



# Temporal wind energy resource assessment at Ghardaia region

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**Abstract**—The aim of this paper is to investigate the monthly and seasonal variation of the wind resource in term of wind energy potential using the wind speed data collected in the last decade for the meteorological station at Ghardaia region situated in the beginning of Algerian Sahara. After the study of temporal Weibull parameters, we proceeded to the vertical extrapolation of Weibull parameters and mean wind speed at a height of 50m. The results show that Ghardaia has a middle wind potential with the annual mean wind speed  $V = 3.57\text{m/s}$  while the annual wind power density is equal to  $62.8\text{w/m}^2$ , where the better seasonal and monthly wind energy potential is given in Spring and April respectively.

**Keywords**—Wind resource, Weibull parameters, Algeria, Ghardaia, assessment.

## I. INTRODUCTION

Generating electricity in North Africa using renewable energy resource has been around for some time now but has recently gained momentum through several plans as Desertec Industrial Initiative, where an export bundled with wind energy is the most feasible option for North African concentrated solar power [1]. Since North African's countries have high levels of direct solar radiation, the aim of these plans is to create new power production capacity bases on renewable energies, especially by solar and wind on the Mediterranean basin [2] even if it is compellingly and apparently economically sensible to harness the resource most at the place it is most readily available [3].

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[4]; recently, BoudgheneStombouli has concluded that there is a considerable potential in Algeria for the utilization of renewable energy sources [5] especially with respect to solar and wind power that produce fewer greenhouse gas emissions [6].

The wind is generated due to the pressure gradient resulting from the uneven heating of earth's surface by the sun. As the very driving force causing this movement is derived from the sun, wind energy is basically an indirect form of solar energy; this means that the wind is driven by the temperature difference [7]. Adaramola et al. concluded their study on the importance to thoroughly carry out intensive and detailed measurements of temperature with direction and wind speed on the targeted site over a defined period and the nature of the topology of the site have to be studied [8]. Soler-Bientz et al. gives the significance of study of the offshore wind and temperature profiles [9]. Recently Lima et al. made an analysis with several meteorological parameters, where air temperature at two levels, 25 and 50m were studied to make wind resource evaluation at Paraiba region in Brazil, concluding that air average temperature has a strong impact on air density value [10].

Concerning Algeria, even if we note with satisfaction the contribution in the actualization of wind map of Algeria adding the study of HassiR'mel in the South of the country at the wind atlas by Chellali et al. [11], few studies have been conducted to assess wind resource and the majority of them were focused at the Sahara in South of Algeria[12-17], result to the good wind resource concluded from wind map by Kasbadji[18,19] and Chellali et al. [11] respectively in Adrar and HassiR'Mel, two regions in Algerian Sahara.

Wind speed is the most important aspect of the wind resource; in fact, AynuarUcar et al. shown that the yearly and seasonal variation of long term mean wind speed provides an understanding of the long term pattern of wind speed and also gives confidence to an investor on the availability of wind power in coming years [20].



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In this study, we choose to contribute on temporal wind assessment at the location of Ghardaïa in the beginning of Algerian Sahara, and try to confirm the correlation between air temperature and wind speed or one of Weibull parameters in this region, knowing that altitude and temperature variations across the country contribute to the amount of wind. For optimal use of wind energy, it is necessary to know the wind speed at heights upward the ground. Since wind speed increases with height, wind energy is usually captured at heights above the height of wind measurements by the National Meteorological Office, which is 10m. As well, the objective of this work is to estimate average wind speed (annual, seasonal and monthly) at anemometer height by numerical simulation and estimating the average wind power density at 50m height.

At first we investigate the wind characteristics, using the wind speed data collected in last decade, a study of the temporal variation of Weibull parameters ( $k$  and  $A$ ) and the mean wind speed was made for whole years, the four seasons and the twelve months year. In the second time vertical extrapolation of wind speed has been made by an empirical model. At the end, the monthly and seasonal distribution of Weibull parameters during the studied time period was made to give an eventual correlation between air temperature and wind speed and its Weibull parameters.

## II. SITES SELECTION AND WEATHER DATA

In this paper, data from the station situated at Ghardaïa region have been analyzed. The geographical coordinates of this meteorological station and the years of measurements are given in Table I.

TABLE I. GEOGRAPHICAL COORDINATES OF THE DATA  
COLLECTION STATION USED IN THE STUDY

Location	Longitude	Latitude	Altitude (m)	Duration (years)	Measurement years
Ghardaïa	32.40	3.81	450	10	01/01/2001 31/12/2010

## III. WIND ANALYSIS MODEL

The Weibull function is used to characterize the frequency distribution of wind speeds over time [21]. It is defined by the following equation:

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

Where  $f(v)$  is the probability of observing wind speed  $v$ ,  $k$  is the dimensionless Weibull shape parameter, and  $A$  is the Weibull scale parameter.

The average wind speed can be calculated on the basis of the Weibull parameters as given below [22,23]:

$$\bar{v} = A \Gamma\left(1 + \frac{1}{k}\right) \quad (2)$$

Where  $\bar{v}$  is the average wind speed, and  $\Gamma$  is the Gamma function.

### A. Wind power density

The power of the wind that flows at speed  $v$  through a blade sweep area  $A$  [m<sup>2</sup>] as the cubic of its velocity and is given by [24]:

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

Where,  $\rho$  [kg/m<sup>3</sup>] is the air density.

The power available in wind can be calculated as follows:

$$P = \frac{1}{2} \rho v^3 A \Gamma \quad (4)$$

### B. Vertical extrapolation of mean wind speed

There exist several mathematical models developed for the purpose of describing vertical profile of the wind speed. According to the literature and responds to the study region, the relation proposed to assess the mean wind speed  $\bar{v}$  at hub height  $Z$  given by the model Power law, resumed by Nfaouiet al.[25] expressed by:

$$\bar{v} = \bar{v}_0 \left(\frac{Z}{Z_0}\right)^{\alpha} \quad (5)$$

Where the power law exponent  $\alpha$  is a variable coefficient, according to the roughness:

$$\alpha = \frac{1}{k} \quad (6)$$

Where  $\alpha$  depending the roughness  $Z_0$  and is equal to:

$$\begin{aligned} \alpha &= 0,25 \text{ for } 0 < Z_0 \leq 0,005 \text{ m} \\ \alpha &= 0,31 \text{ for } 0,005 < Z_0 \leq 0,05 \text{ m} \\ \alpha &= 0,37 \text{ for } 0,05 < Z_0 \leq 0,5 \text{ m} \\ \alpha &= 0,48 \text{ for } 0,5 < Z_0 \leq 4 \text{ m} \end{aligned}$$



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**IV. RESULTS AND DISCUSSION**

The wind speed data at Ghardaia region have been analyzed taking into account the monthly and seasonal variations.

The monthly variation of the mean wind speed and the mean power density at 10 and 50m above the ground level are listed in Table II.

**TABLE II. MONTHLY VARIATIONS OF MEAN WIND SPEED AND POWER DENSITY AT THE STUDIED SITE**

Elevation	10		50	
	V[m/s]	P[w/m <sup>2</sup> ]	V[m/s]	P[w/m <sup>2</sup> ]
January	3,44	79,30	4,60	150,14
February	3,48	62,55	4,69	127,19
March	3,90	110,02	5,13	200,31
April	4,50	109,07	5,88	211,28
May	4,35	86,75	5,73	176,75
June	3,81	55,51	5,13	121,33
July	3,33	39,60	4,55	89,92
August	3,19	33,57	4,40	78,51
September	3,30	40,18	4,51	90,48
October	2,92	36,76	4,03	80,67
November	3,10	50,30	4,23	103,62
December	3,55	67,03	4,77	134,86

It can be observed that the monthly mean wind speed at 10m varies between 2.92m/s in October and a maximum value of 4.50m/s in April, while at the eventual hub height (50m) the monthly wind speed varies between 4.03 and 5.88m/s. Furthermore, at 10m, the mean power density varies between 33.57w/m<sup>2</sup> in August and 109.07w/m<sup>2</sup> in April.

**TABLE III. SEASONAL VARIATIONS OF MEAN WIND SPEED AND POWER DENSITY AT THE FOUR STATIONS**

Elevation	10m		50m	
	V[m/s]	P[w/m <sup>2</sup> ]	V[m/s]	P[w/m <sup>2</sup> ]
Autumn	3,16	47,20	4,31	99,72
Winter	3,61	81,05	4,81	155,57
Spring	4,25	89,04	5,61	178,31
Summer	3,28	37,89	4,49	86,54

The seasonal Weibull wind distribution at 10m for the studied site is shown in Fig.1 and the seasonal variation of the mean wind speed and the mean power density at 10 and 50m above the ground level are listed in Table III. For the studied site, the minimum value of mean wind speed at 10m is in Autumn season with 3.16m/s; while the maximum value of mean wind speed is in Spring season with 4.25m/s. Furthermore the mean power density varies between 37.89 and 89.04w/m<sup>2</sup> at 10m and between 86.54 and 155.57w/m<sup>2</sup> at 50m.

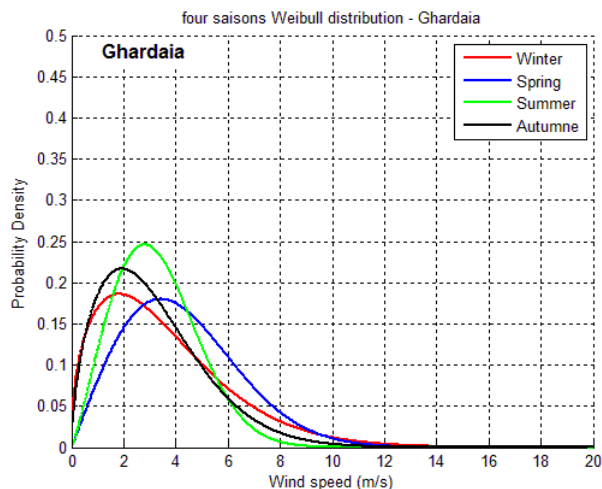


Fig. 1 Seasonal Weibull wind distribution at 10m.

From Fig. 1 we note that for Ghardaia, the wind speed covers the large range of variation in Spring and Winter seasons, and which reaches [0–12m/s], whereas in Summer and Autumn the higher range is limited and does not exceed 10m/s.

**TABLE IV. ANNUAL VARIATIONS OF MEAN WIND SPEED AND POWER DENSITY AT THE FOUR STATIONS**

Elevation	10m		50m	
	V[m/s]	P[w/m <sup>2</sup> ]	V[m/s]	P[w/m <sup>2</sup> ]
Ghardaia	3,57	62,80	4,80	128,93

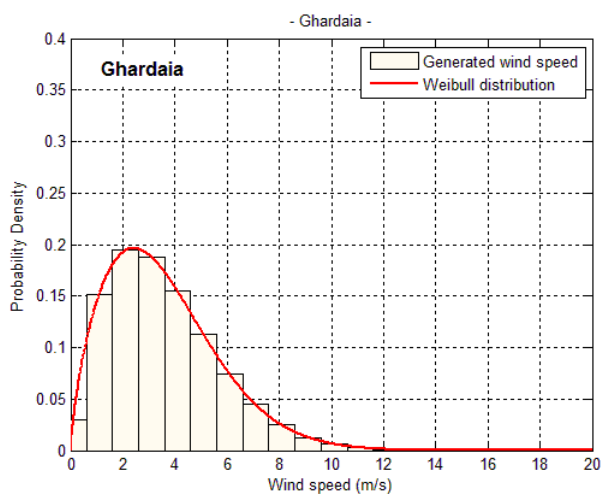
In Fig. 2, histograms of the wind speed observations are shown at the selected sites with fitted Weibull frequency function, we note the tiny percentage of low wind speed in the studied site, less than 1m/s. The wind speed covers a range of variation and which reaches [0–11m/s]. In suitability with the monthly and the seasonal studies, the results at 10m from Table IV give the annual mean wind speed for Ghardaia with a value equal to 3.57m/s.

Fig. 3 represents the Monthly and Fig. 4 the seasonal distribution of both Weibull parameters during the studied time period; the analysis gives the greatest shape parameter equal to 2.38 in June and 2.18 in Summer and the worst value in January with 1.58 and in Winter with 1.46, while the better scale parameter in springer's months for the studied site with a greatest value equal to 7.31m/s in April.



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V. CONCLUSION

Through this study, the monthly, seasonal and annual Weibull parameters, mean wind speed and wind power densities are determined at a height of 10 and 50m in monitoring site at the location of Ghardaia situated in the beginning of Algerian Sahara, in order to provide information of wind resources. This study gives a potential correlation between the shape factor and airtemperature in the studied location where the greatest values of  $V$  is determined in summer's months. Ghardaia site gives in this analysis a wind potential with an annual mean wind speed  $V = 3.57$  at 10m. It can be concluded that Ghardaia gives a lower potential. The better season of wind energy potential is given in Spring while the monthly is given in April. The present study leads to assess fully the wind potential in the beginning of Algerian Sahara regions, between Tell in North and Sahara in South, by setting up much more monitoring meteorological points, and solicits thereafter an eventual feasibility of a wind park project.

Fig. 2 Annual wind speed frequency with fitted Weibull distribution at 10m.

REFERENCES

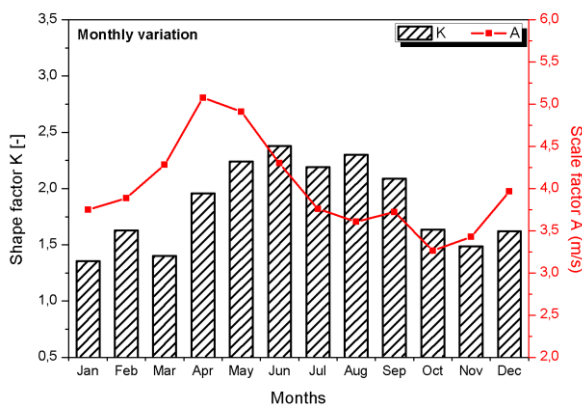


Fig. 3 Monthly Weibull distribution parameters at 10m.

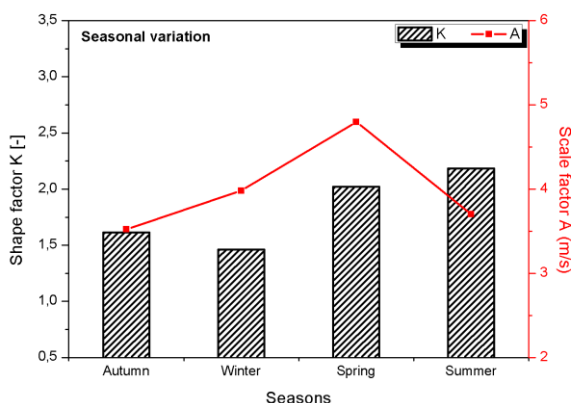


Fig. 4 Seasonal Weibull distribution parameters at 10m.

- [1] Kost C., et al., Fruitful symbiosis: Why an export bundled with wind energy is the most feasible option for North African concentrated solar power. Energy Policy (2011), doi:10.1016/j.enpol.2011.08.032
- [2] Komendantova N., et al., Perception of risks in renewable energy projects: The case of concentrated solar power in North Africa. Energy Policy (2009), doi:10.1016/j.enpol.2009.12.008
- [3] A.J. Folkmanis, International and European market mechanisms in the climate change agenda - An assessment of their potential to trigger investments in the Mediterranean solar plan, Energy Policy. 39 (2011) 4490-4496
- [4] T. Hasni, Former president of NEAL « Développement des Energies Renouvelables en Algérie », National conference on renewable energies and sustainable development. Laghouat, Algeria, 2006
- [5] A.B. Stambouli, Promotion of renewable energies in Algeria: Strategies and perspectives, Renewable and Sustainable Energy Reviews. 15 (2011) 1169-1181
- [6] Y. Hamakawa, Recent Progress in Solar Photovoltaic Energy Conversion, report for New Energy, JSAP International. 5 (2002) 30-35
- [7] M. Sathyajith, Wind Energy Fundamentals, Resource Analysis and Economics, Springer-Verlag Berlin Heidelberg, Netherlands, 2006
- [8] M.S. Adaramola, O.M. Oyewola, On wind speed pattern and energy potential in Nigeria, Energy Policy. 39 (2011) 2501-2506
- [9] R. Soler-Bientz, S. Watson, D. Infield, L. Ricalde-Cab, Preliminary study of the offshore wind and temperature profiles at the North of the Yucatán Peninsula, Energy Conversion and Management. 52 (2011) 2829-2843
- [10] L.A. Lima, C.R.B. Filho. Wind resource evaluation in São João do Cariri (SJC) - Paraíba, Brazil. Renewable and Sustainable Energy Reviews (2011), doi:10.1016/j.rser.2011.08.011
- [11] F. Chellali, A. Khellaf, A. Belouchrani, A. Recioui, A contribution in the actualization of wind map of Algeria, Renewable and Sustainable Energy Reviews. 15 (2011) 993-1002
- [12] Y. Himri, A. Boudghene Stambouli, B. Draoui, Prospects of wind farm development in Algeria. Desalination 239 (2009) 130-138.



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- [13] Y. Himri, S. Himri, A. Boudghene Stambouli, Wind power resource in the south-western region of Algeria. *Renewable and Sustainable Energy Reviews* 14 (2010) 554–556.
- [14] Y. Himri, S. Rehman, B. Draoui, S. Himri, Wind power potential assessment for three locations in Algeria *Renewable and Sustainable Energy Reviews* 12 (2008) 2495–2504.
- [15] D. Saheb-Koussa, M. Haddadi, M. Belhamel, S. Hadji, S. Nouredine, Modeling and simulation of the fixed-speed WECS (wind energy conversion system): Application to the Algerian Sahara area. *Energy* 35 (2010) 4116-4125.
- [16] Bouzidi B., Viability of solar or wind for water pumping systems in the Algerian Sahara regions-case study Adrar, *Renewable and Sustainable Energy Reviews* (2011), doi:10.1016/j.rser.2011.07.108
- [17] M. Djemai, N. Kasbadji Marzouk, Wind farm feasibility study and site selection in Adrar, Algeria. *Energy Procedia* 6 (2011)136–142
- [18] N. Kasbadji Merzouk, Wind energy potential of Algeria. *Renewable Energy* 21(2000) 553-562.
- [19] N. Kasbadji Merzouk, Evaluation du gisement énergétique éolien. Contribution à la détermination du profil vertical de la vitesse du vent en Algérie. Thèse de doctorat. Université Abou Bekr Belkaid, Tlemcen. (2006).
- [20] U. Aynuar, B. Figen, A seasonal analysis of wind turbine characteristics and wind power potential in Manisa, Turkey, *International Journal of Green Energy*. 5 (2008) 466-479
- [21] A.S. Ahmed, Wind energy as a potential generation source at Ras Benas, Egypt, *Renewable and Sustainable Energy Reviews*. 14 (2010) 2167-2173
- [22] M. Jamil, S. Parsa, M. Majidi, Wind power statistics and evaluation of wind energy density, *Renewable Energy*. 6 (1995) 623-628
- [23] E.K. Akpinar, S. Akpinar, An assessment on seasonal analysis of wind energy characteristics and wind turbine characteristics, *Energy Conversion and Management*. 46 (2005) 1848-1867
- [24] M. Li, X. Li, MEP-type distribution function: a better alternative to Weibull function for wind speed distributions, *Renewable Energy*. 3 (2005) 1221-1240
- [25] H. NFAOUI, J. BURET, A. A. M. SAYIGH, Wind characteristics and wind energy potential in Morocco, *Solar Energy*. 63 (1998) 51-60.