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Assessing the wind energy potential locations in province of Qazvin in Iran

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ABSTRACT

In this study, the ten minutes period measured wind speed data for years 2009-2010 at 10 m, 30 m and 40 m heights for one of the provinces of Iran, Qazvin have been statistically analyzed to determine the potential of wind power generation. This paper presents the wind energy potential at three stations in the province Papoli, Jarandagh and Nikoei. Extrapolation of the 10 m data, using the Power Law, has been used to determine the wind data at heights of 30 m and 40 m. From the primary evaluation and determining mean wind speed and also weibull distribution, it is found that Jarandagh has better potential for using wind energy in the province. Also with evaluation the annual wind average power for Jarandagh station at heights of 10, 30 and 40 meters can be seen 40 and 30 meters heights for installing wind turbines are suitable. The objective is to evaluate the most important characteristic of wind energy in the studied site. The statistical attitudes permit us to estimate the mean wind speed and the wind rose in the site at the height of 10m, 30 m and 40 m.

KEYWORDS: wind energy, potential, Qazvin, weibull distribution, power density, wind turbine.

1. INTRODUCTION

The demand for the new kinds of energy has been grown in the recent years. The renewable energies can be good substitutes for the conventional energies. In fact, the increase in the population, industrial development, the growing demand for the energy and the environmental pollution are the crucial reasons for using the renewable energy recourses. Nowadays wind energy is one of the renewable energies that have attracted great attention. In fact, during the recent years, very significant progress has been done in the manufacturing and the implementation of wind turbines for power generation. By considering the range of wind speed, the type and capacity of turbines which were suitable for the region were specified. Studies determining wind duration and strength during a one-year period were conducted in the windy regions. Following the installation of two 550 KW Nordtank wind turbines, the installation of a 90 MW wind farm in Manjil and Roodbar has started a few years ago. Up to now the Manjil wind farm is generating around 25 MW (Figure1).

Figure 1: The Manjil wind farm

1.1. WORLD WIND ENERGY REPORT

It is shown in Figure2 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 [١].

1.2. 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 [٢]. Assessment of wind energy potentialin Iran has been done for some areas such as Manjil in Gilan province [٣], Yazd [٤] and Tehran [٥] provinces; There are also studies about feasibility of offshore wind turbine installation in Iran and comparison with the world [٦], future of renewable energies in Iran [٧] and renewable energy issues in Middle East compared with Iran [٨]; and the present study shows feasibility of wind energy potential in another suitable province. Growth of Wind Energy in Iran was exposed in Figure3.

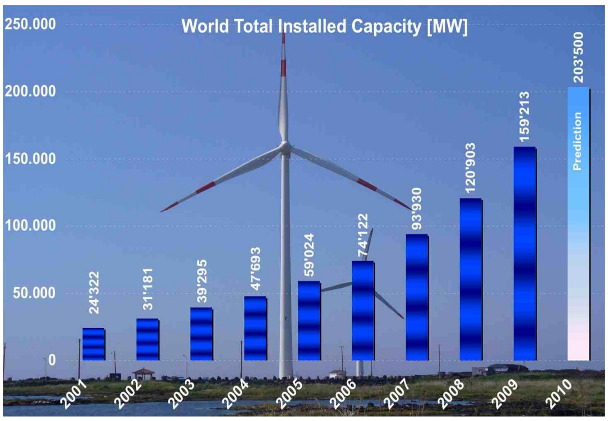

Figure2: Development of World Wind Energy [١]

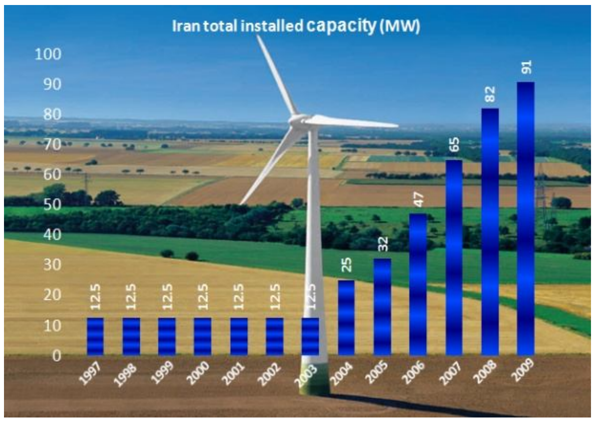

Figure3: Growth of Wind Energy in Iran

1.3. 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, Papoli and Nekouei, and analyzing the speed of the winds and its potentials in period of years 2009 to 2010. In figure 4 Location of Qazvin province in Iran has been brought [٩].

Figure 4: Location of Qazvin province in Iran [٩].

2. ANALYSIS OF WIND DATA

Data collected from years 2009 to 2010 in the time interval of 10 minutes for sites. 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 direction at 30m and 37.5 m [١٠].

2.1. AVERAGE WIND SPEED

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

Table1: Wind speed at 3 heights for Qazvin province (m/s).

Site	**10 m**	**30 m**	**40 m**
Jarandagh	5.96	6.82	7.03
Papoli	4.65	5.58	6.1
Nekouei	5.33	5.82	6.01

Figure 5 to 7 shows the monthly mean wind speed for sites Jarandagh, Papoli and Nekouei at heights 10m, 30m and 40 m. From this figures are seen that average speed at 40 meter height is higher than other heights. In addition, at heights of 30 and 40 meters results are very close.

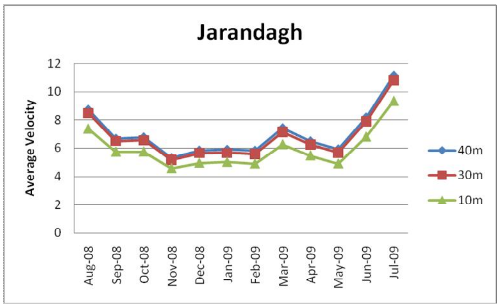

Figure5: Monthly average wind speed for 3 heights

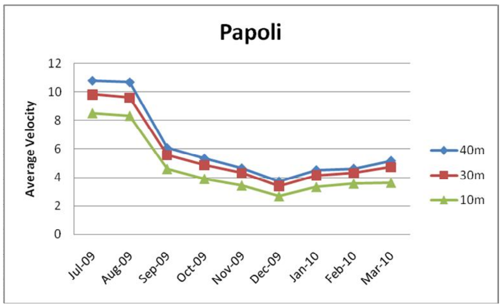

Figure6: Monthly average wind speed for 3 heights

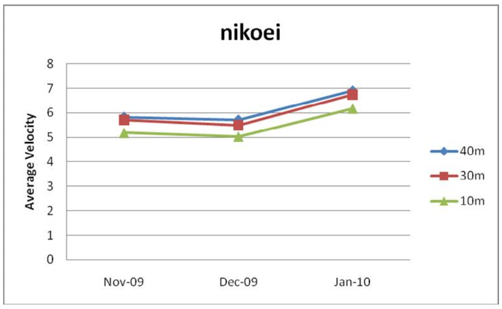

Figure7: Monthly average wind speed for 3 heights

Since renewable energies organization of Iran (SUNA) data were not complete for stations Papoli and Nekoei, stations information in period less than a year were used.

2.2. 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 statisticaldistribution of wind speed, various probability functions can be suitable for wind regimes. According to Gumbel [1١], 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 [1۲]:

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

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 [1۲]:

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

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

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

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 [1۲]:

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

The corresponding wind data and best fits to parameter Weibull distribution at heights of 10m, 30m and 40m for Jarandagh, Papoli and Nekoei are shown in Figs.8-16.

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 [1٢]:

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

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

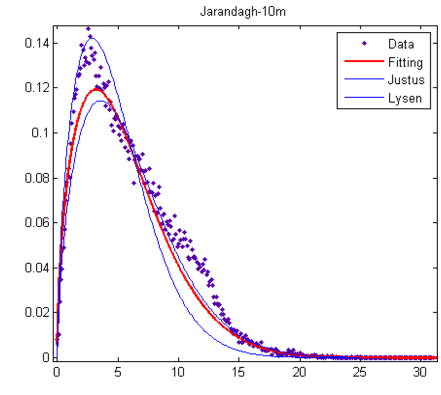

Figure8: Weibull distribution at 10m (Jarandagh)

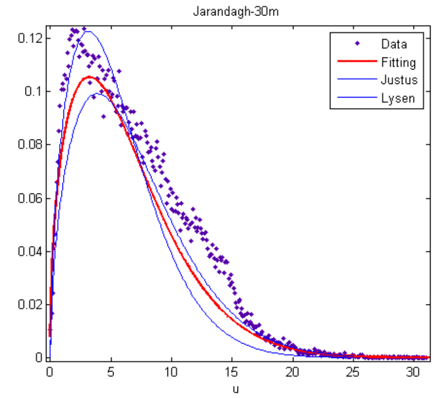

Figure9: Weibull distribution at 30m (Jarandagh)

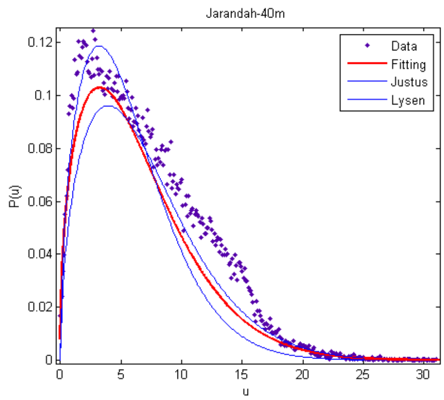

Figure10: Weibull distribution at 40m (Jarandagh)

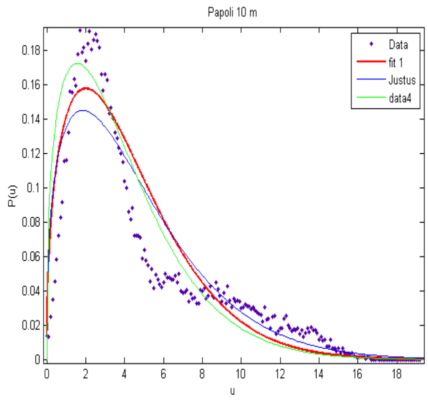

Figure11: Weibull distribution at 10m (Nekoei)

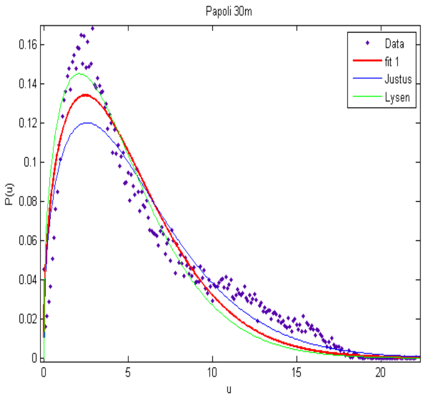

Figure12: Weibull distribution at 30m (Nekoei)

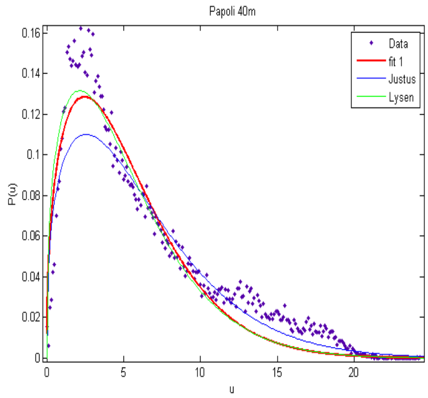

Figure13: Weibull distribution at 40m (Nekoei)

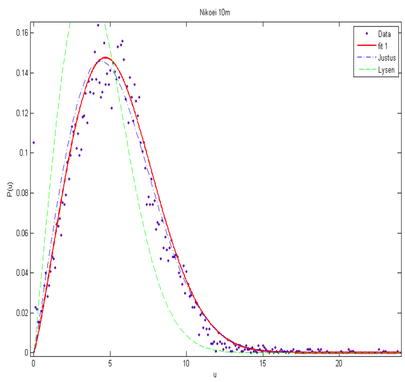

Figure14: Weibull distribution at 10m (Papoli)

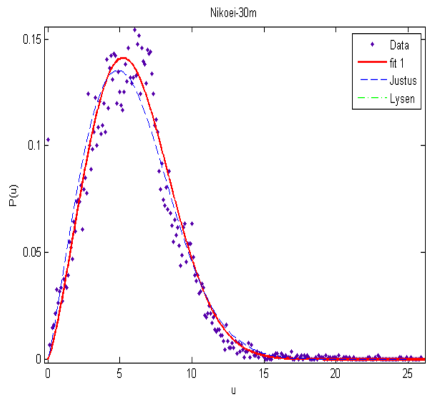

Figure15: Weibull distribution at 30m (Papoli)

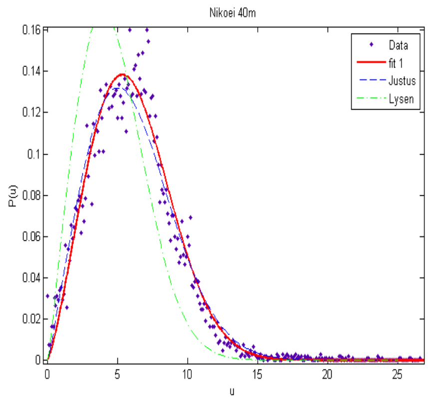

Figure16: Weibull distribution at 40m (Papoli)

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 [١٢]:

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

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

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

Table 2: Wind characteristics of Qazvin Province.

	Parameter	40^m	30^m	10^m
Jarandagh	p/A	552.4797	500.432	500.432
	E/A	4671.952	4231.82	2750.509
	sigma	4.735733	4.563708	3.888927
	Ke	2.509934	2.490316	2.426548
	Cumulative density	0.691673	0.692538	0.69576
Papoli	p/A	435.65	314.748	197.597
	E/A	2276.997	1645.081	1032.773
	sigma	4.58559	4.05892	3.52932
	Ke	1.79088	1.69863	1.84756
	Cumulative density	0.67691	0.6813	0.67519
Nekoei	p/A	246.198	225.51	175.412
	E/A	431.1342	394.9061	307.1747
	sigma	2.99119	2.92666	2.72385
	Ke	1.77779	1.78804	1.81367
	Cumulative density	0.72675	0.7258	0.72408

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 equal to a given wind speed, U. It can be shown in [1۲]:

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

Figs. 17 to 19 show the cumulative distribution for Qazvin province at three heights. The 4 m/s limit is important since this is the cut in speed of many commercial turbines. The cut out speed is generally 20–25 m/s and such speeds are rare at these sites.

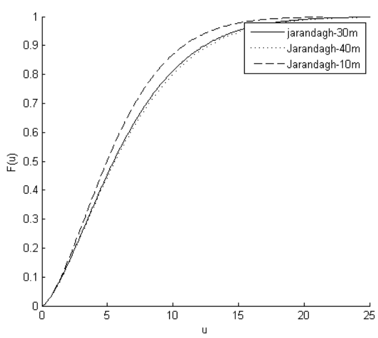

Figure17. Cumulative density at 3 heights (Jarandagh)

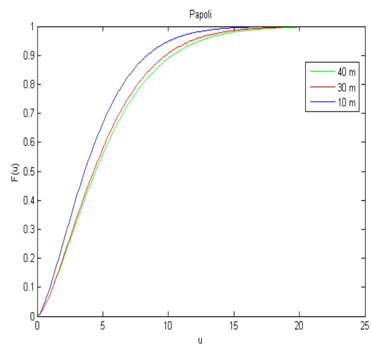

Figure18. Cumulative density at 3 heights (Papoli)

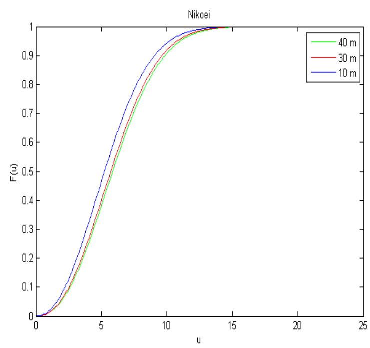

Figure19. Cumulative density at 3 heights (Nekoei)

2.4. 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. A wind rose is a diagram showing the temporal distribution of wind direction and azimuthal distribution of wind speed at a given location (Figs.20 to 25). From figures 20 and 21 are seen that the dominant wind direction for the Jarandagh station between the north and northeast. From figures 22 and 23 are seen that the dominant wind direction for the Papoli station between the west and northwest. From figures 24 and 25 are seen that the dominant wind direction for the Nekoei station between the north and northwest.

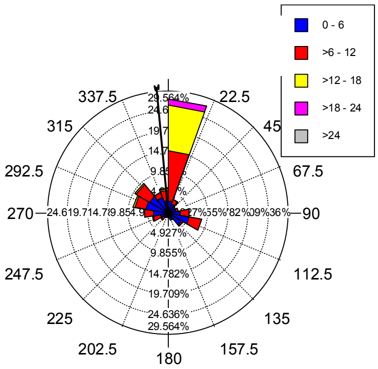

Figure20: Wind rose diagram at 30m (Jarandagh)

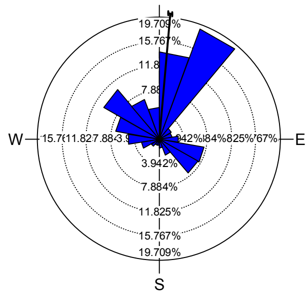

Figure21: Wind rose diagram at 37.5m (Jarandagh)

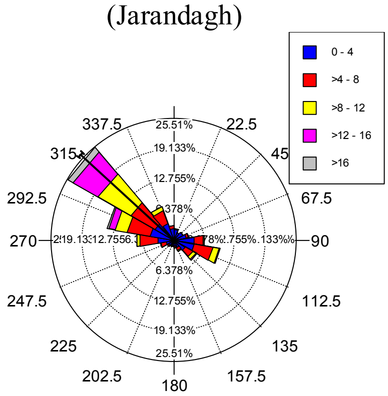

Figure20: Wind rose diagram at 30m (Papoli)

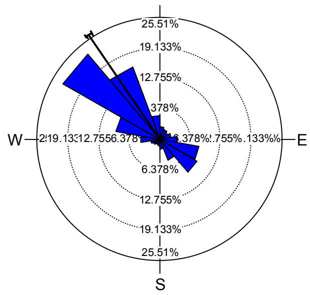

Figure21: Wind rose diagram at 37.5m (Papoli)

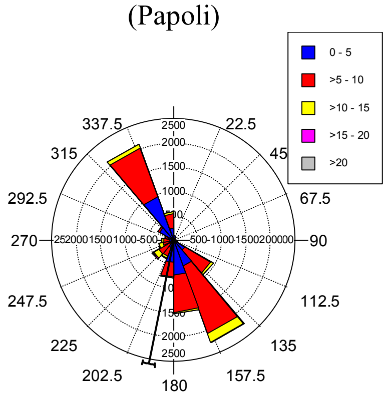

Figure20: Wind rose diagram at 30m (Nekoei)

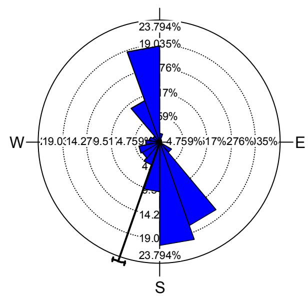

Figure21: Wind rose diagram at 37.5m (Nekoei)

2.5.1. THE AVERAGE ANNUAL WIND POWER

Figs. 22 to 27 illustrate plots of the annual average wind power at heights of 30 m and 40 m. From below criteria [1۲] and below figs., it's found that the Jarandagh 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. Because Nekoei station data is low, average annual wind power at three heights is good.

$$\frac{\overline{P}}{A} \prec 100\frac{w}{m^2} - Poor$$
$$\frac{\overline{P}}{A} \approx 400\frac{w}{m^2} - Good$$
$$\frac{\overline{P}}{A} \succ 700\frac{w}{m^2} - Great$$

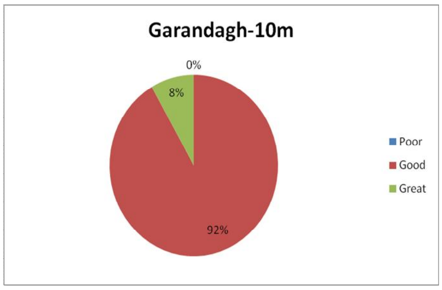

Figure22: Annual wind average power

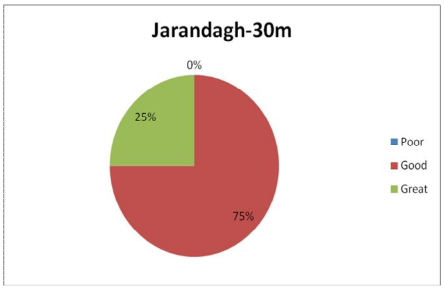

Figure23: Annual wind average power

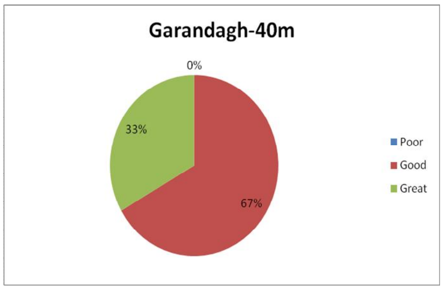

Figure24: Annual wind average power

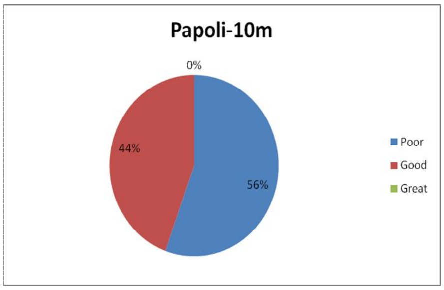

Figure25: Annual wind average power

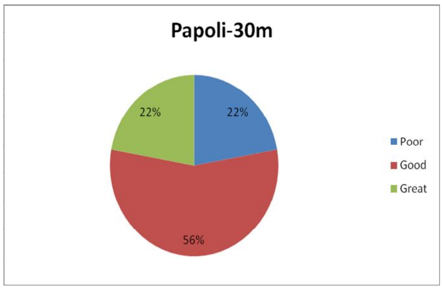

Figure26: Annual wind average power

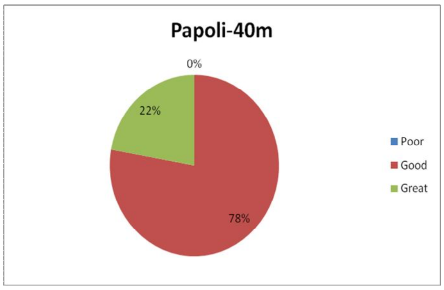

Figure27: Annual wind average power

CONCLUSION

In this study, the ten minutes period measured wind speed data for years 2009-2010 at 10 m, 30 m and 40 m heights for one of the provinces of Iran, Qazvin have been statistically analyzed to determine the potential of wind power generation. This paper presents the wind energy potential at three stations in the province Papoli, Jarandagh and Nikoei. From the primary evaluation and determining mean wind speed and also weibull distribution, it is found that Jarandagh has better potential for using wind energy in the province. Also with evaluation the annual wind average power for Jarandagh station at heights of 10, 30 and 40 meters can be seen 40 and 30 meters heights for installing wind turbines are suitable.

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