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Compilation and Evaluation of Wind Energy Resources in Jebel Awlia Area, South Khartoum

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Abstract

The experiment was conducted at University of Neelain, Faculty of Agricultural Technology and Fish Science at Jebel Awlia. The aim of this study is to know which of the locations in the regions would have more wind power density where wind energy conversion system (WECS) could be installed for electricity generation in Jebel Awlia Area, South Khartoum with excellent percentage of clean energy. In this research we used a horizontal axis wind turbine with a components of a horizontal axis wind turbine (gearbox, rotor shaft and brake assembly) being lifted into position. Material used in this research is blade of a mobile rotor, generator, tower, batteries charge controller, accumulators and inverter. Power was calculated under constant acceleration, the kinetic energy of an object having mass and velocity is equal to the work done in displacing that object from rest to a distance under a force. The result indicated that the system efficiency is very good (79%), also the system gave a very good electrical efficiency of 77%.

Keyword

Wind Energy, Wind Turbine, Blade, Tower, Axis

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1. Introduction

Wind energy is a free, clean and inexhaustible energy source. It has served mankind for many centuries by propelling ships and driving wind turbines to grind grains and pump water. Wind power and other forms of solar power are being strongly encouraged. Wind power may become a major source of energy in spite of slightly higher costs than other traditional sources of energy generation. Considerable progress is being made in making wind powerless expensive, but even without a clear cost advantage; wind power will become important in the world energy sources. Wind energy is the world's fastest growing energy source and it can power industry, businesses and homes with clean, renewable electricity for many years to come. Wind turbines do not consume fuel due to its operation. It does not produce emissions such as carbon dioxide, sulphur dioxide, mercury, particulates or any other type of air pollution (Alsaad, 2013).

The use of wind as a power source has a long history. Man has been familiar with the use of windmills and pumps; sailing ships were, in the past, the most significant example of its technical utilization.

Although the cost of wind energy has decreased substantially during the last couple of decades and the growth rate of installed power is high, its share of total energy is very low. In fact, wind energy produces only about 0.54% of the world's electric power (Bolinger and Wiser, 2001; Jacobson and Masters, 2001). The two main barriers to large-scale implementation of wind power are:

(1) The perceived inter-mittency of winds.

(2) The difficulty in identifying good wind locations,

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especially in developing countries.

Shata (2006) worked on evaluation of wind energy potential and electricity generation on the coast of Mediterranean sea in Egypt. Wind data for 10 coastal meteorological stations along the Mediterranean Sea in Egypt was used in the analysis. Results show that wind energy potential along the coast of Mediterranean sea in north Egypt is quite promising.

Experience in wind energy in Sudan was started since 1950s, where 250 wind pumps from Australian government, had been installed in El Gezira Agricultural Scheme for water pumping. But due to difficulties of obtaining spare-parts and availability of diesel pumps, these machines were not working now (Energy Research Institute, 1997).

In the last 15 years Energy Research Institute (ERI) installed 15 CWD 5000 wind pumps around Khartoum area, northern state, and eastern state. Now ERI with cooperation of Sudanese Agricultural Bank (SAB) introduced 60 wind pumps to be use for water pumping in agricultural schemes, but not yet manufactured due to lack of financial support. Local production of wind machines should be encouraged in both public and private sectors. The presented work on development of a mechanical wind pump has going on in Sudan for several years. It is based on a multi-bladed rotor with high efficiency. The aim has been to develop a wind pump, which needs limited service; and maintenance and meets for mass production (Omer, 1998).

In the beginning, priority has to be given to further industrial improvement of the technology around Khartoum. Once the technology is sufficiently reliable, the focus has to shift to applications in more remote areas for irrigation and for water supply purposes. The overall specifications of modified CWD 5000 wind pump are finally tested at ERI-site "Soba", and again those proved wind pumps were installed at Karima (2 pumps); and Toker (2 pumps). The maximum wind pump efficiency that can be obtained theoretical is 59.3%, known as Betz efficiency. The actual value that can be achieved practically is less than the above because of mechanical losses and aerodynamic problems.

Not all the energy of blowing wind can be harvested, since conservation of mass requires that as much mass of air exits the turbine as enters it. Betz's law gives the maximal achievable extraction of wind power by a wind turbine as 59% of the total kinetic energy of the air flowing through the turbine (Anon, 2010).

Further inefficiencies, such as rotor blade friction and drag, gearbox losses, generator and converter losses, reduce the power delivered by a wind turbine, also efficiency can decrease slightly over time due to wear by about 1.2% per year (Tony, 2001).

Wind turbines can rotate about either a horizontal or a vertical axis, the former being both older and more common (Hugh, 2007).

(1) Horizontal axis: Components of a horizontal axis wind turbine (gearbox, rotor shaft and brake assembly) being lifted into position. They have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind.

(2) Vertical axis: Vertical-axis wind turbines have the main rotor shaft arranged vertically. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective, which is an advantage on a site where the wind direction is highly variable. It is also an advantage when the turbine is integrated into a building because it is inherently less steerable. Also, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, improving accessibility for maintenance.

The key disadvantages include the relatively low rotational speed with the consequential higher torque and hence higher cost of the drive train (Dabiri, 2011).

Annual mean wind speeds were derived from the original monthly mean wind speeds. Annual mean wind powers were derived from monthly mean wind speeds, which were calculated according to the following procedure (Omer, 1997):

$$P = 0.3409 \text{ x } V^3$$

Where: V = monthly mean wind speed in m s^{-1}

P =annual mean wind power in Wm^{-2}.

There are numerous limitations to the implementation of wind energy program in Sudan. The major problem is the inadequate provision of funds and apparently high cost of locally manufactured wind machines. Most of the raw materials such as steel used in the manufacturing process are not locally available and therefore, makes for a significant contribution to the cost.

2. Material and Methods

The experimental was conducted at Elneelain University, Faculty of Agricultural Technology and Fish Science at Jebel Awlia, 70 km south of Khartoum city during 2011/2012 season. The study area falls in the 'arid' climatic zone of the Sudan, the mean annual temperature is 29.90C. The average annual rainfall is about 121 mm. The area also falls under the effects of northerly winds in October through May and south westerly winds from late June through October.

The wind speed data were collected during the period at 10m height using a cup anemometer at Jebel Awlia meteorological station.

Material used in this research is:

1. Blade of a mobile rotor made from aluminum with three wings with angle between each two was 120 degree and length of radius of 1.8 meters, which gave 250 – 300 revolution per minute.

2. Generator (it is synchronous three-phase with excitation from constant magnets voltage =24 V).

3. Tower with the extensions made from a galvanized steel with radius of 20cm and length of 5.5 meters.

4. Batteries charge controller.

5. Accumulators (unattended, automobile's of 24 V capacity, usually).

6. Inverter (= 12 V - > ~ 220 V 50 Hz.). Its name is converter.

3. Results and Discussion

Under constant acceleration, the kinetic energy of an object having mass (m) and velocity (v) is equal to the work done (W) in displacing that object from rest to a distance (s) under a force (F), using the third equation of motion:

$V^2= U^2 = 2as$, we get:

$$a = \frac{(V2-U2)}{2s} .$$

Since the initial velocity of the object is zero, i.e. U = 0, we get:

$$a = \frac{V2}{2s}$$

Then the kinetic energy of a mass in motions is:

$$E = \frac{1}{2} m V^2$$

The power in the wind is given by the rate of change of energy:

$$P = \frac{dE}{dt} = \frac{1}{2} V^2 \frac{dm}{dt}$$

As mass flow rate is given by:

$$\frac{dm}{dt} = \rho A \frac{dx}{dt}$$

and the rate of change of distance is given by:

$$\frac{dx}{dt} = V$$

we get:

$$\frac{dm}{dt} = \rho AV$$

Then the power density evaluation is a fundamental importance in the assessment of wind energy in a given area. The wind power density depends on the air density, the cube of the wind speed and the wind speed distribution.

Therefore, this parameter is generally considered a better indicator of wind resource than the wind speed. It can be estimated by using the equation:

$$P = \frac{1}{2} \rho AV^3$$

Where:

P = Power in watts (W)

A = Area perpendicular to wind speed vector in (m2)

V = Wind speed in (m/s)

ρ = Average density of air in (kg/m^3)

The results obtained are:

m = 2.1 kg

P_{max} (Input)= 754 W

Pi (Output) = 600 W

$$\text{System efficiency} = \frac{600}{754} \times 100 = 79\ \%$$

Electricity obtained= 600 kv

Losses:

Internal resistance = 1.5 %

Cables = 1.5 %

Batteries = 20 %

Output electricity = 462 kv

$$\text{Electricity efficiency} = \frac{462}{600} \times 100 = 77\ \%$$

The result indicated that the system efficiency is very good (79%) and the system gave a very good electrical efficiency of 77%. This result is in agreement with Omer (1998) who mentions that the output power is less than the calculated mechanical power, Also Energy Research Institute (1997) mention that, the maximum wind pump efficiency that can be obtained theoretical is 59.3%, known as Betz efficiency.

The actual value that can be achieved practically is less than the above because of mechanical losses and aerodynamic problems. Also further inefficiencies, such as rotor blade friction and drag, gearbox losses, generator and converter losses, reduce the power delivered by a wind turbine, also efficiency can decrease slightly over time due to wear by about 1.2% per year as mentioned by Tony, (2001).

4. Conclusions

The following is concluded:

(1) Mean wind speeds of 4.5 $ms^{-1}$are available over 50% of

Sudan, which well suited for water lifting and intermittent power requirements.

(2) Local manufacturer, whenever possible, is too emphasized to avail wind pump systems. Low cost designs as well as reliable devices have to be provided.

(3) There are substantial power production fluctuations due to variation in wind speed, and using storage devices can smooth these out.

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