UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

DESIGN AND CONSTRUCTING OF A SMALL SCALE WIND POWER GENERATING SYSTEM BY CONVERTING A SINGLE-PHASE AC MOTOR (CEILING FAN) TO A WIND TURBINE: A CASE STUDY OF THE NORTHERN REGION OF GHANA

SULEMANA MANSURU

AUGUST, 2016

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

DESIGN AND CONSTRUCTING OF A SMALL SCALE WIND POWER GENERATING SYSTEM BY CONVERTING A SINGLE-PHASE AC MOTOR (CEILING FAN) TO A WIND TURBINE: A CASE STUDY OF THE NORTHERN REGION OF GHANA

SULEMANA MANSURU

7141200010

A Dissertation in the DEPARTMENT OF ELECTRICAL AND AUTOMOTIVE TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, submitted to the School of Graduate Studies, University of Education, Winneba in partial fulfillment of the Requirement for the award of the Master of Technology Education (Electrical/Electronic) degree.

AUGUST, 2016

DECLARATION

CANDIDATE'S DECLARATION

I, Sulemana Mansuru, declare that apart from the references to other people's work which have been duly acknowledged and cited, this dissertation is my own original work. It has neither been submitted in part nor in its entirety for another degree in this university or elsewhere.

Signed:……………………………………….

Date:…………………………….…………

SULEMANA MANSURU

SUPERVISOR'S DECLARATION

I, hereby, declare that this thesis was supervised in accordance with the guidelines of supervision of thesis as laid down by the University of Education, Winneba.

Signed:……………………………………….   Date:…………………………..

PROFESSOR WILLIE OFOSU

ACKNOWLEDGEMENT

Unto Almighty Allah the most gracious and most merciful, honour and thanks be given for his providence and guidance throughout my education.

I would like to express my sincere gratitude to my supervisor, Professor Willie Ofosu, Penn State Wilkes-Barre, for his guidance, constructive criticisms and the words of wisdom he gave me throughout this research. He was very patient, generous and kind to me throughout this study. I am very thankful.

I am also indebted to all authors from whose books, publications and websites that I made reference. I am equally grateful to all friends who supported me financially throughout my study of this program especially, Saed Fuseini and Aminu Jetumah.

I also immensely thank the Meteorological Services Department, Energy Commission of Ghana Tamale and Tamale Polytechnic Agric Department for making the wind speeds records available to me. I thank all my colleagues in the Electrical Department in Tamale Polytechnic for their contribution.

DEDICATION

I sincerely wish to dedicate this work to ALMIGHTY ALLAH for His mercy, guidance and kindness towards me and my family and also directing me through this M – Tech program. I also wish to dedicate this work to my lovely Children Mardia, Ubaidullahi, Rafida and Haafiza for giving me comfort during my study.

TABLE OF CONTENTS

Content **Page**

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

ABSTRACT

The main aim of any electric power supply system in the world is to provide uninterrupted power supply to all its consumers at all times. But in developing countries like Ghana, the electric power generated does not meet the demands of the growing number of consumers of electricity hence there is inadequate power supply which results from frequent power outages. This does not promote development in the public and private business sectors it has left many people without electricity. Even investors do not feel secure to come into a country with constant or frequent power failure. In addition, there are processes that cannot be interrupted because of their importance for instance, surgery in hospitals, transfer of money between banks and lots more. Power instability and outage in developing countries (like Ghana) creates the need for the exploration of alternative sources of power for off-grid premises or to backup the existing supply. Wind power generating system can be used for light and to power domestic appliances. Whenever continuity of supply is needed, wind power can be used as an alternative source. This project designed and constructed a Small Scale Wind Power Generating System by converting a single-phase AC motor (ceiling fan) to a wind turbine. The purpose of this project was to provide an alternative electric power source to supply those without electricity such as the villages without light, hospitals, hotels, schools and even consumers who may need backup for the main supply during power outages. The design comprised a generator (wind turbine made up of a coil and magnet), a rectifier circuit, battery charge controller unit, battery bank, circuit breaker, DC to AC inverter, step up transformer and finally connected to the load.

CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

There is global demand for better electric energy source as most industrial, commercial and domestic consumers depend on electricity. Africa as a continent is blessed with renewable energy resources and Ghana is no exception. The country's renewable energy resources are solar, hydro, wind and the biomass sources. Renewable energy has a lot of advantages over conventional sources like thermal generating plants (Francis et al., 2015). Although investing in renewable energy is expensive it is better compared to the fossil fuel alternative due to global warming (Yandra, et al., 2012). The renewable energy option becomes economically viable when environmental cost, health hazards and operating cost are taken into account. Thermal sources release a lot of toxic gases into the atmosphere resulting in global warming. Generation of thermal power is dictated by the availability of fossil fuels which are believed to be exhaustible. Shortage of fossil fuels will lead to shortage of power from this source, either now or in the future (Alfa, et al., 2013).

Ghana currently generates power through thermal and hydro sources. Both sources relay heavily on fuel and water for power generation therefore they suffer when there is fuel and water shortage. This results in shortage in power supply. Renewable energy, on the other hand, is always in abundance (Alfa et al., 2013). This source also does not release toxins into the atmosphere and hence does not cause environmental degradation as thermal power plants do. The wind is an example of renewable energy (Khan, et al., 2004). The wind is harvested and used to generate power in USA and Europe on small, medium and large scales (Addo, 2009). Wind turbines do not produce atmospheric emissions that can cause acid rain or greenhouse gases.

Wind energy can be generated at remote locations to reduce the cost of generation, transmission, support and termination which are associated with thermal and hydro power plants in Ghana. Installation of wind turbines to generated power does not take up large land space therefore it can be done in urban centres for urban power supply, and not only in remote locations (Khan, et al., 2004). Wind turbines can be built on existing farm. Wind power generation plants greatly benefit the economy in rural areas where most of the best wind sites can be found. Farmers and land owners can continue to work on lands since wind turbines use only a fraction of the land. Wind power plants owners will also make payments to the farmer or land owner for the use of his land. Consequently providing land owners with additional income. Furthermore, it has the potential of improving agriculture since most rural dwellers are farmers and could use wind power for water pumping and other agricultural purposes. It can also power a wide range of electrical appliances depending on the size of the turbines used in power generation (US Department of Energy, 2015).

Currently, some European countries are able to meet some percentage of their energy demands through the wind technology. Denmark for example already meets about 36% - 40% of its electricity from wind power generation and at least 83 other countries around the globe are also using wind power to supply electricity consumers (The World Wind

Energy Association, 2014). Countries such as Portugal, Ireland and Germany also use wind power to cater for about 17%, 13% and 11% of their national power needs respectively (The World Wind Energy Association, 2014). In view of the foregoing, although there is no adequate information available to enable any meaningful policy decision for the adaptation of wind power technology in Ghana, it can be done. The introduction of wind technology in Ghana requires on site information such as wind speed characteristics. This research focuses on the prospects of wind power generation in the Northern Region of Ghana using a simple ac motor as a wind mill in conjunction with other electronic equipment. Tamale metropolis is used for a case study in the Northern Region of Ghana using a simple ac motor as a wind turbine in conjunction with other equipment. Northern Region was chosen because very few communities in the region are connected to the National grid. Most of the populace do not have access to electricity as they live in rural areas. Also, some of these rural communities are scattered and far away from their district capitals and hence electricity providers are not easily able to connect them onto the national power grid. These scattered communities require huge capital investments before they can be connected to electricity power supply. This is because hydro and thermal power generated are far-remote from these rural communities (Abavanna, 2010).

1.1 Statement of the Problem

Electricity is the backbone of any nation's economic development. Industrialization, agriculture, health and education all depend on electricity for development. The progress of a nation depends a lot on the availability of enough electrical power, yet this vital resource is becoming increasingly scarce due to some factors. The commonest identified factors are the rising fuel prices, low water levels in dams as a result of global warming and breakdown of machines associated with hydro and thermal power generating plants. Due to the cost involved in hydro and thermal power generation, many rural communities are not connected to the national grid. These communities do not have access to electricity though they wish to. They do not enjoy the benefits that come with electricity such as health care centers using electric energy to power their hospital equipment, using electricity to power milling machines for cereals, use for entertainment facilities like cinemas and even light for children to study or read in the night. Folks from these communities have to travel very long distances just to have access to milling machines. It is therefore necessary to explore for alternative sources of electrical energy for these communities that do not have access to the electricity grid. Also, those who are already connected to the national grid may want an additional source of power for backup during grid generating failure (Abavanna, 2010).

Consequently, wind power generation is an alternative power source that has to be studied. However, according to the meteorological service of Ghana, the coastal belt has been researched as far as wind power technology is concerned. As a result, there is adequate information available to enable the energy providing authority to make any meaningful policy decision for the adaptation of wind power technology in Ghana Meteorological Service of Ghana, (2014) annual report. Also, according to the Meteorological Service department, Tamale, Yendi and Bole have the potential of wind power generating capacity with the wind speed of 3.5m/s for cut in speed and to 25m/s for cut out speed. Thus, this wind circulation can be tapped for electric power generation. This study will step on the principle of operation of motors and generators for electric power generation. It is known that ‘’a motor (e.g a ceiling fan) converts electrical energy to mechanical energy while a generator converts mechanical energy to electrical energy’’. Therefore, this experiment will focus on the principle of operation of a generator to improve on a ceiling fan so that when significant mechanical force is apply on it electricity will be generated. The motor will be turned into a generator that can produce a substantial voltage to charge a battery bank for off-grid use. This research focuses on ‘the design and construction of a small scale wind power generating system by converting a simple AC motor (ceiling fan) into a wind turbine.

1.2 The Purpose of the Study

The purpose of the study is to design and construct a small scale wind power generating system for household use especially in rural communities by converting an AC motor to a wind turbine. The researcher will also investigate into the prospects of wind power generation in the Northern Region of Ghana. According to the Meteorological Service Department in Tamale (Annual Report, 2015), Tamale, Yendi and Bole have the potential of wind power generating capacity. However, this research focuses will only be on Tamale the Northern Regional Capital. The study will assess the potential for wind electrical power in selected communities by conducting test on the designed system and compare the results to the theoretical values recorded by the meteorological Service Department using wind speed data after which some generalizations can be made.

1.3 Objectives of the Study

This research seeks to:

1. Design and construct an off-grid wind power generating system by converting a ceiling fan to a wind turbine
2. Compare the power output of the wind turbine system to the theoretical calculations.
3. Evaluate the visibility of setting up small scale wind power plant in Tamale in the Northern Region.

1.4 Scope of the Study

This study is limited to the Tamale Metropolis.

1.5 Significance of the Study

The success of this research will significantly help rural dwellers in the Northern Region to get access to electricity. First of all, if the findings of this research are positive and the recommendations are fully implemented, the rural folks who has no access to the national electricity grid and can afford to buy the equipment will now have access to electricity. Electrical power from this source will be of help to the sector of education as it will aid teachers to prepare for lessons at night and also help students to study at night. It will be of help to health centers in the locality as they would have electricity to power hospital equipment.

Additionally, the community can use it for entertainment and social functions (Abavanna, 2010). Furthermore, users connected to the national grid will have backup power for use in case the grid power goes off. This research will aid electrical energy providers such as Volta River Authority (VRA) and Electricity Company of Ghana (ECG), to make informed decisions about wind power technology and harness it for large scale wind power generation.

Government, on the other hand, will also get insight into other avenues of electrical power generation such as wind technology and, hence, aid draft policies that will lead to tapping this vital resource for commercial purpose. When wind technology is adequately harnessed it will fill up the shortfall in the production capacity of the hydropower plants in the country. Environmental pollution that led to falling water levels in hydropower plants cause shortfalls in power production as all units at the plants cannot be operated. This coupled with the high cost of power production and resulted in high tariff charges for consumers.

However, these can be solved by using wind to generate power. Aside from wind storm, normal wind energy can be tapped as renewable source that can generate electricity. It will have no negative effects on the environment hence help improve the health condition of Ghanaians (Francis, et al., 2015). In addition, it will also help to increase the nation’s revenue by reducing the amount of money use for fossil fuel import used for power generation. The excess revenue or foreign exchange of the nation can be use to support other developmental projects (Mohammed, 2009). The research if well conducted will create jobs for the youth in rural areas. Consequently, the rural-urban drift will be reduced if not totally eliminated. Some civil servants, who refuse to take up posts in rural areas due to lack of electricity, will be attracted to these villages if wind technology is used to provide electricity for these communities.

Finally, the research work may serve as a reference material for future researchers in wind power.

CHAPTER TWO

LITERATURE REVIEW

2.0 History of Electrical Energy in Ghana

The electricity Company of Ghana was established in 1961 by the first President of the Republic of Ghana, Osagyfo Dr. Kwame Nkrumah to provide electric energy for the people of this country commercially and domestically. The central Government always provides resources to acquire new equipment and tools for the expansion of the plant in order to satisfy the energy needs of the country. This has brought the idea of the rural electrification yet many communities are still leaving without electricity. (P.U.R.C annual conference 2010). The wind energy is new in Ghana and research could be done to promote its usage to partly solve the energy crisis. Ghana's energy crisis presents an opportunity for Universities, Polytechnics and technical Schools to conduct research into alternative energy sources notably solar and wind. (Daily Graphic, 2015, Page 60).

There is the need for energy policy change by the authority to promote the use of alternative sources of power (Energy Commission, 2014). It is found from statistics of energy sources in Ghana that very little fraction of the total power is produced through the renewable technologies, mainly wind and solar power having no contribution, though abundant (Energy commission, 2014). Current rates of electrification in Ghana may not lead to full electrification by 2020, set originally by NES and affirmed by government (Francis et al 2015). Hence, the objective of this research is to design and construct a small scale wing power generating system by converting a single phase Ac motor (ceiling fan) to a wind turbine to enable the rural communities also have some form of electricity.

2.1 Wind Energy

Renewable energy is the term used to describe energy that occur naturally and repeatedly in the environment and can be harnessed for human benefit. This includes energy from the sun, wind, biomass, hydro, waves or tides. The reason to use renewable energy is that fossil fuels are running out of stock and we need to ensure to have a reliable ongoing energy supply. In the UK, energy industry still relies largely on diminishing sources of coal, oil and gas. Renewable sources will reduce our dependence on these imported fossil fuels and help give us a diverse, secure mix of energy. Electric fans as they are design takes about 75W of electricity to generate wind, the windmill does the reverse by converting the kinetic energy from the wind to electrical energy. The blade of a windmill rotates once wind is present. The minimum and maximum speed in which wind turbines operates is set to be 3.5m/s for cut in speed and 25m/s for cut out speed. Full productivity is assumed from a rated wind output speed of 15m/s onwards for homemade or micro wind turbines. A cut in speed of 3.5m/s is considered for micro wind turbines to start operating, whiles a larger commercial wind turbines, a cut in speed of 5m/s is more appropriate (Belward, 2011).

Though renewable energy sources are clean and abundant, there are a number of disadvantages associated with the installation and generating of wind power. Some of the advantages and disadvantages are highlighted in table 2.1.1 below.

Table 2.1: Advantages and Disadvantages of Wind Power Installation

Advantages	Disadvantages
Can create many job opportunities for the youth	Weather dependent
Climatic friendly	Need Storage of Energy
No environmental pollution	Expensive
Low maintenance cost	
Can be installed offshore and on land	
Reduces carbon dioxide emissions	

Source: Friedrike (2014)

2.2 Energy Conversion

- Practical Power and Conversion Efficiency

German aerodynamicist Albert Betz showed that a maximum of only 59.3% of the theoretical power can be extracted from the wind, no matter how good a wind turbine is. He demonstrated mathematically that the optimum occurs when the rotor reduces the wind speed by one third. In practical designs, inefficiencies in the design and frictional losses will reduce the power available from the wind. Converting this wind power into electrical power also incurs losses of up to 10% in the drive train and the generator due to friction and another 10% in the inverter and cabling as a result of component and cable resistance. Furthermore, when the wind speed exceeds the rated wind speed, control systems limit the energy conversion in order to protect the electric generator and the battery bank so that ultimately, the wind turbine will convert only about 30% to 35% of the available wind energy into electrical energy. The power output from commercially available domestic wind turbines is usually specified at a steady, gust free, wind speed of

12.5 m/s. In many locations, particularly urban installations, the prevailing wind will rarely reach this speed as tall buildings and other objects obstruct the free flow of wind.

2.3 Wind Availability

Whether constructing a wind turbine is economically viable at your home or farm depends strongly on the quality of the wind resource. Generally, average annual wind speeds of at least 4.0 - 4.5 m/s for micro wind turbine and 9.0 km/h– 10.2km/h or 14.4km/h - 16.2 km/h; for large turbines are needed to produce enough electricity to be cost-effective. A very useful resource for evaluating a site for its wind energy potential is a wind resource potential map from the meteorological service of Ghana. The most important component of a wind resource evaluation system is an anemometer. Anemometers are typically designed with cups mounted on short arms that are connected to a rotating vertical shaft. The anemometer rotates in the wind and generates a signal that is proportional to the wind speed or power. It is important to consider that certain factors at these weather stations, such as nearby trees and buildings, might influence any wind speed measurements.

2.3.1 Wind speed relationship with height

$V = Vref(H / Href)^{\alpha}$ ………………….(2)

Using equation (2), the wind speed (V) in relation with height (H) is simulated using the software Prottus 8 Professionals.

Where ***(Vref)*** is the reference wind speed at a reference height ***(Href)*** and the exponent **α** is correction factor dependence on obstacles on the ground, the density of the air and wind stability factors. In wind resource assessments **α** is commonly assumed to be a constant 1/7th or 0.142.

Wind speeds *(V)* increase with height *(H).* (Source: United States Department of Energy)

The US department of energy has recommended that towers be 24 -37 m (80 - 120 ft) high

Using the wind speed equation (2) for simulation, the outcome is shown in the histogram in figure 4.1 below.

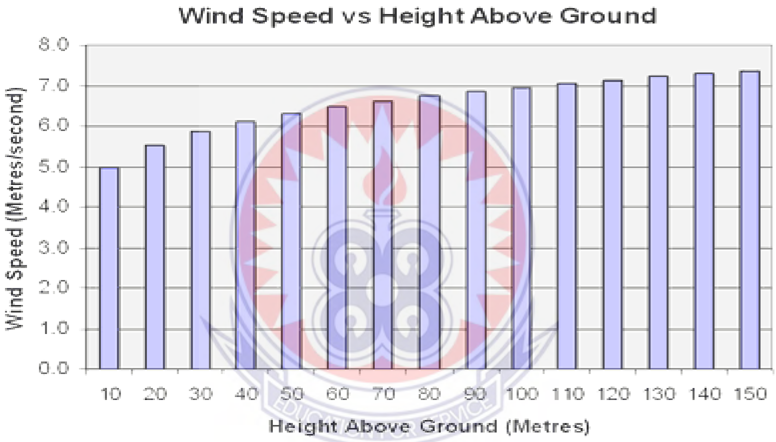

Figure 2.1 Simulation results for wind speed *(V)* m/s versus height *(H) meters*

2.4 Basic Components of a Wind Turbine

A wind energy conversion is a complex system which requires knowledge from a wide range of fields comprising aerodynamics, mechanical and electrical engineering coming together. Designing small scale wind turbine and battery charging equipment gives small scale electricity that is independent of the national electricity network. This has particular benefits for remote communities. Wind power could meet the need of rural communities to replace current generating of hydro and coal fired power stations greatly reducing the demand on the transmission and distribution of electricity. The principal components of a modern wind turbine are the tower, the rotor and the nacelle. The wind turbine captures the kinetic energy of wind in the rotor consisting of two or three blades mechanically coupled to an electrical generator. The main component of the mechanical assembly is the gear box which converts the slow rotational speed of the wind turbine to high rotational speed on the electrical generator. The rotation of the electrical generator shaft drives the wind turbine to generate electricity. The amount of the electrical power generated depends on the instantaneous wind speed values. Power coefficient of a wind turbine is given as 59% (Streedhar, 2005).

2.5 Details of Main Parts of Wind Turbine

2.5.1 The Tower

The main purpose of the tower is to support the nacelle and resist vibration due to the wind speed variations. The cables that connect the generator (on top of the tower, inside the nacelle) and transmission line (down, in the basement of the tower) are inside the tower. The tower is the main component that carries most of the other components such as the turbine, nacelle, blades and generator. The height of the tower for offshore is different from onshore turbines. The high towers are more appropriate for wind energy harvesting since winds contain less turbulence in higher altitudes. Onshore wind systems have higher towers than offshore turbines because the land has higher roughness than the water surface. On the water surface, there are almost no obstacles; hence the low tower length is sufficient to capture the wind. In onshore applications, there may be some objects around the tower that may block the wind speed. In areas with high roughness, high turbine towers are required to avoid the effect of wind blocking objects such as buildings, mountains, hills and trees.

2.5.2 Yaw Mechanism

The yaw mechanism is composed of the yaw motor and the yaw drive. The yaw mechanism turns the whole nacelle in order to face the wind directly. Regardless of the direction of the wind, the yaw mechanism can help the turbine face the wind by changing the direction of the nacelle and the blades. During the rotation of the nacelle, there is a possibility of twisting the cables inside of the tower. The cables will become more and more twisted if the turbine keeps turning in the same direction, which can happen if the wind keeps changing in the same direction. The wind turbine is therefore equipped with a cable twist counter which notifies the controller that it is time to straighten the cables.

2.5.3 The Nacelle

The gearbox, generator and the control electronics are all located inside the nacelle. The nacelle is connected to the tower through the yaw mechanism. Inside the nacelle, two shafts connect the rotor of the turbine to the rotor of the electrical generator through the gearbox. The gearbox is the mechanical energy converter that connects the low-speed shaft of the turbine to the high-speed shaft of the electrical machine. The control electronics inside the nacelle record the wind speed, direction data, rotor speed and generator load and then determine the control parameters of the wind operation system. If the wind changes direction, the controller will send a command to the yaw system to turn the whole nacelle and turbine to face the wind. The electrical generator is the main part of the nacelle. It is the heaviest part and produces electrical energy which is transferred through the cables to the storage facility (battery) before to the load. Wind turbines can operate with either fixed or variable speed. Fixed speed (FS) turbines use synchronous machines and operate at fixed speed. These machines are not best solution for the wind turbines because the wind always changes its speed. Variable speed turbines use DC machines, brushless DC machines and induction machines. DC machines are not commonly used due to the maintenance problems with the brushes. Induction and DC brushless machines are more suitable for wind applications.

2.5.4 The Turbine

The turbine, also called 'low speed rotor', usually has two to six blades. The most common number of blades is three since they can be positioned symmetrically, maintain the system's lightness and ensure the stability of the wind power system. Two-blade turbines have high stresses in cut-in speed; therefore the speed and power of the wind are insufficient for starting the rotation of the turbine and higher minimum wind speed values are required at the beginning. The radius of the blades is directly proportional to the amount of captured energy from the wind; hence and increased blade radius would result in a higher amount of captured energy.

The blades are aerodynamic and they are made of a composite material such as carbon or Plexiglas and are designed to be as light as possible. Blades use lift and drag forces caused by wind; therefore by capturing these forces, the whole turbine will rotate. The blades can rotate around their longitudinal axis to control the amount of captured wind energy called the 'pitch.

2.5.5 Turbine operation

Turbines used in generating electricity come in a wide variety of sizes. Large wind turbines, which are usually installed in clusters called wind farms, can generate large amounts of electricity. Others are installed at homes, farms and small businesses either as a source of backup electricity, or to offset use of utility power and reduce electricity bills. Very small wind turbines (20-500 watt units) are used to charge batteries for sailboats and other recreational uses and off-grid settlements.

2.6 Designing a Small Scale Wind Turbine System (SSWTS)

In the last few years, the idea of having small-scale energy source distribution has gained a significant interest. Innovation in technology, changing economic conditions and environmental regulations has been the main factor behind the growing interest in new technology of electric power generation. Hence, the technology that has become viable and is being developed to improve voltage control as well as the power quality for off grid is the micro or homemade wind power technology system. Such a small scale wind power has offered a variety of benefits and has given the customers a choice for the electricity services best suited for them. Abundant advantages of micro-turbines are quite well known and must develop to serve isolated communities across the world. (Friedrike 2014)

Conventional power system is facing problems around the world due to gradual depletion of fossil fuel resources, global warming cause by environmental pollution and less energy efficiency. Due to having these problems, a new way of electricity generation locally at small scale is by designing micro turbines to use non-conventional or renewable energy sources like wind power to integrate the utility distribution network. This type of electricity generation is termed as design generation (DG) which employs small scale wind power technologies to generate electric power near the consumer's premises (Belward, 2011).

A micro wind turbine can be described as a small-scale power supply network which is designed using simple equipment in conjunction with electronic system to provide power to individual consumers, small community or few buildings. Micro wind turbines bear the promise of considerable environmental benefits, brought about by higher energy integration of renewable sources. By virtue of good match between generating power and load, micro wind turbines have an impact on the rural community electricity network. One possible way forward is for a micro wind project being considered locally supportive by using simple homemade generators and battery for its design. (Qais, 2014).

Consumers have become used to electrical power available on demand. They do not structure their load pattern the entire responsibility for matching power and demand is placed upon the utilities which must have enough generating capacity available at all times. With gradual depletion of fossil fuel resources, global warming and environmental pollution and less energy efficiency that lead to some communities not connected to the national grid or heat by load shedding, creative thinking about the way energy is generated, supplied, used, and controlled has become possible to satisfy the demand for energy by design and constructing a small scale wind turbine for off grid homes. (Streedhar, 2005).

Small scale wind turbine is an electricity supply network that is designed to electrify remote locations, rural areas, domestic homes, small scale businesses and small community. The key figures of the system include the wind turbine connected to the charge controller which is interned connected to the battery, from the battery to an inverter and finally to the load. The small scale generators (wind turbine) are design to attain reliable power for the users at all time. (Leake, 2010).

Micro wind power generation design is gradually widespread and technically proven to encompass many different types of technology at different stages of development and commercialization, from the burning of wood for heat in the residential sector to processes such as biomass gasification for electricity generation. The key issue is how to extract the kinetic energy from the wind effectively and convert it into more useful form of electrical energy. This require the building of a system which include the wind turbine, charge controller, Storage facility (battery) and an inverter to provide high level of efficient energy than fossil fueled generator (diesel generator) which emit carbon dioxide which is one of the main greenhouse gases. (Blyth, A. 1987).

The U.S. Department of Energy (DOE) has launched the wind a power program to accelerate the deployment of wind power sources. The federal government has issued tax-based policy incentives to stimulate the public acceptance of wind energy. A report published by the U.S. Department of Energy in May 2011, has indicated that the federal government allows owners of the qualified renewable energy facilities to receive tax credits of 2.2 cents for each 5 kilowatt-hour (5kWh) of electricity generated by the facility over a period of ten years. This incentive has been provided to promote the deployment of small scale wind power generation to reduce the greenhouse effects. The owners of small wind turbines (100 kW or less) are eligible to receive tax credits worth 30% of the value of the facility. In addition, loans and grants are offered to help the wind power firms to deploy innovative, clean energy technologies that reduce, avoid or sequester carbon dioxide and other emissions. (U.S. Department of Energy May 2011).

The recent advancements in the field of microelectronics has miniaturized the wireless devices and also decreased their power requirement by an order of magnitude. Wireless sensors nodes, need power less than 1 mW to function. Such nodes are used in variety of applications such as gas and chemical production plants, temperature, pressure and humidity monitoring, motion detector, structural health monitoring, and explosives detection. The over-expanding usage of wireless devices in the remote areas has brought challenges in terms of finding a suitable power source. One of the most convenient methods of supplying the required power to the miniature electronic devices is by harvesting the wind energy. The micro-wind turbine which operates in range of 2 m/s-7 m/s has optimal power coefficient of 18% which is quite low. SSWT with the capacity of 500µF is the only turbine which has good overall efficiency value of 25%, its rated wind speed is 12 m/s. In comparison, small scale wind turbines (SSWTs) can operate at low wind speed, generate power minimal noise and there are no known safety hazards. (Siemens Wind Turbine model: SSWT-2.3-12)

2.7 Theory of Devices

2.7.1 Rectifier operation

The rectifier circuit is 120 / 240V AC to 12V DC full-wave rectifier which takes its input from the wind turbine and covert the alternating current to direct current. The 12V DC is fed to the charge controller to charge the battery bank. The rectifier employs four diodes and a capacitor. The diodes permit the flow of current in only one direction to accomplish this conversion whiles the capacitor also filter the wave to ensure signal smoothness. There are two types of AC/DC rectifiers; half-wave and full-wave units. Generally, full-wave rectifiers offer a cleaner, more consistent signal conversion from alternating current to direct current than their half-wave counterparts. This comes at the cost of increased voltage drop across the rectifier connection, as full-wave rectifiers use four diodes for the conversion process, with two diodes active at one time, half-wave rectifiers have two diodes and only one diode works at a time. The rectifier circuit then transmits the DC voltage to the charge controller.

2.7.2 Charge controller operation

The battery charge controller takes the variable output voltage from power source rectified AC from the generator (wind turbine) and provides the fixed system reference DC voltage at its output terminals to charge the battery that fed the inverter.

The general principle of operation behind the controller is that it monitors the voltage of the battery(s) in the system and either sends power from the turbine into the batteries to recharge them, or dumps the power from the turbine into a secondary/dummy load if the batteries are fully charged (to prevent over-charging and destruction of the batteries). Normally the system runs automatically, when the battery is being charged, the yellow LED is lit. On the other hand, when the battery is fully charged and power is being dumped to the dummy load, and the green LED is lit. The schematic is shown above.

2.7.3 Transformer operation

This is a center tapped transformer, evident by the high turn count of the secondary winding and the low turn count of the primary. As a step-up unit, the transformer converts low voltage from the wind turbine into high-voltage. The larger-gauge wire used in the secondary winding is necessary due to the increase in current. The primary windings, which does not have to conduct as much current may be made of smaller-gauge wire. The transformer stepped-up the voltage being converted by inverter from DC to AC to feed the household load circuit by stepping up the voltage from 12V to 200V / 240V. It is possible to operate either of these transformer types backwards (powering the secondary winding with an AC source and allowing the primary winding to power a load) to perform the opposite function: a step-up can function as a step-down and visa-versa. However, efficient operation of a transformer requires that the individual winding inductances be engineered for specific operating ranges of voltage and current. This is so because if a transformer is to be used “backwards”, it must be done within the original design parameters of voltage and current for each winding, or it may prove to be inefficient or be damaged by excessive voltage or current.

2.7.4 Inverter operation

The inverter receives a DC supply of 12V from the battery bank and converts it to AC quantity to be delivered to the user's electrical equipment. In conjunction with a transformer the AC voltage then step-up from 12V to 120V or 240V AC depending on the transformer rating to feed the load connected to the secondary side. The circuit can handle about 300 watts of power which is perfect for lights, small TVs, laptop computers and radio equipment. The input voltage, output voltage, frequency and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power but the power is provided by the DC source that is the battery. The voltage magnification is done by the transformer in conjunction with more powerful transistors Q1 and Q4. High rated transformer and powerful transistors can be substituted for TR4 and Q1 Q4 for more power output.

2.7.5 Relay operation

The relay is an electric switch that opens and closes base upon the operation of the battery charge controller circuit to divert power to the dummy load when the battery bank is fully charge. The relay switched from the battery bank terminals to the dummy load terminals to prevent battery overcharging. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of electrical amplifier. The electromagnetic relay consists of a multi-turn coil wound on an iron core to form an electromagnet. When the coil is energized by current, the core becomes temporarily magnetized and the magnetizing effect triggers the operation.

Some relays used are;

- Interlocking relay
- Phase sequence relays and
- Voltage monitor relay,

But for the purpose of this project the voltage monitor relay is used.

2.8 Converting a Table/Ceiling Fan to a Generator to Serve As a Wind Turbine

Ordinary table fan or ceiling fan can be converted to a windmill generator. The homemade windmill assembled in this project is a table fan that puts out 24 volts AC at a couple of hundred milliamps. While any magnets could be used in theory for electricity generation, it will be pointless using weak magnets such as cheap ceramic magnets to generate electricity practically since it is a low power motor that will not put out much electric energy. For best results, high power magnets such as Neodymium is use to get more energy output.

2.8.1 Disassembled the fan and set all parts aside

This normally requires only a screwdriver. Next, remove the retaining pin on the armature shaft and remove the screws holding the fan casing together. Carefully open the fan casing, take care not to break any of the very fine wires inside the fan motor, remove the armature from the motor. Locate the condenser, remove this by simply cutting it out. Drill out four holes, evenly spaced around the armature. Make the holes the same size as your magnets. Drill just deep enough to fit the magnets flush with the outside edge of the armature. Notice the magnets evenly spaced around the armature. Put the armature back into the motor housing and give it a spin by hand to make sure the magnets do not rub or scrape inside the motor. If they rub or scrape inside, then sand the edges a bit until they fit well. Mount the motor back on the original table fan base. Paint all the parts before you leave them outside for any length of time. Seal all open holes and cracks with silicone to make it water proof and long lasting. Connect this generator's output through a diode bridge rectifier, to charge controller to a 12 volt lead acid battery and charge it with no problem. (htt://www.instructables.com/id/DIY- Wind-Turbine).

2.8.2 Ceiling fan uses only one set of coils at a time

There are two sets of coils at 90 degrees out of phase. Hooking both sets of coils to separate transformers and then separate diode rectifiers give out power otherwise considered almost smooth dc output whether the outputs of the rectifiers are in parallel or in series. The reason for using transformers is that the coils are at a high ohms resistance value, thus they are not the same impedance as the battery's internal resistance. To enable maximum power transfer you must correct the impedance matching, or the higher resistances will absorb the power and waste it as heat in the motor/alternator. Simply removed the original rotor and replaced it with permanent magnets. The most important thing is to find magnet sizes that fit perfectly and yield the smallest possible gap between rotor and stator. Test the turbine output by connecting the power cords to an LED touch light and spin. As it spins, when the touch light is on it means success, when the touch light is not on the polarity must be checked. The main purposes of this project are: (1) have a portable power source to provide small amount of energy by converting AC motor (ceiling fan) to a wind turbine; (2) act as a learning exercise to wind power turbines eventually leading to something bigger.

The advantages to this project are: (1) a box fan is essentially pre-built with most of the necessary parts and requires little tooling; (2) the smaller size of the turbine is much easier to handle for experiments and testing; (3) low voltage and current are much safer to handle and cheaper to do experiments with. (Permanent magnet DC motor by Mabuchi Motor Co. Ltd)

2.8.3 Converting a fan to a generator

A ceiling fan motor is mainly consists of a stator and a rotor. The stator is fixed on the motor axle. In this embodiment, the stator is formed by stacking a predetermined number of metal plates. The stator is surrounded with a number of magnetizing coils, each of which is winded with a second magnetizing coil. The second magnetic coil detects the received EMF around it. The stator has a number of equally spaced coils perpendicularly directed towards the motor axle. When there is a relative movement between the rotor and the stator circuit EMF is generated as magnetic field cut across the windings. In this case, the second magnetizing coil on the stator detects the received EMF. The received EMF is converted by the power distribution controlling circuit into electrical power for output. The power distribution controlling circuit is electrically connected with the illuminating unit at the bottom of the tower frame by charging NiMH batteries. Therefore, the illuminating unit can produce light without additional electrical power. However, it should be mentioned that the energy saving controlling circuit can convert external DC power into AC power when the circuit is operating. The rotor continue to rotate whiles the stator supplies power (Gadkari et al 2014).

CHAPTER THREE

METHODOLOGY

3.0 Design and Specification / Data Collection

The designed and construction of a small scale wind power generating system by using a single-phase AC motor (ceiling fan) as a wind turbine will have a complete system which contains various sub-systems and components arranged and linked to function primarily as a means of manipulating the supply of electrical power to any load.

The basic problem to be addressed will be how to convert kinetic energy of wind to mechanical energy for the motor (that is using a ceiling fan as wind turbine) to generate electricity for off-grid homes. A wind power system consists of a wind turbine, one or more batteries to store power produced by the turbine, battery charge controller, a blocking diode to prevent power from the batteries being wasted while the motor/generators spins. The block diagram in figure 3.1 below shows the interconnection between the power sources, the control system and the load.

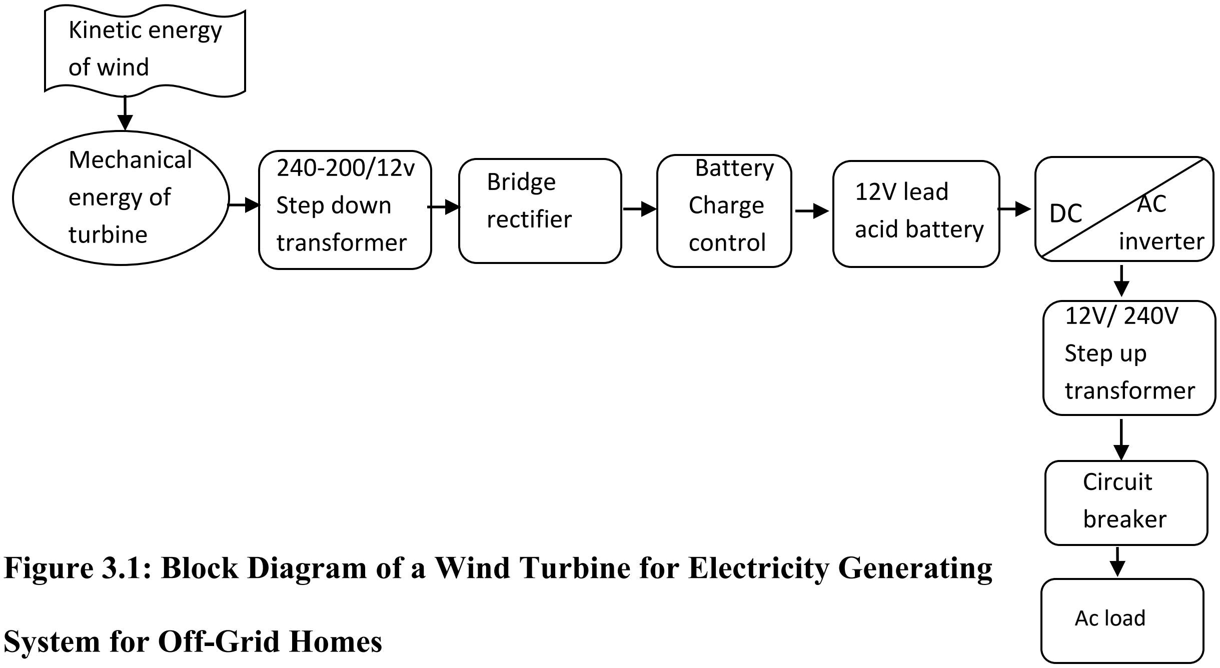

Figure 3.1: Block Diagram of a Wind Turbine for Electricity Generating System for Off-Grid Homes

Electrical method was used for this project as shown in the diagram below.

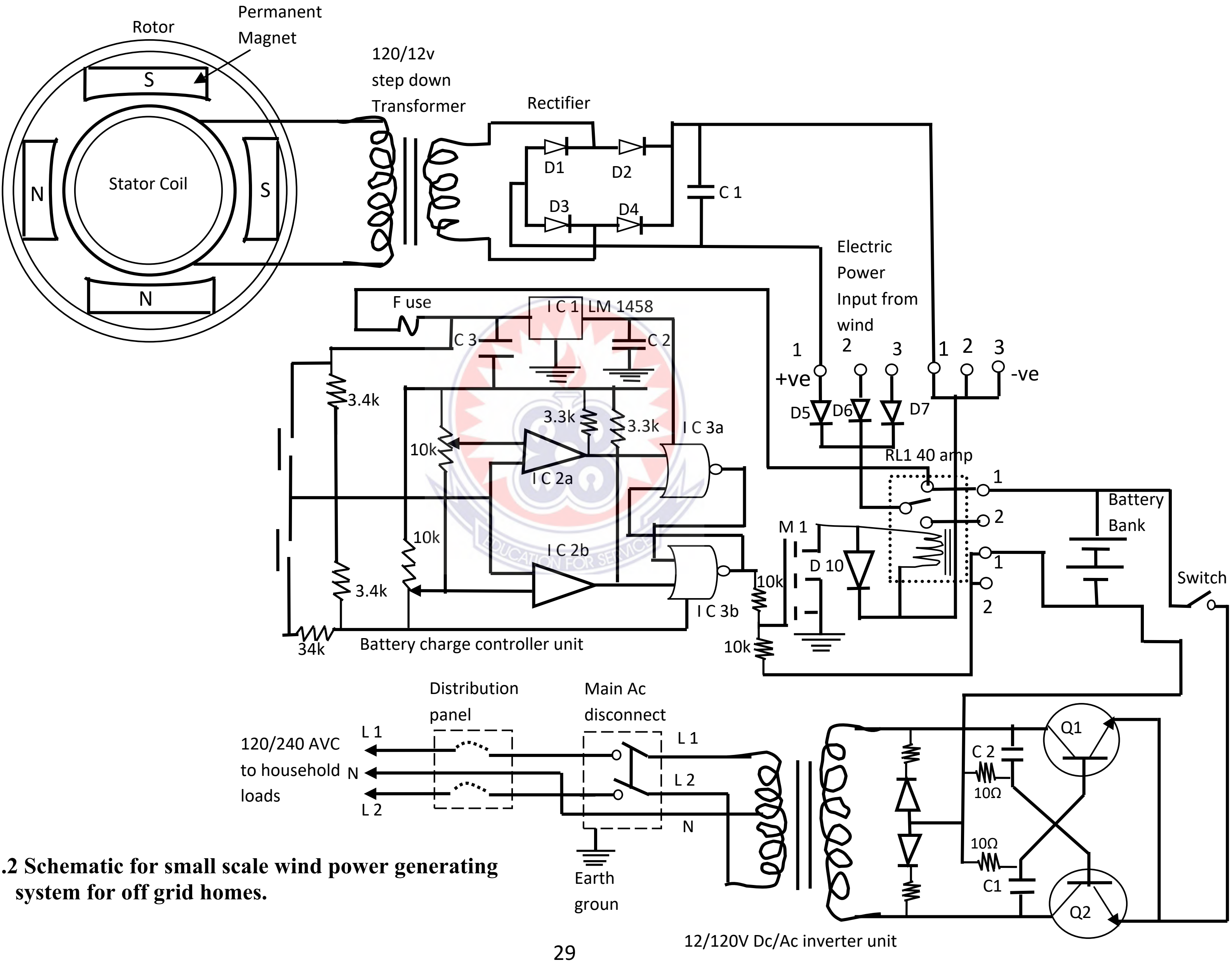

Fig 3.2 Schematic for small scale wind power generating system for off grid homes.

In operation, the wind turbine is connected to a step down transformer which in turn is connected to the bridge rectifier. The bridge rectifier then connected to the charge controller power then flow from the controller to the battery. All loads are taken directly from the battery through Dc / Ac inverter connected to a step up transformer. If the battery voltage drops below 11.9 volts, the controller switches off the dummy load to allow the turbine power to charge the battery. If the battery voltage rises to 14 volts, the controller switches to dumping the turbine power into the dummy load. There are trim pots to adjust the voltage levels at which the controller toggles back and forth between the two states. The researcher choose 11.9V for the discharge point and 14V for the fully charged point based on the information gathered during this research on how to properly charge a lead acid battery. When the battery voltage is between 11.9V and 14V, the system will switched between either charging or dumping. Normally the system runs automatically. When charging the battery, the yellow LED is lit. When the battery is charged and power is dumped to the dummy load, the green LED is lit.

3.1 Generator Design Procedure

The following are the steps by which a ceiling fan is converted to a wind turbine to generate electricity for off grid homes. Figure 3.4.1 is the pitcher of the fan obtained to build the turbine.

Ceiling fans comes in various types and sizes. Such as Binatone, Philips, Crompton etc. All these fans are three blade and takes about 75W of power to operate. Some of the fans are either two blade or four blades. The two blades have a disadvantage of vibration that can easily affect the bearing whiles the four blades also has the disadvantage of high inertia. The researcher chooses the tree blades base on the fact that it makes the generator to operation in a very stable condition without vibration or high inertia.

Figure 3.2: Is a picture of ceiling fan obtained to be use for wing turbine power generating project for off grid homes.

Figure 3.3: Shows the fan with the coil, armature and bearing.

Figure 3.4: Shows a picture of fan with the armature and the capacitor removed to pave way for the magnet to be inserted.

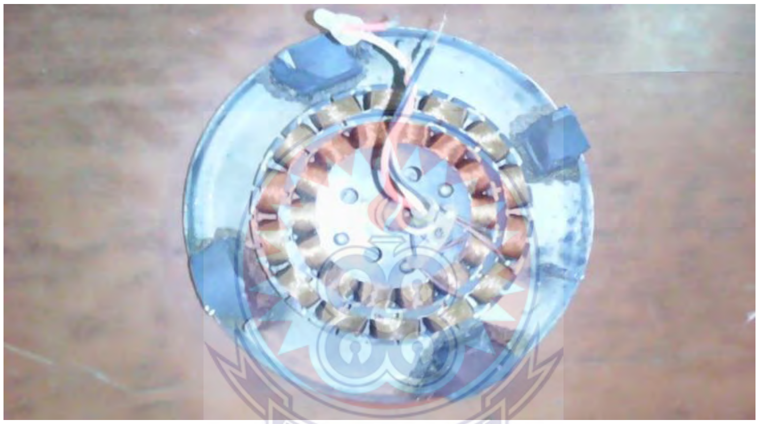

Figure 3.5: Shows the permanent neodymium magnet been inserted on the case of the fan.

Super glue and sand is being used to mount the magnet firmly on the case (rotor).

Figure 3.6: Shows a picture of the generator being re-assembled and tested using a multi meter to measure the current when the generator was put in rotation by hand.

The current recorded is 0.589A as shown in the meter.

Figure 3.7: Shows LED lamp 'on', during testing.

When the turbine is put into rotation, the magnetic field that emanates from the north pole to south pole cut across the windings and EMF is generated leading to power production. Whether the rotation is clockwise or anti clockwise the EMF still generated and the lamp is on.

Figure 3.8: shows the generator connected to the yaw mechanism.

Regardless of the direction of the wind, the yaw mechanism can help the turbine face the wind by changing the direction of the nacelle and the blades.

Figure 3.9: Is a picture of the researcher in a workshop fixing the wind turbine

Figure 3.10: Show the electronic components connection. Charge controller connected to 15 plate 12V lead acid battery and to DC / AC inverter.

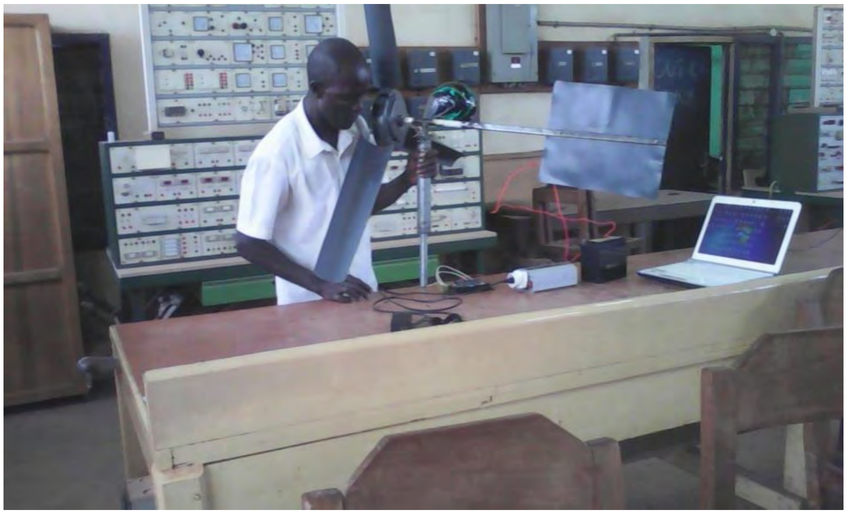

Figure 3.11: Shows the generator (wind turbine) connected to the electronic devices.

When the generator is put into rotation the LED of the charge controller lit, indication that the battery is charging regardless of the direction of the rotation. The laptop connected to the inverter is charging, indication that the system is working

Figure 3.12: Shows the generator (wind turbine) mounted on a pole for testing.

3.2 Selection of Components

This design of wind power generating system is intended to produce an output power that is enough for lighting and house hold electrical gadgets with the voltage level between 120 -240V. Hence, circuit breakers, cable conductors and relays need to be selected to suit this voltage and current output.

3.2.1 Circuit Breaker selection

Circuit breakers with correct ratings are used here. The first breaker is for the power (generator) circuit and the second breaker is for the control circuit.

The breaker to be used for the power circuit must have a rating of more than 2A. For this design, a 5 Amps (1-phase) circuit breaker was used for isolating the generator when the need arise. For the control circuit, the breaker used was also 5 Amps single pole breaker to also isolate the control circuit when the need arise. The current in the control circuit is measured in mA.

3.2.2 Relay selection

A relay with the following parameters has been used for the design of battery charge controller.

D.C rating 10A/12V and A.C rating 5A/120V

3.2.3 Conductor Selection

An approximation used for the selecting of copper conductor (for carrying current of 5Amps) is: 2.5mm^2 flexible strand copper conductor, since full load current is approximately 2Amps, Conductor dimension (cross sectional area) is

$$A = \frac{625mm\ x\ 1.95}{1000} = 1.22m^2 \quad \text{equation ………………….. (4)}$$

Radius 'r' of conductor, can be calculated from the equation;

$$r = \sqrt{\left(\frac{A}{\pi}\right)} \quad \text{Equation…………………(5)}$$

$$r = \sqrt{\frac{A}{3.142}} = \sqrt{\frac{1.22}{3.142}} = 0.62mm$$

cable diameter is; d = 0.62 x 2 = 1.24mm. this can be refered to table 5 of BS 1363 IEE regulation 15th edition, a current of 2A can take a cable size of 2.5mm^2.

Alternatively, to consider the cable size that can handle this voltage and the current output, the electric power formula; $P = V\,I\,Cos\,Ø$, can be use, but due to unstable nature of the wind Cos Ø is considered as unity (1). Therefore power $P = V\,I$ (3), let P = 220W and V =120V

I = P/ V => I = 220 /120 = 1.83A, approximately 2Amp. From table 5 of BS 1363 IEE regulation 15th edition, a current of 2A can take a cable size of 2.5mm^2.

3.3. The Generator (wind turbine)

Figure 3.13 Circuit of Wind turbine

Parts:

- Soft iron stator
- Permanent magnet
- Stator wound with copper conductor

3.3.1 Determining Coil Polarities and Phases

Generally, the coils in the stator have 3 possibilities: 100% in phase, 100% out of phase, and an offset phase. When using coils together, it is very important to determine the phasing relative to the other coils. For example, adding a coil that is 100% out of phase to another coil will essentially cancel out both of the coils and no power will be produced. A coil that is 100% in phase will add power to the coil. At this point, each coil should be identified with a symbol notation.

3.3.2. Bridge rectifier

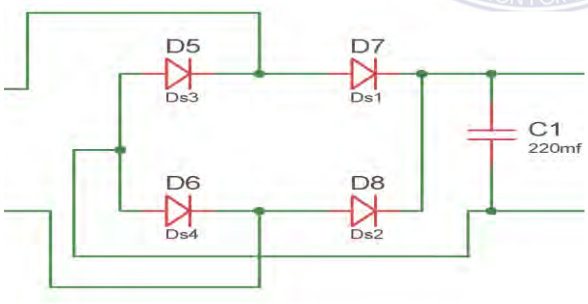

Figure 3.14 Circuit Diagram of Bridge Rectifier

Parts:

- -Diodes
- 220µF capacitor

3.3.3 Battery Charge Controller

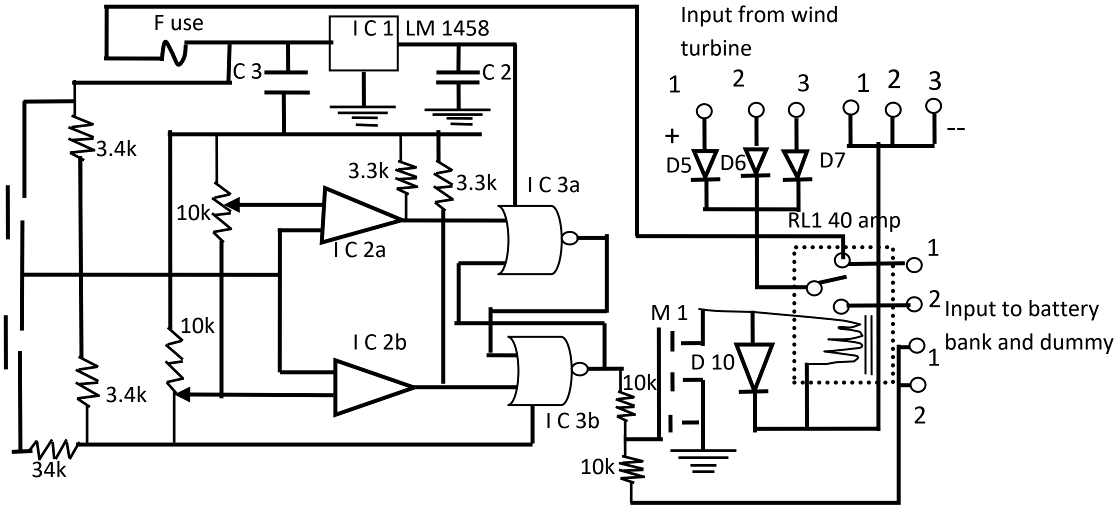

Figure 3.15: Circuit diagram of battery charge Controller

Parts:

- IC3 A, LM 7808
- IC2 B, LM 1458 dual operational amplifier
- IC3,4001 dual 2-input NOR gate
- Q1 RF 340 MOSFET
- D1-3 Blocking diode rated for the medium current each source could produce
- D4 1N4007
- LED1 yellow
- LED2 Green
- F1 Fuse rated at total expectant current at source combined with produced current
- F2 1Amp fuse for controller
- RLY1 40Amp SPDT automatic relay
- Test point A should rate 7.4V

- Test point B should rate 5.95V
- PB1-2 momentary contact NO push button
- All resistors are ¼ watt 10% tolerance

3.3.4 The circuit of battery charge controller

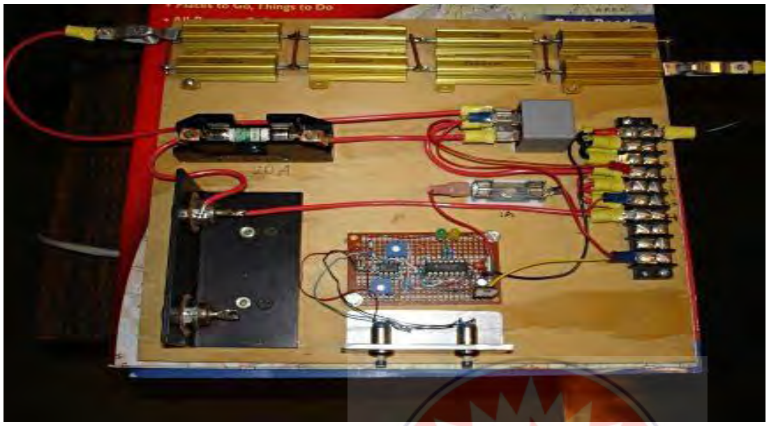

Figure 3.16 Circuit of battery charge controller

3.3.5 240,200 /12V center tapped transformer

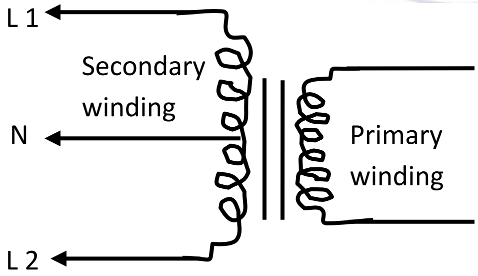

Figure 3.17 Center tapped transformer

Parts:

- Primary windings (copper conductor)
- Secondary windings (copper conductor)
- Insulating material

3.3.6 DC/AC Inverter

An inverter is a device that converts DC volts to AC volts, perhaps, from 12 volts to 120volts.

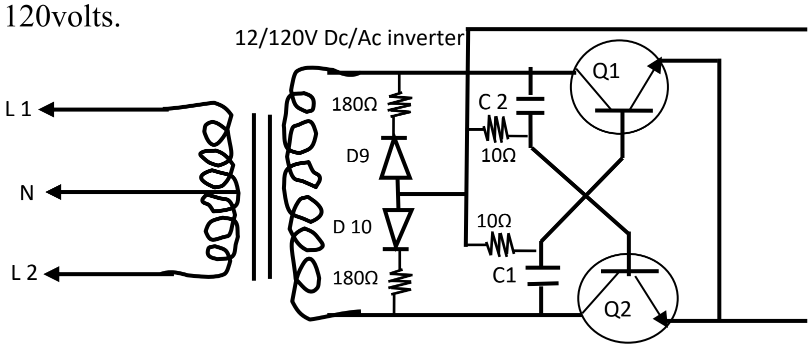

Figure 3.18 Circuit Diagram of DC/AC inverter

Parts:

- C1, C2 2.2PF Tantalum Capacitors
- R3, R4 10Ω, 5W resistor
- R5, R6 180Ω 1W resistor
- D9, D10 HEP 154 Silicon Diode
- Q1,Q4 2N3055NPN Transistor
- TR4 24V center tapped transformer
- Miscellanies, wire, heat sinks and receptacle for 240V out put

3.3.7 Blades Design for Optimum Energy Capture

Figure 3.19. Picture of Turbine Blades

3.3.8 Construction of blades

Modern, high capacity wind turbines, such as those used by the electricity utilities in the electricity grid, typically have blades with a cross section similar to the aero foils used to provide the lift in aircraft wings. However, a lot of designers make their own blades by carving them out of wood. Others also make blades by cutting sections out of aluminum metal sheet and shape them into airfoils. In this research, a PVC pipe was used for the blades in order to connect them to the hub so that the system can spin when wind blows. A 24 inch long piece of pipe was cut around its circumference and its length cut into pieces. Then one blade was cutout and used as a template for cutting out the other 3 blades. Since the pipe was already in a semi-circular form re-shaping was not necessary but some trimming was done to ensure that the hub does not vibrate when it spins. Additionally, the blades were smoothened and sand paper on the cut edges to make them into better airfoils.

3.3.9 Bearing construction

There is the need for, some sort of bearing that would allow the head to freely turn into the wind. A 1 inch diameter iron pipe is a good slip-fit inside 1 1/4 inch diameter steel electrical conduit pipe. Similar piece of conduit that can be used as a tower can also be use to form a bearing. Wires from the generator would pass through a hole drilled down the center of the pipe/conduit unit and exit at the base of the tower run into the home facility for the necessary connection to be made.

3.4. A layout diagram of a small scale wind turbine for domestic use

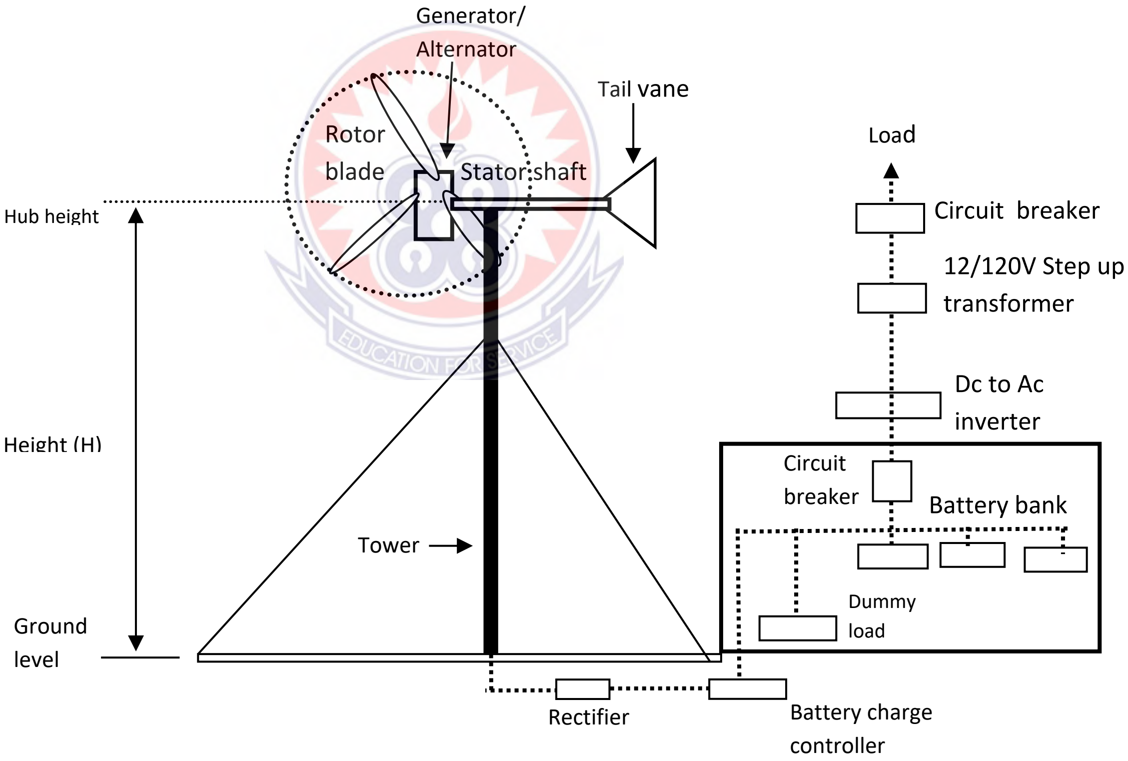

Figure 3.20 layout diagram of a small scale wind turbine for domestic use

In reference to tables 3.1 in appendix B the electric power generated by wind can be determined using the wind power formula as;

$P = \frac{1}{2} . A . Cp . \rho x.V^3$……………………….. (1)

Where A = Л r^2 = swept area of the turbine blades.

.d = ‘2 r’ rotor diameter (m)

Cp = power coefficient of the rotor.

. ρ = density of air.(kg/V^3)

V = wind speed (m/s)

3.5 Wind Speed Relationship with Height

An important factor which determines how much power a wind turbine will produce is the height of its tower. The power available in the wind is proportional to the cube of its speed as stated in equation 1. This means that if wind speed doubles, the power available to the wind generator increases by a factor of 3 (2 x 2 x 2 = 8). Since wind speed increases with height, increasing the tower height can mean enormous increases in the amount of electricity generated by a wind turbine as shown in the figure 3.9 below.

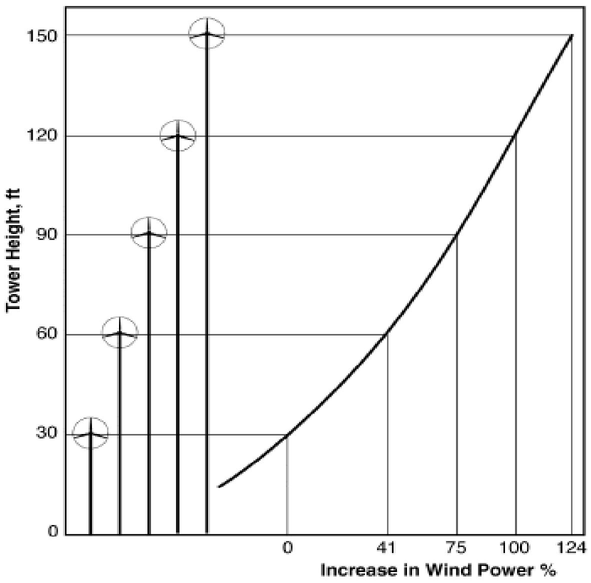

Figure 3.21 Graphical representation of wind speed relationship with height

Wind speeds increase with height. (Source: United States Department of Energy)

It is recommended that towers are between 24 -37 m (80 - 120 ft) high. Installing a wind turbine on a tower that is too short is like installing a solar panel in a shady area. At a minimum mount, a turbine must be high enough on a tower that the tips of the rotor blades remain at least 4m above any obstacle say, within 9 m (30 ft). Ensure that the tower is connected to an underground metal object to ground the tower in case lightning strike. Mounting turbines on rooftops is generally not recommended. Wind turbines tend to vibrate and transmit the vibration to the structure on which they are mounted. As a result, turbines mounted on a rooftop could lead to both noise and structural problems with the building.

Relating wind power to tower height, an empirical formula developed by D.L Eliot of specific Northwest laboratory in the USA give the wind speed (***V)*** at height (*H)* above ground level as

$V = Vref\,(H / Href)^{\alpha}$……………………………(2)

Where ***Vref*** is the reference wind speed at a reference height ***Href*** and the exponent **α** is a correction factor dependent on obstacles on the ground, the density of the air and wind stability factors. In wind resource assessments **α** is commonly assumed to be a constant 1/7th or 0.142.Using the above wind power equation simulation has been carry out using a software (Proteus 8 Professionals) to verify the wind speed **V** (m/s**)** effect against tower height **H** (m).

Because of the behavior of atmospheric boundary layer that flows over the earth's surface, there is zero velocity at the lower level (no slip condition) and the velocity increases gradually with elevation. Several models can be used to calculate this wind shear effect, but this formula has been used because of its simplicity.

3.6 Circuit Breaker

You need a disconnection switch that can electrically isolate the wind turbine from the rest of the wind energy system. An automatic disconnection switch is necessary to prevent damage to the rest of the system in case of an electrical malfunction or a lightning strike. It also allows maintenance and system modifications to be safely made to the turbine.

1. The modal wind speed at which the wind most frequently blow is less than the average wind speed which is the speed often quoted as representing typical wind conditions. For reference, the average wind speed across the UK quoted by the Department of Trade and Industry (DTI), is approximately 5.6 metres per second [m/s] at 10 metres above ground level (agl)."

2. Average wind speeds are only reliable for open rural environments. Wind speeds just above roof level in urban environments will be considerably less than the quoted averages because of turbulence and shielding caused by buildings and trees. A wind turbine sited below the ridge of a building or at a similar height in an urban dwelling is likely to produce low energy.

3. The distribution of power represents the energy content of the wind since this is proportional to the cube of the wind speed.

CHAPTER FOUR

RESULTS AND DATA ANALYSIS / DISCUSSION

4.0 Introduction

This aspect of the thesis consists of two parts, the first part deals with the wind speed data analysis collected from the meteorological services department of Ghana using Anemometer reading. Considering the wind power formula;

$$P = \frac{1}{2} . A . Cp . \rho . V^3 \quad ……….(1)$$

Where A = Л r^2 = *swept area of the turbine blades* (m^2), r = *radius of the blade (metres) and* Л= *velocity constant*

Cp = power coefficient of the rotor.

.ρ = density of air (kg/m^3).

V = wind speed (m/s).

The second part deals with testing the wind turbine for several days to determine its possible electric power output using a wattmeter to measure and compare the results to the theoretical values collected from the meteorological service of Ghana Tamale.

4.1 Wind Speed Data Analysis

The wind speed data which were collected in Knots at 10 meters above ground level for the period of seven years (7) for Tamale is presented in table 1 in appendix B

Considering the wind records for anemometer readings, Tamale area has the highest wind speed (6knots maximum and 3knots minimum) compared to Bole (4knots maximum and 1knot minimum) and Yendi (2knots maximum and 1knot minimum). The period with the highest wind records for Tamale is between January to May, which is a transition period between rainy and hamatan seasons. Also, from June to September the wind maintained a significant speed level between 3 m/s to 4 m/s. On the other hand, the lowest values were recorded in November for Tamale and Bole but in October for Yendi. (Meteorological Services Department, 2015). Graphical representation for wind speed data analysis collected from the meteorological services department of Ghana is shown below in figure 4.

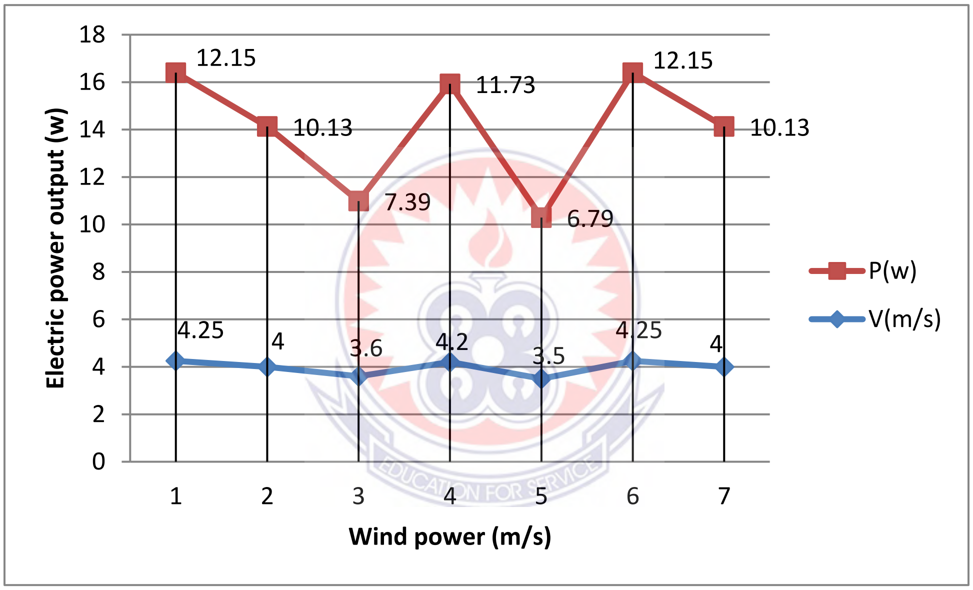

Figure 4.1 Graphical representation of wind speed with corresponding electric power output

Wind speed V(m/s) data analysis in correspondence to electric power ‘P’(w) output for Tamale from January 2008 to December 2014. From the graph shown in fig 4,

(1). when the wind speed ‘V’ is 4.25 m/s the corresponding electric power output is 12.15w.

(2). When the wind speed ‘V’ is 4 m/s the corresponding electric power output is 10.13w.

(3). When the wind speed 'V' is 3.6 m/s the corresponding electric power output is 7.39w.

(4). When the wind speed 'V' is 4.2 m/s the corresponding electric power output is 11.73w.

(5).When the wind speed 'V' is 3.5m/s the corresponding electric power output is 6.79w. From the analysis, the highest electrical power output recoded is 12.15w which correspond to wind speed of 4.25 m/s and the lowest is 6.79kw correspond to wind speed of 3.5 m/s.

4.2 Test Conducted on Small Scale Wind Turbine System using Watt Meter to Record Values

Table 4.1 Represent the test values recorded using watt meter for seven days to record the possible electric power output of the wind turbine. The electric power P (w) recorded then used to calculate the average wind speed in m/s. The method used to calculate for corresponding average wind power is shown in appendix A. The calculation of theoretical power is necessary because it gives a clear picture to researchers and engineers to know which areas have the wind power potential so that preference will be given to those areas when installations are to be done (Welde Ghiorgis, 1988).

Table 4.1 Electric power output recorded during seven day testing of wind power generating system

Days	Average power P (W) recorded using watt meter	Corresponding wind speed V (m/s)
1	7.2	2.1
2	6.8	2.0
3	7.0	2.1
4	6.7	2.0
5	7.4	2.2
6	6.5	2.0
7	7.0	2.1

The measurement was done two times a day and the average value recorded using watt meter with the range between 0 -- 20kw.

Day one recorded the average electric power output of 7.2w corresponding to wind speed ‘V’ of 2.1m/s. Second day recoded the average electric power output of 6.8w corresponding to wind speed ‘V’ of 2.0 m/s. Again, the average electric power output of 7.0w corresponding to wind speed ‘V’ of 2.1 m/s was recorded on the third day. Fourth day recoded the average electric power output of 6.7w corresponding to wind speed ‘V’ of 2.0m/s. Also, day five recorded an average electric power output of 7.4w corresponding to wind speed ‘V’ of 2.2 m/s.

Sixth day recoded the average electric power output of 6.5w corresponding to wind speed ‘V’ of 2.0 m/s.

Finally, Seventh day recoded the average electric power output of 7w corresponding to wind speed ‘V’ of 2.1 m/s.

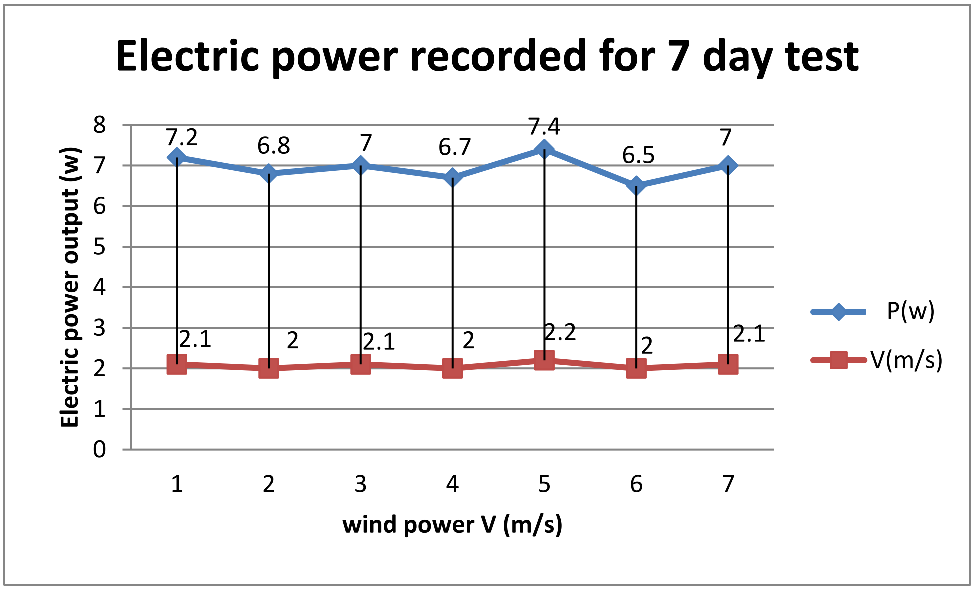

Figure 4.2 Graph of electric power output recorded for seven days for a small scale wind power system for off grid homes

The turbine mounted up on a 30 feet pole was connected to a rectifier circuit as show in picture 11 in chapter three. The cable connection run from the rectifier to charge controller, to a 15 plates, 12V,7.5Amps acid lead battery, then to an inverter which is coupled to 12V/120V AC step up transformer which then connect to load. Initial measurement of the battery wattage was always done using a wattmeter before switching on the system. Measurement was done three times daily and strikes the average value which forms table 4.1. Lap top or any chargeable gadget is normally charged in the system just to draw the wattage to pave way for the next day charging observation.

4.3 Cost of Materials for the Project

Cost of materials changes with time and therefore makes it difficult to give an accurate estimate of how much a particular material will cost. It is therefore very imperative to calculate the cost or amount of electrical power of the utility in the area of the research first, and compare to the cost of the items needed for the project before making an investment in the project, should it proof to be cost effective, then it can be done. Durable components and device must also be used in constructing the wind turbine. Finally, the construction must be done with minimal mistakes and tested to minimize the cost as much as possible. The cost for each component is shown from tables 4 to 8 in appendix B.

4.4 Modifying the ceiling fan into a wind turbine (Construction)

Ceiling fans come in various types and sizes. For the purpose of this project which required modification, a normal 75W, 5 inches ceiling fan with tree blades was used in order for permanent magnets to be well fixed. However, there was difficulty in finding a magnet that fixed perfectly on the rotor. This did not negatively affect the outcome of the project. With small rotation, the rotor gives out power that is enough to charge a 12V acid lead battery. This is how to construct the turbine after purchasing a ceiling fan; Disassemble the component by removing the capacitor, the top case and the original armature (rotor). Replace the armature with powerful neodymium permanent magnets. Additionally, use the input lead to the fan as power cords from the wing turbine to the system. The most important thing is to find magnet sizes that fit perfectly and yield the smallest possible gap between the rotor and the stator. Cure should be taken not to stick the magnets with the same poles facing each other (north, north) or (south, south) will not produce any power. The placement should be north facing south so that there will be magnetic line of force cutting the windings to produce power. After fixing the magnets, apply some adhesive (glue) to hold the magnets firmly in the rotor. Test the generator by connecting the leads to source of light example LED touch and spin the generator. If the light is on that indicate success, but if the light is not on, there must be a checked in other to rectify the problem.

4.5 Observation

The wind power circuit system was designed with the software (proteus 8 professionals) and tested by simulation which responded well. When the generator is operating the transformer steps-down the voltage to 12Vand the rectifier converts AC to DC voltage. Charge controller acts to control and protect the battery bank from over charging and destroying. From the battery, the inverter converts 12V DC to AC. Finally, the 24V to 240V center tap transformer steps up the voltage from 12V to 240V ready for use to power light bulbs, play station, flat screen LED TVs, laptop computers etc.

During the testing of the project, the following observations were made.

1. When the rotor spins beyond its normal speed, the generator produces more power hence it gives a very bright light. In this case if there is a transient fault (fluctuation) in the supply system existing for a long period, the faulty supply will flow through the equipment in the utility area which can cause a significant damage to the battery if not protected.
2. The transformers help set the voltage ranges that are very suitable for the utility area. The lower voltage ranges were from 120V to 200V whiles the upper voltage ranges were from 200V to 244V.

   The voltage set that seems acceptable during the testing were 200V at the lower range and 240V at the upper range.

3. In the charge controller unit, there is a voltage difference range provided that helps to set a tolerance of the lower and upper voltage ranges. The tolerance for voltage difference at both lower and upper voltage ranges are from 11.7V to 12V with an interval of 0.3V. It was realized that when the tolerance is high the unit will take a longer time to operate when there is high or low voltage fault from the supply. Therefore it is acceptable to set the tolerance of the voltage difference at 0.3V for lower voltage and upper voltage respectively
4. Connecting the charge controller to the battery before connecting it to the wind turbine will prevent power spikes from forming. This, in turn, will prevent damage to equipment.

4.6 Analysis of overall Cost of Wind Turbine Project

From table 5, the overall estimated cost for the wind turbine project was four hundred and fifty three Ghana cedis fifty pesewas (GH¢ 453.50p). The cost of the ceiling fan was GH¢140 representing 31% of the total cost. The DC/AC converter cost GH¢ 62.5 representing 14% of the cost. The battery charge controller and the flexible cable cost GH¢50 each representing 11%. The permanent magnet cost GH¢ 40 representing 9%. Also, the cost of the circuit breaker was GH¢ 30 representing 6%. The cost of the bridge rectifier was GH¢ 3 representing 1% of the total cost. Last but not the least, the cost of two transformers was GH¢ 60 representing 13%

The total cost of the project is four hundred and fifty three Ghana cedis fifty pesewas but six hundred (GhȻ 600) Ghana Cedis was earmark so that the additional one hundred and forty six (GhȻ 146) Ghana cedis can be use to cater for other miscellaneous.

The graphical representation of overall cost of the project is shown in *fig 4.3* below.

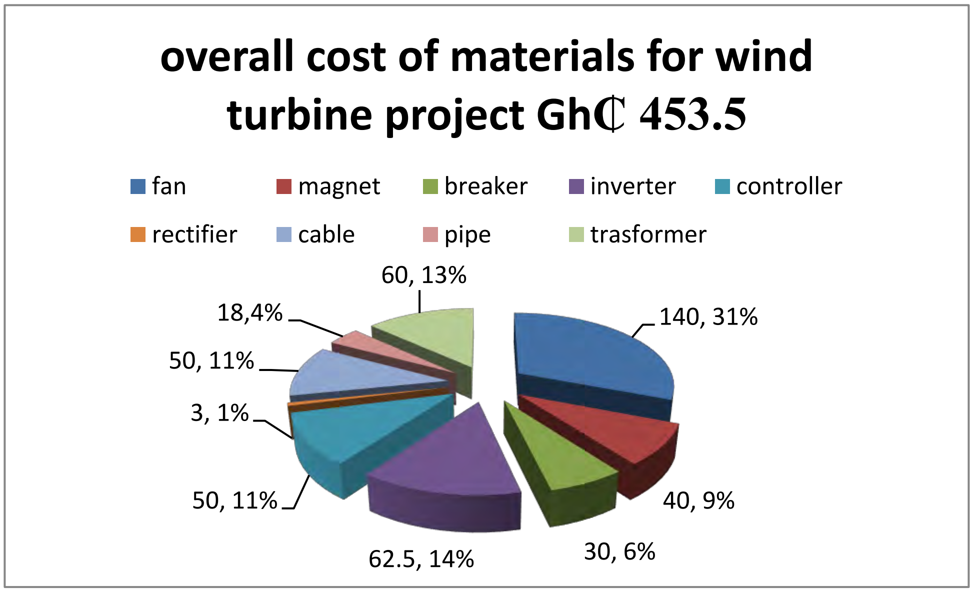

Figure 4.3: Graphical representation of overall Cost of Wind Turbine Project

CHAPTER FIVE

SUMMARY OF FINDINGS, CONLCUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter summarizes the findings in the thesis and draw conclusions. Moreover, many suggestions and recommendations have been raise.

5.1 Summary of Research

The main objective of the thesis is to design and construct an off-grid wind power generating system by converting a ceiling fan to a wind turbine. Compare the power output of the wind turbine to the theoretical analysis made using data from the Meteorological service of Ghana and finally, evaluate the visibility of setting up small scale wind power plant in Tamale in the Northern Region. The frequent power outage or load shedding is crippling business activities in our homes and institutions and further threatening the vision of the energy providers which states that 90% of the country population should be connected to the national grid by 2020. The frequent power outage is a challenge to researchers to find an alternative means, specifically wind power generating system in order to solve the energy crisis. Well extensive search was conducted to enable the researcher gather more credible, more reliable and more current information from the meteorological service department Tamale to enlarge the scope of information with regards to building wind turbine. Vital information was also gathered from books and the internet.

5.2 Conclusions

The overall findings of the research was that, the design and construction of a small scale wind power generating system has yielded positive results that can solve the problem of lack of electric power in our rural areas and off-grid homes because it will provides immense help to areas without electricity. The maximum and minimum electric power ‘P’ calculated using data from the meteorological service is 12.15kw and 7.39kw respectively correspond to wind speed ‘V’ of 4.25(m/s) maximum and 3.6 (m/s) minimum from table 3.1. Comparing to the real test of the wind power project, the maximum and minimum electric power ‘P’ recorded was 7.4kw and 6.5kw corresponding to wind speed ‘V’ of 2.2 (m/s) and 2.0(m/s). All these calculations were done using the swept area of the generator A = 452.44cm^2. In theoretical point of view, magnetic flux is directly proportional to the product of flux density and the area, $\Phi = \beta A$ (wb). The generator is fixed with only four magnets, when the number of magnets in the rotor increase magnetic density will increase. When this is couple with the increase of radius of the turbine blades, the swept area will increase which will result in more electric power output provided the cut in and cut out wind speed still maintained. In effect, future studies on this project can focus on more number of magnets in the rotor and reasonably wide swept area. It is a fact that there is hardly any aspect of human life where electrical power is not required, at homes, offices, hospitals, schools, hotels, etc.

It can be used to supply electricity to areas that have no access to the national grid. It can also be used to supplement and make up for any shortfall in hydropower production.

From the observations made during the testing of the project operation, it can be concluded that:

1. The battery charge controller unit makes it very easy to vary the set voltage from the supply generator to suit the user.
2. The battery charge controller acts like automatic change-over switch which divert power from the main battery to the dummy load to prevent over charging and it is very simple in size and design. Comparing this electrical and electronic components design method, fault tracing will be easy and faulty units can easily be traced and replaced since the whole system has been divided into segments.
3. This wind power generating system is unique compared to other off-grid power supplies in terms of cost of the equipment, maintenance, system reliability and durability.

Even though the construction made out of this design may be considered a prototype the research has achieved its objective of converting a ceiling fan to a wind turbine to generate power. The calculation made from the wind power data collected from the meteorological service has shown that; the maximum and minimum wind speed of 4.25m/s and 3.6m/s respectively which can generate electric power of 12.15w as maximum and 7.39w minimum. On the other hand, the real design when tested has also generated maximum electric power of 7.4w which correspond to wind power of 2.2m/s and the minimum electric power of 6.5w correspond to 2.0m/s wind speed.

The wind turbine electricity generating system has the following advantages:

- It is reliable, efficient and affordable

5.3 Recommendation

It is recommended that further work be done on this wind turbine system on a larger scale. For instance, energy providers such as VRA and ECG can take an initiative to build this on a commercial scale, synchronize them into the existing grid system (wind hydro hybrid) to supplement power supply in times of energy crisis. When this is properly managed both single phase and three-phase consumers can have access to it. This project is also recommended for rural areas that have no access to the grid system. Also, schools, hotels and institutions can also adopt this technology in order to avoid frequent power outage that mostly hampers their daily duties. On the part of reducing unemployment among the youth in the Northern Region, technical institutions can adopt this technology alongside electrical/electronic training, to train the youth on how to make these generators to be use as wind turbines for generating power. This can help some of the trainees or students earn a leaving because many people will patronized the wind power system if they are not connected to the National grid or those connected may need a backup power supply. The project when put in commercial base can serve the energy needs of Ghana up to about 20% especially the rural areas.

REFERENCES

Abavanaa A. (2010). *Rural communities required huge Capital investment to be connected to electricity supply*. Daily graphic, (2010)

Addo, M. (2009). *Harvesting wind to generate electricity*. Kumasi: KNUST, Printing Press.

Alternative source of energy PURC Annual Conference (2010)

Belward, M. (2011). *Small scale wind power technology*. USA: Columbia publishers

Design the hub, Retrieve from http://www.instructables.com/id/DIY-Wind-Turbine-2...

Design turbine blades, Retrieve from htt://www.yourgreendream.com/diy blades.php

EHJ Palleft (1997). *Aircraft electrical systems. Longman Singapore publishers* (Pte) Ltd. P 142.

Energy Commission of Ghana annual report, 2014

Francis, G., Prebem, M. & Giogi, K. (2015). *Global demand for better electric energy source*. Singapore: McMillan publication.

Fredricke, K. (2014). *Micro-turbines. Simple solution for off grid homes*. UK: (Pte) Ltd. Longman publishers

Ghana Meteorological Service Annual Report, 2015

Giorgi, K. (2011). *Wind energy prospects*. Georgia Tbilisi.

Himri, Y. (2008). *Prospects of wind farm development*. Elsevier publishers. P 130-138.

James, K. Blyth, A. & Ardeson, S. (1987). *Extracting kinetic energy from the wind, convert to more useful form of electricity*. Denmark: Delf publishers.

Leake (2010). *Small scale generators reliable source of energy*. Delf Nederland and publication.

Leake, E. W. (2010). *Genset-solar wind hybrid power system for off grid power station for rural applications*. Delft. Nederland. 138 Pages

Meteorological Service Department of Ghana (2015) Annual report.

Micro wind-turbine design, Retrieve from htt://www.instructables.com/id/DIY- Wind-Turbine.

Mukut, A.N.M.M. (2008). *Evaluation of wind characteristics and feasibility of wind energy in the coastal areas of Bangladesh*. Msc theses Dhaka University. P 45-49

Nana Agyemang Minister for Education. Daily Graphic, (July 21st 2015) Alternative energy source notably solar and wind.

Preben, M. (2009). *Wind energy development and application prospects of non –grid connected wind power.* World wind energy institute. Denmark.

Qais, A. (2014). *Micro wind project for isolated communities*. India: McMillan

Ramachandra, K. (2012). Prospects and challenges of decentralised wind applications in the Himalayan terrain. *Journal of energy Bioscience*. 3, (1) P 1-12

Renewable energy, solution to electric power crisis retrieved from http://www.mdpub.com/SolarPanel/

Streedhar, R. G. (2005). *Wind turbine for off grid homes*. Texas: Printing press Montana Lane.

Streedhar, R. G. (2005). *Modelling and power management of a hybrid wind micro turbine power generation system:* Montana, Bozeman.

Welde, G. (1988). *Theoretical wind power calculations for engineers and researchers*. Denmark: Elsivier publishers.

Wind power generator, Retrieve from http://www.tlgwindpower.com/ametek.htm

World Wind Energy Association (2014). *Meeting the world energy demand through wind Technology*. USA: California press

Yandra, S. Khan, M. & Alfa, B. (2012). *Renewable energy economically viable*. Bangladesh, Dhaka university publishers.

APPENDICES

APENDIX A

To determine the expected electric power of wind, this wind power formula is used.

$P = \frac{1}{2} x\ A\ x\ Cp\ x\ \rho\ x\ V^3$………………………. (1)

Where $A = Л r^2$ = swept area of the turbine blades in meters

Cp = power efficiency of the rotor

. ρ = density of air

V = wind speed m/s

Using the above wind power equation;

Let wind average speed V = 6.5 m/s

Area swept by blades $A = 27000cm^2$

Capacity of the turbine $Cp = 0.7$ and

Density of air $\rho = 1.64$, substituting the values, electric power generated by wind is calculated as;

$P = ½\ x\ 27000x\ 0.7\ x\ 1.64\ x\ (6.5)^3 = 220W$

The targeted output voltage between 120 – 140V can be achieve considering equation (3)

$P = V\ I\ Cos\ Ø$, but due to unstable nature of the wind Cos Ø can be considered as unity (1). Therefore power $P = V\ I$. Hence current (I) can be calculated as $I = 220/120\ x\ 10 = 1.83A$

Calculation for expected electrical power P (kw) output for small scale wind power generating system for Tamale in relation to wind speed V (m/s)

Considering equation 1; $P = \frac{1}{2} . A . Cp . \rho . V^3$;.

the average wind speed values from table 4.4 for Tamale calculated.

Let wind average speed $V = 4.25\ m/s$

Area swept by blades $A = 452.44cm^2$

Capacity/coefficient of the turbine $Cp = 0.7$ and

Density of air $\rho = 1$ in kg/V^3.

Substituting the values into equation (1), the corresponding electric power output is calculated as;

(1) $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (4.25)^3 = 12.15w$

(2) When V = 4, $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (4)^3 = 10.13w$

(3) When V = 3.6, $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (3.6)^3 = 7.39w$

(4) When V = 4.2, $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (4.2)^3 = 11.73w$

(5) When V = 3.5, $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (3.5)^3 = 6.79w$

(6) When V = 4.25, $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (4.25)^3 = 12.15w$

(7) When V = 4, $P = ½ \text{ x } 452.44 \text{ x } 0.7 \text{ x}1 \text{ x } (4)^3 = 10.13w$

Calculation for corresponding wind speed in relation to electric power recorded using equation 1

$$P = \frac{1}{2} x\ A\ x\ Cp\ x\ \rho\ x\ V^3$$

(1). $V_1 = \sqrt[3]{\frac{2\ x\ 7.2}{452.44\ x\ 0.7}} = \sqrt[3]{\frac{14.4}{316.708}} = 2.1$ m/s

(2). $V_2 = \sqrt[3]{\frac{2\,x\,6.8}{316.708}} = \sqrt[3]{\frac{13.6}{316.708}} = 2.0\text{m/s}$

(3). $V_3 = \sqrt[3]{\frac{2\,x\,7}{315.708}} = \sqrt[3]{\frac{14}{316.708}} = 2.1\text{m/s}$

(4). .$V_4 = \sqrt[3]{\frac{2x6.7}{316.708}} = \sqrt[3]{\frac{13.4}{316.708}} = 2.0\text{m/s}$

(5). $V_5 = \sqrt[3]{\frac{2\,x\,7.4}{316.708}} = \sqrt[3]{\frac{14.8}{316.708}} = 2.2\text{m/s}$

(6). $V_6 = \sqrt[3]{\frac{2\,x6.5}{316.708}} = \sqrt[3]{\frac{13}{316.708}} = 2.0\text{m/s}$

(7). $V_7 = \sqrt[3]{\frac{2\,x7}{316.708}} = \sqrt[3]{\frac{14}{316.708}} = 2.1\text{m/s}$

Formula for Wind speed V(m/s) in relation with height H(m)

$V = Vref\,(\frac{H}{Href})^{\alpha}$. Equation.......................... (2)

Conductor selection

An approximation used for selection of copper conductor (for carrying current of 5Amps) is: 2.5mm^2 flexible strand copper conductor, since full load current is approximately 2Amps, Conductor dimension is;

$$A = \frac{625mm\ x\ 1.95}{1000} = 1.22m^2 \text{………………..} (3)$$

$$r = \sqrt{\left(\frac{A}{\pi}\right)} \text{……………………………}(4)$$

$$r = \sqrt{\frac{A}{3.142}} = \sqrt{\frac{1.22}{3.142}} = 0.62mm$$

Cable diameter is; d = 0.62 x 2 = 1.24mm, therefore 2.5mm^2 cable is requiered for the job.

APPENDIX B

Table 1 Wind speed V (m/s) for Tamale at 10m above ground level knots

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2008	6	5	5	5	5	4	4	4	3	3	3	4
2009	4	4	4	5	5	5	4	4	3	3	3	3
2010	4	4	4	5	4	4	4	3	3	3	2	3
2011	4	5	5	5	5	5	4	4	3	3	3	4
2012	4	4	4	4	4	4	3	3	3	3	3	3
2013	5	4	5	6	5	5	4	4	3	3	3	4
2014	5	4	5	5	5	4	4	4	3	3	3	3
	4.57	4.3	4.57	5	4.7	4.4	3.85	3.71	3	3	2.85	3.4

Source: Ghana Meteorological Services Department, 20145

Table 2 Annual average wind speed and corresponding electric power output from Jan 2008 to Dec, 2014 for Tamale, using data from meteorological service of Ghana

Year	Average wind Speed V(m/s) in Knots	Average Power Pav (w)
2008	4.25	12.15
2009	4.0	10.13
2010	3.6	7.39
2011	4.2	11.73
2012	3.5	6.79
2013	4.25	12.15
2014	4.0	10.13

Table 3 Electric power output recorded during seven days test of wind power generating system

Days	Average power P (w) recorded using watt meter	Corresponding wind speed V (m/s)
1	7.2	2.1
2	6.8	2.0
3	7.0	2.1
4	6.7	2.0
5	7.4	2.2
6	6.5	2.0
7	7.0	2.1

Table 4. Cost of materials for generator

Component	Specification	Qty	Unit price(Ghc)	Amount(Gh.₵)
Crompton ceiling fan	5” 240V ceiling fan	1	140	140
Neodymium magnet		2	20	40
Circuit Breaker	Single-phase	2	15	30
P V C pipe	4’’	6ft	18	18
Total				228

Table 5 Cost of materials for inverter

Component	Specification	Qty	Unit price(Ghc)	Amount(Gh.₵)
Dc /Ac inverter	Single-phase	1	-	-
Tantalum capacitor	68μF, 25V	3	1	3
Resistor	10Ω, 5W	3	0.5	1.5
Resistor	180Ω, 1W	3	0.5	1.5
Silicon diode	HEP 154	3	0.5	1.5
Transistor	2N3055	3	3	9
Transformer	24V Center tapped	1	40	40
Heat sink	Aluminum	2	3	6
TOTAL				62.5

Table 6 Cost of materials for battery charge controller

Component	**Specification**	**Qty**	**Unit price(Ghc)**	**Amount(Gh.₵)**
Battery charge controller	Single phase	1	-	-
Voltage regulator	IC1 LM 7808, +8V	2	4	8
Dual Operator amplifier	IC2 LM 1458	2	6	12
Quad 2-input NOR gate	IC3 4001	2	3	6
Transistor	RF 340 MOSFET	2	3	6
Blocking diode	Rated for medium current	2	0.5	1
Blocking diode	1N4007	2	0.5	1
LED	Yellow	2	0.5	1
LED	Green	2	0.5	1
Fuse	Rated at total expectant current	2	0.5	1
Fuse	1 amps, for controlling electronics	2	0.5	1
Automatic relay	RLY 40amp SPDT	1	4	4
Press Button	Rated 7.4V	1	0.5	0.5
Press Button	Rated5.95V	1	0.5	0.5
No push button	PB1 momentary contact	1	4	4
Resistor	4.7K, ¼ W 10%	2	0.5	1
Resistor	47K, 2.5V, ¼ W 10%	3		0.5
Resistor	100K, ¼ W 10%	1	0.5	0.5
Resistor	50K, ¼ W 10%	1	0.5	0.5
Resistor	15K, ¼ W 10%	1	0.5	0.5
Resistor	10K, ¼ W 10%	1	0.5	0.5
Total				**50**

Table 7 Cost of materials for bridge rectifier

Component	**Specification**	**Qty**	**Unit price(Ghc)**	**Amount(Gh.₵)**
Bridge rectifier	Ac to dc rectifier	1	-	-
capacitor	220ΩF	1	0.5	0.5
Blocking diode	Ac to dc converter	4	0.5	2
TOTAL				2.5

Table 8: The overall cost of components for the wind turbine project

NO	Component	Specification	Quantity	Amount (GhC)
1	Ceiling Fan (generator)	5'' 240V	1	140
2	Neodymium Magnet	Plano shape type	4	40
3	Circuit breaker	Single - phase	2	30
4	Dc / ac inverter	Single - phase	1	62.5
5	Battery charge controller	Single - phase	1	50
6	Rectifier	Full-wave	1	3
7	Flexible cable	2.5mm^2	1 coil	50
8	P V C pipe	4''	6ft	18
9	Transformers	Step up step down	2	60
Total				**453.5**