SUBMISSION TEMPLATE

Research-2-Practice Forum on Renewable Energy, Water and Climate Security in Africa
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Category: Research and Scientific Contributions

The main topics of the extended abstract should fit within the areas of water, energy, climate change, the nexus within water, energy and climate change. The abstract should also be in line with ongoing projects and priorities of the research agenda at PAUWES as a contribution to the Agenda 2063 of the African union.

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Prospect Of Wind Energy as a Resource For Water Pumping In Ngaoundere

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Short Abstract

The modelling of wind energy conversion systems is of great importance if one intends to develop water pumping applications for a sustainable development. This study presents a technical assessment based on the measured wind data in which we investigate the possibility of coupling piston pump, roto-dynamic pump and electric pump with wind rotors for water pumping applications. Weibull distribution was used to model the monthly mean wind speed for a location in a rural area of Ngaoundere. It has been found that the Weibull distribution can be used to provide accurate estimation of the mean wind speed. The mean electric power and energy was computed based on the Vestas V25 and V100 power curves. Taking into account the wind regime characteristics of our site, we have provided the amount of water which can be expected from each type of wind pumps. From the results, it is clear that electric pump offers better performances than piston and roto-dynamic pumps. Furthermore, if storage devices like batteries are combined to the system, water could be pumped at any time of the day independently of the wind availability. These systems could be very useful for people living in rural areas far from urban cities.

Keywords: Weibull distribution, wind power, water pumping, Ngaoundere

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1. Introduction

In sub-Saharan Africa, operation and control of water in both rural and urban areas have become strategic issues for population growth, diversification of economic activities and the current degradation of the environment. Sensitive and complex subject, water should be open to all without any distinction but there is however still in 2018, a severe water crisis in Africa [1]. The wind pumping could be an interesting solution for people living in rural areas because it uses a free energy source and does not contributes to increased greenhouse gas emissions [2]. This study presents a technical assessment based on the measured wind data in which we investigate the possibility of coupling piston pump, roto-dynamic pump and electric pump with wind rotors for water pumping applications.

2. Methods

2.1 Weibull distribution

The probability density function (PDF) of the Weibull distribution is used to characterize the frequency distribution of wind speeds over the time and is expressed mathematically as [3, 4]:

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

This distribution is characterized by two parameters: a dimensionless shape parameter k and a scale parameter C (m/s).

2.2 Extrapolation of Weibull parameters

For this task we choose the use of the Justus and Mikhail law [4, 5]. The values of Weibull's parameters (k_h and C_h) are then evaluated at any desired height (Z_h) by the following equations (2) and (3):

$$k_h = k_a\left[1 - ALn\left(\frac{Z_h}{Z_a}\right)\right]^{-1} \qquad (2) \qquad\qquad C_h = C_a\left(\frac{Z_h}{Z_a}\right)^{n} \qquad (3)$$

$$n = B - ALnC_a \qquad (4)$$

Where constants A = 0.0881 and B = 0.37

k_a and C_a are, respectively, the shape parameter and the scale parameter at the anemometer height Z_a = 10 m.

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2.3 Wind pump discharges

2.3.1 Piston pump

The pumped volume flow rate expected from a wind driven piston pump [6], installed at a given site, over a period T is obtained by computing equation (5).

$$Q_P = 2C_{Pd}\eta(T,P)\frac{\rho_a}{\rho_W}\frac{\pi D_T^2}{4gH}T\int_{V_I}^{V_O} V^3\left[1-K_O\left(\frac{V_I}{V}\right)^2\right]K_O\left(\frac{V_I}{V}\right)^2\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1}exp\left[-\left(\frac{V}{C}\right)^k\right]dV \quad (5)$$

where C_{pd} is the power coefficient of the rotor at the design point, η(T,P) is the combined transmission and pump efficiency, K_O is a constant taking care of the starting behaviour of the rotor pump combination, V_I and V_O are respectively cut-in wind speed and cut-out wind speed, T is the period of data, H the pumping head.

2.3.2 Roto-dynamic pump

Based on the study of Mathew and Pandey in 2003 [7], we have integrated the wind regime characteristics with the model to obtain the integrated output of the roto-dynamic pump.

$$Q_R = \frac{1}{8}kC_{Pd}\eta_{Pd}D_T\frac{\rho_a}{\rho_W}\frac{V_d^3}{gH}\frac{G\lambda_d}{N_{Pd}}T\int_{V_I}^{V_O}\left(\frac{V}{C}\right)^k exp\left[-\left(\frac{V}{C}\right)^k\right]dV \quad (6)$$

Where C_{pd} is the design power coefficient, η_{pd} is efficiency, D_T is the diameter of the rotor, G is the gear ratio, λ_d is the design tip ratio, N_{pd} is the pump speed at design point and V_d is the design wind velocity.

2.3.3 Electric pump

The pumped volume flow rate of an electric pump is estimated by solving numerically equation (7):

$$Q_E = \frac{\eta T}{\rho_W gH}\left\{\int_{V_I}^{V_R}\left[\frac{P_{i+1}-P_i}{V_{i+1}-V_i}(V-V_i)+P_i\right]\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1}exp\left[-\left(\frac{V}{C}\right)^k\right]dV + P_R\int_{V_R}^{V_O}\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{k-1}exp\left[-\left(\frac{V}{C}\right)^k\right]dV\right\} \quad (7)$$

In the present study, the computation of equations was made through Fortran codes that we wrote using for this task Eclipse Juno which is an open source integrated development environment [8].

3. Results and discussion

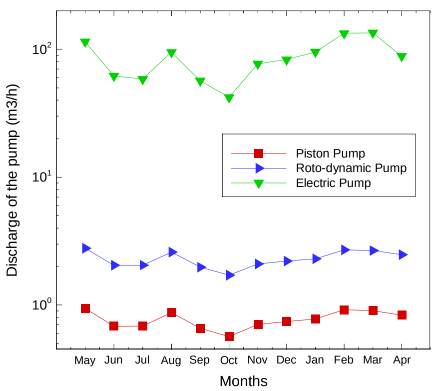

Figure 1: Monthly water discharge

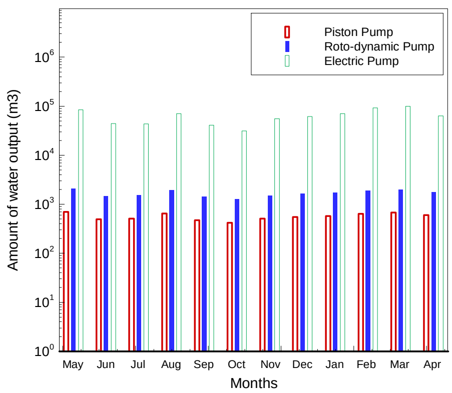

Figure 2: Monthly water amount for each type of pump

Monthly pumped volume flow rate and water amount of piston, roto-dynamic and electric pumps are plotted in Figure 1 and Figure 2. It can be seen that the rate of discharge patterns are similar to each other. On Figure 1, we can clearly see that at the same height, the monthly discharge rate of the electric pump is upper than the one of the roto-dynamic pump which is itself upper than the piston one. Also, we can notice that an important gap exists between the volume flow rate of the electric pump and the two other types of pump. On the other

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hand, it is less important between volume flow rates of piston and roto-dynamic pumps. In the months of May, Aug, Feb, Mar and Apr monthly mean wind speeds are upper than 2.7 m/s and therefore more wind energy can be captured by wind turbines and pumped water flows rates are consequent.

4. Conclusions

In this study the potential of the development of water pumping using wind energy in Ngaoundere is carried out. Energy produced by the rotor in wind regimes following the Weibull distribution and the amount of water output from three types of pump are estimated. The most important outcomes of the study can be summarized as follows:

- The monthly mean wind speeds are recorded as 1.292 and 1.794 m/s in October and February for the minimum and maximum values respectively at 10 m height; the monthly mean electric power and energy at 40 m height are computed as 4.40 kW, 3.274 MWh in October and 14.04 kW, 10.453 MWh in March for the minimum and maximum values. At 80 m height, these values are respectively 123.70 kW, 92.036 MWh in October, 287.94 kW in February and 213.471 MWh in March. These wind speeds, power and energy are found to be suitable for micro wind turbines with lower cut in speeds.
- There is a good agreement between the predicted values of the mean wind speed and those obtained from data suggesting that the Weibull distribution can be used to provide accurate estimation of the mean wind speed.
- The monthly amount of water has minimum and maximum average values of 422 m^3 and 674 m^3 for the piston pump, 1275 m^3 and 1982 m^3 for the roto-dynamic pump and 31334 m^3 and 100042 m^3 for the electric pump.
- At the same height, results show that electric pump offer better performances than piston and roto-dynamic pumps.

Underground water can be pumped using wind power and this can be a first step solution for people living in remote areas. We are expecting that with partnership among African and European institutions this project could be realized.

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