Power of Various Wind Turbines, Simulation for a Site at Laghouat, Algeria

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Article Info

Article history:

Received November 11, 2022
Revised December 01, 2022
Accepted December 03, 2022

Keywords:

Renewable energy
Wind energy
Wind farm
Weibull distribution

ABSTRACT

Algeria is focusing on development of renewable energy including wind energy to increase the share of green electricity to 30% by 2023, of this wind energy will cover 23%. In this study, wind energy potential is assessed for power generation at Laghouat, Algeria. Wind speeds data are analyzed and used to evaluate the annual energy output of various types of wind turbines. The study shows the significant potential of wind energy source at the area. Based on the wind speeds data (2010-2021) and Weibull distribution, the outcomes indicate an average wind speed in the range 6.2-7.125 m/s and average energy density of 236.77 W/m^2. Among five wind turbine types, Siemens SWT-1.62 shows an energy output of 2.935 GWh per year, estimated for 2021. This significant power could support local as well as national green electricity generation.

I. Introduction

Algeria is developing renewable energy is shifting toward green energy after decades of fossil fuel dominated energy. A program is underway to achieve 30% of green electricity [1], corresponding to 22 GW by 2030. About the third of produced green energy is aimed for exportation. Wind energy will provide 23% of this clean energy. The first wind farm was installed in Adrar, Algeria which capacity is 10.2MW. Other projects are planned for this decade. Research has focused on assessment of wind energy potential throughout the country [2]. The Algerian wind map has been developed and updated by several researchers [3-4]. Besides, techno economic investigations have been carried out for wind farm installation in different Algerian sites. For instance, Loussa et al. [5] explored the wind power potential of Ksar Chellala. Abdeslame et al. [2] studied 4 sites to assess the wind power and electrical energy yield. Other attempts were made mainly for the southwest of Algeria [6] where a wind farm is now at work in Adrar, the windiest region in Algeria. The wind speed variability is due to weather as well as the site topography. The first step in any wind farm project is to conduct a preliminary study to figure out the feasibility of wind farm installation. Therefore, wind speed characteristics should be analyzed. Various probability distribution functions have been used to assess wind speed but Weibull distribution is the most common [7, 8]. Since 1951, various important sites were highlighted to be suitable for wind farm including Tadjmout area near Laghouat city [9]. Chellali et al. [10] updated the wind map and included wind speed data on Hassi R'mel, a site located about 100 km south Laghouat city. In this study, assessment of wind energy in a promising area *i.e.* Oued M'zi is carried out. This site is located 50 km north Laghouat city. Weibull distribution is used to characterize wind speeds based on available dataset for 2010-2021. Furthermore, energy density and power generation as well as the annual energy yield that could be produced by five types of wind turbines are estimated and compared.

II. Modeling

The site chosen for this study (Figure 1) is located in Oued M'zi area (33.962 N 2.342 E) on the south border of the Sahran Atlas at an elevation of 1057 m above sea level, 50 Km to the north of Laghouat city, Algeria. The wind speed dataset of the site is collected from NASA power data [11] for 2010-2021.

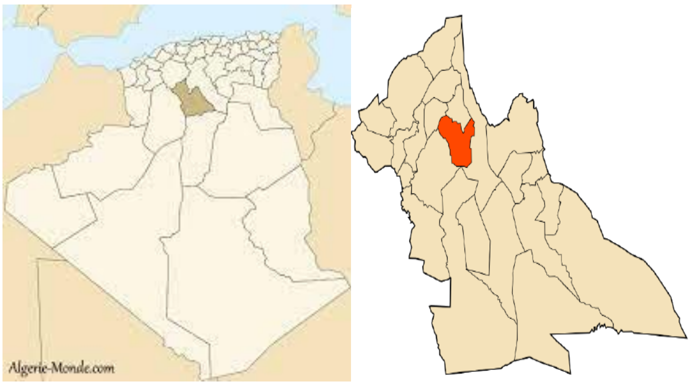

Figure 1. Location of Oued M'zi area (red) in Laghouat province, Algeria

Characterizing of wind speed is made using Weibull distribution [12].

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

Where k and c stand for the shape and scale parameters, respectively. These characterizing parameters can be obtained by linearizing and solving the Weibull equation.
The cumulative density function is derived as:

$$F(u)=1-\exp\left(-\frac{u}{c}\right)^{k} \quad (2)$$

Wind power is estimated for various wind turbines using WindPRO software. Generated power can be computed based on the following formula.

$$P_e=0.5C_p\,\rho\pi\frac{D^2}{4}u^3 \quad (3)$$

Where C_p refers to the turbine efficiency and D is its blade diameter.

III. Results

III.1. Wind direction

The dominant wind direction helps in arrangement of turbines in the wind farm. The wind rose provides the frequency and direction of wind speeds for the given area. The windiest months are January to April. Figure 2 shows the wind rose of Oued M'zi area for April as illustrating example of the windiest period. The frequency of high speeds is dominantly southwest in the area. Besides, the wind rose shows that the less frequent wind is blowing from the southest.

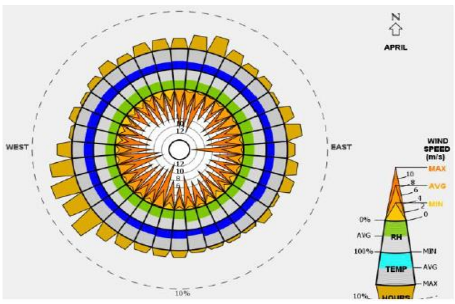

Figure 2. Wind rose of the area.

III.2. Weibull distribution

Analysis of wind speeds is essential for wind energy. Weibull distribution (Figure 3) is characterized by two main parameters *i.e.* the shape and scale parameters. The shape factor indicates the wind speed uniformity. For 2020 and 2021, the shape parameter is higher than 2, meaning more uniform wind speeds throughout the year. The scale parameter indicates the most frequent wind speeds. It ranges between 6.2 and 7.125 m/s. The less frequent speeds are less than the cut-in value of the investigated wind turbines (<3 m/s). This cut-in wind speed determines the speed value enabling to overcome friction and rotate the blades [13].

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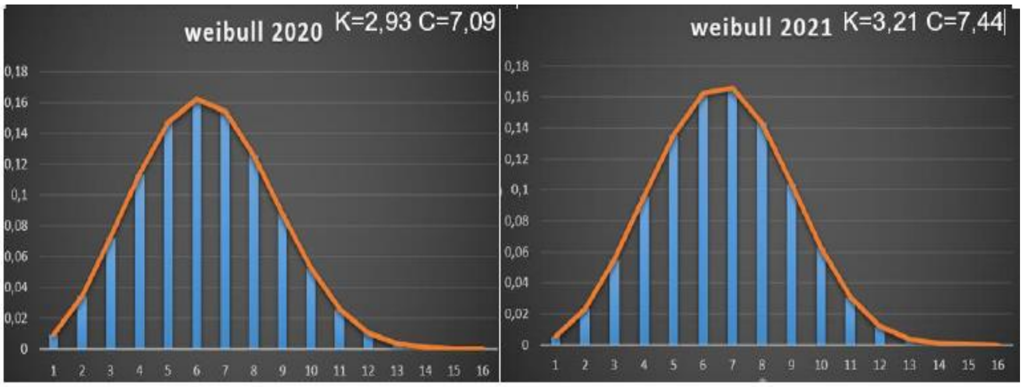

Figure 3. Weibull distribution for Oued M'zi area at 50 m above ground level.

III.3. Wind energy density

Wind energy density of a given site is important since it allows calculating the wind turbine power out. Wind energy density is calculated for the period 2010-2021. Figure 4 shows the variation of wind energy density for the investigated site. The wind energy density is fluctuating between 200 and 300 W/m^2 before 2016 and this fluctuation is limited to 200-250 W/m^2 after 2016 which means that for the last 5 years the wind energy resource declines in the investigated area. This may be attributed to the climate change that affects not only the area but the entire globe.

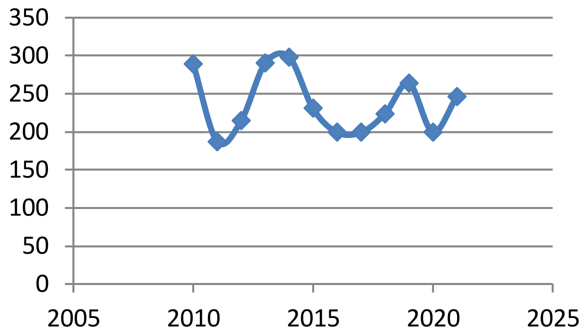

Figure 4. Wind energy density (kW/m^2) for 2010-2021.

III.4. Power

Power is calculated for two years 2020 and 2021 for various turbines (Table 1) including GE, Gamessa, Vestas, Siemens, and Nordex. The turbines power out is depicted in Fig. 5. The computed power is in the range of 144-335 kW. The maximum power is provided by Siemens for 2021 and the minimum power is produced by Nordex for 2020. The power generated by Gamessa and Vestas are approximately the same.

Table 1. Specifications of the investigated wind turbines

Turbines	GE	Gamessa	Vestas	Siemens	Nordex
Model	GE 600A	G4/7660	V47	SWT-1.62	N-43/600
Max Power (kW)	600	700	660	1300	600
Blade diameter (m)	46	47	47	62	43
Cp	0.382	0.462	0.421	0.431	0.373

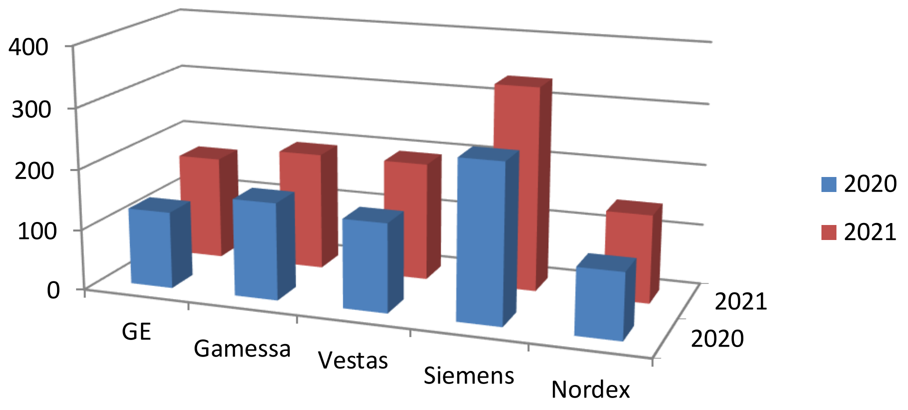

Figure 5. Power (kW) of wind turbines

III.5. Annual energy yield

The annual electrical energy generated by the investigated wind turbines is calculated for two successive years *i.e.* 2020 and 2021. As can be seen in Figure 6, Siemens shows the highest annual yield with 2.274 and 2.935 GWh for 2020 and 2021, respectively. This is explained by the large size of this machine, 63 m of blade diameter. It should be noted that the high energy yield made by a large machine is often costly. Therefore, a techno-economic study is required for optimizing the energy cost. Vestas and Gamessa have comparable energy production. Finally, the lowest yield is observed by Nordex for 2020 by 0.947 GWh.

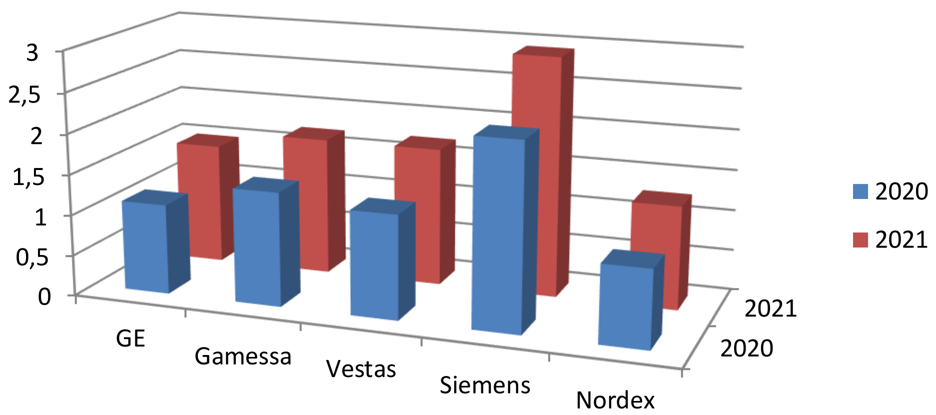

Figure 6. Energy yield (GWh/year) of wind turbines

IV. Conclusions

This above review shows that smart materials such as PCM are more advantageous in terms of thermal performance. They can effectively ensure thermal comfort and reduce energy consumption thanks to their excellent heat capacity that increases thermal inertia of buildings. The review revealed the lack of studies on the Algerian context. Therefore, studies should be carried out to determine suitable PCMs for various climate zones of Algeria enabling effective implementation of this new king of material in the Algerian building. For economic feasibility, a local industry and market of PCM should be promoted by the government to make available PCM at low cost. Knowing that organic PCM can be easily produced based oil which largely available in Algeria. Other bio-PCM can be extracted from plant, there is also a lack of studies on bio-PCM in Algeria. This industry and market would also have social impact mainly by supporting employment. Certification of PCM should also be considered to ensure effective and durable implementation. Finally, reglementation should include this new class of materials in the Algerian building industry. This smart material can enhance thermal performance as well as save energy which will have positive impact on both environment and economy of the country.

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