

# Temporal Assessment of Wind Energy Resource in Algerian Desert Sites: Calculation and Modelling of Wind Noise

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## Abstract

Our study focuses on the assessment of wind resources of three desert sites in Algeria (Adrar, Ain Salah and Tindouf). The data used in this study span a period of 10 years. The parameters considered are the speed and direction of wind. For this purpose, the most energetic and frequent speed as well as the Weibull parameters to plot the wind rose were evaluated. The desert sites are favourable for large ZDE (Zone of Wind Development), why it was decided to investigate the possibility to set up a wind farm of 10 MW consisting of twelve wind turbine type WGT850 kW. Next, its noise was calculated and then modelled. The results obtained from the three sites gave annual mean speeds around 5 m/s; the West store is dominant for Tindouf, the East- North-East (ENE) store for Ain Salah and the East store. Our simulation of the noise propagation for wind farms shows that noise level is estimated around 45 dB at a distance of 300 m from the nearest turbine and 42 dB at a distance of 400 m. We can conclude that these noise levels have no effect on health and comply with the Algerian standard.

**Keywords:** Weibull parameters; Wind rose; Wind power; Wind farm; Noise; Algeria

## Introduction

In Algeria, the objectives established by the joint-stock company NEAL (New Energy Algeria), focused on raising renewable energy production to 1400 MW in 2030 and 7500 MW at the beginning of 2050. Electrical power will be obtained from solar power plants, which are exclusively solar, or from hybrid solar plants, which also use other forms of renewable or conventional energy, preferably natural gas [1].

Harnessing the wind is one of the cleanest, most sustainable ways to generate electricity. Wind power produces no toxic emissions and none of the heat-trapping emissions that contribute to global warming. This, and the fact that wind power is one of the most abundant and increasingly cost-competitive energy resources, makes it a viable alternative to the fossil fuels that harm our health and threaten the environment. Wind energy is the fastest growing source of electricity in the world.

Many work indicated that Algeria was characterized by a competitive electricity generation cost per kW from Wind turbine; in particular, we can cite the Wind Potential Assessment of Three Coastal Sites in Algeria; Calculation and Modelling of Wind Turbine Noise using Matlab, the Wind Potential Assessment of Ain Salah in Algeria, Assessment of wind energy and energy cost in Algeria, Assessment of wind energy and energy cost in Algeria [2-4] and calculation of the Cost Energy the evaluation of electricity generation and energy cost of wind energy conversion systems in southern Algeria [5].

The energy available in the wind varies as the cube of wind speed, so an understating of the characteristics of the wind resource is critical to all aspects of wind energy exploitation, from the identification suitable sites to the prediction of the economic viability of wind farm project. The present study tries to determine various wind parameters and then focuses on the processing and simulation of their hourly data, collected during 10 years. Wind potential, its direction and frequency are assessed by plotting the wind rose, in order to select the appropriate site for future wind turbines. Finally, after the evaluation of wind power, the environmental impact of wind turbines was evaluated. For this purpose, the ISO 9613-2 calculation model is used in the case where octave data are available; otherwise some calculation formulas based on Matlab are developed.

## Site and Weather Data

In this study, the wind speed data were collected over a period of 10 years. The details of the sites are summarized in Table 1.

The meteorological measurements stations were made at 10 meters above ground level and registered every 3 hours. The geographical location of the metrological station is shown in Figure 1.

## Wind Potential

### Weibull distribution

The wind characteristics will determine the amount of energy that can be effectively extracted from the wind farm. In order to determine the properties of a site, measurements of the speed of wind and its direction are needed. This study was carried out over a period of ten years. However, previous studies in the field of wind energy showed that the most important and appropriate characteristic to exploit is the Weibull statistical distribution this is a probability function that can be expressed as [6-9]:

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

k and C are the shape parameter (dimensionless) and the scale parameter (m/s), respectively. Usually, the shape parameter characterizes the symmetry of the distribution. The scale parameter is very close to the average speed of wind. The standard deviation method was chosen to determine both factors k and C. This method is based on the calculation of the standard deviation and the average speed [6].

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Received March 11, 2015; Accepted March 31, 2015; Published April 07, 2015

**Citation:** Benmedjahedl M, Boudaoud L (2015) Temporal Assessment of Wind Energy Resource in Algerian Desert Sites: Calculation and Modelling of Wind Noise. J Fundam Renewable Energy Appl 5: 160. doi:10.4172/20904541.1000160

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If the wind distribution is desired at some height other than the measurement height, the Weibull parameters can be adjusted to any desired height by the model of Justus [7].

### Wind energy

The power of the wind that flows at a speed  $v$  through the blade sweep area  $S$  can be expressed by the following equations [6,8,9]:

$$P(v) = \frac{1}{2} \rho S v^3 \quad (2)$$

A wind turbine allows extracting the kinetic energy from the wind and converting it into and electric energy. The power curves of the wind turbines can be expressed by the following equations [9]:

$$P_e(v) = C_e P(v) \quad (3)$$

Where,  $C_e$  is the wind turbine efficiency. The efficiency of the wind turbines taken into consideration in this study are shown in Figure 2 and technical specifications of the selected wind turbines are listed in Table 2.

The histogram method is used to estimate the energy generated by a wind turbine. The superposition of the energy response curve (kW) and the frequency histogram give [8]:

$$E = \sum_{i=1}^n P_i(v_i) F_i(v_i) \times N \quad (4)$$

### Wind farm planning

To produce a large amount of energy, a wind farm must be installed as followed. We use WGT 850 kW wind turbine model.

When several turbines are installed in block, the turbulence due to rotation of the turbine blades can affect other turbines nearby. To minimize this effect, the spacing of about 3 to 4  $D_T$  (with  $D_T$  the

Location	Latitude	Longitude	Altitude
Adrar	27.88° N	0.28° W	263 m
Ain Salah	27.25° N	2.51° E	269 m
Tindouf	27.70° N	8.17° W	442 m

Table 1 : Geographical coordinates of the data collection stations used in the study.

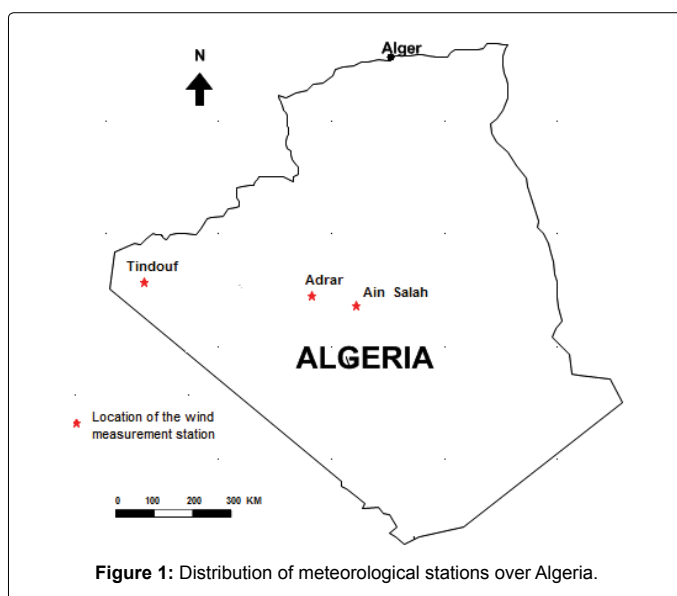


Figure 1: Distribution of meteorological stations over Algeria.

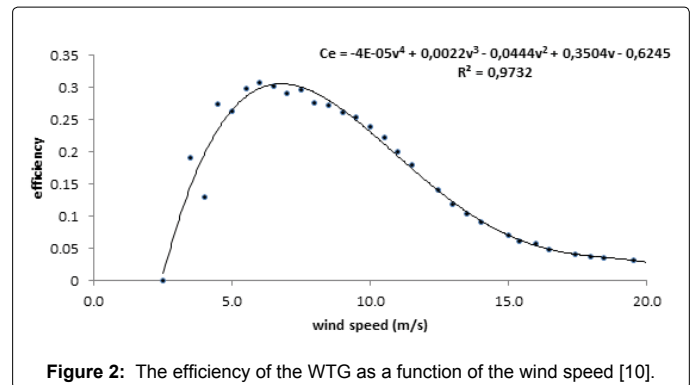


Figure 2: The efficiency of the WTG as a function of the wind speed [10].

Characteristics	WGT 850 kW
Rated power	850 kW
Rotor diameter	52 m
Hub height	55 m
Cut-in wind speed	4 m/s
Rated wind speed	16 m/s
Cut-out wind speed	28 m/s

Table 2: Technical specifications of the considered wind turbine [10].

diameter of the rotor) is provided inside the rows [6].

Similarly, the spacing between the rows may be of the order of 10  $D_T$ , so that the air stream passing through a turbine is restored before its interaction with the following turbine. This spacing can be further increased for better performance but this implies more land used. In general, the energy loss due to the effect of park is about 5%.

### Noise Level

Usually, in order to measure the wind turbine noise, the level of the weighted acoustic power is calculated as an average level at 500 Hz. The impact of noise is calculated according to the international standard ISO 9613-2 [2,10,11] as follows:

$$L_{AT}(DW) = L_{WA} + D_C - A - C_{met} \quad (5)$$

where  $L_{AW}$  is the level of weighted acoustic power of the noise source.  $D_c - D_{\Omega}$  is the Correction made in order to take into consideration the directivity of the source (without directivity= 0 dB) and the reflection on the ground  $D_{\Omega}$  which can be calculated as follows [2,11]:

$$D_{\Omega} = 10 \text{Log} \left( 1 + \frac{d_p^2 - (h_s - h_r)^2}{d_p^2 - (h_s + h_r)^2} \right) \quad (6)$$

$h_s$  is the height of source above the ground (hub height),  $h_r$  is height of point of noise impact (depending on the regulations but also adjustable when defining the calculation) and  $d_p$  is the distance between noise source and point of impact, projected on the ground (m). The distance is calculated from the coordinates (x, y) of the source (index S) to the point of impact (index r) [2,11]:

$$d_p = \sqrt{(x_s - x_r)^2 + (y_s - y_r)^2} \quad (7)$$

A is the attenuation during noise propagation between the source (the wind turbine nacelle) and the point of impact. The total attenuation is given by [2,11]:

$$A = A_{div} + A_{atm} + A_{sol} \quad (8)$$

$A_{div}$  is the attenuation due to spatial propagation [2,11]:

$$A_{div} = 10 \text{Log}(d) + 11 \quad (9)$$

$d$  is the distance between source and point of impact (m) [2,11]:

$A_{atm}$  is the attenuation due to atmospheric absorption [2,11]:

$$A_{atm} = \frac{\alpha d}{1000} \quad (10)$$

$\alpha_{500}$  is the absorption coefficient of air.

$A_{gr}$  is the attenuation of ground [2,11]:

$$A_{gr} = 4,8 - \left[ \left( \frac{2h_m}{d_p} \right) \left( 17 + \frac{300}{d_p} \right) \right] \geq 0 \quad (11)$$

$h_m$  is the average height (m) of noise path above the ground. If no digital model of ground is found, then the average height can be calculated as follows:

$$h_m = \frac{(h_s + h_r)}{2} \quad (12)$$

$C_{met}$  is the weather correction. This is done as follows

$$\begin{cases} c_{met} = 0 & \text{if } d_p < 10(h_s + h_r) \\ c_{met} = c_0 \left[ 1 - \frac{10(h_s + h_r)}{d_p} \right] & \text{if } d_p > 10(h_s + h_r) \end{cases} \quad (13)$$

$C_0$  is a factor, in decibels, which depends on local meteorological statistics for wind speed and direction, and temperature gradients.

## Results and Interpretations

From the measured data for ten years, in the three weather stations (Adrar, Ain Salah and Tindouf) at a height of 10 m from the ground, the Weibull parameters could be calculated for the three sites (Table 2).

The annual shape parameter value range from 2.06 (Adrar) to 3.26 (Ain Salah), which means that winds are stable for all sites and the analysis of the annual scale parameter  $C$  shows that Adrar is the windiest site (7.4 m/s). Statistical data analysis allowed determining the wind rose which is the graphical representation of wind frequency as a function of direction in a polar reference. It is determined for ten years. The results obtained Figure 3 show that:

For Adrar the prevailing wind direction is East (E) with 15% and the predominant directions is East-North-East (ENE) with 14%. The prevailing Wind direction for Ain Salah is the East -North- East t (ENE) with 30% and predominant directions is East (E) with 14% and for Tindouf, the West (W) sector represents 30% of wind frequencies and the North western (NW) sector are predominant sectors with a percentage of around 25% (Figure 4).

Our choice fell on one rows of turbines, has twelve wind turbines. The distance between them 208 m, the wind turbines will be oriented from North to South for Adrar, West-North-west to East-South-East for Ain Salah and North to South for Tindouf. We estimated the power density and the energy produced by wind turbine WGT 8500 kW (Tables 3 and 4).

The power density of wind turbine WGT 850 kW varies from 84.21  $W/m^2$  (Tindouf) to 234.35  $W/m^2$  (Adrar), which means that Adrar has more important power density than Ain Salah and Tindouf. The annual energy we can produce for wind frame in Adrar, Ain Salah and Tindouf account respectively 49.70 GWh, 20.38 GWh, 17.86 GWh.

The noise emitted by a wind turbine constitutes the main impact on environment. Noise can be produced by any obstacle placed on an air flow trajectory. The tone of this noise depends on the shape and

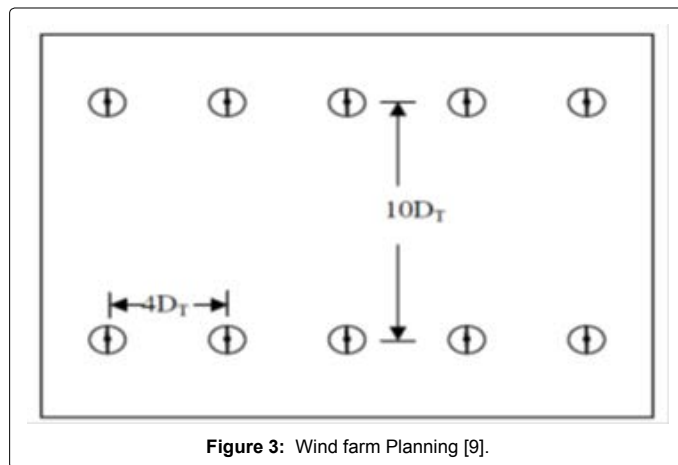


Figure 3: Wind farm Planning [9].

Location	C (m/s)	k	v (m/s)
Adrar	7.4	2.06	6.5
Ain Salah	6.0	2.48	5.4
Tindouf	5.9	2.27	5.2

Table 3: Annual mean wind speed and Weibull parameters at 10 m from the ground level.

Location	Power density ( $W/m^2$ )	Energy (MWh)	
		Wind turbine	Wind farm
Adrar	234.35	4.36	49.70
Ain Salah	96.11	1.79	20.38
Tindouf	84.21	1.57	17.86

Table 4: The power density and the energy produced.

dimensions of the obstacle as well as on the air flow speed, in addition to the mechanical noise from the operation of all components present in the enclosure. The main noise generating components are: the multiplier (except for some recent models), shafts, the generator, and auxiliary equipment (hydraulic systems, cooling units).

The estimation of wind turbine Noise of the WGT850, to be operated at the considered sites has been done under the following assumptions [2]:

- The level of weighted acoustic power of the noise source was considered to be 103 dB  $\pm$  1 dB/(m/s) at wind speed 8 m/s.
- The absorption coefficient of air ( $\alpha_{500}$ ) was taken as 1.9 dB/km.
- The attenuation due to a barrier and the attenuation due to miscellaneous other effects was considered Negligible.

The WGT 850 kW wind turbine was chosen considering its low noise power. We used Matlab software to calculate the noise generated by the wind turbine under the conditions that can be met by our three sites (flat ground). For stated sites, the results of our simulation of the propagation of noise by wind farm in Adrar, Ain Salah and Tindouf is summarized in Table 5. The noise power given by the manufacturer is 103 dB for each wind turbine WGT 850 kW. According to our calculations, using the method (ISO 9613-2), the noise level is about 45 dB (A) at 350 m from the nearest turbine and at a distance of 400 m, the noise level will be about 42 dB for all wind farm.

The noise level of a wind turbine is 42 dB (A), which corresponds to the noise inside quiet house. Hence, these noise levels have no effect on health and are consistent with the national standard (Executive Decree No. 93-184 of July 27, 1993, regulating noise emission).

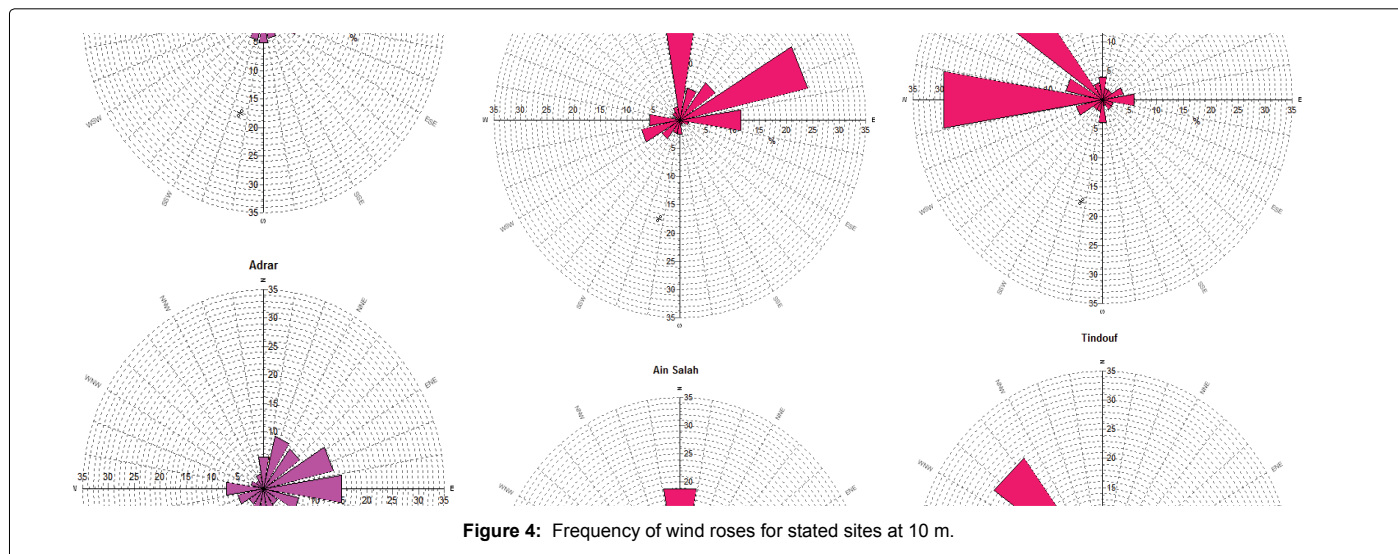


Figure 4: Frequency of wind roses for stated sites at 10 m.

dp(m)	Noise (dB)		
	Adrar	Ain Salah	Tindouf
200	49.46	49.33	49.30
250	46.89	46.76	46.73
300	44.93	44.80	44.77
350	43.37	43.24	43.21
400	42.03	41.90	41.87

dp(m)	Noise (dB)		
	Adrar	Ain Salah	Tindouf
200	49.46	49.33	49.30
250	46.89	46.76	46.73
300	44.93	44.80	44.77
350	43.37	43.24	43.21
400	42.03	41.90	41.87

Table 5: Level noise.

Disturbance from wind turbine noise during operation is low given the animal adaptability and the intermittent nature of noise emitted by wind.

## Conclusion

This study focused on the evaluation of wind potential of three Desert sites in Algeria (Adrar, Ain Salah and Tindouf), in order to use wind 850 kW turbines, based on wind speed measurements recorded during a ten year period. Wind resource analysis in the selected sites shows that South area in Algeria has a wind energy potential that can be effectively exploited. Indeed, statistical treatment of data allowed evaluating the characteristic speeds and wind potential for each site. The results obtained show that:

- The annual shape parameter value range from 2.06 (Adrar) to 3.26 (Ain Salah), which means that winds are stable for all sites.
- The analysis of the annual scale parameter C shows that Adrar is the windiest site (7.4 m/s).
- The West store is dominant for Tindouf, the East- North-East (ENE) store for Ain Salah and the East store.
- The power density of wind turbine WGT 850 kW varies from 84.21 W/m<sup>2</sup> (Tindouf) to 234.35 W/m<sup>2</sup> (Adrar).

- The annual energy we can produce for wind frame in Adrar, Ain Salah and Tindouf account respectively 49.70 GWh, 20.38 GWh, 17.86 GWh.
- The noise level is about 45 dB (A) at 350 m from the nearest turbine and at a distance of 400 m, the noise level will be about 42 dB for all wind farm, these noise levels have no effect on health and are consistent with the national standard (Executive Decree No. 93-184 of July 27, 1993, regulating noise emission).

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