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Wind Energy Conversion Components: A Tool for Sourcing Renewable Electricity Generation

E. Umukoro[1], O. Alebu[2], S. E. Igberaese[3]
[1,2]Department of Science Laboratory Technology, Auchi Polytechnic Auchi, Edo State
[3]Department of Electrical and Electronic Engineering, Auchi Polytechnic, Auchi, Edo State
([1]edafewhuotuumukoro@yahoo.com)

***Abstract*-**The wind is a natural form of energy which can be harnessed for optimal output generation using mechanical and electronic components to generate electricity. The various components which aid the conversion of wind energy into electricity are discussed in this paper. This form of energy can be used to generate electricity using a turbine. The turbine converts the wind energy to electricity and the electronic device converts the electricity to a direct current form before storage. The electricity from the wind can be stored in battery directly which serves as an alternative source to power supply or integrated into the National Grid to burst the electricity supply. The power supply to rural area is difficult due to the location of the settlement from the power generation. The wind energy generation is eco-system friendly and available all through the day and night depending on the geographical location of installation. It is cost effective and can be easily maintain using locally sourced materials.

Keywords- *Wind Energy, Turbine Conversion, Mechanical Component, Electronic Component and Storage*

I. INTRODUCTION

The demand for electricity has been a major concern all over the globe. This has led to conversion of various forms of energy to electricity to meet the high demand for industrial and domestic use. The wind is a natural endowment on the earth surface. The movement of wind creates an energy which can be converted to other forms of energy such as mechanical and electricity. The wind speed varies from one geographical location to another; therefore the components' system to be incorporated varies. The amount of wind energy present in a location determines the amount of electricity to be generated. The wind is a source of renewable energy that is safe, environmentally clean and economical. Recent technological advances in wind turbines of variable speed in power electronics and in machine drives have made wind energy a competitive form of energy, as well as the energy obtained from fossil fuels. The conservation of energy by the more efficient use of electricity has led to a reduction in fuel consumption as well as reduces environmental pollution and preservation in the dwindling fuel resources. In the process of converting wind energy to electricity, various components are involve for maximum output delivering. These components are the mechanical and electronic systems. Wind energy can generate up to 16,630 MW depending on the capacity of the turbine. The wind turbine stand-alone system can be used to produce electricity for pumping water, ice making, charging batteries and compressing air in rural settlement. The energy generated from gas and water is not renewable and has adverse effect to the environment. The converted wind energy can be stored in a battery and be used by the consumers when there is no power supply as an alternative energy source. Wind energy is converted to electricity with the aid of mechanical and electronic components.

II. WIND CONVERSION

The conversion of wind energy to other form of energies (i.e mechanical, electrical, light and heat) is by the process of assembly of components/devices to convert the wind speed available to electricity for social economic development and domestic application in a given environment. There are two types of wind known as the geothermal and wind. Electricity is generated from wind through the use of wind turbines also known as wind energy converters (WEC). The wind turbines convert the kinetic energy of wind into mechanical energy and then to electrical through the generator. The generator may be of fixed or variable speed due to changing wind speed and direction, the yaw mechanism is used to turn the blades of the wind turbines in line with wind direction to increase its output. The main components of a WEC include rotor blade, generator, pitch, wind measurement system, brake, gear box, rotor hub, yaw mechanism, nacelle, transformer, diode, capacitor, battery and tower. These components are categorized into mechanical and electronic components during the conversion of wind energy into electricity. Table 1 shows the variation of blade diameter during wind energy conversion. The schematic diagram for the conversion of wind energy components is shown in figure 1.

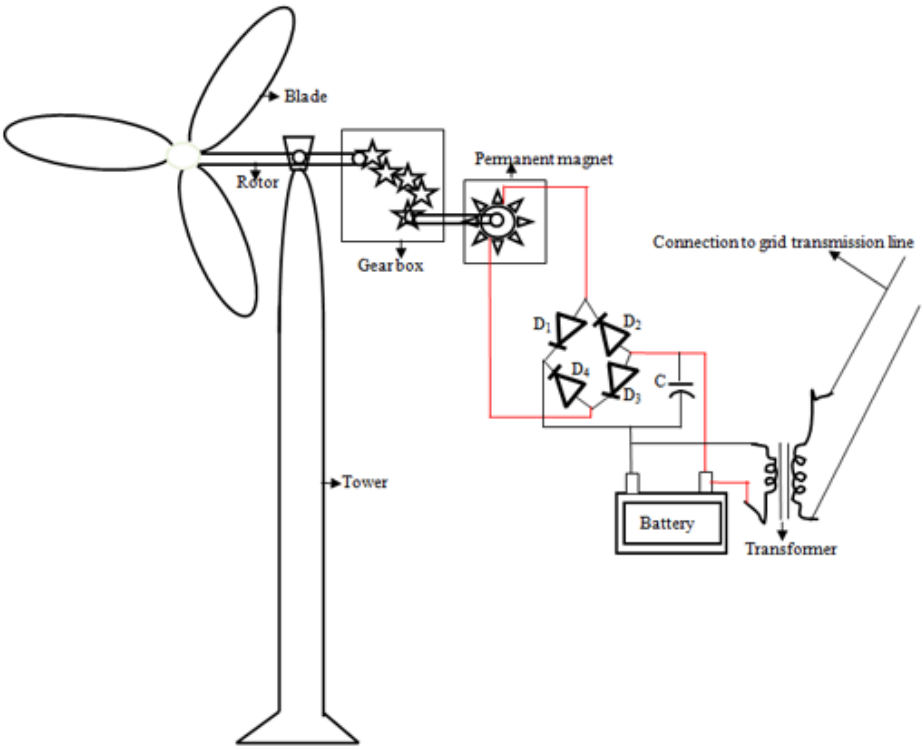

Figure 1. Wind energy conversion components

III. FACTORS AFFECTING WIND ENERGY CONVERSION

During the conversion of wind energy to electricity, the following factors such as wind speed, air density and swept area of the turbine alongside with the mechanical and electronic components must be considered for effective and efficient electrical generation.

A. Wind speed

The amount of energy in the wind varies directly to the cube of the wind speed. When the wind speed is low, the amount of the output power will be low but as the wind speed is high, there will be a corresponding increase in the power generated. Equation 1 shows the relation of power with wind speed.

$$p = \frac{1}{2}\ell \mathrm{A}\left(v^3\right) \tag{1}$$

Where

P = power (watts)

ℓ = density of air

v = wind speed

B. Air density

The density of air determines the energy generation from the wind. The more dense the air, the higher the energy received by the turbine. This factor varies with elevation and temperature of the surrounding air. The air is dense at low temperature and at sea level. Warm air is less dense than cold air. A wind turbine produces high power at lower elevation and in cooler average temperature.

C. Swept area

The swept area is a factor of the blade design. For the blade to rotate at any little movement of air, the radius must be considered for free rotation. Equation 2 shows the dependent of the swept area to the square of the radius.

$$A = Pi\left(r^2\right) \tag{2}$$

Where

A = area of the blade

P = blade pitch

i = inclination angle between blade

r = radius

IV. MECHANICAL COMPONENT

The mechanical parts in the motor system for the generation of electric current in wind conversion comprises of the rotor blade, generator, gear box, permanent magnet and tower. These parts are always in motion for the actualization of the renewable energy generation.

A. Rotor blade

The rotor blade rotates or turns by the kinetic energy from the wind. The direction of the movement of the blade is determined by the direction of the wind. The blade is fixed to the shaft which is connected to the generator and gear. As the blade rotates, the shaft moves in turn in the same direction. The blade material is made of alloy which has high resistance to drought. The angular distance between the blades must be 60^{o} to each other for a particular circle.

B. Generator

The generator is a dynamo or machine that converts mechanical energy into electrical energy. Whenever a conductor is wind on an armature which is connecting the shaft to the mechanical power source. The coil of a generator is made of copper wire and as the conductor moves through the magnetic field, the field will interface with the electrons present in the conductor to induce a flow of electric current in the system. The induced electromotive force (EMF) is equal to the rate of change of flux linkages. The generation of the EMF depends on the relative speed and relative time between the conductor and the magnetic field.

C. A.C generator

Electricity is been consumed mostly in an a.c voltage/current form at home and industry. The a.c operation uses the electromagnetic induction to produce the electricity from the wind turbine. There are two types of generator; the induction and synchronous generator. The induction generator does not require regulation and frequency control since the coils turn in a magnetic field which actuate current and voltage. But the synchronous generator is used in large size power generation. It may be the rotating field and rotating armature type. In the rotating armature type, armature is at rotor and field is at stator. The rotor armature current is taken through slip rings and brush. These limit the current produced due to high wind losses and low power output. The rotating field generator is widely employed for high power output generation since it does not require slip ring and brush components incorporation in the generator.

D. Gear box

The gear is a machine element which teeth are cut around cylindrical or cone shaped surface with equal spacing. It is enclosed in the gear box where it can freely rotate. The gear is mostly clipped to a shaft to transmit rotations and forces from a driving shaft to the driven shaft. The gear operates in pairs to transmit and modify rotary and the movement of the gear turns the armature or coil attached to the pairs of gear.

E. Permanent magnet

A permanent magnet is a device that generate magnetic field as the rotor rotate within the region of space. As the wind sets the rotor in motion, the generated mechanical energy is converted to electrical energy. In this device the rotor winding have been replaced with permanent magnet. It does not require separate DC supply to excites' the circuit or a slip ring and contact brushes. This device reduces loses in the rotor and a cool temperature system. Also, the temperature of the bearings is reduced and hence improves the reliability and lifespan of the bearing. In the conversion of wind energy to electricity, the permanent magnet produces the magnetic field for the rotor. The alternator speed is directly proportional to the output voltage of the alternator.

F. Tower

The tower is a rigid material made of mostly iron or steel that suspends the blade and rotor to a height where the wind energy is in abundant. The tower determines the effectiveness of the conversion of wind energy to electrical energy. The higher the height of the tower, the more effective and efficient electric current output generation from the wind energy.

V. ELECTRONIC COMPONENT

These are the components that convert the electrical energy to DC form for storage or AC form for use by the consumer or for transmission.

A. Diode

The diode is a unidirectional device which allows current to flow in one direction when biased. It is a p-n junction semiconductor material. The diode is use to convert the a.c to d.c before it can be stored in the battery. At times, it is connected across the coil to avert kick-back voltage.

B. Capacitor

The capacitor is used in the circuit as a fitter. This removes the alternating voltage ripples from the DC. This makes the d,c ripple more purer for storage. The higher the value of the capacitor, the better the charges produce.

C. Transformer

A transformer is a device that is used to step up or down voltage/current for transmission or distribution of electricity for home and industrial purposes. The step-up transformer is used for the wind energy conversion. It converts the low voltage energy stored in the battery of about 12 V to 500-800 V before it is integrated into the National grid for transmission to various sub-station.

D. Battery

The battery is a device which stores direct current (d.c). The energy generated from wind can be stored in the battery during the peak wind period and at low wind period; the stored energy can be converted to alternating current (a.c) for transmission. This will prevent shortage of electricity supply or total power outage.

VI. CONCLUSION

Various researches carried out on wind energy have identified that great prospects exist for wind energy utilization for renewable electricity generation. Wind power is a clean energy source that we can rely on throughout the day and night for a long period of time. It has shown from the mechanical and electronic component arrangements in figure 1 that effective and efficient wind energy conversion requires appropriate mechanical and electronic devices installation for

optimal electricity generation for domestic and industrial consumption. A wind turbine creates reliable, cost-effective and pollution-free energy. Also, wind is a source of energy which is non-polluting and renewable energy; the turbines create power without using fossil fuels. Hence, during the conversion of wind energy to electricity there is no production of greenhouse gases, radioactive or toxic waste. This makes the renewable energy conversion system environmental friendly and safe.

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