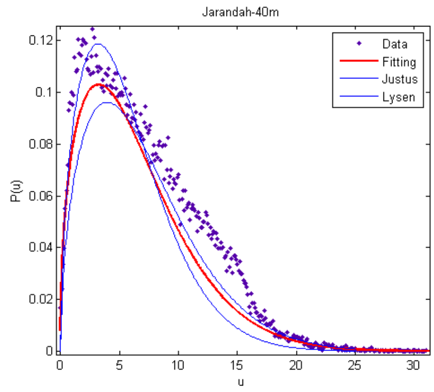
Figure(7) Frequency bandwidth at 40m



Figure(8) Weibull distribution at 10m



Figure(9) Weibull distribution at 30m



Figure(10) Weibull distribution at 40m

One way to define the probability density function is that the probability of a wind speed occurring between U_a and U_b is given by [13]:

$$p(U_a \le U \le U_b) = \int_{U_a}^{U_b} p(U)dU \qquad (7)$$

Also, the total area under the probability distribution curve is given by:

$$\int_0^{\infty} p(U)dU = 1 \qquad (8)$$

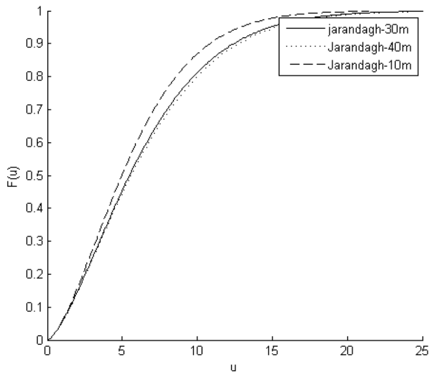
Table(2) Wind characteristics of Jarandagh.

Parameter	40^m	30^m	10^m
p/A	552.479	500.432	500.432
E/A	4671.95	4231.82	2750.50
sigma	4.73573	4.56370	3.88897
Ke	2.50993	2.49036	2.42658
Cumulative density	0.69163	0.69253	0.69576

Another important statistical parameter is the cumulative distribution function F(U). It represents the time fraction or probability that the wind speed is smaller than or equalto a given wind speed, U. It can be shown in [13]:

$$F(U) = 1 - \exp\left[-\left(\frac{U}{c}\right)^k\right] \qquad (9)$$

Figure 11 shows the cumulative distribution for Jarandagh at three heights. The 4 m/s limit is important since this is the cutin speed of many commercial turbines. The cutout speed is generally 20–25 m/s and such speeds are rare at this site.



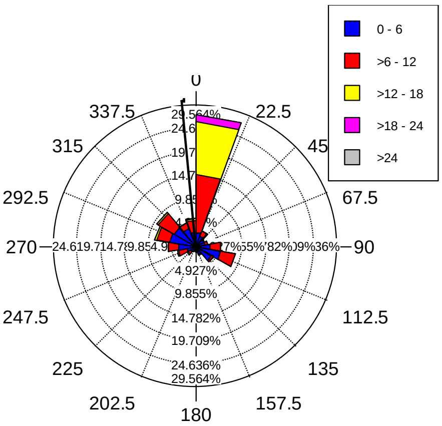
Figure(11) Cumulative density at 3 heights

Wind direction

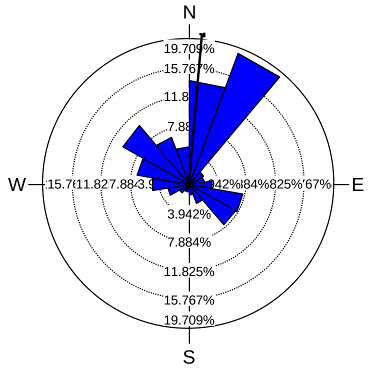
The wind direction is of paramount importance for the possibility assessment of using wind energy and plays a significance role in the optimal positioning of a wind farm in a given area.we present the data collected in the form of wind rose.

Windrose

A wind rose is a diagram showing the temporal distribution of wind direction and azimuthal distributionof wind speed at a given location (Figs.12 and 13). A wind rose is a convenient tool for displaying anemometer data (wind speed and direction) for sitting analysis. This figure illustrates the most common form, which consists of several equally spaced concentric circles with 16 equally spaced radial lines (each represents a compass point). The line length is proportional to the frequency of the wind from the compass point, with the circles forming a scale. The legend of wind rose shows special colors for each wind velocity limit. The frequency of calm conditions is indicated in the center. The longest lines identify the prevailing wind directions(≈ 250°).It's concluded that the most windward directions and the directions where the wind is strongest is between north and northeast for 30m height and is between north and northwest for 37.5m height.



Figure(12) Wind rose diagram at 30m



Figure(13) Wind rose diagram at 37.5m

Power and energy density

The best way to evaluate the wind resource available at a potential site is by calculating the wind power density. It indicates how much energy is available at the site for conversion to electricity by a wind turbine. The wind power per unitarea, P/A or wind power density is [13]**:**

$$\frac{\overline{P}}{A}=\frac{1}{2}\rho\int_{c}^{\infty}U^{3}p(U)dU=\frac{1}{2}\rho c^{3}\Gamma(1+3/k)\approx\frac{1}{2}\rho\overline{U^{3}} \quad (10)$$

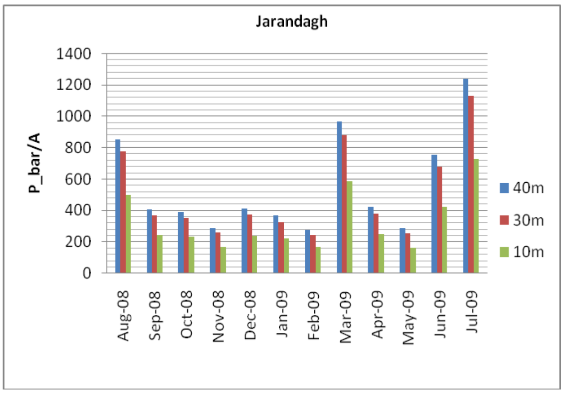
And also wind energy density is:

$$\frac{\overline{E}}{A}=\left(\frac{\overline{P}}{A}\right)(N\Delta t) \quad (11)$$

Where N is the number of measurement periods, Δt.

Monthly power density

In Figure 14 the monthly power density at 3 heights is determinedby measured data and it's found that maximum monthly power density is related to July of year 2009.

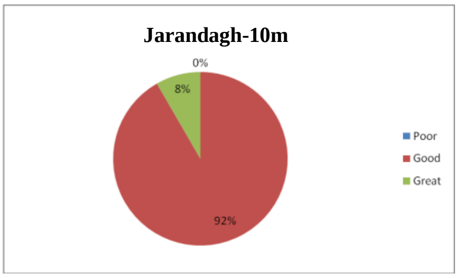


Figure(14) Monthly power density

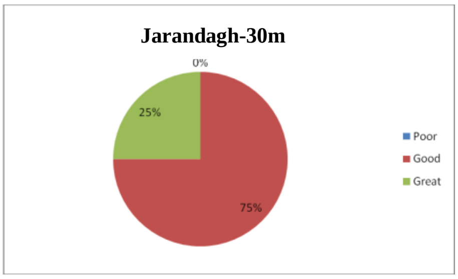
Some sample qualitative magnitude evaluations of the wind resource are [13]:

$\overline{P}/A < 100\ W/m^2$ – poor
$\overline{P}/A \approx 400\ W/m^2$ – good
$\overline{P}/A > 700\ W/m^2$ – great

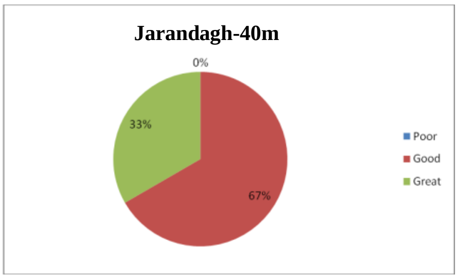
Figs. 15 to 17 illustrate plots of the annual average wind power at heights of 30 m and 40 m. From above criteria and below figs., it's found that the site has a relatively good situation with respect to power density. Moreover, as seen from the below figs. heights of 30 and 40 meters are more appropriate. These results confirm the previous results are taken from before Figure. also Figure18 illustrates monthly wind energy density at three heights.



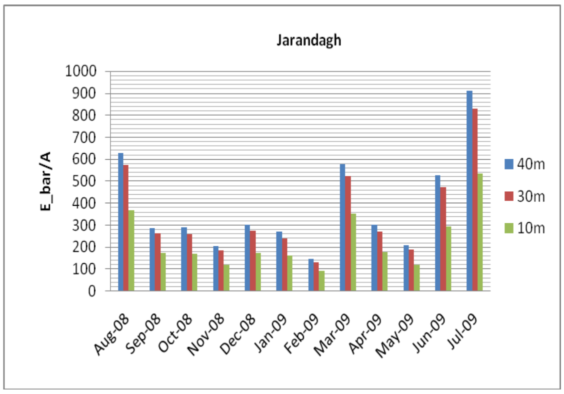
Figure(15) Annual average wind power at 10m



Figure(16) Annual average wind power at 30m



Figure(17) Annual average wind power at 40m



Figure(18) Monthly wind energy density at 10m, 30m and 40m

Conclusion

In this paper Feasibility of installing wind turbines in Jarandagh station of Qazvin province is implemented. Annual wind mean power at 10, 30 and 40 meters height show that maximum of wind power production is on July. Also with evaluation the annual wind average power can be seen that 40m and 30m heights for installing wind turbines are suitable.

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