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Performance of a Wind System: Case Study of Sidi Daoud Site

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Abstract: This paper describes recent developments of systems for the conversion of wind energy. It presents a modeling and simulation of wind energy conversion system at the site of Sidi Daoud using the experimental results obtained by the services of the company STEG and Madee. We determined the performance of machines based on site properties and dimensional characteristics of the device.
Keywords: wind power, performance, dimensional characteristics, site properties

I. Introduction

A wind turbine is a device that converts kinetic energy from the wind into mechanical energy. Most often this energy is itself transformed into electrical energy. Wind turbines are classified according to the electrical power produced. We distinguish the big wind, for machines of more than 250 kW, the average wind power (between 36 kW and 250 kW) and small wind (less than 36 kW). Research on the wind did not cease development [2, 3, 4, 5]. Some work affect component technology [7, 9]. Others interested in conversion systems [6, 7]. But, also there are researches dealing with the profitability wind sites [5, 6, 8 and 10]. Profitability of sites was developed from modeling. This model starts from the wind aerodynamic characteristics, mechanical and electrical engineering. In this paper we study the effect of site properties: wind speed, soil roughness on the performance of a wind turbine. We can divide the parameters influencing the performance of wind turbines into two design characteristics and operating conditions. Concerning the design features we study the effect of the properties of components on the performance of a wind turbine system. Qualities such as wind speed, frequency represent the operating conditions that directly affect the performance of the turbine.

II. Experimental study

The turbine consists of a rotor, two or more blades, a brake, a gearbox, a generator, a nacelle, a guidance system and tower. Its operation is simple and is based on the technology of windmills. The machine consists of three blades (usually) carried by a rotor mounted on top of a mast (tower) vertical. This set is determined by a nacelle that houses a generator. An electric motor designed to orient the top. So that, all energy conversion system is, always, facing the wind. The blades can transform the kinetic energy of wind into mechanical energy. The wind turns the blades. The generator converts mechanical energy into electrical energy. Thus, the multiplier role is to accelerate the slow movement of the blades. The variables studied are: the site of location of the wind speed and the frequency of the wind, the height of the tower, the number and diameter of the blades and finally mechanical energy converted into electrical energy. The experimental results are taken from a report of the final project study [1] conducted on the site of Sidi Daoud wind.

2.1 The windmill site

The wind changes direction and speed over time and space. From anemometer readings and for three years (2000 - 2003), the distribution of wind speeds were recorded. About 120 000 measurements were performed using a height ranging from 0-30 m. It is from these surveys, one can choose the sitting of wind turbines.

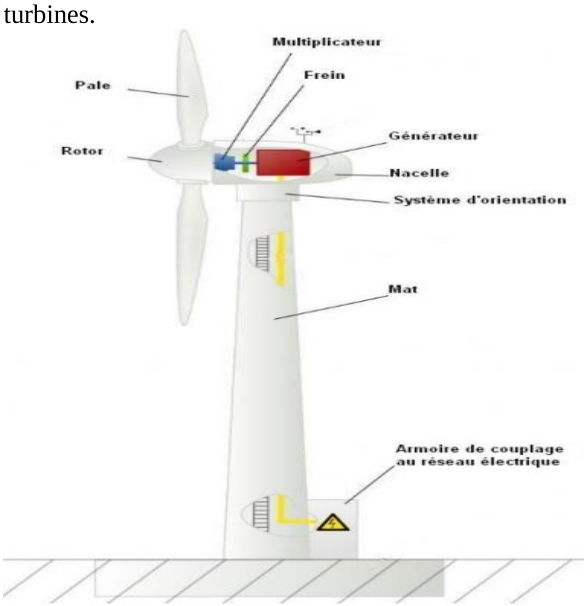

Figure-1: Schematic of a wind turbine

2.2 The mast

The tower produces turbulence behind it. Its height allows use of high wind speeds. It is selected according to the electrical power to be produced. It is known that the wind speed increases based on the ground. In what follows, we will study the effect of the mast height on the recoverable power.

2.3 The diameter of the blades

The diameter of the blades can scan a wide area. This area is an important parameter for converting energy from the wind into electric power. The following formula shows the power output of the wind depending on the characteristics of the wind turbine.

$$P = 1/2\rho VCS \quad (1)$$

Where: P is the power supplied by the wind V, the wind speed, ρ the density of the wind, S, the blade surface and C, a coefficient. The blade surface is proportional to its diameter is that it depends on the height of the mast.

III. Results, discussion and modeling

Measurements performed on wind speed show that the wind is weak in the area of north and south. It is maximum at about 120 ° and 280 ° of latitude. Dominant wind speed is between 5 and 6 m / s, which represent about 30% of the total number of recorded speeds. The average wind speed is 6.8 m / s.

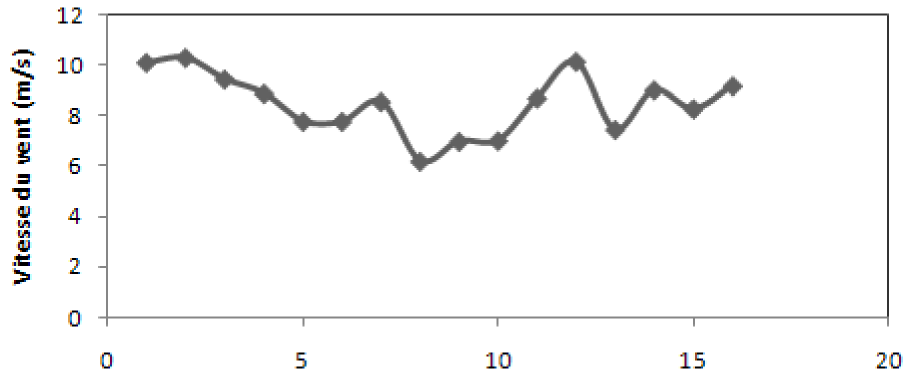

Figure-2: Average monthly wind speeds versus months Sidi Daoud site (January 1999 - April 2000) [5]

3.1 Distribution Weibull

The Weibull distribution represents the variations in the wind speed. This model optimizes turbine design to minimize the costs of electricity generation. Coefficient reflects the Weibull distribution of wind speeds and determined by the Weibull distribution curve (Figure-3).

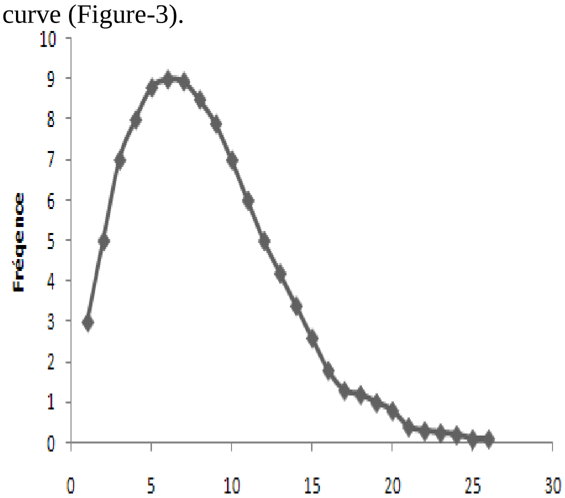

Figure-3: Frequency versus Velocity of winds, Sidi Daoud (from 1/1999 to 3/2000) [5]

The probability function Weibull density is given by the following expression:

$$f(x) = k.c^{-k}.x^{(k-1)}.e^{-(x/c)^k} \quad (2)$$

K: coefficient and C: scaling factor.
The Weibull distribution is 8.42 m / s with a coefficient k = 2.

3.2 Effect of the height of the mast on the output power

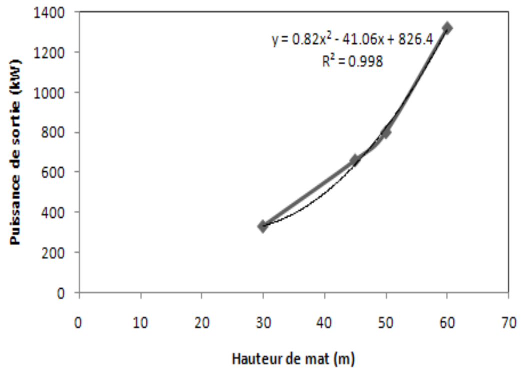

Figure-4: Effect of tower height on the output power [1]

Figure-4, clearly shows that the output power increases as a function of growth in height mat. We have established the following model giving the power output depending on the height of mast:

$$P = 0{,}82H_{mat}^2 - 41{,}06H_{mat}^1 + 826{,}4 \quad (3)$$

3.3 Selection of rotor diameter based on the height of mat

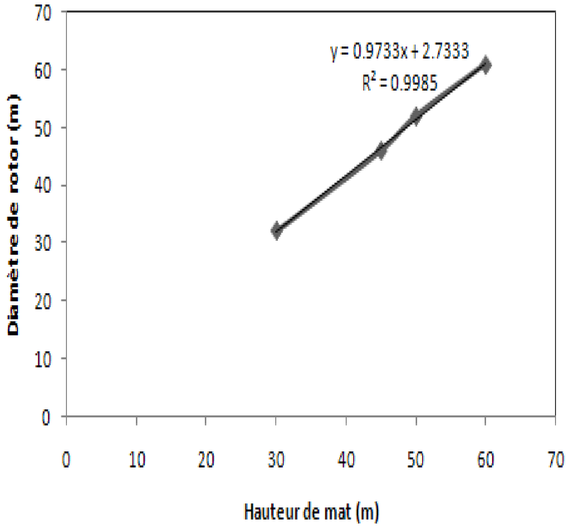

Figure-5: Effect of mast height to the diameter on the rotor [1]

Modeling the change in diameter of the blades depending on the mat height is given by the following expression:

D = 0.9733*H+2.7333 (4)

he energy provided by the wind kinetic energy, is a function of the mass and velocity of the air volume. If we consider that the density of air (air mass per unit volume) is constant, we can say that the energy supplied by the wind speed is a function of:

The kinetic energy supplied by the wind:

$$E_c = \frac{1}{2}.m.V^2 \qquad (5)$$

.m: Mass of the volume of air (kg).
.V: Instantaneous wind speed (m / s).
.E_c: Kinetic energy (Joule).

Since, wind speed increases with height mast increases with the empirical relationship of Davenport and Harris [13].

$$\frac{V_0}{V} = \left(\frac{H_0}{H}\right)^{\alpha} \qquad (6)$$

The reference speed is usually the average speed V0 (observed in ten minutes, for example) at a height of 10 m or the height of the nacelle H0 upstream of the turbine. The coefficient, α, of the soil surface roughness is between 0.1 and 0.4. It is for example 0.16 for a flat or a body of water, 0.28 for woodland or suburban areas and 0.4 in urban centers. While levels of kinetic energy as a function of the felt mast height.

3.4 Effect of the diameter of the rotor on the output power

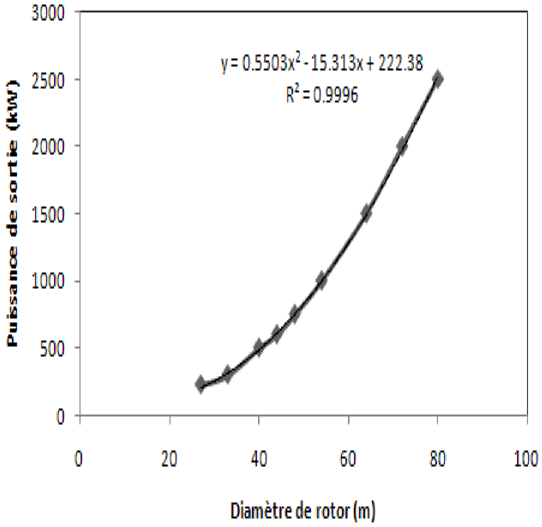

Figure-6: Effect of rotor diameter on the output power [1]

The variation of the output power as a function of rotor diameter is indicated by the following model:

$P = 0.5503*d^2 -15.313*d+222.38$ (7)

The output power as a function of rotor diameter is a branch growing dish. This is explained in the work of BETZ. In the case of a helix of diameter D, the Betz limit is equal to:

$$P = 0,37.\frac{\pi}{4}.D^2.V^3 \qquad (8)$$

Or: $P = 0,29.D^2.V^3$ (9)

because : 0,37.π/4 =0.29 (10)

3.5 Effect of wind speed on the output

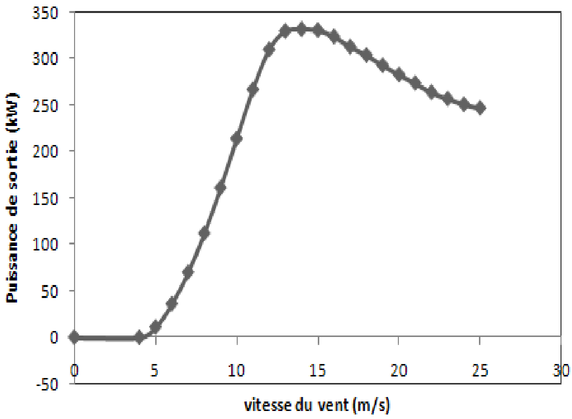

Figure-7: Effect of wind speed on the output power [1]

Curve (Figure-7) can be described by the following model:

If the value of the wind speed is between 0 and 14 m / s, then the electric power to the output is given by the following equation: P(V) = 38.673*V-180.51 (11)

With P (V) in kW regression coefficient $R^2 = 0.9775$
If the value of the wind speed is between 14 and 25 m / s, the output power is described by the following expression: P(V) = -8.9*V+463.55 (12)
With P (V) in kW regression coefficient, $R^2 = 0.9909$
The maximum yield is obtained for a wind speed of between 13 and 15 m / s. beyond this range, the recoverable power drop. This is explained by the turbulence created in the back of the light fixed, which reduces the force of the wind and therefore recoverable power decreases. A speed of 28 m / s, the machine stops because of the turbulence behind the tower.

Compared these results with those obtained by BETZ, we find that the formula BETZ used to draw a set of curves: Power as a function of wind speed with the propeller diameter as a parameter.

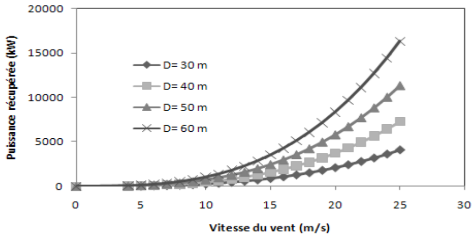

Figure-8: Effect of wind speed and rotor diameter of the recovered power (BETZ model).

Note that the curve 8 reflects limits BETZ. Therefore the curves are almost the same as those plotted in Figure-7 and a speed range from 0 to 14 m / s.

The speed of rotor rotation is set by the number of poles of converting mechanical energy into electrical energy. For example for a frequency equal to the STEG f = 50 Hz, then the number of stoves, P, is connected to the rotational speed N (rev / min) by the following relationship: N= 60 * f / p (13)
If p = 2 then N = 60 * 50/2 1 = 1500 rev / min.

3.6 Effect of the tower height and diameter of the blades on the recoverable power

Combining equations (6) and (9) gives:

$$P = 0.29 * D^2 * V_0^{\alpha} * \left(\frac{H}{H_0}\right)^{3\alpha} \quad (14)$$

Then the recoverable power is proportional to the wind speed, but it is highly dependent to the dimensional characteristics of the wind turbine, including the tower height and diameter of the blades.
The logarithm of equation (14):
Ln (p) = 0.58 * ln (D) + α * Ln (V0) + 3 * α * Ln (H/H0) (15)

Equation (15) clearly shows that if (3 * α> 0.58), while the height has more influence than the diameter of the power, if not otherwise take place.

3.7 Effect of tower height and blade diameter of investment in wind energy

The specific cost of kWh per year, which is defined as follows:

$$C_S = \frac{Cout\ de\ l'investissement}{Energie\ annulle\ produite} \text{ Millimes / Kw / h} \quad (16)$$

The energy for the wind energy potential of the site, performance, availability, location and number of turbines and the load factor. The apportionment of costs of producing a kWh is as follows [5]: 70%: investment, 25%, maintenance and operating costs and 5%: visits. So the investment cost is a very important share. This importance is mainly due to the dimensions of the devices. If this cost is C_{inv} a function of diameter D and the height H of which the shape is similar to that of the recoverable power (Equation 14), then:

$$C_{inv} = a_1 D^{\delta 1} H^{\delta 2} + a_2 \quad (17)$$

With: a1, a2, $\delta 1$ and $\delta 2$ are positive constants which reflect the nature of materials used, type of turbines and so on. So to minimize the investment and reduce the specific cost of kWh, Cs, and the repayment period must maximize the following function:

$$C_S = (a_1 D^{\delta 1} H^{\delta 2} + a_2) \ / \ 0.29 * D^2 * V_0^{\alpha} * \left(\frac{H}{H_0}\right)^{3\alpha} \quad (18)$$

This amounts to finding the optimal diameter and height. To do this, we must first seek data to determine the coefficients a1, a2, $\delta 1$ and $\delta 2$ either we proceed by mathematical calculation to determine the optimal values of these coefficients.

IV. Conclusion

In this work, we modeled the experimental results obtained by the services of the company STEG and Madee, on the site of Sidi Daoud. Site characteristics as well as wind turbines are established in the form of models. Device performance was studied and determined based on site characteristics (wind speed, roughness, etc..) And dimensional characteristics of the device (diameter blades and tower height). We set the equation to compare the effects of diameter and height of the recoverable power and therefore their effects on device performance. The optimization of blade diameters and heights of the unit allow the optimization of specific cost of investment, the recoverable power and the repayment term of the investment.

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