Chapter One

Introduction

1.1 Overview

The wind industry has experienced large growth rates over the past decade and wind turbines have been installed around the world in increasing quantities. As wind energy becomes more prevalent there is growing interest in controlling wind turbines in an intelligent manner to minimize the cost of wind energy. This can be done by controlling the turbines to extract more energy from the wind [8].

1.2 Statement of Problem

The shape and dimensions of the blades of the wind turbine are determined by the aerodynamic performance required to efficiency extract energy from the wind, and by the strength required to resist the forces on the blade.

The aerodynamics of the horizontal axis wind turbine is not straight forward. The air flow at the blades is not the same as the air flow away from the turbine.

The speed at which a wind turbine rotates must be controlled for efficient power generation and to keep the turbine components within designed speed and torque limits.

1.3 Objectives

Simulate the wind turbine system with stepper motor and write an appropriate program in a microcontroller to the system.

1.4 Methodology

The concept of the design is based on using a microcontroller for processing. An optical sensor is used for calculating the RPM of the wind mill. The microcontroller task is to control the pitch of fan in order to acquire max wind thrust. The microcontrollers modify the stepper motors according to the optical sensor input.

The Methodology of work is:

- Study wind turbine system.
- Add stepper motor to the wind turbine system.
- Select an optical sensor as a wind speed sensor.
- Select an ATmega32 microcontroller and program it.

1.5 Research Outline

The research consists of five chapters including chapter one as follows:

Chapter two presents the literature review. Chapter three discusses the circuit components and connection. Chapter four deals with system software and hardware considerations. Chapter five write present the conclusion and recommendations.

Chapter Two

Literature Review

2.1 Back Ground:

Renewable energy is a very important topic to be study to find new sources of energy to produce electricity. Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves, and geothermal heat [1].

Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services [2].

The main advantages of renewable energy are available, clean, low cost, and continuous energy. Renewable energy sources presently provide significant amount of energy in many countries.

The major types of renewable energy sources can be summarized as follows:

- Wind energy
- Solar energy
- Hydro energy
- Tidal energy
- Biomass energy
- Ocean thermal energy conversion
- Geothermal energy

Based on REN21's 2014 report, renewable contributed 19 percent to our global energy consumption and 22 percent to our electricity generation in 2012 and 2013, respectively [3].

Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. Rapid deployment of renewable energy and energy efficiency is resulting in significant energy security, climate change mitigation, and economic benefits [3]. In international public opinion surveys there is strong support for promoting renewable sources such as solar power and wind power [4].

At the national level, at least 30 nations around the world already have renewable energy contributing more than 20 percent of energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond [5].

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas and developing countries, where energy is often crucial in human development [6].

United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity [7].

2.2 Wind Turbine

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines. Human efforts to harness wind for energy date back to the ancient times .Later, wind energy conversion systems have been attracting wide attention as it served the mankind energizing his grain grinding mills and water pumps .Wind energy, even though abundant, varies continually as wind speed changes through the day. It is gaining momentum in this field of clean energy and the energy recourses are becoming very popular in the world where demands for more power and sustainable development are increasing dramatically. While large wind turbines remain the dominant force in wind power, wider adoption may lie with small scale turbines fit for urban and low wind conditions [8].

2.2.1 History for wind turbines

The earliest documented design of wind mill dates back to 200 B.C. The Persians used wind mills for grinding grains during this period .Those were vertical axis machines having sails made with bundles of reeds or wood. The grinding stone was attached to the vertical shaft. The sails were attached to the central shaft using horizontal struts. Examples for wind mills are the tjasker and smock mills which designed by Jan Adriaenszoon. These wind mills reached America by mid-1700; through the Dutch settler's .Figure 2.1 shows the design of the wind mill [9].

Figure 2.1: Wind mills

2.2.2 Design and construction of wind turbine

The wind energy system is consisting of one or more units, operating electrically in parallel. This unit is consisting of the following components:

Wind tower

Two or three blades wind turbine

Yaw mechanism

Mechanical gear

Electrical generator

Speed sensors and control

A wind turbine obtains its power input by converting the force of the wind into torque acting on the rotor blades. The amount of energy which the wind transfers to the rotor depends on density of the air, the rotor area, and wind speed. Figure 2.2 shows the Components of a wind turbine.

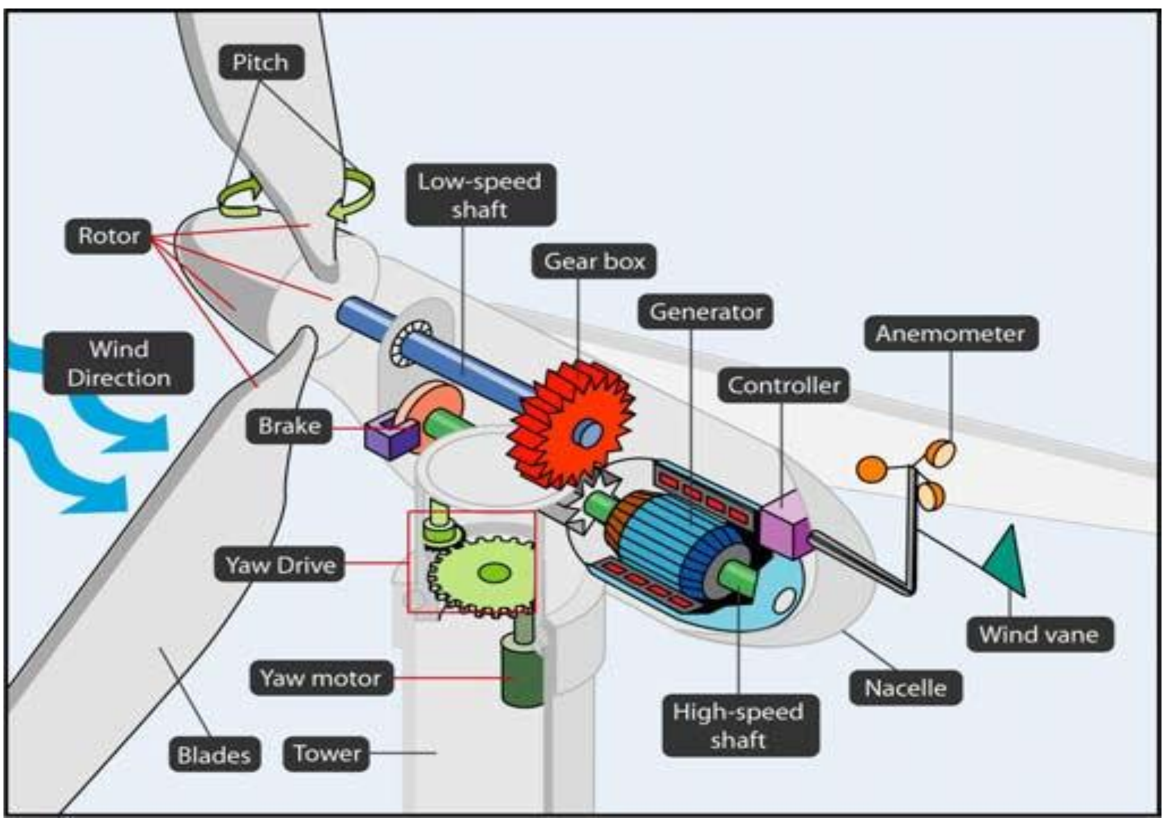

Figure 2.2: Components of a wind turbine

2.2.3 Types of wind turbine

Wind turbines can be separated into two basic types determined by which way the turbine spins Wind turbines that rotate around a horizontal axis are more common (like a wind mill), while vertical axis wind turbines are less frequently used (like Savonius and Darrieus)[10].

i/ Horizontal axis wind turbine

Horizontal Axis Wind Turbines (HAWT), also shortened to HAWT, is the common style that most of us think of when we think of a wind turbine. A HAWT has a similar design to a wind mill, it has blades that look like a fan that spin on the horizontal axis. Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn the turbine into the wind. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator .Figure 2.3 shows the design of the HAWT [10].

Figure2.3: Horizontal Axis Wind Turbine

ii/ Vertical axis wind turbine:

Vertical Axis Wind Turbines (VAWT), as shortened to VAWT, has the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis wind turbine the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT is the low wind energy conversion efficiency. Figure 2.4 shows the design of the VAWT [10].

Figure 2.4: Vertical Axis Wind Turbine

2.2.4 Wind turbines operation:

Wind turbines work by changing the kinetic energy of the wind into torque that causes the wind turbine to turn and drives the electrical generator. The wind is made up of real matter with mass, when the mass is moving it creates kinetic energy. As the wind causes the wind turbine to turn; we are reducing the energy in the wind. The energy that is removed from the wind is converted into mechanical energy that is used to drive the electrical generator and then converted into electrical energy. This procedure leads the wind turbine to work [10].

2.2.5 **Control Methods**:

You can use different control methods to either optimize or limit power output. You can control a turbine by controlling the generator speed, blade angle adjustment, and rotation of the entire wind turbine. Blade angle adjustment and turbine rotation are also known as pitch and yaw control, respectively. A visual representation of pitch and yaw adjustment is shown in figure 2.5 and figure 2.6.

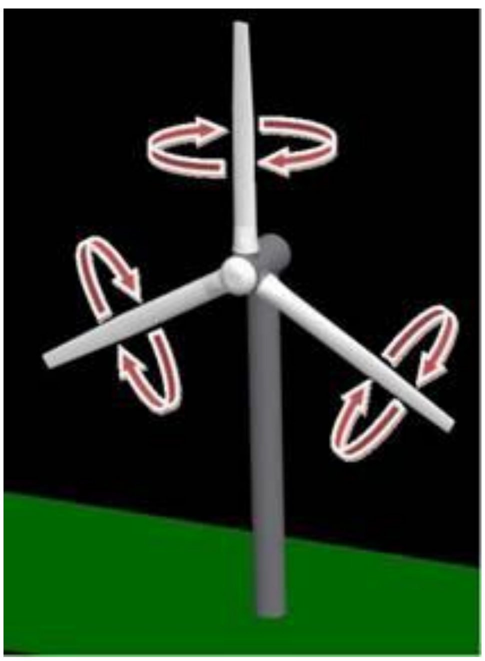

Figure 2.5: Pitch Adjustment

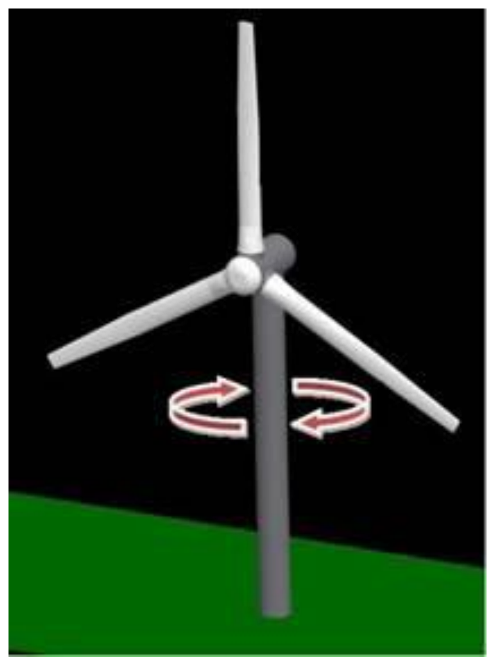

Figure 2.6: Yaw Adjustment

The purpose of pitch control is to maintain the optimum blade angle to achieve certain rotor speeds or power output. You can use pitch adjustment to stall and furl, two methods of pitch control. By stalling a wind turbine, you increase the angle of attack, which causes the flat side of the blade to face further into the wind. Furling decreases the angle of attack, causing the edge of the blade to face the oncoming wind. Pitch angle adjustment is the most effective way to limit output power by changing aerodynamic force on the blade at high wind speeds.

Yaw refers to the rotation of the entire wind turbine in the horizontal axis. Yaw control ensures that the turbine is constantly facing into the wind to maximize the effective rotor area and, as a result, power. Because wind direction can vary quickly, the turbine may misalign with the oncoming wind and cause power output losses. You can approximate these losses with the following equation:

$\Delta P=\alpha \cos(\varepsilon)$ Where ΔP is the lost power and ε is the yaw error angle

The final type of control deals with the electrical subsystem. You can achieve this dynamic control with power electronics, or, more specifically, electronic converters that are coupled to the generator. The two types of generator control are stator and rotor. The stator and rotor are the stationary and non-stationary parts of a generator, respectively. In each case, you disconnect the stator or rotor from the grid to change the synchronous speed of the generator independently of the voltage or frequency of the grid.

Controlling the synchronous generator speed is the most effective way to optimize maximum power output at low wind speeds.

Figure2.7 shows a system-level layout of a wind energy conversion system and the signals used. Notice that control is most effective by adjusting pitch angle and controlling the synchronous speed of the generator [11].

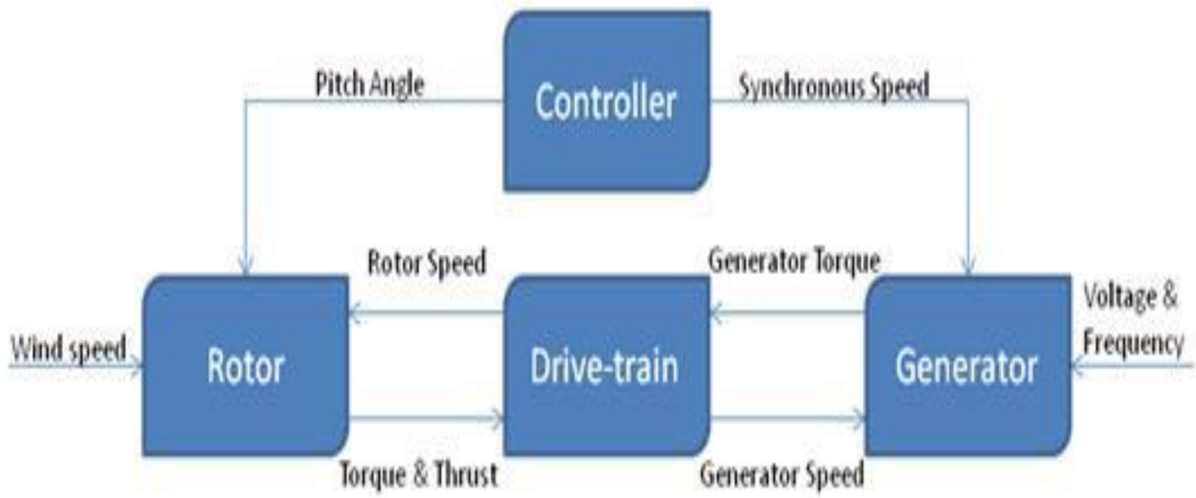

Figure2. 7: System-Level Layout of a Wind Energy System

2.2.6 Disadvantages of Wind Energy:

i) It is Dependent on the Availability of Wind

Disadvantages of wind energy include the fact that it relies entirely on the availability of wind. As long as there is no wind no electricity will be produced. As such, this form of energy cannot be relied on in totality as it is bound to fail every now and then. Due to the fact that this form of energy is not reliable, electricity generators do not invest on it and as such, its technology is not improving. There is therefore a high likelihood that this form of energy will be done away with eventually as the technology of other forms of energy is improving with leaps and bounds.

ii) Wind Turbines Kill Birds

Wind turbines are usually made of blades that rotate continuously and fiercely. Due to the fact that the blades are usually placed high up in the air, they are known to kill birds that fly over it. A research was done that showed that about 45,000 birds that flew over wind turbines have been killed over the past 20 years. The birds that are affected the most are the ones that usually migrate annually, these birds include; kestrels, golden eagles and tailed hawks. Attempts have been made to prevent more birds from dying as they paint the blades with conspicuous colors so that the birds can see and avoid them.

iii) The Speed of the Blowing Wind Has to Be Right

So as to produce the right amounts of electric power, the wind turbines need to rotate at the right pace. The rotation should neither be too slow nor too fast. When the speed of the wind is extremely slow, it is not economical for the turbines to run. This is because the turbines are quite expensive to run. When there is too much wind that is blowing at a fast rate, it is mandatory that the turbines are shut down owing to concerns of safety as if the wind is so strong the turbines might get destroyed or might get detached and hurt people.

iv) The Energy Density of Wind Is Low

Due to the fact that wind is diffuse and it is also spread over a wide area, so as to be able to produce large quantities of electricity it is mandatory that the number of turbines used cover a large area. Since many turbines have to be used, the costs of setting up a wind farm are so high. However, the production of other sources of energy faces the same problems.

v) This Form of Energy is Not Efficient

The system that is usually set up so as to turn wind energy into electric energy is not efficient. This happens to be one of the major disadvantages of this form of energy. The turbines do not have the ability to extract a hundred percent of the energy that is found in the blowing wind. Research shows that turbines extract only fifty nine percent of the wind energy that passes through them. This makes them very insufficient. The fact that experts in this field are not investing on making this system of power generation better means that the insufficiency is bound to continue.

vi) The Energy that is Produced Can't Be Stored in Large Scale

The energy that is produced cannot be stored in large scale. Considering the fact that it is impossible to have wind blowing daily, it is important that the energy storage of this system be sufficient. Seeing as it is not, this shortcoming contributes greatly to the insufficiency of wind energy. Needless to say, this problem is likely to be there for a very long time.

vii) The Turbines are Noisy

One of the reason as to why most people avoid using this form of energy is that the machinery that is used for the production of electricity is very noisy. Although this form of energy is preferred as it does not pollute the environment, the noise that is usually produced in the process of producing electricity is too much: it can be a nuisance. As such, the system setups for this form of power cannot be placed in places that need to be quiet such as residential areas and places of works. This limits the number of places where the setups can be put up.

viii) The Amount of Wind that Blows Is Unpredictable

The amount of wind that is likely to blow in a particular place at a particular time is impossible to predict. This is one of the major disadvantages of wind energy as one has to invest on other alternatives forms of energy. As such one has to incur double costs so as to ensure that they have enough electricity. The best alternatives of energy are geothermal and solar energy. As a result of this shortcoming, before setting up a wind farm, thorough research has to be done so as to make sure that the location is appropriate.

ix) This Form of Energy is Suited to Be Set Up in Specific Places

Wind farms can only be set up on specific places. This limits the use of this form of energy to specific places. The best place to set up a wind farm is in the coastal regions. The reason as to why turbines are placed in the coastal region is due to the fact that coastal regions are always windy. This means that regions which are located hilly areas may not be able to benefit from this form of energy. The place where the turbines are placed ought to have a lot of wind blowing if any electricity is to be produced.

x) The Visual Impact that Turbines Have on the People

Many people are of the ideas that turbines are not appealing to the eye. There is however people who tend to think that they beautify the areas as they are appealing to the eyes. The different views have resulted into people filing petitions to bar the setting up of wind farms in areas that surround them. The fact that there are people who find turbines undesirable is a shortcoming of this form of energy as its use is limited to places where they are accepted.

xi) Land Use

One of the main disadvantages of wind energy is that large tracks of land are needed to so that the appropriate number of turbines can be installed. One of the major reason as to why the installation of turbines is considered to be a waste of time is because the electrical energy that is usually produced is too little to warrant the wastage of huge tracks of land. The fact that a safe area has to be around each farm contributes to wastage of land. A survey was done that showed that the installation of one turbine requires the use of 5 acres of land. However, I am not certain how true this is.

xii) Poor Electricity Production

Many people wonder whether the little electricity produced is worth the costs that come with the buying of the turbines and towers. The amount of electricity that is produced is very little and not worth the cost of installing the wind farms. Also the fact that one may need to replace the turbines and towers after a while makes more expensive and therefore many people think it is not worth it. Although this form of energy is clean, the amount of electric energy produced ought to be enough to warrant the high costs. The amount of electricity produced should be of usable quantities to warrant the costs that are incurred.

xiii) Turbines Interfere With the Reception of Televisions

Many of the people who live near wind farms complain that the wind turbines interfere with their television signals. This explains why most people protest against the putting of wind farms in residential places. Turbines are also known to interfere with radio signals.

The disadvantages of wind energy cannot be ignored. Some of these limitations are so great that they cannot be ignored. Limitations such as the fact that the amount of electricity that is produced is not worth the costs that were incurred to make the wind farms is a major limitation that has to be considered before setting up a wind farm. Wind energy is not a reliable source of power as there are days when the wind will not blow and this result into a situation where electricity will not be available until the wind begins to blow again. It is important to have a reliable source of power as lack power interferes with almost all activities that take place in daily living. The fact that this form of energy is not likely to improve makes it more undesirable [12].

2.3 Previous Studies:

1/Design of a maximum power point tracking System for wind turbine

In this study they show how to design a maximum power point tracking for wind turbine. The major equipment's that used in their design are DC-DC converter, power MOSFET and PIC microcontroller. They use matlab simulink and Pspice simulation so they constructed many graphs in their design. Working on this senior report is enhanced their knowledge in new concept like The DC-DC converter. Also it improved their learning skill and how to work as a team to learn and getting advices from each other. They also learn how to manage their time now, and in the future to achieve and finish their senior design project. They will start implement their design in senior design project II and test it to see if the result matches the theoretical design [13].

2/Control system on a wind turbine

The controller developed in this project can effectively control the rotor speed at a constant value. For large wind fluctuations the rotor speed can increase slightly before the controller manages to compensate for increased oil compression, leakage and generator speed. If a wind gust results in rotor speed over shoot above the rated speed, the blade pitch can be used to reduce the torque and thus the resulting over speed peak effectively [14].

3/Design and implementation of a microcontroller-based wind energy conversion System

In this study, a dsPIC-controlled DC/DC boost converter and a wind turbine control system that tracks the maximum power point are designed and implemented. In practice, the energy generated by a permanent magnet synchronous wind turbine is applied to the load using a circuit that consists of a rectifier, boost converter, and protective load. The converter operates in the designed mode 35% more efficiently than in the normal operation mode. In addition, the wind turbine is protected from over voltages in strong windy weather using the protective circuit. Experimental results show that the ripple value on the direct current belonging to the converter output complies with the IEC 61204 standard. Moreover, the designed system is fast and easily programmable, and it can be adapted to other wind turbine models [15].

4/ Implementation of Wind Turbine Controller Design for Smart Campus

This paper presents the design and construction of charge controller for wind energy source. The charge controller is a small prototype that is suitable to charge small battery. The maximum charging current of the charge controller is about 7 A. The charge controller is designed using PIC 16F877A microcontroller, liquid-crystal display (LCD), silicon-controlled rectifier (SCR), rectifier diodes and other electronic components. The SCR and rectifier diodes in conjunction with other components are used to charge the battery. The battery charging is controlled by the microcontroller circuit. The LCD module displays the status of the battery while it is charging. At the same time the voltage level of the battery is also displayed. The microcontroller controls the charging circuit and diverted the charging current to the diverted load if the battery is fully charged. The microcontroller also produces signal to the audible alarm circuit in the case of full charge battery. The simulation results are based on the ISIS software environments before implementing the hardware description. The experimental results for charge controller are also mentioned [16].

5/Small Wind Turbine Power Controllers

The main focus of our discussion is the control of wind turbines, the techniques and components described here also find use in other alternative power systems, such as solar photovoltaic systems, where they can improve the overall system power extraction. Many alternative power systems incorporate several different power sources, such as wind and solar. Such “hybrid” systems have the advantage of greater power availability (periods of low wind are often characterized by clear skies and good solar power, while strong winds are often associated with cloud activity). We will therefore use examples from both solar and wind power systems in the discussion of the relevant techniques [17].

6/New, Simple Blade-Pitch Control Mechanism for Small-Size, Horizontal-Axis Wind Turbines

In the present research work, the pitch-control is carried out such that the rotor blades are rotated around their longitudinal axis while the rotor continues its normal rotation. It is really a challenge to produce a clever design to pitch the rotor blades by the optimal amount so as to maximize the power output at all wind speeds. The mechanism is implemented to a three-blade, horizontal-axis, home-scale wind turbine. The mechanism is powered by a suitable DC (direct-current) motor. The tests were carried out in the open section of a delivery wind tunnel. The air speed was measured by a suitable anemometer. The corresponding rotational speed (rpm) and output voltage at different wind speeds were measured and recorded for calibration of the control system. The mechanism proved to be successful in controlling the pitch angle over a wide range of wind speeds [18].

7/Application of Micro-controller to Wind Turbine System

The project has particular relevance to companies involved in renewable energy projects such as the generation of electricity by means of wind or water power. Proven Engineering are members of the British Wind Energy Authority and members of the Small Wind Energy Committee within this organization and plan to discuss the project with them to show the benefits of electronics. Targeting similar bodies throughout Europe would further expand the target audience [19].

8/Wind Turbine Control Methods

This document covered some essential wind energy concepts, such as the angle of attack and the power coefficient, as well as different control methods and strategies. Pitch, Yaw, and Rotational Speed Control were the main control methods used to optimize or limit the power extracted from the wind. Wind turbine control is essential for optimal performance, safe operation, and structural stability [11].

9/Efficiency Improvement of a New Vertical Axis Wind Turbine by Individual Active Control of Blade Motion

In this paper, a research for the performance improvement of the straight-bladed vertical axis wind turbine is described. To improve the performance of the power generation system, which consists of several blades rotating about axis in parallel direction, the cycloidal blade system and the individual active blade control system are adopted, respectively. Both methods are variable pitch system. For cycloidal wind turbine, aerodynamic analysis is carried out by changing pitch angle and phase angle based on the cycloidal motion according to the change of wind speed and wind direction, and control mechanism using the cycloidal blade system is realized for 1kw class wind turbine. By this method, electrical power is generated about 30% higher than wind turbine using fixed pitch angle method. And for more efficient wind turbine, individual pitch angle control of each blade is studied. By maximizing the tangential force in each rotating blade at the specific rotating position, optimal pitch angle variation is obtained. And several airfoil shapes of NACA 4-digit and NACA 6-series are studied. Aerodynamic analysis shows performance improvement of 60%. To realize this motion, sensing and actuating system is designed [20].

10/Maximum Peak Power Tracking Control for the new Small Twisted H-Rotor Wind Turbine

A microcontroller based system is proposed for low cost and high efficiency control of small wind turbine. The perturbation and observation method is employed to achieve maximum peak power tracking (MPPT). The algorithm, controller functions, and driving signals are implemented on ATMEGA16 microcontroller. The prototype of MPPT controller was tested with real wind turbine at the laboratory in Germany. The actual operating points of the wind turbine with MPPT controller were compared with power versus rotational speed curve in order to verify the tracking performance. The result confirms that small wind turbine with proposed MPPT controller can operate in the maximum power region for the whole range of assigned wind speeds [21].

11/Maximum Power Point Tracking from a Wind Turbine Emulator Using a DC-DC Converter Controlled

The system maximum energy capture characteristics are simulated in Matlab Simulink environment. The simulation results show that, by controlling the DC converter can realize the goals that wind turbine output power tracking the maximum theoretical power. Wind turbine power coefficient and duty ratio has remained near the optimal value in system design. This has fully demonstrated the correctness of the wind power energy management system and the feasibility of control strategy of maximum power point tracking in this article [22].

Chapter Three

Electronic Circuit Design

3.1 Introduction

In this study, a control circuit for the stepper motor is designed using an AVR microcontroller. Design of the control system includes hardware and software as shown in block diagram Figure 3.1

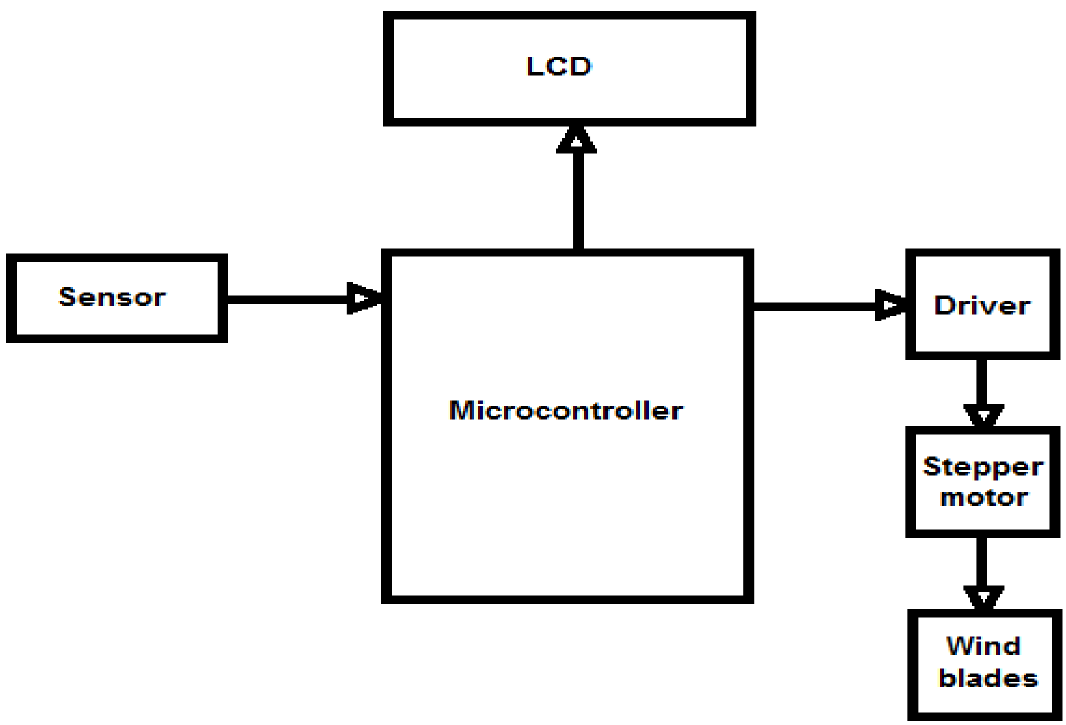

Figure 3.1: system block diagram

3.2 Components of Circuit Design

1) The hardware structure of the control system consist of following components:

1. At mega32 microcontroller
2. Stepper motor(unipolar)

3. ULN2003A motor driver
4. 16*2 LCD
5. Optical switch(slotted interrupter)
6. Supply Voltage
7. 5 resistors of 300
8. Resistors[47k and330]
9. 5 Led(1 red ,4 green)

2) The software of the control system includes the following:

1. Initialization program
2. LCD display program

3.2.1 Microcontroller

Microcontrollers are used in a large variety of application. They can be found in the automotive industry, communication system, electronic instrumentation, hospital equipment, industrial equipment and applications, household appliances, toys, and so forth.

Microcontrollers have been designed to use in applications which they have to carry out a small number of tasks at the lowest possible economic cost. They do this by executing a program permanently stored in their memory, whereas the input/output ports of the microcontroller are used to interact with the outside world. Therefore, the microcontroller becomes part of the application, it is a controller embedded in the system [23].

Figure 3.2 shows the Microcontroller.

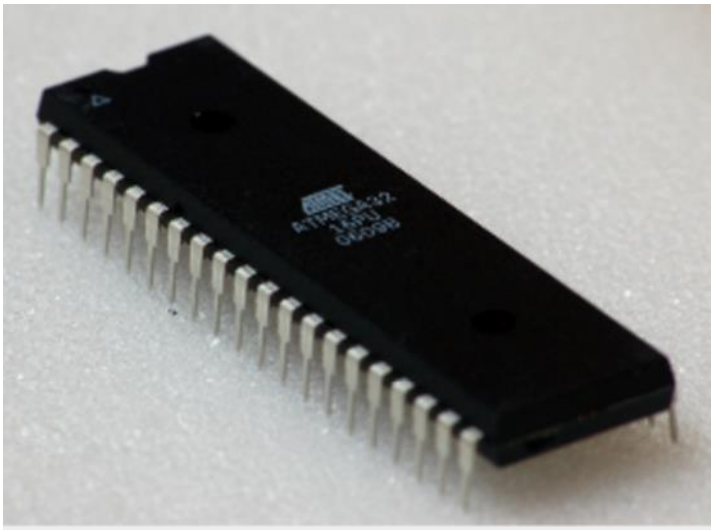

Figure3.2: Microcontroller

❖ **What is a Microcontroller**

It is a highly integrated chip that contains all the components comprising a controller. It includes:-

*CPU

*RAM/ROM

*I/O ports

*Timers

Microcontrollers are sometimes called Embedded Microcontrollers, which just means that they are part of a larger device or system.

Unlike a general purpose computer, which also includes all of these components, a microcontroller is designed for a specific task to control a particular system

❖ **Uses of microcontroller**

Microcontrollers are used in a wide number of electronic systems such as:-

Control systems in industries

Electronic measurement instruments

Printers

Mobile phones

Security systems

Hearing aids

TV, Radio, CD players

❖ What inside the microcontroller

The microcontroller combines into the same chip:-

- The CPU core
- Memory (both RAM and ROM)
- Some parallel digital I/O
- A timer module to allow the microcontroller to perform tasks for certain time periods
- A serial I/O ports to allow data to flow between microcontroller and other devices
- ADC to allow the microcontroller to accept analogue input data for processing.

❖ Memory in Microcontroller

- Rom type memory, is used to store the program code

• Rom memory can be either Rom (as in One Time Programmable memory), EPROM, or EEPROM.

• RAM is used for data storage and stack management tasks (as in the microchip PIC range of microcontrollers).

❖ Port Pins

The digital I/O ports are the means by which the microcontroller interfaces to the environment.

The number of I/O port bits depends on the size of the microcontroller. Some very simple 8 bit microcontrollers have as few as 4 bit of I/O, whilst those at the high end range can have as many as 33 bits of I/O (some 16 microcontrollers could have around 78 bits of I/O)[23].

❖ ATmega32 Microcontroller

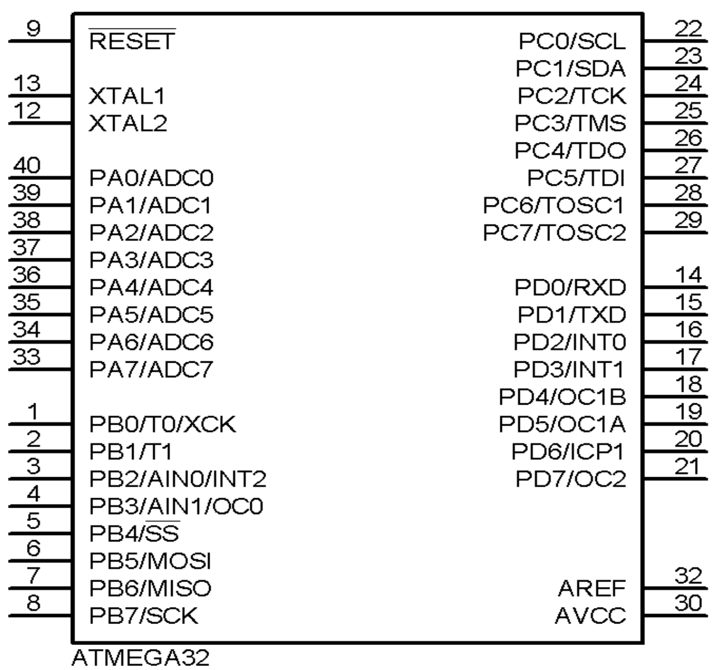

Figure3.3: ATmega32 microcontroller block diagram

The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega32 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

❖ **Pin Descriptions**

VCC Digital supply voltage.

GND Ground.

Port A (PA7-PA0)

Port A serves as the analog inputs to the A/D Converter.

Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port B (PB7-PB0)

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port C (PC7-PC0)

Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running. If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs.

The TD0 pin is tri-stated unless TAP states that shift out data are entered.

Port D (PD7-PD0)

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

RESET

Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a reset.

XTAL1

Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

XTAL2

Output from the inverting oscillator amplifier.

AVCC

AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

AREF

AREF is the analog reference pin for the A/D Converter.

- ❖ **ATmega32 microcontroller pin assignments**

Port A pin numbers [0, 1, 2, 3] are used as output connected to the ULN2003.

Port B pin numbers [0, 1, 2, 3, and 4] are used as output connected to LEDs.

Port C pin numbers [0, 1, 4, 5, 6 and7] are used as output connected to LCD.

Port D pin number [0] is input pin connected to Optical switch.

VCC and AREF pin number [30 and32] connected to +5V power supply.

- ❖ **ATmega32 programming**

Programming of at mega 32 requires several hardware and software tools:

Software tools: BASCOM software.

Hardware tools: A universal programmer is used to program the ATmega32. This programmer provides the hardware interface between the host PC and the ATmega32 for the machine code loading.

3.2.2/ Stepper Motor

A stepper motor (or step motor) is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application. Figure 3.4 shows the steeper motor.

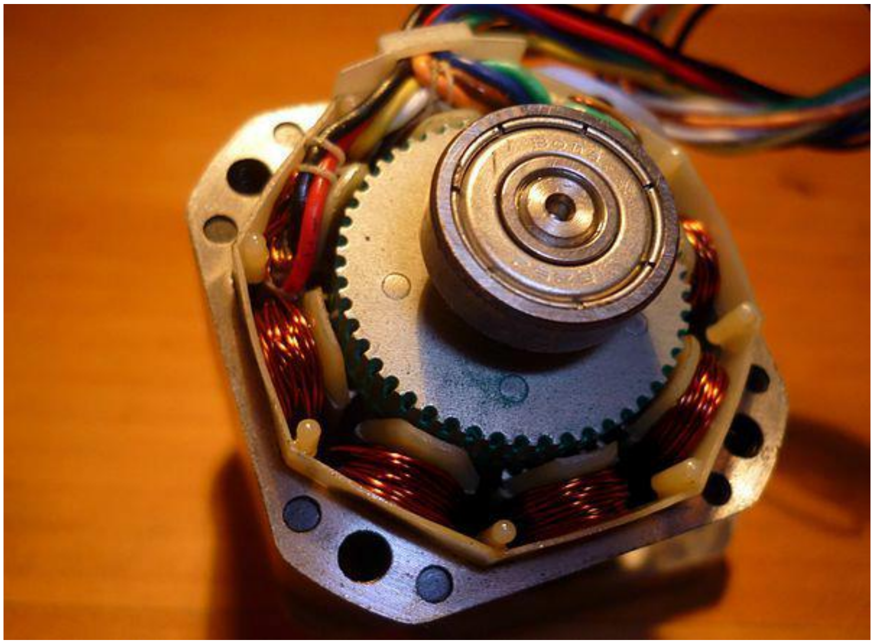

Figure 3.4: A stepper motor

❖ **Advantages/disadvantages of stepper motors**

i. **Advantages**

- Low cost for control achieved
- High torque at startup and low speeds
- Ruggedness
- Simplicity of construction
- Can operate in an open loop control system
- Low maintenance
- Less likely to stall or slip
- Will work in any environment

ii. **Disadvantages**

- Require a dedicated control circuit
- Use more current than D.C. motors
- Torque reduces at higher speeds

❖ Applications of stepper motor

Computer controlled stepper motors are a type of motion-control positioning system. They are typically digitally controlled as part of an open loop system for use in holding or positioning applications.

In the field of lasers and optics they are frequently used in precision positioning equipment such as linear actuators, linear stages, rotation stages, goniometers, and mirror mounts. Other uses are in packaging machinery, and positioning of valve pilot stages for fluid control systems.

Commercially, stepper motors are used in floppy disk drives, flatbed scanners, computer printers, plotters, slot machines, image scanners, compact disc drives, intelligent lighting, camera lenses, CNC machines and, more recently, in 3D printers.

❖ Types

There are four main types of stepper motors:

1. Permanent magnet stepper (can be subdivided into 'tin-can' and 'hybrid', tin-can being a cheaper product, and hybrid with higher quality bearings, smaller step angle, higher power density)
2. Hybrid synchronous stepper
3. Variable reluctance stepper
4. Lavet type stepping motor

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets. Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles. Hybrid stepper motors are named because they use a combination of PM and VR techniques to achieve maximum power in a small package size.

- **Two-phase stepper motors**

There are two basic winding arrangements for the electromagnetic coils in a two phase stepper motor: bipolar and unipolar.

1) Unipolar motors

A unipolar stepper motor is used because it is less cost ,it has five wires and four coils(actually two coils divided by center connections on each coil). The center connections of the coils are tied together and used as the power connection. (Step angle=48).

A unipolar stepper motor has one winding with center tap per phase. Each section of windings is switched on for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (e.g., a single transistor) for each winding. Typically, given a phase, the center tap of each winding is made common: giving three leads per phase and six leads for a typical two phase motor. Often, these two phase commons are internally joined, so the motor has only five leads. A micro controller or stepper motor controller can be used to activate the drive transistors in the right order, and this ease of operation makes unipolar motors popular with hobbyists; they are probably the cheapest way to get precise angular movements. For the experimenter, the windings can be identified by touching the terminal wires together in PM motors. If the terminals of a coil are connected, the shaft becomes harder to turn. One way to distinguish the center tap (common wire) from a coil-end wire is by measuring the resistance. Resistance between common wire and coil-end wire is always half of what it is between coil-end and coil end wires. This is because there is twice the length of coil between the ends and only half from center (common wire) to the end. A quick way to determine if the stepper motor is working is to short circuit every two pairs and try turning the shaft, whenever a higher than normal resistance is felt, it indicates that the circuit to the particular winding is closed and that the phase is working. Figure3.5 shows the unipolar stepper motor coils.

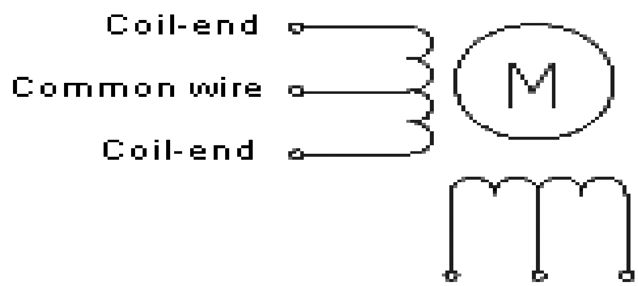

Figure3.5: Unipolar stepper motor coils

2) Bipolar motor

Bipolar motors have a single winding per phase. The current in a winding needs to be reversed in order to reverse a magnetic pole, so the driving circuit must be more complicated, typically with an H-bridge arrangement (however there are several off-the-shelf driver chips available to make this a simple affair). There are two leads per phase, none are common.

Static friction effects using an H-bridge have been observed with certain drive topologies. [24]

Dithering the stepper signal at a higher frequency than the motor can respond to will reduce this "static friction" effect.

Because windings are better utilized, they are more powerful than a unipolar motor of the same weight. This is due to the physical space occupied by the windings. A

unipolar motor has twice the amount of wire in the same space, but only half used at any point in time, hence is
50% efficient (or approximately 70% of the torque output available). Though a bipolar stepper motor is more complicated to drive, the abundance of driver chips means this is much less difficult to achieve.
An 8-lead stepper is wound like a unipolar stepper, but the leads are not joined to common internally to the motor.
This kind of motor can be wired in several configurations:

- Unipolar.
- Bipolar with series windings. This gives higher inductance but lower current per winding.
- Bipolar with parallel windings. This requires higher current but can perform better as the winding inductance is reduced.
- Bipolar with a single winding per phase. This method will run the motor on only half the available windings, which will reduce the available low speed torque but require less current. Figure 3.6 shows the bipolar hybrid motor.

Figure3.6: A bipolar hybrid stepper motor

- **Stepper motor driver circuits**

Stepper motor performance is strongly dependent on the driver circuit. Torque curves may be extended to greater speeds if the stator poles can be reversed more quickly, the limiting factor being the winding inductance.

To overcome the inductance and switch the windings quickly, one must increase the drive voltage. This leads further to the necessity of limiting the current that these high voltages may otherwise induce.

3.2.3 ULN2003 motor drive

ULN2003A figure 3.7 is a high voltage and high current Darlington array IC. It contains seven open collectors Darlington pairs with common emitters. A Darlington pairs is an arrangement of two bipolar transistors.

Figure3.8:ULN2003A block diagram

Figure3.7:ULN2003A

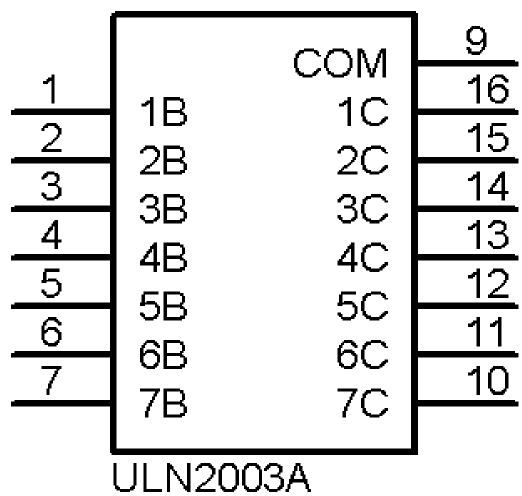

Figure3.8:ULN2003A block diagram

ULN2003 belongs to the family of ULN200X series of ICs. Different version of this family interface to different logic families. ULN2003 is for 5V, COMS logic devices. These ICs are used when driving a wide range of loads and are used as relay drivers. ULN2003 is also commonly used while driving stepper motor [5].

Each channel or Darlington pair in ULN2003 is rated at 500mA and can withstand peak current of 600mA. The inputs and output are provided opposite to each other in the pin layout. Each driver also contains a suppression diode to dissipate voltage spikes while driving inductive loads. The schematic for each driver is given in Figure 3.9.

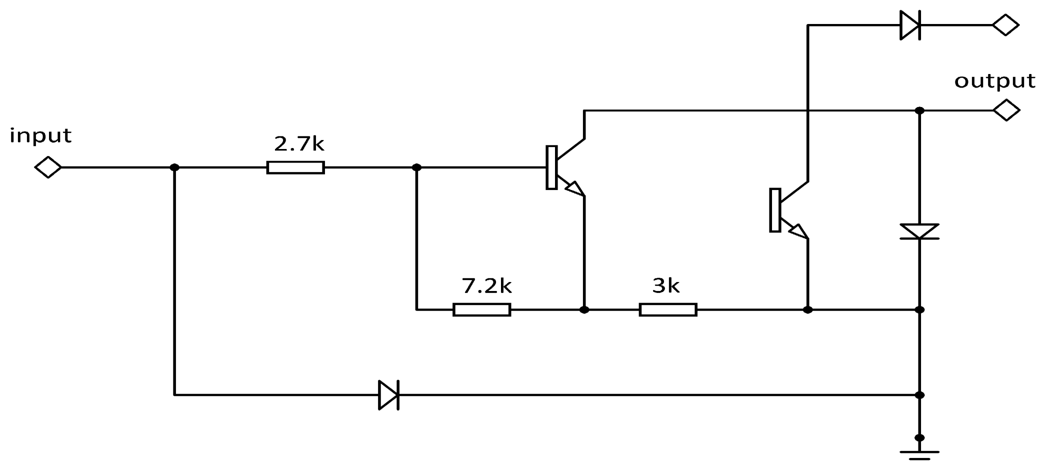

Figure 3.9: Schematic for ULN2003

❖ **UNL2003 pin assignments**

Input pin number [1, 2, 3 and4] connected to at mega 16.

Output pin number [1, 2, 3, and4] connected to stepper motor.

Pin number 9 [com] connected to the +5V power supply.

3.2.4 Liquid crystal display

A Liquid Crystal Display (LCD) as shown in figure 4.2 is a flat panel display, electronic visual display, or video display that uses light modulation properties of liquid crystals (LCs). LCs does not emit light directly. LCDs are considered as output device to display text or numeric information.

Figure 3.10: Liquid Crystal Display (LDC)

It comes a wide variety of configuration including multi-character, multi-line format. The most commonly used character based LCDs are based on Hitachi's HD44780 controller other which is compatible with HD44580. The LCDs are found today are 1 line,2line,4lineLCDs, which have only one controller and support at most of 80 character whereas LCD supporting more than 80 characters make use of 2HD44780 controllers. Most LCDs with 1controller has 14 pins, and LCDs with 2 controllers has 16 pin (two pins are extra in both for back-light LED connections). A 16*2 LCD format is common. That, it has capability of displaying two lines of 16 characters each. The characters are sent to the LCD via ASCTI format a single character at time. LCDs are used in a wide range of applications, including computer monitors, television, instrument panels, aircraft cockpit displays, and signage, etc. they are common in consumer devices such as video players, gaming devices, clocks, watches, calculators, and telephones.

❖ LCD pin assignments

Pins C [4, 5, 6 and 7], RS and E are the data inputs from the microcontroller atmega32.

VSS, VEE and RW pins grounded. VDD pin connected to supply voltage +5.

3.2.5: Optical switch (Slotted Interrupter)

Slotted interrupter is a small device that shines a light from one side to other, where there is a detector. The idea is that if anything breaks that light beam, you take note of it, and use the information as you wish. For example, if you put a disk on a motor shaft with a small hole cut in it, the beam will be broken except for that one spot- so count the “breaks”, to get an RBM for the motor [23].

3.2.6 Supply Voltage

At mega 32 can operate with a power supply of +2.7V to+5.5V. Usually a voltage regulator circuit is used to obtain the required power supply voltage when the device is operated from a main adapter or batteries. [25]

3.3 Electronic Circuit

Figure 3.11 shows the circuit connection in details, and how all components are connected with ATmega32 microcontroller.

Port A pin numbers [0, 1, 2, 3] are used as output connected to the ULN2003.

Port B pin numbers [0, 1, 2, 3, and 4] are used as output connected to LEDs.

Port C pin numbers [0, 1,4,5,6 and7] are used as output connected to LCD.

Port D pin number [0] is input pin connected to Optical switch.

VCC and AREF pin number [30 and32] connected to +5V power supply.

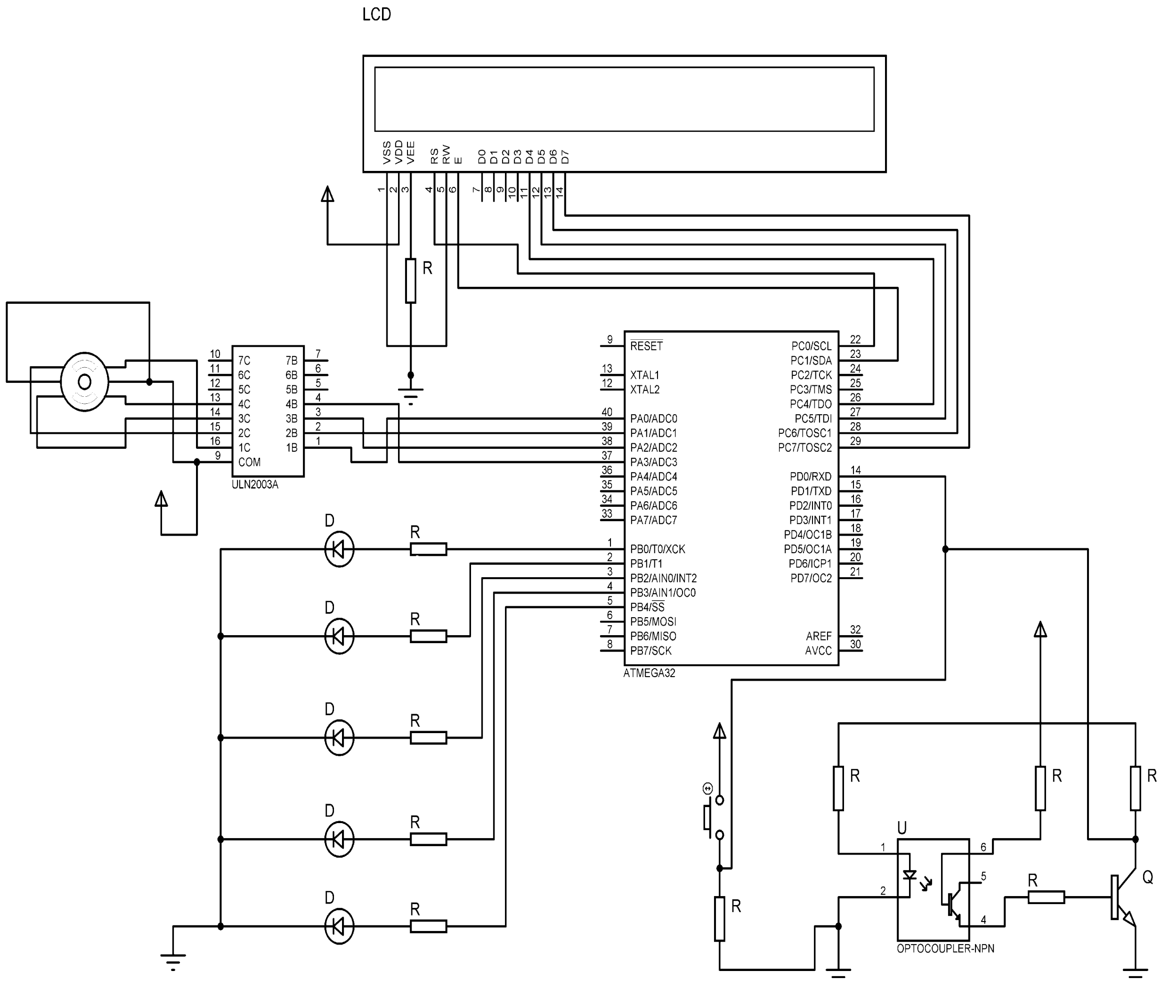

Figure3.11: Electronic circuit

Chapter Four

System Software and Hardware Considerations

4.1 Software considerations

4.1.1 Programming

To program the AVR microcontroller used in this system BASCOM software very suitable for this task. BASTOM is a compiler that uses a version of basic very similar to QBASIC to produce programs for the AVR microcontrollers.

It uses an integrated development environment (IDE) which allows you to write and edit programs, compile them, test them with a simulator and finally write the program to microcontroller for use in a circuit all from one program.

The main program is written using BASCOM program ATmega32 after BASCOM program is compiled during the software development process, the program is converted to the machine code for the specific microcontroller.

The main program starts with definition of file type, set the reference frequency initialize the ATmega32 ports, configure LCD, enters a continuous loop. Within the loop, the ATmega32 monitors for a status change on reference port.

When the switch depressed the ATmega32 detects the status change executes the appropriate program [26].

The flow chart of this code shown in figure 4.1.

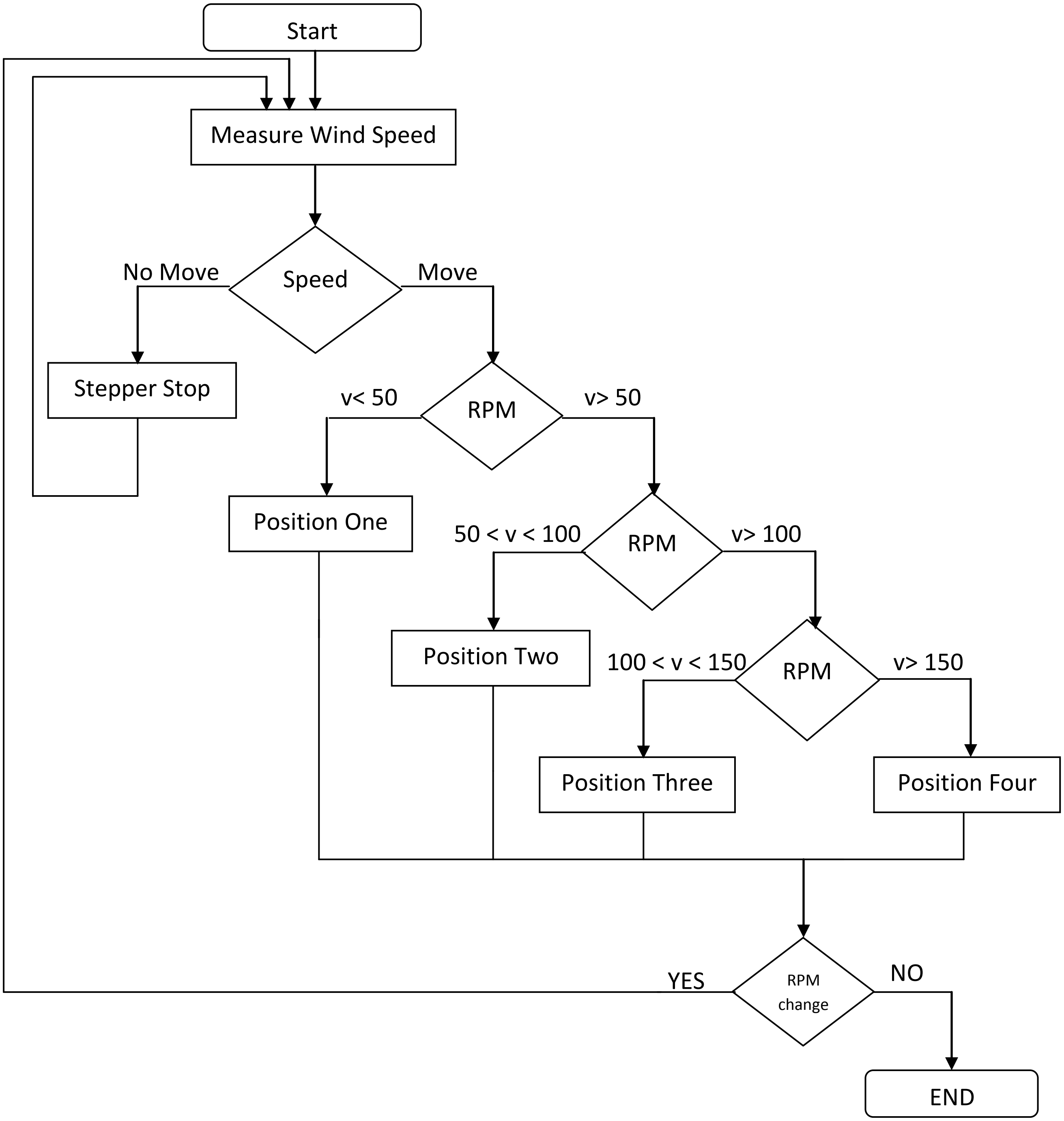

Figure 4.1: flow chart

4.1.2 Simulation

Computer simulations have become a useful part of mathematical modeling of much natural system to observe their behavior. It allows the engineer to test the design before it is built for real. As mentioned earlier, the simulations for this project were performed in PROTEUS program SIMULINK. these software applications are widely used in control engineering, for both simulation and design.

❖ **steps of simulation:**

Before simulation can be run, the procedure is illustrated step by step:

i. Step one:

The PROTEUS program is chosen from program menu and PROTEUS program is chosen from ISIS7 professional. After clicking the ISIS7 professional a work area shows as in figure4.2.

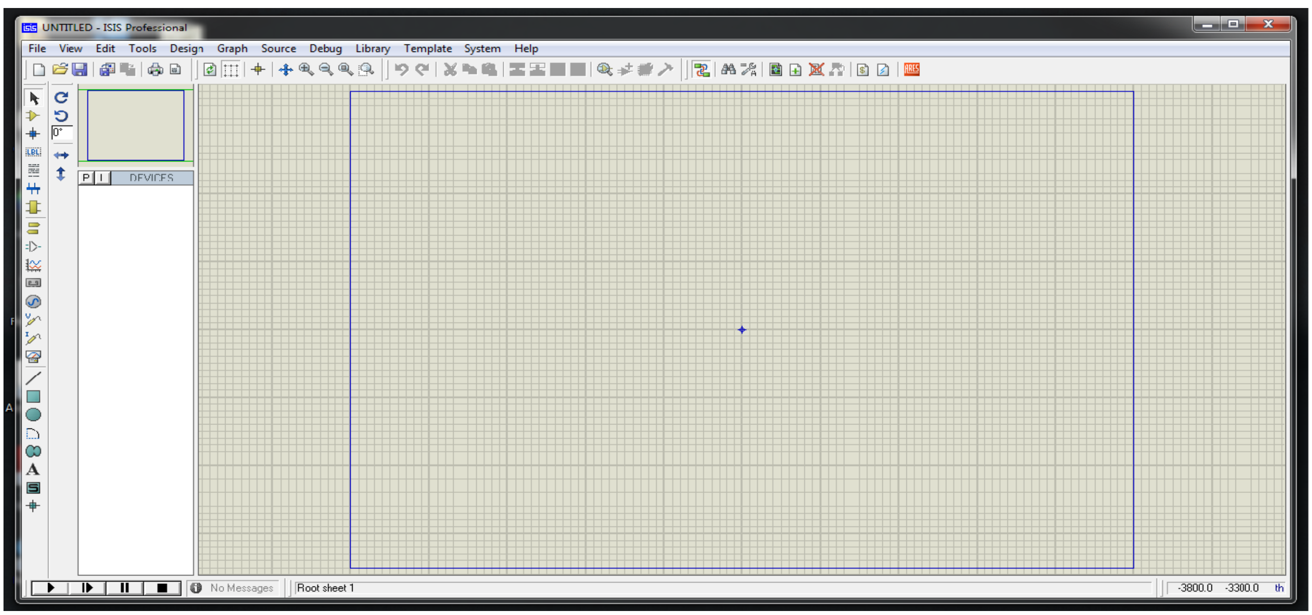

Figure 4.2: the work area.

ii. Step two:

Choosing the tools needed for design as in figure 4.3.

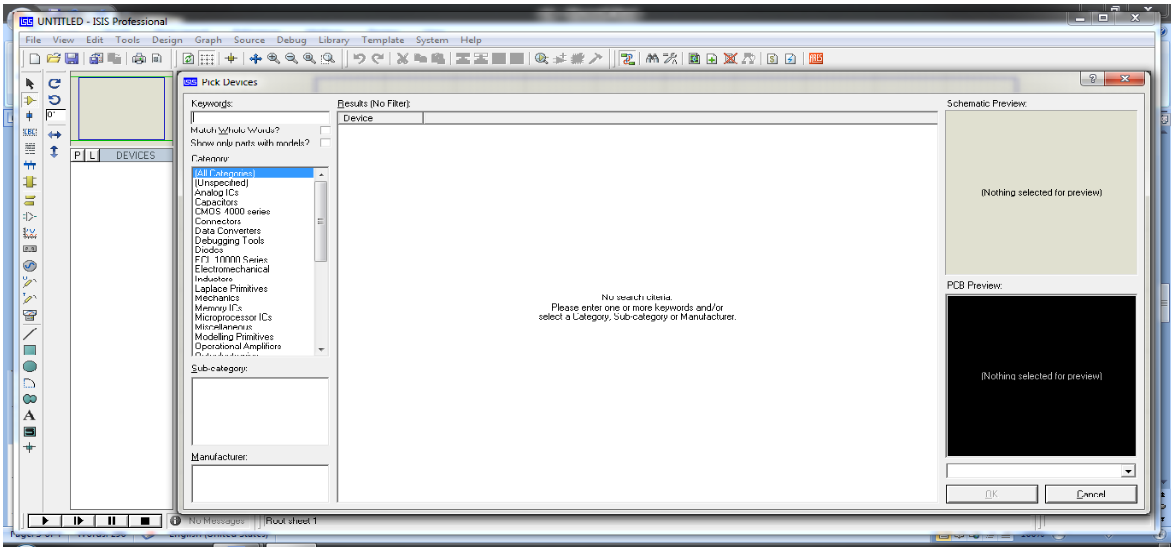

Figure 4.3: tools choosing.

iii. Step three :

Choosing microcontroller ATmega32 as shown in figure4.4.

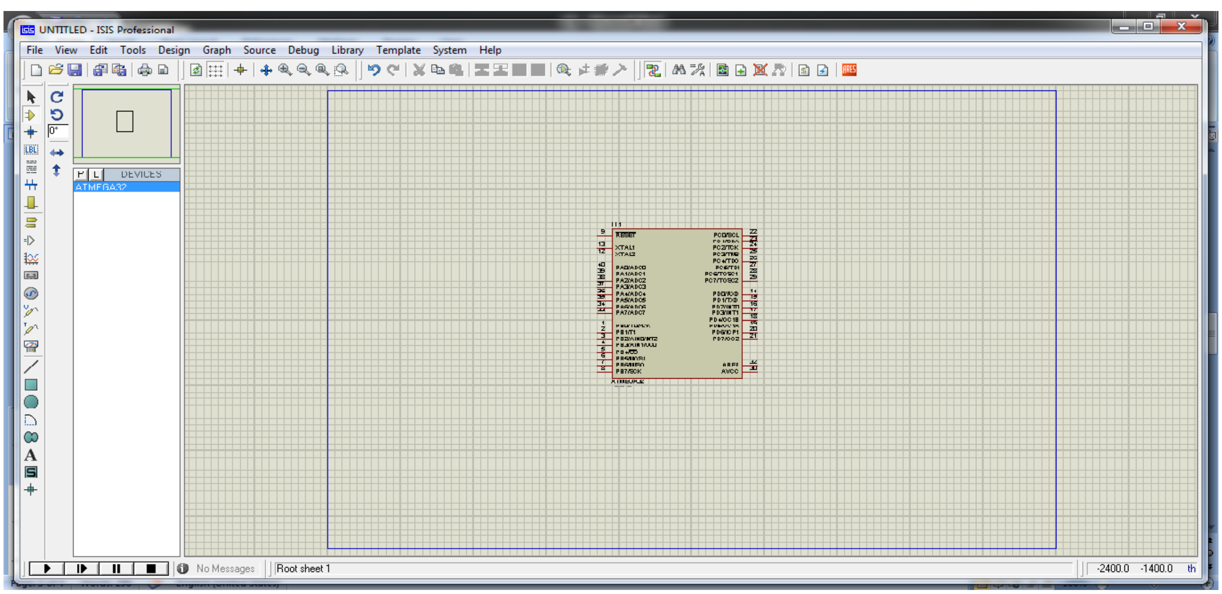

Figure 4.4: choosing ATmega32

iv. Step four:

Choosing stepper motor (unipolar) and connected it via a ULN2003A to atmega16 and determine the circuit of home position as shown in figure 4.5.

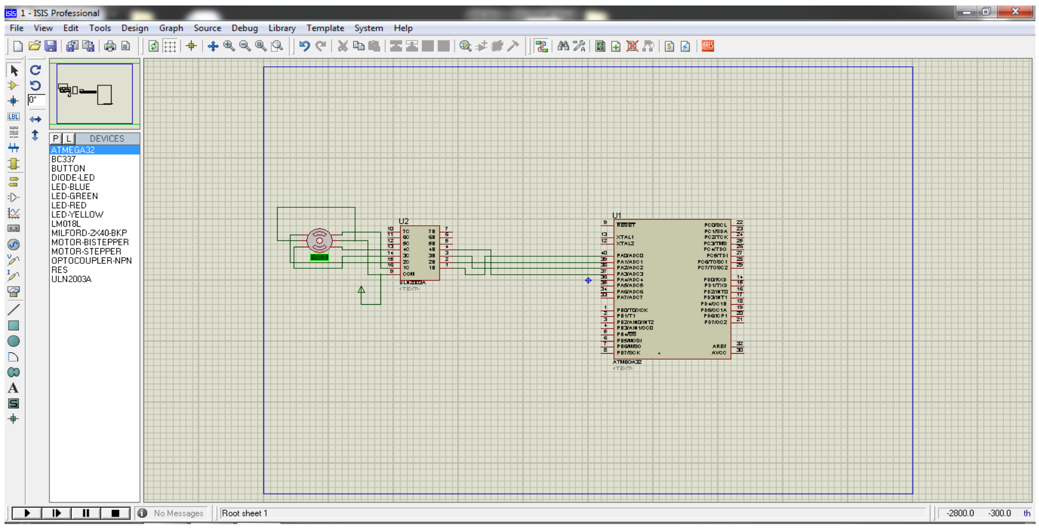

Figure 4.5: stepper motor with atmega32

v. step five:

Choosing the LCD and then connected to the atmega32 as in figure 4.6.

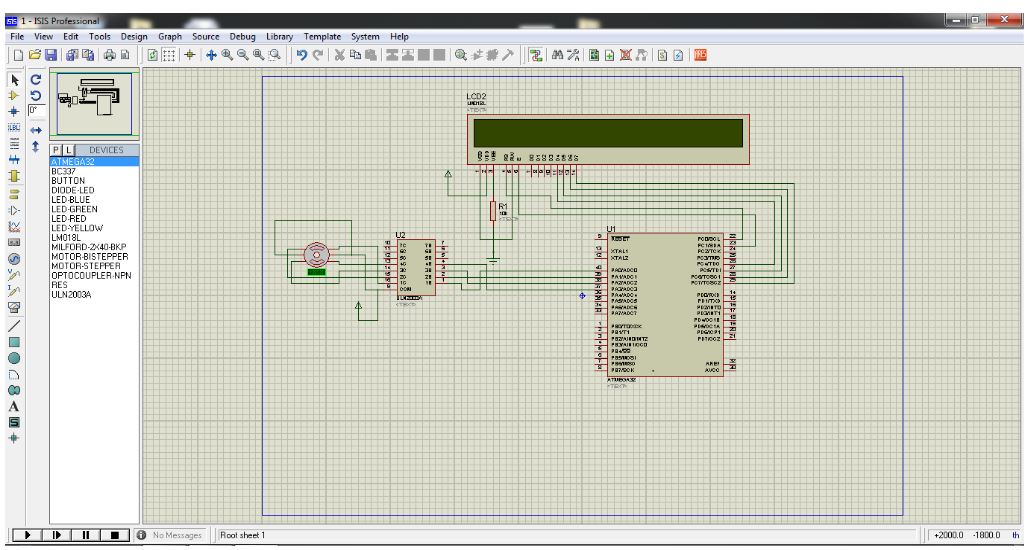

Figure 4.6: LCD with atmega32

vi. step six:

Choosing the LEDs and then connected to the atmega32 as in figure 4.7.

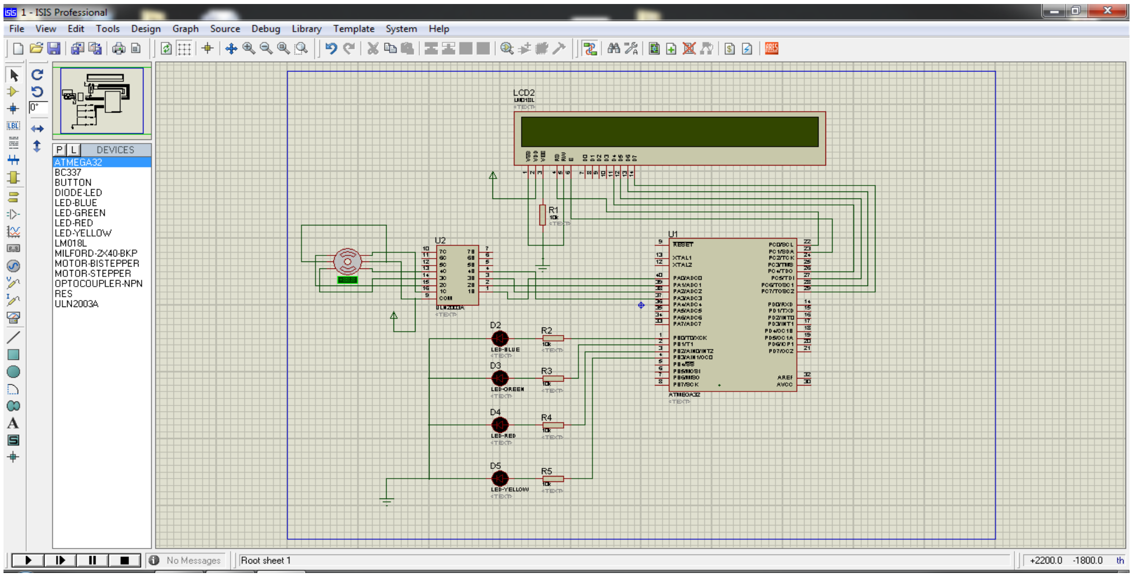

Figure4.7: LEDs with atmega32

vii. step seven:

Choosing the sensor circuit and then connected to the atmega32 as in figure 4.8.

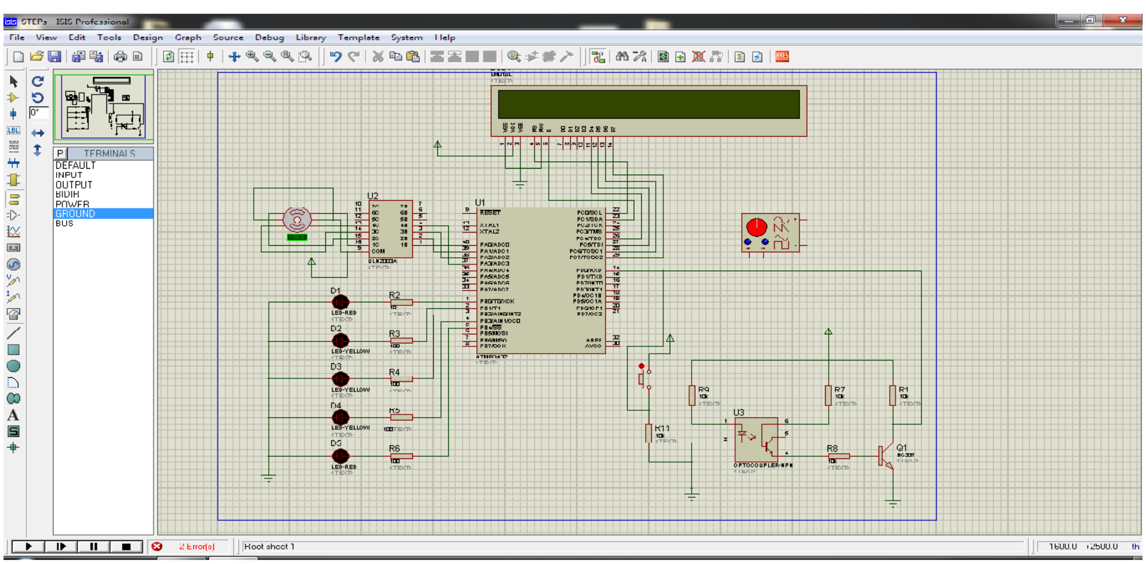

Figure 4.8: the main circuit design

4.2 Hardware considerations

4.2.1 System Implementation

In the final part of the thesis, implementation of control system is developed using stepper motor and microcontroller atmega32 in many steps.

*Step one:

Programming the atmega32 and connecting it's input and output port as shown in figure 4.9.

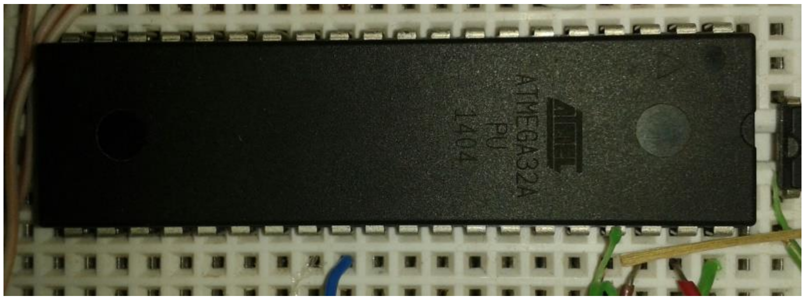

Figure 4.9: connecting atmega32 on port

*Step two:

Connecting the optical sensor as shown in figure 4.10.

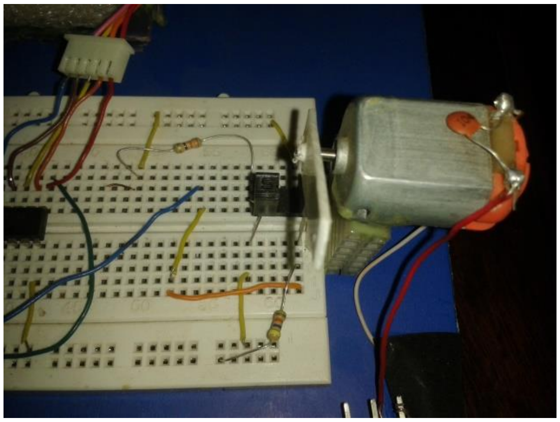

Figure4.10: connecting the optical sensor

*Step three:

Connecting the unipolar stepper motor as shown in figure 4.11.

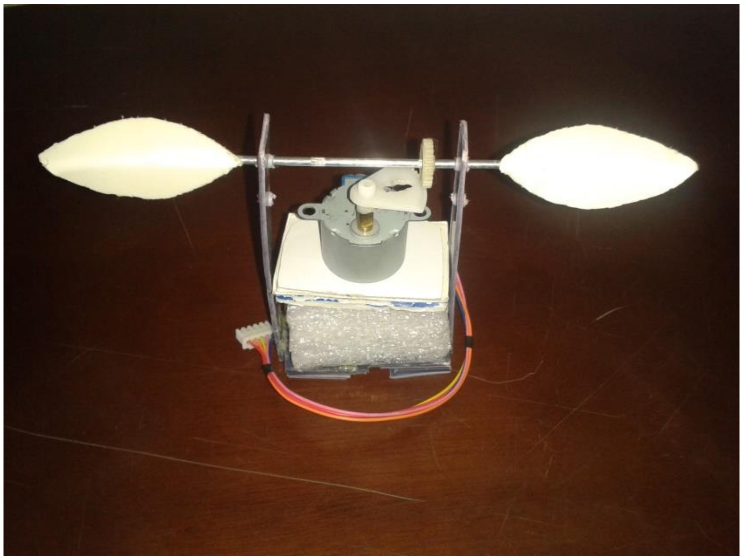

Figure4.11: connecting the unipolar stepper motor with blades.

*Step four:

Connecting the LCD to the circuit as shown in figure 4.12

Figure 4.12: connecting the LCD

*Step five:

Then it is the main circuit.

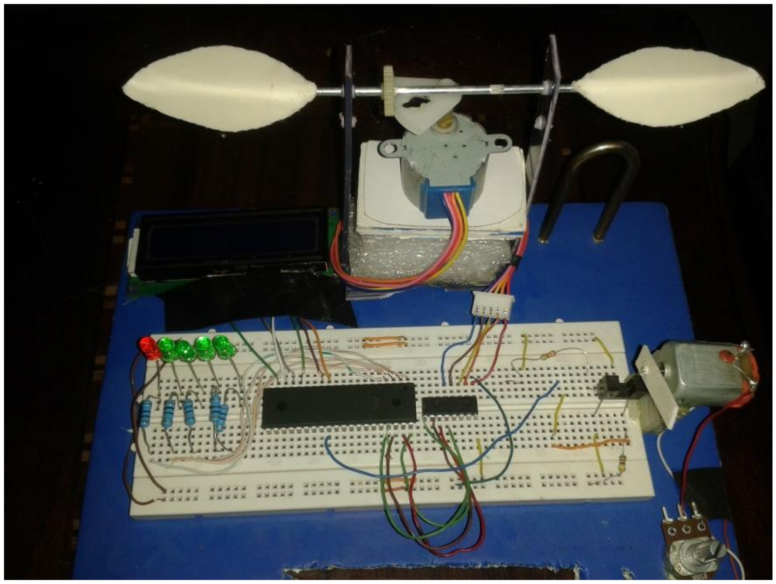

Figure 4.13: The circuit of control system.

4.2.2 System Testing

The circuit is connecting in the simulation program, and implementation as shown in figure 4.13. The result of simulation is taken as shown in figure 4.14.

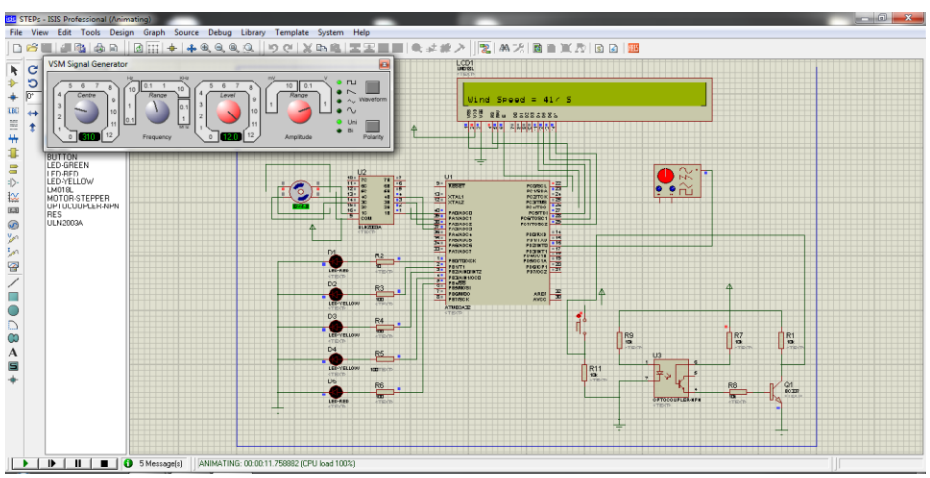

Figure 4.14: the simulation result

The table 4.1 represents the result obtained during system running.

Table 4.1: the result

Speed	position	Remark
24	1	v < 50
54	2	50<v<100
109	3	100<v<150
255	4	v>150

The figure 4.14 shows the circuit simulation during system running.

When the optical sensor measure the speed of the wind and send it to microcontroller, the microcontrollers move the stepper motor in the right position. The result obtained in table 5.1 represents the position taken according to the speed of the wind.

*when speed is 24 m/s, the blade will take position one.

*when speed is 54 m/s, the blade will take position two.

*when speed is 109 m/s, the blade will take position three.

*when speed is 255 m/s, the blade will take position four.

Chapter Five

Conclusion and Recommendations

5.1 Conclusions

The system is well designed and implemented using microcontroller with low cost and easy implementation using Bascom language. The microcontroller used in this study is Atmega32 due to its capability of controlling stepper motor with very precise resolution. The optical sensor used as speed sensor. The position of the blade is taken with high accuracy. Controlling the blade angle enhances turbine efficiency for high power generation.

5.2 Recommendations

- Steps can be subdivided for more accuracy.
- The anemometer sensor can be used instead of optical sensor to enter the speed of the wind throw it.
- Stepper motor can be controlled using the Fuzzy logic controller, as well as the PID controller to obtain better performance.
- Bipolar stepper motor can be used instead of unipolar stepper motor.

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