ASSESSMENT OF WIND RESOURCE AND PRODUCTION IN ORAN, ALGERIA

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ABSTRACT

Algeria engages with determination on the path renewable energies to bring global and long-lasting solutions to the environmental challenges and to the problems of conservation of the energy resources of fossil origin. Our study is interested on the wind spinneret which seems one of the most promising with a very high global growth rate. The object of this article is to estimate the wind deposit of the region of Oran (Es Senia), important stage in any planning and realization of wind plant. In our work, we began with the processing of schedules data relative to the wind collected over a period of more than 50 years, to evaluate the wind potential while determining its frequencies. Then, we calculated the total electrical energy produced at various heights with three types of wind turbines.The analysis of the results shows that the wind turbines of major powers allow producing important quantities of energy when we increase the height of their hubs to take advantage of stronger speeds of wind.

KEYWORDS

Wind energy; Weibull distribution; electricity production; wind ressource; Algeria.

1.INTRODUCTION

The increase in oil prices that occurred in 1973 led for the first time the man to be interested in other sources of energy [1]. In Algeria, even if opinions diverge by wanting to agree on a very precise date, everybody is unanimous to say that one day the depletion of fossil resources will be inevitable [2]. To address these concerns, the use of so-called renewable sources is presented as the ideal solution because, unlike fossil fuels, they are inexhaustible on a human scale and do not harm the environment (less reject of CO_2) . For Algeria, solar energy is undoubtedly the most promising renewable source (overs 16,944 TWh/year [2]). However, wind energy, which is the transformation of the power in the wind into mechanical power and, eventually, electric power, is another renewable energy source whose exploitation is more than interesting.

Currently, the total installed wind power in Algeria is insignificant [3]. However, an ambitious national renewable energy project involves the installation of eight wind turbines with a total capacity of 260 MW in the medium term [3], and 1700 MW by 2030 [3].

In this context, Oran, a coastal city located in western Algeria, adopted in 2013 an extensive program on the use of renewable energy and clean energy for sustainable development [4] So, besides the photovoltaic solar energy, several wind turbines are going to be installed making of her the first common pilot for the introduction of the renewable energies [6]. For that purpose, the research work presented in this article is a contribution to the evaluation of the wind potential in the region of Oran, as well as the study of the electricity production from various types of wind turbines.

2. SITE PRESENTATION

Oran, the second city of Algeria, is a harbor city of the Mediterranean Sea, situated in the northwest of Algeria, in 432 km from the capital Algiers, and is the administrative center of the wilaya of the same name [5].

Figure 1. Localization of Oran (map of Algeria)

In our study, the site from which we were able to obtain the meteorological data which we needed is the municipality of Es-Senia who contains, among others, the second the most important international airport of Algeria.

3. DATA ANALYSIS OF WIND SPEEDS

We used hourly wind speeds values at 10 meters above the ground. These data were obtained via “NCDC Climate Data Online” [6] and we chose the period from January 1st, 1960 to December 31, 2013.

Table 1. Station Code

Region	Latitude/Longitude	Station Code (AWS)
Oran ’’ Es-Senia ’’	35.633 º /-0.6º	604900

From the data which we were able to obtain, we made an average to have one typical year containing 366 hourly values of wind speeds.

3.1. Frequencies of wind speeds

Knowledge of wind speeds for a given site is not always sufficient to estimate the energy in the wind and assess the wind energy potential of this site. Indeed, a statistical study of the distribution of hourly data can often give us clues about the most suitable type of turbine for our installation.

Table 2. Distribution of wind speeds

Speed Interval (m/s)	**Frequencies (%)**
0 → 1	0.29
1 → 2	19.01
2 → 3	31.67
3 → 4	15.33
4 → 5	11.20
5 → 6	10.05
6 → 7	8.74
7→ 8	3.45
8 → 9	0.12
9→ 10	0.10
10 → 11	0.03
11 → 12	0.01
> 12	0

In addition to the above table, we may use the Weibull distribution [7], well known in the wind energy sector, which is characterized by its probability density function:

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (1)$$

v is the wind speed. k and c are, respectively, the shape factor of the distribution (dimensionless), and the scale factor expressed in m/s.

k can be calculated using the likelihood method [7]:

$$k = \left[\frac{\sum_{i=1}^{n} v_i^k \ln v_i}{\sum_{i=1}^{n} v_i^k} + \frac{1}{n}\sum_{i=1}^{n} \ln v_i\right]^{-1} \quad (2)$$

The same case for the parameter c:

$$c = \left(\frac{1}{n}\sum_{i=1}^{n} v_i^k\right)^{\frac{1}{k}} \quad (3)$$

n is the total number of data.

In our case, n = 8784. In figure 2 we can find the frequency histogram of wind speeds (Table 2), and the Weibull distribution for the same speeds (k = 2.2095 and c = 3.9994 m/s).

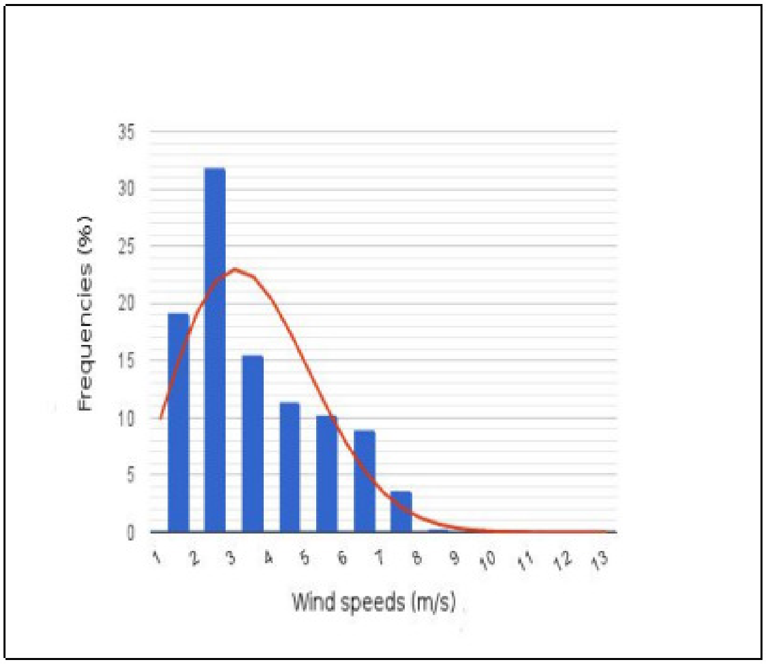

Figure 2. Frequencies Histogram and Weibull Distribution

According to the obtained results(profits), we see that, during one year, approximately 50 % of the wind hourly wind speed are lower than 3 m/s, typical speed of starting up of production of the majority of wind turbines, and that no speed exceeds 12 m/s, speed which the numerous wind turbines reach their rated output. These first observations inform us about the fact that in 10 m above ground level, small wind turbines hubs of which cannot exceed this height cannot extract a big quantity of the present energy in the wind.

3.2. Vertical extrapolation

The wind speed increases with height, and as big wind turbines have hubs often higher than the measurement height (10 m), it's paramount in our study to extrapolate vertically our speeds. For this, we will use the power law [8]:

$$\frac{v_2}{v_1} = \left(\frac{h_2}{h_1}\right)^{\alpha} \quad (4)$$

v_1 is the wind speed at height h_1
v_2 is the wind speed at height h_2
α is a parameter that depends on the roughness of the surface and the atmospheric stability of the place. This parameter can be given depending on the type of ground in the table below [9]:

Table 3. Coefficient for different types of ground

Type of the ground	**Factor α**
Lakes, oceans and smoother grounds	0.10
Grassland	0.15
High cultures with bays and shrubs	0.20
Very Woodlands	0.25
Small towns with trees and shrubs	0.30
Urban areas with skyscrapers	0.40

α can also be determined by the following relation [9]:

$$\alpha = a + b \ln v_1 \quad (5)$$

With:

$$a = \frac{0.37}{1-0.088 \ln\left(\frac{h_1}{10}\right)} \quad (6)$$

$$b = \frac{-0.088}{1-0.088 \ln\left(\frac{h_1}{10}\right)} \quad (7)$$

In our work, we chose three wind turbines: LKX 10 [10], E44 [11] and E53 [12].

Table 4. Weibull Parameters for different heights

Height (m)	**k**	**c (m/s)**
12	2.2455	4.1844
18	2.3300	4.6270
45	2.5465	5.8077

55	5.5994	6.1040
60	2.6231	6.2372
75	2.6857	6.5921

The selected wind turbines can have different hubs heights. We decided to study and extrapolate vertical wind speeds at heights of 12, 18, 45, 55, 60 and 75 meters. The corresponding Weibull parameters are on the table 4.

4. PRODUCED ENERGY

4.1. Average power density

The power density per unit time contained in a mass of wind passing through a section of 1 m² is:

$$P_w = \frac{1}{2}\rho v^3 \tag{8}$$

The average value of the density can be expressed using the Weibull parameters:

$$\overline{P_w} = \frac{\rho \bar{v}^3 \Gamma\left(1+\frac{3}{k}\right)}{2\left[\Gamma\left(1+\frac{1}{k}\right)\right]^3} \tag{9}$$

ρ is the air density and Γ is the gamma function.

We can see in table 5 the annual average power densities for different heights.

Table 5. Annual average power densities for different heights

Height (m)	**Average power density (kW/m^2)**
10	46.0357
12	52.0363
18	68.4000
45	127.5170
55	146.2959
60	155.2860
75	181.0151

4.2. Produced electrical power

In literature many models for calculating the electrical power produced by a wind turbine are used. Studies have shown that no model is really suitable for all types of wind turbines [8]. However, in our work, we have chosen the following model that gives good results [12]:

$$P_e(v) = \begin{cases} 0 \; si \; v \leq v_c \; ou \; v > v_f \\ P_r \frac{v^k - v_c^k}{v_r^k - v_c^k} \; si \; v_c < v \leq v_r \\ P_r \; si \; v_r < v \leq v_f \end{cases} \qquad (10)$$

With:

v_c: Cut-in wind speed.
v_r: Rated wind speed.
v_f: Cut-off wind speed.
p_r: Rated power.

Table 6. Technical data of selected wind turbines

Wind turbine	LKX10	E44	E53
h(m)	12 → 18	45, 55, 65	60, 73 , 75
v_c (m/s)	2.5	3	2
v_r (m/s)	9.5	17	13
v_f (m/s)	50	34	34
P_r (W)	10000	910000	800000

Using the data provided by the manufactures of the wind turbines (table 6); we calculated the total electrical energy E (megawatts) that can be provided by every type of wind turbine for different hub heights, and throughout the year.

Table 7. Electricity production

Model	Produced electricity (MW)					
	12 m	18 m	45 m	55 m	60 m	75 m
LKX10	10	13	/	/	/	/
E44	/	/	431	477	498	/
E53	/	/	/	/	984	1096

We can clearly show from the results in table 6 that the total annual production of electrical energy increases with the increase in hub height (strongest wind speeds).

5. CONCLUSION

In our work, we presented a contribution to the assessment of wind energy potential of the region of Oran, Algeria. We conducted a statistical study of wind speeds that characterize the municipality of "Es Senia" and that for a whole year to assess the wind energy field, and then we calculated the total power that can be produced at different heights through three types of wind turbines.

The analysis clearly shows that the use of wind speeds at ten meters above the ground (typical height for measurements) does not produce high power. Increasing the height of hubs improves energy production.

Big wind turbines can produce large amounts of energy, and this mainly due to the possibility of increasing the height of their hubs to take advantage of higher wind speeds. The use of a single E35 wind turbine over 70 meters in height can produce annually more than one giga watts of electricity, which is an important amount of energy that can be directly used to power autonomous charges, or in the case of a wind farm, inject it into the general electricity distribution network and ensure sustainable development and limiting the use of fossil fuels.

REFERENCES

[1] Y. Jannot, "Thermique Solaire", 2003.
[2] SONELGAZ Group, NOOR, n°10, July 2010.
[3] CDER, "L'énergie éolienne en Algérie: un bref aperçu", [online], http://ww.cder.dz/vlib/bulletin/pdf/bulletin_021_10.pdf (Accessed: 20 March 2014).
[4] "Oran se met au vert", [online], http://www.cder.dz/spip.php?article3551 (Accessed: 24 March 2014)
[5] Wikipedia, [online], http://www.wikipedia.org (Accessed: 20 April).
[6] NCDC, National Climatic Data Center, [online] http://www.ncdc.noaa.gov (Accessed: 13 January 2014).
[7] P.A.Costa Rocha, R.C. de Sousa, C.F. de Andrade, M.E.V. da Silva, "Comparison of seven numerical methods for determining Weibull parameters for wind energy generation in the northest region of Brazil", Applied Energy, vol 89, pp. 395-400, 2012
[8] S. Diaf, D. Diaf, "evaluation du potential éolien et estimation de la production d'une ferme éolienne dans la region d'Adrar", International Seminar on Climatic and Energy Engineering, Algeria, 2010
[9] M. Boudia, "Optimisation de l'évaluation temporelle du gisement énergétique éolien par simulation numérique et contribution à la réactualisation de l'Atlas des vents en Algérie," Doctoral thesis, University of Tlemcen, Algeria, 2013
[10] Datasheet of LKX10, [online], http://www.lkcb.fr/eolienne-2-2 (Accessed: 20 January 2014).
[11] ENERCO Wind energy converters, Product overview, [online], http://www.enercon.de/p/downloads/ENERCON_PU_en.pdf (Accessed: 20 January 2014).
[12] M. Bencherif, "Modélisation de systèmes énergétiques photovoltaiques et éoliens, intégration dans un système hybride basse tension," Doctoral thesis, University of Tlemcen, Algeria, 2010.