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Wind farm feasibility study and site selection in Adrar, Algeria

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Abstract

Wind resources present a promising option to be integrated with the conventional energy sources to match the increased demand of electricity. This paper aims to investigate the possibility to set up a wind farm of 10 MW in Adrar, a region located in the south of the country. Using the wasp software, the wind resources of the zone of interest was performed, it indicates that wind speed reach 8.44 m/s at a height of 80 meters. Then, two sites Kaberten(75 north of Adrar) and Zaouia (80 Km south of Adrar) were selected. The wind farm study show that Aouia present the better performance, it can be expected to achieve from this site a production of 40 GW and a full load hours about 4044 h.

Keywords: Wind energy; Wind farm; Weibull; electricity; Capacity factor; Adrar; Algeria;

1. Introduction

Wind energy becomes today a promising option to complement the conventional energy source, especially in region where the existing power plants are not sufficient to match the increasing electricity demand. This success is principally due the rapid growth of the wind technology which led the wind power to be more competitive by reducing the cost of electricity produced. This prompted the Algerian government to adopt a new energy policy by promoting and to supporting the development of this clean energy. An important result of this policy is the government intention to construct a wind farm in the south west desert of Algeria.

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The choice of this region was justified by the existing of vast inhabited areas which are required for a large scale development of the wind energy, and also the fact that the first wind map of Algeria show that this region is one of the windiest in country, [1,2].

Within this context, some micro-climate studies have been established, [4,5, 6]. A first study done to identify a suitable site in Adrar region has been by Sebaa Ben Miloud F et al in 2010, [7]. The authors did not consider the wind speed data inferior to 3 m/s and it is well known that this class of wind speed influences greatly the performance of the wind farm production.

In the present study, WAsP software is used to evaluate the wind resource of the Adrar region. It is a program, developed by the Riso National Laboratory of Denmark for climate forecast and power productions from wind turbines and farms[8].

In order to ensure the economic success of the future wind farm project in this region, a more accurate wind farm study on Adrar is needed. To answer this need, we perform this work by introducing some losses to evaluate and to determine the most suitable site for the project.

So, the net AEP (net output energy production) is calculated after deducting all the losses that occur during the production and transportation as wake loss, availability and transmission lines losses.

2. Wind assessment

2.1. Adrar location

The Algerian wind map, related to measured data at 10 m above ground level, established by Kasbadji-Merzouk, in 2006 [2] shows that a maximum of mean wind speed is reached in a South – West (Adrar region) of a country with a value of 6.5 m/s, (see Fig 1).

In fact, Adrar is situated in the middle of the Algerian Sahara. The area of the Adrar district is about 427 968 km2. The inhabitant is concentrated at the main city of Adrar and population density has been estimated in January 2011 to 1.01 inh/km2.

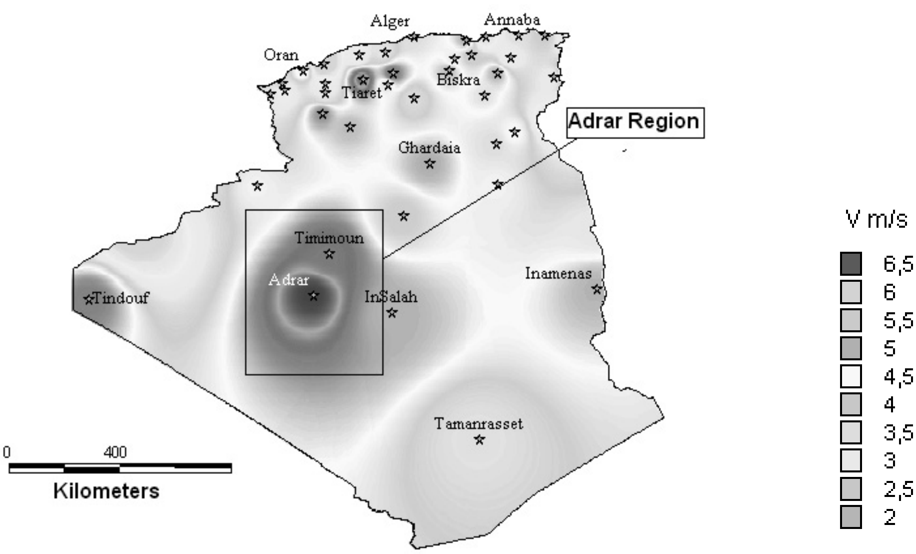

Figure 1 : Yearly mean wind speed map of Algeria, [2]

However, the region is characterized by a saharian arid climate and with a terrain relatively flat where the highest point reach 421 meters.

The network of Adrar consists of two power lines connecting Adrar to other cities over a length of 274 and 190 km. The network also has 3142 km of mean voltage lines and 1400 km of low voltage. It is funded mainly by the central type of Adrar gas turbine (115 MW) but also by other small power plants (13.26MW). The demand for electricity is growing by 5% per year, [9].

2.2. Wind data

The wind speed and direction data were provided from Adrar meteorological station located at latitude 27°40' N and 8°06 W longitude, and with an altitude of 263 m above the sea mar. The data were measured periodically every 3 hours regularly at heights of 10 meters above ground and during the period between 1995 and 1999.

The Weibull probability function is used to estimate the regional wind climate of Adrar region. The finale value obtained for the shape and scale parameters are 2.05 and 6.7 m/s respectively. The high value of shape parameter involves regular winds, concentrated around a mean value. With the scale factor value, it can be concluded that Adrar present a good condition in term of wind resource to host a wind park [3].

Fig. 2 shows the wind speed frequency and the wind rose diagram. It can be observed that the Weibull curve didn't fit perfectly the measured histogram wind speed. This is due mainly to the low density value of estimated frequency at 1m / s. Concerning the wind rose diagram, it can be noted that the prevailing wind direction in Adrar region is coming from the north east sector.

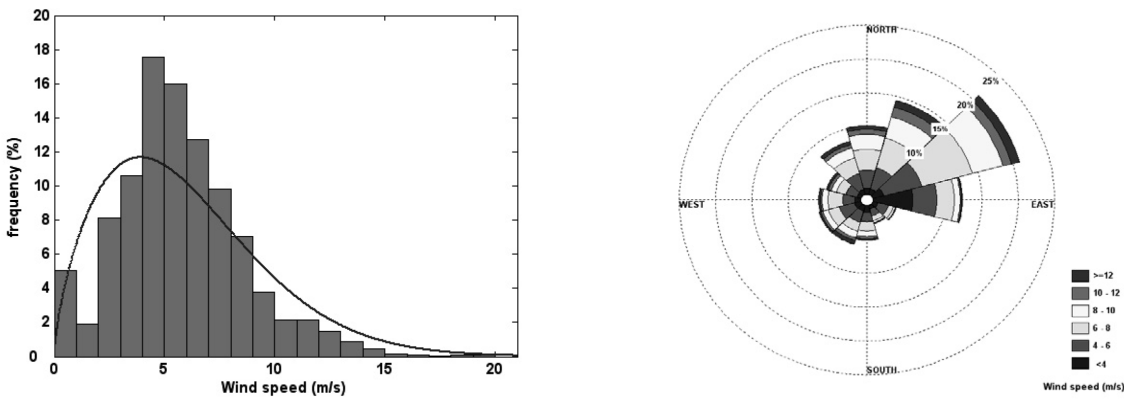

Fig. 2. (a) Weibull distribution (A = 7.0 m/s and k = 2.17) and histogram; (b) Wind rose diagram at a height of 10m

2.3. Wind resource mapping

The wind data corresponding to the 5 years of measurement as presented above were analyzed by the WASP (Wind Analysis and Application Program). It is a powerful tool which was been extensity used to predict the wind resource and developed by the Risø National Laboratory [5] and based on a linear flow model. The Wasp software considers also, a data related to:

- a numerical model of the area,
- a roughness variation model
- and a model for the neighboring obstacles

The digital terrain map is derived from the free NASA SRTM (Shuttle Radar topographic Mission) data, based on a resolution of 90 m [6]. Additionally to the relief; the roughness is a parameter that also influences the wind speed. According to the nature of the surface terrain of this region, two class of roughness can be distinguished:

- The desert area: 0.001.
- The city: 0.5.

The wind resource mapping of a global region at a height of 80 meters is performed by WASP software with a resolution of 300 meters and for the entire area of interest. The wind resources of the region are show on Fig. 3. It can be seen that the wind speed value is ranging between 8.75 m/s and 9.38 m/s.

According to the map obtained, we select two windy sites, Kaberten situated in north and Zouia Kounta, located in the south of Adrar city as presented in Fig 3.

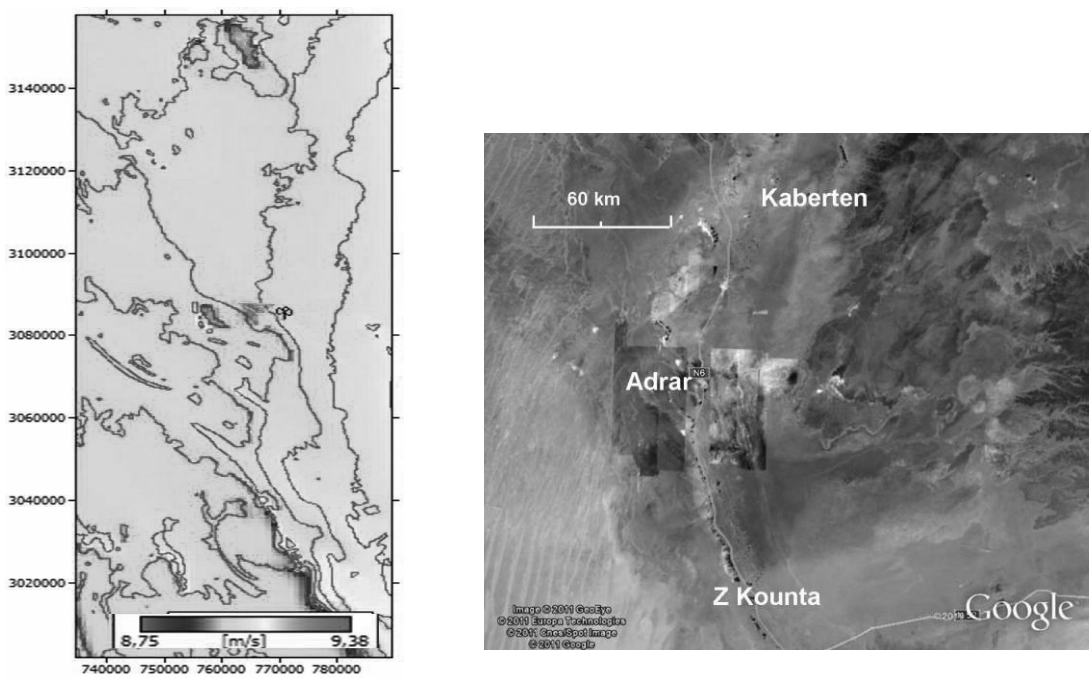

Figure 3 (a) Wind speed map at a height of 80; (b) sites location from the Adrar city

This choice was motivated for the presence near them of a 220/30 KV substation, this will facilitate the integration of the wind farm production to the high tension lines. In the other hand, the cost linked to the infrastructure needed to the wind farm connection to the electrical distribution system will be reduced.

On Fig 4 are presented the variation of the mean wind speed for the two selected zones. It can see that Zouia Kounta is more winded than Kaberten region. This difference is probably due to the fact that the altitude of the first site exceeds that of the second one.

3. Wind farm study

We consider a wind farm with a capacity of 10 MW and constituted by 5 wind turbine placed at height of 80 meters. We opted for the 2 MW of unit nominal power (V80) manufactured by Vestas.

The wind turbine generators, the Weibull parameters, the mean wind speed and the unit mean wind power density for the two sites are given on table 1.

The wind turbines installed in the Kaberten site have the same results because there are positioned at the same height. In the second area, the respective estimated unit annual energy produced, differ from one machine to another, because of the difference in altitude Weak losses are given by Wasp and depend essentially of the position of one machine from another one. This factor is small, so the turbines have the best position in the site.

However, the net AEP (net energy production) must be calculated after deducting all the losses that occur during the production and transportation phases of the electricity generated (wake loss, availability, transmission lines losses).

Table 1 : Energy produced annually by each wind engine

Kaberten site results							
	Height, m a.g.l.	Scale factor, m/s	Shape factor	V m/s	P W/m^2	Net AEP GWh	Wake loss [%]
Turbine1	250	10,2	2,69	9,08	687	8,519	0,01
Turbine 2	245	10,2	2,69	9,08	686	8,513	0,03
Turbine 3	249	10,2	2,69	9,07	686	8,508	0,03
Turbine 4	247	10,2	2,69	9,07	686	8,510	0,03
Turbine 5	248	10,2	2,69	9,07	686	8,508	0,01
Zouia Kounta site results							
	Height, m a.g.l.	Scale factor, m/s	Shape factor	V m/s	P W/m^2	Net AEP GWh	Wake loss [%]
Turbine1	269	10,3	2,69	9,18	710	8,661	0,02
Turbine 2	275	10,4	2,69	9,22	720	8,721	0,03
Turbine 3	277	10,4	2,69	9,21	718	8,713	0,02
Turbine 4	280	10,3	2,69	9,18	711	8,661	0,04
Turbine 5	280	10,4	2,68	9,23	725	8,736	0,03

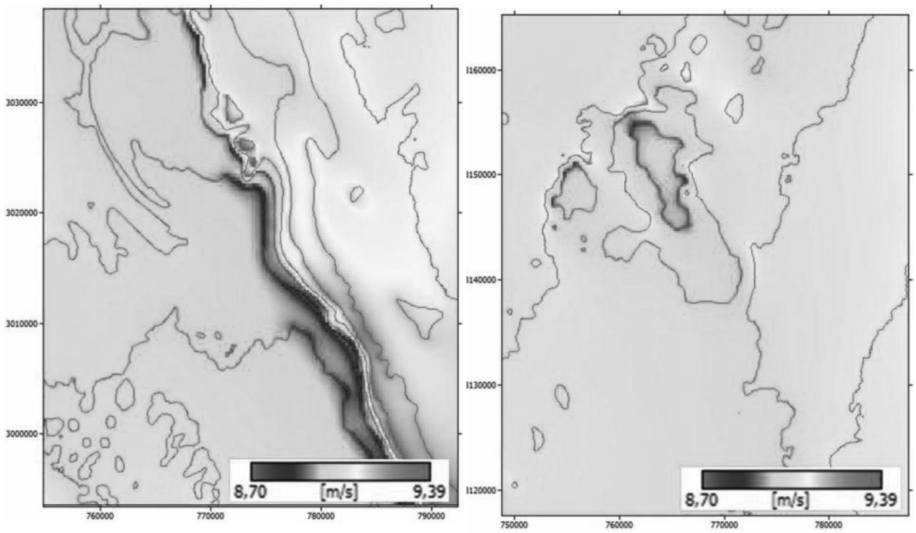

Fig. 4. (a) wind speed in Z. Kounta site; (b) wind speed in Kaberten site

The transmission line used in the Adrar region is 30KV, so in accordance with the result given by Ackermann T R. [11], the transmission losses can be assumed to be equal to 4 % .The availability losses are given by the manufacturer and for this study, the value is fixed at 3%. On table 2 is reported the net AEP estimated for the two sites.

An important point which needs to be taking in account is the intermittent natures of wind which differentiate them from other conventional energy source. An analyze of this effect can be done by some factors like capacity factor and full load hours. They are given by the relations [12]:

$$\text{Full load hours} = \frac{\text{Annual production per year}}{\text{Nominal power}} \tag{1}$$

And

$$\text{Capacity factor} = \frac{\text{Annual production per year}}{\text{Nominal power} \times 8760} \tag{2}$$

The weak and the total losses values, the Gross, the net AEP, capacity factor and a full load hour are reported on table 2.

Table 2 : Results of the net output electrical production of the two selected sites

Site	Average speed [m/s]	Gross AEP [GWh]	Weak loss [%]	Total loss [%]	Net AEP [GWh]	Capacity factor [%]	Full load hours [h]
Kaberten	9.08	42.56	0.02	7,07	39.57	45	3957
Z. Kounta	9.20	43.5	0.03	7,03	40.44	46	4044

The results show that the two sites are suitable to install a wind farm. However, it can be expected for a planning wind farm on Zouia Kounta, where electrical productions that can reach a 40 GWh in the year and with a capacity factor about 45 %. These initial results can be considered as promising and show that this site is suitable for wind energy.

4. Conclusions

The evaluation of the wind potential of Adrar region has be done using the Wasp software, According to the wind resources map obtained, two sites (Kaaberten and Zouia Kounta) that are located near a 220/30 KV transformer were selected.

In terms of wind power resources, the wind maps show that Adrar region is best location to install wind farm where the wind speed is about 9 m/s at 80 m a.g.l.

The results show that the wake loss of the first region is greater than the second one. This indicates that the wind turbine generators have a better position in the second zone.

The net AEP was calculated for each site and it was found that the site of Z. Kounta the net electrical production per year is about 40 GWh and the full load hours is about 4040 h.

In addition, the region has all the arguments that tells in favour of a wind farm installation, namely accessibility, low density of population, significant naked spaces and absence of protected zones.

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