

Assessment of wind energy resource in southern Algeria

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(reçu le 18 Avril 2007 - accepté le 25 Septembre 2007)

Abstract - Wind has been proven as a cost effective and reliable energy source. Technological advancements over the last years have placed wind energy in a firm position to compete with conventional power generation technologies. Algeria has a vast uninhabited land area where the south (desert) represents the greatest part with considerable wind regime. In this paper, an analysis of wind energy utilization as a viable energy substitute in six selected sites widely distributed all over the south of Algeria is presented. In this presentation, wind speed frequency distributions data obtained from the Algerian Meteorological Office are used to calculate the average wind speed and the available wind power. The annual energy produced by the Fuhrlander FL 30 wind machine is obtained using two methods. The analysis shows that in the southern Algeria, at 10 m height, the available wind power was found to vary between 160 and 280 W/m², except for Tamanrasset. The highest potential wind power was found at Adrar, with 88 % of the time the wind speed is above 3 m/s. Besides, it is found that the annual wind energy generated by that machine lie between 33 and 61 MWh, except for Tamanrasset, with only 17 MWh. Since the wind turbines are usually installed at a height greater than 10 m, an increased output of wind energy can be expected. However, the wind resource appears to be suitable for power production on the south and it could provide a viable substitute to diesel oil for irrigation pumps and electricity generation.

Résumé - La filière énergie éolienne est aujourd'hui une filière fiable et rentable. Les progrès technologiques au cours des dernières années ont placé l'énergie éolienne dans une position forte stimulante pour concurrencer les sources d'énergies classiques. L'Algérie a une vaste superficie inhabitable où le sud (désert) représente la plus grande partie avec un régime considérable de vent. Dans cet article, une analyse d'utilisation d'énergie éolienne, comme source d'énergie de remplacement dans six sites choisis, est présentée. Ces sites sont largement distribués dans le sud de l'Algérie. Dans cette présentation, des données de distributions de fréquence de vitesse de vent obtenues à partir de l'Office National de la Météorologie sont utilisées pour déterminer la vitesse moyenne du vent, la puissance et le potentiel de vent disponible. L'énergie annuelle produite par l'éolienne Fuhrlander FL 30 est obtenue en utilisant deux méthodes. Au sud algérien, l'analyse montre, à une altitude de 10 m, que le potentiel éolien disponible varie entre 160 et 280 W/m² à l'exception de Tamanrasset. Le maximum est obtenu à Adrar, avec 88 % du temps où la vitesse de vent est au-dessus de 3 m/s. Cependant, l'énergie éolienne annuelle produite par ce type de machine peut varier entre 33 et 61 MWh, à l'exception de Tamanrasset, avec seulement 17 MWh. Comme les éoliennes sont habituellement installées à une altitude de plus de 10 m, une augmentation considérable de la production d'énergie éolienne pourrait être atteinte avec la même éolienne. En conclusion, la ressource de vent semble convenir à la production d'énergie sur le sud et elle pourrait présenter une source d'énergie viable pour remplacer les groupes diesel utilisés pour les pompes d'irrigation et pour la production d'électricité.

Keywords: Wind data - Wind energy - Wind power density - Wind resources assessment - Weibull distribution.

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1. INTRODUCTION

The population of Algeria is about 32 millions with an area of 2.381.741 km². More than eighty per cent of the country is desert. The installed power capacity of the country is about 7000 MW which is enough to meet the total power requirements. At present about 90 % of this power is met by gas and water vapour power and the rest is generated from hydro and diesel centrals.

Since Algeria is enriched with a high insolation level and ample wind regime, a considerable fraction of its energy requirements may be tapped from wind and solar energy. The use of the alternative sources of energy reduces combustion of fossil fuels and the consequent CO₂ emission which represents, without doubt, the principal cause of the greenhouse-effect/global warming [1].

The south of Algeria, characterized by the desert nature, presents a very low population density. Less than thirty per cent of the population lives in this part of the country. In addition, in large areas of the southern Algeria there is no existence of main grid line and the extension of the conventional utility grid to the remotely located community is uneconomical. Fuelling of engines in remote areas is difficult and costly.

Instead, there are free and inexhaustible energy resources that can provide significant quantities of energy to support a country's needs. In this situation, solar or wind power plants are suitable to fulfil durably the primary energy needs, which is an appropriate solution for the basic welfare.

In Algeria, Wind energy utilization knew a considerable delay due to two main reasons. Firstly, fossil energy is available in the country. Secondly, a large proportion of electricity is generated by gas and water vapour turbines. Some attempts have been made to analyse the potential in Algeria [2-6].

This study presents as part of the research program on solar and wind energy undertaken by the development centre of renewable energy. Our primary goals in this endeavour are:

- Analysis of the wind data in the southern part of the country
- Assessment of the wind energy potential that can be exploited to meet the southern Algeria energy demand and
- Localization of the sites favourable to the use of wind energy
- Use of large wind turbines to meet these region.

Table 1: Geographical data for the selected stations

Station	Latitude (deg)	Longitude (deg)	Altitude (m)	Data collection period
Adrar	27.88 N	0.28 W	263	1977 - 1988
Béchar	31.62 N	2.22 W	811	1976 - 1988
Ghardaïa	32.38 N	3.67 E	468	1978 - 1987
In Aménas	28.05 N	9.50 E	561	1977 - 1988
Tamarasset	22.78 N	5.52 E	1377	1976 - 1988
Tindouf	27.67 N	8.17 W	401	1976 - 1984

Source: Algerian Meteorology National Office (ONM)

2. PREVIOUS STUDIES ON WIND ENERGY IN ALGERIA

Until the middle of the Eighties, only measurements of the parameters of the wind available in Algeria were reported in the meteorological bulletin of the meteorological Algerian office which gives the mean wind speed and frequency for different meteorological stations [2].

Many studies related to wind power resources in Algeria have been conducted in the past. In [3] a wind speed classification, according to the topography of the country and using the data reported in the meteorological bulletin, is proposed. In 1988, the author published the mean wind

and frequency wind of 22 stations, as well as the parameters of Weibull for two sites Algiers and Oran.

In [4], the author published the Algerian Wind Atlas containing the wind results statistics of 37 meteorological stations for the period spanned between 1976 -1988.

That while using the Wind Atlas Analysis and application Program (WA³P) used as part of the European wind atlas conception.

The wind mapping has been undertaken by several authors [5-7]. In parallel, the Aiolos model was used for the establishment of charts relating to the microclimates of the broken areas in Algeria. Additionally, the author in [7] presented a contribution to the determination of the vertical profile of the wind speed in Algeria. However, a few attempts have been made to analyse the wind potential in some regions of Algeria. Among these, the author, in [8], has analysed the wind resource in the eastern part of Algeria.

3. ANALYSIS OF WIND REGIMES

The locations of the meteorological stations selected for the detailed presentation of results in this article are shown in Fig. 1. **Table 1** shows the geographical location and the period for which wind data were available for each station.

Wind data for six meteorological stations in the southern part of Algeria were obtained from the Algerian Meteorological National Office. The data were collected over a period spanned between 1976 - 1988 with different collection periods for each site [4].

At all stations the measurements were obtained at a height of 10 m a.g.l (above ground level).

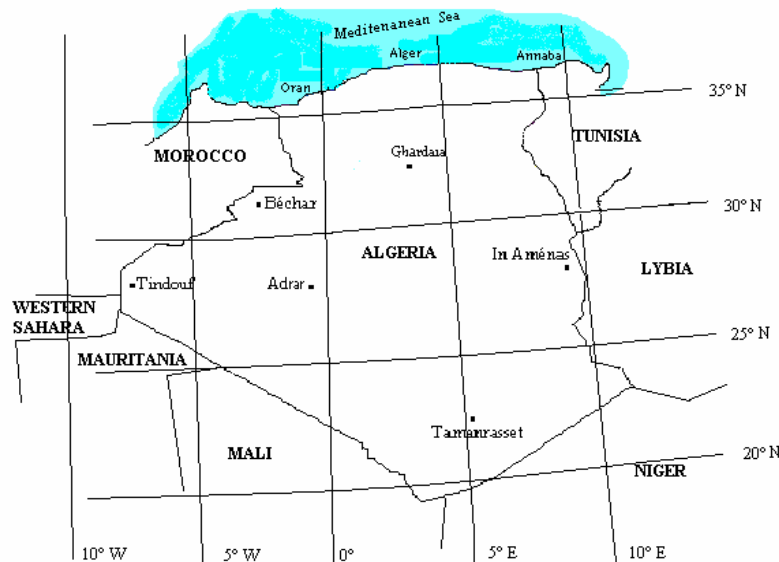


Fig. 1: Map of Algeria showing the location of the stations utilized in this study

3.1 Wind speed frequency distribution

Since the energy is proportional to the cube of wind speed, wind speeds above the annual mean will have a disproportionate amount of the wind energy. As a result, two sites with identical mean wind speeds that have differing wind speed distributions could have quite different levels of wind energy resources. Then, the frequency distribution of wind speed is essential in estimating the wind power potential at a candidate site. Furthermore, the frequency of occurrence of various

wind speeds must be known to determine how well the operating range of a particular wind turbine under consideration matches the wind speed distribution.

The data used for this study consisted mainly of wind speed frequency distribution derived from the wind data, published by the Algerian Meteorological National Office, collected over a period spanned between 1976 - 1988 with different collection periods for each site [4]. In **Table 2**, the wind speed frequency distributions for all the sites used in this paper are given in per cent.

A part from the frequency distribution of the wind speeds over a year given in **Table 2**, it is important to know the number of hours per year during which the wind remained in a certain wind speed interval. This is calculated by using the following formula:

$$T_i = \frac{f_i T}{100} \quad (1)$$

Where T_i is the number of hours corresponding to the i^{th} speed interval; f_i is the percentage frequency distribution of the wind speeds in the i^{th} interval and T is the total number of hours ($T = 8760$ h for a whole year).

The duration distribution, as shown in **Table 3**, will be used to calculate the energy output of a wind turbine by multiplying the duration of the wind speed in hours of each interval with the power output that the wind turbine supplies at that wind speed interval. The average wind speed of a given frequency distribution is calculated as follows [9]:

$$\bar{V} = \frac{\sum_i (T_i \cdot V_i)}{T} \quad (2)$$

where \bar{V} is the average wind speed (m/s); V_i is the mid point wind speed for the i^{th} interval.

3.2 Mathematical representation of wind regime

The wind speed frequency may be represented by several different distribution functions. Hammouche [4] published the Algerian Wind Atlas containing the wind results statistics of 37 meteorological stations where the Weibull distribution was found to be satisfactory. However, the Weibull parameters for the frequency distribution at 10 m a.g.l are calculated. The resulting Weibull A (m/s) and k parameters for six stations selected in this study are listed in the **Table 4**.

4. WIND POWER ESTIMATES

The power that can be generated by a wind energy conversion system is directly proportional to the cube of the wind speed at the height of the wind turbine. This fact demands the importance of having accurate wind speed data when the wind energy resource and the wind turbine size are being evaluated and determined.

4.1 Available wind power (P_{av})

Available wind power, expressed in Watt per square meter (W/m^2), takes into account the frequency distribution of the wind speed and the dependence of wind power on air density and the cube of wind speed. Therefore, available wind power is generally considered a better indicator of the wind resource than wind speed. According to the wind speed, the available wind power is calculated as:

$$P_{av} = \frac{1}{2} \rho \sum_i (V_i^3 \times T_i) \quad (3)$$

where, ρ is the air density assumed equal to 1.225 kg/m^3 at $15 \text{ }^\circ\text{C}$ and standard atmospheric pressure at sea level.

Table 2: Wind speed distribution at different speeds interval at 10 m above the ground for the six sites

Wind speed frequency (%)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-11	11-13	13-15	15-17	>17
Site ↓														
Adrar	6.4	1.3	4.1	8.7	11.3	16.0	16.1	11.0	8.1	9.6	3.9	2.0	1.0	0.3
Béchar	32.2	3.1	6.7	12.1	10.0	9.0	7.6	5.1	4.1	5.4	2.3	1.4	0.6	0.4
Chardaia	23.1	2.4	7.6	11.7	11.3	12.1	9.1	7.0	4.9	6.1	2.5	1.3	0.5	0.3
In Aménas	17.7	2.8	8.1	13.2	13	12.6	10.9	7.6	5.3	5.9	1.8	0.7	0.3	0.1
Taman.	34.1	6.0	9.7	11.7	9.7	10.2	7.3	4.7	3.1	2.7	0.6	0.2	0	0
Tindouf	17.8	2.2	7.6	10.3	11.6	13.0	11.3	9.2	6.6	6.6	2.5	1.1	0.3	0.1

Table 3: Wind speed duration D (h) and power density P_{av} (W/m^2) calculated by equation (3) for the six various stations

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-11	11-13	13-15	15-17	>17	Total	
Adrar	D	561.8	114.1	359.9	63.6	991.9	1404.4	1413.2	965.5	711	842.6	342.3	175.6	87.8	26.3	8760
	P	0.05	0.027	0.393	2.29	6.318	16.335	27.132	28.476	30.544	58.923	41.381	33.614	25.088	9.848	280
Béchar	D	2820.7	271.6	586.9	1060	876	788.4	665.8	446.8	359.2	473	201.5	122.6	52.6	35	8760
	P	0.025	0.064	0.641	3.178	5.581	9.171	12.784	13.178	15.422	33.075	24.343	23.53	15.053	13.13	169
Chardaia	D	2025.6	210.5	666.4	1025.9	990.9	1061	798	613.8	429.7	534.9	219.2	114	43.8	26.3	9760
	P	0.018	0.05	0.728	3.075	6.313	12.341	15.324	18.114	18.431	37.424	26.46	21.849	12.544	9.848	183
In Aménas	D	1550.5	245.3	709.6	1156.3	1138.8	1103.8	954.8	665.8	464.3	516.8	157.7	61.3	26.3	8.8	9760
	P	0.012	0.053	0.712	3.183	6.664	11.792	16.838	18.035	18.309	33.188	17.496	10.805	6.912	3.05	160
Taman.	D	2987.2	525.6	849.7	1024.9	849.7	893.5	639.5	411.7	271.6	236.5	52.6	17.5	0	0	8760
	P	0.026	0.124	0.928	3.073	5.414	10.394	12.279	12.145	11.661	16.538	6.35	3.361	0	0	82
Tindouf	D	1556.2	192.3	664.4	900.5	1014.1	1136.5	987.9	804.3	577	218.6	96.2	26.2	8.7	8.7	8760
	P	0.014	0.045	0.725	2.7	6.463	13.217	18.974	23.721	24.788	40.364	26.354	18.488	7.526	3.283	187

In terms of the Weibull parameters A and k , the available wind power density can be expressed as:

$$P_{av} = \frac{1}{2} \rho A^3 \Gamma \left(1 + \frac{3}{k} \right) \quad (4)$$

where Γ is gamma function, k is the shape parameter and A the scale parameter.

However, the extractable power depends on the efficiency of the wind energy conversion system (WECS). The maximum extractable power from a system working at its optimum efficiency is limited by the power coefficient C_p , for an ideal rotor $C_{p_{max}} = 0.59$, which makes the maximum extractable power about 59.3 % of the theoretical wind power and is given by :

$$P_e = \frac{1}{2} \rho C_p \sum_i (V_i^3 \times T_i) \quad (5)$$

$$\text{or} \quad P_e = \frac{1}{2} \rho C_p A^3 \Gamma \left(1 + \frac{3}{k} \right) \quad (6)$$

The estimation of the available wind power for the selected sites using the equations (3) and (4) are shown in tables 3 and 4 respectively.

Table 4: Average wind speed, Weibull distribution parameters and wind power density at 10 m height calculated by equation (4) for the various stations shown in Fig. 1

Station	V (m/s)	k	A (m/s)	Wind power density (W/m ²)
Adrar	6.34	2.15	7.2	283
Béchar	4.15	1.35	4.8	168
Ghardaia	4.69	1.65	5.6	183
In Aménas	4.77	1.86	5.6	155
Tamanrasset	3.37	1.46	4.0	83
Tindouf	5.06	1.98	6.1	187

5. POWER OUTPUT CURVES OF WIND TURBINE

The electric power output of a Wind turbine generator in the up state depends strongly on the wind regime as well as on the performance characteristics of the generator. When the wind speed is less than the cut-in wind speed, the turbine will not be able to produce power. When the wind speed exceeds the cut-in speed, the power output varies nonlinearly and increases with increasing wind speed to a maximum value, the rated power, until the rated speed; thereafter the output is almost constant. The power drops to zero for wind speeds higher than the cut-out speed.

In this context, several models have been used to describe the power output characteristic of wind turbines. The most simplified model with a linear output characteristic between cut-in and rated wind speed, [10], in other case studies, [11, 12] similar form model is also applied regarding the Weibull shape parameter k .

Additionally, there are other types of models to describe the power output of wind turbines. In this paper, the turbine power curve is approximated by a quadratic equation in the range between the cut-in and rated speeds, as follows [13]:

$$P(V) = \begin{cases} 0 & 0 \leq V \leq V_{in} \\ (A_1 + BV + CV^2) \cdot P_r & V_{in} < V \leq V_r \\ P_r & V_r < V \leq V_{out} \\ 0 & V > V_{out} \end{cases} \quad (7)$$

where P_r , V_{in} , V_r and V_{out} are the rated power output, the cut-in wind speed, the rated wind speed and the cut-out wind speed for the wind electric generator respectively.

The constants A_1 , B and C depend on V_{in} and V_r as expressed in equations:

$$A_1 = \frac{1}{(V_{in} - V_r)^2} \left(V_{in} (V_{in} + V_r) - 4 V_{in} V_r \left[\frac{V_{in} + V_r}{2 V_r} \right]^3 \right) \quad (8)$$

$$B = \frac{1}{(V_{in} - V_r)^2} \left(4 (V_{in} + V_r) \left[\frac{V_{in} + V_r}{2 V_r} \right]^3 - (3 V_{in} + V_r) \right) \quad (9)$$

$$C = \frac{1}{(V_{in} - V_r)^2} \left(2 - 4 \left[\frac{V_{in} + V_r}{2 V_r} \right]^3 \right) \quad (10)$$

6. WIND TURBINE ENERGY OUTPUT

Now that, we possess both the power output curves of windmills and the wind velocity distribution of the wind regime we can combine them to calculate the output energy of a wind turbine.

This section deals with methods to determine the energy output. Two methods are described here: a computational method and an estimation method.

6.1 Computational method

The computational method utilizes the velocity frequency distribution, and consists of multiplying the number of hours in each wind speed interval with the corresponding power output. The sum of all these products gives the energy output of the wind turbine at the specific site.

The energy output, expressed in (kWh), can be calculated using the following equation:

$$E = T P_r \left[\sum_{V=V_{in}}^{V=V_r} (A_1 + BV + CV^2) T_v + \sum_{V=V_r}^{V=V_{out}} T_v \right] \quad (11)$$

where, T is the total period of time (year, month, week etc.) (h); T_v the relative duration corresponding to the wind speed V $\left(T_v = \frac{T_i}{T} \right)$.

6.2 Estimation method

The estimation method is basically identical to the computational method, but utilizes mathematical approximations for the velocity frequency curve and for the output curve of the windmill.

The energy output of a wind electrical generator, with a power-wind speed curve $P(V)$ in a wind regime with a frequency distribution $f(V)$ in a time period T can be written as follows:

$$E = T \int_0^{\infty} P(V) f(V) dV \quad (12)$$

where, $P(V)$ is the power-wind speed curve given by the equation (7), it increases from 0 to P_r between V_{in} and V_r and equal to P_r between V_r and V_{out} . $f(V)$ is the frequency distribution

of the wind speed which is assumed as Weibull distribution whose the Weibull parameters at 10 m a.g.l. are calculated by Hammouche [4].

Thus, equation (12) changes into:

$$E = T \int_{V_{in}}^{V_r} P(V) f(V) dV + T P_r \int_{V_r}^{V_{out}} f(V) dV \quad (13)$$

With a quadratic power curve defined in equation (7), equation above takes the form:

$$E = T \int_{V_{in}}^{V_r} P_r (A_1 + BV + CV^2) f(V) dV + T P_r \int_{V_r}^{V_{out}} f(V) dV \quad (14)$$

This can be also written as:

$$E = \int_{V_{in}}^{V_r} T P_r (A_1 + BV + CV^2) f(V) dV + \int_{V_r}^{V_{out}} T P_r f(V) dV \quad (15)$$

The integral (15) can be solved numerically with Gauss' rule.

Graphically, the energy output can be given by the area under the curve obtained from the function defined as the product of power-wind speed $P(V)$, frequency distribution $f(V)$ and time period T . In this study, T is taken equal to 8760 h (one year).

7. RESULTS AND DISCUSSION

Table 2 gives a summary of wind speed frequency distributions in terms of percentages for six sites in the southern part of Algeria. This table shows that the location of Adrar has the maximum percentage of the wind speed above the 3.0 m/s cut-in wind speed, which contributes to the generation of electricity from wind, is about 88 % with about 7 % falling in the full power range (12 m/s to cut-out). At the sites of Béchar, Ghardaia, In Aménas and Tindouf, the wind speed is higher than 3 m/s for 58 %, 67 %, 71 % and 72 % of the time, respectively, and with about 3-5 % of the time the wind blows in the full power range. While at Tamanrasset about 50 % of the wind speed recorded was less than 3 m/s, with less than 1 % falling in the full power. This quite significant as it implies that wind machines at Tamanrasset would be at a standstill more times than they would be at the others sites.

The values of the Weibull parameters and the average wind speed at 10 m height during the considered periods are summarized in **Table 4**. As can be seen, the site of Adrar has the highest wind energy potential compared to the other sites with average wind speed of 6.34 m/s. The site of Tindouf ranks in the second position with a wind speed average of 5 m/s.

The analysis of Weibull parameters shows that the shape parameter k varies between 1.35 and 2.15 while the scale parameter A varies between 4.0 and 7.2, as shown in **Table 4**. It can be seen that the highest values of k and A are found in Adrar, located in the southwest part of the country. Whereas the lowest values of the two parameters were found in Tamanrasset.

In Figure 2, are shown histograms of the wind speed observations at selected sites over the collected periods (shown in **Table 1**) together with fitted Weibull frequency functions. As shown in Fig. 2, the Weibull distribution fits the observed distribution reasonably well in the relevant wind speed range, hence indicating that it describes the data adequately. Exception is made for the sites with high frequencies for smaller interval. The case of Tamanrasset and Béchar is noteworthy in this regard where over 30 % of the observations were between the 0 and 1 m/s range as shown in **Table 2**. This distribution shows that the higher average wind speeds generally correspond to higher values of k . Small values of k imply that the data tend to be distributed over a relatively wide range of wind speeds.

The analysis of the results indicates that there is potential for wind energy utilization in south of Algeria. **Table 3** shows the wind speed duration as well as the available wind power for the selected sites. The available wind power was calculated from equation (3) depending on the available wind data formats and compared with the one calculated by using equation (4), using the Weibull parameters A and k , given in **Table 4**. The agreement of the available wind power predicted by Weibull distribution with that calculated by the wind frequency distributions was found good as shown in **Tables 3** and **4**. Even though, the utilization of the adjusted Weibull parameters may be adequate for the evaluation of wind energy potential in the south of Algeria.

The results indicate that a potential of 280 W/m^2 , at 10 m a.g.l., is available for the site of Adrar representing the maximum value, while the lowest value is found at Tamanrasset site with a potential of 82 W/m^2 .

Additionally, the energy output of the wind turbine, using computational and estimation methods, has been calculated.

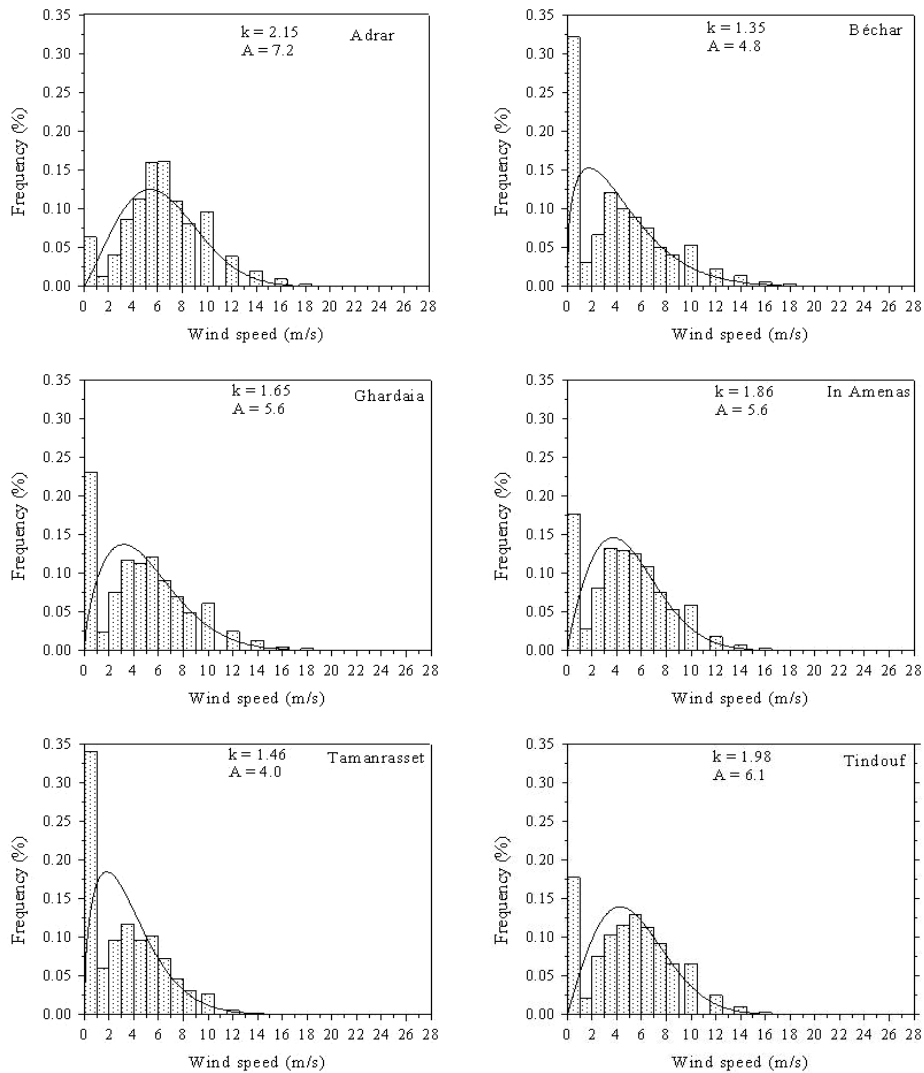


Fig. 2: Wind speed frequency with fitted Weibull distribution for different station

The results relating to the Adrar site are given as example and are shown in figures 3 and 4 for illustration purposes. Similar figures are obtained for the selected sites and are used for the determination of the total annual wind energy generated by the Fuhrlander FL30 wind machine. The technical data of the wind machine used are summarized in **Table 5**, [14].

As shown in Fig. 3, for the computational method, the total annual wind energy is given by the sum of all the products resulting from multiplying the number of hours in each wind speed interval with corresponding power output, while for the estimation method, the total annual wind energy output is given by the area under the curve (Fig. 4).

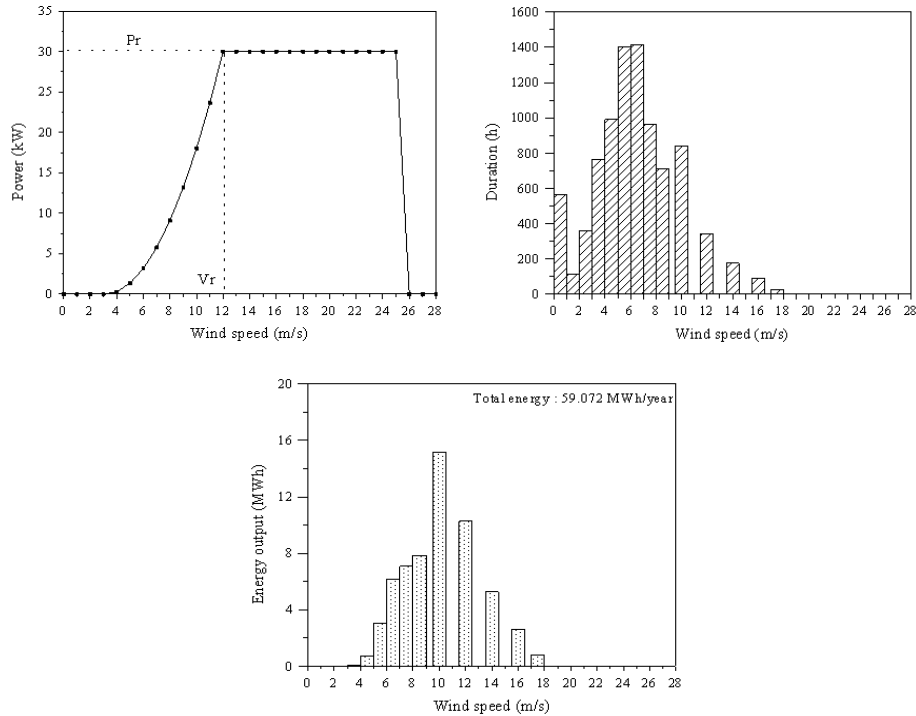
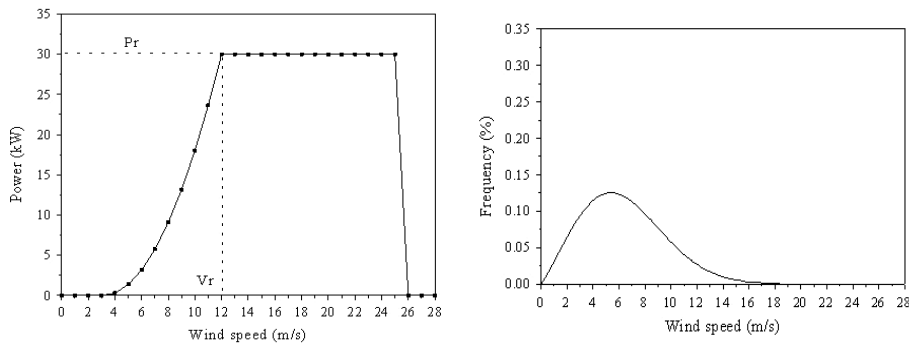


Fig. 3: Calculation of the energy generated by the wind turbine by using the computational method – Case for Adrar



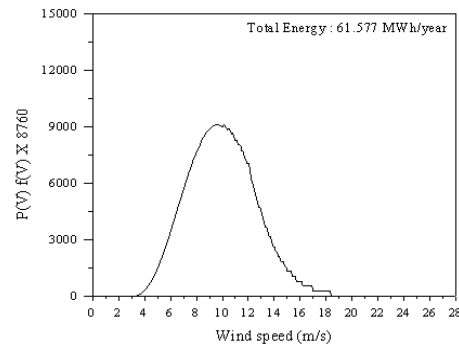


Fig. 4: Calculation of the energy generated by the wind turbine by using the estimation method – Case for Adrar

Figure 5 shows a comparison of total annual wind energy generated by the Fuhrlander FL30 wind machine for the selected sites, using the two methods described above.

Therefore, the maximum energy obtained from this type of wind machine is about 60 MWh/year for Adrar, region in the southern Algeria with high wind speed. Concerning Tindouf, Ghardaia, In Aménas and Béchar, the annual energy are about 41, 38, 34 and 33 MWh/year, respectively, while at Tamanrasset site, the Fuhrlander FL30 will only produce about 17 MWh/year.

The results indicate that there is no significant difference between the annual energy generated by the wind machine based on the computational method and that based on the estimation method.

Table 5: Technical data of wind machines from Fuhrlander FL 30

Cut-in speed (m/s)	3
Rated speed (m/s)	12
Cut-out speed (m/s)	25
Survival wind speed (m/s)	67
Rated output (kW)	30
Hub height (m)	27
Rotor diameter (m)	13

8. CONCLUSION

The use of wind potential as source of energy for the six locations in southern Algeria has been broadly assessed. The analysis shows that there are good prospects for wind energy utilization except for Tamanrasset. The southwest area located in the west of 0° longitude and between 25° N and 30° N latitudes is the windiest part of southern Algeria with an average wind speed exceeding 6 m/s for Adrar and 5 m/s for Tindouf at a height of 10 m.

The fit of the Weibull distribution to the data is shown to be a good approximation in a majority of cases. Consequently, the available wind power may be computed utilizing the Weibull parameters.

According to the wind speed frequency distributions and the Weibull parameters distribution, the available wind power at the height of 10 m were computed, and were found to be between 82

and 280 W/m^2 approximately with the highest value at Adrar site and the lowest at Tamanrasset, while the operating percentage of the wind turbine is also very high, around 70 % - 90 %, for the most sites, which means that the wind turbine can operate in most time of a year.

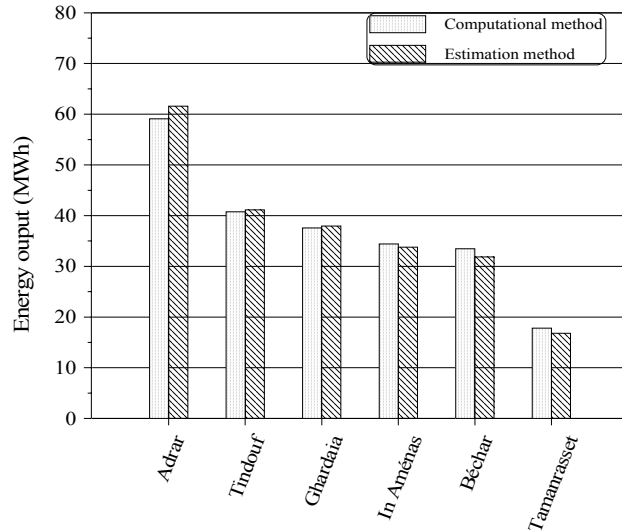


Fig. 5: The annual wind energy produced by the Fuhrlander FL30

The estimated energy that can be produced from Fuhrlander FL30 is about 60 MWh and 40 MWh at Adrar and Tindouf, respectively.

Although, Tamanrasset site has the lowest generated energy and wind blows less than 3 m/s for 50 % of the time (no energy production). In this case the size of storage tanks can be more than in others sites

In conclusion, the investigation showed that:

- The wind resource is good enough in southern Algeria, especially Adrar and Tindouf, to supply people with basic energy needs.
- On this ground, projects for wind-power utilization become feasible and desirable.
- The site of Tamanrasset can be considered as a region with low wind speed. This site may not be suited for electricity generation.
- No significant difference between the annual energy generated by the wind machine based on the computational method and that based on the estimation method.
- In these regions wind power could provide a viable substitute to diesel oil for irrigation pumps and electricity generation.

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