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Wind Energy Resource Assessment for Electricity Generation In Maroua

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Abstract

In order to secure future energy and protect the environment, it is important to consider the possibilities of wind as a resource for electrical energy supply. The locality of Maroua in the Far North of Cameroon has been selected to carry out our study in which, an assessment of the wind energy resource has been made. Different kinds of data have been collected about wind, topography, and roughness. The Wind Atlas and the wind speed map have been determined and illustrated especially in the high wind resource areas using for this task, the WAsP software. The Annual Energy Production (AEP) of one hypothetical wind farm consisting of six 2.5 MW turbines has been estimated. The computed AEP is 16,330 MWh and this production could save the rejection of 3300 tons of CO_2 per year. On the other hand, we have carried out a CFD study of the flow around a naca0012 airfoil. For an optimal wind turbine performance, the maximum lift to drag ratio has been obtained for an angle of attack of 9°. We are expecting that with the African research collaborations, the involvement of public and private investors, this project could be more investigated and realized in the future.

Keywords: Resource assessment, wind energy, wind potential, CFD, airfoil.

1.0 INTRODUCTION

Promoting sustainable development and combating climate change have become integral aspects of energy planning, analysis and policy making in many countries. In Cameroon, development and environment issues are at the heart of the energy transition. The wind energy which confirmed its status as the number two source of renewable electricity production in 2012 (Observ'ER 2013) is now the most likely renewable energy source to back up the hydropower supply in halting the relentless increase in fossil fuel used to generate power (Furkan 2011). To obtain the initial feasibility of generating electricity from the wind power through a wind farm in Maroua, we have carried out wind climate characteristics and energy potential. Furthermore, we have provided a wind resource map useful for the selection of suitable areas for future wind farm. On the other hand, we have performed the analysis of the two dimensional subsonic flow over a NACA 0012 airfoil at various angles of attack and operating at a Reynolds number of 1×10^6. The CFD package which has been used for the study is ANSYS-Fluent. This work highlighted that an angle of attack of 9° is required for good performances of the wind power plant on our site.

2.0 METHODS

2.1 Data

The one hour data of the wind speed and direction collected at 10 m above the ground level at the meteorological station of Maroua were used in this work.

The digital terrain map based on a resolution of 30 m derived from the NASA SRTM (Shuttle Radar Terrain Mission) data obtained from the Jet Propulsion Laboratory of The Californian Institute of Technology has been used to prepare the necessary digitized topographical map, sheltering obstacle and roughness data.

2.2 Modelling of the observed wind speed distribution

The probability density function *f(v)* indicates the fraction of time for which the wind is at a given speed v (Bataineh and Dalalah 2013)

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

The cumulative distribution function *F(v)* gives us the fraction of time that the wind speed is equal or lower than v.

$$F(v) = 1 - exp\left[-\left(\frac{v}{C}\right)^{k}\right] \tag{2}$$

According to Seguro and Lambert (2000), when the wind speed data are available in the frequency distribution format, Weibull parameters are estimated using Eqs. (3) - (4).

$$k = \left(\frac{\sum_{i=1}^{n} v_i^k Ln(v_i) f(v_i)}{\sum_{i=1}^{n} v_i^k f(v_i)} - \frac{\sum_{i=1}^{n} Ln(v_i) f(v_i)}{F(v \geq 0)}\right)^{-1} \tag{3}$$

$$C = \left(\frac{1}{F(v \geq 0)} \sum_{i=1}^{n} v_i^k f(v_i)\right)^{\frac{1}{k}} \tag{4}$$

In this work, Eq. (3) is solved using an iterative procedure with a Fortran 90 code. The initial guess is k = 2 (Seguro and Lambert 2000). After the convergence of the k value, Eq. (4) is solved explicitly.

The mean wind speed and power density of a regime, following the Weibull distribution is given by Eq. (5)-(6)

$$\bar{V} = C\,\Gamma\left(1 + \frac{1}{k}\right) \tag{5}$$

$$E_D = \frac{1}{2}\rho C^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{6}$$

2.3 Simulation of the flow over the airfoil naca 0012

The flow was obtained by solving the steady-state governing equations of continuity and momentum conservation combined with the k-ω shear stress transport (SST) turbulence model.

2.3.1 Mathematical formulation and turbulence model

For all flows, the solver solves conservation equations for mass and momentum. The equation for conservation of mass or continuity equation can be written as follows:

$$\frac{\partial \rho}{\partial t} + \vec{\nabla}(\rho\vec{u}) = 0 \tag{7}$$

Conservation of momentum is described by Equation (2)

$$\rho \frac{du_i}{dt} = -\frac{\partial p}{\partial x_i} + \rho g_i + \mu \Delta u_i + \frac{\mu}{3} \frac{\partial}{\partial x_i} (\vec{\nabla}.\vec{u}) \tag{8}$$

As the flow is turbulent, an additional transport equation is also solved. The k-ω SST model is more accurate and reliable for a wider class of flows such as flow around airfoils (Eleni *et al.*, 2012).

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left(\Gamma_k \frac{\partial k}{\partial x_j}\right) + \tilde{G}_k - Y_k + S_k \tag{9}$$

$$\frac{\partial}{\partial t}(\rho \omega) + \frac{\partial}{\partial x_i}(\rho \omega u_i) = \frac{\partial}{\partial x_j}\left(\Gamma_\omega \frac{\partial \omega}{\partial x_j}\right) + G_\omega - Y_\omega + D_\omega + S_k \tag{10}$$

2.3.2 Computational method

The flow has been described as incompressible. Calculations were done for angles of attack ranging from 0° to 19°. The geometry is a C-type mesh with 230,529 quadrilateral cells.

3.0 RESULTS AND DISCUSSION

The purpose of this study is the wind resource assessment. Weibull parameters, the mean wind speed, the energy density and the Annual Energy Production (AEP) have been computed and the results are presented in Table 1.

Table 1: Weibull parameters, mean wind speed, mean energy density and AEP on our site in Maroua

	k	***C***	$\bar{V}$ 10 m	E_D ^{10m}	**AEP** (GWh)
	-	(m/s)	(m/s)	(W/m^2)	
On our site	1.910	3.200	3.0	29.00	16.33

[kazet et al.] [-]

The values of Weibull parameters computed by the modified maximum likelihood method are very close to those obtained by WAsP. An agreement is also observed on the mean wind speed and the energy density calculated at 10 m.

In order to identify suitable areas for future wind farm, we have used Sufer package to illustrate the wind speed map yielded from WAsP calculations (Figs. 1(a)-(b)).

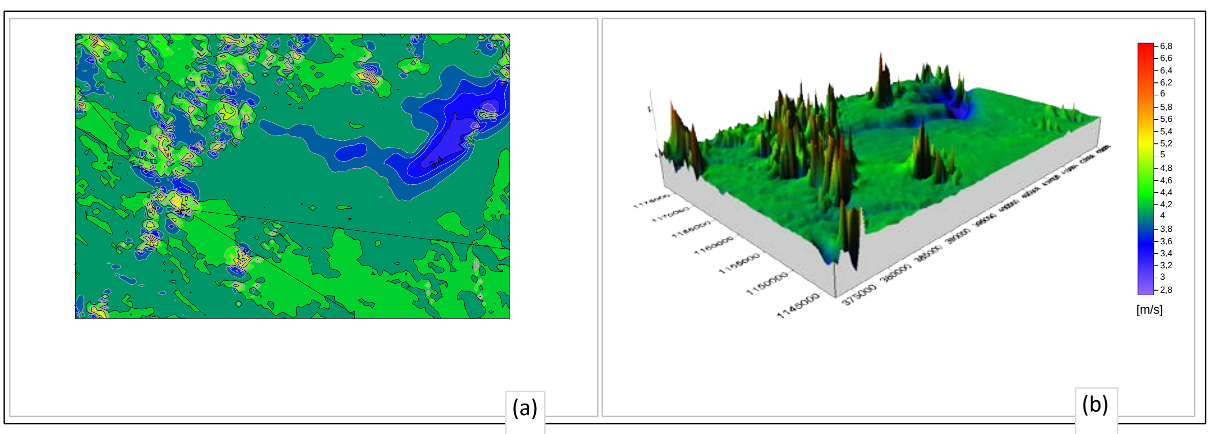


Fig 1: Mean wind speed maps on our site in Maroua.

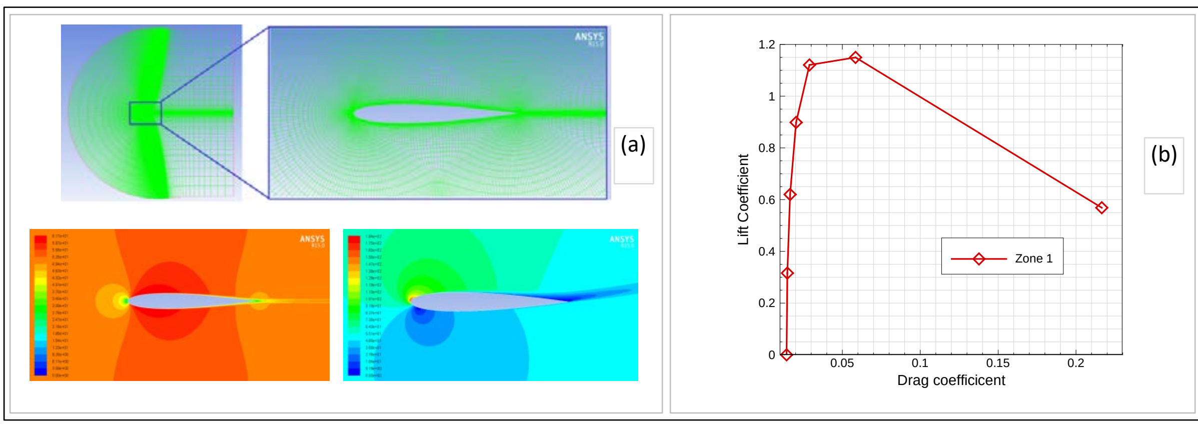
Zones with high wind resource are coloured in red. As expected, the resource is relatively high along the crest of the hills and in particular over big hills at the West side of the wind map. However, the wind resource is low around the data collection site and lower over zones with small elevations in the eastern part of the resource map. For the future wind farm, six turbines (Nordex N100) were considered. Table 2 gives the main outputs. The turbine height is 70 m.

Table 2: The wind turbine siting and their annual energy production

Site description	X-location [m]	Y-location [m]	Elev. [m]	U [m/s]	Gross [GWh]	Net [GWh]	Loss [%]
Turbine site 001	395566.5	1152491.0	527.6	4.23	2.973	2.973	0.0
Turbine site 002	394835.3	1152534.0	532.1	4.14	2.756	2.756	0.0
Turbine site 003	395100.7	1151895.0	530.5	4.13	2.741	2.447	10.72
Turbine site 004	395889.7	1151894.0	526.1	4.17	2.841	2.8408	0.01
Turbine site 005	395223.7	1151179.0	531.1	4.09	2.663	2.566	3.67
Turbine site 006	396027.6	1151215.0	519.7	4.14	2.754	2.746	0.27

[kazet et al.] [-]

The AEP which has been computed for the wind farm is 16,330 MWh. This production represents the reduction of 3300 tons of CO_2 According to the International Energy Agency statistics (IEA Statistics 2013).



ar.

As we wanted to determine the maximum lift to drag ratio for an optimal performance of the wind turbine on our site, simulations for various angles of attack have been done. The wind speed magnitude around the airfoil at angle of attack of 0° and 10° respectively is shown in Fig 2a. The curve of the lift coefficient as a function of the drag coefficient is shown for various angles of attack in Fig 2b (drag polar). From this curve we have determined that the maximum lift to drag ratio is 9°.

4.0 CONCLUSION

In this study, we aimed to provide a wind resource map and an assessment of the energy potential of the locality of Maroua. Also, in order to determine the best angle of attack offering good performances to the wind power plant on our site, we have studied the numerical flow around the airfoil naca0012.

From the wind atlas generated, we have computed and illustrated the wind resource map of the locality of Maroua. It has been assumed a hypothetical wind farm, consisting of six 2.5 MW wind turbines in appropriate configurations. AEP of that wind farm has been computed to be 16,330 MWh and it is expected that this AEP would lead to avoid the rejection of 3300 tons of CO_2 per year in the environment.

It was also found that the predictions of models that were used compared to WAsP predictions agreed well. Weibull distribution appears to be fine for the assessment of the wind potential and the energy output.

For an optimal performance of the wind turbine on our site, the maximum lift to drag ratio has been determined by a CFD simulation.

On a global level, CO_2 emissions are growing with the energy demand. Because it is now an urgent need to reconcile our development model with the increasing environmental and social stakes, we expect that this work will contribute in making wind power one of the future pillars for the electricity supply in the rural areas in the Far North of Cameroon and then consolidate our implication in the sustainable development.

We are expecting that with the African research collaborations, the involvement of public and private investors, this project could come true and hence solve the problem faced by the people living in rural areas.

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