OPTIMIZING THE INTEGRATE OUTPUT OF A WIND ELECTRIC WATER PUMPING SYSTEM

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Received: 8 Dec 2007; accepted: 28 Dec 2007

In this work we are interested in a theoretical analysis of wind electric water pumping system of 1.5 kw and its use to meet the domestic needs for water and irrigation in the arid regions. The monthly flow could be obtained by this system in the area of Adrar is estimated for various heights of the tower and various total heads. The performances of the system depend on several parameters especially of the type of pumps installed. Thus, the use of four pumps of 5, 10, 15 and 19 stages is considered.

Keywords: electric pumping, wind speed, total head, flow rate, centrifugal pump

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Introduction

Water is the primary source of life for mankind and one of the most basic necessities for rural development. The rural demand for water for crop irrigation and domestic water supplies is increasing. At the same time, rainfall is decreasing in many arid countries, so surface water is becoming scarce. Groundwater seems to be the only alternative to this dilemma, but the groundwater table is also decreasing, which makes traditional hand pumping and bucketing difficult. As these trends continue, mechanized water pumping will become the only reliable alternative for lifting water from the ground. Diesel, gasoline, and kerosene pumps (including windmills) have traditionally been used to pump water. However, reliable solar (photovoltaic [PV]) and wind turbine pumps are now emerging on the market and are rapidly becoming more attractive than the traditional power sources. These technologies, powered by renewable energy sources (solar and wind), are especially useful in remote locations where a steady fuel supply is problematic and skilled maintenance personnel are scarce. Although traditional windmills have been used to pump water for centuries, small wind turbines are especially appealing because they can be located further from the borehole, where the wind is strongest. Because these turbines can directly produce alternating current (AC) power, they lend themselves to applications such as lighting and other infrastructure services when water does not need to be pumped. In this work, a wind pumping system of 1.5 kW nominal output is presented. The performances of this turbine coupled with various pumps are given in [1, 2], in the form of the flow rate variation according to the wind speed for various total heads, these data are used with those of the wind atlas of Algeria. The monthly flows rate which can be obtained with pumps of various stages and for various depths of well are estimated for the site of Adrar; this enables us to determine for each total head the type of pump which is appropriate best.

Estimation of the flow rate

The annual average power provided by an aerogenerator is given in the following form:

$$\overline{P} = \int_0^\infty P(V) \cdot f(V) \cdot dV. \quad (1)$$

The variation of the provided useful output is expressed with the assistance of the system of equations according to, also called quadratic law (2, 3):

$$P(V) = \begin{cases} 0 & si V \langle V_d \\ \alpha + \beta V + \gamma V^2 & si V_d \langle V \langle V_x \\ P_x & si V_x \langle V \langle V_c \\ 0 & si V \rangle V_c \end{cases} \quad (2)$$

With

$$f(V) = \left(\frac{k}{C}\right) \cdot \left(\frac{V}{C}\right)^{k-1} \cdot \exp\left[-\left(\frac{V}{C}\right)\right]^k. \quad (3)$$

After having calculated the power, the flow rate is given by the following form (4):

$$Q = \frac{\eta \cdot \overline{P}}{p_c \cdot g H_m}. \quad (4)$$

Another approach for evaluating the flow rate without passing by the calculation of the power provided by the wind turbine rests on the following relation (4, 5):

$$Q(\nu) = \int_{\nu_d}^{\nu_c} q(\nu) \cdot f(\nu)\, d\nu, \quad (5)$$

$q(\nu)$: curves expressing the variation of the flow of the used pump according to the speed of the wind.

Results and interpretations

The principal characteristics of the wind turbine chosen in our study are summarized on the following Table 1 [3].

Table 1

Principal characteristics of the wind turbine Bergey 1500

Constructor	Power output (watts)	Number of blades	Speeds (m/s)
Bergey (USA)	1500	3	V_d = 3.6 V_n = 10 V_c = 20

Fig. 1-4 represent the variation of the flow according to the speed of the wind which would provide this wind turbine coupled with a pump of 7, 10, 15 and 19 stages respectively. These pumps are immersed multicellular and of grundfos mark.

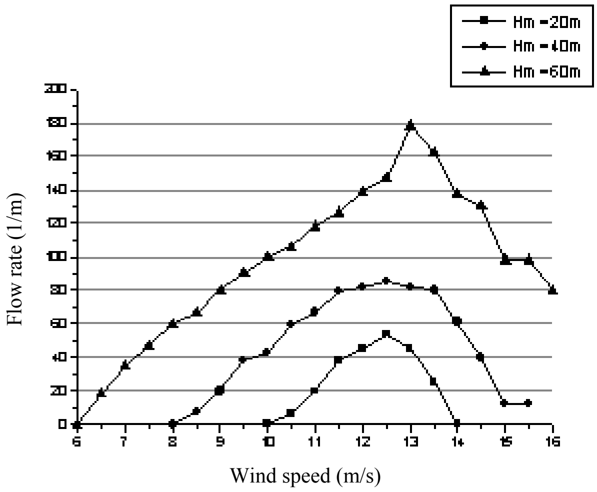

***Fig. 1.** Characteristics of a pump of 7 stages coupled with wind turbine Bergey 1500 W*

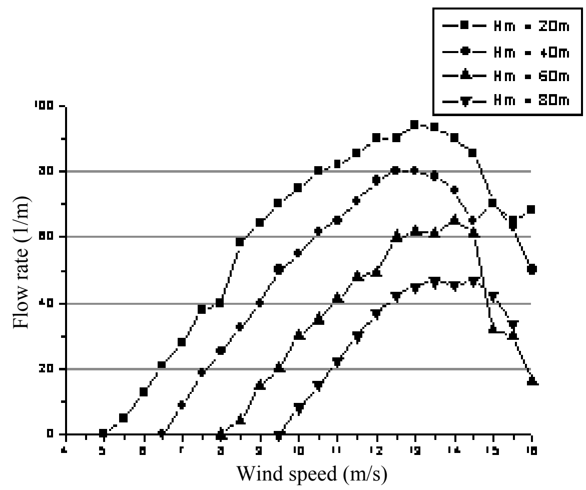

***Fig. 2.** Characteristics of a pump of 10 stages coupled with wind turbine Bergey 1500 W*

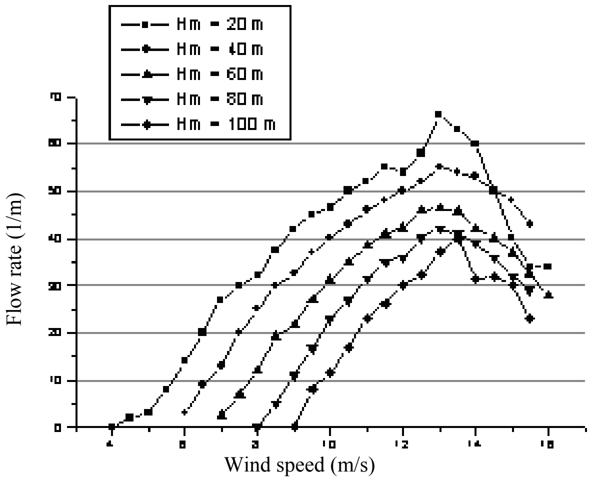

Fig. 3. *Characteristics of a pump of 15 stages coupled with wind turbine Bergey 1500 W*

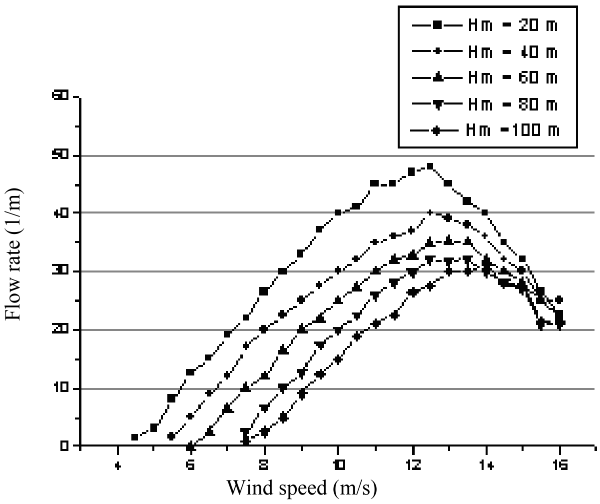

Fig. 4. *Characteristics of a pump of 19 stages coupled with wind turbine Bergey 1500 W*

Estimation of the flow rate in the site of Adrar in Algeria

A study of the wind potential available in the site of Adrar is necessary, is based on the Atlas wind of Algeria established by the ONM (National office of Meteorology).

The wind average annual speed and the annual parameter *K* have as respective values of 5.9 m/s and 2.15 m/s. The evolution of the monthly mean wind speed on the site of Adrar is presented in Fig. 5.

The examination of the curves (Fig. 6) enables us to recognize a relationship between the water flow pumped and the total head on the one hand and the height of the tower of another share. Indeed, the volume of daily water pumped varies according to the height of the pylon and the depth of the well. As an example, installed on a tower of 15 and 30 meters height, this turbine can provide on average 35.75 and 42.30 m^3/d respectively in Adrar, and this for a total head of 70 meters. For a total head of 20 meters, the medium flow provided by this wind turbine is more significant, it is about 125.13 and 148.06 m^3/d with 15 and 30 meters respectively. In Tindouf, having the same heights of the pylon, the flow is respectively 30.57 and 36.58 m^3/d for a total head of 70 meters and 107.00 and 128.05 m^3/d for a height of 20 m, which enables us to deduce what follows:

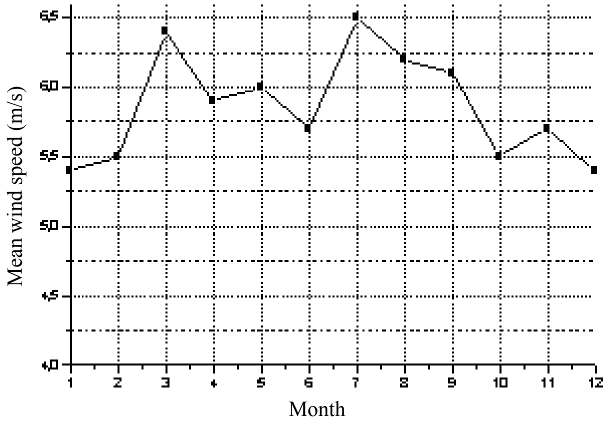

Fig. 5. *Evolution of the monthly mean wind speed in Adrar*

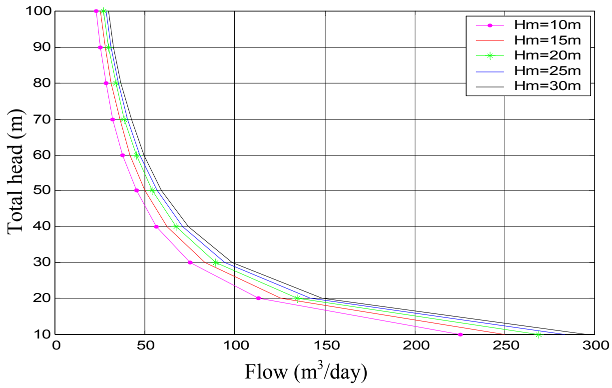

Fig. 6. *Variation of the mean flow rate provided with the total head for various heights of the tower on the site of Adrar (Bergey 1500 W)*

– The mean flow rate proves more significant when the height of the tower is considerable (because the mean power produced by the wind generator increases with the height of the pylon). So the number of hearths supplied with water will be more significant.

– When one pumps with low depths, the medium flows are more significant than those obtained with great depths.

The fact of doubling the height of the tower while passing from 15 to 30 meters makes it possible to gain up to 12 % on the speed of the wind, approximately 20 % on pumping for the two sites (Table 2).

Table 2

Hydraulic and energy profit for two heights of the tower

Height of the tower (m)	Energy profit, %	Hydraulic profit, %
15	11	11
30	16,7	20

Fig. 7-11 represent the daily outputs which a wind electric pumping system of 1500 watts can provide to the level in Adrar. Various total heads were simulated: 20, 40, 60, 80 and 100 m.

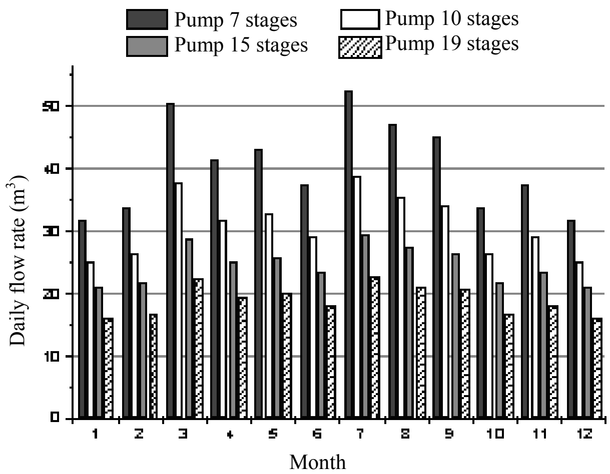

Fig. 7. *Flow rate for H_m =20 m*

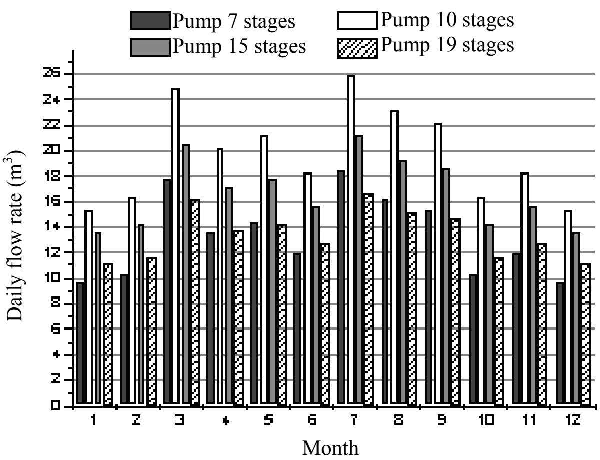

Fig. 8. *Flow rate for H_m = 40 m*

The quantities of daily water pumped for a total head of 20 m are represented on the Fig. 7. On notices that the flow reached more than 50 m 3 per day for the most been windy months (March and July), we also note that the pump with 7 stages is that which provide the greatest flow and that for every month of the year.

The difference between the flow obtained by the pump on 7 stages and the other pumps having a number of more significant stages exceeds sometimes the double.

For a total head of 40 m, Fig. 8, the quantities of water pumped decreased almost by half compared to the preceding height (20 m). Indeed for the pump of 10 stages, which is the most powerful pump for H_m = 40 m, the flows maximum reached for certain months is 25 m^3/day.

As regards the heads total 60 m and 80 m respectively represented on Fig. 9 and 10, one can say that the pump of 15 stages is the best adapted.

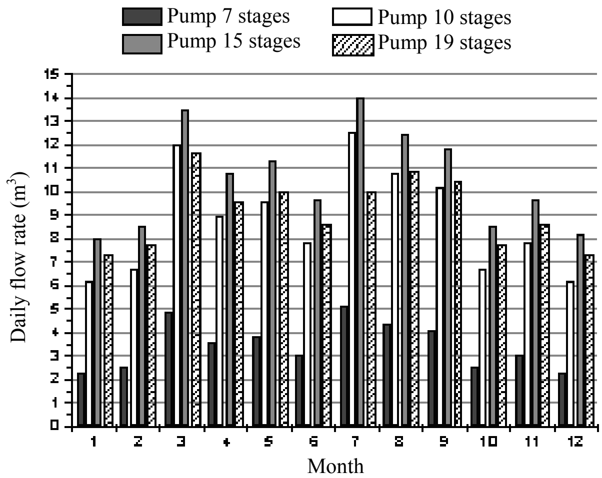

Fig. 9. *Flow rate for H_m = 60 m*

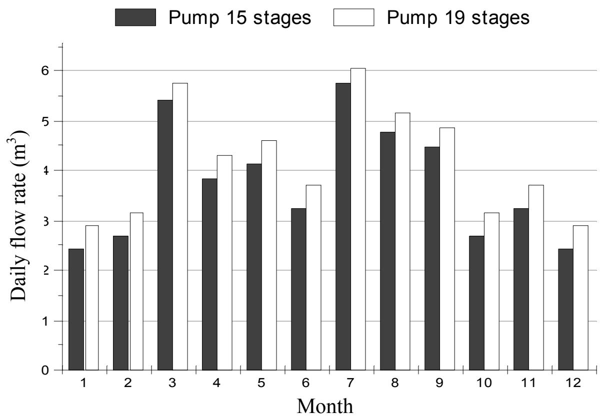

Fig. 10. *Flow rate for H_m = 80 m*

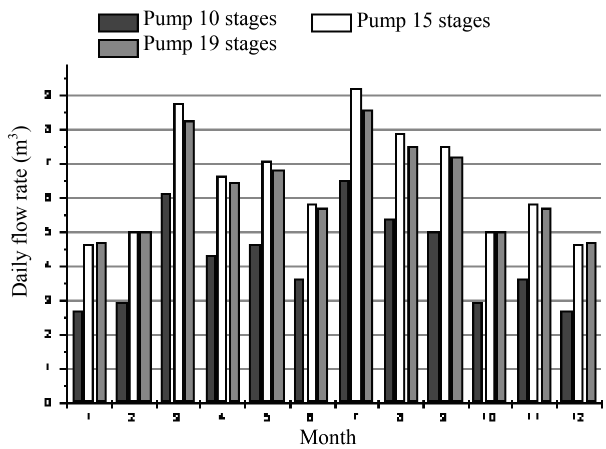

Fig. 11. *Flow rate for H_m = 100 m*

For Fig. 11 representative of the water flow pumped for a total head of 100 m. We note that the pump of 19 stages provides the best flows. Therefore it is that which is appropriate best for this height, no matter what the quantities of water pumped are rather weak of about 2.4 to 6 m^3/ day.

Conclusion

For an isolated and windy site well, the use of the wind power for pumping water can prove to be essential and very competitive compared to other sources of energy. We presented in this work a method of wind pumping electric starting from wind turbine of 1.5 kw. The monthly flows rate of water were estimated for the area of Adrar, for each simulated total head the optimal pump was obtained, one can note that more the total head is significant more the number of stage of the pump must increase. We have to as show as:

– The mean flow is significant when the height of the pylon is considerable (because the average power produced by the wind generator increases with the height of the pylon). So the number of hearths supplied with water will be more significant.

– When one pumps with low depths, the mean flows more significant than those are obtained with great depths.

Nomenclature

V – Mean wind speed, m/s
V_c – Cut out wind speed, m/s
V_d – Cut in wind speed, m/s
V_n – Rated wind speed, m/s
$f(\nu)$ – The density of probability
C – Scale parameter, m/s
k – Form parameter
Pn – Rated power, Watt
g – Average intensity of gravity, m/s^2
H_m – Total head, m
Q – Average flow rate, m^3/s
ρ – Water mass density, kg/m^3

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