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Research Paper

Alternate Power Source: Wind Turbine

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ABSTRACT: Power generation is key to economic prosperity and strength of a nation. Nations need clean, sustainable, and efficientelectric power generation system. The natural sources of energy available to man are: the sun, fossil fuels, flowing water and wind. Making the decision on which of the aforementioned sources to utilize requires careful considerations such as: Availability, Extraction costs and feasibility, Conversion costs, Efficiency, Sustainability, and Economic implications.The most desirable source would be one that is non-pollutant, available in abundance, renewable, and can be harnessed at an acceptable cost in both large-scale and small-scale systems. Of all these natural energy sources, Wind seems to be the most promising as it satisfy these requirements. Wind energy is one of the most available and exploitable forms of renewable energy. Wind results due to the rotation of the earth, and the heating and cooling of the earth surface by the Sun. Wind power has been used for centuries in sailing ships, for pumping water, grinding grain, etc. The worldwide interest in developing wind power plants is due to the rapidly increasing demand for electrical energy and the consequent depletion of fossil fuels, namely, oil and coal, whose reserves are limited.The essence of this project is to design an interface unit that would ensure a steady output voltage irrespective of the variable input voltage resulting from variation in wind speed.

Keywords: *Earth, Electricity, Fossil Fuels, Power Generation, Sun, Water, and Wind.*

I. INTRODUCTION

I.1 The Philosophy behind Wind Turbines

As key pointer to economic prosperity and strength of a nation, power generation capabilities can never be understated. A nations access to a clean, sustainable and efficient (in all ramifications) electric power generation system goes a long way in determining that nations destiny.

However, being products of nature ourselves it is only natural that our major sources of nature come from nature itself. The natural sources of energy available to man include; the sun, fossil fuels, flowing water and wind. Therefore, to make the decision on which of the aforementioned sources to use, a careful process of consideration has to take place. These considerations include: Availability, Extraction costs and feasibility, Conversion costs, Efficiency, Sustainability, and Economic implications.

Research efforts for developing alternative sources of energy for electricity generation, has heightened. The most desirable source would be one that is non-pollutant, available in abundance, and renewable, and can be harnessed at an acceptable cost in both large-scale and small-scale systems. The most promising source satisfying all these requirements is wind, a natural energy source.

Wind energy is one of the most available and exploitable forms of renewable energy. Wind blows from a region of higher atmospheric pressure to one of lower atmospheric pressure. The difference in pressure is caused by:

a) the fact that the earth's surface is not uniformly heated by the sun, and

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b) the earth's rotation

Of the various renewable energy sources, wind energy has emerged as the most viable source of electrical power, and is economically competitive with the conventional sources. Before the invention of the steam engine, wind power has been used for centuries in sailing ships, for pumping water, grinding grain, etc.

In the late nineteenth century, as electricity was used to transmit and consume energy, with thermal and hydro power becoming the favored sources, wind energy fell further into disfavor. Some countries however lacked adequate fuel and water-power resources which led them to look for alternative ways of generating electricity. Denmark pioneered the development of windmills for the generation of electricity in the late 19^{th} century. Since then, there has been an increasing endeavor to build wind-driven generators for use in isolated communities with negligible resources (in the form of water power or coal) and at places which cannot be economically connected to public supply networks. Another reason for the worldwide interest in developing wind power plants is the rapidly increasing demand for electrical energy and the consequent depletion of fossil fuels, namely, oil and coal, whose reserves are limited.[1]

I.2 Project Description

The essence of this project is to design an interface unit that would ensure a steady output voltage irrespective of the input voltage as a result of the wind speed.

The wind (irrespective of the speed) hits the blades of the windmill causing a transfer of kinetic energy from the air molecules to the blades which in turn results in a rotation of these blades. The blades are coupled to a shaft which is equally coupled to a gear box and finally the generator. The rotation of the blades causes a resulting rotation of the shaft. The speed of rotation of this shaft is amplified once it goes into the gear box. The increased speed from the gear box powers the generator which results in the generation of electricity. The magnitude of the generated voltage is dependent on the initial kinetic energy during impact with the blades.

However, this variable voltage being an input and a steady voltage being the output is the significance of this project. The key components here are: [2]

a) The inverter, and
b) The uninterrupted power supply (UPS) device.

I.3 Objective of the Project

Using the simulated wind-powered electricity generator it would be demonstrated that a steady state output is achieved irrespective of the high or low wind speed from this simulated generator. The load would be supplied with a constant voltage with the source alternating between the mains and the accumulator. This project shows the stabilization of fluctuating power from the wind to the load.

II. LITERATURE REVIEW

Turbines are rotary engines that convert the energy of a moving stream of water, steam, wind or gas into mechanical energy. The basic element in a turbine is a wheel or rotor with paddles, propellers, blades, or buckets arranged on its circumference in such a fashion that the moving fluid or air exerts a tangential force that turns the wheel and imparts energy to it. This mechanical energy is then transferred through a drive shaft to operate a machine, compressor, electric generator, or propeller. Turbines are classified as hydraulic, or water, turbines, steam turbines, wind turbines or gas turbines. Today turbine-powered generators produce most of the world's electrical energy. Windmills that generate electricity are known as wind turbines.[3][4][5][6]

II.1 Energy Sources

World Energy Supply, combined resources by which the nations of the world attempt to meet their energy needs. Energy is the basis of industrial civilization; without energy, modern life would cease to exist. During the 1970s the world began a painful adjustment to the vulnerability of energy supplies. In the long run, conserving energy resources may provide the time needed to develop new sources of energy, such as hydrogen fuel cells, or to further develop alternative energy sources, such as solar energy and wind energy. While this development occurs, however, the world will continue to be vulnerable to disruptions in the supply of oil, which, after World War II (1939-1945), became the most favored energy source.

Wood was the first and, for most of human history, the major source of energy. It was readily available, because extensive forests grew in many parts of the world and the amount of wood needed for heating and cooking was relatively modest. Certain other energy sources, found only in localized areas, were also used in ancient times: asphalt, coal, and peat from surface deposits and oil from seepages of underground deposits. This situation changed when wood began to be used during the middle ages to make charcoal. The charcoal was heated with metal ore to break up chemical compounds and free the metal. As forests were cut and wood supplies dwindled at the onset of the Industrial Revolution in the mid-18th century, charcoal was replaced by

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coke (produced from coal) in the reduction of ores. Coal, which also began to be used to drive steam engines, became the dominant energy source as the Industrial Revolution proceeded. Due to the non-renewable nature of coal and other fossil fuels, alternative sources of energy have been sought after. Some of which are discussed below.

II.1.1 Solar Energy

Solar energy is generated by harnessing power from the sun. It is a renewable source of energy. Recurring cost is low since the facility for harnessing power from the sun has little or no moveable parts that may require periodical servicing. Cost of implementation however is very high. Solar energy does not refer to a single energy technology but rather covers a diverse set of renewable energy technologies that are powered by the Sun’s heat. Some solar energy technologies, such as heating with solar panels, utilize sunlight directly. Other types of solar energy, such as hydroelectric energy and fuels from biomass (wood, crop residues, and dung), rely on the Sun’s ability to evaporate water and grow plant material, respectively. The common feature of solar energy technologies is that, unlike oil, gas, coal, and present forms of nuclear power, solar energy is inexhaustible. Solar energy can be divided into three main groups—heating and cooling applications, electricity generation, and fuels from biomass.

II.1.2 Hydro-electric Energy

Hydro-electric Energy can be achieved by harnessing power from a reasonable volume of water. The prime mover in this case is the flow of water. Power derived from the fall of water from a higher to a lower level, and extracted by means of waterwheels or hydraulic turbines. Waterpower is a natural resource, available wherever a sufficient volume of steady water flow exists. The development of waterpower today requires extensive construction, including reservoirs, a dam, bypass canals, and the installation of large turbines and electric generating equipment. Because the development of hydroelectric power requires a large capital investment, it is often uneconomical for a region where coal or oil is cheap, even though the cost of fuel for a steam-powered generating plant is higher than the cost of running a hydroelectric plant. However, increasing environmental concerns are focusing attention on renewable energy sources. For an electricity generator, the flowing liquid creates an impact on the blades of a turbine, which in turn generates the appropriate amount of required electricity. The efficiency of this renewable source of energy is hindered by the seasonal variations of the level of liquid (in this case, water).

II.1.3 Thermal Energy

Thermal Energy is as a result of the generation of heat. This source of energy entails the movement of turbines with the flow of agitated fluids. These fluids can be in the form of steam, which is generated by the heat from the combustion of fossil fuels, natural gas, synthetic gas, biomass, etc. An advanced form of thermal energy is nuclear energy. A natural form of thermal energy is geothermal energy. Fossil fuels, which include petroleum, coal, and natural gas, provide most of the energy that powers modern industrial society. The gasoline that fuels our cars, the coal that powers many electrical plants, and the natural gas that heats our homes are all fossil fuels.

The majority of fossil fuels are used in the transportation, manufacturing, residential heating, and electric-power generation industries. Crude petroleum is refined into gasoline, diesel fuel, and jet fuel, which power the world’s transportation system. Coal is the fuel most commonly burned to generate electric power, and natural gas is used primarily in commercial and residential buildings for heating water and air, for air conditioning, and as fuel for stoves and other heating appliances.

Once fossil fuel has been extracted and processed, it can be burned for direct uses, such as to power cars or heat homes, or it can be combusted for the generation of electrical power.

Fossil fuels are primarily burned to produce energy. This energy is used to power automobiles, trucks, airplanes, trains, and ships around the world; to fuel industrial manufacturing processes; and to provide heat, light, air conditioning, and energy for homes and businesses. About two-fifths of all energy consumed in the United States is used by industry, one-third by homes and businesses, and about one-fourth by transportation. To provide fuel for transportation, petroleum is refined into gasoline, diesel fuel, jet fuel, and other derivatives used in most of the world’s automobiles, trucks, trains, aircraft, and ships. In the United States, transportation accounts for about two-thirds of total petroleum consumption—more than two-thirds of which is burned as automobile gasoline. Demand for natural gas, historically considered a waste by-product of petroleum and coal mining, is growing in business and industry because it is a cleaner-burning fuel than petroleum or coal. Natural gas, which can be piped directly to commercial plants or individual residences and used on demand, is used for heating and for air conditioning. Residential uses of natural gas also include fuel for stoves and other heating appliances.

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In addition to direct combustion for commercial uses, fossil fuels are also burned to generate most of the world's electric power. In 2002 fossil fuel fired power plants produced 64 percent of the world's electrical power, down from 71 percent in the late 1970s. In 2002 the world's remaining electricity supply was generated primarily by hydroelectric power (17 percent) and nuclear fission (17 percent), with solar, geothermal, and other sources accounting for a relatively small amount.

The by-product of this conversion process is the emission of smog or radiation (in the case of nuclear) which is environmentally hazardous. This is not a renewable source of energy.

II.1.4 Wind Energy

One important factor of the wind is its variance is speed. Coupled to a wind-powered electricity generator, this variance in wind speed would result to a proportional variance in voltage. For a generic wind turbine, the mechanical power that could be extracted from the wind depends on the rotor speed. The output from this rotor, when connected to a load, would cause a fluctuation of both current and voltage leading to an inevitable damage of the device or load. A device would therefore have to act as an interface with the load and the output of the windmill.[1][3][4]

II.1.5 Merits and Demerits of the Various Energy Sources

The advantages and disadvantages of the various energysources is as summarized in the table 1 below:[2][3]

Table 1: Advantages and Disadvantages of various energy sources

Source	***Advantages***	***Disadvantages***
Coal	➢ Inexpensive ➢ Easy to recover	➢ Requires expensive air pollution controls (e.g. mercury, sulfur dioxide) ➢ Significant contributor to acid rain and global warming ➢ Requires extensive transportation system
Nuclear	➢ Fuel is inexpensive ➢ Energy generation is the most concentrated source ➢ Waste is more compact than any source ➢ Extensive scientific basis for the cycle ➢ Easy to transport new fuel ➢ No greenhouse or acid rain effects	➢ Requires larger capital cost because of emergency, containment, radioactive waste and storage systems ➢ Requires resolution of the long-term high level waste storage issue in most countries ➢ Potential nuclear proliferation issue
Hydroelectric	➢ Very inexpensive once dam is built	➢ Very limited source since it depends on water elevation ➢ Many dams available are currently ceasing to exist (not much of a future source) ➢ Dam collapse usually leads to loss of life ➢ Dams have affected fish (e.g. salmon runs) ➢ Environmental damage for areas flooded (backed up) and downstream
Gas / Oil	➢ Good distribution system for current use levels ➢ Easy to obtain ➢ Better as space heating energy source	➢ Very limited availability as shown by shortages during winters several years ago ➢ Could be major contributor to global warming ➢ Expensive for energy generation ➢ Large price swings with supply and demand
	➢ Wind is free if available	➢ Limited to windy areas.

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Wind	➢ Good source for periodic water pumping demands of farms as used earlier in 1900's ➢ Generation and maintenance costs have decreased. Wind is proving to be a reasonable cost-effective renewable source. ➢ Well suited to rural areas.	➢ Limited to small generator size; need many towers. ➢ Need expensive energy storage (e.g. batteries) ➢ Highly climate dependent - wind can damage equipment during windstorms or not turn during still summer days.
Solar	➢ Sunlight is free when available	➢ Does require special materials for mirrors/panels that can affect environment ➢ Current technology requires large amounts of land for small amounts of energy generation ➢ Procurement of solar panels and other photovoltaic equipment is very expensive
Biomass	➢ Industry in its infancy ➢ Could create jobs because smaller plants would be used	➢ Inefficient if small plants are used ➢ Could be a significant contributor to global warming because fuel has low heat content
Refuse Based Fuel	➢ Fuel can have low cost ➢ Could create jobs because smaller plants would be used ➢ Low sulfur dioxide emissions	➢ Inefficient if small plants are used ➢ Could be a significant contributor to global warming because fuel has low heat content ➢ Fly ash can contain metals as cadmium and lead ➢ Contain dioxins and furans in air and ash releases
Hydrogen	➢ Combines easily with oxygen to produce water and energy	➢ Very costly to produce ➢ Takes more energy to produce hydrogen than energy that could be recovered.
Fusion	➢ Hydrogen and tritium could be used as fuel source ➢ Higher energy output per unit mass than fission ➢ Low radiation levels associated with process than fission-based reactors	➢ Breakeven point has not been reached after ~40 years of expensive research and commercially available plants not expected for at least 35 years.

III. SYSTEM DESIGN AND IMPLEMENTATION

III.1 Description of the system building blocks

The simulated wind turbine was achieved using 4 discrete blocks:[7][8][9][10]

- Control switch (key pad, fan)
- Inverter
- Display unit (7-segment display) and
- Battery backup unit (battery, charging circuit).

III.1.1 Control Switch

The key pad is where speed of the fan is regulated. It acts as a power change-over switch alternating from battery to the mains supply. This key pad contains 3 soft button switches fed into the priority encoder (74LS147) which sends active low signals into the encoder whenever the switch is pressed. Ordinarily, the 1kΩ resistors act as pull-up resistors, making the decimal input of the encoder high. The active low signal goes to the priority encoder (74LS147) and is changed from decimal to Binary Coded Decimal (BCD). The output BCD goes into a hex-inverter (74LS04) whose function is to invert the output of the encoder.

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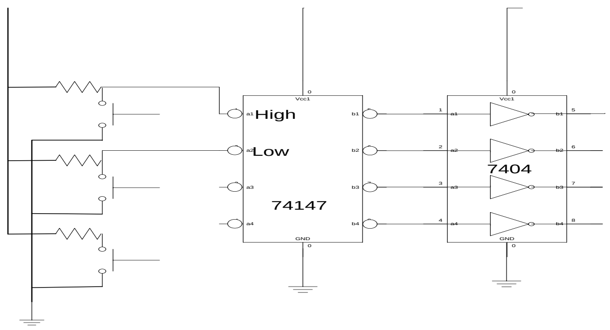

Figure 1: Key Pad

III.1.2 Display Unit

The inverted BCD signal then goes to a BCD to 7-segment decoder (74LS47) which de-multiplexes the 4 bits into 7 bits. The 7 bits of information is displayed on a 7-segment display.

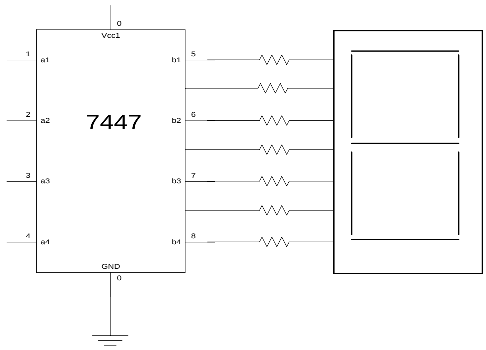

Figure 2: Display Unit

III.1.3 Inverter

The BCD signal is also tapped and channeled to the BCD to decimal decoder (74LS42). Its function is to change the 4 bits (BCD) to decimal output where the transistor static switching network is designed to energize the relays.[7][8]

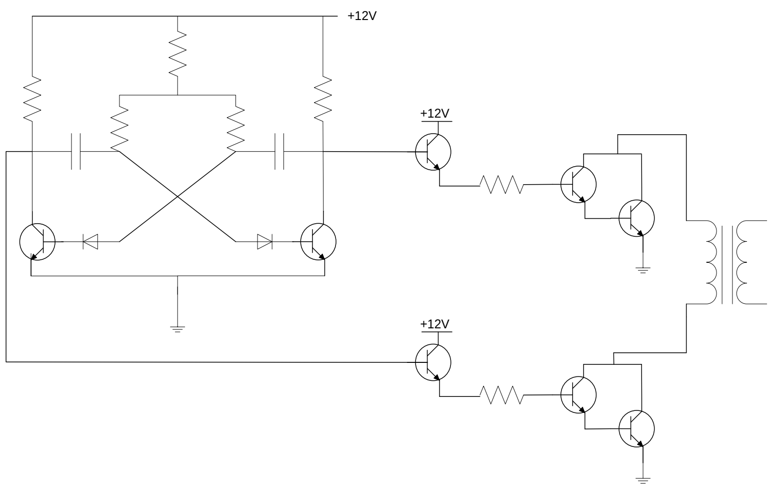

Figure 3: Inverter

III.1.4 Battery Backup Unit

These relays are used to switch the DC to AC inverter over to mains or battery, and used to alter the speed of the fan which simulates the wind vane. The DC to AC inverter produces 220V AC supply from 12V battery source.

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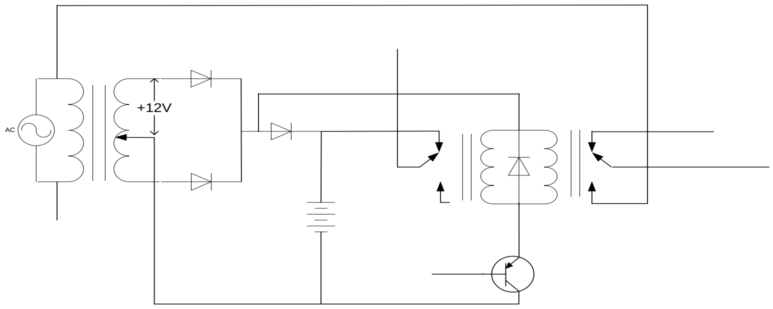

Figure 4: UPS

III.1.5 Fan Control Unit

The fan circuit is switched 'on' at different voltages like +5V for low speed, then +9V for high speed.

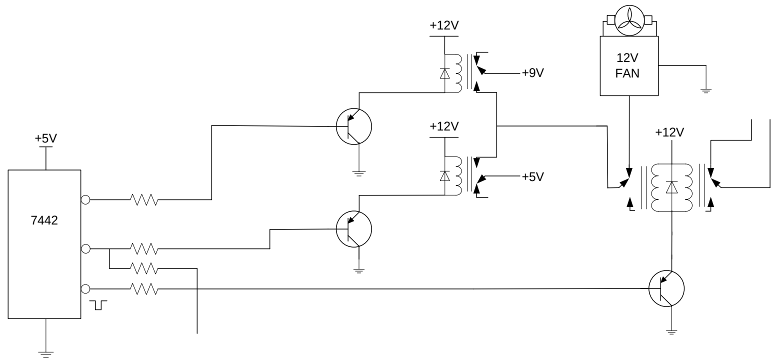

Figure 5: Fan and Relay Units

III.1.6 The power supply unit

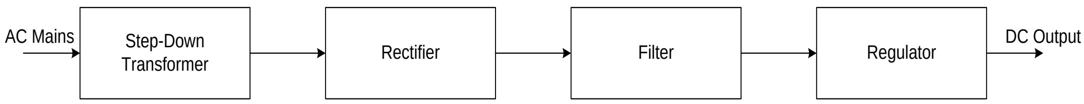

Figure 6: Block Diagram of a Power Supply

The power supply is meant to supply up to 247.2mA at 12V. The product of these two values, give the minimum VA rating of the transformer that will be used. Hence, a 12VA transformer is needed. For maximum safety, a full-wave bridge rectifier with a continuous current rating of 3A is also needed. The filter capacitor needed will be large enough to provide acceptably low ripple voltage, with rating sufficient to handle the worst case combination of no load and high line voltage. Thus, for a 12V RMS transformer, the off-load filter voltage will be calculated as $12\sqrt{2} = 19.97V$. A filter capacitor that has a working voltage of 35V is needed. A 9V and 5V three terminal regulator IC will be used.

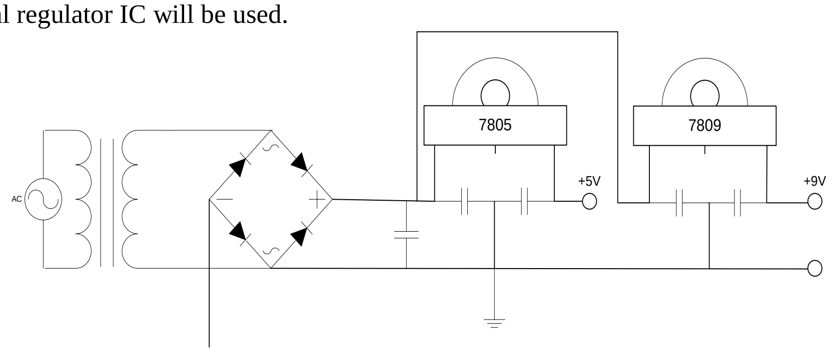

Figure 7: +9V and +5V Power Supply

$$V = RMS\,(V_{AC} - 2V_{DROP})$$
$$= \sqrt{2}\,(V_{AC} - 2V_{DROP})$$

Where V_{DROP} is the voltage drop across eth diode rectifiers D, and V_{AC} is the transformer step down voltage.

$$V = \sqrt{2}\,(12 - 2*0.7)$$
$$= \sqrt{2}\,(12 - 1.4)$$

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$= 14.99 \approx 15.0$ volts

This voltage feeds the regulators 7805 and 7809 to produce +5V and +9V respectively. The amount of ripple voltage is directly proportional to the load current and inversely proportional to the capacitance.

$$\Delta V_R\,(P - \rho) = \frac{Idc\Delta t}{C}$$

In order to contend with a ± 10 % worst case line voltage variation, the ripple voltage was kept below 1.5 V (P – ρ).

III.2 Design Specification

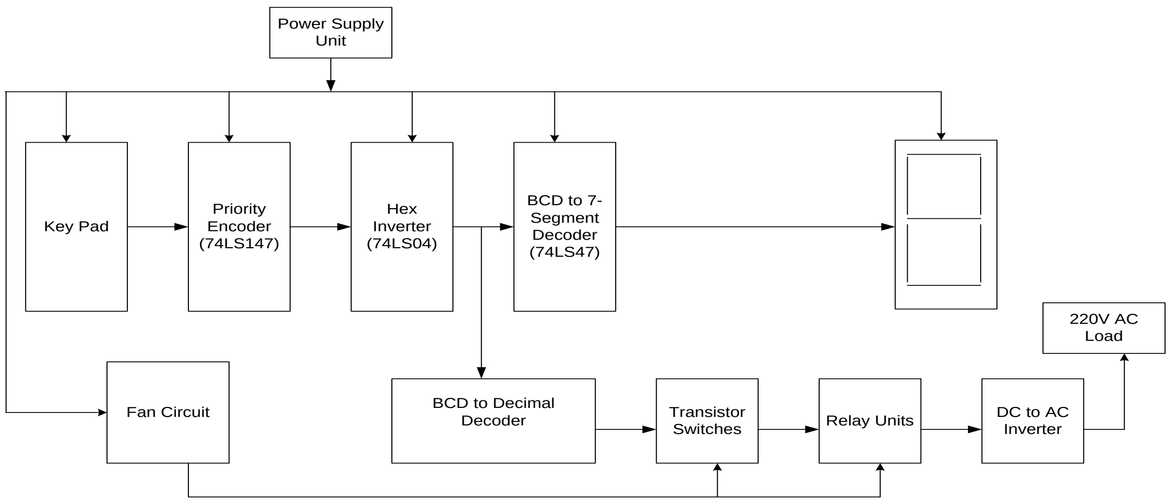

Figure 8: Block Representation of the Wind Turbine with Battery Facility

I. The digital IC's are all transistor-transistor logic (TTL) 74 series
II. All the IC linear voltage regulators are 78 series positive voltage and must be mounted to aluminum heat sink.
III. The transformer for the DC to AC inverter must be 12V-0V-12V to 220V step-up transformer with current rating of about 2000mA
IV. The 7-segment display must be common anode type RS586-526
V. All the freewheeling diode connected across the relay coil must be silicon IN4007
VI. 12V battery of 50AH and 100AH maximum must be provided for the DC to AC inverter unit
VII. Relay of 12V, 10A max and 400Ω coil resistance must be employed
VIII. A regulated DC supply of +9V and +5V must be employed to power the entire control unit.

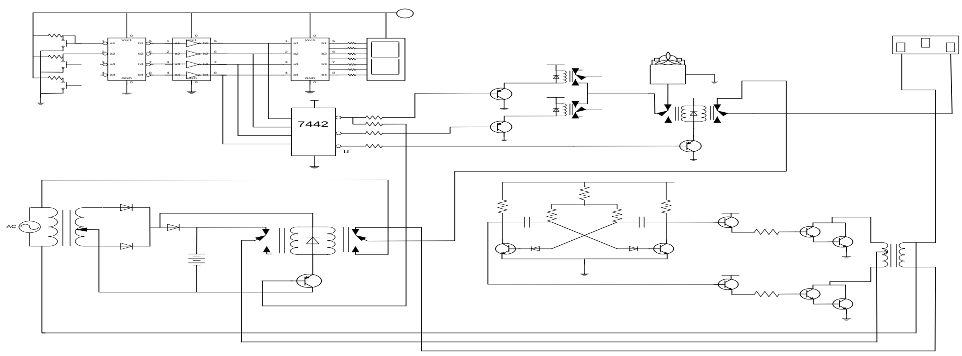

Figure 9: Circuit Diagram

IV. CONCLUSION

Wind energy has been harnessed since the 7th century making it a very old energy source. Now with the ability to convert with increasing efficiency, this free resource of nature, it would be unwise of policy makers and executors in the energy sector of this nation to overlook the implementation of this system and hence fail to adopt the system.

After a thorough evaluation of the project, its set objectives were met. These objectives are as follows;

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- To bring to the fore, a fast growing energy source that if harnessed would make contributions to the technological growth of the country.
- Keeping to generally accepted standards, design and implement an inverter/battery facility that has application in wind turbines and other electrical power generation systems.
- To develop our abilities to work in multifaceted engineering environments.

IV.1 Cost Analysis

The system design for this project was achieved using locally available components and the total cost incurred in the procurement of these components summed up to a total of NGN 5,375.00 (which is about $34 USD).

IV.2 Recommendations

The following recommendations were made:

- The project could serve a better purpose if executed as an inter-disciplinary collaboration cutting across the various departments in the faculty with vested interests in this topic. In this way the students gain invaluable experience that would benefit them in the industry.
- For the battery facility, a bigger accumulator should be employed to provide longer periods of backup power.

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