MPRI-JERT | INTERNATIONAL JOURNAL OF ENGINEERING & RESEARCH TECHNOLOGY
VOL. 11 NO.5 JUN-2020 ISSN: 1074-4741

DESIGN AND CONSTRUCTION OF A 500W/240V WIND TURBINE GENERATOR.

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Abstract

In Nigeria, insufficient electricity supply had been a major challenge for many years, several methods of supplementing the generation and distribution of electricity to meet the demand . the major components of wind turbine are: the rotor component which includes the blades for converting wind energy into low speed rotational energy, the generator components which includes electrical generator for generating 13.5 volts D.C maximum , which is later inverted to 240 volts a.c by 12 volts D.C/240 volts a.c inverter. The control system which controls output obtained from the generator, preventing it from exceeding 12 volts d.c required for charging 12 volts d.c battery,while the gear box arrangement was made to convert low speed incoming rotation to a high speed rotation .the wind turbine is capable of powering a small load of not more than 500W power which can be used as a source of electricity for domestic or an office use and again for further modification of this work, the turbine speed needs to be enhanced to generate more power for a bigger load application.

[redacted]

KEYWORDS: *Generation, Turbine, rotor, inverter, battery*

INTRODUCTION

Electricity is a set of physical phenomena associated with conversion of electric energy from other primary energies. The fundamental principle of electricity generation was discovered in the 1820s by British scientist Michael Faraday.

A wind turbine, or alternatively referred to as a wind energy converter, is a device that converts the kinetic energy (wind velocity) into electrical energy. The wind turbines are manufactured in a wide range of vertical and horizontal axis. Large turbine can be used for making contribution to a domestic power supply.

WIND ENERGY

Power has been extracted from the wind over hundreds of years with historic design known as windmills, constructed from wood, cloth and stone for the purpose of pumping water or grinding corn. A wind energy system transforms the kinetic energy of the wind into mechanical or electrical energies that can be harnessed for practical use. mechanical energy is most commonly used for pumping water in rural or remote locations. The farm windmill still seen in many rural areas and also be used for many other purposes like grinding grains, sawing, pushing a sailboat, etc. wind electric turbines generate electricity for homes and businesses and for sale to utilities.

Wind energy is an environmentally inert, clean and inexhaustible source of electric power. That is, it is another form of solar energy. The sun create wind by it uneven heating of the planet atmosphere. It is moderated by the earth rotations and irregularities on its surface. The planet's terrain, water bodies and vegetation which then affect the wind flow patterns. With the invention of wind turbines, wind energy can be harnessed and used instead of purchasing electricity from utility companies which are derived from non-renewable sources.

Furthermore, the term wind power or wind energy is used to described the process by which wind is used in generating electricity with various constraints which affect the flow of wind patterns such as vegetation, with the invention of wind turbines, wind energy can be harnessed and used to described the way by which wind is used in generating electricity or the production of mechanical power.

AIM &OBJECTIVES

The aim of this paper is to design a land-based 500W/240V wind turbine. While the objectives are:

INTERNATIONAL JOURNAL – ERT
VOL. 11 NO.5 JUN-2020 ISSN: 1074-4741

To design and construct a wind turbine generator using locally sourced materials.
To utilized the abundant wind energy available in the country to provide an alternate source of electricity.
To supply a load of 500W

STATEMENT OF PROBLEM

The unreliability of constant electrical energy supply in the country, high price and shortage of diesel, insufficient power supply from the authorities has brought about the necessity for a backup.The backup energy source should have an affinity so as to provide the anticipated power depending on the area its required to cover. The need for power supply in our today's society has become very alarming because the provision of most goods and services has a great dependence on power supply.

MOTIVATION

Vision of providing stable and reliable power supply in Nigeria. Various energy has been considered, such as nuclear, coal, gas and hydro energy of which wind energy stand oil as one with considerable quantities and potentials suitable for the country to develop a suitable model that may translates it in terms of best practice towards achieving universal access to electricity for all Nigerians in 2030.

LITERATURE REVIEW

HISTORICAL BACKGROUND

Wind energy has been used for thousands of years for milling grain, pumping water and other mechanical application. Wind power is not a new concept. The first mills were used in PERSIA (present day Iran) as early as 200 B.C. The wind wheel of hero of Alexandria marks one of the first known practical wind mill were built in Sistani, on the eastern province of Iran from the 7th century. Vertical drive shaft covered in red matting or cloth material, these wind mills were used to grind grain or draw up water and were used in grist milling and sugar cane industries (Wikipedia 2015) Windmills first appeared in Europe during the middle age. The first historical record of their use in England date to the 11th to 12th centuries and these are reports of German crusade taking their windmill making skills to Syria around 1190. By the 14th century. Dutch wind mill were used to areas of the Rhine delta. In the 20th century early wind turbine designs were driven by three basic philosophies for handling loads; (1) Withstanding (2) shedding or avoiding load and (3) Managing load mechanically, electrically or both. In the midst of this evolution, many wind turbine design saw light of day, include horizontal axes and vertical axes turbines. Turbines that spin about horizontal and vertical axes respectively and are equipped with one, two, three or multiple blades and can be classified as two or three bladed turbines with horizontal axes and upwind rotors, the choice between two or three bladed turbines is merely a matter of a tradeoff between aesthetics. Addition key turbine design consideration includes wind, rotor type, generator type, load and noise minimization, and control approach. More overcurrent trends, driven by the operating regime and the market environment, evolve development of low cost, megawatt scale turbine and light weight turbine concept. Whereas turbine operating at constant rotor speed have been dominating up to now, turbines with variation rotor speed are Becoming increasingly more common in an attempt to optimize the energy capture, laver the loads, obtain better power quality, and enable more advance power control aspects. As energy need continuously change, change the structure element associated with the new energy source need to be develop and understanding for the design and management of this project.

FACTORS AFFECTING WIND SPEED

Wind speed is affected by a number of factors, situations operating on varying scales (from micro to macro scale) . These include pressure gradient, jet steam and local weather condition. They are also links to be found between weather direction, notable with pressure gradient and surfaces that the air is to be found over.

PRESSURE GRADIENT FORCE.

This is the force generated due to the difference in horizontal pressure, and it operates from the high pressure area to a low pressure area. It is vital to wind speed, because the greater the difference in pressure, the faster the wind flows (from high to low pressure) to balance out the variation and when combined with the Coriolis Effect and friction also influences wind speed. Since a close space gradient implies a steep pressure change, it also indicates a strong wind speed. The wind direction follows the direction of change of pressure i.e. perpendicular to the isobars.

CORIOLIS EFFECT.

Due to the earth rotation, wind does not cross the isobars at right angles as the pressure gradient force direct, but gets deflected from their original path. The deviation is the result of the earth rotation and is called Coriolis Effect or Force. It changes wind direction and not its speed.

ROSSBY WAVE

Are strong wind in the upper troposphere these operates on a global scale and moves from west to east (hence bag known as westerly's) the rossby wave are themselves a different wind speed to what we experience in the lower troposphere.

LOCAL WEATHER CONDITION

Local weather condition plays a role in influencing wind speed, as the formation of hurricane, monsoon or cyclones as freak weather condition can drastically affect the velocity of the wind.

DESIGN AND CONSTRUCTION

Introduction

This aspect entails the most important aspect of the paper which includes design approach, construction, calculation and determination of certain parameters and specification used in the construction of a wind turbine generator.

Before designing equipment, decision has to be made on the choice of materials because there is always a strong interaction or relationship between material selection and design. The choice of materials made at early stage of the design may prevent the use of some special method or renders it application difficult and expensive. Some factors were put into consideration when selecting and designing of suitable materials for this paper:

The shape, size, mechanical strength, dimension, tolerance and electrical properties of the materials and their application.

Durability capability of the materials when they are subjected to operation under normal and abnormal conditions.

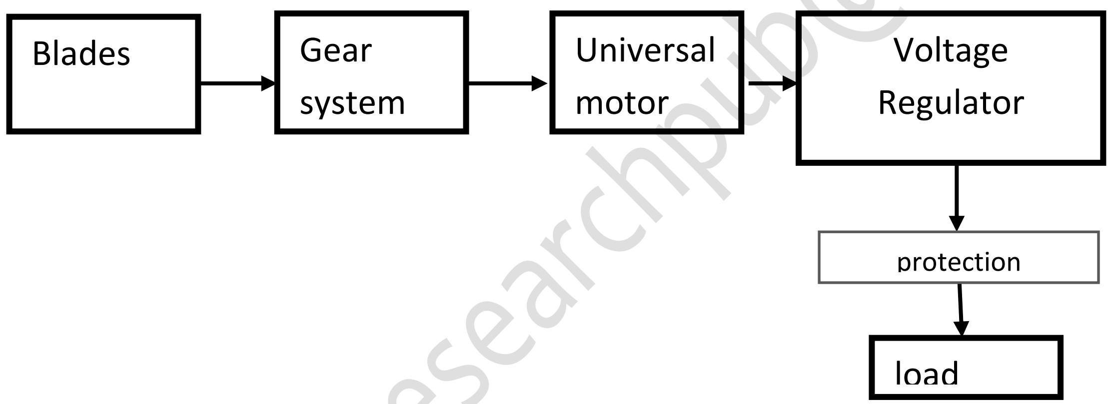

Figure 1 Block Diagram of Wind Turbine

From the block diagram above, wind blows from the region of higher pressure to low pressure in the process turn the blades of the wind turbine at high speed of about 40m/s which as a result causes the generator to generate an output power of 500w. The voltage generated by the turbine was 240Volts.

The Determination of Rotor Diameter

Assuming the main measurements of the three bladed aero generators required to power an electric power of 2.5kw at wind velocity of 8m/s (rated wind speed) and having a minimum efficiency for tip speed ratio 80 of 5 and if the rated speed of the alternator, i.e. the speed of rotation is 60rev/min / (rpm).

The diameter is estimated as:
Assuming that the efficiency of the alternator and step up generator is 80%, the mechanical power provided on the rotor shaft at 8m/s is equal to:
Power (P) = required power

$$\frac{(2.5\times10^{3})}{0.8}=31.125KW\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots1$$

But from $p=0.2VD^{2}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots2$

Which holds for a high speed wind machine?
Where V is the rated wind speed in meter per second (m/s).

I.e. D = $\frac{P}{0.2V^{3}}=\frac{3.142\times10^{3}}{0.2\times8^{3}}=\frac{3.142\times10^{3}}{102.4}=30.5CM\ldots\ldots\ldots3$

Where D = is the diameter
Therefore, the diameter of the rotor could be 30.5cm

Determination of the Magnetizing Strength of the magnets

Given that, the diameter of the coil is 16mm2 (16 x 10-6)2,

The cross-sectional area (A) = $\pi r^{2}=\pi d\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots4$

$$\frac{3}{}\quad\frac{\times(16\times10^{-6})^{2}}{4}=2.01\times10^{-10}m^{2}$$

But the magnetizing strength in Ampere tones per meter (AT/M)

$$H=\frac{\sqrt{2.1}}{(3.142\times a)}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots5$$

Where H = is the magnetizing strength of the magnet in ampere turn per meter

I = is the total current flowing through the coil in ampere and

A = is the length of side of the square coil in centimeter

From equation (4),

$$H=\frac{\sqrt{2.1}}{(3.142\text{x}0.051)}=8.8391(ATM)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots6$$

Also P = IV cosθ ……………………………………………7

Let the power factor of the generator be 0.8 leading, at a voltage output of 240 volts then,

$I = \frac{P}{V\cos\theta}$ ……………………………………………8

$I = \frac{3.125 \times 103}{240\times0.8} = 16.28 Amps$

Substituting 1 into equation (6) where $H = 8.839 \times 1628 = 14286 (ATM)$

Determination of the Magneto motive Force

The magneto motive force (mmf) generated is obtained as:

M.M.F= NI ……………………………………………9

Where N is the number of turns of coil given by:

MMF = 250 turns x 16.28 4070 (A/T)

Total M.M.F (4 coils x 4070) = 16280 (A/T)

Determination of Force on Conductor Coil

The force on a current carrying conductor lying on a magnetic field is given by

F = BILsinθ ……………………………………………10

Where L is the length of conductor in meter

Length of a coil = 5.1 x 4 = 20.4cm

Assuming, there are 600 coils; therefore the length of 600 coils will be 600 x 20.4cm = 12240cm = 122.4m

This implies that:

F = B x 122.4 x 16.28 sin θ

But cos-1θ = 36.90

F = B 122.4 x 16.28 sin 36.90

F = 1196.44 B Newton's ……………………………………………11

Where B = is the magnetic flux density of the coils and it is the flux per unit area of coil. It's deducted from;

$B = \frac{\Phi}{A}$ ……………………………………………12

Where:

B = the flux density

Φ = the magnetic flux

A is the active area cut by the flux. However;

$B = \frac{L}{4}$ ……………………………………………………13

Given the diameter 2 x radius,

Then the radius (r) = $\frac{D}{2}$ = $\frac{16 \text{ x } 10-6}{2}$= 8.0 x 10-6meter

B= $\frac{\text{L}}{4\text{x}3.142\text{r}2}$ = (8.0x10-6)2 and L = 10wb/m2

Therefore B = $\frac{10}{8.042\text{x}10-11}$ = 1.24 x 1010wb/m2

Therefore, the force F is given by: from equation 11

F = 1196.44 x 1.24 x 1010

F = 1.488 x 1013 Newton for 1m length.

Blade Design

The air is flowing from blade to blade, generating high pressure on two concave parts. The inner flow is prominent, giving a more efficient transformation of the kinetic energy into pressure at the concave faces. At B4, the flow is not efficiently captured by the blade, leading to a loss in kinetic energy (high exit velocity). The separation bubbles in the wake of the two convex parts (B5 and B6) illustrate well the negative drag. There is not much flow in the zone behind B2. There is also a separation bubble in the wake of B2 and B3, resulting in a lower pressure zone at B3 and B4, thus lowering the efficiency but B1 and B2 capture much of the wind which opposes and help eliminate the negative drag force and optimize the overall system efficiency.

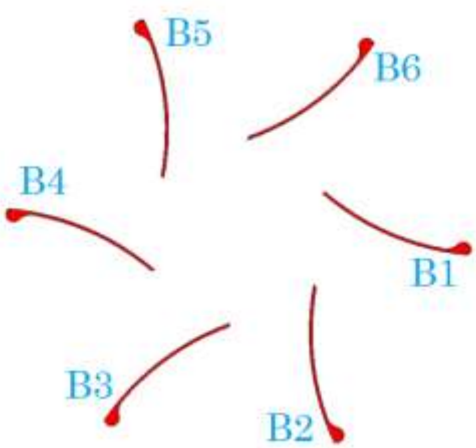

Fig 2 Blades directions

Tower

The tower is designed to resist the loads acting on it based on the desired scale of the wind turbine and desired hub height. A taller tower translates to an exponential increase in the amount of wind that is being harvested from the wind turbine because wind speed increases as the harvest height increases.

The "increase factor" of the wind speed increases exponentially as the height above a surface increases,as shown in Figure 2 from this graph, one can see that at low heights, the wind speed decreases significantly.The wind speed will also vary due to the surrounding area. The increase factor of wind speeds is higher in open areas (such as over a body of water) than in highly vegetated areas (such as wooded or built-up areas). Through years of experience, turbine manufacturers and consultants have recommended that a turbine should be at least 30 feet higher than any object within 300 feet. This rule of thumb is used to avoid rapid changes in wind velocity and direction, or turbulence.

A reduction in turbulent winds also reduces the wear and fatigue on the wind turbine.

The most widely used design of a wind turbine tower today is a freestanding, continuously tapered, cylindrical hollow steel double pole. The conical shape is efficient in simultaneously increasing the tower strength and saving materials as well as reducing the exposed profile for wind forces at higher elevations. The tower is constructed in sections from rolled steel at a desired thickness of 2inch, and is transported on site and bolted and/or welded together to create the massive towers.

The code used in conjunction with the design method is also listed. It is the responsibility of the engineer to design the wind turbine tower against local buckling, bending and combined axial and bending failures.

Height of the tower

The meteorological department in Kenya from which the design data was collected does not specify the height and the environment it obtains the data from. In this design, it is assumed that the data is collected at the minimum hub height of hub recommended by most designers of 20 meters. To harvest the needed power the rotor height should be of similar height because above that height the wind speeds would be higher by wind shear phenomenon and could cause damage to the generator. We decided that the height of the tower is approximately 8metres in height. The tower was constructed out of metal beams. Tower of such height was best suited

INTERNATIONAL JOURNAL – ERT
VOL. 11 NO.5 JUN-2020 ISSN: 1074-4741

because it was well over height of all other surroundings. This implies there was no obstruction of the wind path towards the turbine

Energy Output

The electricity output must be predicted using a probabilistic model which accounts for many different uncertainties in the wind. In order to do this, many different factors must be considered and analyzed. The key to this analysis is the power curve for the specific wind turbine, the power curve depicts the amount of electricity that the given wind turbine can generate at varying wind speeds. Because the energy contained in the wind raises exponentially for every 1 mile per hour increase in wind velocity, the electricity output of the machine also rises exponentially. The manufacturer generally produces these power curves for each of their products and provides these to the general public so that they can show how much electricity their product could produce the power output ranges from 6KW to 8KW at maximum possible running speed of 900RPM. In our design, the generates to a maximum speed of 1000s RPM after which any speed increases causes it to stall therefore minimizing the speed of rotation of the blades to the prescribed one. The probability curve above in Figure 2 estimates the amount of time the wind will be blowing at any given wind speed at a specific location. In order to do this, the average wind speed for a site is used and is evaluated using a statistical formula to model the probability density of the distribution of wind speeds. The curve that defines the assumed distribution of wind speeds is generated using certain factor that is common in the wind energy community. This factor is called the Weibull K factor, and for a curve that is predicting wind speeds the factor is assumed to be 254. This factor defines the shape of the parabola being used as shown in Figure 2. Once this parabola is developed, other factors must be taken into consideration in order to more accurately derive an expected value for the amount of electricity that will be generated by the wind turbine in the specific location. The altitude and temperature of a site also affect the expected value for the overall electricity the turbine generates. Both of these factors play a direct role in the density of the air in a given

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area, and the density of the air changes the amount of energy it contains. Equations are used to evaluate the change in energy contained in the wind colliding with the turbine, and these equations are incorporated into the spreadsheet. Often, these factors play a small role in affecting the electricity produced by the machine; however it still must be analyzed to produce results which consider all factors. The equations below are for the altitude and temperature correction in evaluating the energy in the wind coming in contact with the wind turbine:

$$\frac{1.2252 - (0.0001194 \times A)}{1.2252} = x_a$$

A = Altitude (m)

$$\frac{1013250}{2870000 \times (273.15 + T)} \times \frac{1000}{1.2252} = x_t$$

T = Temperature (°C)

The efficiency of the wind turbine is an attractive fact to know. This can be calculated by dividing the power curve energy (kW) for a given wind speed by the energy actually contained in the wind (kW) at that speed. The actual energy contained in the wind is calculated in the equation below. The entirety of this energy cannot be harvested by a wind turbine, and the energy that can be harvested is defined by the power curve of the turbine given by the manufacturer. By comparing these two numbers the efficiency of the turbine (at a given wind speed) is found:

$$E_W = \frac{(W_S 3 \times (\frac{1.225}{2}) \times A_S)}{1000}$$

$W_S =$ Wind Speed (mph)

$E_W =$ Energy in the Wind

$A_S =$ Swept Area of Blades

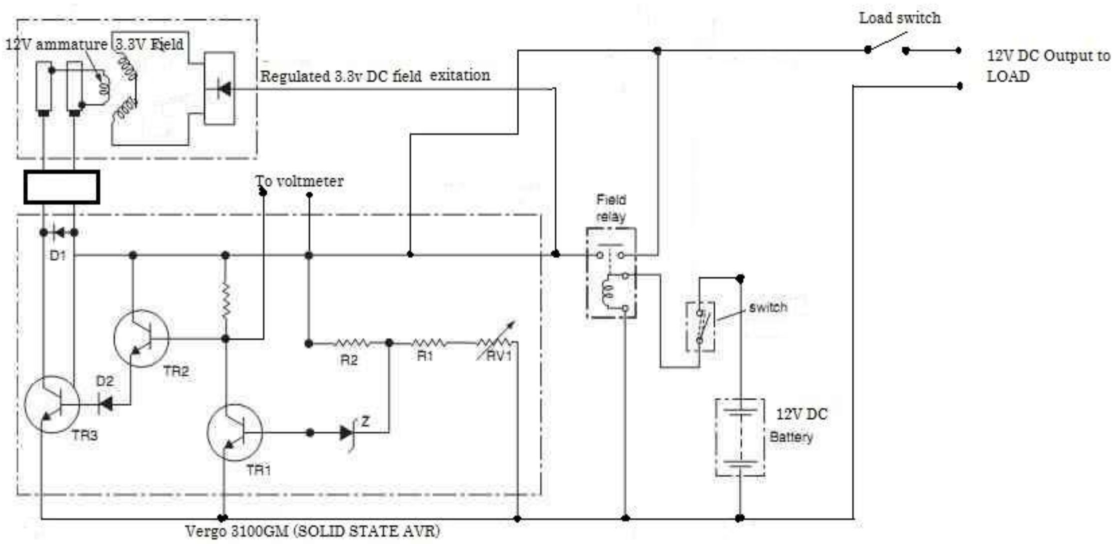

fig3. Wind turbine circuit diagrams

OBSERVATIONS, CONCLUTION AND RECOMMENDATION

Observation

A wind turbine is a device that converts the kinetic energy from the wind into electrical power. It consists of the wind turbine blades, generator (alternator), MCBs and power regulator. In the course of its design, theoretical and practical application of electric power and machine were both employed. The turbine constructed is capable of providing 500w power which can be used as a source of electricity for domestic or office use.

Conclusion

Despite the challenges involved with the design and construction of this project, the aim of generating an alternate source of electricity apart from hydro-electric generation, nuclear power plant, desiel engines and steam engines was successful using wind turbine electricity generation approach, to which a power of 500watts was realized at the end of the construction to supply electric power for either domestic or office use.

Recommendation

For further modification of this research work, the wind turbine should be designed such that the wind speed of above 5km/hr can be achieved and the power output should be able to reach at least 5KVA which can be used as a main source for industrial use that can be able to power three (3) phase electric motors/ machines for production or manufacturing of consumer goods/ equipment and I also recommend a gear box to improve the output i.e. the gear ration to be 1:100 which will enhance the system performance.

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APPENDIX: A

The BLADE

APPENDIX: B

THE GEAR SYSTEM

INTERNATIONAL JOURNAL – ERT
VOL. 11 NO.5 JUN-2020 ISSN: 1074-4741

APPENDIX C

The wind Turbine

APPENDIX D

The universal motor