Consideration the possibility of utilizing wind energy for optimum using in rural area (agricultural and domestic consumptions)

Case study: Qazvin province of Iran
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ABSTRACT

Based on the present pattern of resource utilization in country, Iran, obviously in not far future not only is able to export energy (in form of petroleum) but also will be in group of countries as a main and whole sale importer of energy. In any case, the main sources of energy in Iran is fossil sources and considering the increase in its demand process, would cause country many problems on advancement of social and economic sections in future. On the one hand, undoubtedly economic expansion is not possible without agricultural and rural development in Iran. Therefore, exploitation of wind energy is possible, according to considerable potential of this kind of renewable energy in different parts of country among others, rural and agricultural districts. On the other hand, using of wind turbines for the purpose of generating electricity or carrying water to farms and gardens in windy and susceptible districts can generate required electricity for the use of domestic and rural and agricultural parts without creating environmental pollution and moreover, would be effective in decreasing energy costs in prolonged time. In this research, potential meter (measuring) of wind energy utilization has been done for the purpose of recognizing the possibility of applying wind energy to generate a percentage of rural energy consumptions of Kouhin district in Qazvin province. To this end, information of standard wind meter station in this district was used by recording speed and point data in short time spaces (10 minutes) during 5 years. The results of this research showed that this district with average of annual speed of 6.7 m s^{-1} in height of 10 meter and power density of 800 Wm^{-2} has suitable conditions for settling of wind turbines to generate the electricity for domestic consumptions in rural and agricultural irrigation operations. Also, in this essay, usage of geographical information system (GIS) in farm management, applying of renewable wind energy, localization and necessity of wind energy exploitation based on existed information have been discussed.

Keywords: Wind energy, rural development, GIS, Iran

1. Introduction

In this century, high fossil fuel consumption and meanwhile growth of energy demand has made irreparable damages to environment. Although, fossil fuel sources are more valuable
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and within reach but they would be very limited and terminable (non-renewable) in not far future. Thus, exploiting other sources of energy with optimum utilizing of them in different regions and districts of country is very important and essential. Using other sources of energy (such as renewable sources) must be logically based on existed criteria and potentials such as easy accessibility priority and economic factors. This fact in rural communities is important in regarding to hygienic and environmental harm risks in result of supplying energy from traditional sources (Talebi, 2003). Fast growth of industry and technology in world showed higher technology retardation of rural districts in comparison with previous years. Generally, villagers have less income and enjoy less social services as compared with city dwellers and this situation makes them immigrate from villages to cities. The main reasons of this happening are the geographical distribution of villages, lack of economic savings for providing of social services, absence of agricultural activities, limitation of territorial sources (as a result of population growth) and lack of accurate management of responsibilities (Azkiya and Imani, 2008). So, development can be defined as a qualitative and quantitative changes and promotion of environment, production, native culture and human societies during the time (Azkiya and Imani, 2008). Wind energy was used by making first wind machines in old years. It is believed that Iranian or Greek have made the first wind machines. Iranian used wind energy to grind of grains and Egyptians, Romans and Chinese used it for boating and irrigation. Later, wind turbines with right angle axis were used in Middle East countries (Peykarjoo, 1998). In next 30 years, amount of CO2 emission in result of production and consumption of energy will increase faster growth than the consumption growth of basis energy. The growth amount of this kind of emission during 2000 up to 2030 would be 1.8 % per year and finally will reach to 38 billion tons per year which means 70 percentages increase to the annual emission rate up to now. Applying renewable energy sources instead of coal for production process of one kWh electricity decreases emission about 1 kg CO2 , so as an example, for each one percent of common energy (which is produced from non-renewable sources) which is replaced by wind energy, about 13 percent of CO2 gas emission will decrease. In addition, another environmental advantage of wind energy is reduction of sulfide and nitrate oxide (Heydari, 2005). In 1997, European Union of Energy Committee announced that about 12% of electricity demand of Europe will be supplied by renewable sources up to 2010. World energy reports showed that potential of using wind energy is high and it is predicted that about 16.5% of electricity will be provided from wind energy up to 2020 (Ben Amar, 2007).

It is obvious that according to Iranian energy consumption pattern which is high, Iran in not far future not only can export energy (as petroleum) but also will be in group of energy importer countries. In any case, the main sources of energy in Iran is fossil sources and with respect to increase of energy demand in future, there will create lots of problems in advancement of social and economic parts. With respect to specified facts applying different sources of energy is necessary. In recent years almost 3% of whole country energy consumption has been supplied by renewable sources (Rahimi, 2008). Wind energy is a valuable source of energy which is considered as renewable energy during recent decade in country. There is a high potential of wind energy in different districts (specially rural districts) of Iran. Using wind turbines for the purpose of generating electricity or carrying water to farms and gardens in windy districts can provide electricity needs in rural districts without any environmental pollution. Wind energy in comparison with other renewable energy sources has various specialties and advantages as follows:
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1. There is no fossil fuels need for wind turbines which decrease fossil fuel consumption rate
2. Wind energy is free with no cost
3. Fixed and variable costs of wind energy is lesser in long period of time
4. Variation of energy sources and creating permanent system is more
5. There is more ability to maneuver for exploitation in each capacity and size
6. There is no water need
7. There is no environment pollution in comparison with fossil fuels
8. Wind energy needs small area for constructions

In Iran, existence of proper ecological field and sun radiation in most of districts and seasons and also ups and downs in course of rivers, owning districts with high potential of wind and abilities for generating energy and necessary and suitable heat field for utilizing and expansion of clean energies have been provided. Nevertheless, Iran is faced by basic obstacles in utilizing new energies. One of these obstacles is existence of cheap oil sources and rich sources of hydrocarbon in country. Low level of knowledge about renewable sources of energies, obscurity of their advantages by people and responsibilities are other obstacles of accessibility to new energies especially in recent years. In this situation, it is essential that government pay long term loans and subsidies and by capitalizing in renewable energies and making the possibility to transfer technological knowledge provide fields for expansion of new energies in country (unknown, 2010).

One of the most important elements of wind energy potential studies is finding the potential windy energy sites for electricity generation in districts. According to geographical and topographical position, Iran is a country which has local winds and littoral regions. Estimation of wind energy potential is dependent to collecting statistics of wind speed, calculation the process of vertical profile and also its continuance in prolonged time periods (Saghafi, 2005; Sharifi, 2005). In Figure 1, condition of wind speed and also density of wind power in different districts of Iran in height of 20 meter is shown. Based on this figure, north of Iran such as Manjil, Roudbar and Kouhin districts of Qazvin province have a good condition for wind potential studies.

Figure 1: Condition of wind speed and also density of wind power in different districts of Iran in height of 20 meter.
Different usages of wind energy in villages

Water pumping

For a long time mechanical water pump machines have worked with wind force to pump wells water. Modern mechanical machineries pump water by a simple technology and moreover supplying their spare parts is not difficult. Windy pumping system is a simple machinery which works by wind. This system generates electricity and sets in electricity pump periodically. Pump systems of windy electricity have more output in changing wind energy and increasing water ejection.

Grinding cereals

The first mills were expanded for mechanization of some works such as grinding cereals and pumping water. First known pattern of that mills were vertical axis system which were used 500 - 900 years B.C in Iran.

Generation of electricity

In most of cases, in regions which are far from public Trans-electric substation, wind energy is the best choice (with low cost) for providing houses and offices electricity demand. Based on several research results, wind with more than average speed of 4 m s\(^{-1}\) in far regions generates more electricity with less cost in comparison with diesel generators. More expanded electricity generation systems can generate more electricity which can be used for social centers, hygienic clinics or schools. Electricity in hygienic centers is used for keeping vaccines and radio messages at emergency times.

Other applications of wind energy can be mentioned in following cases: wind pump for carrying water and providing water needs of animals in far regions, irrigation in low scale, carrying water for aquatic animal production, providing domestic consuming water and usage of small wind turbines as electricity generator. In regard to this fact that Iran is located in a low pressure region with average wind speed of 6 m s\(^{-1}\), generation of electricity from wind energy is a good choice for outland regions. Other research results indicated the generation capacity of about 96,265,000 kW h\(^{-1}\) for Manjil and Rudbar districts which shows high potential of wind energy in specified regions (Abbaspour et al, 2009).

GIS and optimum utilizing of wind energy

Wind speed data are usually measured at airports and weather stations but these data are affected by regions specialties which decrease the accuracy of measured data. Applying geographical information system (GIS) which analyzes the relation between geographical condition and average wind speed, increases the accuracy of wind energy potential prediction in different regions. In order to provide wind Atlases with highest accuracy this system can be applied. Figure 2 is the sample photo of wind speed in height of 50 and 70 m in California which is produced by geographical information system.

Several studies have been conducted on wind energy in different regions and countries. Weisser (2003) studied the estimative energy of wind at west district of India in 2002. Results showed that Weibull function is an appropriate function to estimate the wind energy by
applying hour data. Also, changes of wind speed during day and night and estimation parameters of Weibull function in order to estimate output energy were analyzed (Weisser, 2003). Himri et al. (2008) calculated the total generation cost for every kW h\(^{-1}\), the capacity coefficient for suppositional turbines and the amount of greenhouse gas reduction by applying RETScreen software and weather recorded data in Ardar district for a suppositional power house (with production of 30 MW) which consist of 30 unit of 1 Mega Watt output in yearly energy.

Results showed that based on calculated factors and parameters, creation of windy power house in specified region is economical (Himri et al., 2008). Saghafi (2005) calculated density distribution function of Weibull by recorded data in 2003 in Siyapushan region of Qazvin province and showed that this region had proper conditions to have a windy power house (placed in grade 7 of power) with annual average speed of 8.2 m s\(^{-1}\) in height of 40 m and power density of 992 W m\(^2\) (Saghafi, 2005). In a research which was done in Qazvin province by Sharifi, it was concluded that this district is very suitable for fixing windy turbines. He used data which were recorded every 10 minutes, and estimated yearly power density by applying Windpro software and distribution function of Weibull (Sharifi, 2005). Montes and Martín (2007) considered economic usefulness of wind energy and introduced effective economic factors in wind energy industry. Also, he reported different levels of Montkarlo’s method in economic analysis by introducing different ways for risk assessment and conditions of uncertainty (Montes and Martín, 2007). Rahimi and Saghafi (2006) studied 10 year recorded data of Borujerd district with annual wind speed of 3.5 m s\(^{-1}\). They estimated distribution frequency functions of Weibull, its parameters, speed distribution in day and night, maximum speed of wind and power density by applying Windpro and Wasp softwares. Moreover they calculated the price of generative electricity for sample turbine, environmental costs of decreasing greenhouse gas emissions, incomes of selling windy electricity and return time of capital for project. Finally applying of small windy turbines was recommended by them (Rahimi and Saghafi, 2006).
2. Materials and methods

This study was done in Qazvin province (Figure 3) which is situated in the north of Iran within 36°07' and 36°48' north latitude and 48°59' and 50°50' east longitude. This province is situated 300 m above sea levels. The annual average rainfall is almost 320 mm, respectively. Kouhin district was chosen for this study due to several reasons:

1. Dispersion of villages in district and their far distance from urban centers
2. The existence of numerous villages in district having different herbal layers
3. High fuel cost in comparison with rural families income
4. Low level of efficiency in heater systems which increases wood and fuel usage in the district
5. Nearness of this district to Manjil district which has high generation potential from windy, aquatic and solar energies.

This region consists of two rural districts of eastern Ghaghazan and western Ghaghazan and 159 villages which among them 64 villages have residents and the others are without residents.

At first, in order to assess the possibility of applying wind energy for providing some percentages of rural energy demand in the research region, potential measurement must be done. For this purpose, information of a standard wind meter station was used by recording speed and direction data every 10 minutes during 5 years. Furthermore, the existed information was completed by adding geographical and aero logy studies of district. So, in the first place, the physical specialties of wind and geography of the district under study has been specified by applying some concepts such as temperature, pressure, density and
coverage of earth surface. Then statistic distribution functions was applied to model the behavior of wind.

Table 1: Ecological and geographical specialties of Kouhin district in a year

<table>
<thead>
<tr>
<th>Specialties (unit)</th>
<th>Average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>6.67</td>
</tr>
<tr>
<td>Pressure (k Pa)</td>
<td>84.5</td>
</tr>
<tr>
<td>Density ($\frac{kg}{m^3}$)</td>
<td>1.088</td>
</tr>
<tr>
<td>Daily pattern value</td>
<td>0.108</td>
</tr>
<tr>
<td>Peak of velocity (hour of day)</td>
<td>17</td>
</tr>
<tr>
<td>Power law index ($\alpha$)</td>
<td>0.148</td>
</tr>
<tr>
<td>Surface Roughness (m)</td>
<td>0.0373</td>
</tr>
</tbody>
</table>

Finally, modeling of wind behavior can be used to calculate the power density of wind in different heights of earth surfaces. Curve of speed changes or windshear is a curve indicating changes in wind speed with height of sea level. Form of this curve is dependent to different factors which the most important of them are roughness of earth surface and atmosphere stability. After determining daily pattern of wind speed and the intensity of wind turbulence, the graphical graphs which show abundance distribution of speed in different directions (wind rose) can be determined. These graphs usually show dominant winds in different districts and are the best guide of fixing windy turbines in rural districts. Criterion of power grade is used for showing position and potential of wind after calculation of wind power density. It is clear that, higher power grade of district in research area means more potential of wind energy in comparison with other districts. Table 2 shows classification of wind power in height of 10 meter.

Table 2: Classification of wind power in height of 10 meter (Manwell et al., 2002)

<table>
<thead>
<tr>
<th>Wind power class</th>
<th>Power Density (W m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 100</td>
<td>1</td>
</tr>
<tr>
<td>100 – 150</td>
<td>2</td>
</tr>
<tr>
<td>150 -200</td>
<td>3</td>
</tr>
<tr>
<td>200 -250</td>
<td>4</td>
</tr>
<tr>
<td>250 – 300</td>
<td>5</td>
</tr>
<tr>
<td>300 – 400</td>
<td>6</td>
</tr>
<tr>
<td>400 - 1000</td>
<td>7</td>
</tr>
</tbody>
</table>

The following functions (probability of wind speed) are the important implements in statistic study of wind speed and calculations of potential rates of wind energy on a district. In this study, probability distribution function of Weibull has been used for analyzing wind speed.
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(Akpınar et al, 2005). The following formulas (Eqs.(1,2)) show probability distribution function \( f(v) \) and cumulative distribution function \( F(v) \) for Weibull function with two parameters (Mathew et al, 2002).

\[
\begin{align*}
    f(v) &= \frac{k}{c} \left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k} \\
    F(V) &= 1 - e^{-\left(\frac{v}{c}\right)^k}
\end{align*}
\]  

Where “\( v \)” is wind speed (m s\(^{-1}\)), “\( k \)” is coefficient of distribution function shape (without dimension) and “\( c \)” is the coefficient of scale (m s\(^{-1}\)).

Eq.(3) shows the relation between these parameters (which are in Eqs.(1) and (2)) with average values of wind speed during a long period of time.

\[
v_m = c r \left(1 + \frac{1}{k}\right)
\]

Where “\( v_m \)” is average speed in long period of time (for example one month or one year), “\( r \)” is the gamma function, “\( k \)” shows the expansion and width of function. The low rate of “\( k \)” in function has small peak and more width.

After calculating wind potential of district, the possibility of applying this kind of energy for villages and different districts was shown by applying GIS 9.3 software. Also in this research the wind rose graphs is posed with WRPLOT view version 7.0.

3. Results and discussion

Observational data of wind which has been recorded in height of 10 meter, was analyzed by applying statistic methods. These data which were recorded in every 10 minutes, were converted to average data of hour at first. Then the statistic specialties and distribution functions parameters of Weibull were determined on the basis of monthly and yearly and in this way power density of monthly and yearly wind was estimated. According to Eqs. (1-3) and the unity of surface, it is concluded that rate density of wind energy on a district has a complete dependency to parameters of Weibull function. The results of this research showed that only 81 villages has maximum wind energy which can ensure the supply of village electricity needs and also agricultural electricity demands. As analysis of windy system in this research showed, by accounting turbines which can be fixed in district, generative electrical power by applying Gamesa G 58 turbines are at electricity limitation of Kouhin in Qazvin province. The considerable speed for calculating generative power of windy turbines is 6.7 m s\(^{-1}\) signifying that mean rate of yearly average speed of wind is in limitation which turbine can be fixed. Generative power of each turbine in specified speed of wind is nearly 290 kW h and ultimate rate of generative electric power with considering waste of whirl pool flows (wake) and without waste is 1900 and 2200 MW, respectively. Also, yearly windy electricity energy can be calculated by considering continual coefficient of approximate charge of 25% which its rate for Kouhin district is 800-950 MW h day\(^{-1}\).
As, it is clear in Figure 5 that the potential of wind energy in most parts of research area is almost 800-1000 W m\(^{-2}\).

As it is obvious in Figure 6, northern and southern part of Kouhin (the central part between two eastern and western province) have the highest potential of wind energy generation. The results of this research in comparison with Saghafi (2005) research result showed that the average speed in Kouhin district of Qazvin province was equal with Kahak district and thus fixing of windy turbines in Kouhin district is economical. Sharifi (2005) found similar results (equal values for speed and density of wind power) for Qazvin district. Results of this study showed that great part of necessary energy for supplying electricity energy for rural consumptions and also obtaining water from agricultural wells can be supplied by wind energy in research area. District executors of windy powerhouse of Manjil (a district near Kouhin district with windy powerhouse) stated that existence of 2000 h wind with speed of 7-25 m s\(^{-1}\) in creation of windy power house is economical and necessary. Saghafi (2002) declared that if power density of wind is achieved 1000 k Wh m\(^{-2}\) at a site; it will be a suitable place for fixing windy turbine. According to above cases and also according to speed of wind and power density in district under studying, applying wind energy in this station and
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Fixing windy turbines are possible and it can be economical. Figure 6 shows the wind rose of wind data (direction and velocity).

Figure 6: Wind rose graph of wind data (direction and velocity)

4. Conclusion

Because wind energy is not a concentrated energy and can be find in faraway regions has being considered in developing and developed countries. This kind of energy had significant effect on rural progress and development.

The results of this research showed that 30-65% of villages electricity (electricity energy) demand in research region can be supplied by electric power of wind. Moreover it was observed that the power of wind in research area had a better situation in comparison with other existed kinds of energy resources with regard to local accessibility. With regard to physical security and security of supplying wind energy was in next rank after solar energy. As a recommendation, because wind energy has no pollution and there is a good potential for wind energy it is necessary to prepare conditions to use the highest potential of wind energy in research area. Finally, considering fundamental methods in local and national programs is essential for expansion and application of renewable sources of energy in which the most important of them are as following points:

1. Expansion of technology and knowledge promotion and making capacity and training for expansion the application of renewable sources of energy.
2. Expansion cooperation in private part and economize application of energy sources.
3. Increasing the share of renewable energies in total energy.
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4. Increasing the number of companies which are active in fixing, establishment and maintenance of renewable energy sources.

Acknowledgement

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