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Temporal assessment of wind energy resource in algerian highlands regions

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Abstract - *The aim of this paper is to investigate the monthly, seasonal and annual variation of the wind resource in term of wind energy potential using the wind speed data collected in the last decade for the meteorological stations at four locations situated in Algerian highlands from East to West boundaries. After the study of temporal Weibull parameters, the vertical extrapolation of Weibull parameters and mean wind speed at a height of 50 m was made and the analysis of annual energy efficiency, seasonal and monthly was made for wind energy conversion systems of 600 kW rated capacity. The results show that M'Sila has the highest wind potential among the studied sites with the annual mean wind speed V = 4 m/s and the annual wind energy production equal to 2.4GWh/year, while Kasr Chellala gives a good potential too but affected by an important rate of zero wind frequency. The study gives the regions situated in Algerian highland with an average wind potential, where the better wind energy potential is given in coldest months.*

Résumé - *Le but de cette étude est l'investigation mensuelle, saisonnière et annuelle en terme d'énergie éolienne, en utilisant des vitesses de vent collectées sur une période comprise dans la dernière décennie par les stations météorologiques de quatre régions situées dans les Hauts Plateaux algériens, allant de la frontière Est à la frontière Ouest du pays. Après une étude temporelle des paramètres de Weibull, nous avons procédé à leur extrapolation verticale, ainsi que de la vitesse moyenne du vent à une hauteur de 50m. Ensuite une analyse mensuelle, saisonnière et annuelle de l'efficacité énergétique a été calculée pour une éolienne type d'une puissance de 600 kW. Les résultats donnent la région de M'Sila étant la mieux ventée des quatre, avec une vitesse moyenne annuelle V=4 m/s et une production énergétique annuelle égale à 2.4 GWh/année, bien que le site de Kasr Chellala ait pu donner un aussi bon potentiel, mais lésé par un fort pourcentage de fréquence nulle. La présente étude, donne les régions situées dans les Hauts Plateaux avec un potentiel éolien moyen, où la meilleure production énergétique ne peut être extraite qu'en saison froide.*

Keywords: Wind resource – Assessment - Algerian highlands.

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1. 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 join-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, Boudghene Stambouli 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 50 m 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 Hassi R'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-Merzouk [18, 19] and Chellali *et al.* [11] respectively in Adrar and Hassi R'Mel, two regions in Algerian Sahara.

Wind speed is the most important aspect of the wind resource; in fact, Aynuar Ucar *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].

Highland region was chosen for it hypothetical good wind potential and it previously selection by Kasbadji-Merzouk to defend her doctoral thesis [19].

It is why, in this study, we choose to contribute on temporal wind assessment at four locations in Algerian highlands from East to West boundaries, and try to give a correlation between air temperature and wind speed in this regions, 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 (ONM), 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 calculating the average energy generated by the Fuhrländer FL600 wind energy conversion systems of 600 kW rated capacity at 50 m height hub.

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 (A and k) and the mean wind speed V was made for whole years, the four seasons and the twelve months year.

Vertical extrapolation of wind speed has been made by an empirical model. In the second time, the monthly distribution of Weibull parameters during the studied time period was made to give an eventual correlation between air temperature and wind speed.

At the end, we estimate the average energy density recovered by the wind energy conversion systems versus years, seasons and months.

2. SITES SELECTION AND WEATHER DATA

In this paper, data from four stations distributed over Algerian highlands (Fig. 1) have been analyzed. The geographical coordinates of these meteorological stations and the years of measurements are given in **Table 1**.

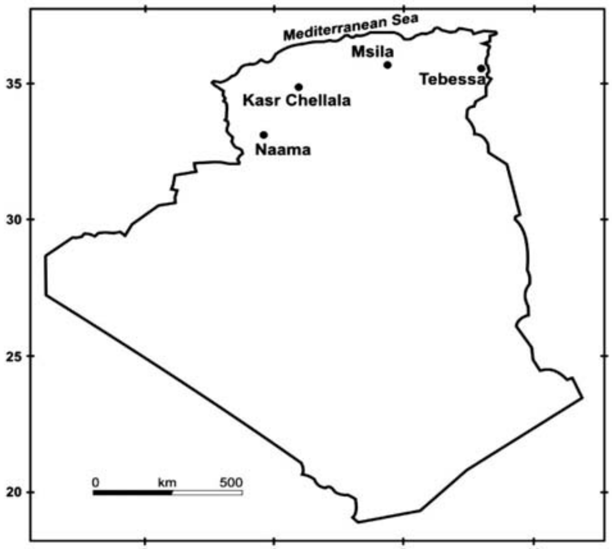


Fig. 1: Map of Algeria

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

Location	Longitude (°)	Latitude (°)	Altitude (m)	Duration (years)	Measurement (years)
Kasr Chellala	35,16	2.31	801	09	01/01/2002-31/12/2010
M'Sila	35,66	4.5	442	03	01/01/2002-31/12/2010
Naâma	33,26	-0.30	1166	03	01/01/2002-31/12/2010
Tebessa	35,41	8.13	813	10	01/01/2002-31/12/2010

3. 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:

$$f(v) = \left(\frac{k}{A}\right) \times \left(\frac{v}{A}\right)^{k-1} \times \exp\left[\left(\frac{v}{A}\right)^{k}\right] \tag{1}$$

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]:

$$V_m = A \times \Gamma\left(1 + \frac{1}{k}\right) \tag{2}$$

where V_m is the average wind speed, and Γ is the Gamma function.

3.1 Wind power density

The power of the wind that flows at speed v through a blade sweep area S (m^2) as the cubic of its velocity and is given by [24]:

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

where, ρ (kg/m^3) is the air density.

The power available in wind can be calculated as follows:

$$P = \frac{1}{2} \times S \times \rho \times A^3 \times \Gamma\left(1 + \frac{3}{k}\right) \tag{4}$$

3.2 Extrapolation of the Weibull parameters at hub height

If the wind distribution is desired at some height other than the anemometer level, the advantage of the use of the Weibull distribution is that A and k values can be adjusted to any desired height by different relations.

According to the literature and responds to the study region, the relation proposed to assess the Weibull scale parameter A_2 at hub height Z_2 is given by the model of Justus [25] expressed by:

$$\frac{A_2}{A_1} = \left(\frac{Z_2}{Z_1}\right)^m \tag{5}$$

where the power law exponent m is given by:

$$m = \left(\frac{0.37 - 0.0881 \times \ln A_1}{1 - 0.0881 \times \ln\left(Z_1 / 10\right)}\right) \tag{6}$$

and the relation proposed to evaluate the Weibull shape parameter k_2 at hub height is given by:

$$\frac{k_2}{k_1} = \left(\frac{1}{1 - 0.0881 \times \ln\left(Z_2 / Z_1\right)}\right) \tag{7}$$

3.3 Wind energy density

Under the above mentioned hypothesis, the electric energy E (kWh) which can be produced per time period t and including the blade sweep area S (m^2) is given by [25, 26]:

$$E = \frac{1}{2} \times C_p \times \rho \times S \times A^3 \times \Gamma\left(1 + \frac{3}{k}\right) \times \frac{t}{1000} \tag{8}$$

with C_p is the power coefficient for each wind turbine.

4. AIR DENSITY

The air density is defined as the mass of a quantity of air divided by its volume. This parameter has a great importance in the estimation of the power density and factors like temperature, atmospheric pressure, elevation and air constituents affect the density of air. So, to calculate the air density we commonly use the following expression [27]:

$$\rho = 3.484 \times (P / T) \tag{9}$$

where P is the air pressure and T is the air temperature.

This law represents a fairly good approximation, especially in regions where large temperature differences can be observed between the different seasons.

5. WIND ENERGY YIELD ESTIMATION

The monthly, seasonal and annual wind energy potential will be assess using a hypothetical commercialized 600 kW wind energy conversion systems installed at 50m above ground level. Energy calculations requires the wind turbine power coefficient curve, the rotor swept area and hub height. The wind turbine related parameters given by the manufacturer are summarized in **Table 2**.

Table 2: Wind turbine parameters

Model	Fuhrländer FL600
Rated power	600 kW

Rotor diameter	50 m
Hub height	50 m
Swept area of rotor	1962 m^2
Cut-in-wind speed	3 m/s
Rated wind speed	14.5 m/s
Cut-out-wind speed	19 m/s

6. RESULTATS AND DISCUSSION

The wind speed data at the four locations in Algerian highlands 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 50 m above the ground level are listed in **Table 3** for Kasr Chellala and M'Sila and in **Table 4** for Naâma and Tebessa.

Table 3: Monthly variations of mean wind speed and power density at Kasr Chellala and M'Sila

Station	**Kasr Chellala**				**M'Sila**			
Elevation	10 m		50 m		10 m		50 m	
Parameters	V (m/s)	P (W/m^2)	V (m/s)	P (W/m^2)	V (m/s)	P (W/m^2)	V (m/s)	P (W/m^2)
Jan.	3,37	421,49	4,69	669,72	4,12	277,06	5,77	533,77
Feb.	4,07	351,40	5,66	631,31	4,31	206,65	6,09	439,40
Mar.	4,05	226,91	5,73	458,93	4,97	281,16	6,91	581,85
Apr.	4,04	163,38	5,77	361,33	4,70	163,49	6,66	384,39
May	3,73	115,63	5,41	272,44	5,14	178,29	7,24	424,77
June	3,37	70,07	4,98	182,00	3,97	80,93	5,80	216,19
July	2,58	34,80	3,96	98,53	3,48	59,37	5,17	163,73
Aug.	3,08	47,47	4,64	132,52	3,24	46,10	4,86	132,40
Sep.	2,70	94,92	3,99	207,43	3,69	70,91	5,43	190,58
Oct.	2,50	116,43	3,68	233,59	3,10	74,21	4,59	183,37
Nov.	3,67	485,74	5,08	768,00	3,73	238,76	5,28	460,67
Dec.	3,50	306,68	4,93	539,32	4,22	269,57	5,91	528,25

Table 4: Monthly variations of mean wind speed and power density at Naâma and Tebessa

Station	**Naâma**				**Tebessa**			
Elevation	10 m		50 m		10 m		50 m	
Parameters	V (m/s)	P (W/m^2)	V (m/s)	P (W/m^2)	V (m/s)	P (W/m^2)	V (m/s)	P (W/m^2)
Jan.	3.49	92.09	5.11	224.86	3.14	62,34	4,68	162,41
Feb.	4.19	145.52	6.00	337.29	3.67	73,95	5,40	195,98
Mar.	4.70	143.29	6.70	349.69	3.74	78,94	5,48	206,96
Apr.	4.43	122.69	6.37	305.23	3.89	68,77	5,71	190,54
May	4.72	113.71	6.77	296.81	3.55	49,95	5,30	145,84
June	3.59	52.31	5.34	151.44	3.18	32,74	4,83	102,81
July	3.88	67.06	5.72	187.10	3.05	26,78	4,67	87,45
Aug.	3.30	36.61	4.98	113.15	2.94	22,19	4,54	75,32
Sep.	3.18	44.59	4.79	128.35	2.81	24,87	4,34	80,13
Oct.	3.12	66.19	4.65	169.28	2.66	32,65	4,07	95,13
Nov.	3.51	95.48	5.13	231.26	3.08	51,02	4,62	139,47
Dec.	4.17	122.95	6.00	297.90	3.32	72,74	4,91	185,79

For Kasr Chellala site, it can be observed that the monthly mean wind speed at 10 m varies between 2.50 m/s in October and a maximum value of 4.07 m/s in February, while at the hub height the monthly wind speed varies between 3.68 and 5.77 m/s. Furthermore, at 10m, the mean power density varies between 36.61 W/m^2 in August and 145.52 W/m^2 in February.

For M'Sila site, it can be observed that the monthly mean wind speed at 10 m varies between 3.10 m/s in October and a maximum value of 5.14 m/s in May, while at the hub height the monthly wind speed varies between 4.59 and 7.24 m/s. Furthermore, at 10m, the mean power density varies between 46.10 W/m^2 in August and 281.16 W/m^2 in March.

For Naâma site, it can be observed that the monthly mean wind speed at 10 m varies between 3.12 m/s in October and a maximum value of 4.72 m/s in May, while at the hub height the monthly wind speed varies between 4.65 and 6.77 m/s. Furthermore, at 10 m, the mean power density varies between 36.61 W/m^2 in August and 145.52 W/m^2 in February.

For Tebessa site, it can be observed that the monthly mean wind speed at 10 m varies between 2.66 m/s in October and a maximum value of 3.89 m/s in April, while at the hub height the monthly wind speed varies between 4.07 and 5.71 m/s. Furthermore, at 10 m, the mean power density varies between 75.32 W/m^2 in August and 206.96 W/m^2 in March.

From Fig. 2, we note that for Kasr Chellala, the wind speed covers the large range of variation in each seasons, and which reaches [0–19 m/s], whereas in Summer the higher range is limited at 12 m/s but we note the high zero frequency proportion in the coldest seasons.

For M'Sila, the wind speed covers a large range of variation in Autumn, Winter and Spring seasons, and which reaches [0–19 m/s], whereas in Summer the higher range is limited at 11 m/s.

For Naâma, the wind speed covers a less range of variation in Autumn, Winter and Spring seasons, and which reaches [0–15 m/s], whereas in Summer the higher range is limited at 10 m/s.

For Tebessa, the wind speed covers the less range of variation in Winter and Autumn seasons, and which reaches [0–15 m/s], whereas in Spring the higher range is limited at 12 m/s and in Summer it does not exceed 7 m/s.

For the all stations at 10 m, it can be observed that the seasonal mean wind speed varies between 2.85 and 3.82 m/s at Kasr Chellala, between 3.45 and 4.82 m/s at M'Sila, between 3.37 and 4.39 m/s at Naâma site and between 2.94 and 3.63 m/s at Tebessa site at the extreme East Algerian Highlands.

We rated also that the seasonal mean wind power density varies between 50 and 368W/m^2 for Kasr Chellala, between 54.98 and 270 W/m^2 for M'Sila, between 53.48 and 131 W/m^2 at Naâma and between 23.77 and 71 W/m^2 at Tebessa site.

The annual wind speed frequencies with fitted Weibull distribution at 10 m is shown in Fig. 3. Where, histograms of the wind speed observations are shown at the selected sites with fitted Weibull frequency function, we note the low percentage of low wind speed in each studied site, less than 1 m/s with 4.5 % for Naâma, 4 % for Tebessa, 10 % for M'Sila but we note in adequacy with seasonal analysis in Kasr Chellala the highest percentage of low wind equal to 33 %.

The wind speed covers the larger range of variation in Kasr Chellala, and which reaches [0–19m/s], followed by M'Sila and Naâma which reaches [0–17 m/s] and [0–15m/s] respectively. For Tebessa, annual mean wind speed covers the less range where it does not exceed 11 m/s.

In suitability with the monthly and the seasonal studies, the results at 10m give the better annual mean wind speed for M'Sila with a value equal to 4.03 m/s followed by the three other sites with a values equal to 3.85, 3.37 and 3.25 m/s for Naâma, Kasr Chellala and Tebessa respectively.

While the better annual mean wind power density is given by Kasr Chellala with 156 W/m^2, due in large part to the low value of shape parameter in this region.

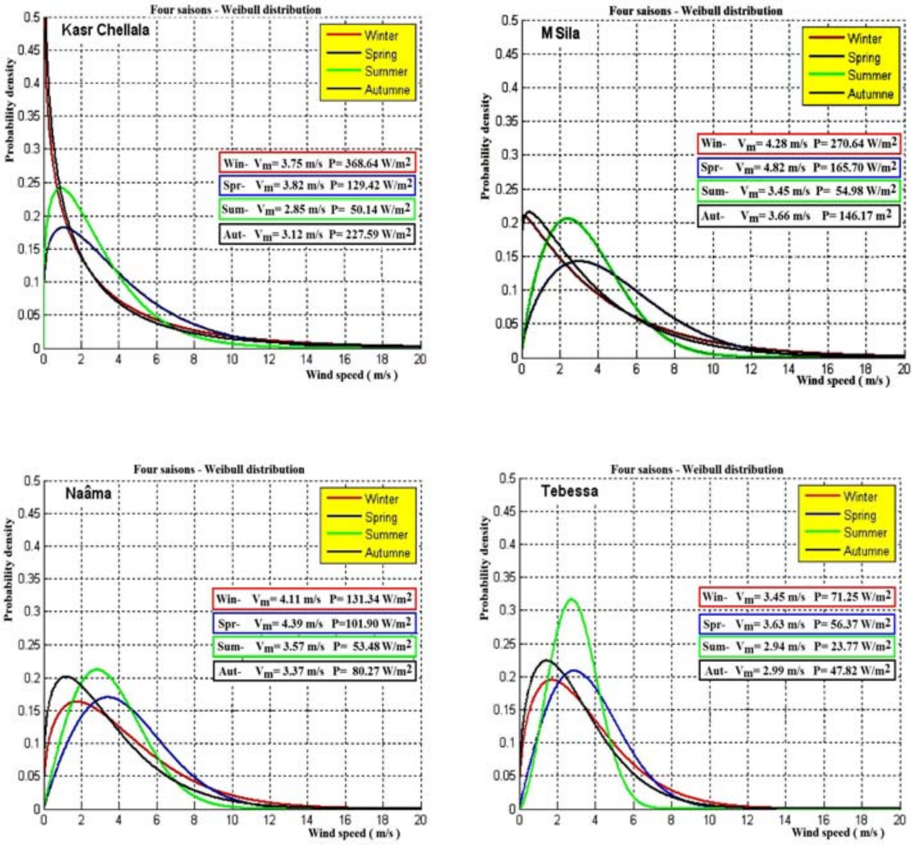


Fig. 2: Seasonal Weibull wind distribution at 10 m

Fig. 4 represents the distribution of both Weibull parameters during the studied time period. The analyses give a good shape parameter k in hottest months and the better scale parameter A in coldest months. We note also the tiny shape parameter in Kasr Chellala site.

To estimate the energy output of the wind turbine, a procedure was developed. So, in every time step, the power exponent and the power output of wind turbine are estimated.

The monthly assessment of wind energy produced by the wind turbine 600 kW rated power is shown in Fig. 5, the seasonal assessment in Fig. 6 and the annual assessment in Fig. 7 at the four localizations.

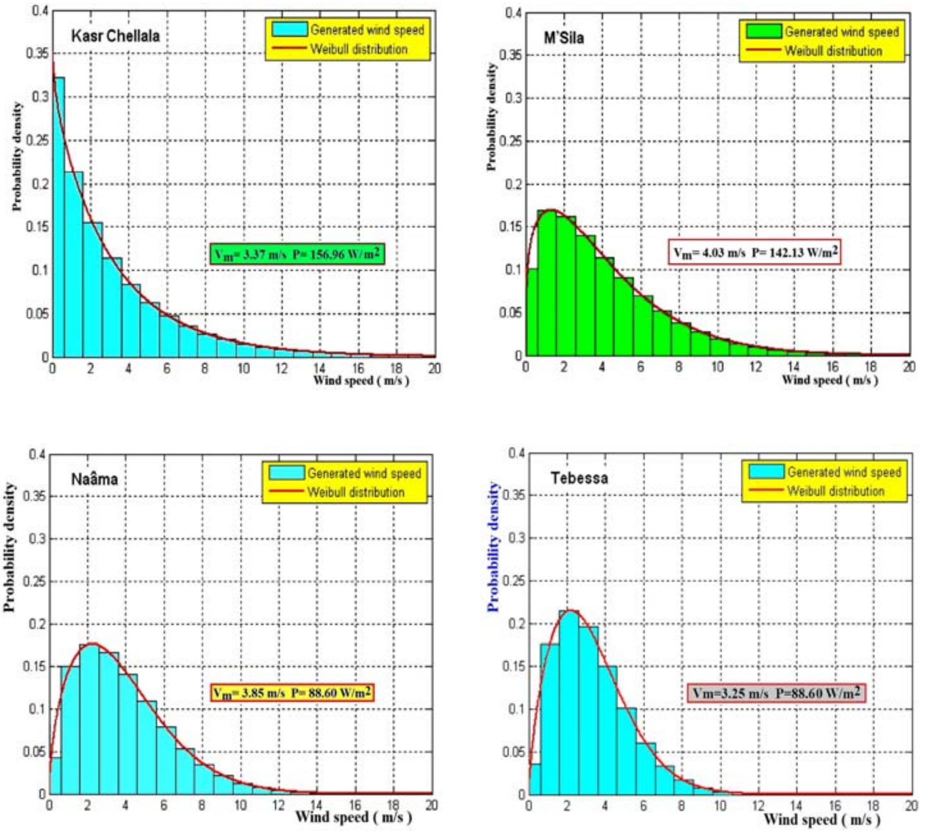
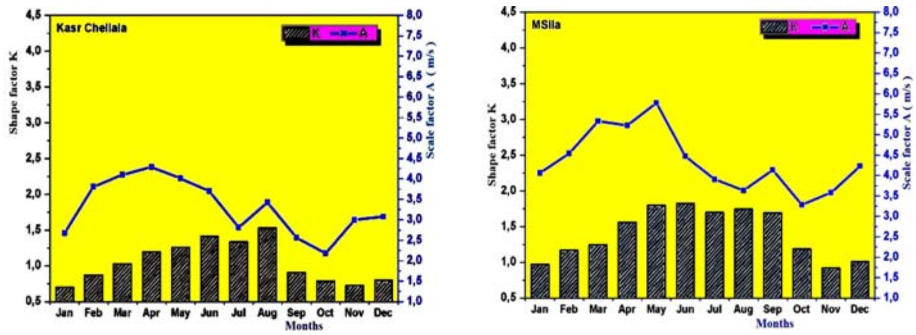


Fig. 3: Annual wind speed frequency with fitted Weibull distribution at 10 m



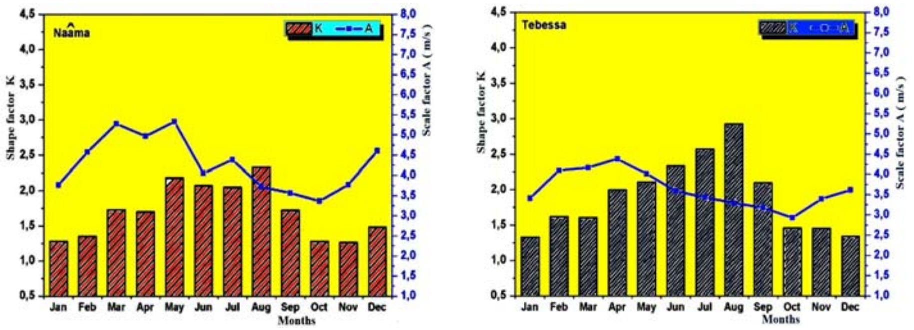


Fig. 4: Monthly Weibull distribution parameters at 10 m

In adequacy with the precedents results, from (Figs. 5, 6 and 7) the analysis gives M’Sila situated in central highlands and Kasr Chellala in West half Algerian highlands as the better studied sites, dominates fully most temporal analysis with an annual wind energy production equal to 2.4 GWh/year for M’Sila and 2.2 GWh/year for Kasr Chellala wich dominate the coldest seasons and M’Sila the hottest seasons. Naâma is behind with an annual energy production equal to 1.6 GWh/year, while Tebessa is far behind with 0.9 GWh/year as annual energy production.

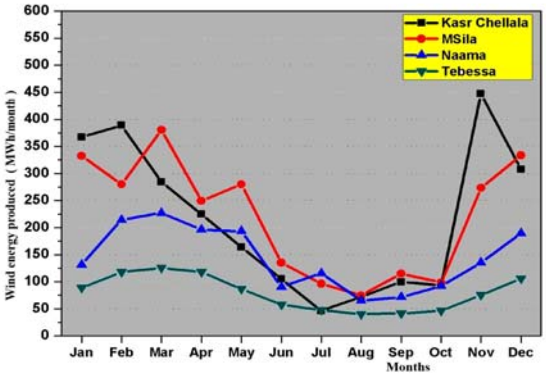


Fig. 5: Monthly wind energy produced results

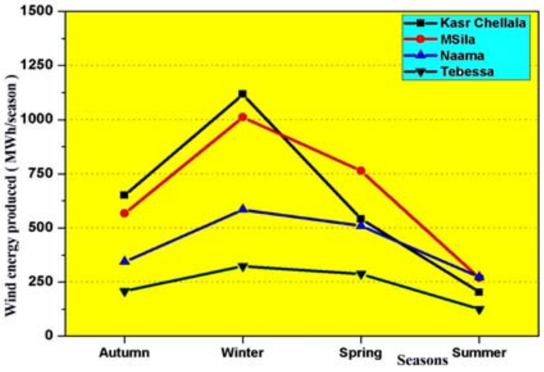


Fig. 6: Seasonal wind energy produced results

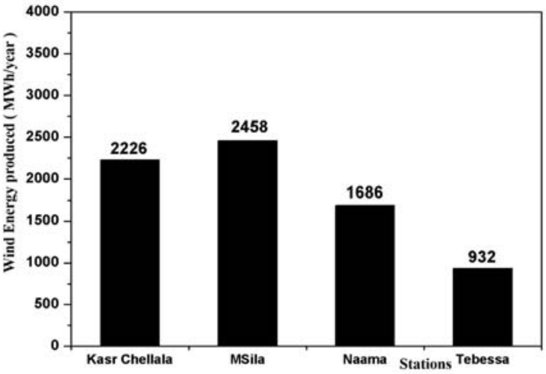


Fig. 7: Annual wind energy produced results

7. 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 50 m in monitoring sites at four locations situated in Algerian highlands, in order to provide information of wind resources.

This study gives a potential correlation between wind speed and air temperature in the studied locations where M'Sila site gives in this analysis the better wind potential with an annual mean wind speed $V = 4\ \mathrm{m/s}$ at 10 m.

Further assessment of the monthly, seasonal and annual wind energy output of a wind turbine 600 kW rated power have been done at the four sites. It can be concluded that M'Sila and Kasr Chellala have the highest wind energy potential, followed by Naâma site and far behind Tebessa in extreme East of Algerian highlands which gives the lower potential.

We rated also that October is the less windy month, Spring gives the best windy season, Winter provides the greatest mean wind power density and Summer the worst mean wind power density at the four studied sites in Algerian highlands. In suitability with air temperature, where the better wind energy potential is given in coldest months in Winter, the present study leads to assess fully the wind potential in Algerian highlands regions, between North and South, at Saharan gate.

REFERENCES

[1] C. Kost, B. Pfluger, W. Eichhammer and M. Ragwitz, '*Fruitful Symbiosis: Why an Export Bundled with Wind Energy is the Most Feasible Option for North African Concentrated Solar Power*', Energy Policy, Vol. 39, N°11, pp. 7136 – 7145, 2011.

[2] N. Komendantova, A. Patt, L. Barras and A. Battaglini, '*Perception of Risks in Renewable Energy Projects: The Case of Concentrated Solar Power in North Africa*', Energy Policy, Vol. 40, pp. 103 – 109, 2009.

[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. Vol. 39, N°8, pp. 4490 - 4496, 2011.

[4] T. Hasni, '*Développement des Energies Renouvelables en Algérie*', National Conference on Renewable Energies and Sustainable Development, Laghouat, Algeria, 2006.

[5] A. Boudghene Stambouli, '*Promotion of Renewable Energies in Algeria: Strategies and Perspectives*', Renewable and Sustainable Energy Reviews, Vol. 15, N°2, pp. 1169 - 1181, 2011.

[6] Y. Hamakawa, '*Recent Progress in Solar Photovoltaic Energy Conversion, report for New Energy*', Japan Society of Applied Physics International, Vol. 5, pp. 30 - 35, 2002.

[7] M. Sathyajith, '*Wind Energy Fundamentals, Resource Analysis and Economics*', Springer-Verlag Berlin Heidelberg, Netherlands, 2006.

[8] M.S. Adaramola and O.M. Oyewola, '*On Wind Speed Pattern and Energy Potential in Nigeria*', Energy Policy, Vol. 39, N°5, pp. 2501 - 2506, 2011.

[9] R. Soler-Bientz, S. Watson, D. Infield and L. Ricalde-Cab, '*Preliminary Study of the Offshore Wind and Temperature Profiles at the North of the Yucatán Peninsula*', Energy Conversion and Management, Vol. 52, N°8-9, pp. 2829 - 2843, 2011.

[10] L.A. Lima and C.R.B. Filho. '*Wind resource evaluation in São João do Cariri (SJC) - Paraiba, Brazil*'. Renewable and Sustainable Energy Reviews, Vol. 16, N°1, pp. 474 – 480, 2011.

[11] F. Chellali, A. Khellaf, A. Belouchrani, A. Recioui, '*A Contribution in the Actualization of Wind Map of Algeria*', Renewable and Sustainable Energy Reviews, Vol. 15, N°2, pp. 993 - 1002, 2011.

[12] Y. Himri, A. Boudghene Stambouli and B. Draoui, '*Prospects of Wind Farm Development in Algeria*', Desalination,Vol. 239, N°1-3, pp. 130 - 138, 2009.

[13] Y. Himri, S. Himri and A. Boudghene Stambouli, '*Wind Power Resource in the South-Western Region of Algeria*', Renewable and Sustainable Energy Reviews, Vol. 14, N°1, pp. 554 - 556, 2010.

[14] Y. Himri, S. Rehman, B. Draoui and S. Himri, '*Wind Power Potential Assessment for Three Locations in Algeria*', Renewable and Sustainable Energy Reviews, Vol. 12, N°9, pp. 2495 - 2504, 2008.

[15] D. Saheb-Koussa, M. Haddadi, M. Belhamel, S. Hadji and S. Nouredine, '*Modeling and Simulation of the Fixed-Speed WECS (Wind Energy Conversion System): Application to the Algerian Sahara Area*', Energy, Vol. 35, N°10, pp. 4116 - 4125, 2010.

[16] B. Bouzidi, '*Viability of Solar or Wind for Water Pumping Systems in the Algerian Sahara Regions - Case Study Adrar*', Renewable and Sustainable Energy Reviews, Vol. 15, N°9, pp. 4436 – 4442, 2011.

[17] M. Djamaï and N. Kasbadji-Marzouk, '*Wind Farm Feasibility Study and Site Selection in Adrar, Algeria*', Energy Procedia, Vol. 6, pp. 136 – 142, 2011.

[18] N. Kasbadji-Merzouk, '*Wind Energy Potential of Algeria*', Renewable Energy, Vol. 21, N°3-4, pp. 553 - 562, 2000.

[19] N. Kasbadji-Merzouk, '*Evaluation du Gisement Energétique Eolien. Contribution à la Détermination du Profil Vertical de la Vitesse du Vent en Algérie*', Thèse de Doctorat, Université Abou Bakr Belkaid, Tlemcen. 2006.

[20] A. Ucar and F. Balo, '*A Seasonal Analysis of Wind Turbine Characteristics and Wind Power Potential in Manisa, Turkey*', International Journal of Green Energy, Vol. 5, N°6, pp. 466 - 479, 2008.

[21] A.S. Ahmed, '*Wind Energy as a Potential Generation Source at Ras Benas, Egypt*', Renewable and Sustainable Energy Reviews, Vol. 14, N°8, pp. 2167 - 2173, 2010.

[22] M. Jamil, S. Parsa and M. Majidi, '*Wind Power Statistics and Evaluation of Wind Energy Density*', Renewable Energy, Vol. 6, N°5-6, pp. 623 - 628, 1995

[23] E.K. Akpinar and S. Akpinar, '*An Assessment on Seasonal Analysis of Wind Energy Characteristics and Wind Turbine Characteristics*', Energy Conversion and Management, Vol. 46, N°11-12, pp. 1848 - 1867, 2005.

[24] M. Li and X. Li, '*MEP-Type Distribution Function: A Better Alternative to Weibull Function for Wind Speed Distributions*', Renewable Energy, Vol. 30, N°8, pp. 1221 - 1240, 2005.

[25] C.G. Justus, W.R. Hargraves, A. Mikhaeil and D. Graber, '*Methods for Estimating Wind Speed Frequency Distributions*', Journal of Applied Meteorology, Vol.17, N°3, pp. 350 - 353, 1977.

[26] T. Diveux, P. Sebastian, D. Bernard, J.R. Puiggali and J.Y. Grandidier, '*Horizontal Axis Wind Turbine Systems: Optimization using Genetic Algorithms*', Wind Energy, Vol. 4, N°4, pp. 151 - 171, 2001.

[27] S. Rehman and N.M. Al-Abbad, '*Wind Shear Coefficient, Turbulence Intensity and Wind Power Potential Assessment for Dhulom, Saudi Arabia*', Renewable Energy, Vol. 33, N°12, pp. 2653 - 2660, 2008.