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Estimation and Technico-Economic Analysis of the Wind Power Potential in North of Cameroon

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RESUME

An evaluation and a technico-economic study was conducted in this paper in the three cities of Cameroon on the wind potential. The model chosen is the model that takes into account the variation of the air density that varies with altitude. The technico-economic analysis is based on the wind energy. The results show that the cost per kWh varies with the city. By installing 6 Nordex wind turbines, this will help to solve the energy deficit problem in the North of Cameroon which has a good wind speed.

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1. Introduction

The need for electrical energy in Cameroon is covered by hydroelectric dams. The various dams in operation in Cameroon are: the Song Lou Lou dam located on the Sanaga River with a capacity of 384 MW, the Nachtigal dam with a capacity of 3 TWh and the hydroelectric dam of Edéa. Given the growing demand for electrical energy, these do not fully cover the needs of the population. In recent years, the demand for power generation in Cameroon has increased rapidly due to population growth and industrialization. Many researchers are studying how to use energy sources such as solar, biomass and wind power as substitutes for traditional energy resources. At the same time, most countries are trying to use renewable energy to replace fossil fuels in order to preserve a better environment. Regarding wind energy, higher conversion rate, cleanliness and safety are its main advantages compared to other types of renewable energy compared to other types of renewable energy [1]. In the last two decades, global wind energy has been rapidly intensifying among the available renewable energy resources [2]. The lack of organized data on the country's wind potential, covering entire regions, has been one of the reasons for the limited applications in Cameroon. Within the framework of this work, it is a question of estimating the energy potential in each region of Cameroon and carrying out a technical-economic study.

2. Methodology

The average meteorological data (wind speed) were collected via the meteorological stations of Ngaoundéré, Garoua and Maroua. The processing of these data is done with the Matlab software.

2.1. Wind data processing

The choice of the analysis of the statistical wind data was made using the weibull distribution method. The wind distribution is done using the Weibull distribution given by equation 1[1].

$$f(V) = \left(\frac{K}{C}\right)\left(\frac{V}{C}\right)^{K-1}\exp\left(-\left(\frac{V}{C}\right)^{K}\right)(1)$$

f(V) is the probability density of the velocity; K is the form factor of the Weibull distribution (dimensionless) and C is the scale factor of the Weibull distribution in m/s. K and C are determined by the EPF method. This method is more accurate and efficient [2]. K is determined using equation (2).

$$\mathrm{K} = 1 + \frac{3.69}{(\mathrm{Epf})^2}(2)$$

Epf denotes the factor energy obtained as a function of the instantaneous velocity by the relation given by equation (3). Equation (4) gives the value of C.

$$\mathrm{Epf} = \frac{\frac{1}{n}\sum_{i=1}^{n}\mathrm{Vi}^3}{\left(\frac{1}{n}\sum_{i=1}^{n}\mathrm{Vi}\right)^3}(3)$$

$$\mathrm{C} = \frac{VmK^{2.6674}}{0.184+0.8116K^{2.73855}}(4)$$

2.2.Wind Speed Extrapolation

Wind turbines are generally located at distances greater than 10 m from the ground. At these heights, the wind has a good speed that can be used by the turbines. The wind speed used to calculate the recoverable power is then exploited at the height of the wind turbine mast. Equation (5) is used for this purpose [4].

$$V(z_2) = V(z_1)\left(\frac{Z_2}{Z_1}\right)^{\alpha}(5)$$

$$\text{with}\,\alpha = \frac{1}{\ln\left(\frac{\bar{z}}{zo}\right)} - \left(\frac{0.0881}{1-0.00881\times\ln\left(\frac{z_1}{z_0}\right)}\right)\times\ln\left(\frac{V(z_1)}{6}\right)(6)$$

$$\text{and}\,\bar{z} = \sqrt{z_1 \times z_2}(7)$$

V(z) is the reference velocity measured at z meters from the ground; z velocity measurement altitudes z_1 and z_2 are the reference height and the variable value above the reference, respectively; z_0 is the ground roughness.

Extrapolation of Weibull parameters as a function of height

The following equations 8 and 9 are used to extrapolate the K and C values to a height z[4].

$$Kz = \frac{K_{10}}{1-0.00881\ln\left(\frac{z}{10}\right)}(8)$$

$$\mathrm{C_z} = \mathrm{C_{10}} \times \left(\frac{z}{z_{10}}\right)^{n}(9)$$

$$\text{with}\,n = (0.37 - O.088\ln(\mathrm{C_{10}}))(10)$$

2.3. Recoverable wind potential of the site

The wind turbine does not fully recover the wind speed and taking into account the altitude the recoverable power is the wind turbine does not fully recover the wind speed and taking into account the altitude the recoverable power is[5]:

$\langle Pr \rangle = 0{,}295.(\rho_0 - 1{,}194.10^{-4}.h_m).\langle V^3 \rangle$en kW/m^2(11**)**

$\rho_{0=}1{,}196 kg/m^3$(12)

h_m is the elevation of the site from the sea.

The average maximum energy recoverable in one year is :

$\langle Er \rangle = 0{,}295.24.365{,}25(\rho_0 - 1{,}194.10^{-4}.h_m).\langle V^3 \rangle$en kWh/m^2(13)

2.4. **Output power of wind turbine**

Taking note that of the fact that each wind turbine have its pover curve by the manufacturer, the output power of the wind turbine is:

$$\langle Pr \rangle = \frac{1}{2}.C_p(v).A.(\rho_0 - 1{,}194.10^{-4}.h_m).\langle V^3 \rangle \quad (14)$$

Where $C_p(v)$ is the power coefficient at a speed , A is a surface area of the wind turbine blades.

2.5. Estimation of the cost of energy

The factors governing the cost of energy are[2] (Gokcek, 2009):

-Investment cost (including auxiliary fees for findings, connection to the network, etc.),

-Operating and maintenance cost,

-Electricity production/average wind speed,

-The life span of the turbine,

-Discount rate,

-The total energy produced.

The factors governingthe present cost value (PVC) are:

- The lifetime of the machine (n) was assumed to be 20 years.

- The interest rate (r) and inflation rate (i) were taken to be 15 and 12%, respectively.

- Operation maintenance and repair cost (Comr) was considered to be 25% of the annualcost of the machine (machine price/lifetime).

-Scrap value S was taken to be 10% of the machine price and civil work.

-Investment (I) includes the machine price plus its 20% for the civil work and other connections.

The present cost value (PVC) of wind turbine (WT) is given in the following relationship[6];[7]; [8]:

$$PVC_{WT} = I_{WT} + c_{omr,WT}\left(\frac{1+i}{r-i}\right)\left[(1-(\frac{1+i}{1+r})^n\right] - S_{WT}\left((\frac{1+i}{1+r})^n\right) \quad (15)$$

CostPer Unit (CPU) is [9]:

$$CPU = \frac{PVC_{WT}}{E_{served}} \quad (16)$$

Many parameters come into play for the choice of the wind turbine that corresponds to the chosen site. These parameters are: the starting speed, the nominal speed, the stopping speed, its length, the number of blades. The choice was oriented on Nordex wind turbines because of their starting speeds which correspond to the lowest speeds in each region.

3. **Results and discussion:**

Using meteorological stations, wind speeds at 10m from the ground in the three main cities in the far north of Cameroon (Ngaoundéré, Garoua, Maroua) were determined.

Table 1. Wind speed at 10m from the ground in Northern Cameroon

Month	Jan	feb	march	April	May	Jun	Jully	August	Sept	Oct	Nov	Dec	Town
Wind speed (m/s)	3.4	3.4	3.7	3.9	3.6	3.1	2.9	2.8	2.6	2.8	3.2	3.5	Ngaoundere
	3.8	3.8	4.1	4.3	3.9	3.3	3.1	2.9	2.7	3	3.5	4	Garoua
	4.1	4	4.4	4.6	4.2	3.5	3.2	3.1	2.8	3.2	3.8	4.3	Maroua

At 10m from the ground, the wind is disturbed by the forest and the houses. At higher heights, the wind has a good speed. For this reason, the wind speeds were extrapolated to different heights for each city. Figure 1 shows the wind speed at different heights in the city of Ngaoundéré. At 70m, this speed is 5.80 m/s in April. This is the maximum speed, which means that it is the most windy month in the city. The least windy month in this city is September with a wind speed of 3.87 m/s. Similarly, in the cities of Garoua and Maroua, at the same height, the most windy month is always April but with an increase in wind speed, in Garoua 6.4 m/s and 6.84 in Maroua. The least windy month is September. With a wind speed of 4.01 in Garoua and 4.16 in Maroua. Table 2 shows the estimated power produced in each region. The region with the highest wind power is the Far North with a power of 145,234 W/m2.

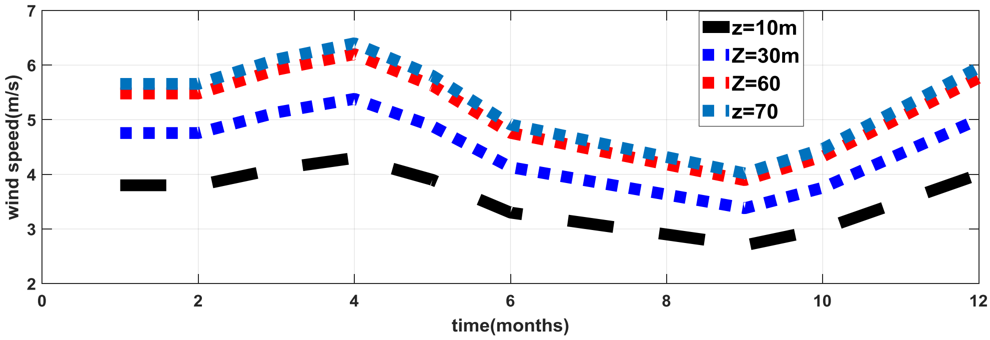

Figure 1. Extrapolated annual average speeds in Ngaoundere

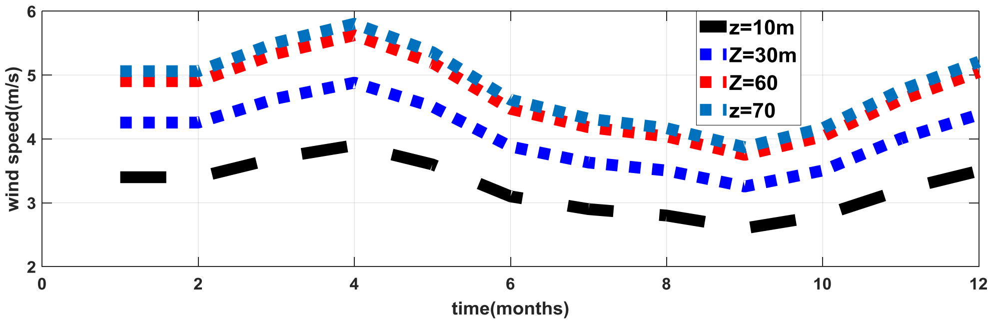

Figure 2. Extrapolated annual average speeds in Garoua

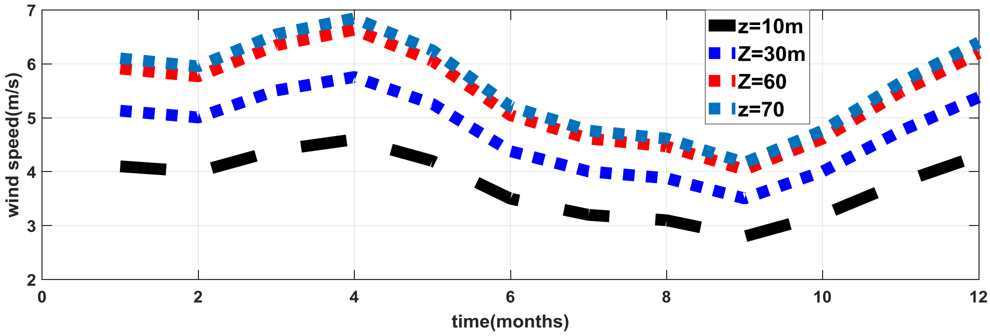

Figure 3. Extrapolated annual average speeds in Maroua

4. The choice of the wind turbine

Many parameters come into play for the choice of the wind turbine that corresponds to the chosen site. These parameters are: the starting speed, the nominal speed, the stopping speed, its length, the number of blades.

Table 2. Characteristics of Nordex wind turbines

Type of the wind turbine	**N29/250**	**N43/600**	**N54/1000**
Power rating (KW)	250	600	1000
Start-up speed (m/s)	3-4	3-4	3-4
Nominal speed (m/s)	15,5	13,5	14
Cut-off speed (m/s)	25	25	25
Diameter of rotor, m	27,5	43	54
Hub height, m	30, 40, 50	40, 50,60	50,60,70

The evaluation of the wind energy is done with the wind turbine type N43/600 because it has the lowest nominal speed (13.5 m/s) which corresponds to the wind speed in the North of Cameroon. Its nominal power is 600 kW.

Economic analysis

By installing a wind farm with 5 wind turbines to produce at least 31536 MWh annually and 11510.640 GWh over 20 years in the city of Maroua. 29541 MWh annually and 10782.465 GWh over 20 years in the city of Garoua. 21376MWh annually and 7802.240 GWh in Ngaoundéré. The economic analysis gives a cost of $0.347 in Ngaoundéré, $0.305 in Garoua and $0.297 in Maroua. This variation in the price per kilowatt-hour in these cities is influenced by differences in production

5. **Conclusion**

It was in this work to evaluate the energy potential in the three cities of Cameroon (Ngaoundere, Garoua and Maroua), the wind speeds were collected at 10 m from the ground. These speeds were extrapolated because the wind turbines are more than 10m above the ground. The Nordex type wind turbine (N43/600) for a height of 60 m was chosen. An economic study was made. It appears from this study that the cost of the kilowatt-hour is not the same in the three cities of Cameroon.

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