Wind Energy Based Power Storage System

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UNDER THE SUPERVISION OF

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Abstract

This paper presented a design and implementation of a wind energy based power storage system by using a smart wind sensing device. The entire system was connected with a plain voltage regulated rechargeable battery storage system for storing the energy. Here a 1.5V, 1300mAhr Ni-MH battery was used as a storage device. For automated control of the arrangement a well known microcontroller BASIC Stamp 2 was used by the help of an assembly programme. For boosting up the power of wind generator an energy harvester module was used. An optical encoder used as a direction sensing device here. A servo motor was used for rotating the wind generator by the help of microcontroller kit.

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Declaration of Originality

I the undersigned, declare that the work contained within this report is completely my own. Any material that has not been originated by me has been clearly marked and the creators identified.

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Date: 13-05-2011

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Chapter 1

Introduction

1.1 History & Background

Renewable energy was a natural energy which could be used repeatedly and would never extinct. It was keeping pace alongside with the conventional power system. The reasons for its popularity and large scale of using were consistency, friendly, low expense, availability and other ecological features. There were various forms of renewable energy. Wind energy was one of them. In the year of 1890, first electricity generating wind powered machine was introduced in Denmark [1]. As the time passes by, the engineers made well advancement in renewing wind powered machine. They focused on the efficient electricity generation with the help of this. Wind turbine had turbine tower, turbine rotor, blades and hub attached with rotor. As the technology advanced, the whole system shaped in a new way. Modern turbine had three blades with the tower and the nacelle in which vital components such as gearbox, brakes, generators, and control system were installed. Wind turbine or generator converted the mechanical energy into electrical energy. Wind power rotated the blades and step by step increased the rotation of the blades. In wind turbine three generators were used such as DC generators, synchronous and asynchronous exchange alternators. Wind direction sensors were used to move the generator in the wind direction to harness the wind. Generally wood used for the construction of blade for small rotor. Large propellers were used in big wind power plant. But small blade would be preferable in small wind generator [2]. Consistent and reasonable operation for renewable power system could be obtained specially in wind power by incorporating energy storage system or device in the whole system.

1.2 Focus on Present State of Art

Wind sensors were used to direct the wind generator in the wind direction. Such as a micro solid state silicon plate, micro-integrated wind sensor, thermal image based wind sensing sensor and sensor based on thermal delta modulation [3, 4, 5, 6]. Various smart techniques were introduced in developing the controlling of the wind generator [7, 8, 9]. A storage system would be a key factor in power system. As storing device battery, super capacitor or other possible factors could be used [10, 11, 12, 13, 14, 15] and storage performance could be improved by integrating a harvester [16, 17, 18, 19].

1.3 Aims and Objectives

The aim of this research would be to design and implement a wind energy based power storage system. For this, the objective would be designed and implemented a wind direction sensor that could sense the direction of wind and moved the wind generator into the wind with the aid of a motor. A microcontroller aided rotational system would be implemented which could move the wind generator in a perfect position and the whole system would be tested for a desired result. Flow chart would be made to develop algorithm for the microcontroller scheme. An energy storage and retrieval system would be designed and implemented to fulfil the requirement. This project involved designing, implementation, testing and result between a rigid time frame. For that correct information was obligatory in whole process. A technical papers, applicable resources and good references were needed to write a good formal statement. An improvement in understanding of the specific problems and verdicts out the solutions of the problem would be gathered.

1.4 Project Deliverables

The deliverables were the appropriate decisive factors which would establish the objectives of any project, improvement or investigation at any stage. The project deliverables were given by the supervisor which was listed below:

- Design and implement an electronic wind direction sensor.
- Use the wind direction sensor to point the wind generator into the wind.
- Design and implement an energy storage and retrieval system for use with the wind generator.

1.5 Project Portrayal

Nowadays, renewable energy in every form became popular and widely used all over. The project was entitled simple but smart one. As from the above mentioned deliverables a smart sensor system had to be designed and implemented which could sense the direction of the wind. So when the wind blew, the sensor would sense the direction of wind and it would aid the motor by means of microcontroller device to move the wind generator into the wind direction. A storage system would be used which was an AA battery that would be implemented to store energy which would be produced by the generator. An energy harvester would be added with the storage system to maintain the flow of energy in the storage system. As a result some updated technologies would be required for making the system.

1.6 Block Diagram

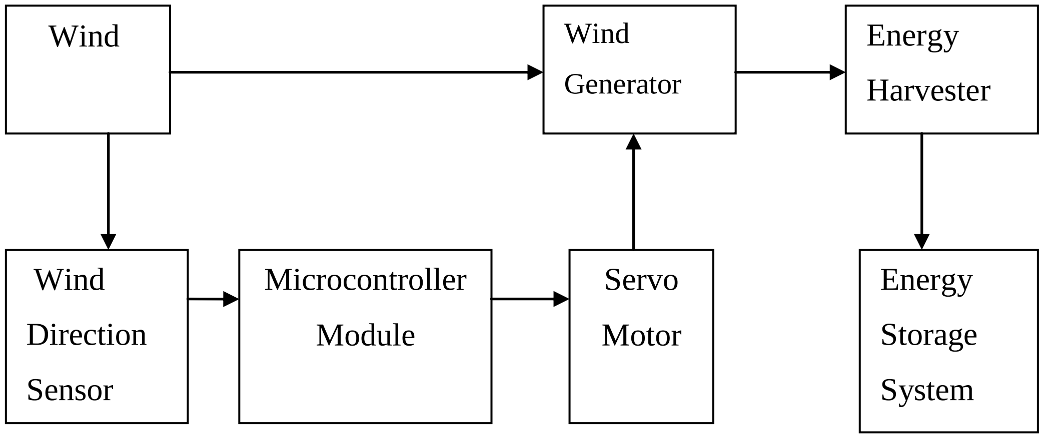

Figure 1: Proposed System Block Diagram

Chapter 2

Literature Review

2.1 Thematic Analysis of References

2.1.1 Core Themes

The references were collected on the point of view of wind sensor and their behaviour according to wind, wind generator and controlling techniques, harvesting and storage system for wind energy.

2.1.2 Wind Sensor

Diverse systems were introduced in wind direction sensing technology. A drag force micro solid state silicon plate wind velocity sensor used cantilever torque in measuring wind velocity and direction that could be measured by two perpendicularly integrated sensors. It was beneficial for its size, system and measurement techniques [3]. The system was simulated by ANSYS software (ANSYS software constructed computer aided replica of formation, machine apparatus or structure that applied operating loads and other design aspects and studied material reaction like stress, temperature, pressure and so on. It estimated a design of without building and destroying numerous examples in analysis) and fabricated by MEMS (Micro Electro Mechanical System) technology (MEMS tools could be fluctuated from simple structures with no moving elements to intricate systems with several moving parts under the control of combined microelectronics).

For both low and high wind speed detection a micro-integrated wind sensor was effective. Its two (mechanical, thermal) parts were effective in two different velocities. The wind direction could be measured by placing the two sensors perpendicular to each other. It was shown that one cantilever system was better than two cantilever systems in wind direction measurement [4].

Newer technology of wind sensor was introduced based on the concept of thermal image measurement which used a temperature sensor that measured the velocity and the direction of the wind. This model allowed wind sensors to act without moving parts and it gave data from the strained convection by wind which puts thermal reflection on heater and that provided velocity and direction of wind. It provided fast response with time and better accuracy in the measurements of direction [5]. Another way of wind direction measurement was the using of two dimensional thermal flow feeler recognized in silicon [6]. Here three thermal sigma delta modulations based comparators were used which managed and digitized heat circulation on the chip. Among them one modulator kept the chip's temperature at a steady level and others rejected orthogonal elements of temperature steep and the bit flow provided output for accurate wind direction as well as velocity.

2.1.3 Controlling Techniques of Wind Generator

The performance of the system could be improved and maximum power could be harnessed if the generator would be controlled and pointed that all time in wind direction. Control system of wind generator had developed with the advancement of time. Various methods were evolved by the engineers from time to time. One of them is pitch control [7]. Wind generator could be controlled with the aid of variable pitch control system by stepping motor and gear system. Speed of the generator could also be controlled by means of controlling pitch and field current.

Control of erratic wind generator could be done by the means of fuzzy system or simulated neural network [8]. Takagi-Sugeno-Kang (TSK) fuzzy controller or regulator would used to haul out utmost energy from wind on the basis of sensor less peak power following control. Another smart controlling system would be the use of PIC microcontroller [9] for induction generator based wind turbine. Here the controller structure sense the factors of grid and generator and made a judgement whether to connect or not. This would be the convenient way of reducing power loss and financial loss. In this technique the decisive elements would be the voltage and frequency of grid and generator.

2.1.4 Harvesting Method and Storage System

A storage system would be the key part for any renewable energy and energy harvester played a catalytic role to maintain the flow of energy in the system. A significant change had been done so far in the field of storing system. From the economic and the ease of operational point of view, battery storage technology performed a vital role in the renewable energy in recent time [10]. In the near future, this would be acted as a bridge between conventional and renewable power system and it would be the major parameter in the improvement of the system. Such as in the high penetration wind diesel hybrid system, which operated in three forms had Ni-Cd battery storage system which acted a vital role for the diesel engine as active power supply during the period of wind only mode to wind diesel mode because it could hoarded plenty of retrieval power supported by converters and battery bank [11].

On the other hand, combination of diesel engine and battery energy storage system increased the frequency of system during power failure and reduced voltage deviation and operational time to a great extent [12]. For cut off wind diesel system the Ni-MH battery bank storage system had been found an improved technology for demonstrating a significant development in the system because of its high quality features over other battery [13].

Flywheel could be another promising device of storing system. Excess generated electrical energy from generator could be stored in flywheel as a kinetic energy through alteration [14]. This energy could be reused in the operating of the wind generator by converting it in an electrical form in case of power failure in the system. As a result a certain level of better performance would be maintained in the system. Wind speed variation which in results of power instability and excessive fuel utilization had a negative impact on wind diesel engine. This problem would be overcome by interfacing a fuzzy logic controlled flywheel based storage system [15].

Instability of voltage supplied by wind generator puts harmful effect in power generation [16]. So a medium would be needed to maintain the constant operation. Energy harvester would be a good option in this regard. Such as piezoelectric elements gave electricity where there was demand and it would be a good choice for its different characteristics and size (typically AA battery size) [17]. In some area for steady power operation an advanced technology needed which would convert adjacent energy into electrical energy [18]. For instance, a harvester driven by vibration (acted on the basis of piezoelectric effect) would be the possible solution in which it dragged surrounding energy in a tiny structure and the performance could be improved if the materials were substituted with electro active polymer. Corona discharge method of charging the harvester material increased the productivity and performance of the harvester. It would need a needle where corona ion would pass and applied bias voltage of electrode established electron from corona ion to material [19].

Chapter 3

Requirements Analysis

3.1 Wind Power

From medieval era to the modern world wind power system had experienced a vast exploration of innovative technologies in terms of structures, turbines, blades, energy harvesting methods and storage systems. Newer technology in wind sensing system and wind turbine and no adverse ecological effect made it a lucrative solution for more power generation in an effective way.

System efficiency depended on the wind tracker technology. For low power system, wind sensor acted a key role because of the detection of available wind and made the wind generator to point in that direction of wind. So the harnessing of more power depended on the characteristics of sensor as well as high rating generator. Controlling method also depended on the higher rate of energy harvesting from the wind. But some factors would be raised in implementing the low or high wind based power system.

3.1.1 Factors of Wind Power

Wind energy efficiency depended on several criteria like speed and force of wind, height and rotor size. Both the speed and force of the wind would be the decisive factors because the more wind speed and force, the greater power would be generated by generator. Wind speed also depended on area. Place with higher altitude with no obstruction from surrounding also needed for higher efficiency. On the other hand energy produced by wind turbine would be proportional to the size of the rotor used because a bigger rotor generated more power. Weather would be another reality for wind speed because in summer, spring, winter and rainy seasons speed would not be same and it would also differed from the environmental aspects. A few equations would make the wind efficiency apparent:

$$\text{Power in the wind} = d*(D)^2 *(V)^3 *C$$

Where, d meant density of air, D meant turbine blade diameter, V meant velocity of wind and C was a constant. Three parameters would be important for efficiency increasing. Such as- density of air, blade diameter and wind velocity. But on the other hand according to Betz law turbine could only extracted 59 percent of power from wind.

3.2 Concept of Wind Sensor

Wind sensor dealt with the precised measurement and decided the origin of the wind. Different types of valuable measurements of the wind direction could be done with the help of sensor. The main principle of it's to determine the direction with more precision with the help of signals in the form of electrical quadrature. Its operation relied on the building and the fitting of the wind direction sensors. Normally it had arrow kike head arrangement connected with the pivot and total circuit was operated with the help of electrical signals. As the wind blew it hit the wind direction sensor and the device moved to the reverse direction which detected the direction of the wind. The electronic equipment connected with the wind direction sensor made it feasible for the detector to calculate the direction with more exactness and recorded the reading. This device was used mostly because of its low power and the wide range coverage. It had the ability to measure the wind direction from 0 to 360°.

3.3 Features of Battery

Battery performance had to be considered in building a storage system. Better performance of the battery was interrelated with the capacity. It could be characterized by two parameters such as state of charge and floating charge voltage [20]. Other several aspects were important for battery like ampere hours, charging/ discharging characteristic (C rate), energy density, trickle charge, battery life and capacity retention. Such as-

- Basically energy density was the energy stored per kg of mass. So weight of the battery relied on the energy density that meant lighter the battery, higher the density.

  Energy density= Watt hour/ Kg

- Ampere hours meant the total energy storage ability of a battery.

Watt= Ampere Volt*

Ampere= Watt/ Volt

- Capacity retention of a battery meant the little bit of the full capacity available after storage for a period of time.
- C rate was a constant value and it meant a maximum discharge rate that would be delivered to a specified hours of service during a given cut-off voltage. So discharge rate of 1C meant of a 1Ah battery would be 1amp.
- Trickle charge would be the minimum continuous charging current that required continuing a full charge on a fully charged battery.
- Battery life stated as the cyclic life. If the battery did not cycle much, battery life increased and vice versa. But when a battery would cycle regularly, its life would rely on the depth of the discharge cycle and the number of cycles it had to do.

3.4 Requirement of Energy Scavenging

When wind would not be available that much or the generator could not produce sufficient power from the wind then a technology would be required to boost up the level of energy up to the expectation level. This was so called energy harvesting or energy scavenging [21]. It would provide a way out of energy enhancement in small wind power system, passive solar power system, biomass and other forms of renewable energy as well. It offered two noteworthy advantages over battery powered solutions. One was virtually unlimited sources and another was little or no bad environmental effects.

3.5 Requirement of Energy Storage

Wind power could be produced only when there would be sufficient wind. While it would not be possible to produce wind power without wind, so energy storage would be considerably important especially in developing countries and other parts as well. This energy could be used as backup power source and it could be integrated with the main grid. It could also be a great option in heating and cooling system for cold and hot regions respectively. Today’s world wind power would be also used in high power applications, where storage system with longer life time and less weight would be crucial.

3.6 Study and Realization of Deliverables

From the first deliverable a smart electronic wind sensing system would be required which would save the space, maintenance and unwanted structural problems. For this an intelligent sensor would be required that would sense the direction of wind accurately from any direction. So identifying an accurate sensor would be important.

In terms of second deliverable increasing the wind power efficiency or system efficiency would be possible if the wind generator would properly point in the wind. This tracking would be possible by both analogue and digital processes. But digital way would be better because it eliminated the use of analogue to digital converter. A stepper or servo motor would be a possible for tracking system. A sensing device would be helpful here which would sense the direction of wind and made the motor's rotation by the help of microcontroller.

According to the third deliverables building of an appropriate storage device would be requisite. Although wind power system produced DC power so it could be stored in a storage system like battery, super capacitor and fuel cells. Battery storage system would be the most essential part for renewable energy. Generally deep cycle lead acid batteries were used in wind power system. The reason for choosing this was it could provide power for a longer period of time and batteries of absorbed glass mat or GEL could be used in this work because there were less chance of hydrogen gas building and decay. Different types of rechargeable batteries would be used according to their charging time, trickle charging, life cycle, weight. Generally lead-acid batteries were used in the wind energy based power storage system. Others were such as AAA, AA, C, D and 9V rechargeable batteries would be used. Alkaline, Ni-Cadmium, NiMH, Lithium polymer and Lithium ion were also used for renewable power system. Energy harvester played a key role in boosting up the voltage produced by the generator when it would generate below the expectation level. On the other hand, when the produced voltage and current would higher or lower than the battery's rating than a voltage regulator and current limiter would used to manage the charging characteristic. Several IC would be useful for making a voltage or current regulator circuit.

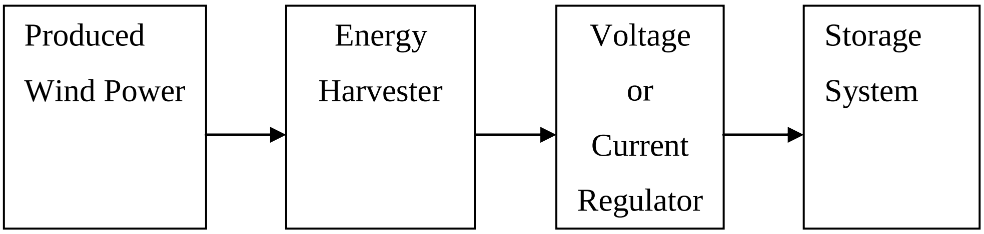

Figure 2: Block Diagram of Storage System

Wind sensor would sense the direction of available wind. According to that direction it would send pulses to microcontroller to move generator in that direction. The generator would harness power from the wind and stored that in the storage system with the help of energy scavenger. For this automated control a programme would be needed.

3.7 Tasks Needed to Be Done

- A circuit design and construction would be needed for wind direction sensor.
- A circuit design and construction would be needed for wind generator rotational system.
- A simple storage system with voltage and current regulator and a harvester would be needed for design and implementation.
- A user friendly microcontroller module would be needed for interfacing sensor and rotational system and a study would be required for a new microcontroller user which would make the work easier and lucid.
- By the help of a flow chart a program would be needed to make wind direction sensing system.
- By the help of a flow chart a program would be needed to make a wind generator controlling system.
- A Gantt chart would be needed to make a work plan for.

Chapter 4

Possible Problem Solutions

4.1 Diverse Technologies for Wind Direction Sensing

- **Weather Vane:** This was the oldest method for wind direction sensing. It provided the wind direction while dangling around the wind. It could be in various shapes. Some of them were the pointing arrow which indicated the direction from where the wind blew.
- **Wind Sock:** Wind sock showed both direction and speed of wind. When wind blew at the open end of wind sock it indicated the direction of wind and it was easy to visualize the direction. The shape of sock also indicated the speed. When it became straight the wind speed was strong and when it moved gently the wind speed was low.
- **Ultrasonic Wind Sensor:** This sensor placed on the higher altitude places. When the air stroked this sensor through hygrometer or thermometer, then it sent signal to observing tools via wired arrangement or wirelessly. The calculation was displayed on the display module. It measured velocity and direction up to 60m/s and 359° respectively.
- **Mechanical Wind Sensor:** It used cups for measuring speed and vane for direction and this arrangement moved with the change of wind. These moving parts were connected to a datalogger or other data recording device and gave a data of direction and speed.

The previous two methods were not able to provide actual wind direction. Though ultrasonic sensor gave actual direction but it was expensive and complex to install. On the other hand mechanical sensor was less precise and weak. Their external structure was deteriorating because of the material. Their speed measurement was also comparatively sluggish than others.

For this work a smart sensing device would be needed which was inexpensive, gave accurate data and easy to build. An optical encoder would be the good option for implementing this task. An optical encoder comprised of a metal rotor and a plastic optical patterned disc was mounted on the shaft. This disc was electromechanically decoded and had transparent gray code (GRAY CODE-cyclic arrangement of bits which in results showed one bit change from one value transition to next value) which provided location information. The stator composed of pairs of LED and phototransistors and the arrangement was in the way that when LED shined through the disc, it was received by phototransistor from other part. After amplification and conversion, signals were used for position evaluation and it was able to provide accurate value up to 360°.

4.2 Control Scheme

For controlling method different microcontrollers and motor drives aspects were depicted below:

4.2.1 Diverse Microcontrollers

Control system could be analogue or automated. But for wind direction sensing, automated control structure would be needed. Controlling system could be done by using MOSFET, Relay, Op-amp, Current Controlled Thyristors but these all were controlled manually and analogue. For automatic control system pulse generation would be needed for device control. Analogue to digital converter could be used to make the system automatic. Different types of microcontroller kits like BASIC Stamp, PIC, PLC and microcontroller 8086 would be used for automatic and smart control. Different Programming languages such as assembly language, visual basic, C++ and machine code were used for these microcontrollers control. In industrial purposes Programmable Logic Controller (PLC) was used because of its ease of using and consistency.

4.2.2 Selection of Microcontroller

For this job BASIC Stamp 2 was used for its ease of using than other ones where it used assembly language as programming language. It was appropriate for educational point of view. PIC and PLC would be another option of using. But because of their less ease of using they were not chosen for this work. On the other hand for PIC a good command on C++ would be required. Table-1 provided fundamental information about various control method.

Table 1: Basic Comparison among Control Methods

Type	Programming Language	Operation Mode	Power Supply	Price
PIC	C++	Less Easy	External	Low
PLC	Ladder Logic	Complex	External	High
BASIC STAMP	Assembly	Easy	Internal	Less high

For small purposes such as educational works, BASIC Stamp and PIC were better choice in lieu of PLC. Table-2 depicted the comparison between BS2 and PIC after an investigation.

Table 2: BS2 and PIC Comparison [28]

Type	Module	Code Maintenance	Security	PWM	ADC (Analogue to Digital Conversion)	Current Growth
PIC	Not Compact	No	High	Available	Available	Average
BS2	Compact	Yes	Low	Not Available	Not Available	High

4.2.3 Different Motor Drives

There were some motors which were microcontroller compatible and could be used for controlling wind generator. Here operating principle of some of them were focused below:

- **Steeper Motor:** This motor was an electromechanical machine. Here it converted electrical pulses into discrete mechanical movements. When electrical command pulses were applied to the motor in proper sequence, the shaft of this motor rotated in discrete step increase as it provided. Motor rotation related to applied input pulses. The speed of shaft rotation was directly relied on the input pulses frequency. As well as the rotation length was straight related applied input pulse numbers.

- **Servo Motor:** A servo motor contained control circuit and a potentiometer. This arrangement was connected to the output shaft. Here control circuit monitored the present angle of the servo motor by the help of potentiometer. If the shaft was at the correct angle, then the motor was shut off. When the control circuit found that the angel was incorrect then it rotated servo motor in correct direction until the correct angle. When it found the correct angle it simply stopped the motor rotation. It was capable of rotating 180 degrees. Here the control wire was used in angle measurement and motor rotation. Pulse duration and pulse length to the control wire determined the angle and motor turns respectively. Table-3 below showed comparison between servo motor and steeper motor on the basis of some important factors.

Table 3: Comparison between Servo Motor and Steeper Motor

Factors	**Servo**	**Steeper**
Encoder	Yes	No
Brush	Yes	No
Resolution	Wide range	Normally 0.9°-1.8°
Operation	Open Loop	Close Loop
Speed and Power	Higher	Low
Simplicity	Complex	Simple
Efficiency	80% to 90%	About 70%
Reserve Power Supply	Yes	No

For this work servo motor would be a good option rather than other because of its high efficiency. It was able to give same level of performance in low speed and high speed application. On the other hand it had the wide range of resolution and it did not have any issue of vibration and resonance like other.

4.3 Energy Storage System

Energy storage system varied on the basis of operation mode, capability and dynamic attributes. A suitable system design could be relied on some factors. Such as- various compensated variation, storage ability, power system aspects, charging-discharging time, time of minimum storage and minimum storage cycle, energy density, life cycle, position and environmental factors.

4.3.1 Different Technologies for Energy Storage System

Some of the possible energy storage solutions were described below:

- **Fuel Cell:** An electrochemical device that changed the chemical of fuel in dc energy was known as fuel cell [22]. It was composed of two porous electrodes and an electrolyte in between them. Hydrogen gave up electrons to the electrode at anode, and entered the electrolyte as a positive ion (H^{+}). On the other hand at cathode, the oxygen entered electrolyte as negative ion ($O^{2-)}$ by taking electrons. Both ions combined to form water, while the electrons moved throughout the external circuit to generate electric current with less energy losses and the operation continued as long as the reactant and oxidant flows were maintained.
- **Supercapacitor:** Super capacitor had higher stored energy and power [23]. A double layer capacitor or super capacitor stored electricity by separating positive and negative ions bodily. It could deliver power quickly without moving any parts. The process of super capacitor working was electrochemical just like fuel cell. In a single super capacitor cell the positive electrode attracted the negative ions in the electrolyte; on the other hand the negative electrode attracted the positive ions. There was a dielectric separator which prevented the charge from moving between the electrodes. It had fast charge-discharge rate and its stored energy was greater compared to an ordinary capacitor because of the vast surface area formed by the porous carbon electrodes and the little charge division produced by the dielectric separator.
- **Compressed Air Energy Storage:** Compressed Air Energy Storage (CAES) used outer power source electrically like wind turbine to power

the air compressor. After then it was stored in a storage system and at peak time this high pressurised air was used that to drive generator. It had the capability of eight hours generation period.

- **Battery:** Battery was a portable storage device where the operation went on electrochemically just likes fuel cell and super capacitor [24]. Electrons were flown from anode to cathode through electrolyte when current was drained from battery. During discharge time terminal voltage started to decrease while charging time terminal voltage raised to above nominal voltage of cell. It was popular among the other system because of its longer period of storing steady charge.

Table 4: Comparison among Some Common Storage Device

Factors	Battery	Fuel Cell	Supercapacitor
Working Voltage	1.25 to 4.2 volt per cell	0.6 volt per cell	2.3 to 2.75 volt per cell
Working temperature	-20 to +65° C per cell	+25 to +90° C per cell	-40 to +85° C
Energy Density	8-600 Wh/kg	300-3000 Wh/kg	1-5 Wh/kg
Power Density	0.005-0.4 kW/kg	0.001-0.1 kW/kg	10-100 kW/kg
Charging-Discharging Time	1-10 hrs	10-300 hrs	Milliseconds to Seconds
Weight	1g-10kg	20g to over 5 kg	1-2 g
Life Cycle	150-1500 cycles	1500-10000 hrs	Average above 30000 hrs

Table-4 described the difference among some storage device on the basis of vital factors.

4.3.2 Selection of Storage Device

A range of battery technologies were used for wind power system. As mentioned before that Lead acid battery was used in this area. But for low power purpose AA and AAA batteries were broadly used. Charging of these types of rechargeable batteries could be possible and it would need any complex system for charging. For this work AA NiMH battery was chosen for its plainness and market accessibility while it had high cost.

Table 5: AA Ni-MH Battery Features (Appendix 11.1(D))

Name	Capacity (mAh)	Nominal Voltage (V)	Standard Charging Current (mA)	Internal Resistance (mΩ)	Life Cycle
Ni-MH	800	1.5	80	≤ 60	>500
Ni-MH	2400	1.5	240	Approximately 25	>500
Ni-MH	1300	1.5	130	≤ 30	>500
Ni-MH	2700	1.5	250	≤ 25	>500
Ni-MH	2850	1.5	240	≤ 30	>500
Ni-MH	2100	1.5	210	< 32	>500

Table-5 explained the electrical features of the different Ni-MH AA batteries. According to the capacity and amount of charging current 130 mA Ni-MH battery was attractive instead of others because of temporary scarcity.

Table 6 depicted the comparison of various types of rechargeable batteries which were used in various purposes. Among them lead acid battery was used particularly for wind powered system because of long life cycle even if it had low discharge rate. On the other hand rechargeable alkaline manganese had long life cycle but it provided less amount of voltage.

Table 6: Various Rechargeable Battery Comparisons [25]

Type	Price	Voltage (Min)	Discharge Rate (Max)	Charging Time (hr)	Energy Density	Life Cycle
Lead Acid	Low	2	0.2C	8-16	30	Long
Ni-Cd	Mediu-m	1.2	> 2C	14-16	40-60	Long
Ni-MH	High	1.2	0.2C-0.5C	2-4	60-80	Medi-um
Li-ion	Higher	3.6	< 1C	3-4	> 100	Long
Rechargeable Alkaline Manganese	Low	1.1	0.3C	2-6	30	Long

4.3.3 Regulator Circuit

A wind power acted as an input for the storage system. This supply differed from time to time because of the fluctuation of wind speed. This input supply which was in the form of current or voltage might be higher or lower than the battery power. Too much of voltage or current flow could damage the battery. On the other hand for both quick and slow charging rate battery life could be reduced. So an arrangement would be needed in between input supply and battery to prevent this problem. It was the regulator which gave constant output voltage even if there was a variation in input supply. This regulator circuits were relied on the amount of input voltage and current supply [26]. When current flow would be less than the particular battery aptitude, while supply voltage would be higher than the battery voltage then a voltage regulator was essential. There was a method of limited current controlling in some few voltage regulators which eliminated the use of current limiter. Various types of regulator with different voltage and current level were available. A current limiter contained simple voltage regulator would be used for this work. Some regulator circuits were explained below:

- **Switching mode voltage regulator:** It worked on the basis of gaining PWM (Pulse Width Modulation) which regulated output voltage at an expected level and a range of fixed frequency switching current controlled the requisite voltage. Duty cycle of PWM increased with the increase of output voltage load current and duty cycle dropped at the time of decrement.
- **Low drop-out regulator:** It worked on the basis of using its minimum voltage to maintain expected output voltage. The chief benefit of it was the dissipation of inner power which relied on the level of the drop out voltage of this IC. Average drop out voltage of this IC was 0.6 volt and maximum was 0.8 volt.
- **Linear Regulators:** This was known as fixed type regulator for its fixed output and it was generally used. As voltage controlled current source was a vital part of it, there was a feedback system which attuned output voltage level in respect of current source. This current source worked as current limiter because it provided necessary current for meeting up expected voltage level at the time of voltage drop. It rejected spare power as heat which was a lacking of it.

For this purpose 3 terminal adjustable IC was used. Its voltage was adjustable from 1.2-37 volt and they were able to deliver 1.5 amps [27]. This type of IC stopped from damaging by stopping it down in the time of overheating. It was possible because of its inner circuit arrangement. It returned to its operation state after being cool

4.4 Flow Charts

a. Flow chart of wind direction sensing with rotation angle.

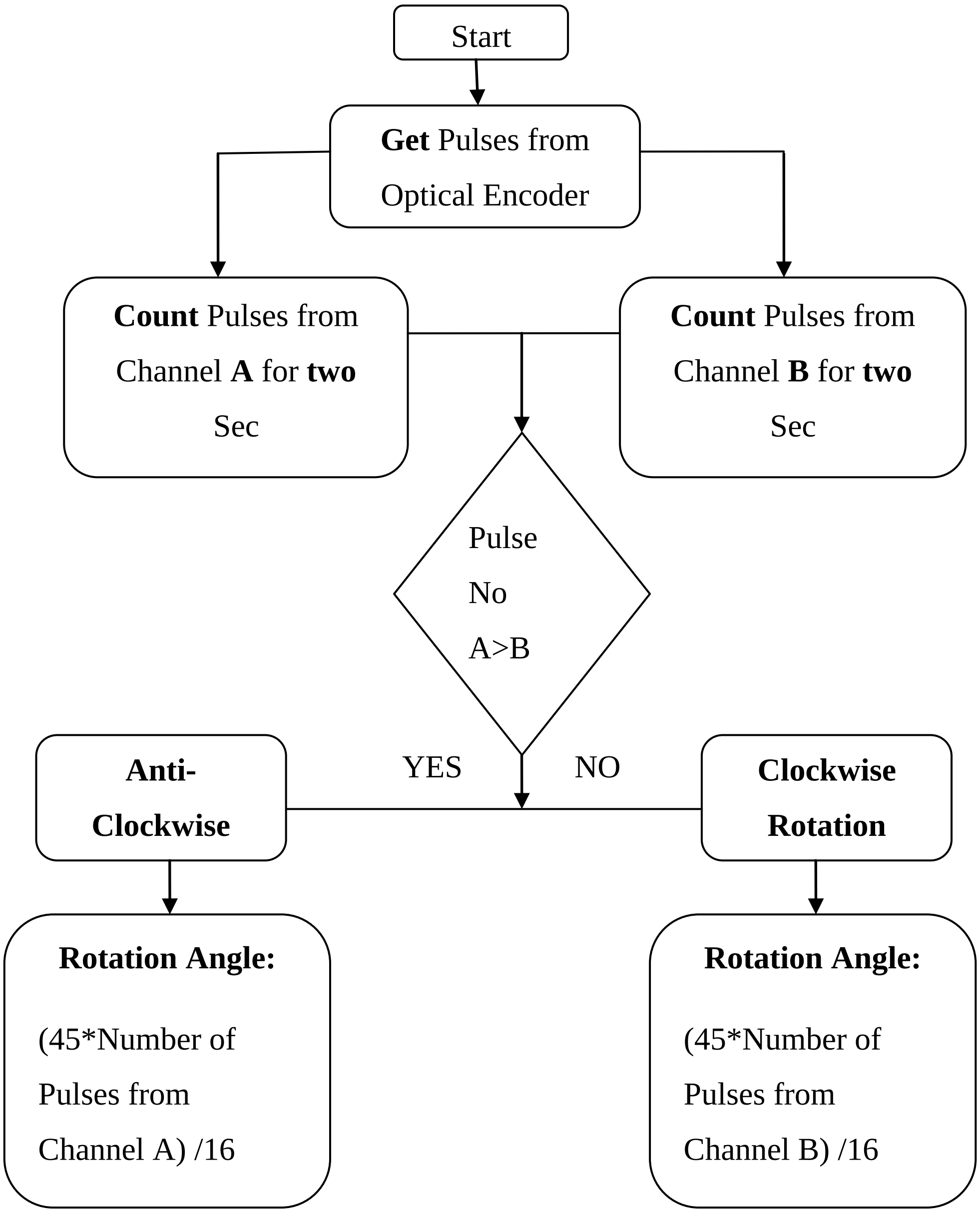

Figure 3: Flow chart of Wind Sensing

b. Motor Controlling:

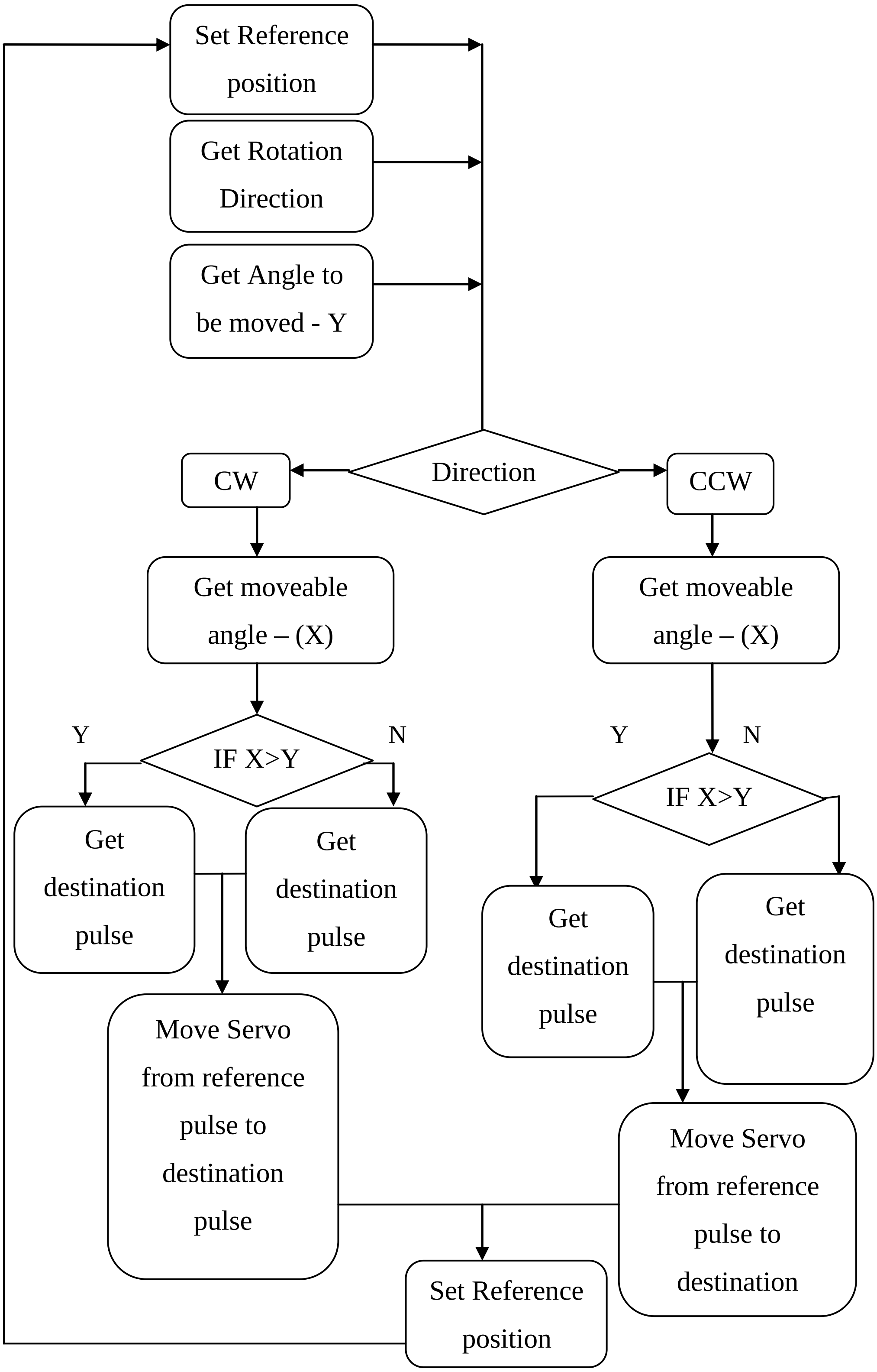

Figure 4: Flow chart of Motor Controlling

4.5 Energy Boosting Method

Flow of energy was vital issue in wind power system. Fluctuation of wind puts negative impact in energy flow. So boosting of energy would be needed. Such as a DC-DC converter (step up) with a higher output voltage than input voltage [29]. It normally contained diode, transistor and an energy storage device (inductor). In this circuit the key parameter was the inductor where it worked like resistor and battery as well. During the time of charging it absorbed energy, and worked as energy resource in the time of discharging. The output voltage became higher because it changed with current not by the charging current. Another solution would be op-amp which had higher output voltage than its differential inputs. A strain gage was a resistor which acted as a sensor where its resistance changed with strain. In this sensor output voltage varied with resistance and output voltage variation.

For this, low power system energy harvesting module could be good choice because of their self powered trends. When electrical energy was supplied to its input it stored charge in its capacitor bank. It worked on two states. One was maximum supply voltage (V_H) and another was minimum supply voltage (V_L). When capacitor voltage which was also the positive supply voltage (+V) reached at V_H its output (V_P) supplied power. If there was any fluctuation in input voltage or lower than the demand, then V_P reached V_L and stopped power supply. The main advantage of this module was it started Charging from 0 volt and could be operated both on AC and DC.

Above all the choice of right components, execution of correct programmes, cost minimization and proper testing were the key responsibilities of a designer.

Chapter 5

Implementation

5.1 Main Components

The components which were used to implement the entire system were described below:

Servo Motor and Wind Generator: Sanwa SRM 102Z servo motor was used here to control wind generator. It started operation when its inner resistance varied frequently or when a pulse was given from any microcontroller kit. It had rotation speed of 60° per 0.2 second [Appendix-A (3)]. Its three wires were connected together in a ‘Z’ connecter. Red one was for positive terminal, black for negative and blue for signal. This servo motor had supply voltage of 4.8V dc and input current of 8mA (idle). It was easily compatible with the latest BASIC Stamp kit which had four connectors where servo motor could be connected directly and it could take its input voltage from kit’s 6V built in power supply. Table-7 showed servo position according to pulse and rotation angle.

Table 7: Servo Motor Position

Position	Pulse (ms)	Rotation Angle
Left	1	-45°
Centre	1.5	0°
Right	2	-45°

Figure 5: Sanwa 102 Z Servo Motor

For this low power system a motor with high torque was required as a wind generator. A MM28 motor was used as a wind generator here. It had the operating voltage of up to 6 volt [Appendix-A (2)]. This motor supply current and speed was 0.21 ampere and 17100 RPM respectively. At utmost efficiency it drew current and power of 1.28 ampere and 4 watt.

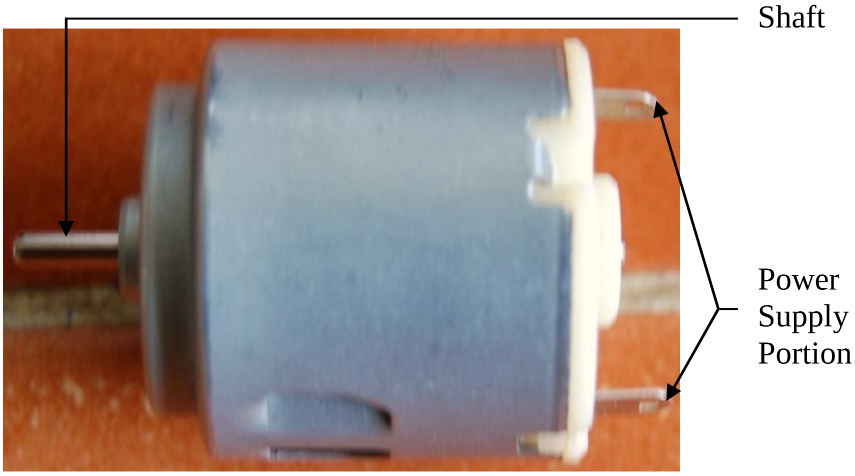

Figure 6: MM28 DC Motor

LM317T: It was a three terminal adjustable voltage regulator where it adjusted voltage from 1.2V to 37V at a current up to 1.5 ampere [Appendix-A (5)]. With this regulator output voltage and current could be varied by using a POT or by changing the resistance. Minimum output voltage could be gained by using simple resistance divider. It reduced the use of excess amount of IC.

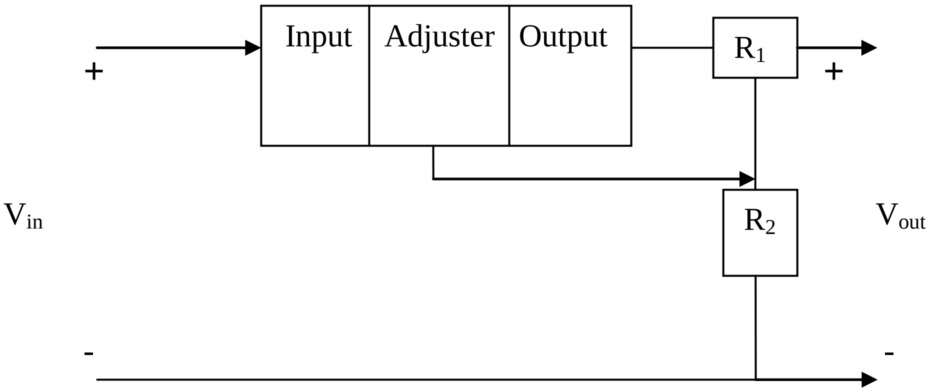

Figure 7: LM317T arrangement

Energy Harvesting Module: For energy scavenging EH301 energy harvesting module was used which was compatible for 3.1 volt to 5.2 volt operation [Appendix-A (7)]. The main advantage of this module was its all time active mode. This module maximum supply voltage and current was 0 to +/- 500 volt and 400 mA respectively. Its 6 volt capacitor bank charged with 300 nA and 1800 nW power.

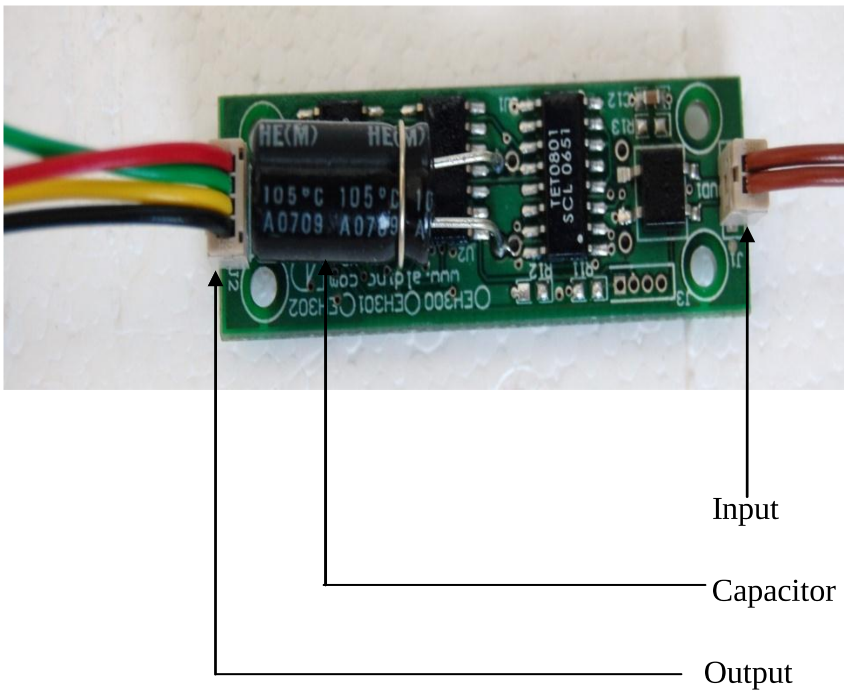

Figure 8: EH301 Energy Harvesting Module

Optical Encoder: For electronic wind direction sensor 600EN128CBL rotary optical encoder was used here [Appendix-A (9)]. It gave output of two square waves where its channel A led channel B in counter clockwise direction by 90° electrically. It also gave 128 pulses per revolution. It would be operate on 5 volt DC and 30 mA current. The chief advantage of it was the elimination of analogue to digital converter. In this module there were four leads of which red was supply, green for ground, yellow and orange for channel A and B respectively. For ease of shaft movement according to pointer rotation a push fit button was used.

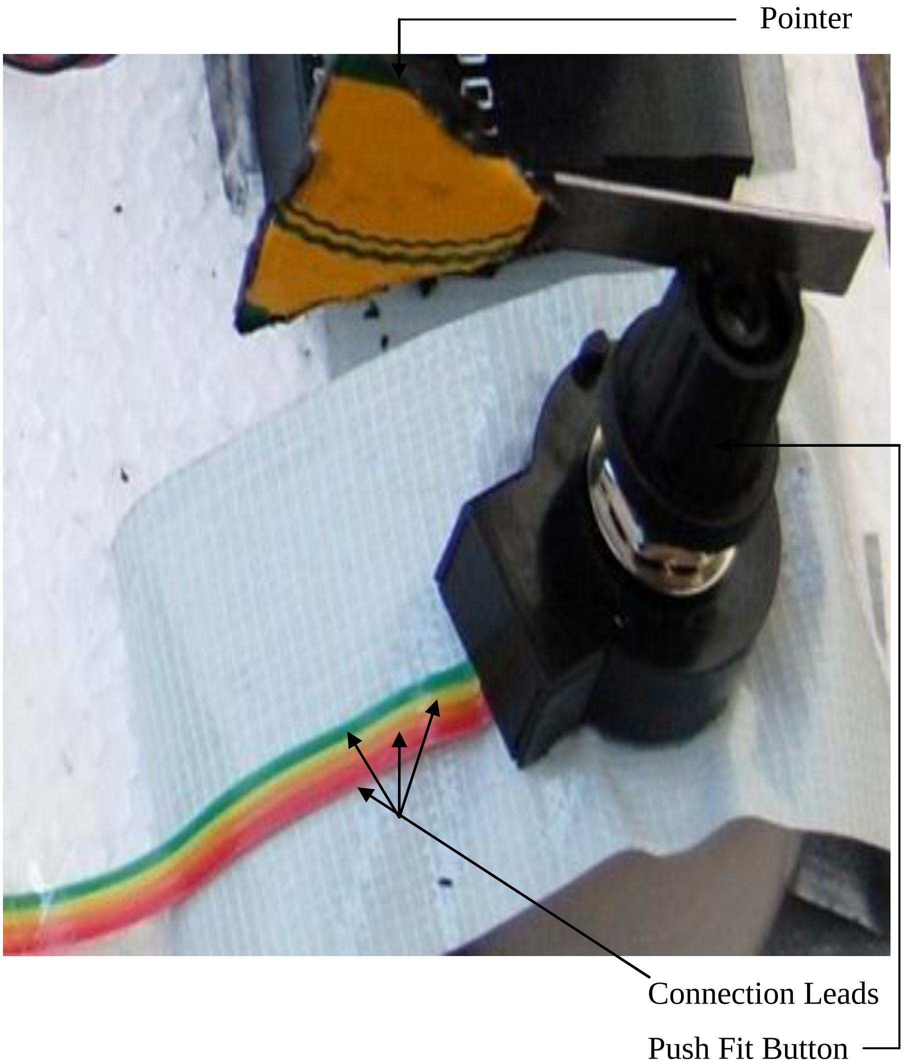

Figure 9: Optical Encoder

5.2 Physical Structure Arrangement

The entire system physical structure was divided into several parts. Such as-

a) Wind Turbine construction

b) Circuit making on Microcontroller kit

c) Entire System construction

5.2.1 Wind Turbine Construction

For wind turbine tower a piece of polystyrene with a width and height of 1.75 inch and 7.75 inch respectively were used. A hole was made in that structure in order to put a DC motor which would act as a generator. A 140 mm diameter propeller

[Appendix-A (8)] was attached with the 2 mm diameter shaft of the motor. This structure was mounted on a 1.75 inch square sized piece of plastic and was attached to a servo motor with screws and insulating tape.

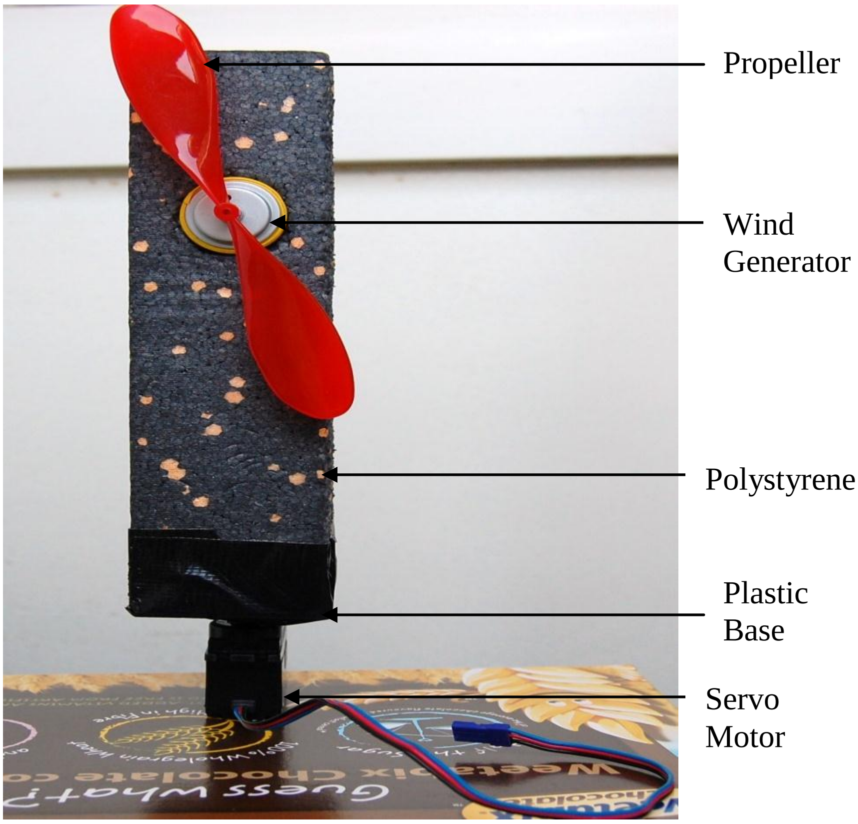

Figure 10: Wind Turbine Construction

5.2.2 Circuit Making on Microcontroller kit

BASIC Stamp 2 microcontroller was a user friendly device where an assembly language was used [Appendix-A (1)]. In this module there were two ways of supply- 9 volt battery and 6-9 volt wall mounted supply. A voltage regulated supply of 5 volt was provided in V_{dd} which could be used in its built in breadboard. There were two 3 pin Z connector which could be used for powering servo motor (X4 and X5 parts were used) and a power selector jumper selected a power connection. A built in LED indicated supplied power on the board. Here the socket was useable for 24 pin BS2 IC and a reset button which was used for restart the loading programme. It had a 3 position power switch. Built in bread board was connected through X1, X2 and X3 part. The programme was downloaded to the kit via USB cable. In figure-11 main parts of BASIC Stamp kit were depicted.

Figure-12 illustrated the connection on BASIC Stamp 2 kit. Optical encoder's channel A and B were connected in P13 and P14 of X2 respectively. Optical encoder's red lead was put in V_{dd} and green lead in V_{ss} of X3. Servo motor was first connected in 14 number pin of X4, and then it was changed to 15 from 14 while compiling a programme.

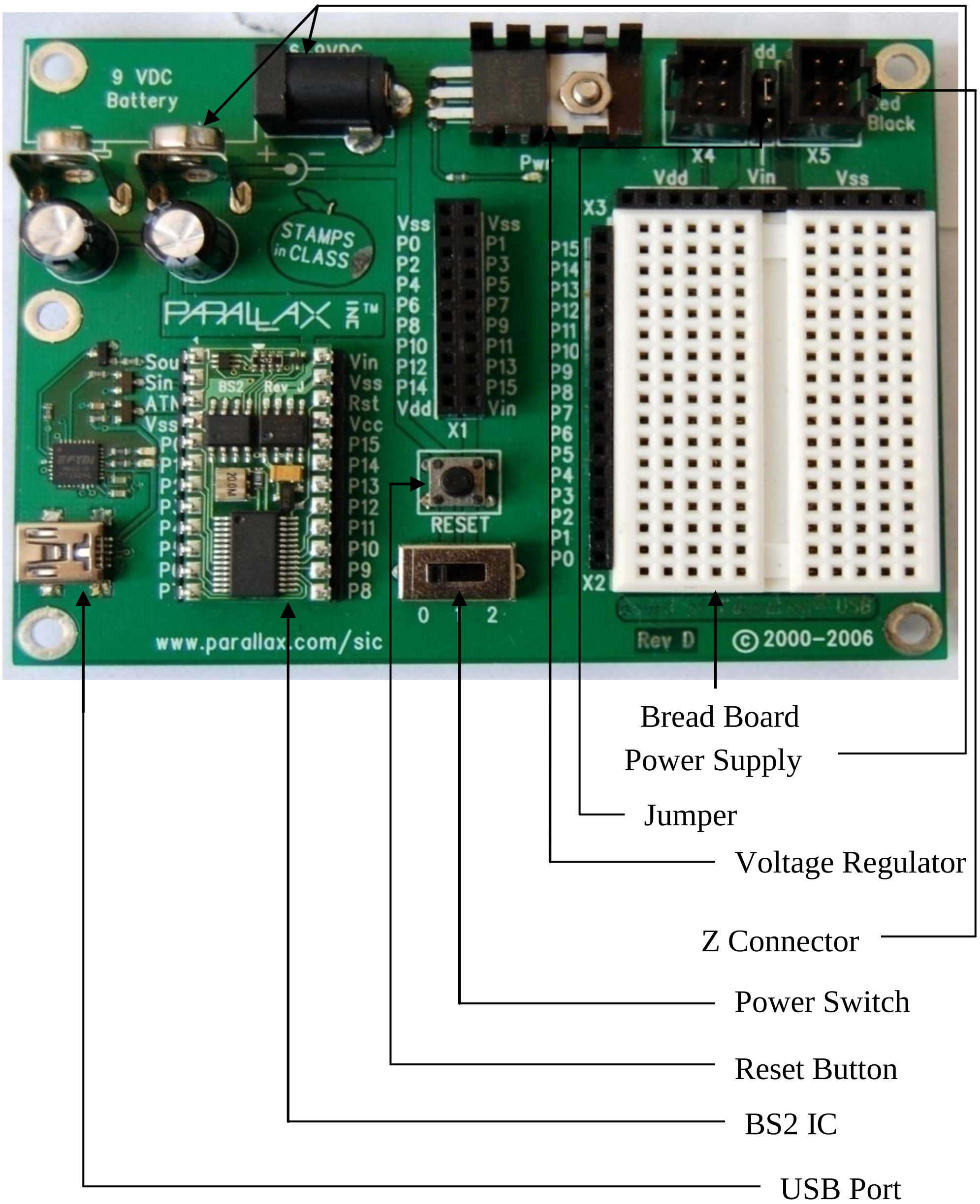

Figure 11: Basic Stamp 2 Microcontroller

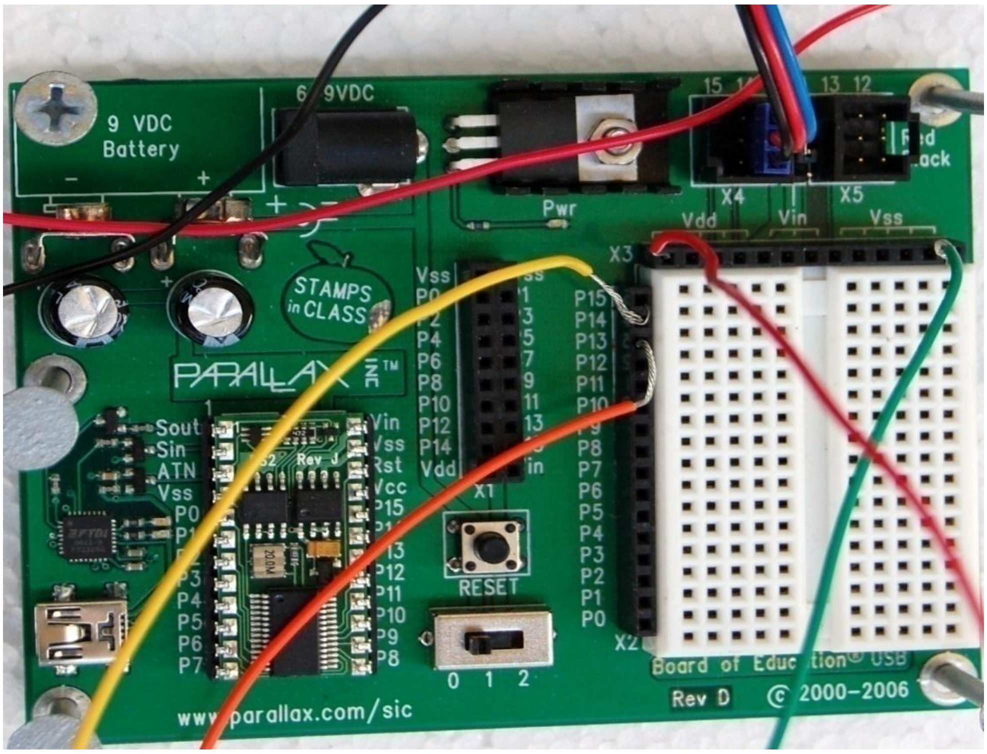

Figure 12: Connection on BASIC Stamp 2 Microcontroller Kit

5.2.3 Entire System Construction

The entire system was placed on a piece of polystyrene with a height and width of 8.5 inch and 13 inch respectively. A wooden base with a height and width of 9.5 inch and 13.5 inch respectively was attached with the polystyrene. The attachment works were done with sello tape, adhesive and pin. The wire extension was done with the help of heat shrinker. The connection of the system was depicted in figure-13 which would provide a clear idea.

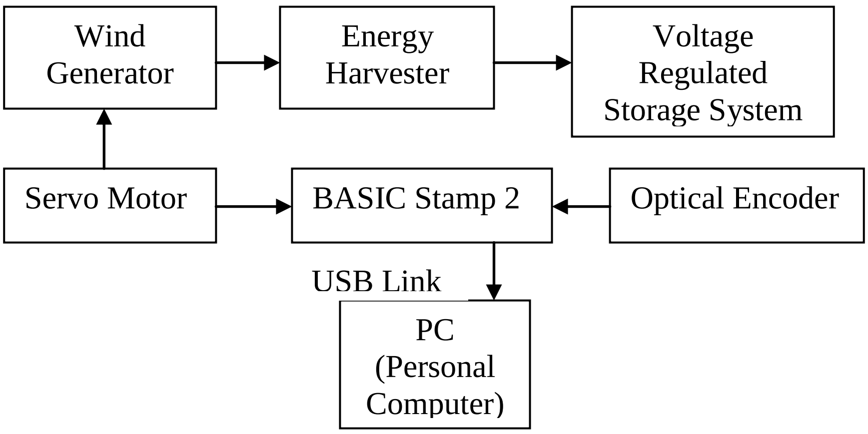

Figure 13: Block Diagram of Entire Constructed System

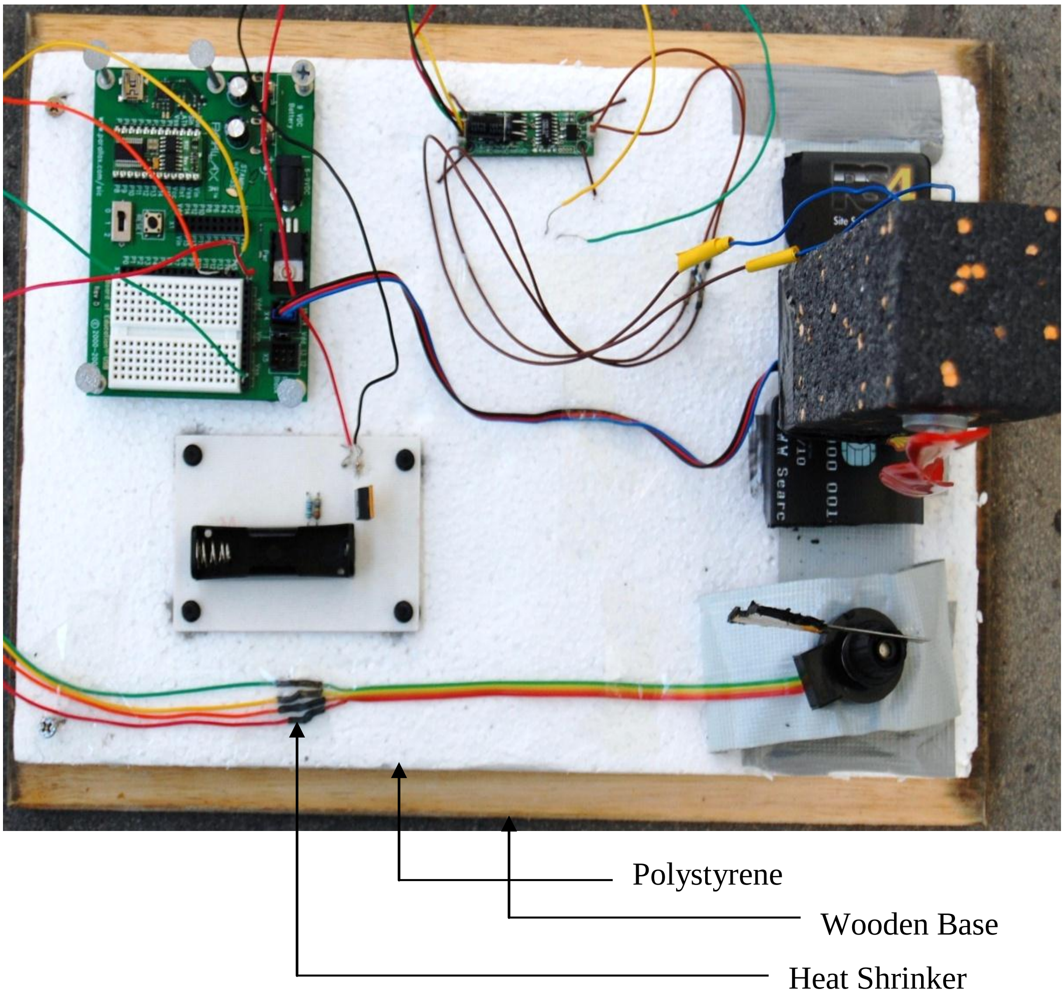

Figure 14: Connection of Entire System

5.3 PCB Construction

5.3.1 Circuit Design by Using ISIS

A storage system was designed by ISIS 7 which was an element of Proteus 7 circuit design and simulation software. Here battery was used for simulation purpose (as an input supply) in lieu of wind generator and energy scavenger because of their unavailability in ISIS library.

In figure-15, B1 was connected with the terminal 3 of voltage regulator LM317T IC. One edge of R2 was connected with terminal 1 and other edge was connected with terminal 2 of IC. R1 was connected in the joint of terminal 1 and resistor R2. R1 would be changed according to the required range of output voltage. An equation could make it easy to understand and calculate.

$$V_{out} = V_{ref} * (1+R1/R2)$$

Here 270Ω resistor was used because of the unavailability of 240Ω resistor. R1 was set up at 47Ω to show output of 1.51V which would be enough for charging a single 1.5V, 130 mA Ni-MH battery.

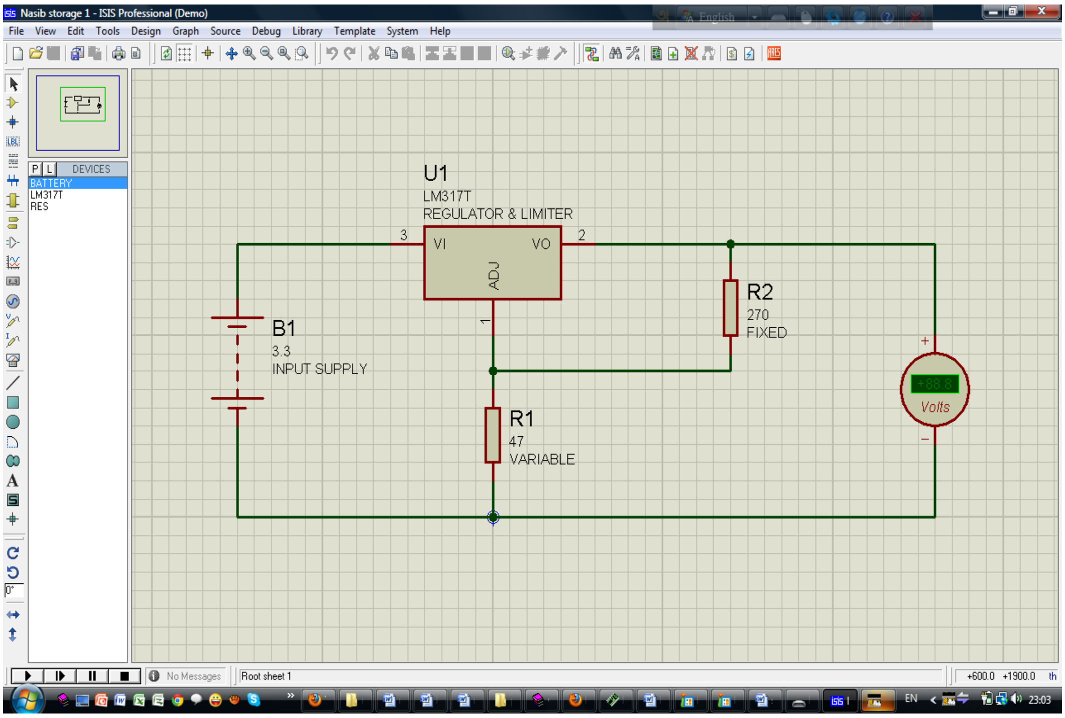

Figure 15: Design of Voltage Compensation at Storage System using ISIS

5.3.2 PCB Layout by Using ARES:

ARES was used to switch the ISIS schematic design into the printed circuit board (PCB). Figure-16 PCB layout was produced by converting the above circuit and manual routing. The routes were linked in blue colour because the arrangements were done on a single side.

5.3.3 Drilling and Soldering of Components:

Drilling and soldering of PCB was important because the circuit performance was depended on it. Various forms of drilling machines were used for various sizes of pin. After the collection of PCB from laboratory the holes of resistors and IC of PCB were drilled by 0.8mm pin, rubber fits were by 3mm pin and Vero pins by 1mm pin. Soldering of components was done smoothly by keeping the soldering iron all time at 325° C. There were chances of short circuit and damage of IC if the soldering was not that much good. After drilling and soldering components were placed according to their places (Figure-18).

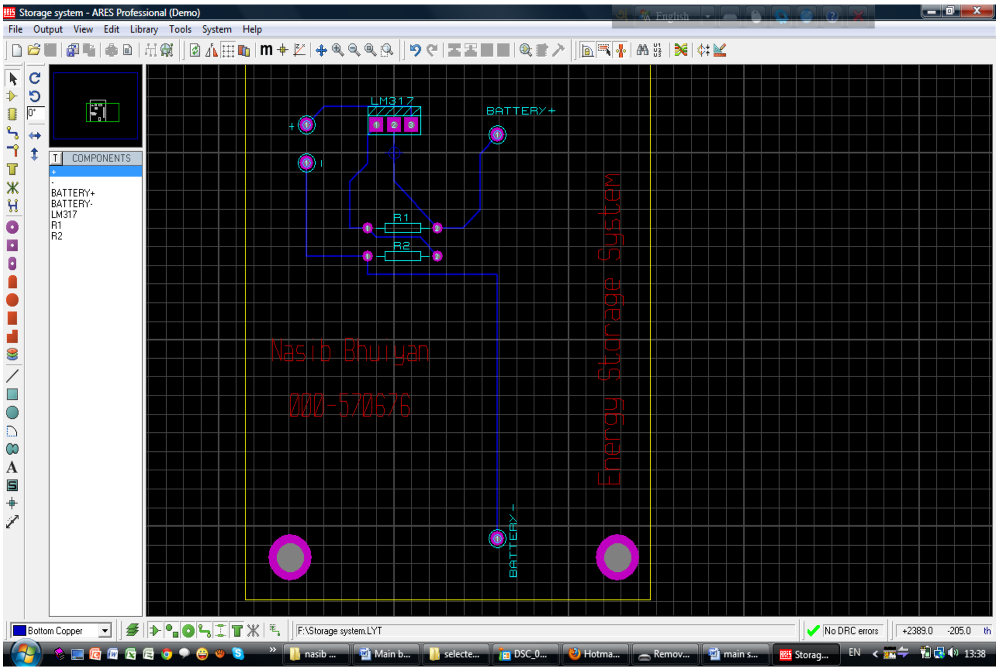

Figure 16: PCB layout of Storage System

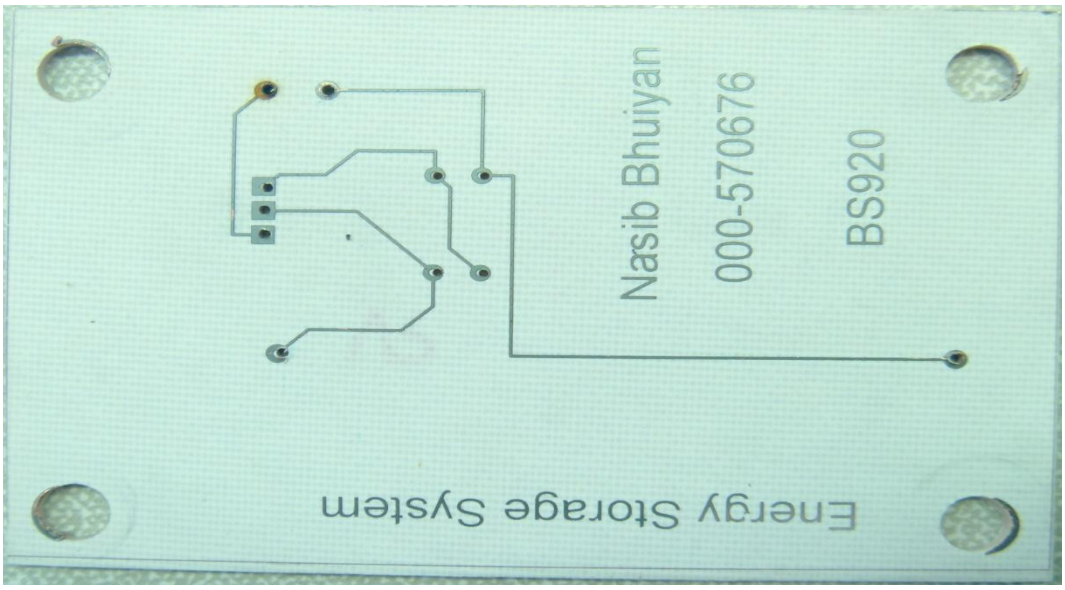

Figure 17: Unconstructed PCB of Storage System

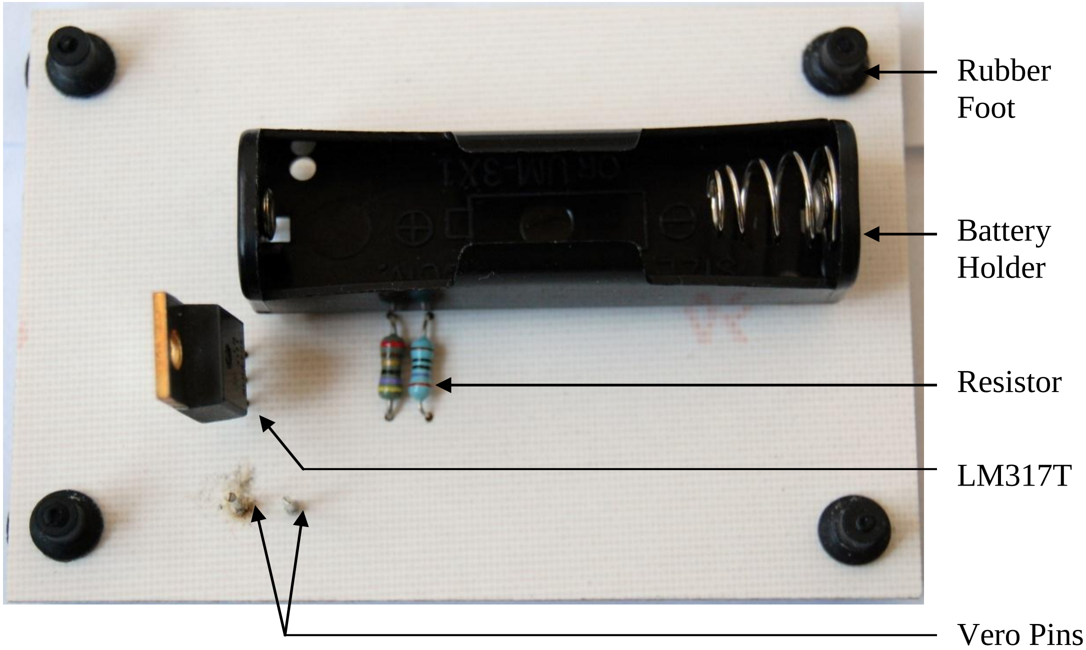

Figure 18: Constructed PCB for Storage System

5.4 Main Programme Description

The program was made by using pooling method which scanned the pin inputs for getting pulses from channel A and Channel B of optical encoder again and again [Appendix-C]. Then it was checked which port's pulses were greater or smaller than other. In case of pulses A>B it would be Counter clockwise direction. In case of B>A it would be rotated in clockwise direction. Otherwise no movement was assumed in optical encoder. Then rotation angle was evaluated by taking pulses from channel A when A>B and from B when B>A. As optical encoder produced 128 pulses for 360 degree rotation, by counting the pulses from particular channel, rotation angle was evaluated. Reference point was calculated by increasing or decreasing the rotation angle. Extreme point was restricted to 180 degrees as servo was able to move up to 180 degrees.

5.4.1 Programme for Pulse Count and Rotation

```
' {$STAMP BS2}
' {$PBASIC 2.5}

opt_Enc_OutputA         PIN     13      ' Encoder on P13
opt_Enc_OutputB         PIN     14      ' Encoder on P14
Servo                   PIN     15      ' Servo on   P15

numof_Pulses            VAR     Word
```

```
numof_PulsesB            VAR     Word
Duration                 VAR     Word
rotation_Angle           VAR     Word
reference_Position       VAR     Word
degree_Angle_TobeMoved   VAR     Word
moveable_Degree_Angle    VAR     Word
reference_Pulse          VAR     Word
destination_Pulse        VAR     Word
pulse                    VAR     Word
counter                  VAR     Word

Capture                  CON     1000         ' 10 second
DurAdj                   CON     $100         ' / 1

reference_Position = 90                             ' For
the very first time it will be in center

DO
   Duration=(Capture */ DurAdj)
   COUNT opt_Enc_OutputA, Duration, numof_Pulses
   DEBUG ? numof_Pulses

   rotation_Angle=((45* numof_PulsesB)/16)
   DEBUG ? rotation_Angle

LOOP
```

5.4.2 Programme for Servo Rotation

```
' {$STAMP BS2}
' {$PBASIC 2.5}

opt_Enc_OutputA          PIN     13     ' Encoder on P13
opt_Enc_OutputB          PIN     14     ' Encoder on P14
Servo                    PIN     15     ' Servo on   P15

numof_PulsesA            VAR     Word
numof_PulsesB            VAR     Word
Duration                 VAR     Word
rotation_Angle           VAR     Word
reference_Position       VAR     Word
degree_Angle_TobeMoved   VAR     Word
moveable_Degree_Angle    VAR     Word
reference_Pulse          VAR     Word
destination_Pulse        VAR     Word
pulse                    VAR     Word
counter                  VAR     Word
```

```
Capture                 CON     1000              ' 10
second
DurAdj                  CON     $100              ' / 1

reference_Position = 90                           ' For
the very first time it will be in center

DO
   Duration=(Capture */ DurAdj)
   COUNT opt_Enc_OutputA, Duration, numof_PulsesA
                                  'Put value of pulses
in pin 13
   COUNT opt_Enc_OutputB, Duration, numof_PulsesB
                                  'Put value of pulses
in pin 13


   IF  numof_PulsesA < numof_PulsesB THEN  DEBUG "
CW",CR
   IF  numof_PulsesA > numof_PulsesB THEN DEBUG  "
CCW",CR
   IF  numof_PulsesA = numof_PulsesB THEN  DEBUG "
Still",CR
LOOP
```

5.4.3 Programme for Servo Reference Position and Angle to Be Moved

```
' {$STAMP BS2}
' {$PBASIC 2.5}

opt_Enc_OutputA         PIN     13      ' Encoder on P13
opt_Enc_OutputB         PIN     14      ' Encoder on P14
Servo                   PIN     15      ' Servo on   P14

numof_PulsesA           VAR     Word
numof_PulsesB           VAR     Word
Duration                VAR     Word
rotation_Angle          VAR     Word
reference_Position      VAR     Word
degree_Angle_TobeMoved  VAR     Word
moveable_Degree_Angle   VAR     Word
reference_Pulse         VAR     Word
destination_Pulse       VAR     Word
pulse                   VAR     Word
counter                 VAR     Word
```

```
Capture                 CON     1000                 ' 10
second
DurAdj                  CON     $100                 ' / 1

reference_Position = 90                              ' For
the very first time it will be in center

DO
   Duration=(Capture */ DurAdj)
   COUNT opt_Enc_OutputA, Duration, numof_PulsesA
   DEBUG ? numof_PulsesA
 'Put value of pulses in pin 13
   COUNT opt_Enc_OutputB, Duration, numof_PulsesB
                     'Put value of pulses in pin 13
   DEBUG ? numof_PulsesB

LOOP
```

Chapter 6

Results

Testing of the entire system was done after the completion of design, implementation and programme writing. The system was tested in various ways. They were described below with their findings.

6.1 Optical Encoder Pulse Count and Rotation

The programme [sub chapter-5.4.1] was downloaded in the microcontroller via USB port and the screen dumps were taken while rotating the encoder.

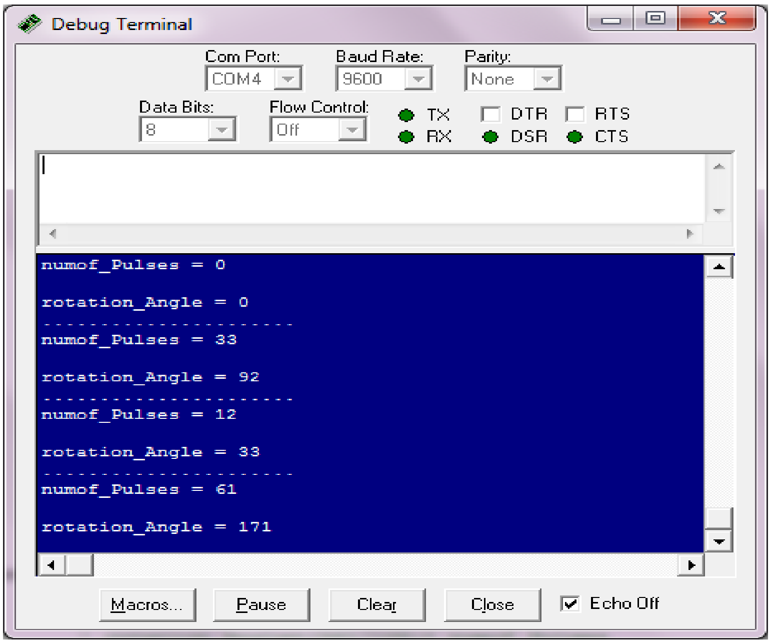

Figure 19: Result of Pulse Count and Rotation

According to the logic of calculating rotation angle {(45* Number of pulses from channel A or B) /16} it was found that it showed the almost accurate rotation angle in terms of number of pulse.

6.2 Servo Rotation

Servo rotation was checked in three states- still, clockwise(CW), counter clockwise(CCW) and accurate results were shown on debug terminal depending on the encoder rotations when the programme [sub chapter-5.4.20] was downloaded.

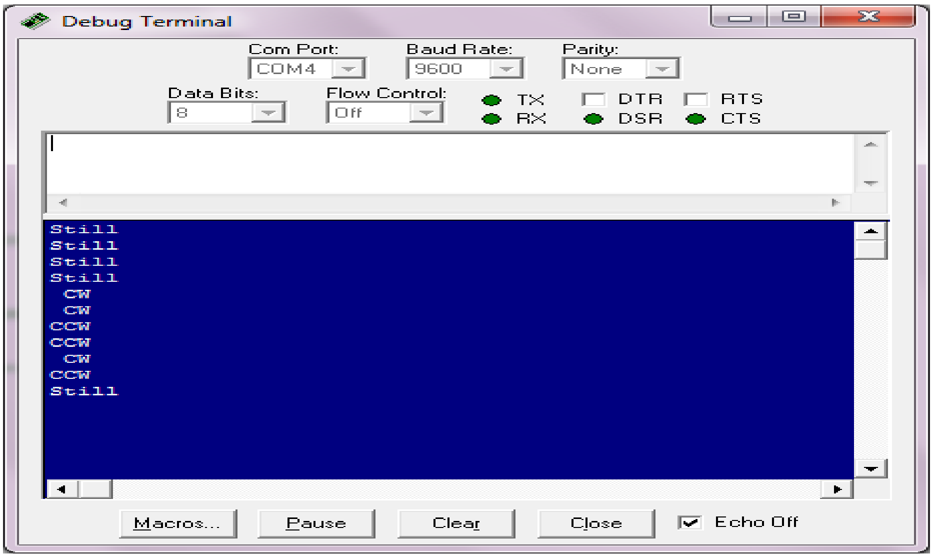

Figure 20: Result of Servo Rotation

6.3 Servo Reference Position

Before getting the signal of which direction it should rotate servo went to reference point (Reference position 90°). After getting the signal, servo started to rotate from its reference poisition in repect of encoder direction [Programme on sub chapter-5.4.3].

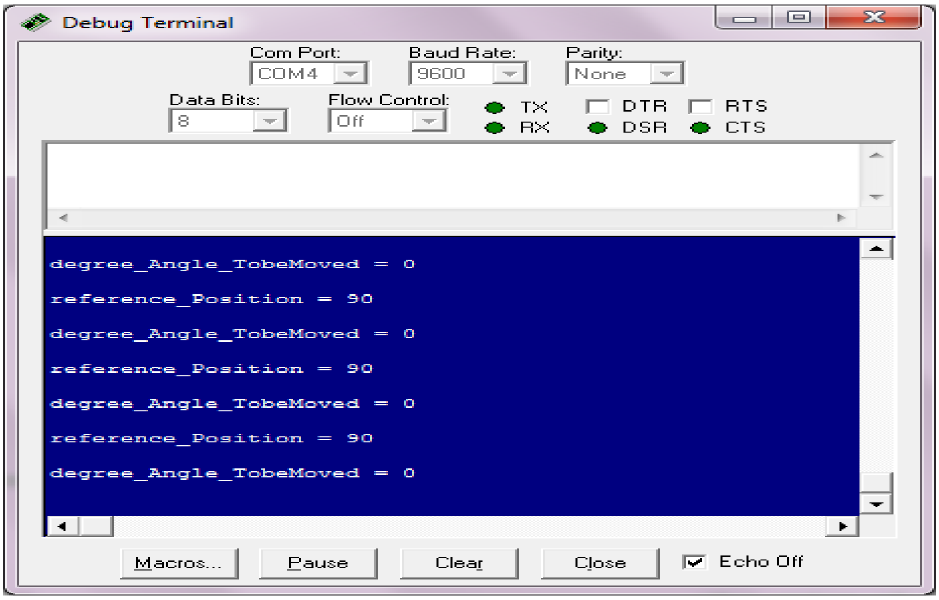

Figure 21: Servo Reference Position

6.4 Angle to Be Moved (Servo Motor)

According to the encoder rotation (CW or CCW) the servo got pulse through channel A or B. Then it rotated to that angle depending on the channel's number of pulses. The rotation of servo depended on basis of previously mentioned [Sub Chapter- 6.1] logic [Programme on sub chapter-5.4.3].

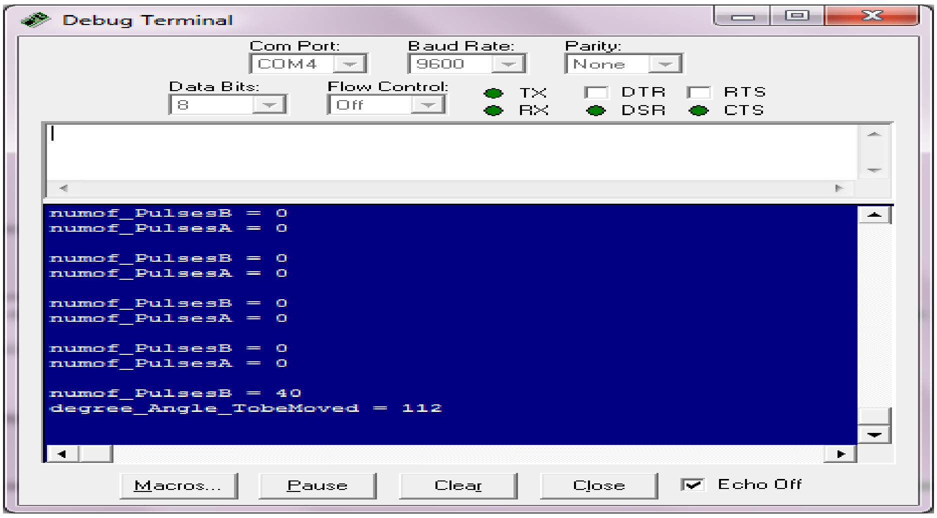

Figure 22: Degree angle To Be Moved

6.5 Wind Generator Testing

When the wind turbine structure was tested in front of table fan it could not harness thatmuch of power. So wind generator performance was tested by coupling with another DC motor and speed was measured by tachometer. Here one acted as a motor and another as a generator. The output voltage was tested via energy harvester. This module was used for boosting up the output of wind generator.

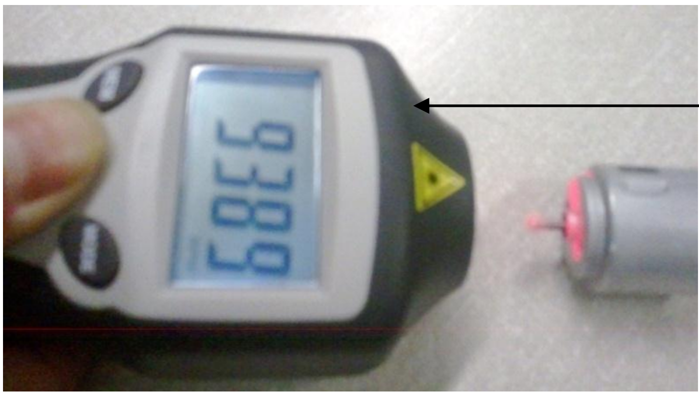

Figure 23: Rotation Measurement (in RPM)

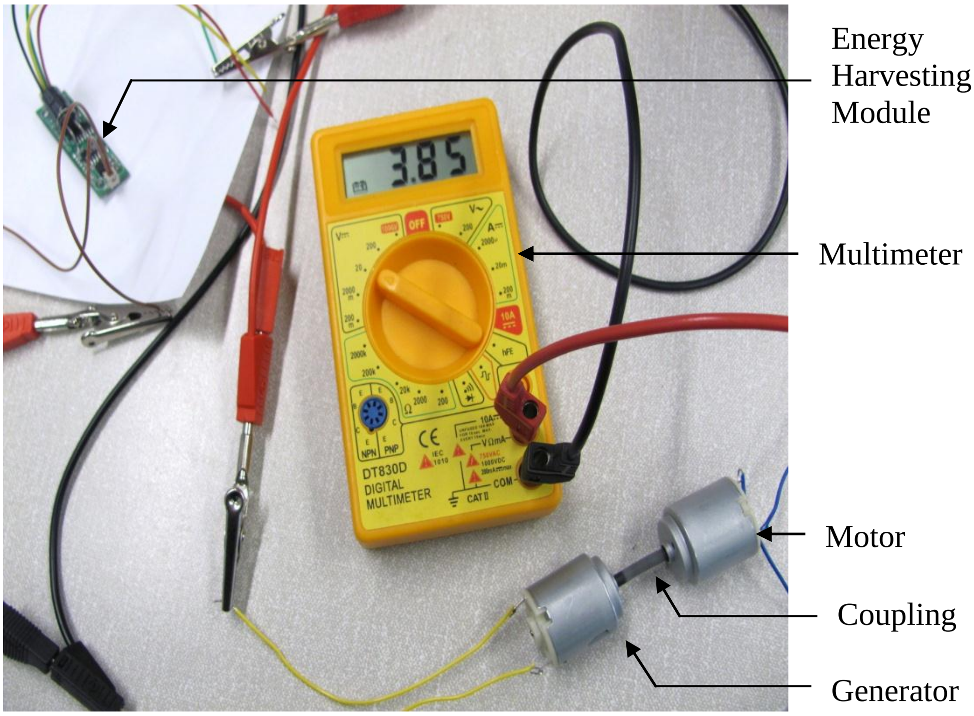

Figure 24: Testing of Wind Generator Performance

Figure 23 and 24 showed wind generator rotation measurement and voltage production respectively. Figure-25 showed the relationship among input power, rotation and output voltage. From figure 26 it showed that output voltage increased with the increase input power and it increased almost linearly. So the wind generator could produce more power if it rotated with great speed and had more input power.

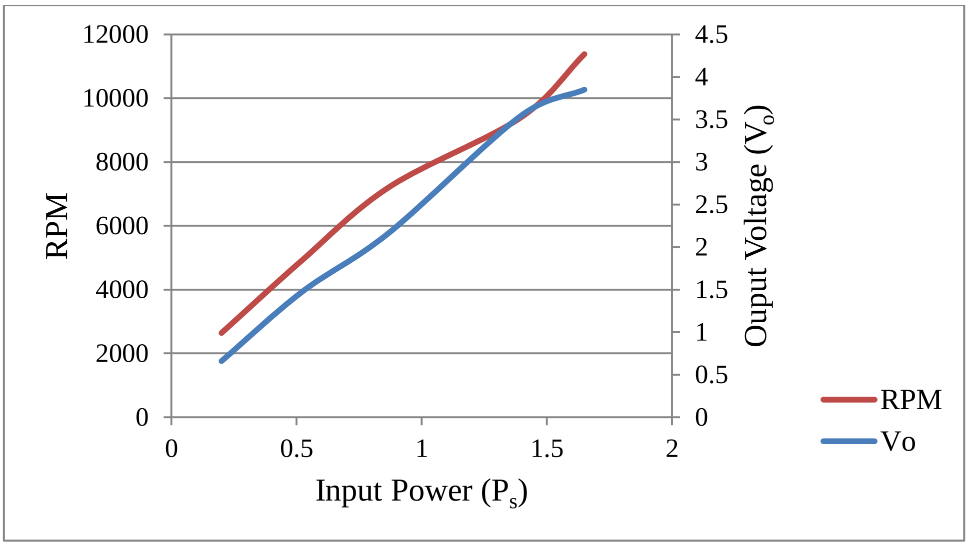

Figure 25: RPM and Output Voltage Vs Input Power [Appendix-D]

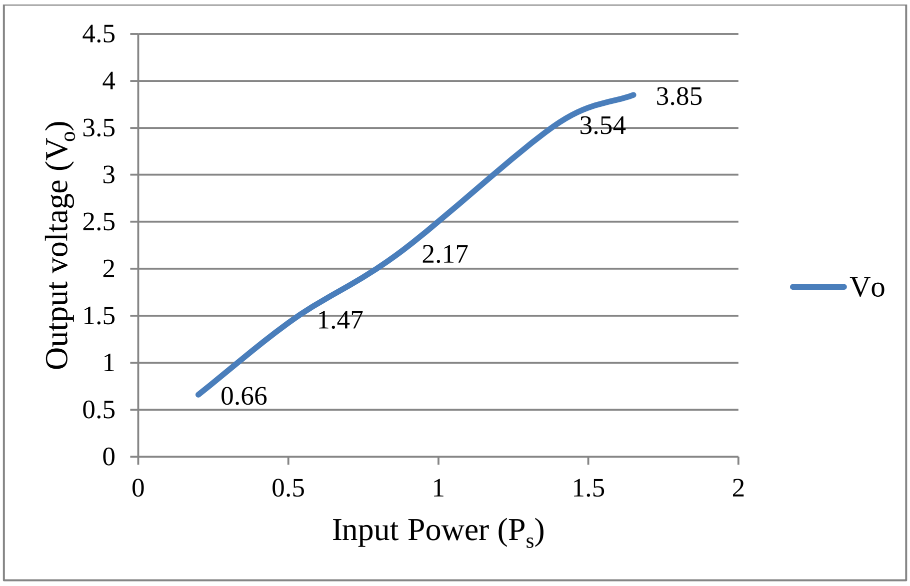

Figure 26: Output Voltage Vs Input Power [Appendix-D]

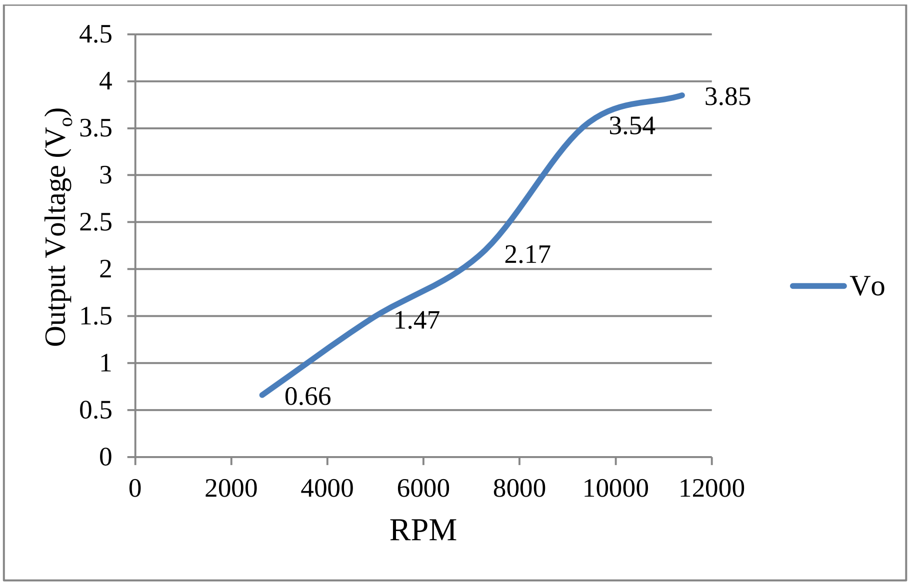

Figure 27: Output Voltage Vs RPM [Appendix-D]

With the increase of the motor rotation output voltage also increased almost linearly with some fluctuation (Figure-27). So from the graphs it was depicted that wind generator could produce more power if it rotated with great speed and had more input power.

6.6 Storage System Testing

6.6.1 Result from Simulation

From ISIS circuit simulation, it showed that when 3.3 volt (as generator supply produced voltage) was applied in input supply it provided 1.32 volt regulated output which feasible for charging a single 1.5 volt AA Ni-MH rechargeable battery.

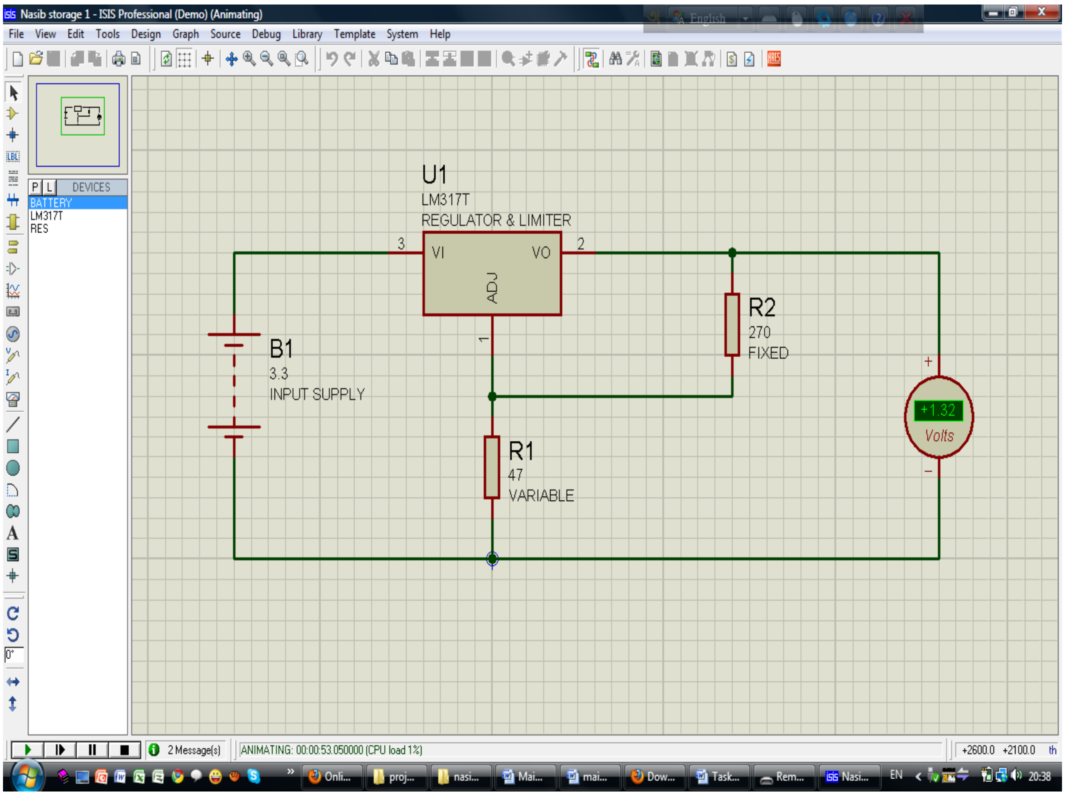

Figure 28: Result from Storage System Simulation

6.6.2 Practical Result

During practically testing time the regulated output showed a bit higher than the simulation. These values varied with the variation of supply voltage and it showed the desired result as it was expected. A range of regulated output was depicted in the below table with the supply variation.

Table 8: Measurement of Regulated Output

Supply voltage, V_s (volt)	Regulated Output Voltage, V_o (volt)
3.3	0.93
3.5	1.00
3.8	1.14
4.0	1.28
4.2	1.35
4.5	1.51
5.0	1.51
5.5	1.51

Table 9 showed the regulated output voltage while applying different input voltages. At initial stage it showed variance in output but after 4.5 volt it showed the expected value.

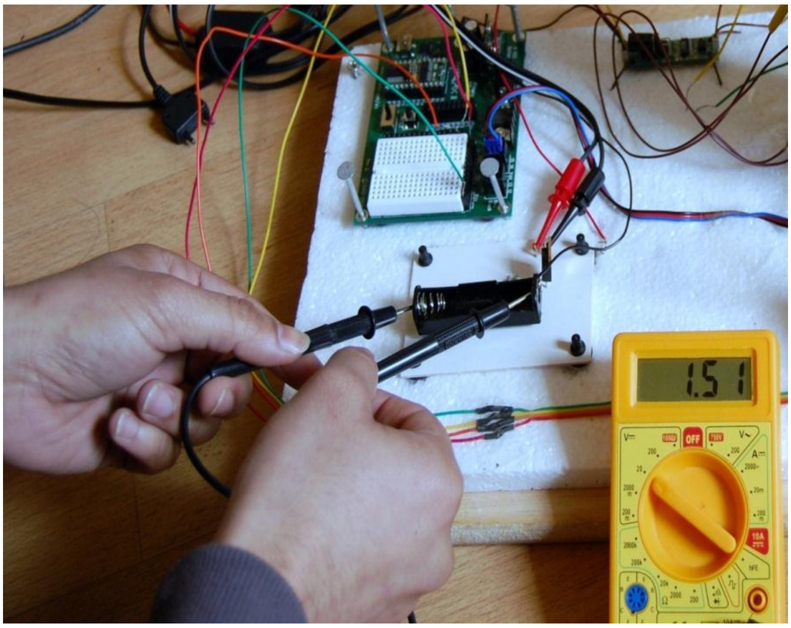

Figure 29: Storage System Testing (Practically)

Chapter 7

Discussions

7.1 Discussion of Results

The result obtained from section 6.1, 6.2, 6.3 and 6.4 showed perfect result as per expectation. The logic (Sub chapter-6.1) used for servo movement and pulse count and rotation worked properly. All the programmes execuated in a proper way and they did not show any error. When the main programme was execuated the wind generator rotated according to the optical encoder rotation.

For clockwise and counter clockwise rotation of optical encoder only a phase difference was given between two channels. In this aspect start and end time of a pulse could have been one of the solutions. For this operation a timer had to be started at the beginning and ended at the ending of a pulse for channel A and B. Timer had to stop at the end of each operation and loop. But no timer operation was found to be used readily like other programming languages. Channel A leaded 45 degrees of B while rotating in counter clockwise so if a pulse generation frequency of optical encoder and clock frequency of basic stamp operation would both have the same frequency then XOR of consecutive eight bits of channel A (new) and B (old) would produce 0 in all cases. This would happen for clockwise rotation as well. It would be used to determine the direction. But the bit produced frequency and clock frequency both was different and this logic would not work. A counter function was used for counting of pulses for a period of time, keeping that in mind as channel A led B when rotating in counter clockwise direction. It would produce some more pulses when it moved counter clockwise direction. It would also produce more pulses for channel B when it would rotate clockwise direction. As ‘counter’ function could only return one channel’s pulses for a period of time and then wait for another channel for the same amount of time. For that it would lose some pulses in the channel; in this case channel B. So having no accurate solutions it was chosen method C as it used less memory and much simpler method to implement. On the other hand, P Basic language had loosely care for fractional operation and following function was used to evaluate required pulses = (50 * moveable degree angle)/9, there would be a possibility that some portion of pulses less than 9 would be lost in worst cases. Storage system worked properly but showed a slight difference between simulated and practical value. Due to the heat and temperature loss of IC the practical result of storage system differed from simulation one (Table-9). Scarcity of resistance accelerated both practical and simulation value. But after a certain input supply (4.5 volt) it showed expected regulated output voltage. It showed a constant output voltage of 1.51 volt while a range of different input voltage was applied. In figure 26 and 27 both the graphs were almost linear with a sudden variation in graph 27 where the motor produced 2.17 volt at a speed of 7215 RPM. During wind generator voltage measurement the energy harvester worked properly where it boosted the power at an expected level within its defined range (Table-10). Modification of programme (using of interrupt method) and varieties of testing would make situation better than the current one. Within a short span of time the main targets of this work was obtained with some short comings.

7.2 Updated Gantt chart

7.2.1 Project Plan

The whole project plan was divided into twenty technical tasks. These were stated in brief:

Knowledge Gathering

In this phase, the main task was to study the references of current technology of the system and the guidelines from supervisor. Component and pattern selection and analyzing were also the tasks in this phase.

Software and Hardware Design

This phase dealt with components ordering, software and hardware designing, mechanical structure arranging, and programme writing for wind sensor, generator controlling system and also designs of energy storage system.

Implementation and Testing

This phase consisted of implementation of wind sensor, wind generator controlling method and storage system. Programme for microcontroller, collection of data and images of results and above all possible risk evaluation were also the part of this phase.

Modification and Testing

This was the last part which dealt with helpful ideas for error reduction of the entire project through hardware and software amendment and fresh upgraded result if necessary and available.

7.2.2 Modification of Gantt chart

In first phase literature survey and component selection were carried out within the fixed time. Modification in second phase was done because there hardware and software design and mechanical arrangements were the main part. Within the short span of time it was not achievable of doing every task. Extra time was added there for the task completion. Hardware and software design and implementation and program writing required to be done within the expanded time. Second phase modification made third phase shorter. But if all the components were available in time the system would work within the expectation. In fourth phase modifications of programs and testing of wind sensor, wind generator controlling and storage system were done.

7.3. Concerned Topic and Encountered Problems:

Wire extension by using a shrinker was at first troublesome because of unfamiliar to it. Choosing of sensor, controlling scheme and power boosting was also a challenging work in this project. Writing of logical programme, mechanical arrangement, choosing of right components were also a concerned issues in this toil. Making of turbine structure was problem some. Polystyrene was used for making of wind turbine. A bit of mechanical calculation took place on the attachment of this structure with servo motor. It was done in the way that servo could move the structure easily.

Chapter 8

Conclusion

An optical encoder as an electronic wind direction sensor's function and design was described here. For controlling of wind generator according to sensor output was demonstrated with the help of BASIC Stamp 2 microcontroller and servo motor. For maintaining a constant power flow, an energy harvester module was used for boosting up the generator output which was applied at the input of storage system. Storage system with rechargeable battery and a regulator was also depicted in this work. A voltage regulator IC was used for compensating the excess of voltage and maintaining a constant voltage in storage system. Execution of programme, hardware design, implementation and testing were done around the fixed time frame. The main goals of this project were attained with some shortcomings.

Management of ideas, analysis of problems and to establish that within the time frame would be mandatory for any successful project. Gantt chart project management software would be a better option as a guideline for any engineering project that had to be finished within a fixed time range.

Current technology surveying, making of to do list on the basis of problem analysis, selecting of appropriate apparatus and finding out of potential way out through some practical work could be learned from this toil. Above all this type of study based work made engineers to become capable of doing and getting result in an unknown circumstance. In the UK and USA and some other European countries wind power system was keeping pace with other renowned alternative energy which was solar system and recently it was able to grab attention of developing countries. Working in this project was comparatively simple and educational which had a notable significance for the contemporary competitive world.

Chapter 9

Future Work

Research based work on a particular project would not be the only final outcome. More rationalized and pensive ideas were linked with the project. Here some novel ideas for this project were described below:

A smart relay based cut-off storage system could be presented between the system and user end. LED could be used as an indicator to make it more convenient. During the time of power failure this intelligent power storage system could be used as a backup.

As a storing device fuel cell, capacitor, battery and other hybrid systems were used. Batteries were commonly used in everywhere. But it had some shortcomings associated with charging and discharging time, mass, weight and other aspects. So in place of battery super capacitor could be a better choice as a storing device.

Development of an algorithm (using interrupt method) could be possible which would measure the actual wind speed and direction precisely with the variation of weather condition and time.

Conversion of DC to AC for wind power could be an important part to make the system AC compatible and effective so that it could be connected with the grid system or domestic devices.

Wind speed sensor or a sensor which measures the both criteria of wind could be used with the system so it could sense the direction as well as the actual speed of the wind. A display system could be introduced with the entire system so that it could display wind speed, direction and available power to the user.

A super capacitor could be adjoined with battery storage system to increase the life of battery.

Chapter 10

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Appendices

A. Data Sheets

Data sheets website links were given below:

(1) http://www.parallax.com/dl/docs/prod/stamps/web-BSM-v2.2.pdf (Basic Stamp 2)

(2) http://www.maplin.co.uk/media/pdfs/N72CH.pdf (DC motor)

(3) http://www.servodatabase.com/servo/sanwa/srm-102z (Servo motor)

(4) http://uk.farnell.com/jsp/search/browse.jsp?N=500006+1003772&Ntk=gensearch_001&Ntt=AA+rechargeable+battery&Ntx=mode+matchallpartial (Rechargeable AA battery)

(5) http://www.datasheetcatalog.org/datasheet/SGSThomsonMicroelectronics/mXwqrz.pdf (Voltage regulator)

(6) http://www.farnell.com/datasheets/66281.pdf (Battery holder)

(7) http://www.farnell.com/datasheets/8008.pdf (Energy harvesting module)

(8) http://www.maplin.co.uk/media/pdfs/N69CH.pdf (Propeller)

(9) http://stevenengineering.com/pdf/73ENCODER_600-128-CBL.PDF (Optical Encoder)

B. Functional Description of the programme

COUNT: Syntax: **COUNT** Pin, Duration, Variable

The COUNT function counted the number of cycles (0-1-0 or 1-0-1) on the specified pin during the Duration time frame and stored that number in Variable.

- **Pin** was a variable that specified the I/O pin to use. This pin needed to be set to **input** mode.
- **Duration** was a variable that specified the time during which to count.
- **Variable** (usually a Word) in which the count would be stored.

PULSOUT: Syntax: **PULSOUT** Pin, Duration

A pulse generated on Pin with a width of Duration.

- **Pin** was a variable that specified the I/O pin to use. This pin needed to be set to output mode.
- **Duration** was a variable that specified the duration of the pulse.

DO LOOP: Syntax: DO ...LOOP

A repeating loop created that executed the program lines between DO and LOOP, optionally testing before or after the loop statements.

IF THEN ELSE: Syntax**:** IF Condition **THEN** Statement

Evaluating condition and if it was true, executed the statement(s) following **THEN**, otherwise jumped to and evaluated the **ELSEIF** condition. If no **ELSEIF** statement/block was provided, jumped to and executed the statements that follow **ELSE**. If no **ELSE** block was provided, the program would continue at the line that followed **ENDIF** (or the next line when single-line syntax was used).

BINARY OPERATOR: */ (Multiply Middle operator**)**

The Multiply Middle operator (*/) multiplied variables, constants and returned the middle 16 bits of the 32-bit result. This had an effect of multiplying a value by a whole number and a fraction. The whole number was the upper byte of the multiplier (0 to 255 whole units) and the fraction was the lower byte of the multiplier (0 to 255 units of 1/256 each). The */ operator gave workaround for the BASIC Stamp's integer-only math.

For an example: To multiply a value by 1.5. The whole number was the upper byte of the multiplier, would be 1(256/256), and the lower byte (fractional part) would be 128, since 128/256 = 0.5.

To calculate constants for using with the */ operator, the constant multiplied by 256, then converted the result to a whole integer: For instance, if our target multiplier was Pi (3.14159), the resulting constant to represent that value for the */ operator was INT (3.13159 * 256) = INT (801.25) = 801 ($0324). The upper byte was $03 (decimal 3; the whole number), and the lower byte was $24 (decimal 36; the fractional part that meant 36/256= 0.140625). So the constant Pi for using with */ would be $0324 with error about 0.1%.

C. Main Programme

```
 ' {$STAMP BS2}

' {$PBASIC 2.5}

opt_Enc_OutputA     PIN     13        ' Encoder on P13

opt_Enc_OutputB    PIN     14         ' Encoder on P14

Servo             PIN     15          ' Servo on   P15

numof_PulsesA          VAR     Word

numof_PulsesB          VAR     Word

Duration               VAR     Word

rotation_Angle         VAR     Word

reference_Position     VAR     Word

degree_Angle_TobeMoved  VAR     Word
```

```
moveable_Degree_Angle   VAR     Word
reference_Pulse         VAR     Word
destination_Pulse       VAR     Word
pulse                   VAR     Word
counter                 VAR     Word
STOP_inCenter           VAR     Word
Capture               CON     500         ' 10 second
DurAdj                CON     $100              ' / 1
reference_Position = 90    ' For the very first time it
will be in center
FOR counter = 750 TO 0  STEP 7' 45 degrees for about 3
sec.
     PULSOUT Servo, 750
     PAUSE 7
  NEXT
DO
   Duration=(Capture */ DurAdj)
   COUNT   opt_Enc_OutputA,   Duration,   numof_PulsesA
'Put value of pulses in pin 13
   COUNT   opt_Enc_OutputB,   Duration,   numof_PulsesB
'Put value of pulses in pin 13
   DEBUG  DEC? numof_PulsesA, CR
   DEBUG  DEC? numof_PulsesB
IF  numof_PulsesA = numof_PulsesB THEN
     'IF(STOP_inCenter=0) THEN
     ' STOP_inCenter=STOP_inCenter+1
     ' DEBUG  DEC? STOP_inCenter, CR
     'ELSE
     ' DEBUG  DEC? STOP_inCenter, CR
     'rotation_Angle=((45* numof_PulsesB)/16)
      'degree_Angle_TobeMoved = rotation_Angle
```

```
    'DEBUG  DEC? reference_Position, CR
    'DEBUG  DEC? degree_Angle_TobeMoved, CR
    'ENDIF
     ENDIF
IF numof_PulsesA < numof_PulsesB THEN
    rotation_Angle=((45* numof_PulsesB)/16)
    degree_Angle_TobeMoved = rotation_Angle
    moveable_Degree_Angle = (reference_Position-0)
    reference_Pulse     =     250     +     ((50     *
reference_Position)/9)
    DEBUG  DEC? degree_Angle_TobeMoved, CR
    IF            (moveable_Degree_Angle              >=
degree_Angle_TobeMoved)                           THEN
' No problem
       destination_Pulse  =  reference_Pulse  -  ((50  *
degree_Angle_TobeMoved)/9)              'Convert it to
pulse number
       FOR     pulse     =     reference_Pulse     TO
destination_Pulse
        PULSOUT Servo, destination_Pulse
        PAUSE                                          7
' PULSOUT PIN, Duration
       NEXT
    reference_Position    =    (reference_Position -
degree_Angle_TobeMoved)
       DEBUG  DEC? reference_Position, CR
       ELSE
       destination_Pulse  =  reference_Pulse  -  ((50  *
moveable_Degree_Angle)/9)             ' Convert it to
pulse number
       DEBUG  DEC? degree_Angle_TobeMoved, CR
      FOR pulse = reference_Pulse TO destination_Pulse
        PULSOUT Servo, destination_Pulse
```

```
          PAUSE                                              7
' PULSOUT PIN, Duration

         NEXT

         reference_Position= 0

         DEBUG  DEC? reference_Position, CR

      ENDIF

   ENDIF

      IF  numof_PulsesA > numof_PulsesB THEN

       rotation_Angle=(45* numof_PulsesA)/16

       degree_Angle_TobeMoved = rotation_Angle

       moveable_Degree_Angle = 180-reference_Position

       reference_Pulse     =     250     +     ((50     *
reference_Position)/9)

       DEBUG  DEC? degree_Angle_TobeMoved, CR

       IF           (moveable_Degree_Angle             >=
degree_Angle_TobeMoved)                            THEN
' No problem: Will move upto rotation angle

       destination_Pulse  =  reference_Pulse  +  ((50  *
degree_Angle_TobeMoved)/9)             ' Convert it to
pulse number


         FOR     pulse     =     reference_Pulse     TO
destination_Pulse

          PULSOUT Servo, destination_Pulse

          PAUSE 7

         NEXT

         reference_Position   =   (reference_Position   +
degree_Angle_TobeMoved)

         DEBUG  DEC? reference_Position, CR

         ELSE
' Will move  up to movable degree

         destination_Pulse  =  reference_Pulse  +  ((50  *
moveable_Degree_Angle)/9)  ' Convert it to pulse number

          DEBUG  DEC? degree_Angle_TobeMoved, CR
```

```
FOR pulse = reference_Pulse TO destination_Pulse

         PULSOUT Servo, destination_Pulse

         PAUSE                                        7
' PULSOUT PIN, Duration

        NEXT

        reference_Position            =             180
'In degree

  ENDIF

  ENDIF

 LOOP
```

D. Table for Wind Generator Performance

Table 9: Wind Generator Testing

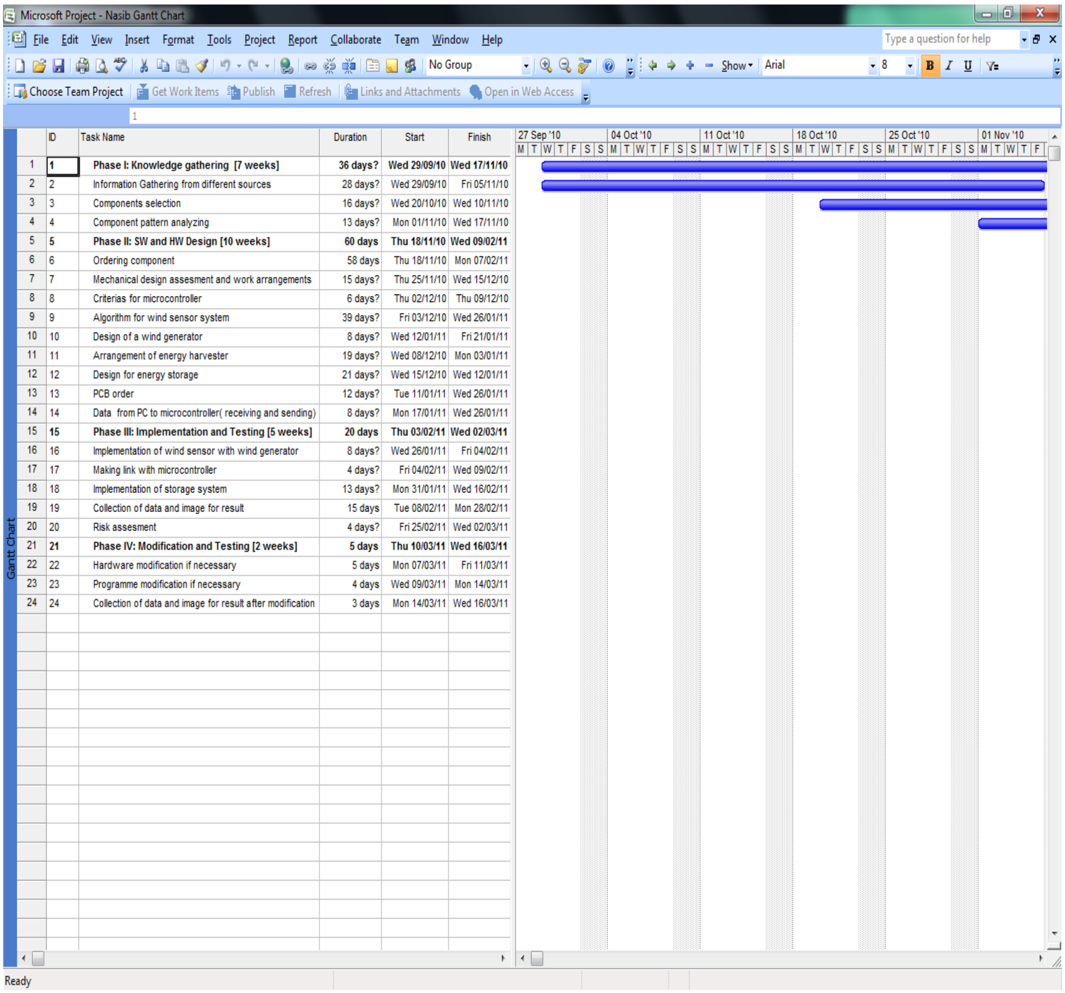
Input Voltage (V_s)	Input Current (I_s)	Rotation (RPM)	Output Voltage (V_o)	Input Power (P_s)
1	0.20	2642	0.66	0.2
2	0.26	4908	1.47	0.52
3	0.29	7215	2.17	0.87
4.5	0.31	9389	3.54	1.395
5	0.33	11381	3.85	1.65

E. List of Components and Cost Analysis

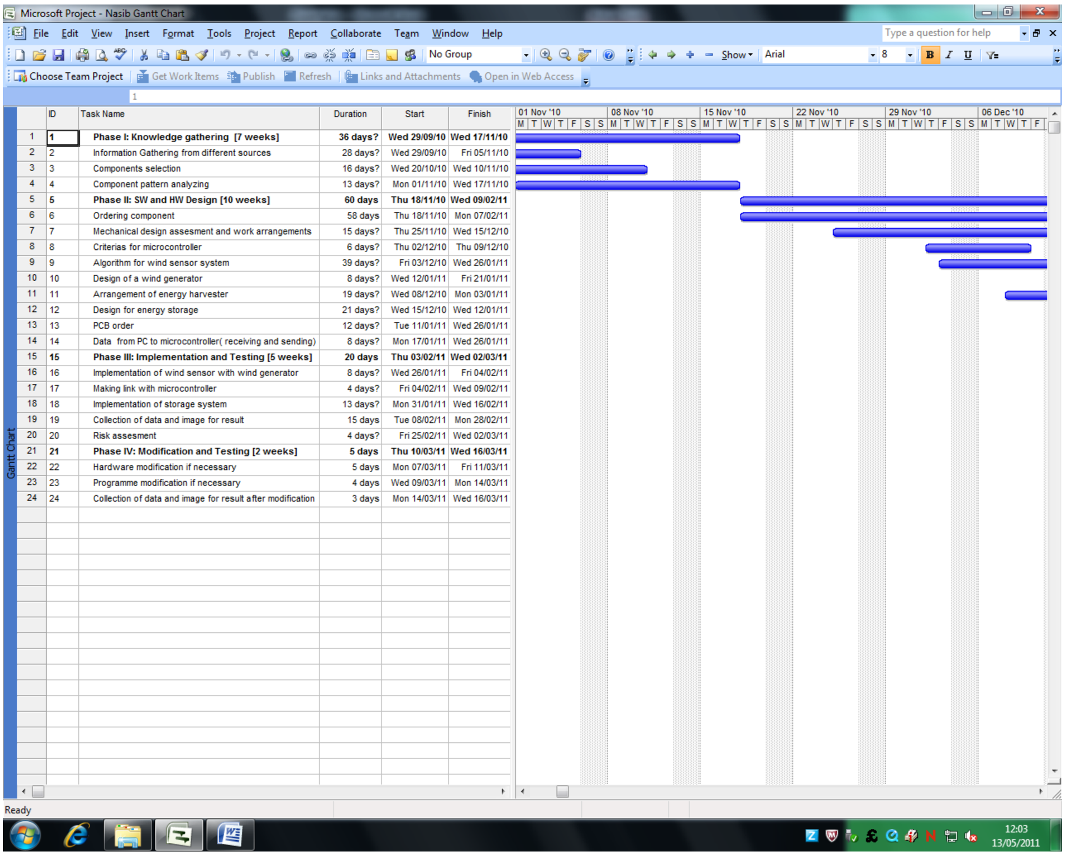
Table 10: System Components and Cost

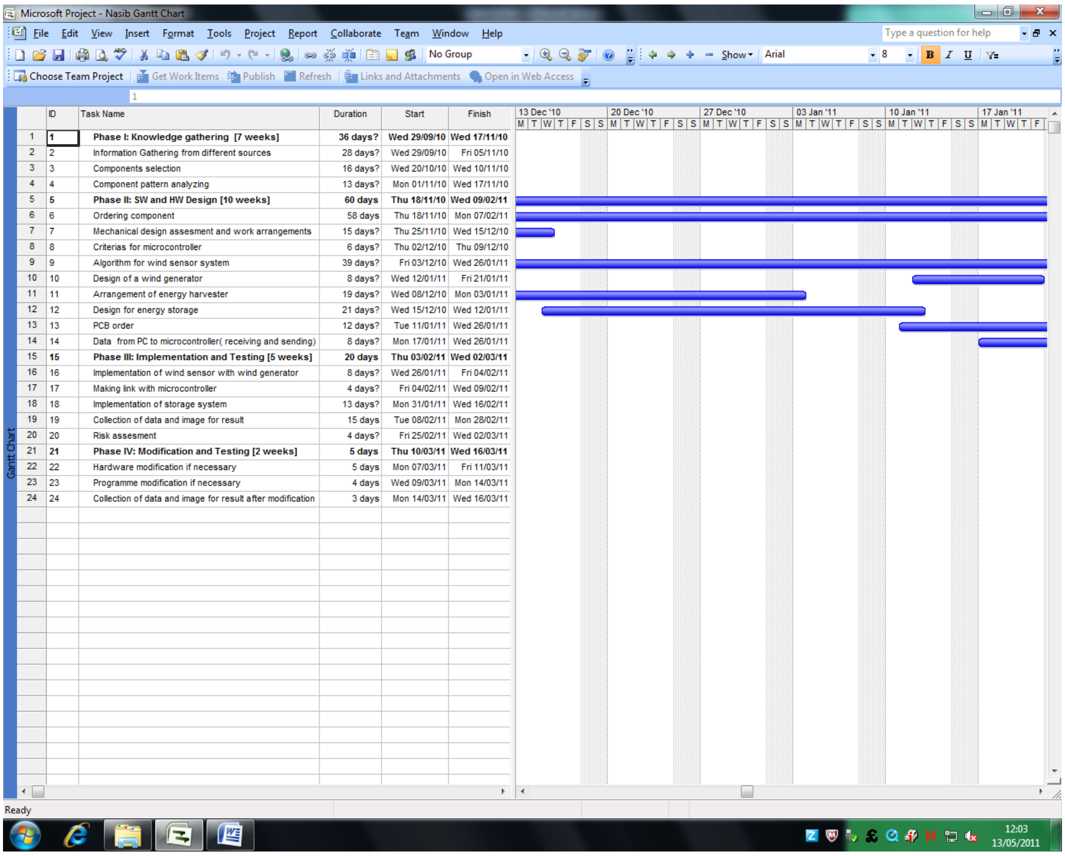
Components	**Cost**
Sanwa SRM 102Z servo Motor	Collected
Duracell Alkaline Battery- 9 volt	£3.395
Camlink AA Ni-MH Battery- 1.5 volt	£4.29
Basic Stamp 2 module	Collected
AA battery holder	Collected
Adhesive	Collected
Resistors	Collected
LM317T IC	Collected
PCB	Collected
Rubber feet	Collected
Propeller	£5.99
DC Motor	£5.99
Energy Harvesting Module	£37.21
Optical Encoder	£27.15
Polystyrene	Collected
	Total Cost.............. £84.025

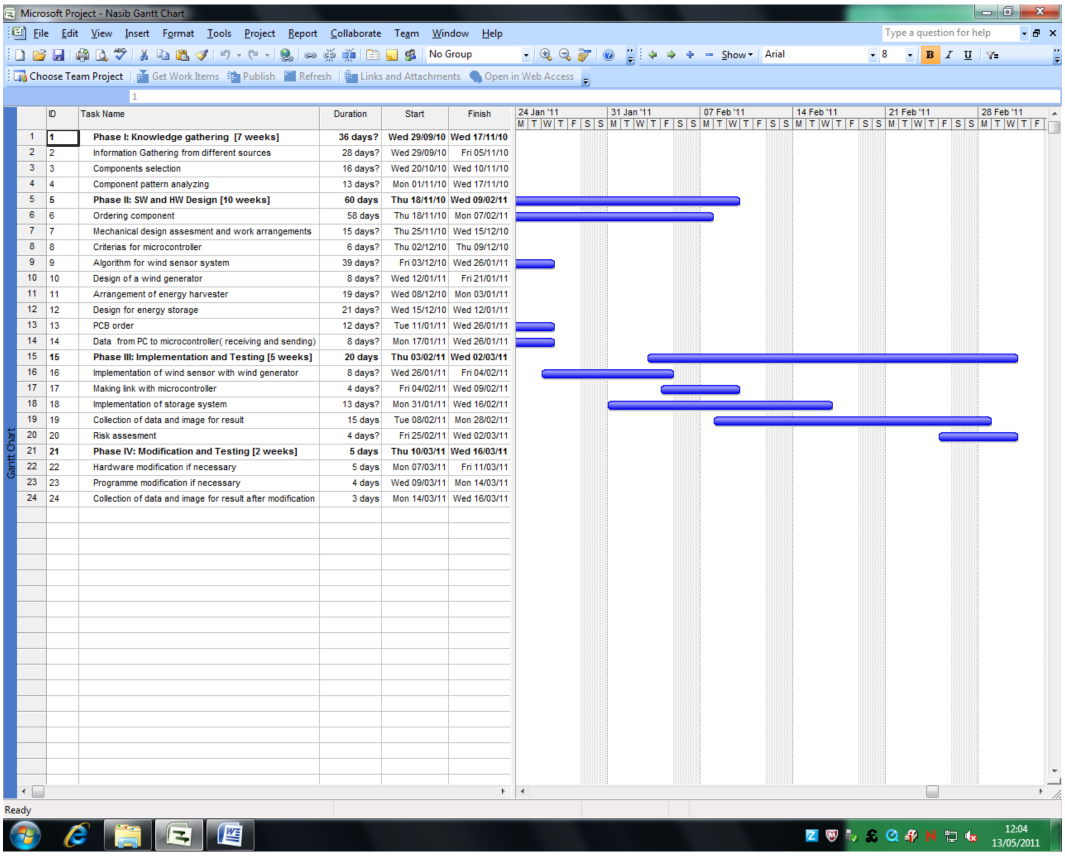
GANTT CHART Screen shots are below:



	ID	Task Name	Duration	Start	Finish
1	1	**Phase I: Knowledge gathering [7 weeks]**	**36 days?**	**Wed 29/09/10**	**Wed 17/11/10**
2	2	Information Gathering from different sources	28 days?	Wed 29/09/10	Fri 05/11/10
3	3	Components selection	16 days?	Wed 20/10/10	Wed 10/11/10
4	4	Component pattern analyzing	13 days?	Mon 01/11/10	Wed 17/11/10
5	5	**Phase II: SW and HW Design [10 weeks]**	**60 days**	**Thu 18/11/10**	**Wed 09/02/11**
6	6	Ordering component	58 days	Thu 18/11/10	Mon 07/02/11
7	7	Mechanical design assesment and work arrangements	15 days?	Thu 25/11/10	Wed 15/12/10
8	8	Criterias for microcontroller	6 days?	Thu 02/12/10	Thu 09/12/10
9	9	Algorithm for wind sensor system	39 days?	Fri 03/12/10	Wed 26/01/11
10	10	Design of a wind generator	8 days?	Wed 12/01/11	Fri 21/01/11
11	11	Arrangement of energy harvester	19 days?	Wed 08/12/10	Mon 03/01/11
12	12	Design for energy storage	21 days?	Wed 15/12/10	Wed 12/01/11
13	13	PCB order	12 days?	Tue 11/01/11	Wed 26/01/11
14	14	Data from PC to microcontroller(receiving and sending)	8 days?	Mon 17/01/11	Wed 26/01/11
15	15	**Phase III: Implementation and Testing [5 weeks]**	**20 days**	**Thu 03/02/11**	**Wed 02/03/11**
16	16	Implementation of wind sensor with wind generator	8 days?	Wed 26/01/11	Fri 04/02/11
17	17	Making link with microcontroller	4 days?	Fri 04/02/11	Wed 09/02/11
18	18	Implementation of storage system	13 days?	Mon 31/01/11	Wed 16/02/11
19	19	Collection of data and image for result	15 days	Tue 08/02/11	Mon 28/02/11
20	20	Risk assesment	4 days?	Fri 25/02/11	Wed 02/03/11
21	21	**Phase IV: Modification and Testing [2 weeks]**	**5 days**	**Thu 10/03/11**	**Wed 16/03/11**
22	22	Hardware modification if necessary	5 days	Mon 07/03/11	Fri 11/03/11
23	23	Programme modification if necessary	4 days	Wed 09/03/11	Mon 14/03/11
24	24	Collection of data and image for result after modification	3 days	Mon 14/03/11	Wed 16/03/11


Microsoft Project - Nasib Gantt Chart
ID | Task Name | Duration | Start | Finish
1 | Phase I: Knowledge gathering [7 weeks] | 36 days? | Wed 29/09/10 | Wed 17/11/10
2 | Information Gathering from different sources | 28 days? | Wed 29/09/10 | Fri 05/11/10
3 | Components selection | 16 days? | Wed 20/10/10 | Wed 10/11/10
4 | Component pattern analyzing | 13 days? | Mon 01/11/10 | Wed 17/11/10
5 | Phase II: SW and HW Design [10 weeks] | 60 days | Thu 18/11/10 | Wed 09/02/11
6 | Ordering component | 58 days | Thu 18/11/10 | Mon 07/02/11
7 | Mechanical design assesment and work arrangements | 15 days? | Thu 25/11/10 | Wed 15/12/10
8 | Criterias for microcontroller | 6 days? | Thu 02/12/10 | Thu 09/12/10
9 | Algorithm for wind sensor system | 39 days? | Fri 03/12/10 | Wed 26/01/11
10 | Design of a wind generator | 8 days? | Wed 12/01/11 | Fri 21/01/11
11 | Arrangement of energy harvester | 19 days? | Wed 08/12/10 | Mon 03/01/11
12 | Design for energy storage | 21 days? | Wed 15/12/10 | Wed 12/01/11
13 | PCB order | 12 days? | Tue 11/01/11 | Wed 26/01/11
14 | Data from PC to microcontroller(receiving and sending) | 8 days? | Mon 17/01/11 | Wed 26/01/11
15 | Phase III: Implementation and Testing [5 weeks] | 20 days | Thu 03/02/11 | Wed 02/03/11
16 | Implementation of wind sensor with wind generator | 8 days? | Wed 26/01/11 | Fri 04/02/11
17 | Making link with microcontroller | 4 days? | Fri 04/02/11 | Wed 09/02/11
18 | Implementation of storage system | 13 days? | Mon 31/01/11 | Wed 16/02/11
19 | Collection of data and image for result | 15 days | Tue 08/02/11 | Mon 28/02/11
20 | Risk assesment | 4 days? | Fri 25/02/11 | Wed 02/03/11
21 | Phase IV: Modification and Testing [2 weeks] | 5 days | Thu 10/03/11 | Wed 16/03/11
22 | Hardware modification if necessary | 5 days | Mon 07/03/11 | Fri 11/03/11
23 | Programme modification if necessary | 4 days | Wed 09/03/11 | Mon 14/03/11
24 | Collection of data and image for result after modification | 3 days | Mon 14/03/11 | Wed 16/03/11
01 Nov '10
08 Nov '10
15 Nov '10
22 Nov '10
29 Nov '10
06 Dec '10


Microsoft Project - Nasib Gantt Chart
13 Dec '10
20 Dec '10
27 Dec '10
03 Jan '11
10 Jan '11
17 Jan '11



	ID	Task Name	Duration	Start	Finish
1	1	**Phase I: Knowledge gathering [7 weeks]**	**36 days?**	**Wed 29/09/10**	**Wed 17/11/10**
2	2	Information Gathering from different sources	28 days?	Wed 29/09/10	Fri 05/11/10
3	3	Components selection	16 days?	Wed 20/10/10	Wed 10/11/10
4	4	Component pattern analyzing	13 days?	Mon 01/11/10	Wed 17/11/10
5	5	**Phase II: SW and HW Design [10 weeks]**	**60 days**	**Thu 18/11/10**	**Wed 09/02/11**
6	6	Ordering component	58 days	Thu 18/11/10	Mon 07/02/11
7	7	Mechanical design assesment and work arrangements	15 days?	Thu 25/11/10	Wed 15/12/10
8	8	Criterias for microcontroller	6 days?	Thu 02/12/10	Thu 09/12/10
9	9	Algorithm for wind sensor system	39 days?	Fri 03/12/10	Wed 26/01/11
10	10	Design of a wind generator	8 days?	Wed 12/01/11	Fri 21/01/11
11	11	Arrangement of energy harvester	19 days?	Wed 08/12/10	Mon 03/01/11
12	12	Design for energy storage	21 days?	Wed 15/12/10	Wed 12/01/11
13	13	PCB order	12 days?	Tue 11/01/11	Wed 26/01/11
14	14	Data from PC to microcontroller(receiving and sending)	8 days?	Mon 17/01/11	Wed 26/01/11
15	15	**Phase III: Implementation and Testing [5 weeks]**	**20 days**	**Thu 03/02/11**	**Wed 02/03/11**
16	16	Implementation of wind sensor with wind generator	8 days?	Wed 26/01/11	Fri 04/02/11
17	17	Making link with microcontroller	4 days?	Fri 04/02/11	Wed 09/02/11
18	18	Implementation of storage system	13 days?	Mon 31/01/11	Wed 16/02/11
19	19	Collection of data and image for result	15 days	Tue 08/02/11	Mon 28/02/11
20	20	Risk assesment	4 days?	Fri 25/02/11	Wed 02/03/11
21	21	**Phase IV: Modification and Testing [2 weeks]**	**5 days**	**Thu 10/03/11**	**Wed 16/03/11**
22	22	Hardware modification if necessary	5 days	Mon 07/03/11	Fri 11/03/11
23	23	Programme modification if necessary	4 days	Wed 09/03/11	Mon 14/03/11
24	24	Collection of data and image for result after modification	3 days	Mon 14/03/11	Wed 16/03/11