WIND ENERGY POTENTIAL IN THE SITE OF BATNA IN ALGERIA.

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Algeria has not only extensive gas reserve, but also huge renewable energy resources especially solar and wind power. Batna is a growing town located in the North East of Algeria. In this article and as a first step of a techno-economic study of a tri-hybrid system (wind, solar and diesel), we analyzed ten years of daily wind speed data at the region of Batna. The wind power availability is estimated. Annual mean values of wind speed and power were also calculated and discussed and frequency distribution of daily totals of wind speed data were counted and illustrated.

Keywords: renewable energy, wind, wind velocity, Weibull distribution

1. Introduction

Demographic and economic development of countries have two main consequences: on the one hand they require a growing amount of energy, contrasting with the progressive depletion of fossils energies, and on the other hand they contribute to environment pollution and greenhouse gas emissions. These tow consequences call for a pressing and an essential reflection on the future of energy resources. Indeed, renewable energy resources represent not only an answer to the rising need of energy but contribute also to the reduction of greenhouse emissions and of the pollution of air, water, ground and biosphere, without missing that they enhance energy security and provide opportunities for poverty eradication, particularly in rural and remote regions.

In spite of its important fossil energy, Algeria has set up a national program for the promotion of renewable energy sources in the frame of its sustainable energy development plan for 2020. The first target is to increase electricity production by the renewable energies to 10-12% of the total production by 2015. This program has been concretized by the creation of the NEAL (New Energy Algeria) which is Algeria renewable energy agency [7].

Actually, wind and solar energy are considered as the most important renewable energy resources. Solar energy is not available during cloudy weather or at night, but wind energy is available much of the time. Both of solar and wind energies can be combined to compensate each other, the so-called hybrid system. We can optimize energy output of such system by adding another "spare wheel"

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whish is diesel energy in case of insufficiency of the two other resources, creating a tri-hybrid system.

Hybrid systems are now a possible economical alternative to running the classical electric grid all the way to the isolated and remote areas. At the other hand, these areas need energy for especially domestic and agricultural applications that are largely covered by small or intermediate-scale wind generators available in the commercial wind turbine market.

This concept of hybrid system in remote areas has been already exploited in many countries: Danmark, Egypt, India, Libya…etc [9-13]. Remote areas may include, not only villages and rural zones, but also military installations, desalinations plants, telecommunication stations, and remote stations for data logging of environmental parameters [12]. There are some authors who tried to create logistical models to evaluate the prediction of energetic performance of hybrid systems in remote areas, and also to optimize sizing of the generating groups and energy storage [3].

Our study aims to establish an accurate assessment of wind energy resource in the region of Batna located in the North East of Algeria.

2. Geographic and socioeconomic data of the region of Batna

Batna territory is vast; it extends form 4° to 7° East longitude and from 35° to 36° North latitude. Its surface of 12 192 km² is peopled with approximately 1 108 779 inhabitants who have a variety of activities ranging from traditional professions (craft industry, agriculture and trade) to modern industry.

Batna has an important and a diversified natural potential (forests and underexploited ground water, fertile grounds and mineral deposits) and its actual principal vocation is the development of the agronomic sector. Like other regions in Algeria, Batna has known an important rural migration movement since several decades; this phenomenon induced the apparition a growing number of isolated and remote areas. The other paradoxical reason for this growing number is the development of the region and the apparition of industrial parks and varying utilities like Batna airport and new agglomerations at its periphery.

The territory of Batna fits almost entirely in the physical unit made by the junction of two chains of mountains (Tellien and Saharien), this explains the fact that Batna has a mountain and hill farming at strong potential. However, this potential remains under-exploited because of the difficulty to link the rural areas to the electrical mains and so also is the communication network.

3. Wind speed data

Wind data was collected every 3 h at 10m above ground level (AGL) in the meteorological station of Batna located near Batna International Airport and during 10 years (from 1999 to 2008). Wind speed and direction were measured, respectively, using a cup-type anemometer and a weathercock.

Windographer software was used to analyze raw wind data. It reads the data of almost all the data recorders, products good graphs and carries out elaborate statistical treatments.

Batna annual average of wind speed was found to be 4.36 m/s for the studied period.

Long term seasonal wind speeds were found to be relatively higher during the period from March to September (Fig. 1A). We can say that this period corresponds roughly to a period of maximum demand of electricity because it includes warm season (operating air-conditioners, refrigerators and irrigation pumps). In cold season, the major source of energy used for heating in Algeria is gas energy because it is cheaper than electricity.

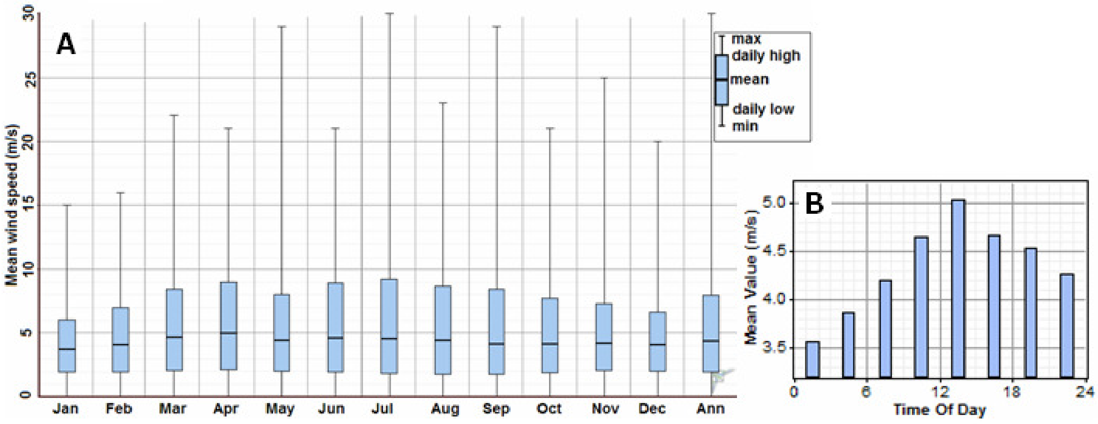

Fig. 1: (A) Seasonal variation of long-term mean wind speed. (B) Mean daily speed

We notice that, approximately, higher wind speeds were observed between 09:00 and 18:00. This means that electricity production is the most important during this period of the day, which coincides with higher electricity demand period (Fig. 1B).

Considering the fact that rotors of the actual wind turbines are placed at heights varying between 40 and 110m AGL and in order to choose the height of the pylons handling the wind turbines, it is necessary to know the variations of wind speed with altitude.

The variations of wind speed with altitude can be estimated using the following relationship:

$$V_2 = V_1\left(\frac{Z_2}{Z_1}\right)^{a}, \tag{1}$$

where V_2, in m/s, is the calculated wind speed at height z_2, V_1 is the observed wind speed at height z_1 and α is the wind speed power law exponent.

The only factor to estimate for this formula is the value of the power law coefficient. It varies following the roughness of the location (Mikhaiel et al. 1981). The formula that calculates α is:

$$\alpha = \frac{1}{\ln\frac{\overline{Z}}{Z_0}} - \left[\frac{0.0881}{1-0.0881\ln\frac{Z_1}{10}}\right]\ln\left(\frac{V_1}{6}\right), \tag{2}$$

$$\text{with: } \overline{Z} = \exp[\ln Z_1 + \ln Z_2]/2 \tag{3}$$

After analysis, a value of $\alpha = 0.16$ was found as the power law exponent factor for the station of Batna where z_0 (roughness of the location) value is equal to 0.01 m.

Thereby, the collected wind speed data was calculated at 40m and 60m hub height using formula (1). At these heights the annual average of wind speed became 5.44 m/s and 5.76 m/s, respectively, while it was only 4.36 m/s at 10m AGL, this corresponds to increases of, respectively, 24.78% and 32.31% from the 10m average annual wind speed.

Knowledge of wind speed frequency distribution is a very important factor to evaluate the wind potential in windy areas. The Weibull distribution is the most commonly used model. It is a good match with the experimental data. The idea is that only annual or monthly average wind speeds (V) are sufficient to predict the complete frequency distribution of the year or the month (1). The Weibull probability density function is written as:

$$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1}\exp\left[-\left(\frac{V}{c}\right)^{k}\right] \tag{4}$$

k (dimensionless) and c (m/s) are the shape and scale parameters of this distribution deduced from the experimental wind data, respectively. In this study, we found that $k = 1.61$ and $c = 4.91$ m/s.

The frequency distribution of wind speed shows in the case of Batna location that wind speed remained at the modal value 3 m/s and below it for about 17% of time during the entire year and above it for the rest of the period (Fig. 3).

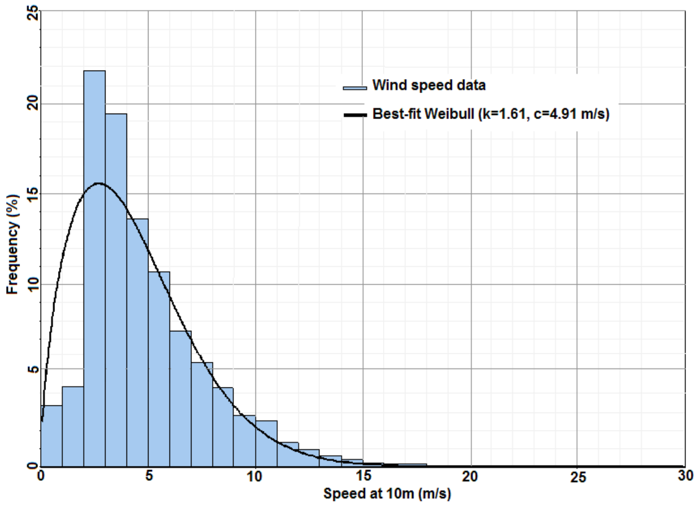

Fig 3: Probability Distribution Function.

4. Wind power and wind energy

Wind energy is the kinetic energy of the moving air mass.

4.1. Available wind power

The power available, Pa (in watts), possessed by wind blowing with a speed of V (in m/s) is directly proportional to the rotor swept area A (in m²), and to the cube of the wind speed. It is given by:

$$P_a = \frac{1}{2}\rho A V^3 \tag{5}$$

The area A perpendicular to the direction of flow can be calculated by this relation:

$$A = \pi\left(\frac{D}{2}\right)^2 \tag{6}$$

4.2. Wind power output

Wind turbine can not utilize all the available power. The amount of power which can be extracted (power output, *P*) is, in realty, inferior to P_a , and is given by the following relationship:

$$P = C_p \cdot P_a \tag{7}$$

Cp evaluation is based on Rankine-Froude theory [5-10]; it is given by this formula:

$$C_p = 4a(1-a)^2 \tag{8}$$

When the variable *a*=1/3, *Cp* reaches its maximum which is called Betz limit (0.59). So, we can say that the maximum power output is:

$$P = 0.59 \cdot P_a \tag{9}$$

4.3. Wind power density

The average wind power density is calculated as the integral of the wind power:

$$\int P\,dV = C_p \int P_a dV = C_p \int \frac{1}{2}\rho A V^3 dV \tag{10}$$

It is used to determine the annual and seasonal wind power densities.

4.4. Wind energy output

The electric energy produced by a turbine over the year is given by the following relationship:

$$E = N_h \int P\,dV = N_h C_p \int \frac{1}{2}\rho A V^3 dV \tag{11}$$

Considering the Weibull distribution equation (4), we can write the equation (11):

$$E = N_h C_p \frac{1}{2}\rho A \int V^3 f(V) dV \tag{12}$$

Using the equation (6) we can write (12) as:

$$E = N_h C_p \frac{1}{2}\rho \pi \frac{D^2}{4} \int V^3 f(V) dV \tag{13}$$

This equation calculates the maximum yearly mean wind energy per unit cross sectional area. Thereby, this entity was estimated for wind energy extracted at different heights: 10m, 40m and 60m. As expected, mean wind energy is proportional to hub height (data not shown).

5. Choice of wind turbine

Considering the socio-geographical features and wind potential of the region of Batna, and looking for machines with good performance and reasonable cost, five types of wind turbines from different manufacturers have been chosen: Bergey Excel-R, Bergey Excel-S, Bergey XL.1, Enercon E33 and Fuhrländer FL 100.
All these turbines have a "cut-in wind speed" that is inferior to the mean wind speed observed in Batna (i.e.; 4.36 m/s), as shown in Table 1. This table shows also other features of the chosen turbines:

Table 1

Main characters of five different commercial wind turbines.

Type	Manufacturer	Blades	D(m)	Nominal speed (m/s)	Nominal power (kW)	Cut-in speed (m/s)
Bergey Excel-R	Bergey Windpower Co	3	6.7	11	7.50	4
Bergey Excel-S	Bergey Windpower Co	3	6.7	16	10	3
Bergey XL.1	Bergey Windpower Co	3	2.5	18	1	2.5
Fuhrländer FL	Enercon	3	21	11.5	100	3
Enercon E33	Lorax energy	3	33.4	13	335	3

The power output can divide the selected turbines in tow groups. This is another criterion added to the raison of our choice. Indeed, Bergey wind turbines used in combination with a back-up diesel generator, and with optional photovoltaics, provide a cost-effective and reliable alternative to conventional methods of electricity supply in remote areas. This fits well with the aim of this study.
At the other hand, the Enercon E33 and Fuhrländer FL 100 turbines chosen here, operate with variable rotor speed and are thus capable of producing electric power efficiently at low wind speeds, and utilizing the energy of gusts without overloading the grid or turbine components.

The output energy *E* of each turbine has been calculated for the region of Batna using Windographer software.

6. Conclusion

The aim of this study was to asses the potential wind power in Batna, Algeria. Hourly measured long term wind speed data of Batna during the period of 1999-2008 have been statistically analyzed.

The probability density distributions have been derived from long term wind speed data and the distributional parameters were identified (the mean annual value of Weibull shape parameter k is 1.61 while the annual value of the scale parameter c is 4.91 m/s). The wind speed frequency distribution of location was found by using Weibull distribution function (mean wind speed measured at

10m above ground level is determined as 4.36 m/s for the studied period, this speed increases by, respectively, 24.78% and 32.31%, when it is extrapolated to 40 and 60m hub height.). The wind energy potential of the location has been studied based on the Weibull mode.

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Nomenclature

D diameter, m
A sweep area, m^2
V wind speed, m/s
c Weibull scale parameter, m/s
k Weibull shape parameter, dimensionless
E wind energy output, kW h/year
P power of wind per unit area, W/m^2
P_a power available, W
N_h number of hours over the year, (i.e.; 365 x 24 = 8760 h)
C_p power coefficient, dimensionless
ρ air density ≈ 1.225 kg/m^3