

Original Research Paper

The Appropriate Use of Wind Energy in Sistan Region to Generate Electricity

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Abstract: Sistan (Zabol) region is located in Sistan and Baluchestan province and in southeastern part of Iran. The specific atmospheric condition of this region, especially high-speed and continuous winds, can provide the necessary condition for Electricity generation from wind power. 120-day winds of Sistan region are one of the renewable energy sources in the province, which has been neglected in recent years. This paper examines how to beneficially use this power source, in particular to generate electricity, using field research, written reports, reviewing wind speed atlases and wind energy in the region and interviewing authorities and relevant organizations. The results demonstrate that, considering the climatic features and recent drought in the region, correct use of wind energy can lead to creating new line of employment, preventing the emission of fossil fuels, exporting electricity to neighboring countries in need of electricity and saving on fossil fuel sources. To achieve these goals, more attention and cooperation from related authorities and government and private sector investment is significantly required.

Keywords: Sistan Region, 120-Day Winds, Wind Energy, Power Generation, Wind, Wind Speed Atlas

Introduction

Supply and demand of energy have turned to one of the most important issues in the world. Fossil energies such as oil, gas and coal will be finished one day and their termination ties to the termination of the human civilization cycle, directly germane to the energy. This has led industrial nations to take as much consideration as possible to the use of other renewable energies in nature, such as solar energy, wind power energy, heat of the earth energy and tidal energy. Recently, significant advances have been made regarding the wind energy use. The main objective of this paper is to evaluate the potential of wind energy to generate electricity in Sistan region. Wind

energy is often available and does not contain any kind of contamination and can be economically viable in the long run as compared with other sources of energy (Saghafi, 2003). In Iran, due to the presence of windy areas, a suitable platform is Department of Water Engineering, College of Agriculture, Isfahan University of Technology, Isfahan, 8415683111, Iran ready for the expansion of the operation of wind turbines. One of the most important projects in the field of wind energy has been the preparation of the wind atlas of the country, a project that has been carried out at the New Energy Organization of Iran and is considered as one of the national projects in the wind energy industry. According to the Atlas of Wind and the information received from 60 stations of distinct areas

of the country, the nominal capacity of the sites is about 60,000 megawatts (NEOI, 2013). Wind power plants are being specially considered from variant angles all over the world and have led to the rapid development of electricity generation from renewable energy sources. Some of the advantages of power generation at wind power plants are as follows (Hosseini-Nia, 2013):

1. Diversification into the energy package
2. Dependence reduction on fossil fuels, especially gasoline
3. The production of clean power energy
4. The use of saved resources for the production of goods
5. Employment creation in the supply chain and operation of the power plant
6. Dependence reduction on land and saving water resources

According to the forecasts, the country's economically recoverable amount of energy is estimated at 18,000 megawatts, which confirms the significant potential of the country in building wind power plants as well as the economic viability of investments in the wind energy industry (NEOI, 2013).

Status of Wind Energy in Iran and the World

In recent years, the average annual wind energy in the world has been around 30%, which has the highest growth rate among other energy sources in the world. Currently, the global wind energy market is dominated by five countries, Germany, the United States, Spain, Denmark and India, with a production capacity of more than 1000 megawatts a year. The Table 1 shows the capacity of wind power house in some of the world's leading companies in the world. In Iran, due to the existence of wind farms, windmills have been designed and manufactured since 2000 BC and are now also a good basis for the expansion of the operation of wind turbines. Wind power generators can be a good alternative to gas and steam generators. Studies and calculations in the field of wind energy potential estimation in Iran have shown that in only 26 regions of the country, including more than 45 sites, the nominal capacity of sites, with a total efficiency of 33%, is about 6,500 megawatts (Houshmand and Hosseini, 2013).

Table 1: Wind power generation in the world in 2010 (TWh)

Row	Country name	Wind power generation (TWh)
1	America	70.8
2	Germany	37.2
3	Spain	36.6
4	China	26.9
5	France	7.8
6	The whole world	340.0

Source: Renewable Energy World Magazine

A Review of Studies in the Field of Wind Power

Kaldellis and Gavras (2000) analyzed the economic construction of wind power house in Greece and concluded that investing 25% in costs would not be profitable in this area. Benitez *et al.* (2008) While emphasizing the necessity of investing in the construction of a wind power house as a complement to hydro and thermal power house, the profitability of the wind farm project is influenced by the fluctuation of the cost of turbines and the cost of reducing carbon dioxide. Hamouda (2012) examined the feasibility of building a wind farm in Cairo and emphasized that, despite the weakness of Cairo's city of wind power, the construction of such a unit, especially for investors who provide electricity outside the global network Egyptian electricity will be useful. Himpler and Madlener (2011) have studied the economics of supplying electricity through wind turbines in Denmark and concluded that more government incentives are needed to develop wind energy. Shakouri-Ganjavi and Hatami (2012), in their review of the wind energy conversion system as a dispersed generation source, concluded that the profitability required to encourage the private sector to invest in this area entails the introduction of government incentive policies for the development of this energy.

Position of the Studied Area

The Sistan region is located in the southeast of Iran, in the geographical range between 15' and 60°, 50' and 61° longitude, 5' and 30° and 28' and 31° latitudes in the northeast of Sistan and Baluchestan province. The Sistan plain with an area of about 8117 Km² is part of the Afghan block of tectonic blocks (Aqa-Nabati, 2004), the vast majority of which are widespread in the territories of Afghanistan "Fig. 1". Climatologically speaking, the land of Sistan has a desert climate "Table 2". The warm climate and low rainfall are some of its prominent features (Ebrahimzadeh, 2009), severe winds are one of the important factors in soil erosion, the displacement of sand, filling of rivers and irrigation canals along with the adjustment of ambient temperature in the warm season of summer in this region. In terms of climate, Sistan plain receives less than 65 mm of rainfall annually. The lowest rainfall in Sistan plain has been reported in the last 30 years with an average annual value of about 50 mm. The annual evaporation rate is more than 4000 mm per year (MPOSBP, 2013). These conditions cause a severe dryness in the region "Table 2". In those years when the amount of water entering the Hirmand River decreases, the devastating droughts have been developed and the 120-day winds that sweep from late spring to the end of the summer have been very active in exacerbating evaporation and expanding desert areas throughout the region. The 120-day winds are intense winds that began to blow in the Sistan region during the year, especially

during the spring and summer, from about mid-June and they constantly blow at about 10-20 m till early October. The blowing alternately continues to the winter (Sahebzadeh and Jahed, 2012).

Research Method

In order to investigate the winds of the Sistan area, especially 120-day winds and its proper use in this

area, the field research, library and internal reports of the Ministry of Energy and the website of the New Energy Organization of Iran and its related organizations and Wind Speed Atlas surveys and the wind energy of the region, research centers and interviews with relevant authorities at the regional and provincial level were used and obtained information and data were reviewed.

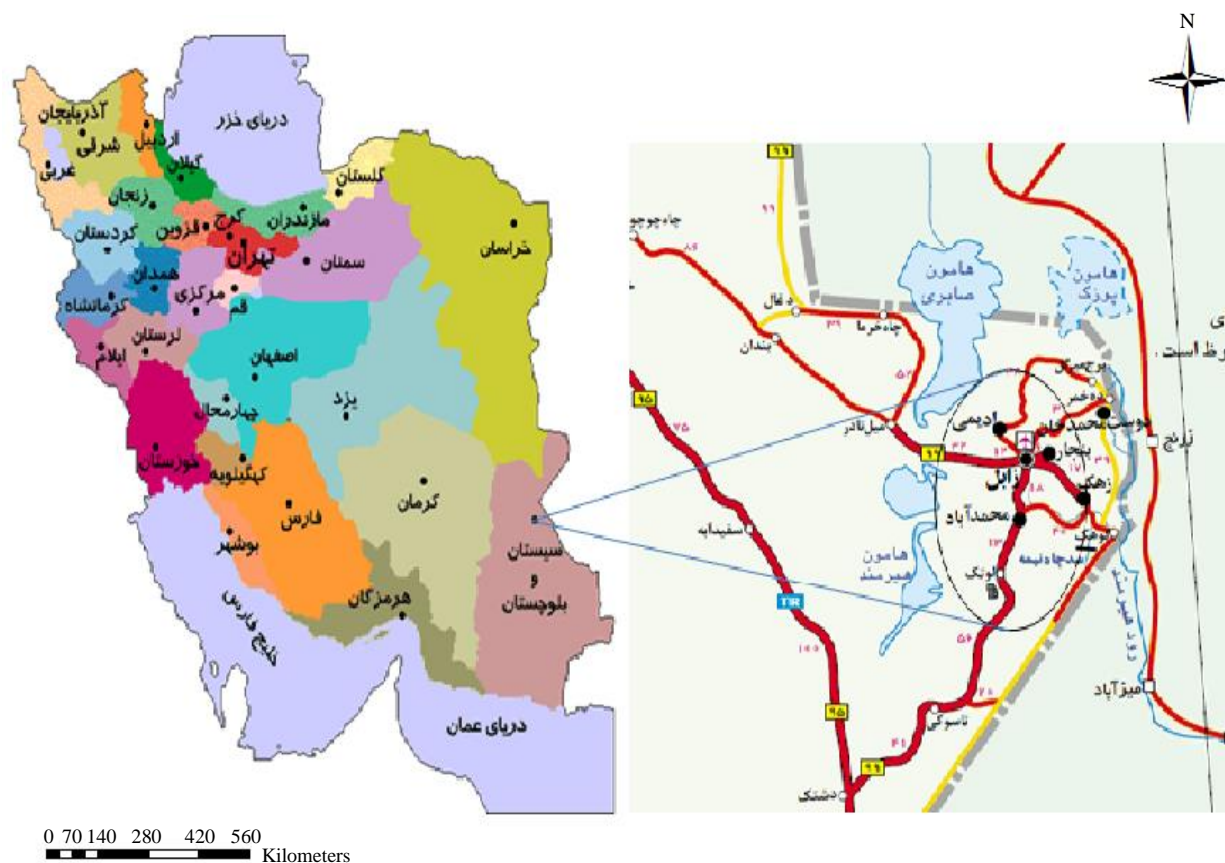


Fig. 1: Location of the studied area

Table 2: Natural specifications of Sistan Area

The average altitude from the sea level	480 m
The average slope of the plain	25% per thousand
Average annual precipitation	60 mm
Average annual evaporation	4000 to 5000 mm
Average annual temperature	21.8°C
Absolute maximum temperature	47.2°C - July
Absolute minimum temperature	-11.9°C - February
Average relative humidity	39.2%
Number of freezing days	45 days
Maximum sunlight hours	11.6 h in May
Minimum sunlight hours	6.1 hours in January
Climate features the	120-day monsoon winds

Results

According to the history of wind power utilization in the east of the country and scientific research conducted in Sistan and Baluchestan over the past 5 years, Sistan has been registered as one of the most important areas of wind power in Iran. Studies indicate that appropriate winds for rotating wind turbine engines blow in Sistan at least for ten month of a year. The Sistan region is on the verge of atmospheric interconnections between the relative centers of high pressure in the northeast of the country and relative centers of low pressure in the south-east and the winds are heavily influenced by these interactions. The 120-day winds of Sistan blowing commence from May 20 to the end of May for 120 to 130 days, or sometimes even for 170 days. The maximum wind speed is 100 km. h in July and in some sources, the higher figures are also mentioned for the maximum speed of this wind. The average wind speed is estimated to be 26 km. h in the summer months and 13 km. h in the winter months. Displacement of hot air of Sistan plain with cold air of north latitude cause blowing of this wind. Creating a low-pressure system in the summer months on the Rigestan desert and moving upward to balance with the dry air of the steppes of Central Asia leads to the movement of dry air from the north and northwest to the south and south-east and due to the constancy of the wind, It's famous for the 120-day wind. According to the weather department of Sistan and Baluchistan province, this wind is also affected by the monsoon winds of India, in such a way that in northern Afghanistan, due to the establishment of a high-pressure system that lost its humidity because of heavy rains and simultaneously a low-pressure seasonal system of the thermal type in the Zabul plain is created, which is formed due to the difference in air pressure between the mountains of Afghanistan and the plain of Sistan. The wind has a northern or northwest direction and it can be considered as a great blessing in terms of power generation for the province, but for the time being, the devastating aspects are much more than the beneficial aspects. The wind-blowing and prolonging it in the region causes dust to disperse in the air, thereby disrupting the lives of the people in the area and disturbing them a lot. Due to the recent drought in Sistan, the report on the estimation of the capacity of the Iranian hydroelectric power plants by 2010 (the web site of New Energy Organization of Iran) in Sistan and Baluchestan demonstrates that electricity generation cannot be occur due to water shortages and droughts of the region and in the future it is not possible to produce electricity in this way which

clearly reveals the significance of using wind power energy. In 2002, the New Energies Organization of Iran launched a national potentiometric project and provided a color atlas of the country's wind, which was completed in 2009. In this atlas, 26 regions of the country, including 45 sites, have been studied. According to the Atlas, the total potential of wind energy utilization in 20 of these sites is equal to 6,500 megawatts and the amount of electricity extracted from wind energy in the whole country is estimated about 20,000 Megawatt. By the end of 2009, the turbines installed on the sites (Ashkelon, Herzwil and Blackpool) of Manjil, Binalod, LootkZabul and Aoun bin Ali Tabriz were equal 92 megawatts (SNC, 2010).

Different Kinds of Winds in Sistan Region

In addition to the 120-day winds of the region, other types of Sistani winds include the following (Ebrahimzadeh, 2009):

- 1- 7th wind (Black wind or Gavkosh wind): This wind is from the winter winds and it accompanies with a severe, dry frost which flows from the mountains of southern Khorasan to the Sistan province
- 2- Arc wind: This wind blows in December, causing a brief rainfall in the area
- 3- Pelvic wind (swallow wind): This wind is always inaugurated in mid-March and it is a sign of the beginning of the spring
- 4- Qibla wind (Bakhtar): This wind blows from the west of the province in different seasons of the year
- 5- Lava wind: This wind is a continuation of the monsoon winds of the Indian Ocean, which covers Sistan and blows to the north-southwest direction

"Table 3" demonstrate the average annual wind power over a ten-year period in this region, with the highest average wind speed occurring between June and September each year, that some part of them are among 120-day winds of Sistan. In other months of the year, the wind also runs at different speeds.

Investigating Sistan Winds Using Iran's Speed and Wind Energies' Atlas

Investigating the wind speed Atlas of Iran at a height of 20 m (NEOI, 2013), indicates that Sistan is one of the regions with high-speed winds in the country. The wind speed in this range is more than 8.8 m. s "Fig. 2".

Investigating the areas with wind energy density, it is also observed that the Sistan region has the highest potential of wind energy with values higher than 142

watts per square meter in the country "Fig. 3". Since 2005, 9 automatic anemometers have been established to measure speed, power and sustainability of the wind, the intensity of the sun radiation and the percentage of air humidity in the province and to withdraw information from them. According to the topography of Sistan and its height from sea level as well as access to power transmission lines, priority is given to the construction of the first wind turbine in the plains surrounding the new city of Ramsar, the adjacent areas of the Shahre sukhte artifacts, the plains around the Hamoon lagoon and the Zabol road to the Nehbandan and plains of the Tasuki area of Zabol to the Dashtak triathlon. In this vein, to begin and complete the studies, a unit of 660 kilowatt was constructed in Iran with a total cost of 10 billion riyals alongside the Lodak station in Zabol and was routed to the Zabol network from June 2002. The first pilot wind turbine constructed in Sistan by the provincial power company with a power output of 1,970 MWh per year and covering about 400 subscribers. In northern part of Sistan and Baluchestan, exploiting the abundant and powerful winds of Sistan in building wind electricity farms is feasible. The initial capital of a power plant with wind power is slightly higher than the combined gas and combined power plants, but the wind power plant after construction does not have the costs of fuel, water, maintenance and even the construction of wind power plants is one of the cheapest and affordable the most energy available.

According to a survey conducted by the authorities of the regional power company Sistan and Baluchestan province, the Ministry of Energy informed Iran's Power Development Organization of the authorization to build a 50-megawatt farm in Sistan, which is the consultant and contractor of the project, The initial studies of this site with a number of 25 turbines 2 MW to 50 MW costing more than 750 billion Rials credit from the Tavanir company on the Zabol road to the Nehbandan with the capability and the ideal wind regime has begun.. The conducted research pinpointed that abundant wind electricity farms can be designed in the north of the province considering the vastness of suitable lands adjacent to Hamoon Lake and Sistan plain ensuring to produce electricity from wind power of the region several times more than the consumption peak of the country. Employment for young people in the region, preventing the spread of pollutants from burning fossil fuels, exporting electricity to neighboring countries in need of electricity, preventing electricity imports to the country and the region, preventing currency exit to supply fuel and electricity, not requiring water for cooling systems such as thermal power plants, not needing spare parts and special external equipment with regard to the built-in facilities, the return of initial capital after several months of useful operation of wind power plants and several other benefits can be pointed out as the most significant advantages of wind power plants.

Table 3: The average wind power per year in Sistan area in km. h (2003-2013)

Year	March	April	May	June	July	August
2003	25	24	40	29	48	40
2004	27	22	35	31	38	36
2005	18	22	39	27	38	41
2006	26	22	31	46	36	39
2007	26	19	32	42	47	38
2008	24	25	45	33	44	40
2009	24	25	35	29	42	44
2010	20	27	42	42	40	38
2011	29	28	47	43	38	42
2012	18	21	40	44	43	40
2013	24	26	46	44	39	45
Year	September	October	November	December	January	December
2003	22	15	12	9	10	20
2004	17	13	10	7	13	18
2005	10	12	8	8	11	21
2006	15	11	9	8	10	14
2007	15	13	9	8	10	15
2008	18	10	10	9	10	15
2009	10	9	10	10	10	17
2010	9	9	10	9	13	22
2011	12	9	9	7	16	24
2012	11	11	8	9	10	22
2013	10	12	8	7	12	23

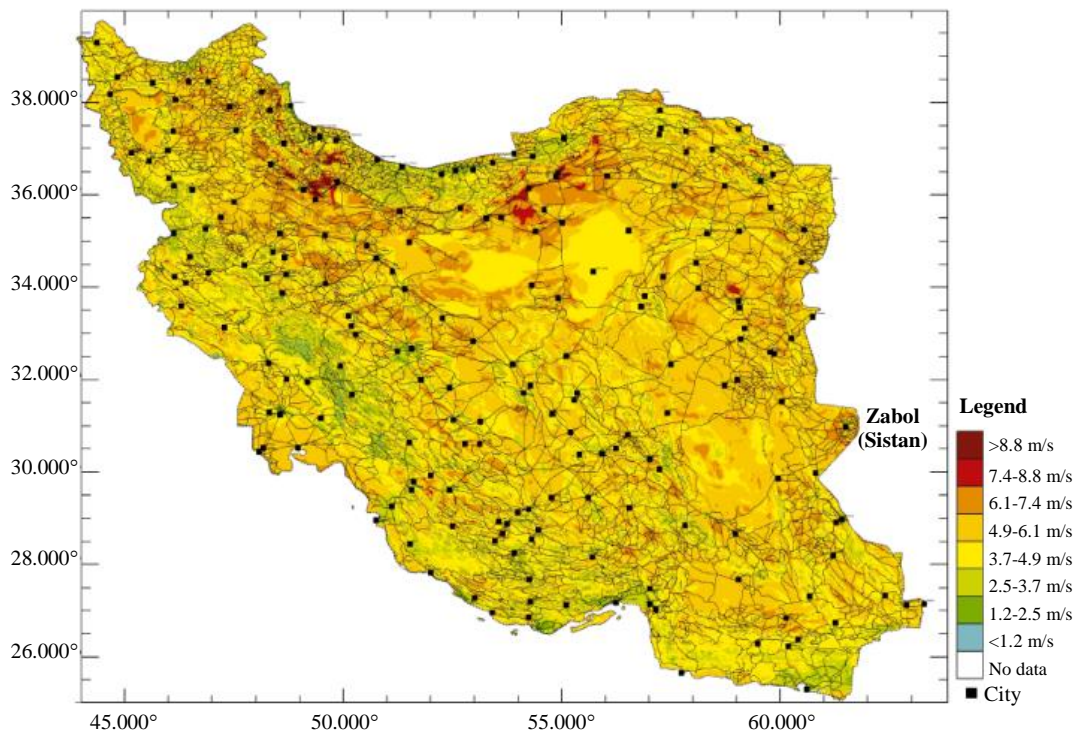


Fig. 2: Wind speed atlas of Iran with the height of 20 m

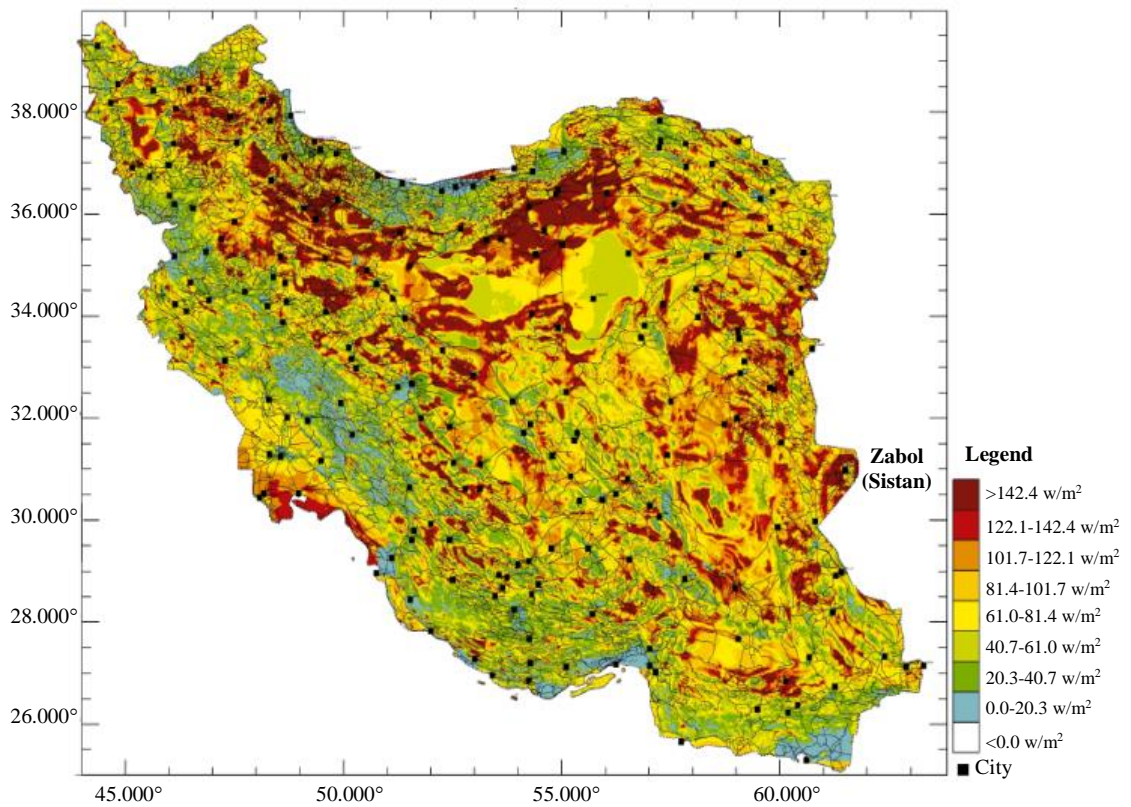


Fig. 3: Atlas of wind energy in Iran with the height of 20 m

Electricity Generation Capability of Sistan Winds

Investigations demonstrate that there is only one turbine in the Sistan region that has entered orbit since 2008 and has produced 3,200 megawatts of electricity. Each liter of gasoline can only produce two kilowatts of electricity, while the aforementioned turbine in the Sistan region produces 3,200 megawatts of electricity; it saved one million and 600 thousand liters of gasoline. In the case of investment and construction of wind turbines, this region has the capability of producing at least half of the production of electricity in Iran. In addition, there have been no devastating earthquakes in this area during the past 100 years. Hence, geographical and natural conditions heighten the security of installing wind turbines.

Necessity to Use Wind energy in Current Conditions of Sistan

Considering the political situation of the region and the difficulty of transporting oil products and the costs of supplying fuel for thermal power plants, it is of utmost importance to use wind power projects to provide the required electricity in the province. The urgent need of the region for energy, the construction of a high-power consumer infrastructure and the growing demand from neighboring countries for energy convince us to build dominant power plants in the north of the province. Since the gas supply network for the north of the province and the cities of Sistan has not been scheduled for the coming years and since it is required to use fossil fuels such as gasoline and mazut for putting these plants to operation, investment in renewable energies such as wind power is of significant importance. According to the officials of the country wind projects and solar power

plants, currently, more than 4 million liters of gasoline and Mazut are transported by fuel tankers from Hormozgan and Isfahan provinces providing two-thirds of the electricity consumed in the province power plants. The production and burning of this amount of fossil fuel in power plants, apart from the cost and environmental pollution caused by the production of harmful gases, increase the traffic load and the consequent damage on the roads of the province. On the contrary, investment in wind turbines, especially in Sistan, will lead to a reduction in the cost of electricity in the long-term, due to the windy region. The capacity of the implemented wind power plants in Iran by the end of 2012 shows that despite the abundant windy days with high-speed winds, the Sistan region is located in the eighth place of the capacity of the Iranian wind power plants "Table 4" and statistics on the production of 660 Kw wind turbines from different sites Operating time by the end of February 2012 in Sistan, the wind turbines generated by this region are 2223243 kwh and are in fourth place "Table 5", (NEOI, 2013).

Advantages of Sistan in Using Wind Power Turbines

Several advantages can be highlighted for the construction of large turbines and for exploiting wind energy in Sistan region. The wind blowing throughout the year, especially in the Mil Nader region and the border of the Hamoon plain have been constantly continuing with the speed of over 10 m.s and roughly 300 days a year. Constant, unchanged wind and geographically flattened land in most areas have been among other advantages in constructing wind farms in Sistan region. In demand neighboring countries such as Afghanistan and Pakistan can even trace advances to more economical advantages.

Table 4: Capacity of implemented wind power plants in Iran by the end of 2012

Row	The turbine type	Number and capacity of implemented ones	Location
1	300 kilowatts	27(8100 kilowatts)	Manjil power plant site
2	500 kilowatts	2 (1000 kilowatt)	Manjil power plant site
3	550 kilowatts	18 (9900 kilowatts)	Manjil power plant site
4	600 kilowatts	1(600 kilowatts)	Manjil power plant site
5	660 kilowatts	70 (46,200 kilowatt)	Manjil power plant site
6	660 kilowatts	9 (5940 kilowatt)	Manjil power plant site
7	660 kilowatts	43(28380 kilowatts)	Binalood power plant site
8	660 kilowatts	1 (660 kilowatts)	Zabul (Sistan)
9	660 kilowatts	1(660 kilowatts)	Babakouhi in Shiraz
1	660 kilowatts	3 (1980 kilowatts)	Aoun Ibn Ali in Tabriz
11	660 kilowatts	1(660 kilowatts)	Sarein (Ardebil)
12	660 kilowatts	1(660 kilowatts)	Isfahan
13	660 kilowatts	1(660 kilowatts)	Mahshahr
14	1.5 MW	1 (11.5 MW)	Kha (Khorasan Razavi)
15	2.5 MW	1 (2.5 MW)	Kha (Khorasan Razavi)
		109.4	Total Capacity in MW

Table 5: Statistics for electricity generation of wind turbines of 660 Kw of different sites since operation till the end of February 2012

Row	Site		Production rate (Kilowatts per hour)
1	Aoun ibn Ali in Tabriz	Unit 1	3030520
		Unit 2	2136849
		Unit 3	2648464
2	Mahshahr	534778	
3	Baba Kohi in Shiraz	1122320	
4	Zabul (Sistan)	2223243	
5	Soffe in Isfahan	573387	
6	Sarein in Ardabil	666261	

Comparison of Electricity Generated by Sistan and Manjil Station

Comparing of the electricity generated by Sistan Station with the Manjil Station, the most important power station in the country through wind turbines, indicates that the Manjil station power generation is estimated between 550 and 600 kWh in the high seasons (July and August), with average wind speed of 25 Km.h and in the same direction with fast north winds. The windiest time in this area is around 6 p.m. In contrast, the station generates 660 kilowatt per hour in Sistan region between the months of June and September, with an average speed of more than 26 Km. h and in the same direction as rapid northwest winds. The windiest time of the day with a longer period is between 6 to 12 p.m. This comparison delineates insufficient and inappropriate use of Sistan station in generating electricity regardless of Sistan profitable situation.

Discussion

Several works have already been carried out to study the sources of wind energy in Iran, including the preparation of the country's Atlantic Atlas by the New Energy Agency (New Energy Organization of Iran). Also, the wind energy potential in the Manjil region was investigated by Mostafaepour and Abarghoeei (2008), which has been introduced as one of the world's most windy regions. In another research, Mirhosseini *et al.* (2010), Assessed the wind energy potential in Semnan province and finally, Damghan city was the best site for wind power plant installation. Take into consideration the interviews with the executives of the country's wind and solar power plants and other officials of the province, the main reasons for the lack of constructive use of wind energy in Sistan includes lack of interest of senior officials and representatives of the province, as well as the abusive rules and lack of necessary supports which all cause many local and foreign investors as the private sector to announce their withdrawal from the construction of a wind farm in Sistan. On the other hand, according to the law of the state and in accordance with

Article 44 of Constitution Law, such activities must be fully implemented by the private sector, but strict administrative regulations, on one hand and economic sanctions on the other hand and most importantly instability in the Sistan-Baluchistan Security exacerbate the situation for the private sector investors.

Conclusion

Scrutinizing the winds of the Sistan region, especially the 120-day winds, their appropriate use, the researches carried out in this region, investigating Iran Atlas of wind speed and density of 20 m high, revealed that this region is among areas with high wind velocity and density in the country. Alternatively, existence of other winds including 120-day winds and constant blowing during the whole year without many changes have made the construction of more wind farms in this area economically justifiable. Besides, due to the decreased energy prices comparing wind energy and fossil fuels, it can have a considerable share in the country's economy. The possibility of exploitation, rapid construction, lack of environmental pollution comparing to fossil fuels and reduction of greenhouse gases are among the main advantages of wind energy. Regarding Sistan location (adjacent to the border), job creation resulting from the implementation of wind turbines, sending electricity to villages and tribes as well as exporting electricity to other countries outside of the border are among proportional advantages that that no one can ignore them. Due to the fact that Sistan is located in dry and less developed areas where the amount of power energy generation is low and also because of the high cost of electricity supply for these areas, constructing wind farms is vital. In the case of investment and construction of wind turbines, this region even has the potential of providing at least half of electricity required in Iran. In addition, Sistan has the proper security for implementing wind turbines due to geographical and natural conditions. The most crucial reasons for the lack of profitable use of wind energy in Sistan can be pinpointed aslack of senior officials' interest and representatives of the province, the existence of abusive rules, lack of required support from many investors as the private

sector and most prominently, the instability of security in Sistan and Baluchistan region.

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All authors equally contributed in this work.

Ethics

In this article, all ethical principles related to scientific-research articles such as: validity and authenticity, originality, data collection in a standard manner, integrity and accuracy of research and ... are observed.

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