Estimation of the energy production of a 15kW wind turbine in the site of BORJ-CEDRIA

A.W. DAHMOUNI [a], M.M. OUESLATI [a], M. BEN SALAH [b], F. ASKRI [c], C. KERKINI [a], A. GUIZANI [b], S. BEN NASRALLAH [c]

[a] Laboratoire de Maîtrise de l'Energie Eolienne et de Valorisation Energétique des Déchets, Centre de Recherche et des Technologies de l'Energie, Technopôle de Borj-Cedria, BP 95 Hammam Lif 2050, Tunisia.
[b] Laboratoire des Procédées Thermiques, Centre de Recherche et technologies de l'Energie, Technopôle de Borj-Cedria, BP 95 Hammam Lif 2050, Tunisia.
[c] Laboratoire d'Etudes des Systèmes Thermiques et Energétiques, Ecole Nationale d'Ingénieurs de Monastir, avenue Ibn El Jazzar 5019, Monastir, Tunisia.

Email: dahmouni_anouar_wajdi@yahoo.fr

ABSTRACT

To satisfy increases in the world energy requirement it is necessary to find solutions and to diversify them. Renewable energy like wind, solar and hydraulic energy seems to be the suitable solution in the future. In fact many developments have been made in these domains and especially in the wind energy technologies. In this paper we present a study of the electrical wind energy production in the site of Borj-Cedria. The data collected at 20 and 30 m height during 2008 and 2009, have been used to estimate the monthly net energy output of the a 15 kW wind turbine. Results show a promising performance and affirm that Borj-Cedria is one of the best sites for wind project in Tunisia.

Keywords: Wind speed distribution, Wind Turbine, Wind energy, Net energy output.

1. INTRODUCTION

In the last report of Intergovernmental Panel on Climate Change, observations carried out on all the continents and in the majority of the oceans show that a multitude of natural systems are affected by the climate changes, in particular by the increase of temperature IPCC (2008). The scientists affirm that these ecological problems are directly related to the rise of fossil fuel uses. Furthermore, Oil price fluctuations are one of the major sources of disturbance for the economy of oil importing countries. To cure these problems, governments have already adopted programs aiming to increase the contribution of renewable sources in their energy balance. According to last statistics, wind energy seems to be most reliable solution with the highest growth rate.

Recently, many researchers are interested to the evaluation of wind resource and wind turbine production. In fact, Shata and Hannitch (2008), have presented a data bank of electricity generation and wind potential assessment of Hargada i.n Egypt. Moreover, the study of Omer (2008), showed the estimation of the wind energy resources of Sudan using the data collected over the country and propose a study of wind pump profitability in the Soba site. Gökçek and Genç (2009) have evaluated the electricity generation and energy cost of eight wind energy conversion systems in many locations at Central Turkey. A comparative simulation of wind park design and siting in five locations in Algeria has been presented by Ettoumi et al. (2008). They have compared nine commercialized wind turbine with different power output. In the United States of America, Wichser and Klink (2008) have used the data collected in four sites in Minnesota during three years at the altitude of 70-75m to estimate the wind resources in this location. They have also conducted a comparative simulation of three configurations of the GE 1.5 MW series wind turbine to evaluate the potential gain in power production that may be realized with low wind speed technology. In Tunisia, Ben Amar, Elamouri and Dhifaoui (2008), have presented the energy assessment of the first wind farm section of Sidi Daoud. The energetic and aerodynamic characteristics of aerogenerator Made AE-32 installed on site were also studied over 4 years. Dahmouni et al. (2009) have presented the wind potential in the Gulf of Tunis as well as the net energy production of the Enercon E82 wind turbine.

In this general context our study is devoted to the simulation of the electrical production of the a 15kW wind turbine. Using over then 105 264 observations collected during 2008-2009, we estimate the annual Weibull distribution functions, the monthly and the annual net energy production in the site of the Centre of Research and Technologies of Energy (CRTEn) in Borj-Cedria area.

2. THEORETICAL MODEL

2.1. Weibull Distribution

Wind velocity distribution can be modeled by several functions. According to Gumbel (1958), the best one is Weibull distribution. This function can be described by two or three parameters.

The advantages of the use of the function of Weibull with two parameters were highlighted by Justus, Hargraves and Yalcin (1976); Justus, Hargraves, Mikhail and Graber (1976). A model of Weibull with three parameters was proposed by Van Der Auwera, De Meyer and Malet (1980). This model is a generalization of the Weibull function with two parameters.

In wind industry, the use of the Weibull function with two parameters is frequent. It is expressed by

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

Where f(V) is the probability density function, c and k are respectively the scale and the shape parameters which can be calculated using Eqs. 2 and 3

$$k = \left(\left(\frac{\sum_{i=1}^{n} V_i^k \ln(V_i)}{\sum_i V_i^k}\right) - \left(\frac{\sum_{i=1}^{n} \ln(V_i)}{n}\right)\right)^{-1} \quad (2)$$

$$c = \left(\frac{\sum_{i=1}^{n} V_i^k}{n}\right)^{\frac{1}{k}} \quad (3)$$

Where n is the observation number and V_i the wind speed.

2.2. Wind Power Density And Net Energy Production

For a series of measurements, the mean wind power density in the site is given by the following expression

$$\overline{P} = \frac{1}{2}\rho\overline{V^3} \quad (4)$$

Eq. 4 depends on the frequency of each velocity, therefore the mean wind power density is given by

$$\overline{P} = \int_0^{\infty} \frac{1}{2}\rho V^3 f(V)dV \quad (5)$$

Thus, the Eq. 5 has the advantage of making it possible to quickly determine the average of annual production of a given wind turbine if its characteristics and the Weibull distribution on the site are known.

For any wind turbine the electrical power output for each wind speed is given by

$$P_{out}(V) = C_p(V) S \frac{1}{2}\rho V^3 \quad (6)$$

Where $C_p(V)$is the performance coefficient of the wind turbine at the wind speed V and S is the rotor area of the wind turbine.

Eqs. 5 and 6 give the mean power output:

$$\overline{P}_{out} = \int_{V_{min}}^{V_{max}} C_p(V) S \frac{1}{2}\rho V^3 f(V)dV$$
$$\overline{P}_{out} = \int_{V_{min}}^{V_{max}} P_{out}(V) f(V)dV \quad (7)$$

V_{min} and V_{max} are respectively the minimal and the maximal wind speed in the site.

2.3. Wind speed extrapolation

The wind speed measurements are collected in the site at 20 and 30m above ground level. For wind turbine simulation, it is necessary to estimate the wind speed at the turbine hub height. According to the literature, the most commonly used method to adjust the wind velocity at one level to another is the power law method expressed by

$$V = V_{mes}\left(\frac{h}{h_{mes}}\right)^{\beta} \quad (8)$$

Where V_{mes} is the wind speed recorded at anemometer height h_{mes}, V is the wind speed to be determined for the desired height h and β is the power law exponent.

3. SIMULATION AND RESULTS

Using the data collected in the site, we estimate the wind speed at the wind turbine hub height (25m) using values of power low exponent equal to 0.185 and 0.155 respectively in 2008 and 2009. Figs. 1 and 2 show the wind speed distribution function in the two years at the altitude of 25m.

The annual Weibull distribution functions at 25m are expressed by

$$f_{2008}(V) = \frac{1.81}{6.14}\left(\frac{V}{6.14}\right)^{0.81} \exp\left(-\left(\frac{V}{6.14}\right)^{1.81}\right) \quad (9)$$

$$f_{2009}(V) = \frac{1.82}{6.62}\left(\frac{V}{6.62}\right)^{0.82} \exp\left(-\left(\frac{V}{6.62}\right)^{1.82}\right) \quad (10)$$

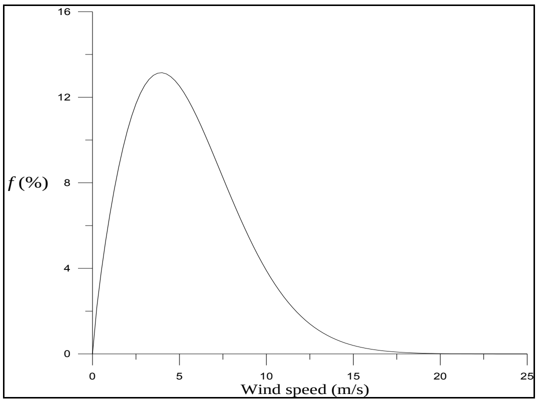

Figure 1: Annual Weibull distribution in the site (2008)

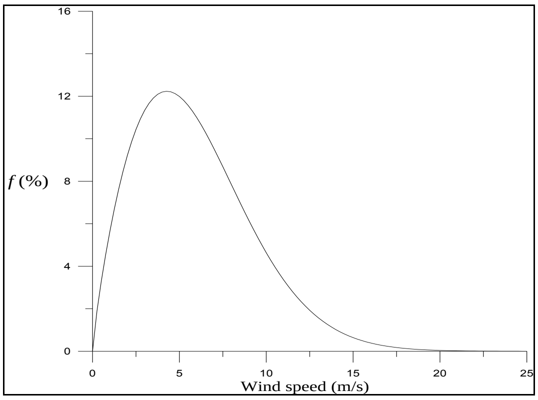

Figure 2: annual Weibull distribution in the site (2009)

To estimate the power output in each month, a procedure was developed according to the International Electrotechnical Commission recommendations (IEC standard 61400-12-1 (2005)) and using the linear interpolation, the characteristic of the wind turbine and the Eq.7.

Fig. 3 presents the power curve of the studied aerogenerator which is the “Proven 15” wind turbine manufactured by “Proven Energy” Scottish company. As shown, this wind turbine represents the advantage of a lower cut-in wind speed.

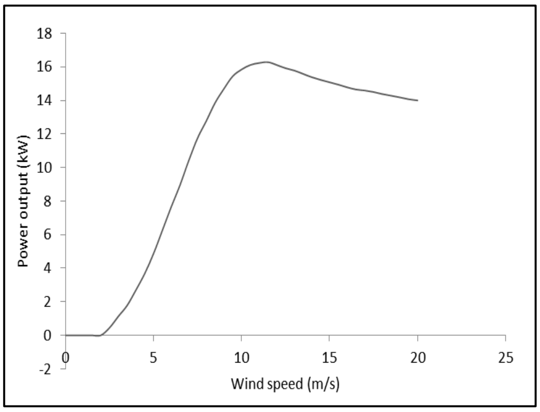

Figure 3: Characteristic of the “Proven 15” wind turbine

Fig. 4 and 5 show the variation of the mean net energy output of the studied wind turbine respectively in 2008 and 2009. We can clearly observe that the production undergoes a monthly basis according to the existing wind resource in the site. So, the highest mean energy output is observed during March with a value of 5445 kWh in 2008 and 5485 kWh in 2009. However lowest values are obtained in October during 2008 and in August during 2009. We can note again that a large production difference was recorded in October, December and February between the two years.

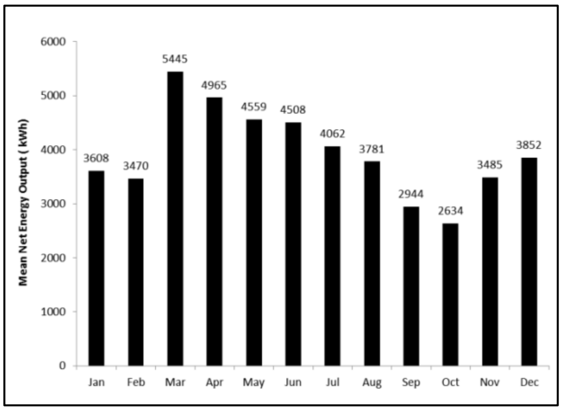

Figure 4: Net energy output during 2008

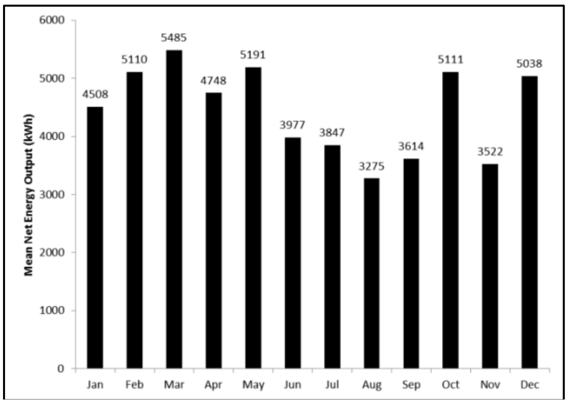

Figure 5: Net Energy output during 2009

So with these results we can confirm that:

- The site of Borj-Cedria presents a good wind energy potential in camper with many other sites presented in various paper.
- The “Proven 15” wind turbine seems to have a good performance in the site of Borj-Cedria with over than 38% of capacity factor.

4. CONCLUSION

In this study, the electrical generation of a 15kW Wind turbine was discussed. Using the estimated Wiebull distributions in the site of Borj-Cedria and the data provided by manufacture, a procedure given the mean net energy output in each month has been developed. Results for 2008 and 2009 years show that Borj-Cedria is a good site for wind project implantation. Furthermore, with a total energy output of about 50 325 kWh/year we can affirm that the "Proven 15" wind turbine is one of the best commercialized wind turbine adapted to the site conditions. The obtained results will be compared to experiment for validation and optimization of the used method.

ACKNOWLEDGMENTS

This paper presents a contribution in the European project Optimal Engineering Design for Dependable Water and Power Generation in Remote Areas Using Renewable Energies and Intelligent Automation (OPEN-GAIN).

REFERENCES

Dahmouni A.W., Ben Salah M., Askri F., Kerkeni C., Ben Nasrallah S., 2010, Wind energy in the Gulf of Tunis, Tunisia, Renewable and Sustainable Energy Reviews 14;1303–1311.

Ben Amar F., Elamouri M., Dhifaoui R., 2008, Energy assessment of the first wind farm section of SidiDaoud, Tunisia, Renewable Energy 33; 2311–2321.

Ettoumi F.Y. , Adane A.H., Benzaoui M.L., Bouzergui N., Comparative simulation of wind park design and siting in Algeria,2008, Renewable Energy 33; 2333–2338.

Gumbel E. J., 1958, Statistics of extremes, Columbia University Press.

Gökçek M. , Genç M.S. , 2009, Evaluation of electricity generation and energy cost of wind energy conversion systems (WECSs) in Central Turkey, Applied Energy 86; 2731–2739.

Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report, 2008, GIEC publication, Suisse.

Justus C. G., Hargraves W. R., Yalcin A., 1976, Nationwide assessment of potential output from wind-powered generators, Journal of Applied Meteorology 15; pp 673-678.

Justus C. G., Hargraves W. R., Mikhail A., Graber D., 1978, Methods for estimating wind speed frequency distribution, Journal of Applied Meteorology 17; pp350-353.

Omer A.M., 2008, On the wind energy resources of Sudan, Renewable and Sustainable Energy Reviews 12; 2117–2139.

Shata A.S.A., Hanitsch R. , 2008, Electricity generation and wind potential assessment at Hurghada, Egypt, Renewable Energy 33; 141–148.

Van Der Auwera L., De Meyer F., Malet L. M., 1980, The use of the Weibull three parameter model for estimating mean wind power density, Journal of Applied Meteorology 7; pp 819-825.

Wichser C., Klink K., 2008, Low wind speed turbines and wind power potential in Minnesota, USA, Renewable Energy 33; 1749–1758.