Evaluating wind energy potentials for four cities of Fars province, Iran

Ali Mostafaeipour
Industrial Engineering Department, Yazd University, Yazd, Iran
mostafaei@yazd.ac.ir

Ahmad Sedaghat, Mohammad Khayyami
Department of Mechanical Engineering, Isfahan University of Technology,
Isfahan, 84156-83111, Iran
Sedaghat@cc.iut.ac.ir, Sedaghat@cc.iut.ac.ir

Ehsan Gorakifard
iRMB - Institute for Computational Modeling in Civil Engineering, TU Braunschweig,
Braunschweig, Germany
Sedaghat@cc.iut.ac.ir

Mojtaba Qolipour
Industrial Engineering Department, Yazd University, Yazd, Iran
qolipourmojtaba@yahoo.com

Abstract

With increasing demand for energy usage and decreasing fossil fuel resources, more attention has been made to the renewable energy resources such as wind energy. Wind map of Iran has indicated a good potential to use this resource. In this paper, the wind energy potential for four cities: Abadeh, Joyum, Eqleed, and Marvdasht are assessed in the province of Fars in the south of Iran. Wind speed at 10 m, 30 m and 40 m heights and wind direction at 30m and 37.5m have been recorded in ten minutes intervals for one year period from 20 June 2006 to 20 June 2007. Since data from this period was complete and also available to authors, so data for last year was not used in this research because were not complete. Wind energy characteristics has been statistically analyzed to determine the potential of wind power generation. It is found that Abadeh has better potential for using wind energy among other cities studied in the province of Fars. Statistical analyses for the 40m height at Abadeh indicate the nominal wind speed of 7.47 m/s which produces maximum energy and the annual power density of 220 W/m^2 with dominant wind direction towards south west. It is concluded that the Fars province has an average wind farming potential for installing grid connected wind turbines.

Keywords
Renewable, wind energy, wind power, fossil fuel, Wind direction

1. Introduction

With the dramatically increase of industrial application in all over the world, demand of energy is increasing sharply. Generally, using of energy plays bare bone essential in our lives and with fast growth of population and industrials. On the other hand, none renewable resources of energy are decreasing on earth. More than 80 percentage of energy in the world are provided by fossil fuel which was consumed increasingly in recent years. Moreover, problems related to lack of resources, environmental considerations, melting glaciers and consequently, raising the level of seas as the result of heating earth up, and air pollution are reasons that cause researchers to look for other resources of energy. One of the solutions to overcome these problems is to use the wind energy as one of the renewable resources (Haas et al, 2011).

Iran is located in south-western Asia and its boundaries are limited to the Republic of Armenia, the Republic of Azerbaijan, and the Republic of Turkmenistan, and the Caspian Sea to the north, the Persian Gulf and the Gulf of Oman to the south, Pakistan and Afghanistan to the east and Turkey and Iraq to the west (Mostafaeipour, 2005). In 2008 the production of 85 MW electricity using wind energy in Iran has ranked Iran as the 30th place among all other countries in this field (Alijani et al, 2008). In recent years, tendency of using wind energy to produce electricity in Iran has been significantly increased and the Government has placed appropriate reimbursements for renewable production of electricity. Among the Middle East countries, Iran is one of the countries that has generated wind power. The potential of generation electricity by wind energy in Iran is about 10,000 (MW).The main power stations in Manjil and in Binalood have capacities 70(MW) and 28(MW) to generate electricity, respectively (Mostafaeipour and Abarghooei, 2007).

Many researchers have recently studied wind power generation in Iran (Mostafaeipour and Sadeghian, 2005; Mostafaeipour, 2005; Emami, 2008; Saghafi, 1995). Mostafaeipour (2005) has assessed the wind energy potential for installing the wind turbine among 11 sites in Yazd (one of provinces of Iran) with using wind data measured during 13 years. Harat city has been suggested by him as the best place for setting up wind turbines. Furthermore, because of high potential of Manjil city, probability of increasing of production power and the number of turbines has been considered by Mostafaeipour and Abarghooei (2008). An assessment of wind energy potential as a power generation source in the capital of Iran, Tehran, has been studied by Keyhani et al (2010). However, they have found that Tehran is not appropriate for setting up large wind turbines. Mirhosseini et al and Saeidi et al (2011) have studied two provinces of Semnan and Khorasan in Iran, respectively. New energy organization in Iran has also implemented considerable work in this field; one of them is Suna which has produced wind map of Iran.

In this study, the wind energy potential locations in province of Fars are assessed for four cities, Abadeh, Joyum, Eqleed and Marvdasht. Authors studied and evaluated different renewable energy sources (Alavi et al, 2016a; Alavi et al, 2016b; Shamshirband et al, 2015a; Mohammadi et al, 2016; Mostafaeipour and Sadeghian, 2005; Shamshirband et al, 2015b; Mostafaeipour et al, 2016b; Qolipour et al, 2016; Erratum to: shamshirband et al., 2016; Hosseini-Ezzabadi et al., 2015; Sajjadi et al., 2016; Shamshirband et al., 2015c).

There have been many studies related to implementing renewables. Mohammadi et al (2013a) studies wind potential for Aligoodarz, Iran. They concluded that there was a reasonable energy for this purpose in the region,. Mostafaeipour et al. (2013b) investigated the wind potential for Binalood region in Iran. Mostafaeipour (2013b), and Mohammadi et al. (2013b) investigated wind potential for other regions of Iran. Mohammadi et al. (2014a) investigated the hybrid wind-solar for three zones of Iran; Chabahar, Kish and Salafchegan. It was concluded that all regions had good potentials for utilizing different solar energy systems. Khorasanizadeh et al. (2014) studied solar potential for city of Tabas in Iran. They established a diffuse solar radiation model for determining the optimum tilt angle of solar surfaces.

Many other researches have been done on designing and building different kinds of renewables in the world (Mostafaeipour and Abesi, 2010; Mostafaeipour, 2010; Dinpashoh et al, 2013; Mostafaeipour, 2011; Shamshirband et al, 2015a; Shamshirband et al, 2015b; Mostafaeipour et al, 2014a; Mohammadi et al. (2014a).

The purpose of this work is to evaluate wind energy potentials for four cities of Fars province in Iran. It is postulated that all four cities have adequate potential for harnessing wind energy. Outcome of this work is to identify the best city for wind turbine installation.

The rest of this paper is structured as follows: in sections 2, the wind characteristics is extensively explained. In section 3, statistical analysis is presented. Finally conclusions are drawn in section 4.

2. Wind characteristics in the province of Fars

2.1. Wind speed distribution

It is a matter of common observation that the wind is not steady and in order to calculate the mean power delivered by a wind turbine from its power curve, it is necessary to know the probability density distribution of the wind speed. This is simply the distribution of the proportion of time spent by the wind within narrow bands of wind speed. The basic measure of the unsteadiness of the wind is the standard deviation (or root mean square) of the speed variations and this almost certainly representative of the unsteadiness of the wind everywhere in order to calculate the mean power from a wind turbine over a range of mean wind speeds. A generalized expression is needed for the probability density distribution. An expression which gives a good fit to wind data is known as the Weibull distribution (Seyit and Dinler, 2009). Accordingly, Weibull distribution usually used as the function distribution, is applied for analyzing wind data. This function depends on two parameters, k, shape factor and c, scale factor. With using this function, the wind energy potential of a given site can be estimated as is given by the Eq. 1 (Manwell et al, 2005; Lun and Lam, 2000).

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

c and *k* are obtained by (Manwell et al, 2005; Chang, 2000).

$$k=\left(\frac{\sigma_U}{\bar{U}}\right)^{-1.086},\ \frac{c}{\bar{U}}=\frac{k^{2.6674}}{0.184+0.816k^{2.73855}} \tag{2}$$

where σ_U and $\bar{U}$ are the standard deviation and mean wind speed, respectively.

$$\sigma_U=\bar{U}\sqrt{\left(\frac{\Gamma(1+2/k)}{\Gamma(1+1/k)}-1\right)} \tag{3}$$

2.2. Wind power and energy density

A quantitative measure of the wind energy available at any location is called the wind power density (Manwell et al, 2005; Aslan, 1994). It is a calculation of the mean annual power available per square meter of swept area of a turbine, and is tabulated for different heights above ground. Calculation of wind power density includes the effect of wind velocity and air density. Therefore, one of the significant parameters which must be computed to indicate how much energy is available at the site is wind power distribution(P/A). This amount is proportional to air density (ρ) and the cubic of average speed $\bar{U}^3$ (Ahmed and Hanitsch, 2006)

$$\frac{\bar{P}}{A}=\frac{1}{2}\rho K_e\overline{U}^3 \tag{4}$$

Or wind energy density is,

$$\frac{\bar{E}}{A}=\left(\frac{\bar{P}}{A}\right)(N\Delta t) \tag{5}$$

Where N is the number of measurement period, and Δt is the time interval. The energy pattern factor, K_e, is defined as the total amount of power available in the wind divided by the power calculated from cubing the average wind speed and given by:

$$K_e=\overline{U^3}\Big/(\bar{U})^3 \tag{6}$$

In Eq. 7, $\overline{U^3}$ is the average speed cubed.

The following criterion using power density per area is useful measure to evaluate suitability of the sites:

$$\frac{\overline{P}}{A} < 100\frac{W}{m^2} \quad poor$$
$$\frac{\overline{P}}{A} \approx 400\frac{W}{m^2} \quad good \qquad (7)$$
$$\frac{\overline{P}}{A} > 700\frac{W}{m^2} \quad great$$

As it is indicated in Eq. 6, if the power density per area is smaller than 100(w/m^2), it cannot be suitable to setting up wind turbines and if it is equal to 400(w/m^2), the condition is appropriate and finally if power density per area is more than 700(w/m^2), the great performance may be expected from wind turbines (Manwell et al, 2005).

2.3. Turbulence intensity

The most important considerations in planning the tower height for a wind turbine are avoidance of turbulent air flow produced near ground level by the 'roughness' of the terrain over which the wind flows. A wind turbine must never be located such that it is subject to excessively turbulent air flow. Light turbulence will decrease performance since a turbine cannot react to rapid changes in wind direction, while heavy turbulence may reduce expected equipment life time or result in wind turbine failure and causes the fatigue stress in the wind turbine as well.

Turbulence intensity is one of the main parameters of turbulence and is defined as the ratio of the standard deviation of the wind speed to the mean (Manwell et al, 2005; Frost and Long, 1978)

$$TI = \frac{\sigma_U}{\overline{U}} \qquad (8)$$

The length of this time period is approximated about an hour. The mean wind speed, the surface roughness, the atmospheric stability are some parameters which can change turbulence intensity

2.4. Nominal and most probable wind speeds

The nominal wind speed is another substantial character and can be defined as a speed that produces maximum energy along the year. With using nominal wind speed, maximum energy can be captured throughout of a year (Manwell et al, 2005).

$$U_{me} = c\left(\frac{k+2}{k}\right)^{\frac{1}{k}} \qquad (9)$$

And the most probable wind speed for the area is given by (Manwell et al, 2005):

$$U_{mp} = c\left(1-\frac{1}{k}\right)^{\frac{1}{k}} \qquad (10)$$

This is a good measure in power capture of a wind turbine.

2.5. Cumulative distribution function

the cumulative distribution function F(u) is a function than can be used to represent the time fraction or probability that the wind speed is smaller than or equal to a given wind speed and is given by (Manwell et al, 2005):

$$F(u) = 1 - \exp\left(-\left(\frac{U}{c}\right)^k\right) \qquad (11)$$

2.6. Wind speed duration curve

Wind speed duration curve is defined as a graph that indicates the distribution of wind speeds as a function of the cumulative number of hours that the wind speed exceeds a given wind speed in a year. When comparing the energy potential of candidate wind sites, velocity duration curves can be beneficial. As, the velocity duration curve is a graph with wind speed on the y-axis and the number of hours in the minute for which the speed equals or exceeds each particular value on the x-axis.

2.7. Wind continuity factor

This factor, which is called wind stability factor as well, plays fundamental impact on assessing of wind energy in sites. In meteorology, the positive directions in equations are eastward and northward so that X-axis and Y-axis are located in the eastward and northward directions on the axis, prospectively. According to these directions, velocity directions $\overline{u_x}$ and $\overline{u_y}$ are defined with the Eq. 12.

$$\overline{u_x} = \frac{\sum W - \sum E + 0.707\left(\sum NW + \sum SW - \sum NE - \sum SE\right)}{N_t}$$
$$\overline{u_y} = \frac{\sum S - \sum N + 0.707\left(\sum SW + \sum SE - \sum NE - \sum NW\right)}{N_t} \quad (12)$$

Where N_t is the amount of wind monitor and NW, W, SW, S, SE, E, NE and N are defined as velocity in correspondent directions. The number 0.707 is the cosine of angle between SE, SW, NE, NW directions and X-axis, Y-axis. The magnitude of velocity is:

$$R = \sqrt{\overline{u_x} + \overline{u_y}} \quad (13)$$

Where R is mean direction of wind speed and $\overline{u}$ is the mean magnitude of wind speed. The dominant direction of wind flow in the site studied is calculated by Eq. 14.

$$\tan\beta = \frac{\overline{u_y}}{\overline{u_x}} \quad (14)$$

Wind stability characteristics can be acquired with regard to $\overline{u_x}$, $\overline{u_y}$, R and β.

2.8. Wind direction and rose diagram

Another characteristic which should be considered is wind direction. The more the wind direction is smoothly, the less design of wind turbine needs expense. For having better simulation, wind rose is used to indicate wind direction. In fact, a wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. Using a polar coordinate system of gridding, the frequency of winds over a long time period are plotted by wind direction, with color bands showing wind ranges. The directions of the rose with the longest spoke show the wind direction with the greatest frequency. Each concentric circle represents a different frequency, emanating from zero at the center to increasing frequencies at the outer circles. A wind rose plot may contain additional information, in that each spoke is broken down into color-coded bands that show wind speed ranges. Wind roses typically use 16 cardinal directions, such as north (N), NNE, NE, etc., although they may be subdivided into as many as 32 directions. In terms of angle measurement in degrees, North corresponds to 0°/360°, East to 90°, South to 180° and West to 270°.

3. Statistical analyses

The main criteria are considered in feasibility study is the mean annual wind speed. Table 1 summaries the mean wind speeds at three heights 40m, 30m, and 10m for four areas in the province of Fars from 20 June 2006 to 20 June 2007 based on 10 minutes wind monitoring intervals. Among these sites, Abadeh has the highest mean wind speed and then has better potential for considering setting up wind turbines.

Table 1. Annual mean wind speed (m/s) in 2006-2007 at three heights for four areas in the province of Fars

Sites/heights	40m	30m	10m
Abadeh	5.38	5.17	4.52
Joyum	2.58	2.42	1.85
Eqleed	4.39	4.20	3.84
Marvdasht	3.41	3.28	2.88

Monthly mean wind speeds for three heights of Abadeh are shown in the Figure 1 The mean wind ranges are 4.41-7.67 for 40m, 4.21-7.35 for 30m and 3.58-6.44 for 10m. The maximum and minimum wind speeds occur in March and August, respectively.

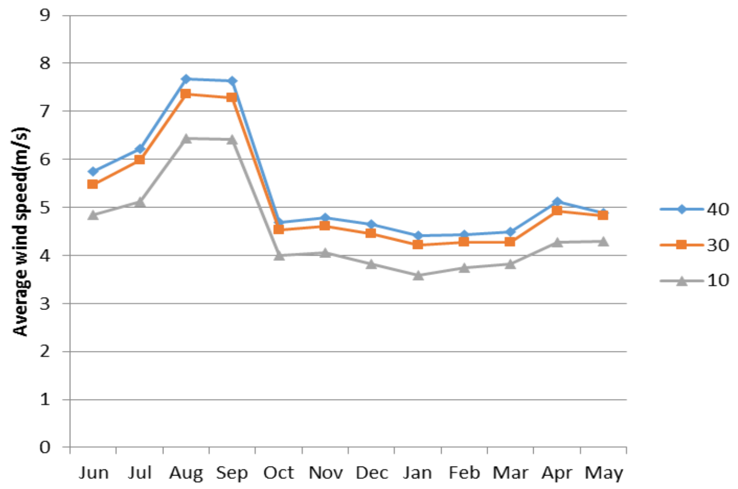

Figure 1. Monthly mean wind speed for three heights of Abadeh from 20 June 2006 to 20 June2007

For assessing the potential of having access for a month, power densities for 3 heights at different months during a year are shown in the Figure 2.

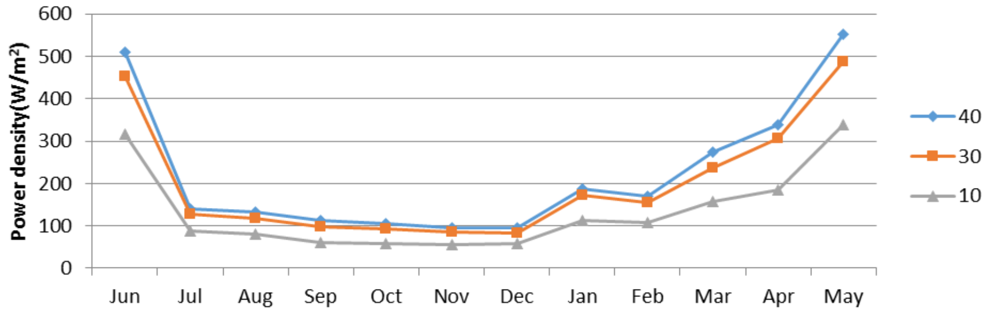

Figure 2. Power densities for 3 heights at different months of Abadeh from 20 June 2006 to 20 June2007

Wind characteristic including Weibull parameters, *k* and *c* for four areas of Fars province at 40m are given in the Table 2. There other methods to calculate k and c parameters of Weibull distribution function. Six common methods of graphical method (GP), empirical method of Jestus (EMJ), empirical method of Lysen (EML), energy pattern factor method (EPF), maximum likelihood method (ML) and modified maximum likelihood method (MML) are frequently used in different research works to calculate the k and c (Mohammadi et al., 2016).

Table 2. Wind characteristics for four cities in Fars province

Sites/parameters	*k*	*c*	*Ke*	*P/A*	*E/A*	*TI*
Abadeh	1.732	4.795	2.36	225.2	1972.7	0.603
Joyum	1.246	2.412	3.83	40.7	356.6	0.817
Eqleed	1.105	4.239	1.69	87.9	770.3	0.912
Marvdasht	1.657	3.051	2.46	60.0	525.7	0.628

According to Table 2, Abadeh has the highest condition compared to other cities. Thus, Abadeh site is considered and analyzed in detail to show capacity of this site. Wind characteristics of Abadeh at three heights are shown in Table 3.

Table 3. Wind characteristics of Abadeh city in Fars province

Parameters/heights	40	30	10
k	1.732	1.734	1.734
c	4.795	4.606	4.031
Ke	2.36	2.36	2.37
TI	0.603	0.602	0.602
P/A	225.2	200.4	134.6
E/A	1972.7	1754.9	1179.1
U_{me}	7.47	7.16	6.27
U_{mp}	2.24	2.24	2.20

Probability density distribution of the wind speed and best fits to a two-parameter Weibull distribution at heights of 10 m, 30 m and 40 m for Abadeh are shown in Figures 3-5.

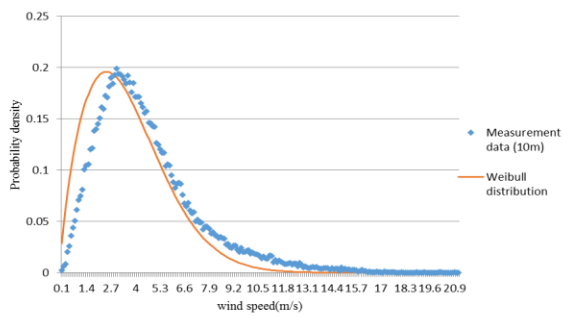

Figure 3**.** Abadeh probability density distribution of the wind speed at 10 m height

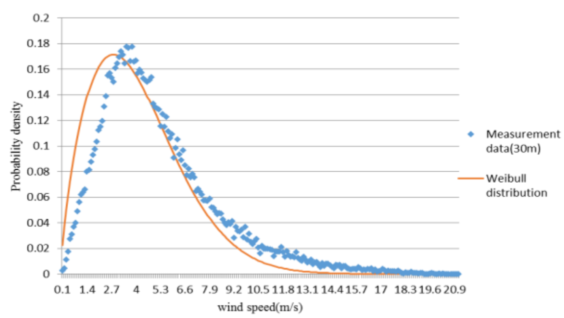

Figure 4**.** Abadeh probability density distribution of the wind speed at 30 m height

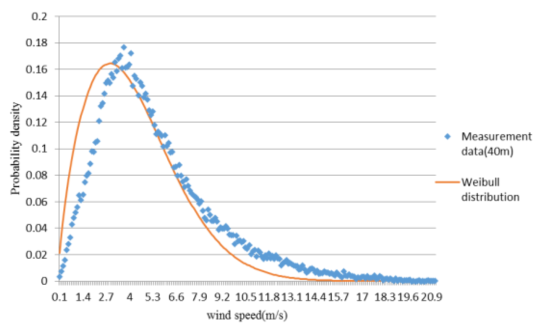

Figure 5**.** Abadeh probability density distribution of the wind speed at 40 m height

Annual power and energy densities at 10m, 30, 40m are demonstrated in the Figures 6 and 7 in order to assess the potential of exploiting of this energy and determine height of turbine. According to the criterion (Eq. 5), the site is fairly good and acceptable to install wind turbines. The winds are giving power densities of between (169–173)W/m^2 at 10m,(200–205)W/m^2 at 30mand(220–225)W/m^2 at 40m height.

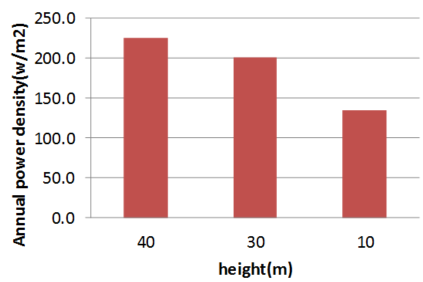

Figure 6**.** Annual power density at 40 m, 30 m and 10 m

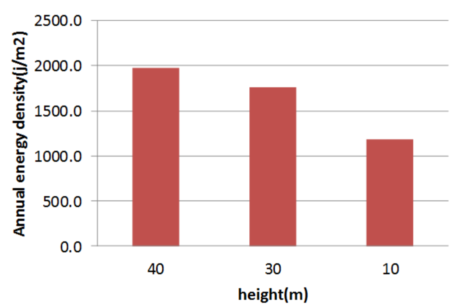

Figure 7**.** Annual energy density at 40 m, 30 m and 10 m

The cumulative distribution functions at three heights for Abadeh are illustrated in Figure 8 It is seen that the wind speed at 10 m, 30 m and 40 m heights is greater than 4 m/s for 49%, 57% and 60% of the time in the year, respectively. The 4 m/s limit is crucial because the cut-in speed of many commercial turbines is this speed. The cut-out speed is generally 20–25 m/s and such speeds are rare at this site.

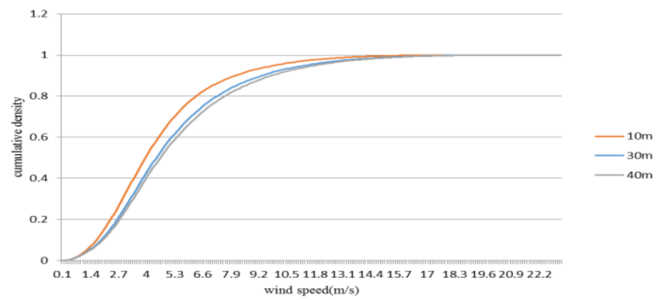

Figure 8. Cumulative distribution function at three height for Abadeh

Monthly mean wind direction at 30 m is depicted in Figure 9. The annual mean wind direction is 197.653 at 30m.

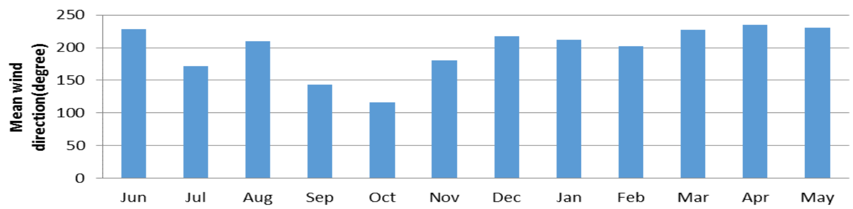

Figure 9. Monthly mean wind direction at 30 m height from June 2006 to June 2007

As it is shown in the Figure 10, the majority of windward directions (18% of the total available energy) and the directions where the wind is strongest are southwest. This figure ascertains the suitability of this site for grid connection and stand-alone applications.

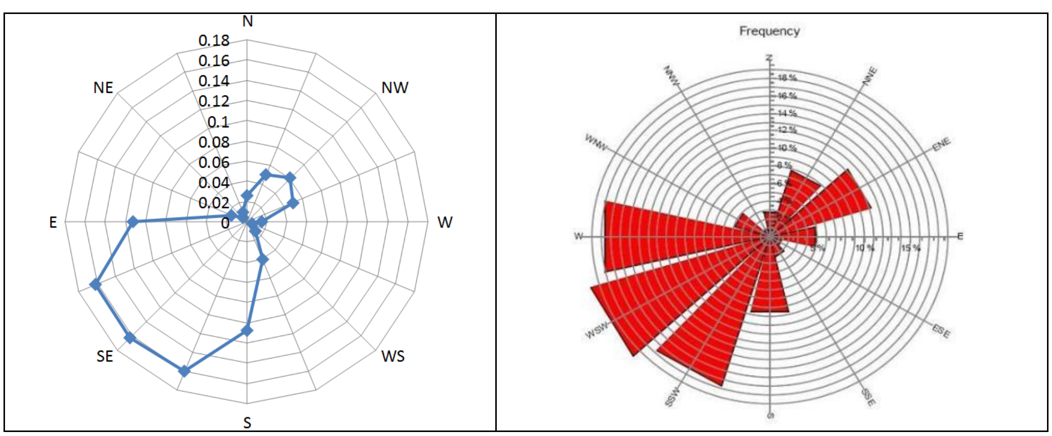

Figure 10. Wind rose diagrams at 40m height

In the table 4, mean wind speed for eight directions are shown and also mean directional wind and continuity factors are given in the table 5.

Table 4. Mean wind speed for eight directions

directions	N	NW	W	WS	S	SE	E	NE
$\bar{u}$	4.222	4.788	4.261	3.932	6.212	5.932	5.221	3.454

Table 5. Mean directional wind and continuity factors

parameters	u_x	u_y	R	β
values	-0.17	-0.39	0.430	204

Velocity duration curve at 10 m is illustrated in Figure 11.

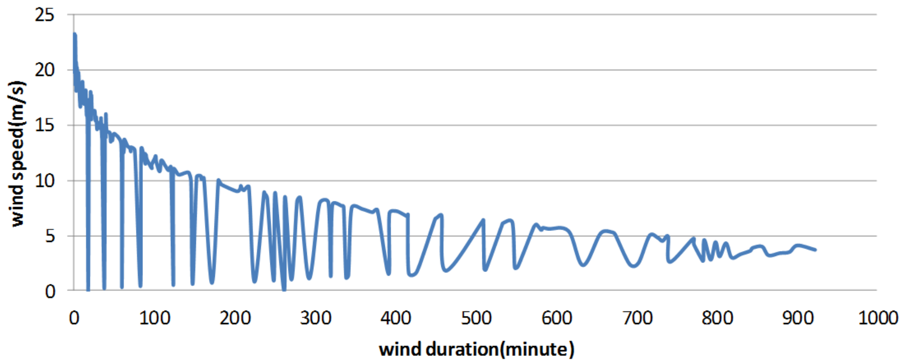

Figure 11. Velocity duration curve at 10m

4. Conclusion

Some statistical analyses are applied for four city of Fars provinces in Iran, namely Abade, Eghlid, Marvdasht and Joyum. After the analysis of wind for 10m, 30m and 40m heights, Abade is found to be the best site in Fars province among four cities studied. With using Weibull probability density function, wind speeds are modeled. Weibull parameters *k* and *c* are presented for four different cities in Fars province. Data for mean wind speeds and Weibull distributions are given in the Tables 2 and 3 that show Abadeh as the potential site for installing wind turbines in Fars province. Other characteristics are given to assess Abadeh site in detail. Power densities for different height are given between (169–173) W/m^2 at 10m, (200–205) W/m^2 at 30m and (220–225) W/m^2 at 40 m. The majority of wind directions are about (200–260) degrees and it is shown in the wind rose diagrams for 30 m height. It is evident that the major wind direction is towards southwest for most of the months in Abadeh. Researchers in the future could select suitable wind turbines using these data for mentioned cities. Also there is another way to select the best city and prioritize them for wind turbine installation like Multi Criteria Decision Making (MCDM) like Data Envelopment Analysis (DEA) which is the most common. Therefore other inputs like population of cities, amount of pollutions like dust and CO_2, distance to the grid, and so on could be implemented for decision making.

References

Ahmed S., Hanitsch R., Evaluation of wind energy potential and electricity generation on the coast of Mediterranean sea in Egypt, *Renew Energy*, vol. 31, pp. 1183-1202, 2006.

Alavi, O., Sedaghat, A., Mostafaeipour, A., Sensitivity analysis of different wind speed distribution models with actual and truncated wind data: A case study for Kerman, Iran, *Energy Conversion and Management*, vol. 120, pp. 51-61, 2016a.

Alavi, O., Mostafaeipour, A., Qolipour, M., Analysis of hydrogen production from wind energy in the southeast of Iran, *International Journal of Hydrogen Energy*, pp. 1-14, 2016b.

Alijani B., Ghohroudi M., and Arabi. N, Developing a climate model for Iran using GIS, *Theor Appl Climatol*, vol. 92, pp. 103–112, 2008.

Andrea M., and Emanuela M., The impact of behavioral factors in the renewable energy investment decision making process: Conceptual framework and empirical findings, *Energy Policy*, vol. 40, pp. 28-38, 2010.

Aslan Z., Global wind energy assessment of Turkey and a case study in the northwest, Int. *Energy Symp in 21st Century*, *Istanbul*, pp. 28–30, 1994.

Being comfortable with wind, *Shahid Beheshti University*, Tehran, Iran.

Chang TJ, Wu YT., Hsu HY., Chu CR., and Liao CM., Assessment of wind characteristics and wind turbine characteristics in Taiwan, *Renew Energy*, vol. 28, pp. 851–871, 2000.

Dinpashoh, Y., Mirabbasi, R., Jhajharia, D., Abianeh, HZ., Mostafaeipour, A., Effect of short-term and long-term persistence on identification of temporal trends, *Journal of Hydrologic Engineering*, vol. 19, no. 3, pp. 617-625, 2013.

Erratum to: Shamshirband, S., Mohammadi, K., Tong, C.W., Petcock, D. , Porcu, E., Mostafaeipour, A., Ch, S., Sedaghat, A., Application of extreme learning machine for estimation of wind speed distribution, *Climate Dynamics*, vol. 46, no., (5-6), pp. 1893-1907, 2016. DOI 10.1007/s00382-015-2682-2

Emami L., Feasibility study of electricity production in Yazd. Iran: *Yazd University*, 2008.

Francisco X., and Zhen. C., Exploratory analysis of prospects for renewable energy private investment in the U.S. *Energy Economics*, vol. 32, no. 6, pp. 1245-1252, 2010.

Frost W., Long B., Engineering handbook on the atmospheric environmental guidelines for use in wind turbine generator development, *NASA Technical Paper* 1978.

Gumbel EJ., Statistics of extremes. New York: *Columbia University Press*, 1958.

Haas, R., et al., A historical review of promotion strategies for electricity from renewable energy sources in EU countries, *J Renew Sustain Energy Rev*, vol. 15, no. 2, pp. 1003-1034, 2011.

Hosseini-Ezzabadi, J., Saryazdi, M.D., Mostafaeipour, A., Implementing Fuzzy Logic and AHP into the EFQM model for performance improvement: A case study, *Applied Soft Computing*, vol. 36, pp. 165-176, 2015.

http://en.wikipedia.org/wiki/Fars_Province.

http://www.farsmet.ir.

ISET. 2000. Wind Energy Report Germany 1999-2000 *Annual Evaluation of WMEP, Kassel*.

Keyhani A., et al., An assessment of wind energy potential as a power generation source in the capital of Iran, Tehran, J Renew Sustain Energy Rev, vol. 35, pp. 188–201, 2010.

Khorasanizadeh, H., Mohammadi, K., Mostafaeipour, A., Establishing a diffuse solar radiation model for determining the optimum tilt angle of solar surfaces in Tabass, Iran, *Energy Conversion and Management*, vol. 78, pp. 805-814, 2014.

Lun IYF., and Lam JC., A study of Weibull parameters using long-term wind observations, *Renew Energy*, vol. 20, pp. 145–153, 2000.

Manwell JF., McGowan JG., and Rogers AL., Wind energy explained: theory, design and application, Amherst, USA: *John Wiley & Sons*, 2002.

Mirhoseini M., Sharifi F., and Sedaghat A., Assessing the wind energy potential locations in province of Semnan in Iran, *J Renew Sustain Energy Rev*, vol. 15, pp. 449-459, 2011.

Mirhoseini M., Sharifi F., and Sedaghat A., Feasibility study of wind energy potential in two provinces of Iran: North and South Khorasan, *J Renew Sustain Energy Rev*, vol. 15, no. 8, pp. 3558-3569, 2011.

Mohammadi, K., Mostafaeipour, A., Dinpashoh, Y., Pouya, N., Electricity generation and energy cost estimation of large-scale wind turbines in Jarandagh, Iran, *Journal of Energy* 2014b.

Mohammadi, K., Mostafaeipour, A., Economic feasibility of developing wind turbines in Aligoodarz, Iran, *Energy Conversion and Management*, vol. 76, pp. 645-653, 2013a.

Mohammadi, K., Mostafaeipour, A., Sabzpooshani, M., Assessment of solar and wind energy potentials for three free economic and industrial zones of Iran, *Energy*, vol. 67, pp. 117-128, 2014a.

Mohammadi, K., Mostafaeipour, A., Using different methods for comprehensive study of wind turbine utilization in Zarrineh, Iran, *Energy Conversion and Management*, vol. 65, pp. 463-470, 2013b.

Mohammadi, K., Alavi, O., Mostafaeipour, A., Goudarzi, N., Jalilvand, M., Assessing different parameters estimation methods of Weibull distribution to compute wind power density, *Energy Conversion and Management*, vol. 108, pp. 322-335, 2016.

Mostafaeipour A., and Abarghooei H., Harnessing wind energy at Manjil area located in north of Iran, *J Renew Sustain Energy Rev*, vol. 12, pp. 1758–1766, 2007.

Mostafaeipour A., and Sadeghian A., Development of wind turbine in Iran. *Melbourne, Australia*: WWEC, 2005.

Mostafaeipour A., Method of capturing wind energy in ancient city of Yazd in Iran, *Melbourne, Australia*, 2005.

Mostafaeipour A., Proceedings of the world wind energy conference on development of wind turbine in Iran, 2005.

Mostafaeipour, A., Abesi, S., Wind Turbine Productivity and Development in Iran, Biosciences (BIOSCIENCESWORLD), *International Conference on Cancun Mexico*, pp. 112-118, 2010.

Mostafaeipour, A., Bardel, B., Mohammadi, K., Sedaghat, A., Dinpashoh, Y., Economic evaluation for cooling and ventilation of medicine storage warehouses utilizing wind catchers, *Renewable and Sustainable Energy Reviews*, vol. 38, pp. 12-19, 2014b.

Mostafaeipour, A., Economic evaluation of small wind turbine utilization in Kerman, Iran, *Energy Conversion and Management*, vol. 73, pp. 214-225, 2013a.

Mostafaeipour, A., Historical background, productivity and technical issues of qanats, *Water History*, vol. 2, no. 1, pp. 61-80, 2010.

Mostafaeipour, A., Jadidi, M., Mohammadi, K., Sedaghat, A., An analysis of wind energy potential and economic evaluation in Zahedan, Iran, *Renewable and Sustainable Energy Reviews*, vol. 30, pp. 641-650, 2014a.

Mostafaeipour, A., Productivity and development issues of global wind turbine industry, *INTECH Open Access Publisher*, 2011.

Mostafaeipour, A., Sedaghat, M., Ghalishooyan, M., Dinpashoh, Y., Mirhosseini, M., Sefid, M., Pour-rezaei, M., Evaluation of wind energy potential as a power generation source for electricity production in Binalood, Iran, *Renewable Energy*, vol. 52, pp. 222-229, 2013b.

Mostafaeipour, A., Khayyami, M., Sedaghat, A., Mohammadi, K., Shamshirband, S., Sehati, MA., Gorakifard, E., Evaluating the wind energy potential for hydrogen production: A case study, *International Journal of Hydrogen Energy*, vol. 41, no.15, pp. 6200-6210, 2016a.

Mostafaeipour, A., Sadeghian, A., Development of wind turbine in Iran. Proc, *World wind energy conference, WWEC Press*, Melbourne, Australia, 2005.

Mostafaeipour, A., Qolipour, M., Mohammadi, K., Evaluation of installing photovoltaic plants using a hybrid approach for Khuzestan province, Iran, *Renewable and Sustainable Energy Reviews*, vol. 60 pp. 60–74, 2016b.

Pablo del R., and Gregory. U., Overcoming the lock-out of renewable energy technologies in Spain: The cases of wind and solar electricity, *J Renew Sustain Energy Rev*, vol. 11, no. 7, pp. 1498-1513, 2007.

Qolipour, M., Mostafaeipour, A., Shamshirband, S., Alavi, O., Goudarzi, H., Evaluation of wind power generation potential using a three hybrid approach for households in Ardebil Province, Iran, *Energy Conversion and Management*, Vol. 118, pp. 295-305, 2016.

Saghafi M., Wind energy and its implementation in agriculture, 1995.

Sajjadi, S., Shamshirband, S., Alizamir, M., Yee, L., Mansor, Z., Manaf, A.A., Altameen, T.A., Mostafaeipour, A., Extreme learning machine for prediction of heat load in district heating systems, *Energy and Buildings*, vol. 122, pp. 222-227, 2016.

Shamshirband, S., Mohammadi, K., Tong, C W., Petković, D., Porcu, E., Mostafaeipour, A., Sedaghat, A., Application of extreme learning machine for estimation of wind speed distribution, *Climate Dynamics*, vol. 46, no. 5, pp. 1893-1907, 2015a.

Shamshirband, S., Mohammadi, K., Yee, L., Petković, D., Mostafaeipour, A., A comparative evaluation for identifying the suitability of extreme learning machine to predict horizontal global solar radiation, *Renewable and Sustainable Energy Reviews*, Vol. 52, pp. 1031-1042, 2015b.

Shamshirband, S., Mohammadi, K., Yee, L., Petković, D. and Mostafaeipour, A., A comparative evaluation for identifying the suitability of extreme learning machine to predict horizontal global solar radiation. *Renewable and Sustainable Energy Reviews*, vol. 52, pp.1031-1042, 2015c.

Seyit A., and Dinler A., A new method to estimate Weibull parameters for wind energy applications, *Energy Conversion and Management*, vol. 50, pp. 1761–1766, 2009.

www.suna.org.ir.

Ali Mostafaeipour is an assistant professor of Industrial Engineering at Yazd University, Iran. He has been teaching at Yazd University since 1989. He studied at Winona State University (University of Minnesota) in state of Minnesota, USA; University of Wisconsin at Platteville, Wisconsin, USA; Alabama A&M, Alabama, USA; and Iran University of Science and Technology, Tehran, Iran. He has served as a committee member, guest speaker, and co-chairman of 145 international conferences. He has been reviewer of 17 international journals mainly Elsevier. He has presented 78 mostly International conferences throughout the world. He has undertaken and managed 18 research projects, and holds 3 patents. He has been editorial board of several professional journals. Finally, he has published 54 journal articles mostly at Elsevier (ISI), and he authored 4 books. He holds an award for excellence from Yazd University as the year 2013 distinguished researcher, also distinguished author of “Wind Energy” book (INTech publisher, 2012, Croatia) with more than 5000 downloads in six months. His research interest lies in renewable energies, wind energy, value engineering, economic evaluation, and feasibility study of project.

Ahmad Sedaghat is an associate Prof. at Isfahan University of Tech.