IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE)
e-ISSN: 2348-019X, p-ISSN: 2348-0181, Volume 12, Issue 3 (May. – June. 2025), PP 25-30
www.iosrjournals.org

Design and Implementation of Improvised Portable Wind Turbine System for Domestic Applications

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Abstract
This research carried out the design, construction and performance analysis of locally made portable wind turbine for domestic applications. Today, world is immensely seeking clean, renewable and cost effective energy to reduce greenhouse gases, which problem is becoming a global issue. Constructing a small wind turbine provides useful quantity of environmental friendly energy, to supply houses and workshops, without ejection of carbon-monoxide into the atmosphere. The conversion of kinetic energy in form of mechanical energy is transformed to generate electrical energy by vertical axis wind turbine, derived from 12 Volts car alternator. The car alternator used differs from a DC motor in that it contains no permanent magnet, instead there are two concentric wound coils of wire within the alternator. A stator coil, which does not rotate and a rotor coils were attached to the alternator's shaft for movement. Electromagnetic field is created whenever current flows through the field coil, the resultant magnetic field sweeps clockwise through the coil of wire and electricity is generated in the stator coil.
Keywords: *Wind, Turbine, electricity, renewable energy, car alternator.*

I. Introduction

Wind power has been utilized throughout history, dating back to 500 A.D. in Persia, when the first windmills were developed for grain-grinding and water pumping. The wind power industries did not adopt any substantial growth however, until the 1970 when oil prices rose sharply and people began to question the world's reliance on non-renewable fossil fuels. It was not until then that the interest in wind power rose again. Following the 1970's, wind energy programs were established in United States and most European nations. Both private companies and the government began to conduct research on wind generators. This development sparked the creation of larger wind generators, some capable of producing megawatts of electric power, and they soon began to be installed in a number of countries worldwide. Presently, wind generated power is highly sought after and the technology is on a rapid increase due to the high price, environmental degradation and diminishing quantity of fossil fuel resources. The earliest use of a windmill to generate electricity was carried out by Charles F. Brush in Cleveland, Ohio in 1888 and by 1908 there were over 70 windmills in operation with capacities ranging from 5 to 25 KW. By the 1930s, windmills with capacities as high as 100 KW were in use as a source of electricity, particularly in remote areas where centralized distribution systems had not yet been installed. A wind turbine is a device that converts the kinetic energy of the wind into mechanical energy. This mechanical energy can be used for specific tasks (such as grinding grain or pumping water) or for driving a generator that converts the mechanical energy into electricity, which could be supplied to the power grid or individual users.

II. Methodology

Wind turbines are not generally connected directly to electrical loads. This is because wind power varies constantly, so the voltage and frequency will constantly be changing. The simplest solution is the use of a battery bank with inverter or stand-alone inverters, depending on the system.
These are the two types of wind turbine connection:

i. Stand-alone system
ii. Grid-connected system

2.1 Stand-alone System

This is a system that is not connected to the Grid of supply. It requires the use of batteries to store the excess generate energy, which will be used when wind is not available. Figure 1 gives the description of a stand-alone arrangement. This system also requires a controller to protect the batteries from overcharging, an inverter for rectifying the direct current from batteries to alternate current and a smoothing stage. Although this disposition lowers slightly the efficiency and capacity to achieve industrialization of the system, it however allows the electric installation of workshops and homes (Liten 2007).Stand-alone is designed for system alternating current, which is the better option for electric official standards, but the problem for this large loads is high power consumption; three-phase motor consumes intensively very large power in a short time and the system will not be qualified for such operation. For home-use safety, batteries should be installed in isolation away from the living areas and away from electronics equipments because they contain corrosive and explosive substances. At the final stage, the Lead-acid batteries need to be protected from extreme temperatures.

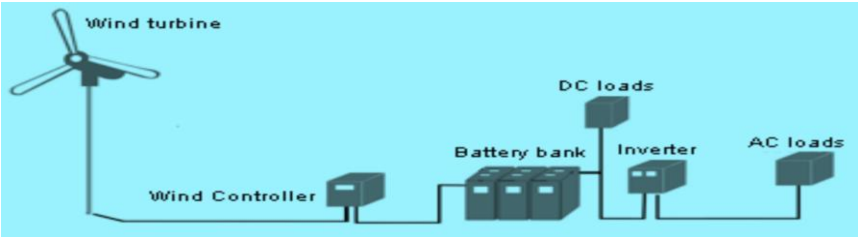

Figure1:Standalone System

2.2 Grid-Connected Systems

In this research, grid-connected system has been chosen for the design of small wind turbine system for domestic use, to save electricity bills. This small wind turbine system cannot supply power to the entire house. A gird-connected system allows it to power a home or small business with renewable energy during those periods; diurnally as well as seasonal, when the sun is shinning or the wind is blowing. Any excess electricity generated is fed back into the grid. When renewable resources are unavailable, electricity from the grid supplies the home, thus eliminating the expense of electricity storage devices like batteries.In such systems, the only additional equipment required is the inverter, which makes the electricity produced by the turbine compatible with the network.

2.3 Design Procedure

The procedure on how the construction of small wind turbine is carried out with the use of arc welding machine, hack saw, fabrication, grinding machine and drilling machine is discussed along with the result analysis carried out with the multi-meter, to test the current and voltage produced to charge battery.

2.3.1 ***Small Wind Turbine Voltage Selection***

The wind turbine was designed as horizontal axis upward machine. This produces a higher efficiency than vertical axis machines (Clarke, 2003). The fundamental idea of this design is to make a realistic study on constructing a small wind generator to power few home appliances. Therefore, a system (car alternator) with installed power capacity of was 12 V has been chosen.

2.3.2 ***Construction Procedures***

The construction work and design for this wind turbine was carried out at a welder a shop in Malete, Kwara State University in which all the sketching, cutting, fabricating, drilling and arc welding were done at the welders' workshop.

2.4 Design of 3-dimensional blades

The construction of each blade, with the use of 0.5 mm steel plate, the cutting of the steel plate is done with the use of chisels and hammer-force. 1 ft blade length was measured with the tape rule; the blade length was chosen to be 1 ft so as to minimize imposition on the base blade (2.7 inch), and top blade (1.8 inch). A 4.5 mm thick steel plate with a diameter of 86 mm was measured with vernier caliper. Hub pipe length measured to be 31 mm was welded to the 4.5 mm thick plate, with a hole drilled on the pipe. A ten-spanner size (6 mm tap tread) bolt was welded on pipe, to hold the complete blade hub firm and tight on the alternator shaft. The blade network is flexible enough to be driven by wind, as shown in Figure 2.

Figure 2: constructed Turbine (3-dimensional blade)

2.4.1 Alternator Frame (3-angle bar steel) Welding

The frame made up of 3-angle bar steel, which was cut in three different lengths (top breath 6.7 inch, base breath 6.2 inch and height 7.8 inch), was welded together joint to joint of the three joint firmly with gauge 12 electrode. This is shown in Figure 3. There was a need to use the square bar to check if the 3-angle bar is perfectly square. This will make the angles to be at 90^{o} to one another, before securing a permanent welding.

Figure. 3: Alternator Frame (3-angle bar steel)

2.4.2 Welding of Galvanized Pipe Stand

The galvanized pipe, measured to length 50.6 inch was welded to the 4 mm thick steel plate, the plate was improvised to balance the galvanized steel pipe, and connected to the alternator to generate wind direction, mounted on the galvanized pipe. The 4 mm thick plate holds the whole wind turbine rigid from falling due to high wind speed. The reason behind the use of galvanized steel pipe is to resist corrosion due to moisture and rain fall, hence increasing the life span of the component materials.

2.4.3 Welding of Tale (Wind Direction)

Steel plate of 0.5 mm thick was cut out with the use of grinding machine, cutting disc tighten to the grinder was use for cutting of the tale for this wind turbine and welded to steel of (3-angle bar) with length of 21 inch. The tail keeps the turbine facing the wind direction, as shown in figure 4. The small wind turbine cannot put motors with orientation of rotor facing the wind direction; almost all small wind turbines have directional arms to guide the rotor into the wind.

Figure 4: Tail (wind direction) welded with Frame

2.5 Mounting of Alternator on Galvanized Steel Pipe

Alternator connected to the blade with the tail was tighten with two 17 spanner size bolt & not of 10 mm tap tread, which hold tight the alternator connected to the blade with the tail together with the galvanized steel pipe stand.

Figure 5: Coupled Alternator, Turbine, Frame and Galvanized Pole

2.6 **Performance analysis of wind turbine**

Wind turbines work by converting the kinetic energy of the wind first into rotational kinetic energy in the turbine and then to electrical energy that can be supplied. The energy available for conversion mainly depends on the wind speed and the swept area of the turbine. When planning a wind farm, it is imperative to know the expected power and energy output of each wind turbine to be able to calculate its economic viability.

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*, i.e.:

$$E = W = Fs \quad (1)$$

According to Newton's second Law, we have:

$$F = ma \quad (2)$$

Hence,

$$E = mas \quad (3)$$

Using the third equation of motion:

$$v^2 = u^2 + 2as \quad (4)$$

We get:

$$a = \frac{v^2 - u^2}{2s} \quad (5)$$

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

$$a = \frac{v^2}{2s} \quad (6)$$

Substituting it in equation (1), we get that the kinetic energy of a mass in motions is:

$$E = \frac{1}{2} m v^2 \quad (7)$$

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

$$P = \frac{dE}{dt} = \frac{1}{2} v^2 \frac{dm}{dt} \quad (8)$$

As mass flow rate is given by:

$$\frac{dm}{dt} = \rho A \frac{dx}{dt} \quad (9)$$

The rate of change of distance is given by:

$$\frac{dx}{dt} = v \quad (10)$$

We get:

$$\frac{dm}{dt} = \rho A v \quad (11)$$

Hence, from equation (3), the power can be defined as:

$$P = \frac{1}{2} \rho A v^3 \quad (12)$$

A German physicist Albert Betz concluded in 1919 that no wind turbine can convert more than 16/27 (59.3%) of the kinetic energy of the wind into mechanical energy turning a rotor. To this day, this is known as the ***Betz Limit*** *or* ***Betz' Law*****.** The theoretical maximum ***power efficiency***of *any* design of wind turbine is 0.59 (i.e. no more than 59% of the energy carried by the wind can be extracted by a wind turbine). This is called the "power coefficient" and is defined as:

$$C_{\rho max} = 0.59 \quad (13)$$

Also, wind turbines cannot operate at this maximum limit.
We can then calculate the power converted from the wind into rotational energy in the turbine using this equation 14.

$$P_{avail} = \frac{1}{2}\rho A v^3 C_p \quad (14)$$

The swept area of the turbine can be calculated from the length of the turbine blades using the equation 15 (for the area of a circle):

$$A = \pi r^3 \quad (15)$$

Where the radius is equal to the blade length as shown in the figure below:
The following table shows the definition of various variables used in the equation above.

Table 1: Equation (Symbols and Terms)

Symbols	Definition of Terms	Symbols	Definition of Terms
E	Kinetic energy (J)	P	Density (kg/m^3)
M	Mass (kg)	A	Swept area (m^2)
V	Wind speed (m/s)	C_p	Power coefficient
P	Power (W)	R	Radius (m)
dm/dt	Mass flow rate (kg/s)	s and x	Distance (m)
dE/dt	Energy flow rate (J/s)	T	Time (s)

III. Conclusion

In this research, small wind turbine was constructed, with the use of car alternator (DC) as it power generator and test were analyze. Metrological data collected from some selected weather stations in Nigeria, analysis of such data shows that wind power prospects in Nigeria are high. From the analysis, it was clearly seen that coastal and hilly areas are excellent sites for wind power development. Therefore, it was shown that Ilorin axis with mean wind speed of about 3.78 m/s will be cost effective if it were to be put into use in which it will increase the electricity of Nigeria.

With the assumption of placing the turbine in a location with a very moderate wind, you get a very high power generation but we must take into account the hours of operation of the turbine, since this result can be reduced, and also the performance of the facility is low. Application performance depends on the performance of the blades and alternator performance. Basically the performance of wind turbines is low for the process of transforming wind into mechanical energy (performance of the blades). Thus the choice of grid-connected system will be successful for those which the wind blowing won't be enough to drive the blade.

It is therefore recommended that renewable source of energy especially wind turbine power is one of the most use renewable energy in the world and is nature and CO_2 emission free. It will increase the current electricity in Nigeria if the Government were to put it into use, state like Sokoto and Jos should have a wind power plant to generate electricity, which will reduce the power failure we a having in Nigeria.

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