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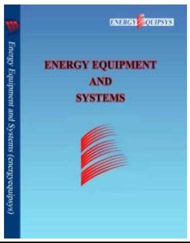

Wind resource assessment of Khuzestan province in Iran

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ABSTRACT

In this research paper, a 10 minute period measured wind speed data at 10 m, 30 m, and 40 m heights are presented for one of the major provinces of Iran. Four stations in Khuzestan- Abadan, Hosseyneh, Mahshahr, and Shushtar- are analyzed to determine the potential of wind power generation in this province. From the primary evaluation and by determining mean wind speed and also the Weibull function, the results show that the measurement site falls under class 2 of the International System Wind Classification for Abadan, Hosseyneh, and Mahshahr and class 1 for Shushtar station. It means that the first three stations have mediocre conditions for installing and operating wind farms, but Shushtar does not have a significant condition for connection to national power grid applications. By using wind roses of speed, turbulence, and the power distribution, the best direction of installing wind turbines for each station was determined. Finally, by utilizing power curves of five typical wind turbines, the annual wind energy, which is produced by a typical wind turbine for one of four stations, Mahshahr, was determined for showing the appropriate annual energy received from a wind turbine.

Keywords: Weibull function, Wind Energy, Wind roses, Wind speed, Wind turbine.

1. Introduction

1.1. Wind power energy

Wind energy is considered a renewable energy source. It is the conversion of wind energy into a useful form of energy. Historically, wind power in the form of windmills has been used for centuries for such tasks as grinding grain and pumping water. Modern wind turbines benefit from wind speed to produce electricity by using rotational energy to drive a generator. They are made up of a blade or rotor and an enclosure called a nacelle that contains a drive train atop a tall tower. Large wind turbines can have a blade length of over 60 meters and be placed on towers 120 meters tall. Smaller turbines can be used to provide power for individual homes. Wind farms are areas where a number of wind turbines are grouped together, providing a larger total energy source [1].

As of 2014, the largest onshore wind farm in the world was the Alta Wind Energy Center in California, which produces 1,320 MW [2]. By the early 21[st] century, wind was contributing slightly more than 1 percent of the word’s total electricity, and electricity generation by wind has been dramatically increasing because of concerns over the cost of petroleum and the effects of fossil fuel combustion on the climates and environment. From 2004 to 2014, for example, total wind

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power increased from 47.6 GW to 365.4 GW worldwide. By 2014, China has the most installed wind capacity worldwide by generating 114,763 MW which is about 31% of all installed wind capacity in the world. The wind power industry estimates that the world could feasibly generate 12 percent of its total electricity from wind power by 2020. Various estimates put the cost of wind energy between 3 and 12 cent per kilowatt-hour, depending on the location. This is comparable to the cost of fossil energy (the cost of coal-generated electricity is estimated at 4-8 cents per kilowatt-hour) [3].

In the past decades, in many countries, many studies have been conducted about available wind energy resources. Some of these studies have been developed to form a wind energy resource atlas, such as Wind Energy Resource Atlas of the United States [4], Europe's Energy Portal [5], etc. In addition, a wind map of China, Spain, Peru, Egypt, Jordan, Somalia, Ethiopia, and also a wind map of the world have been published [6].

Iran is one of the major countries in the Middle East and one of the main oil exporters to the west. As the conventional fuels are depleting, the need to switch to renewable energy has attracted substantial interest. In Iran, in the field of wind energy, much work has been carried out so far, such as creating Iran wind energy resources atlas by Renewable Energy Organization of Iran (SUNA) [7]. Also, wind energy potential of Manjil was investigated by Mostafaipoor and Abarghooi and this area was designated as one of the most suitable areas for wind power plants [8]. In another research, Mirhosseini et al. evaluated the potential of wind energy in Semnan province and, finally, Damghan was determined as the best place to install wind power plants [9]. In another research by Mirhosseini et al., the potential of wind energy in the South and North Khorasan provinces was evaluated and, finally, these provinces were determined as suitable areas to install wind power plants [10]. Also, in further research, Alamdari et al evaluated the potential of wind energy in Ardebil and this province was determined as a suitable area to install wind power plants [11], and also Mostafaipoor et al. evaluated the potential of wind energy in Shahrebabak and, finally, it was not recommended to install wind power plants, but it was suggested for utilization for out-grid applications [12].

1.2. Wind energy in Iran

Here is a graph which explains the situation of wind power In Iran. In Fig.1, the capacity of wind power in Iran from 1997 to 2013 is shown. This graph shows that the capacity of wind power from 1997 to 2003 is almost constant. The growth of the wind power capacity starts from 2004. In 2013 the capacity of wind power has a 6.3% growth compared to 2012 and is about 100 MW [13].

Status of Iran's geographical shows that low air pressures produces strong air flows over the country, generally during the summer and winter seasons compared to high pressures in the northern areas.

The potential of wind energy in Iran is estimated to be at about 6500 MW. Actually, by this potential, Iran is classified into medium level energy between different countries [7].

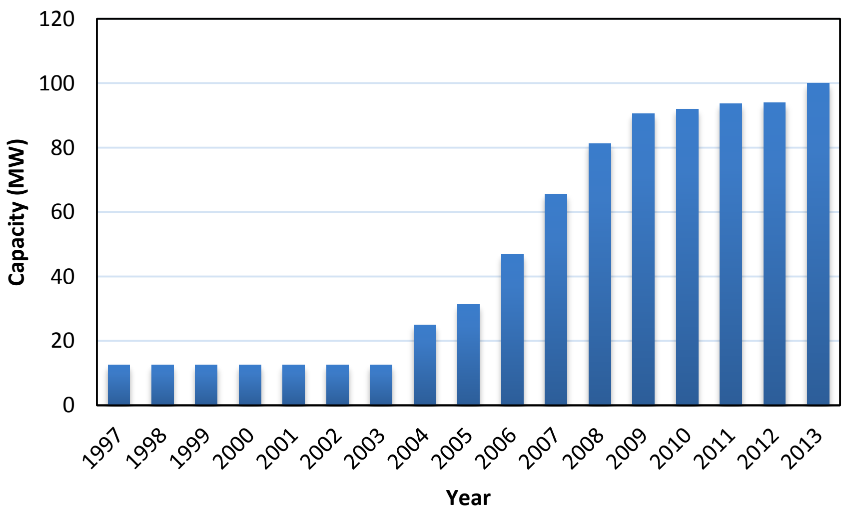


Fig. 1. Growth of wind energy in Iran

Iran's first experiment in installing and handling modern wind turbines dates back to 1994, when two sets of wind turbines were installed in Manjil and Rudbar. These sites produced more than 1.8 million kWh per year. Manjil and Roodbar wind farm is a wind farm located in Gilan province, this is one of the provinces of Iran in the north of the country located beside the Caspian sea. This wind farm by 2009 used 171 NEG Micon and Vestas turbines with capacities ranging from 300 to 660 kW [14].

Wind power in Iran has been experiencing a growth in wind generation in recent years, and has a plan to substantially increase wind generation each year. Iran is the sole center in producing wind turbines in the Middle East [15].

1.3.Khuzestan

Khuzestan is the 7th largest province of Iran with an area of 62,328 km^2. It is in the southwest of the country, bordering Iraq's Basra province and the Persian Gulf. Its capital is Ahvaz that is the heart of the oil production in Iran and has a significant role in the Iran's economy. Other major cities include Behbahan, Abadan, Andimeshk, Khorramshahr, Bandar Imam, Dezful, Shushtar, Omidiyeh, Izeh, Mahshahr, Susangerd, Ramhormoz, Shadegan, Masjed soleiman, Minoo Island, and Hoveizeh.

The province of Khuzestan can be basically divided into two regions, the rolling hills and mountainous region to the north of Ahvaz ridge, and the plains and marsh lands to its south. The area is irrigated by the Karoun, Karkhe, Jarahi, and Maroun rivers. Figure 2 shows the geographical situation of Khuzestan province in Iran.

The climate of Khuzestan is generally hot and occasionally humid in the summer, particularly in the south, whilst winters are much more pleasant and dry. Summertime temperatures routinely exceed 50 degrees Celsius and in the winter it can drop below freezing, with occasional snowfall, all the way south of Ahvaz. Khuzestan province is known to possess one of the hottest temperatures on record for a populated region in the world. Many sandstorms are frequent with the arid and desert-style terrains.

In this research paper, the feasibility of using different stations of Khuzestan province is studied. These stations are Abadan, Hosseyneh, Mahshahr, and Shushtar. Among the cities surveyed, Abadan with a population of 212,744 (covering an area of 2,063 hectare) is the most populous and Mahshahr, Shushtar and the district of Hosseyneh, are followed with populations of 153,778 (covering an area of 2,063 hectare), 106,815 (covering an area of 2436 hectare) and 1,935, respectively. The locations of meteorological sites for all studied regions are summarized in Table 1.

2.Analysis of wind data

Data was prepared over a period of about two years. The period of usage data is different for each station. For Abadan, data was collected from 09/27/2007 to 08/19/2009, for Hosseyneh, the duration was from 11/28/2007 to 08/11/2009. For another station, Mahshahr, it was from 09/27/2007 to 08/28/2009. And, finally, for Shushtar station, data was prepared from 11/30/2007 to 08/11/2009.

Fig. 2. Map of Iran (Khuzestan province has been highlighted)

Table 1. Geological location of meteorological sites for Khuzestan province

Site	latitude	Longitude
Abadan	$48^o\ 28^/$	$30^o\ 53^/$
Hosseyneh	$48^o\ 18^/$	$30^o\ 79^/$
Mahshahr	$49^o\ 08^/$	$30^o\ 57^/$
Shushtar	$48^o\ 75^/$	$31^o\ 79^/$

Fig. 3. Location of the surveyed cities of Khuzestan province

All data are in the time intervals of 10 minutes. The meteorological poles with 40 m height were set in appropriate coordinates by the Renewable Energy Organization of Iran (SUNA). The data logger used in these sites, has 3 velocity sensors at 10, 30, and 40 m heights and also two direction sensors at 30 and 37.5 m heights.

2.1.Mean wind speed

In the first step of this study, yearly mean wind speed in the time intervals of 10 minutes for four mentioned sites, Abadan, Hosseyneh, Mahshahr, and Shushtar are examined.

The annual mean wind speed for 10 m, 30 m, and 40 m are shown for each station of Khuzestan province in Table 2. According to this table all stations have normal mean wind speed.

Figures 4-7 show the monthly mean wind speed at three mentioned heights which show what months have suitable wind speed. Using the following diagrams can be helpful to show distribution of monthly speeds measured in three heights during the month of the year; for example Hosseyneh's monthly speed is at its highest in the month of July. This information is very important for installing wind farms, because of estimation of how much power a wind farm can deliver to national power grid at any month of year.

2.2.Wind direction

One of the major factors for the feasibility assessment of using wind energy is the wind direction. It also plays an important role in the optimal positioning of a wind farm in a specific area.

To define the prevailing wind direction(s), wind vanes should be installed at all significant monitoring levels. Wind direction frequency information is important for identifying preferred terrain shapes and orientations and for optimizing the layout of wind turbines within a wind farm [16].

For wind direction, the average should be a unit vector (resultant) value. Average data is used in reporting wind speed variability, as well as wind speed and direction frequency distributions [16]. Variations in wind direction are due to the common circulation of the atmosphere.

Table 2. Annual mean wind speed at 3 heights for four sites in Khuzestan province (m/s)

Site \ Heights	10 m	30 m	40 m
Abadan	4.1707	5.0850	5.8612
Hosseyneh	4.1872	5.4388	5.1900
Mahshahr	4.2838	5.2816	6.0407
Shushtar	2.2759	3.1463	3.5102

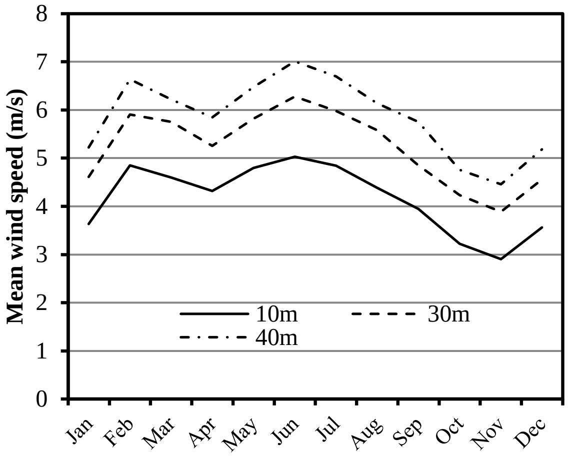


Fig. 4. Monthly wind speed for 3 heights of Abadan

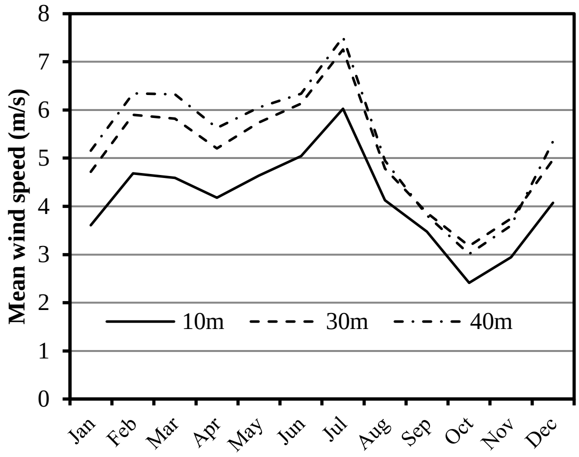


Fig. 5. Monthly wind speed for 3 heights of Hosseyneh

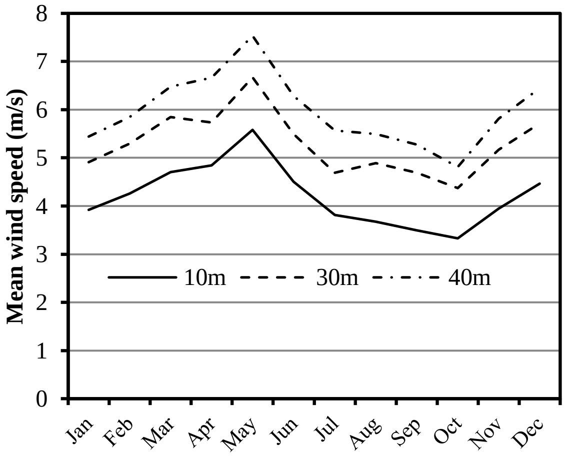


Fig. 6. Monthly wind speed for 3 heights of Mahshahr

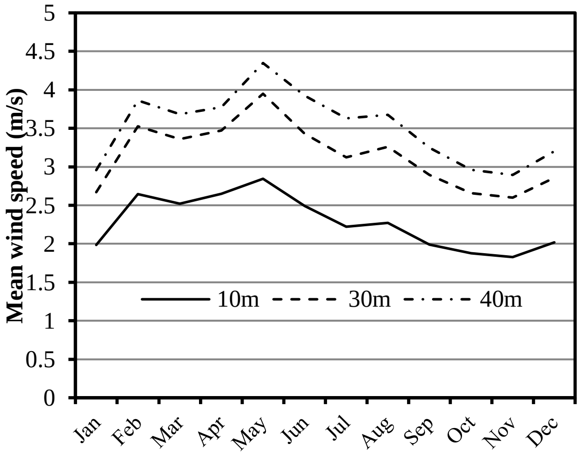


Fig. 7. Monthly wind speed for 3 heights of Shushtar

2.3. Wind rose

A wind rose is a graphic tool used by meteorologists to give a sufficient view of how wind speed and direction are typically distributed at a particular location. Historically, wind roses were predecessors of the compass roses, as there was no differentiation between a cardinal direction on the wind which blew from such a direction. Using a polar coordinate system of gridding, the frequency of wind over a long time period is plotted by wind direction, with color bands showing wind ranges. The direction of the rose with the longest spoke shows the wind direction with the greatest frequency [17].

Figure 9 shows the rose diagram which displays the frequency of wind speed, turbulence, and total wind energy in 12 equally spaced radial lines (each representing a compass point).

The comparison of the polar diagrams by rose diagrams displays, in direction that wind has highest frequency; the wind has highest speed. With this information, the most suitable direction of installing wind turbines for each station was identified. As shown in this figure, in Abadan, the best direction for installing wind turbines is 337.5^0 because the velocity in this direction is the most.

2.4. Turbulence

Wind turbulence is the rapid disturbances or irregularities in the wind speed, direction, and vertical component. It is an important site characteristic because high turbulence levels may decrease a power output and cause extreme loading on wind turbine components. The most common indicator of turbulence for siting purposes is the standard deviation of wind speed [16].

Turbulence can be considered as accidental swings of wind speed inflicted on the mean wind speed. These swings occur in all three directions: longitudinal (in the world direction), sidelong (perpendicular to the average wind), and vertical.

2.4.1.Turbulence intensity

The most common indicator of turbulence for siting purpose is the standard deviation (σ) of wind speed. Normalizing this value with the mean wind speed gives the turbulence intensity (TI). This value allows for an overall assessment of a site's turbulence. TI is a relative indicator of turbulence with low levels which indicated by values less than or equal to 0.10, moderate levels to 0.25, and high levels greater than 0.25. TI is given by [16]:

$$TI = \frac{\sigma_u}{V} \tag{1}$$

where σ_u and V are standard deviation and mean wind speed.

Standard deviation is defined in simplified form of [18]:

$$\sigma_u = \sqrt{\frac{\sum_{i=1}^{N_s}(u_i - U)^2}{N_s - 1}} \tag{2}$$

In Table 3, the mean TI and their classification for four investigated stations are shown. As shown in this table, Shushtar with 0.115 has moderate level of TI so has mediocre condition from turbulence aspect.

2.5.Monthly wind speed distribution

In order to specify the potential of wind energy of the given sites and evaluating the wind energy outputs at these sites, actuarial analysis can be used. To explain the statistical distribution of wind speed, different probability functions can be appropriate for regimes of wind. According to Burton [19], the Weibull distribution has been found to give a good representation of the variation in hourly mean wind speed over a year at many typical sites.

Use of the Weibull probability density function requires knowledge of two parameters; k, a shape factor, and c, a scale factor. Both of these parameters are functions of $\bar{U}$ and σ. The weibull probability density function and the cumulative distribution function are given by [18]:

$$P(U) = (\frac{k}{c})\left(\frac{U}{c}\right)^{k-1} \exp[-\left(\frac{U}{c}\right)^{k}] \tag{3}$$

It is not a straightforward process to get c and k in terms of $\bar{U}$ and σ_u. However, there are a number of approximations that can be used. Here we use analytical/empirical (Justus, 1978).

For $1 \le k \le 10$, a good approximation for k is [18]:

$$k = (\frac{\sigma_u}{\bar{U}})^{-1.086} \tag{4}$$

$$c = \frac{\bar{U}}{\Gamma(1 + \frac{1}{k})} \tag{5}$$

where $\Gamma(x)$ = gamma function and defined as $\int_0^\infty e^{-t} t^{x-1} dt$, and σ_u, and $\bar{U}$ are respectively standard deviation and mean wind speed. Standard deviation was defined in Eq. (2).

The frequency of occurrence of wind speeds may be described by the probability density function, P(U), of wind speed. This mathematical function was previously mentioned as a means of characterizing turbulence. The probability density function may be used to express the probability of wind speed occurring between U_a and U_b and is calculated as below [18]:

$$P(U_a \le U \le U_b) = \int_{U_a}^{U_b} P(U) dU \tag{6}$$

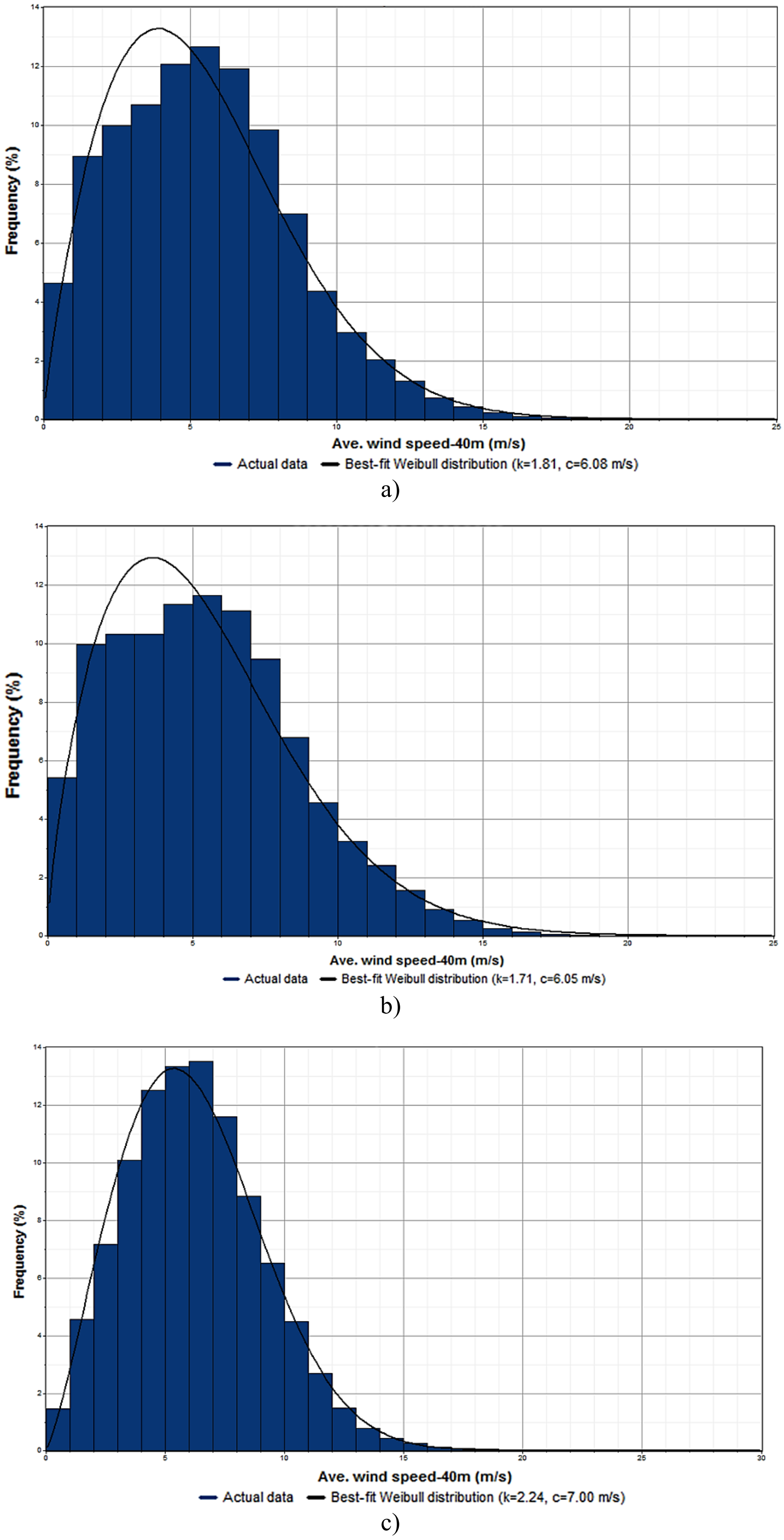
Also, the total area under the probability density curve is given by [18]:

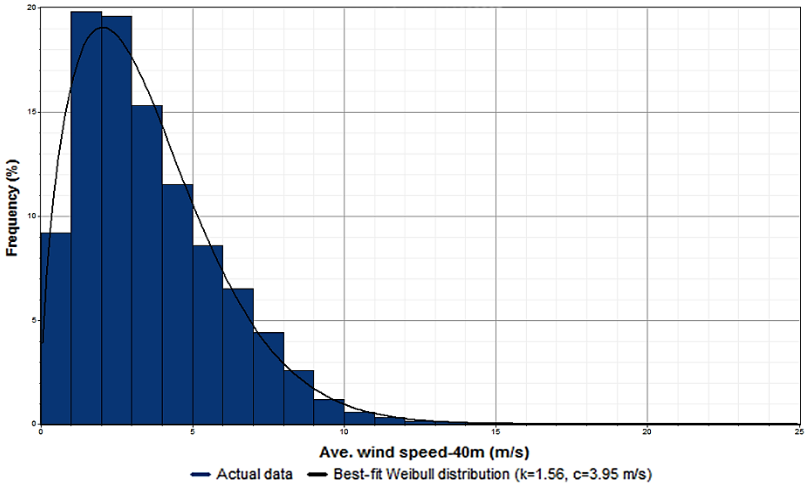
$$\int_0^\infty P(U) dU = 1 \tag{7}$$

In Fig. 8, wind speed distribution and best-fitted curve for Weibull distribution at height of 40 m and respective parameters of Weibull function for each station are shown.

Table 3. Amounts of TI of Khuzestan province

Station \ Parameter	TI	Level
Abadan	0.131	moderate
Hosseyneh	0.097	low
Mahshar	0.080	low
Shushtar	0.115	moderate


Frequency (%)
Ave. wind speed-40m (m/s)
Actual data
Best-fit Weibull distribution (k=1.81, c=6.08 m/s)
a)
Frequency (%)
Ave. wind speed-40m (m/s)
Actual data
Best-fit Weibull distribution (k=1.71, c=6.05 m/s)
b)
Frequency (%)
Ave. wind speed-40m (m/s)
Actual data
Best-fit Weibull distribution (k=2.24, c=7.00 m/s)
c)



d)

Fig. 8. Wind speed distribution and best-fit Weibull distribution at 40m of a) Abadan, b) Hosseyneh, c) Mahshahr, d) shushtar

2.6.Most probable wind speed

In order to achieve the most frequent wind speed for a given possibility distribution, the most probable wind speed is utilized. From shape and scale parameters of Weibull distribution function (a, c), it can be easily gained from the following equation [20]:

$$V_{mp} = c(1 - \frac{1}{k})^{\frac{1}{k}} \quad (m/s) \tag{8}$$

2.7.Maximum energy bearing by the wind speed

By using scale and shape parameters of Weibull distribution function, the maximum wind energy carried by the wind speed can be computed. The wind speed which is carrying maximum wind energy can be represented as follows [21]:

$$V_{max.E} = c(1 + \frac{2}{k})^{\frac{1}{k}} \quad (m/s) \tag{9}$$

In Table 4, amounts of V_{mp} and $V_{max.E}$ for each station and for 3 heights are presented.

2.8.Power density

Wind power density is more real indication of a site's wind energy potential than wind speed alone. Its value combines the effect of a site's wind speed distribution and its dependence on air density and wind speed. The wind power per unit area, P/A or wind power density is defined as [18]:

$$\frac{\bar{P}}{A} = \frac{1}{2}\rho \int_c^{\infty} U^3 P(U) dU = \frac{1}{2}\rho c^3 \Gamma(1 + \frac{3}{k}) \approx \frac{1}{2}\rho \bar{U}^3 \tag{10}$$

From the Eq. 10, it is obvious that the most important factor in the available wind power is the velocity of the wind. An increase in the wind speed by only 20%, from 5 to 6 m/s, for example, increases the available wind power by 73% [22].

It should be noted that the wind power density is proportional to the density of the air. The mean air density of each station is shown in Table 5.

Table 4. Amounts of V_{mp} and $V_{max.E}$ parameters for 3 heights of Khuzestan province

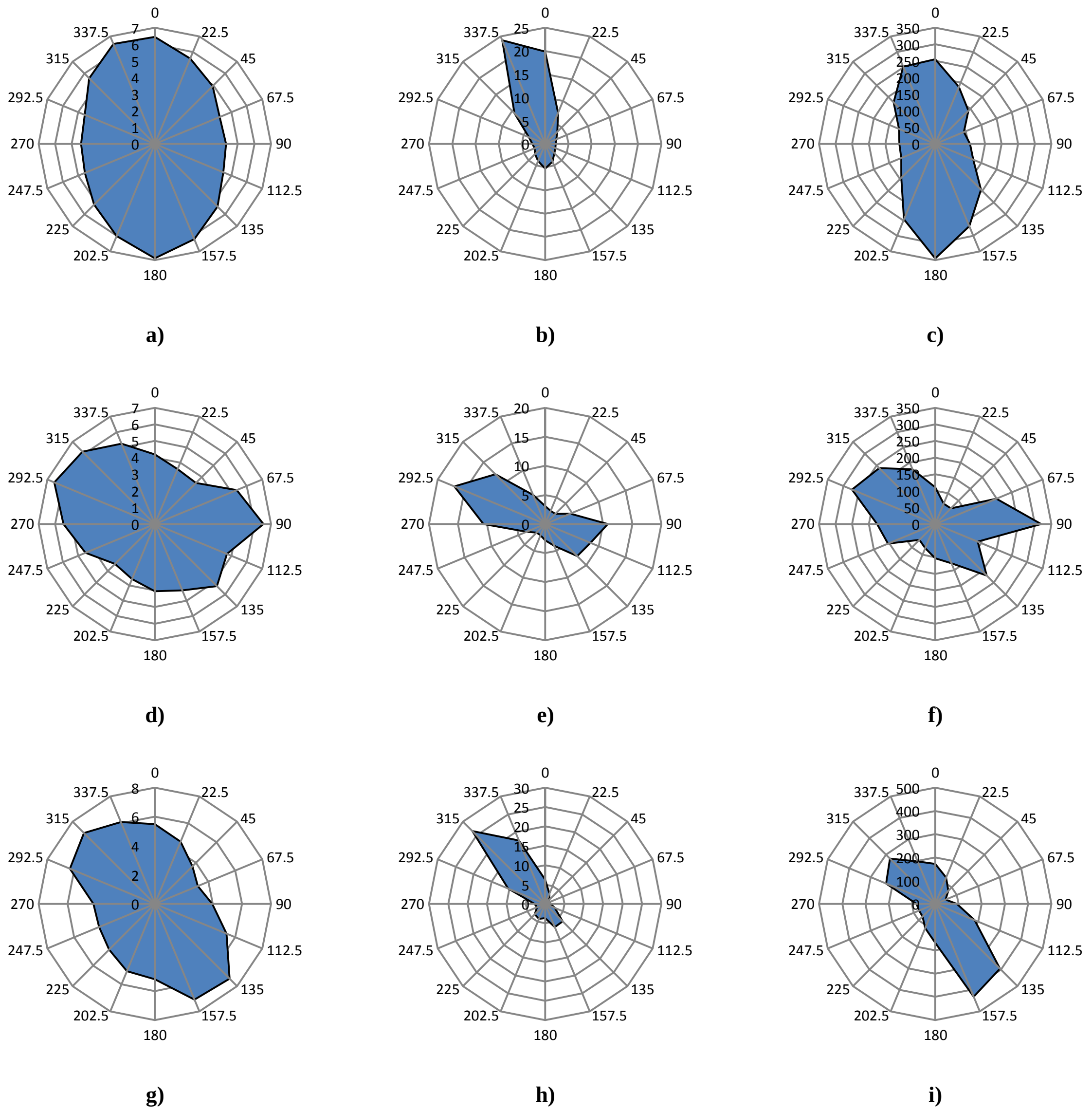
Parameter / Height / Station	V_{mp} 10	V_{mp} 30	V_{mp} 40	$V_{max.E}$ 10	$V_{max.E}$ 30	$V_{max.E}$ 40
Abadan	2.8482	3.9470	4.7984	7.3121	8.3971	9.1494
Hosseyneh	2.5437	3.9191	3.7281	8.1843	9.8310	9.3518
Mahshar	3.2321	0.8150	5.2004	7.1158	10.9446	9.0950
Shushtar	1.3120	1.6874	2.0482	4.3695	6.1748	6.7034

Table 5. Mean air density of four stations of Khuzestan province

Station	Mean air density (kg/m^3)
Abadan	1.181
Hosseyneh	1.191
Mahshahr	1.186
Shushtar	1.189

In Fig. 9, wind speed, wind direction, and total energy of 12 directions at 40 m height are shown for four investigated stations. From these diagrams, it is possible to achieve to the directions that produce the most potential. As shown in parts e to f, the most potential of wind power in Hosseyneh is at 292.50 directions.

Figures 10-13 represent the monthly wind power density at heights 10 m, 30 m, and 40 m. There are two major methods to calculate the power density: 1. from measured data and 2. Utilizing probability distribution function like Weibull function. Certainly, the first method is more accurate and generally used.



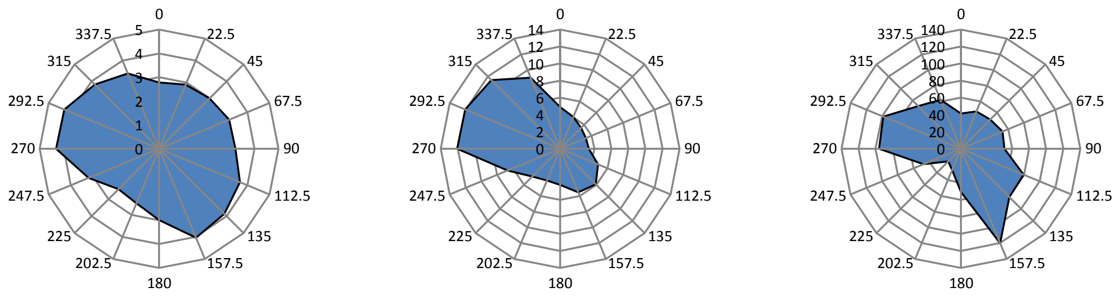
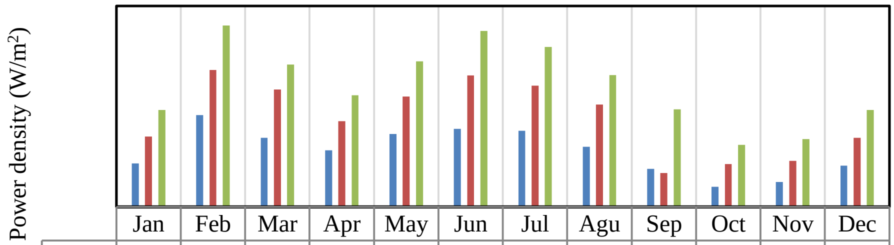
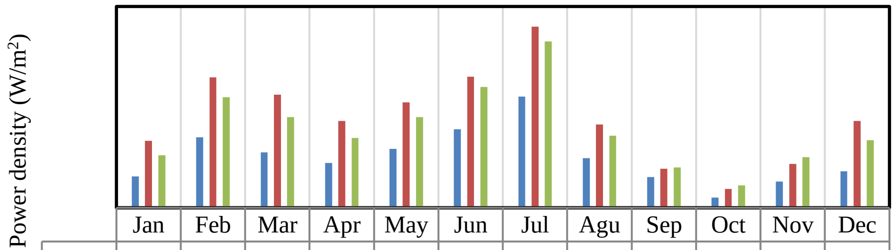


Fig. 9. Wind rose of wind speed, wind direction, and total energy at 40m for Abadan (a-c), Hosseyneh (d-f), Mahshahr (g-i), and Shuhtar (j-l)



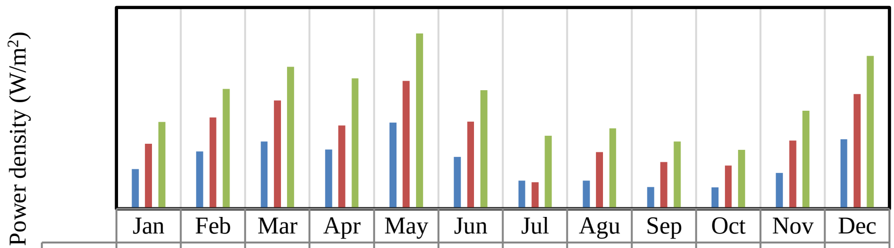
	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
10m	75.39	159.6	120.1	98.18	126.6	136	132.4	104.7	66.24	34.76	43.19	71.65
30m	122.6	238.3	204.1	148.9	191.8	228.7	211.2	178.3	58.69	74.46	79.8	120.1
40m	168.7	315.9	247.6	194.2	253.3	306.5	278.5	229.4	169.7	107.8	117.7	168.7

Fig. 10. Monthly power density of Abadan at 10m, 30m, and 40m



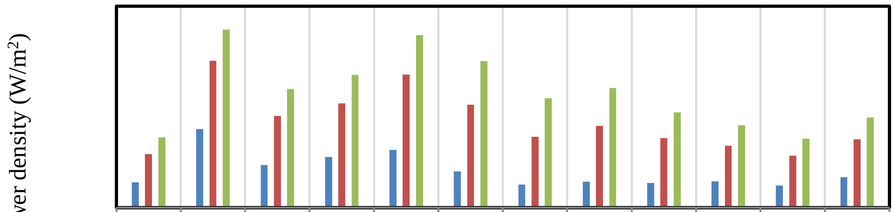
	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
10m	69.76	157.2	123.9	100.4	131.6	174.9	248.1	110.9	68.6	22.73	58.44	81.33
30m	149.5	291.4	252.9	194.2	235.4	292.8	404.4	186.2	86.97	41.66	98.19	193.7
40m	117.3	246.9	202.2	155.9	202.4	269.9	371.5	160.9	89.66	49.93	113.2	151.2

Fig. 11. Monthly power density of Hossyneh at 10m, 30m, and 40m



	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
10m	78.42	114	133.3	117.5	171.3	102.7	55.87	56.04	42.84	42.4	71.1	137.7
30m	129.2	181.6	215	165.4	254.1	173.2	52.43	112.6	92.61	85.83	135.1	228
40m	172.1	237.9	281.6	258.8	348.4	235.6	144.9	159.8	133.8	116.8	194.6	303.3

Fig. 12. Monthly power density of Mahshahr at 10m, 30m, and 40m



	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
10m	15	46.82	25.29	30.14	34.35	21.53	13.62	15.4	14.69	15.6	13.17	18.05
30m	31.74	87.4	54.6	62.1	79.28	61.34	42.18	48.71	41.39	36.78	30.93	40.54
40m	41.71	105.9	70.53	79.01	102.7	87.19	65.01	71.15	56.65	49.07	40.95	53.54

Fig. 13. Monthly power density of Shushtar at 10m, 30m, and 40m

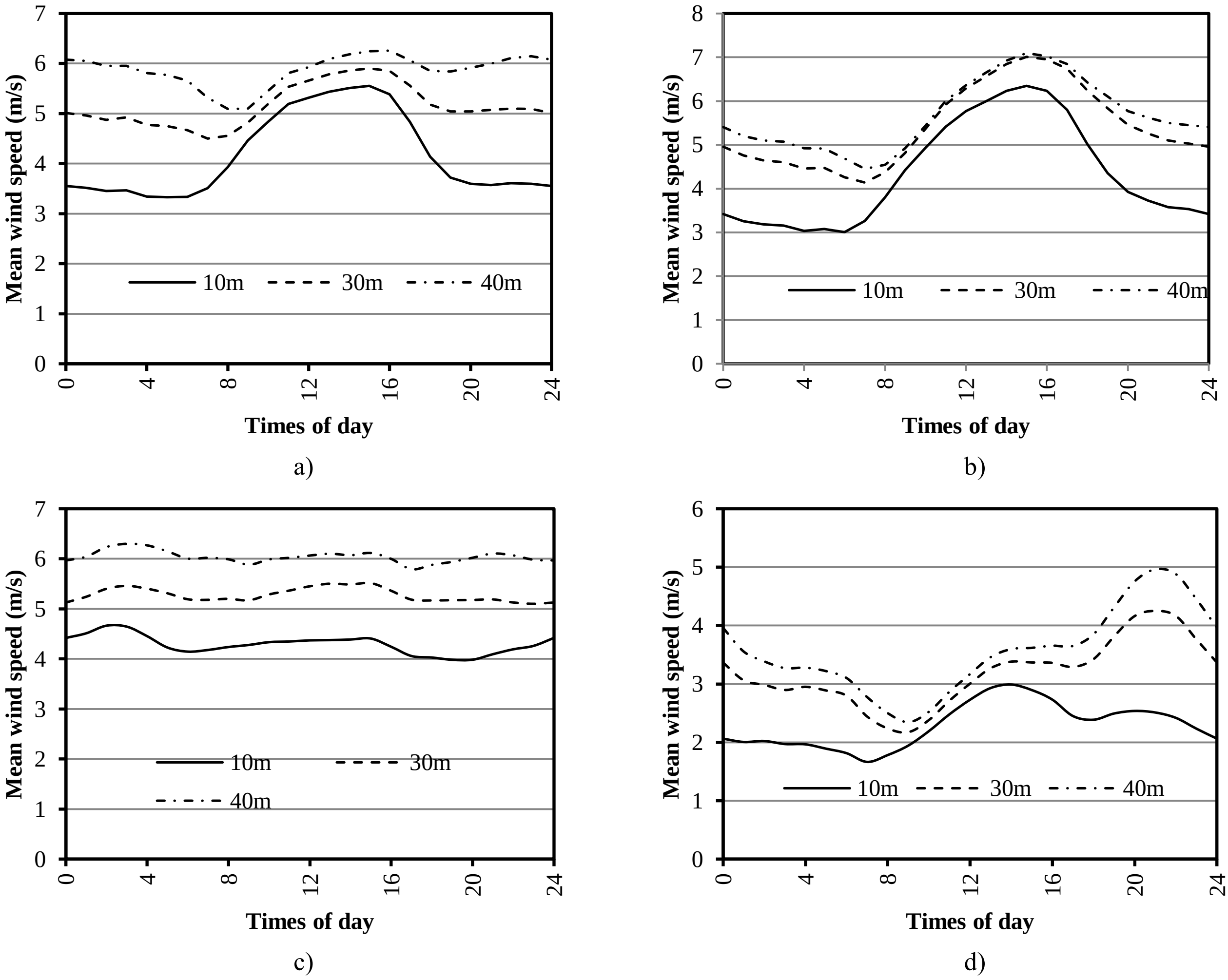


Fig. 14. Mean wind speed at different times of the year
a) Abadan, b) Hosseyneh, c) Mahshahr, d) Shushtar

2.9. Annual power density

The yearly power density for each station using measurement data and Weibull distribution function using Eqs. (10) and (3) was computed. The results are shown in Figs. 15-18.

2.10. Monthly power density

In Figs. 10-13, monthly power densities at 10m, 30m, and 40m heights specified by the first method for all four stations are presented. By using the following diagram, the monthly power density can be found in three heights.

For example, in February, Abadan station has the highest power density.

2.11. Daily mean wind speed

In Fig. 14, the mean wind speed at different times of the year at three heights for each station is shown. As shown in these figures, the maximum wind speed is almost between 10 and 20 hours. It represents that maximum power of wind turbines contains the peak power consumption. It means that using wind turbines in these stations is appropriate because of their match to the electricity consumption patterns.

2.12. Wind turbine energy production

For a known wind probability distribution function, *P(U),* and machine power curve, $P_w(U)$, the average wind machine power, P_w, is given by [18]:

$$\bar{P}_w = \int_0^\infty P_w(U)P(U)dU \tag{11}$$

For each wind speed the energy that captured can be calculated from:

$$\bar{E}_v(\bar{v}_w) = \bar{P}_w(\bar{v}_w) \times t(\bar{v}_w) \tag{12}$$

where

$$t(\bar{v}_w) = \bar{P}_w \times t_{year} \tag{13}$$

The captured energy in the year is now found by summing up all the captured energy for each wind speed, which can be expressed mathematically as [23]:

$$E = \sum_{j=1}^{m} \bar{E}_v(\bar{v}_{w,j}) \tag{14}$$

Hereunder, the numbers of factual horizontal axis wind turbines are evaluated to determine the amount of energy that can be absorbed. In this section, productions of 5 different wind turbines that have the popular capacity which have been used mainly in Iran were calculated. These wind turbines can be seen in Table 6. All wind turbines are compared at the same height, 40 m. Wind turbine models are selected based on their capacity. The curves of their power and annual energy which captured from wind turbines for Mahshahr station are shown in Figs. 19 and 20, respectively. These figures show that a wind turbine can generate about 2 MWh energy per year which is an acceptable value. Also, the installation of wind farms will allow more generating energy at a site. Wind farm or wind park is a focus group of turbines that work in concert with each other. Useful wind resources are restricted to different geographical places. The presentation of multiple turbines into these places grows the collected wind energy produced. The concentration of maintenance material and extra sections decreases costs from an economic point of view.

The number of turbines in the wind farm is actually disparate. But, as the quantity and size of wind farms grow, the interplay between wind farms and grids becomes more. Then, with the whole amount of power joined to a repartition network, some power quality difficulties can arise because of the swing nature of the wind, e.g., voltage and power disorders that degenerate the network efficiency. Many technical problems arise with the nearby spacing of multiple wind turbines. But the most important question is that where and how closely turbines should be placed. The wind resources may change among a wind farm as a conclusion of field effects. Also, the exploitation of energy by those wind turbines that are upwind of another turbines result in lower speeds of wind at the downwind turbines and grow turbulence. These wake effects can reduce generating energy and grow wake-induced fatigue in turbines downwind of others. Also spacing of wind turbine affects swings in the generating power of a wind farm.

Table 6. Characteristic wind turbines

Model	Power (KW)	Rotor diameter (m)
Enercon E33	330	33.4
Fuhrlander FL 600	600	50
Nordex N80	2500	80
Vensys 70	1500	70
Vestas V47	660	47

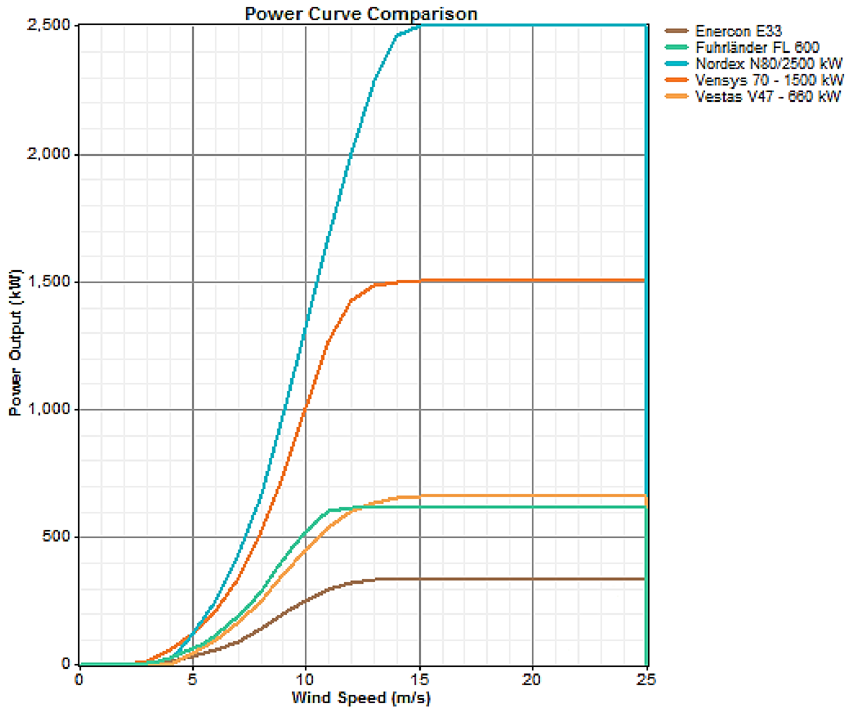


Fig. 19. Characteristic machine power curves

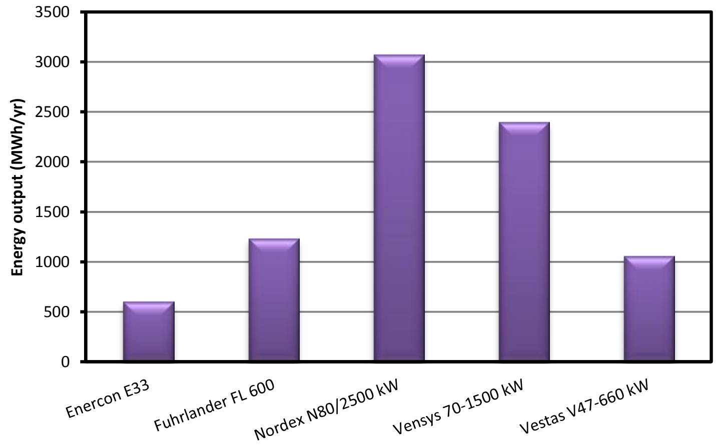


Fig. 20. Annual energy received from wind turbines for Mahshahr station

Conclusion

With an aim of careful planning for the future, a sharp decline in fossil fuel consumption can be achieved with proper implementation of new sustainable technologies. Wind turbine technology, which is one of the most appropriate and potential alternatives of fossil fuels for decision-making bodies in the field of renewable energy, is used for various purposes. Iran has ample potential for the utilization of wind energy in many places.

The most important results of this research study can be summarized as follow:

1. Wind speeds using the Weibull probability function are modeled.
2. Weibull distribution parameters and their results of wind power density show that investigated stations in Khuzestan province are in rather good conditions.
3. Power density and Weibull distribution diagrams, monthly and daily mean wind speed, and monthly and annual wind power density were shown for each station.
4. Assessment of the wind resource shows that Abadan, Hosseyneh, Mahshahr and, Shushtar are respectively classified into 2, 2, 2, and 1 classes due to wind power density classes published by the U.S. Department of Energy. It represents that Abadan, Mahshahr and Hosseyneh all are

suitable for both network connections and any other individual applications; However, Shushtar does not have a significant potential for network connection, but wind turbines can be used for a non-network connection application, such as water pumping and battery charging.

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