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Analysis of the Wind Resources in Saharan Atlas of Algeria: Adrar Region as a Case Study

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A B S T R A C T

An objective analysis of the wind atlas map of the region of Adrar (Algeria) at a height of 10 meters above ground is essential, in order to classify these velocities according to the Pacific Northwest Laboratory (PNL) classification, and then to develop the separation velocity map. The present work is conducted in the region of Adrar to determine the monthly, seasonal, and annual energy generated by the Whisper200 wind turbine by using the Rayleigh distribution and the wind data recorded every three hours from January 1st, 1961 to December 31st, 2018. From the obtained findings, the northeast region of Adrar is a suitable region for wind applications. The surface of this area is equal to 16587 km^2, where two sites are located (Kaberten and Aougroute). However, the second PNL class is divided into seven zones. The wind speed in this region (2nd PNL class) is favourable for the setup of isolated wind turbines or hybrid systems. The following cities are located in this region (2nd PNL class): Adrar, Aoulef, Bor dj Baji Mokthar, Timaiaouine, Regagne, and Timimoune.

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NOMENCLATURE

C	Rayleigh scale parameter at h, m/s	S	Section, m²
C_2	Rayleigh scale parameter at h_2, m/s	t	Period, hour
c_e	Wind turbine efficiency	T	Temperature, °K
D	Wind turbine diameter, m	v	Wind speed at h, m/s
E	Electrical energy, kWh	v_2	Wind speed at h_2, m/s
$f(v)$	Rayleigh distribution	v_a	Cut-out wind speed, m/s
h	Measuring height, m	v_d	Cut-in wind speed, m/s
h_2	Height hub, m	Z	Altitude, m
P	Power, Watt	α	Exponent of power law
P_r	Rated power, Watt	ρ	Air density, kg/m^3

INTRODUCTION

The characteristic of the wind at a particular location leads to the ideal use of wind energy and the most important aspect of the assessment of wind resources is the distribution of wind speed. In 1980s Algeria, Ibrahim [1] was the first one to start studying the measurements of the available wind parameters that have been summarized in the ONM meteorological reports, which identify the average wind speeds and frequencies for various meteorological stations. Bensaid [2] proposed a classification of wind speeds according to the topography

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of the country. However, these results are based on measurements made over short periods. Benmemdejahed and Mouhadjer [3] performed a statistical investigation of 37 stations with the help of the Wasp software that is used for the wind mapping of Europe. The obtained findings were employed to achieve the first wind map of Algeria by Merzouk [4]. Chellali et al. [5] updated the wind data by proposing a new wind map that included the Hassi Raml site as a strong wind site, which was neglected by the maps. Boudia [6] improved the temporal evaluation of wind deposits and thus contributed to updating the wind map in Algeria (update of the wind atlas for 10 meters above the ground and development of the wind potentials in the eastern zone of the desert and the western zone of the highlands. Nedjari et al. [7] updated the wind map with the addition of 74 new locations in Algeria eligible for wind projects.

Although different wind maps did not take into account the topography of Algeria, they agreed that the Adrar region has good wind potentials, which makes it suitable for the installation of wind farms or isolated wind turbines. This region is very large and has a low population density. It is remote difficult to connect with the national network; therefore, the use of isolated wind turbines is the solution. Indeed, Adrar region is chosen as the first region of Africa to install wind turbines in 1953. This region was also chosen to install the first Algerian wind farm (Kbarten wind farm) in 2014 [3].

In this article, the wind atlas map of the Adrar region at a height of 10 m above the ground is analysed. The analysis allows to make a classification based on the Pacific Northwest Laboratory (PNL) orientation, and then to establish a map of speed classes for the studied region. The monthly, seasonal, and annual energy generated by the Whisper200 wind turbine is determined by using the Rayleigh distribution and the wind data recorded every three hours from January 1st, 1961 to December 31st, 2018.

WIND RESOURCE

Adrar region

The Adrar region is located in the southwest of Algeria, more than 1200 km from Algiers. It is located between the meridians: 2 ° E and 6 ° W, and the parallels: 20 ° N and 32° N °. Its total area is 427.948 km², or about 18% of the total area of Algeria. It is bounded from the North by the Grand Erg West, from the South by the Tinzoft tray, from the East by the Tademaït tray, and from the West by Erg Chech [8].

The climate of this region is desert. According to the Classification of Köppen BWh [9], the desert climate is characterized by an extreme dryness with rare and weak precipitations, very hot heats with excessively high temperatures during a long period, a very strong solar irradiation with a record duration of sunshine in a large part, as well as a very low humidity.

The hydrographic grid of Adrar is part of the western basin of the northern desert, and it testifies to the internal surface flows during the humid wet periods. In the studied region, there are two main rivers, namely Oued Messaoud and Oued Tilia [3].

The nature of the plant tissue of the Adrar region is typically Saharan. The vegetation is found mainly in Orchards, Ksour, and in Oases. An abundant flora in places, for example in Bordj Badji Mokhtar, where species like the Acacia, Aristide and others thrive are encountered. This region also has a significant number of birds, about 83 species, where more than 50% of which are migratory [3].

The studied region has 399.712 inhabitants, with a population density equal to 0.9 inhabitants per km². Adrar, Timimoun, and Aoulef are the largest cities in the region among the 28 cities that make it up, while the cultivated agricultural area increased to more than 70,000 hectares in the region for the agricultural season (2017-2018) [3].

Wind atlas analysis

Using the carat global wind atlas, the wind speed atlas at 10 m above the ground in the region under study was established (Figure 1). From Figure 1, it can be said that the average wind speed is related to the graphical character, the windiest zone is located at Tademaït tray in the northeast. The wind speed in this zone ranges from 6 to 7 m/s, while the second windiest zones are located in Northwest and West. The wind speed in this zone ranges from 5 to 6 m/s. However, the wind speed is weak in the central and southern zones, except for some locations as Bordj Baji Mokthar and Timaiaouine.

PNL classification

The PNL Classification, which was used by Boudia et al. [10], is a form of classification of wind resources proposed in 1987 by Elliott et al. [11]. Each class (from 1

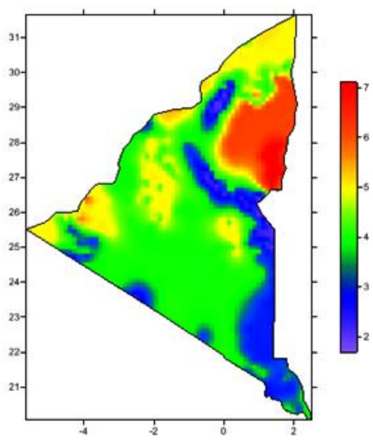

Figure 1. Adrar wind atlas at 10 m from ground

to 7) presents a range of wind power density in (W/m²) and an equivalent average speed range in (m/s) at different heights. From class 4, where the average wind speed $\bar{v} \geq 5.6$ m/s, the site is considered suitable for wind applications. Class 3 or $5.2 \leq \bar{v} \leq 5.6$ m/s are considered to be an area conducive to the development of wind energy using very high pylons. Class 2 with $4.4 \leq \bar{v} \leq 5.2$ m/s is considered a marginal area for the development of wind energy. As for class 1, it is considered as an area not suitable for such energy installations.

Adrar classification according to PNL is illustrated in Figure 2. From this figure, it can be noticed that the northeast zone belongs to the 4th classes of PNL classification. This means that is a region suitable for isolated wind turbine or wind farms. The surface of this zone is equal to 16587 km², where two sites are located, namely Kaberten and Aougroute.

It is also noticed that four zones belong to the third class, with a total surface of these zones of approximately 41777 km². In these zones, where two sites are found (Zaouiet Debagh and Tinerkouk), a wind park composed of wind turbines characterized by a high hub is installed.

The second PNL class is divided into seven zones; this wind speed class is favourable for the setup of hybrid systems or isolated wind turbines. The following cities are located in this region: Adrar, Aoulef, Bordj Baji Mokthar, Timaiaouine, Regagne, and Timimoune.

WIND TURBINE PERFORMANCE

Wind data

Values of the temperature and wind speeds are recorded in every 3 h from 01/01/1961 to 31/12/2018. The Rayleigh distribution, which is a special case of the Weibull distribution, was used to find out the wind distribution. It is expressed as follows [12–18]:

$$f(v) = 2\frac{v}{C^2} exp\left(-\left(\frac{v}{C}\right)^2\right) \quad (1)$$

The Rayleigh distribution was used at the same height of the wind turbine. To calculate the energy produced, the values of the wind speed v were extrapolated to the height of the wind turbine model introduced by Justus et al. [19] (the exponent of power law) to determine the wind speed v_2 at the height hub h_2, expressed by the following equation:

$$\frac{v_2}{v} = \left(\frac{h_2}{h}\right)^{\alpha} \quad (2)$$

where the exponent of power law α is given by [19]:

$$\propto = \frac{0.37 - 0.881 ln(v)}{1 - 0.881 ln\left(\frac{h}{10}\right)} \quad (3)$$

The annual, seasonal, and monthly distributions at 10 m and 25 m from the ground are presented in Table 1. At the 1st height (i.e., 10 m), the scale parameter C varies from 4.6 m/s (February) to 6.9 m/s (April), while the average wind speed ranges from 4.2 m/s (February) to 6.1 m/s (April). This makes the seasonal scale parameters ranging from 5.3 m/s (Winter) to 6.4 m/s (Springer), while the average wind speed is varying between 4.7 m/s (Winter) and 5.6 m/s (Springer). The annual scale parameter and average wind speed were found to be equal to 5.8 and 5.1 m/s, respectively.

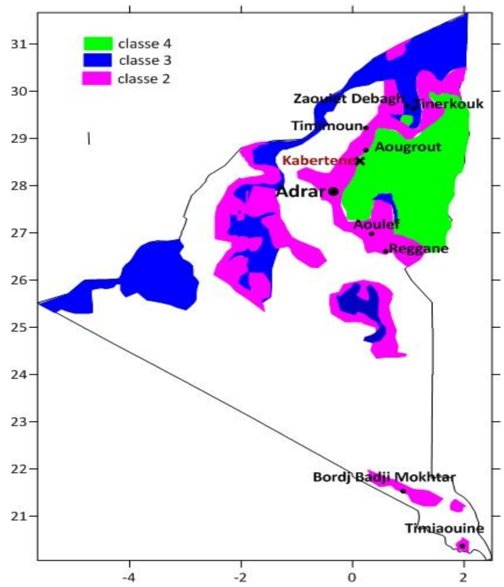

Figure 2. Adrar wind classification according to PNL

Table 1. Annual, seasonal, and monthly distributions at 10 m and 25 m from the ground

Distributions		Measured at 10 m		Estimated at 25 m	
		C (m/s)	$\bar{v}$ (m/s)	C (m/s)	$\bar{v}$ (m/s)
Monthly	January	5.5	4.9	6.6	5.8
	February	4.7	4.2	5.7	5.1
	March	6.5	5.8	7.7	6.8
	April	6.9	6.1	8.1	7.1
	May	5.6	5	6.7	5.9
	June	6.1	5.4	7.2	6.4
	July	5.9	5.2	7.0	6.2
	August	4.9	4.3	5.8	5.2
	September	6.0	5.3	7.1	6.3
	October	5.6	5	6.7	5.9
	November	5.8	5.1	6.8	6.1
	December	5.6	5	6.7	5.9
Seasonal	Autumn	5.8	5.1	6.9	6.1
	Winter	5.3	4.7	6.4	5.6
	Spring	6.4	5.6	7.5	6.6
	Summer	5.6	5.0	6.7	5.9
Annual		5.8	5.1	6.8	6.1

At the 2nd height (i.e., 25 m), the esteemed scale parameter C varies from 5.7 m/s (February) to 8.1 m/s (April), while the average wind speed ranges from 5.1 m/s (February) to 7.1 m/s (April). This makes the seasonal scale parameter ranging from 6.4 m/s (Winter) to 7.5 m/s (Spring), while the average wind speed is varying between 5.6 m/s (Winter) and 6.6 m/s (Spring). The annual scale parameter and average wind speed were found to be equal to 6.8 and 6.1 m/s, respectively.

Wind turbine

The monthly distributions of wind were used to estimate the energy that can be obtained using a small wind turbine (Whisper200) [20]. The characteristics of the wind turbine of the classical model are summarized in Table 2.

Wind energy

The wind power is related to the average wind velocity (v) by a section S with an air density ρ as follows [21–25]:

$$P(v) = \frac{1}{2}\rho S v^3 \tag{4}$$

The density of air (ρ) vs. the temperature T and the altitude Z is given by [26–32]:

$$\rho = \frac{335.49}{T} exp\left(-0.034\frac{z}{T}\right) \tag{5}$$

Based on the above hypothesis, the electrical energy E (kWh) that can be generated by a wind turbine during a period t, is given by :

$$E = \frac{t}{1000}\frac{\rho S}{C_2}\int_{v_d}^{v_a} c_e(v) v^4\ exp\left(-\left(\frac{v}{C_2}\right)^2\right) dv \tag{6}$$

The trapezoidal rule is employed to determine the electrical energy E induced by the wind turbines. This rule, that is provided by Newton and Kutz, is more accurate than the primary method, called rectangles, which corresponds to the Riemann amounts consisting of replacing the initial function by stepped approximation [33–37]:

$$\int_a^b g(v)\, dv = \frac{p}{2}\sum_{i=0}^{n} g(v_{i+1}) + g(v_i) \qquad p = \frac{b-a}{n} \tag{7}$$

A procedure has been developed to evaluate the energy efficiency of the different turbines. The monthly assessment of wind energy produced by Whisper200 with a rated power equal to 1 kW is shown in Figure 3. It can be observed that the wind turbines (Whisper200) are more efficient in March than the other months. The monthly electric power ranges from 241.92 kWh (February) to 327.36 kWh (March).

Table 2. Wind turbine parameters of stander model

Name	*Pr* (Watt)	*D* (m)	*h*2 (m)	*V*d (m/s)	*V*a (m/s)
Whisper200	1000	2.7	25	3.1	20

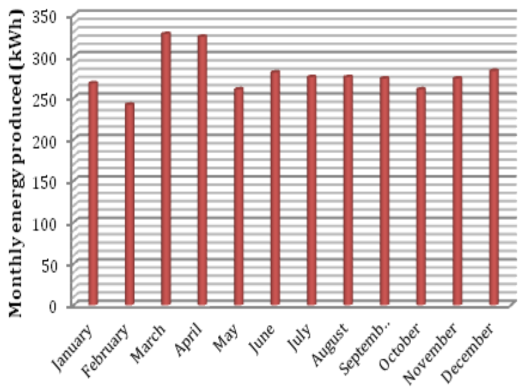

Figure 3. Monthly energy produced by Whisper200

The seasonal and annual assessments of the wind energy produced by Whisper200 are summarized in Table 3. From Table 3, it can be observed that the wind turbines (Whisper200) are more efficient in Springer than the other seasons. The monthly electric power ranges from 792.48 kWh (Winter) to 911.76 kWh (Spring). As a result, the annual electric wind energy produced by Whisper200 in Adrar location was found to be equal to 6.8 m/s and the annual average wind speed equal to 3343.20 kWh.

Table 3. Annual and seasonal energy produced by Whisper200

Period	Energy (kWh)
Autumn	807.60
Winter	792.48
Spring	911.76
Summer	831.36
Annual	3343.20

CONCLUSIONS

This paper aimed to evaluate wind resources in the southern region of Algeria, Adrar as a case study. The results obtained are:

- The average velocity of wind is related to the geographical position of the studied region, where the windiest zone is located at Tademaït tray in the northeast;
- The northeast zone of the investigated case is suitable for isolated wind turbines (IWT) or wind farm, since it belongs to the 4th classes of the PNL classification.
- Four zones with a total surface of approximately 41777 km^2 belong to the third class. The wind park that is composed of wind turbines characterized by a high hub may be installed in these zones, where two sites are found, namely Zaouiet Debagh and Tinerkouk;
- The following cities: Adrar, Timimoune, Regagne, Aoulef, Timaiaouine, and Bordj Baji Mokthar, belong to

the 2nd PNL class. These cities are suitable for the setup of IWT or hybrid systems.

- The wind turbines (Whisper200) are more efficient in March than the other months. The monthly electric power ranges from 241.92 kWh (February) to 327.36 kWh (March), while the monthly electric power ranges from 792.48 kWh (Winter) to 911.76 kWh (Spring). The annual electric wind energy produced by Whisper200 in Adrar location was found to be equal to 3343.20 kWh and the annual average wind velocity was equal to 6.8 m/s.

REFERENCES

1. Ibrahim, S. M. A. 1984. "Energy in the Arab world." *Energy*, 9(3), pp.217–238. https://doi.org/10.1016/0360-5442(84)90109-9
2. Bensaid, H. 1985. "The Algerian programme on wind energy." *Proceeding of WEAC*, pp.21–27.
3. Benmemdejahed, M., and Mouhadjer, S. 2016. "Evaluation of wind energy cost and site selection for a wind-farm in the south of Algeria." *AIP Conference Proceedings*, 1758. https://doi.org/10.1063/1.4959397
4. Merzouk, N. K. 2006. Evaluation of the eoliem energy deposit contribution to the determination of the vertical profile of the wind speed in Algeria. Doctoral dissertation, Université de Tlemcen. Retrieved from http://dspace.univ-tlemcen.dz/bitstream/112/4379/1/KASBADJI.pdf
5. Chellali, F., Khellaf, A., Belouchrani, A., and Recioui, A. 2011. "A contribution in the actualization of wind map of Algeria." *Renewable and Sustainable Energy Reviews*, 15(2), pp.993–1002. https://doi.org/10.1016/j.rser.2010.11.025
6. Boudia, S. M. 2013. 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 dissertation, Université de Tlemcen-Abou Bekr Belkaid.
7. Daaou Nedjari, H., Haddouche, S. K., Balehouane, A., and Guerri, O. 2018. "Optimal windy sites in Algeria: Potential and perspectives." *Energy*, 147, pp.1240–1255. https://doi.org/10.1016/j.energy.2017.12.046
8. Petit-Maire, N., Commelin, D., Fabre, J., and Fontugne, M. 1990. "First evidence for Holocene rainfall in the Tanezrouft hyperdesert and its margins." *Palaeogeography, Palaeoclimatology, Palaeoecology*, 79(3–4), pp.333–338. https://doi.org/10.1016/0031-0182(90)90026-4
9. Peel, M. C., Finlayson, B. L., and McMahon, T. A. 2007. "Updated world map of the Köppen-Geiger climate classification." *Hydrology and Earth System Sciences*, 11(5), pp.1633–1644. https://doi.org/10.5194/hess-11-1633-2007
10. Boudia, S. M., Benmansour, A., Ghellai, N., Benmedjahed, M., and Tabet Hellal, M. A. 2012. "Monthly and Seasonal Assessment of Wind Energy Potential in Mechria Region, Occidental Highlands of Algeria." *International Journal of Green Energy*, 9(3), pp.243–255. https://doi.org/10.1080/15435075.2011.621482
11. Elliott, D. L., Holladay, C. G., Barchet, W. R., Foote, H. P., and Sandusky, W. F. 2003. "Wind energy resource atlas of the United States." *Choice Reviews Online*, 41(04). https://doi.org/10.5860/CHOICE.41-2192
12. Celik, A. N. 2004. "A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey." *Renewable Energy*, 29(4), pp.593–604. https://doi.org/10.1016/j.renene.2003.07.002
13. Akpinar, E. K., and Akpinar, S. 2004. "Statistical analysis of wind energy potential on the basis of the Weibull and Rayleigh distributions for Agin-Elazig, Turkey." *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, 218(8), pp.557–565. https://doi.org/10.1243/0957650042584357
14. Tuller, S. E., and Brett, A. C. 1985. "The goodness of fit of the weibull and rayleigh distributions to the distributions of observed wind speeds in a topographically diverse area." *Journal of Climatology*, 5(1), pp.79–94. https://doi.org/10.1002/joc.3370050107
15. Jowder, F. A. L. 2006. "Weibull and Rayleigh Distribution Functions of Wind Speeds in Kingdom of Bahrain." *Wind Engineering*, 30(5), pp.439–445. https://doi.org/10.1260/030952406779502650
16. Pishgar-Komleh, S. H., Keyhani, A., and Sefeedpari, P. 2015. "Wind speed and power density analysis based on Weibull and Rayleigh distributions (a case study: Firouzkooh county of Iran)." *Renewable and Sustainable Energy Reviews*, 42, pp.313–322. https://doi.org/10.1016/j.rser.2014.10.028
17. Bidaoui, H., Abbassi, I. El, Bouardi, A. El, and Darcherif, A. 2019. "Wind Speed Data Analysis Using Weibull and Rayleigh Distribution Functions, Case Study: Five Cities Northern Morocco." *Procedia Manufacturing*, 32, pp.786–793. https://doi.org/10.1016/j.promfg.2019.02.286
18. Mathew, S. 2006. "Book Review: Wind Energy Conversion Systems: Wind Energy — Fundamentals, Resource Analysis and Economics." *Wind Engineering*, 30(4), pp.357–360. https://doi.org/10.1260/030952406779295426
19. Justus, C. G., and Mikhail, A. 1976. "Height variation of wind speed and wind distributions statistics." *Geophysical Research Letters*, 3(5), pp.261–264. https://doi.org/10.1029/GL003i005p00261
20. Éolienne terrestre WHISPER 200 - 1000W, 12 A, (12, 24, 48V configurable) avec contrôleur, https://www.elysun-store.fr/eolienne-terrestre-whisper-200-1000w-12-a-12-24-48v-configurable.html. (n.d.).
21. Abderrahim, A., Ghellai, N., Bouzid, Z., and Menni, Y. 2019. "Wind Energy Resource Assessment in South Western of Algeria." *Mathematical Modelling of Engineering Problems*, 6(2), pp.157–162. https://doi.org/10.18280/mmep.060201
22. Maouedj, R., Bouchouicha, K., and Boumediene, B. 2011. "Evaluation of the wind energy potential in the Saharan sites of Algeria." In 2011 10th International Conference on Environment and Electrical Engineering (pp. 1–4). IEEE. https://doi.org/10.1109/EEEIC.2011.5874582
23. Maouedj, R., Barbaoui, B., Benmedjahed, M., Mammeri, A., Saba, D., Ghaitaoui, T., and Laribi, S. 2018. "Wind Energy Resource Assessment at three Sites in the Algerian Highlands." In 2018 6th International Renewable and Sustainable Energy Conference (IRSEC) (pp. 1–6). IEEE. https://doi.org/10.1109/IRSEC.2018.8702275
24. Rachid, M., Said, D., and Boumediene, B. 2012. "Wind Characteristics Analysis for Selected Site in Algeria." *International Journal of Computer Applications*, 56(5), pp.39–46. https://doi.org/10.5120/8890-2896
25. Benmedjahed, M., and Maouedj, R. 2018. "Wind Power Assessment In Algeria; Methods Development." In 2018 International Conference on Wind Energy and Applications in Algeria (ICWEAA) (pp. 1–6). IEEE. https://doi.org/10.1109/ICWEAA.2018.8605049
26. Benmedjahed, M., 2014. "Choix du site et optimisation du dimensionnement d'une installation éolienne dans le nord Algérien et son impact sur l'environnement", Doctoral dissertation.
27. Benmedjahed, M. 2015. "Wind Potential Assessment of Ain Salah in Algeria; Calculation of the Cost Energy." *International Journal of Energy and Power Engineering*, 4(2), pp.38. https://doi.org/10.11648/j.ijepe.20150402.14

28. Benmedjahed, M., Maouedj, R., and Mouhadjer, S. 2017. "Wind Potential Assessment of M'sila in Algerian Highlands Regions; Modeling of Wind Turbine Noise." *Energy Procedia*, 119, pp.642–649. https://doi.org/10.1016/j.egypro.2017.07.090
29. Benmedjahed, M., Ghellai, N., and Benmansour, A. 2012. "Wind Potential Assessment of Three Coastal Sites in Algeria: Calculation and Modeling of Wind Turbine Noise using Matlab." *International Journal of Computer Applications*, 56(2), pp.20–25. https://doi.org/10.5120/8864-2827
30. Benmedjahed, M., Maouedj, R., and Mouhadjer, S. 2020. "Wind energy resource assessment of desert sites in Algeria: energy and reduction of CO2 emissions." *International Journal of Applied Power Engineering (IJAPE)*, 9(1), pp.22. https://doi.org/10.11591/ijape.v9.i1.pp22-28
31. Benmedjahed, M., Ghellai, N., Bouzid, Z., and Chiali, A. 2015. "Temporal Assessment of Wind Energy Resource in 'Adrar' (South of Algeria); Calculation and Modeling of Wind Turbine Noise" (pp. 33–42). Springer, Cham. https://doi.org/10.1007/978-3-319-16901-9_5
32. Lahouaria Boudaoud, M. B. 2015. "Temporal Assessment of Wind Energy Resource in Algerian Desert Sites: Calculation and Modelling of Wind Noise." *Journal of Fundamentals of Renewable Energy and Applications*, 05(03). https://doi.org/10.4172/2090-4541.1000160
33. Wu, Y. S., and Smolinski, P. 2000. "A multi-time step integration algorithm for structural dynamics based on the modified trapezoidal rule." *Computer Methods in Applied Mechanics and Engineering*, 187(3–4), pp.641–660. https://doi.org/10.1016/S0045-7825(99)00343-6
34. Tuck, E. O. 1967. "A Simple ''Filon-trapezoidal" rule." *Mathematics of Computation*, 21(98), pp.239–239. https://doi.org/10.1090/S0025-5718-67-99892-4
35. Rahman, Q. I., and Schmeisser, G. 1990. "Characterization of the speed of convergence of the trapezoidal rule." *Numerische Mathematik*, 57(1), pp.123–138. https://doi.org/10.1007/BF01386402
36. Trefethen, L. N., and Weideman, J. A. C. 2014. "The Exponentially Convergent Trapezoidal Rule." *SIAM Review*, 56(3), pp.385–458. https://doi.org/10.1137/130932132
37. Waldvogel, J. 2010. "Towards a General Error Theory of the Trapezoidal Rule" (pp. 267–282). https://doi.org/10.1007/978-1-4419-6594-3_17

Persian Abstract

چکیده

برای طبقه‌بندی سرعت‌ها بر اساس طبقه‌بندی PNL آزمایشگاه شمال غربی اقیانوس آرام، و سپس برای توسعه جدایی، تجزیه و تحلیل عینی از نقشه اطلس باد از منطقه آدرار (الجزایر) در ارتفاع ۱۰ متر ضروری است. نقشه سرعت کار حاضر در منطقه آدرار برای تعیین انرژی ماهانه، فصلی و سالانه تولید شده توسط توربین بادی Whisper200 با استفاده از توزیع ریلی و داده‌های باد ثبت شده هر سه ساعت از اول ژانویه ۱۹۶۱ تا ۳۱ دسامبر ۲۰۱۸ انجام شده است. از یافته های به دست آمده، منطقه شمال شرقی آدرار منطقه مناسبی برای کاربردهای بادی است. سطح این منطقه برابر با ۱۶۵۸۷ کیلومتر مربع است، جایی که دو سایت (Kaberten و Aougroute) واقع شده است. با این حال، کلاس PNL 2 به هفت منطقه تقسیم می‌شود. سرعت باد در این منطقه (PNL 2) برای راه اندازی توربین‌های بادی جدا شده یا سیستم‌های ترکیبی مطلوب است. شهرهای زیر در این منطقه کلاس PNL 2 واقع شده‌اند: Adrar، Aoulef، Bordj Baji Mokthar، Timaiaouine، Regagne و Timimoune.