ANALYSIS AND FABRICATION OF BRAKING SYSTEM FOR SMALL WIND TURBINE

Project Report

Submitted by

A.DIVYA - 71205105009
V.SARANYA - 71205105041
SUGANYA SRINIVASAN - 71205105049

In partial fulfillment for the award of the degree

of

Bachelor of Engineering
in
Electrical and Electronics Engineering

DEPARTMENT OF ELECTRICAL &ELECTRONICS ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE – 641 006

ANNA UNIVERSITY: CHENNAI 600 025
APRIL 2009

BONAFIDE CERTIFICATE

Certified that this project report entitled "**Analysis and Fabrication of Braking system for small wind turbine**" is the bonafide work done by

	Register No
Ms. A.DIVYA	**71205105009**
Ms. V.SARANYA	**71205105041**
Ms. SUGANYA SRINIVASAN	**71205105049**

Who carried out the project work under my supervision.

Signature of the Head of the Department
(Prof.K.Regupathy Subramanian)

Signature of the guide
(Mr.S.Titus)

Certified that the candidates with university Register No: 71205105009, 71205105041, 71205105049 were examined in project Viva – voce examination held on 24/4/09

Internal Examiner

External Examiner

DEPARTMENT OF ELECTRICAL &ELECTRONICS ENGINEERING

KUMARAGURU COLLEGE OR TECHNOLOGY

COIMBATORE – 641 006

ABSTRACT

It is well known that the development of renewable energy sources is strongly encouraged now-a-days due to fast depletion of traditional energy sources and the environmental pollution caused by them. The wind power generating system is one of the most useful generating systems, which harnesses the natural energy. In a wind turbine, if the wind velocity is so high, there is a possibility of runaway of blades. In order to avoid such situations, a suitable braking system has to be designed. The various types of braking commonly used are Dynamic Braking, Regenerative Braking and Hydraulic Braking. The common problem faced in dynamic braking is that more heat is dissipated as more number of resistive elements is involved in the circuit and hence the field coils are damaged. On the other hand by making use of Regenerative Braking, there is a possibility that the blades will be blended and the circuit is more complex when compared with the previous method as it makes use of feedback circuit and the cost is very high. Hydraulic Braking is mainly used in large wind turbines and requires routine maintenance. In order to overcome the above problems a suitable braking system has to be designed. Therefore in this project, a suitable braking system called as Electromagnetic Braking System (EBS) has been designed and fabricated. The Electromagnetic Braking System is placed over the shaft with a small air gap. Whenever the generator exceeds the rated speed the coil will get energized and it affects the turbine speed to get reduce. This process deals with two methods. The first method is open loop system and the second method is closed loop system. The second method is found to be more reliable for the effective operation of Braking system.

ACKNOWLEDGEMENT

The satisfaction and Euphoria that accompanies the successful completion of any tasks would be incomplete without acknowledging the people who were responsible for the completion of the project.

We express our deepest gratitude to our guide **Mr.S.Titus**, Senior Lecturer, Electrical and Electronics Engineering Department who has motivated to do this project and gave us valuable technical guidance, timely suggestions and providing us the necessary facilities which went along way towards successful completion of this project.

We express our gratitude to **Tamilnadu State council for Science and Technology** for providing financial assistance which helped us to complete the project successfully.

We are grateful to our **Teaching and Non Teaching Staffs** of Electrical and Electronics Engineering department for their kind assistance and support.

Last but not least, we extend our heartfelt thanks to our lovable **Parents and Friends** without whom this project would have been virtually impossible.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER – 1
INTRODUCTION

1.1 Introduction:

It is well known that the development of renewable energy sources is strongly encouraged now-a-days due to fast depletion of traditional energy sources and the environmental pollution caused by them. The wind power generating system is one of the most useful generating systems, which harnesses the natural energy. In a wind turbine, if the wind velocity is so high, there is a possibility of runaway of blades, as the blades gets blown away the neighboring materials and human beings are subjected to disaster. In order to avoid such situations, a suitable braking system has to be designed. Therefore the wind velocities were taken for a period of one year and accordingly a system is designed satisfying the aerodynamic principles.

1.2 Objective:

Design and fabrication of braking system for low power wind turbine system.

CHAPTER 2

OVERVIEW OF WINDTURRINE SYSTEM

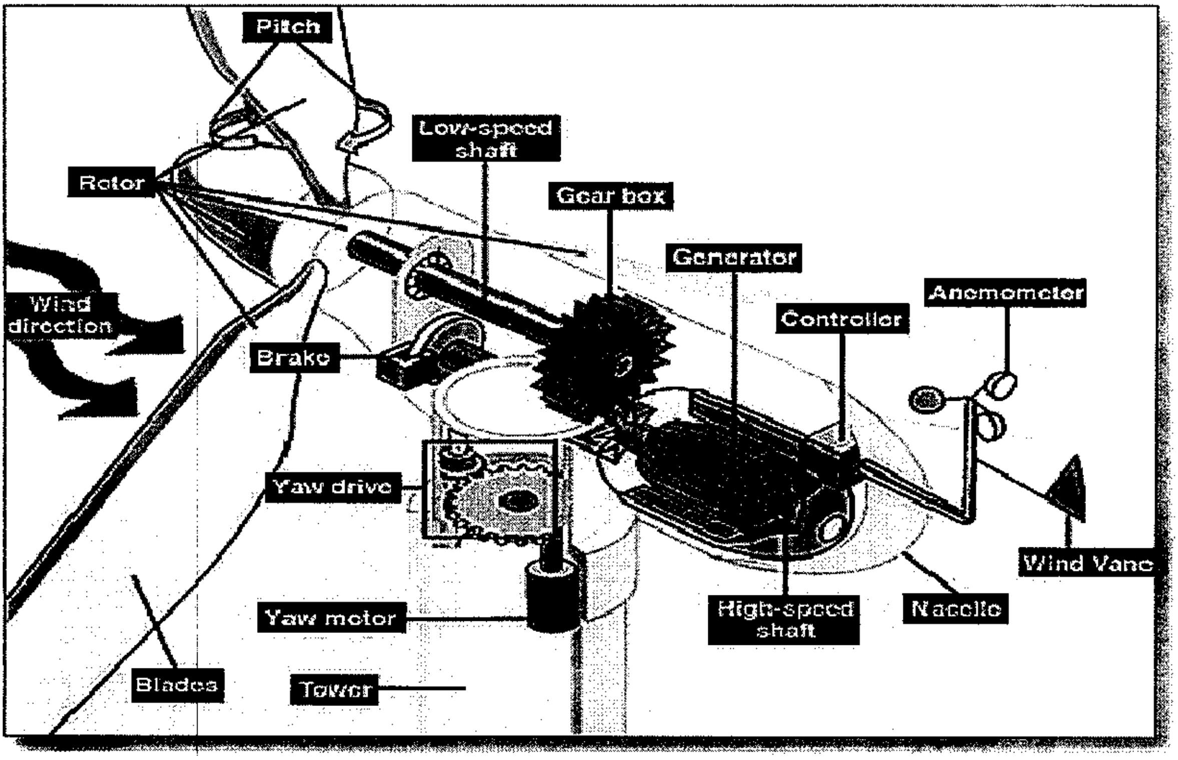


Figure 2.1 An overview of wind turbine

2.1 Introduction:

Wind technologies have been developing rapidly over the last few decades, as it is renewable, cost-effective and among the different renewable energy sources, wind energy is currently making a significant contribution to the installed capacity of power generation, and is emerging as a competitive option.

Wind power is the conversion of wind energy into a useful form, such as electricity, using wind turbine. At the end of 2008, worldwide nameplate capacity of wind-powered generators was 120.8 gigawatts. Although wind produces only about 1.5% of worldwide electricity use, it is growing rapidly, having doubled in the three years between 2005 and 2008. In several countries it has achieved relatively high levels of penetration, accounting for approximately 19% of electricity production in Denmark, 10% in Spain and Portugal, and 7% in Germany and the Republic of Ireland in 2008.

Wind energy has historically been used directly to propel sailing ships or converted into mechanical energy for pumping water or grinding grain, but the principal application of wind power today is the generation of electricity. Wind power, along with solar power, is non-dispatchable, meaning that for economic operation all of the available output must be taken when it is available, and other resources, such as hydroelectricity must be used to match supply with demand.

Large scale wind farms are typically connected to the local electric power transmission network, with smaller turbines being used to provide electricity to isolated locations. Utility companies increasingly buy back surplus electricity produced by small domestic turbines. Wind energy as a power source is favoured by many environmentalists as an alternative to fossil fuels, as it is plentiful, renewable, widely distributed, clean, and produces lower greenhouse gas emissions, although the construction of wind farms is not universally welcomed due to their visual impact and other effects on the environment. The intermittency of wind seldom creates problems when using wind power to supply a low proportion of total demand. Where wind is to be used for a moderate fraction of demand, additional costs for compensation of intermittency are considered to be modest. One study indicates that an entirely renewable energy supply based on 70% wind is attainable at today's power prices by linking wind farms with an HVDC super grid.

The power in the wind

Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air, like a sail or a propeller, can extract part of a energy and convert into use and work. Three factors determine the output from wind energy converter :

1. the wind speed
2. the cross section of wind swept by the rotor and
3. the overall conversion efficiency of the rotor, transmission system and generator or pump.

No device, however well designed , can extract all of the wind's energy because the wind would have to be brought to a halt and this would prevent the passage of more air through the rotor. The most that is possible is for the rotor to decelerate the whole horizontal column of intercepted air to about one – third of its free velocity. A 100% efficient aero generator would therefore only be able to convert up to a maximum of around 60% of the available energy in wind into mechanical energy. Well designed blades will typically extract 70% of the theoretical maximum, but losses incurred in the gear box, transmission system and generator or pump could decrease overall wind turbine efficiency to 35% or less.

We know that power is equal to energy per unit time. The energy available is the kinetic energy of the wind. The kinetic energy of any particle is equal to one half its mass times the square of its velocity, or **½ Mv^2**. The amount of air passing per unit time, through an area A ,with velocity V is A.V, and its mass m is equal to its volume multiplied by its density ρ of air , or

$$m = \rho A V$$

Substituting this value of the mass in the expression for the kinetic energy, we obtain,

$$\textbf{Kinetic energy} = \tfrac{1}{2} \rho A V^3 \textbf{ watts.}$$

This equation tells us the maximum wind available the actual amount will be somewhat less because all the available energy is not extractable - is proportional to the cube of the wind speed. It is thus evident that small increase in wind speed can have a marked effect on the power in the wind.

This equation also tells us that the power available is proportional to air density. Since the area is normally circular of diameter D in horizontal axis aero turbines, then $A = \pi/4\ V^2$ **(m2).**

Therefore, **Wind power** $Pa = 1/2\ \rho\ \pi/4\ D^2 V^3$

This equation tells us that the maximum power available from the wind varies according to the square of the diameter of the intercept area, normally taken to the swept area to the aero turbine. Thus doubling the diameter of the rotor will result in a four-fold increase in the available wind power.

Major factor that have led to the accelerated development of wind power are as follows:

1. Availability of high strength fiber composites for constructing large low cost rotor blades
2. falling prices of power electronics
3. variable speed operation of electrical generators to capture maximum energy
4. improved plant operation, pushing the availability up to 95%.
5. economy of scale, as the turbines and plants are getting larger in size.
6. accumulated field experience improving the capacity factor.

7. short energy payback period of about one year.

Example : To calculate the power in the wind

Power in the wind = 0.5 ρ A V^3

V = 5 metres (m) per second (s)

ρ = 1.0 kg / m^3

A = 0.125 m^2

Power in the wind = 0.5 ρ A V^3

= 0.5 * 1.0 * 0.125 * 5^3

= 7.85 watts

units = (kg/ m^3) * m^2 * (m^3 / s^2)

= N m / s = watt

2.2 Operating characteristics of wind mill:

The wind mills have certain operating characteristics, such as cut-in, rated and cut-out wind speeds.

Cut-in- Speed:

Cut-in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically between 10 and 16 kmph.

Rated Speed:

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. Rated speed for most machines is in the range of 40 to 55 kmph. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases.

Cut-out Speed:

At very high wind speeds, typically between 72 and 128 kmph, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed.

Betz Limit:

It is the flow of air over the blades and through the rotor area that makes the wind turbine to function. The theoretical maximum amount of energy in the wind that can be collected by a wind turbine's rotor is approximately 59%. This value is known as the Betz limit.

2.3 Wind Power Conversion:

The function of a wind turbine is to convert the linear motion of the wind energy into rotational energy that can be used to drive a generator. Wind turbines capture the power from the wind by means of aerodynamically designed blades and convert it into rotating mechanical power. The aerodynamic power, P, of a wind turbine is given by:

$$P = 1/2\ \rho\ \Pi\ R^2\ V^3\ C_p$$

Where ρ is the air density, R is the turbine radius, V is the wind speed and Cp is the turbine power coefficient which represents the power conversion efficiency of a wind turbine. Cp is a function of the tip speed ratio (λ) as well as the blade pitch angle (β) in a pitch controlled wind turbine. λ is defined as the ratio of the tip speed of the turbine blades to wind speed, and given by:

$$\lambda = \frac{R.\omega}{V}$$

Where ω is the rotational speed of the wind turbine. The Betz limit C_p max, (theoretical) = 16/27=0.529 the maximum theoretically possible rotor power Coefficient.

2.4 Generation of electricity from wind turbine:

Wind power is converted into electricity by a wind turbine. In a typical, modern, large-scale wind turbine, the kinetic energy in the wind (the energy of moving air molecules) is converted to rotational motion by the rotor – typically a three-bladed assembly at the front of the wind turbine. The rotor turns a shaft, which transfers the motion into the nacelle (the large housing at the top of a wind turbine tower). Inside the nacelle; the slowly rotating shaft enters a gearbox that greatly increases the rotational shaft speed. The output (high speed) shaft is connected to a generator that converts the rotational movement into electricity at medium voltage (a few hundred volts). The electricity flows down heavy electric inside the tower to a transformer, which increases the voltage of the electric power to the distribution voltage (a few thousand volts). (Higher voltage electricity flows more easily through electric lines, generating less heat and fewer power losses). The distribution-voltage power flows through underground lines to collection point where the power may be combined with other turbines. In many cases, the electricity is sent to nearby farms, residences and towns where it is used. Otherwise, the distribution-voltage power is sent to substation where the voltage is increased drastically to transmission-voltage power (a few hundred thousand volts) and sent through very tall transmission lines many miles to distant cities and factories.

2.5 Types of Wind Turbine:

Horizontal axis

Horizontal Axis Wind Turbines (HAWT) has the main rotor shaft electrical generator at the top of the tower, and must be pointed into the wind. Simple wind vane points small turbines, while large turbines generally use a wind sensor coupled with a servomotor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable for generating electricity. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Turbines blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount. Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in the line with the wind, and because in high winds, the blades can be allowed to leads to fatigue failures and reliability is so important, most HAWT's are upwind machines.

Advantages of horizontal wind turbines

- Blades are to the sides of the turbine's center of the gravity, helping stability.
- Ability to wing warp, which gives the turbine blades the best angle of attack.
- Ability to fold up the rotor blades in a storm, to minimize damage.
- Tall tower allows access to stronger winds, and can be built offshore away from residential areas. Every ten maters up, the wind speed usually increases by 20% and the power output by 34%
- Since the rotor blades are shaped like a pinwheel, the airfoils can withstand greater force

- Self-starting
- Cheaper because of higher production volume.

Disadvantages of horizontal wind turbines

- Poor performance at low altitudes, due to lower wind speed.
- Location is determined by latitude and weather. This can prove a problem in low-lying areas.
- Horizontal wind turbines in urban areas tend to cause a lot of drag that reduce Efficiency in power production.
- Downwind variants suffer from fatigue and structural failure caused by turbulence.

Vertical Axis

Vertical Axis Wind Turbine (or VAWTs) have the main rotor shaft running vertically. The advantages of this arrangement are that the generator and/or gearbox can be placed at the bottom, near the ground, so the tower doesn't need to be pointed into the wind. Drawbacks are usually the pulsating torque produced during each revolution, and the difficulty of mounting vertical axis turbines on towers, meaning they must operate in the slower, more turbulent air flow near the ground, with lower energy extraction efficiency.

Advantages of vertical wind turbines

- Easier to maintain because their generator is located on the ground. This is due to the vertical wind turbines shape. The airfoils or rotor blades are placed on top of a shaft that is connected to a generator, enabling a safe and easy work environment.
- Due to the turbine's large surface area, very little wind is required to turn the rotor blades to generate power. Vertical wind turbines have two subgroups: During and Savonius. Both were invented for the same multipurpose role of generating electricity in a flat open area far inland to create high torque, also creating a high voltage output that can power residential and commercial applications, such as televisions and lighting.
- Vertical wind turbines have a higher airfoil pitch angle, giving improved aerodynamics while decreasing drag at low and high pressures.
- Being near the ground allows the turbine to collect extra from wind that bounces off a forty-five degree slope from the base of the turbine to the ground; when the wind hits the

ground and is directed up the slope, around twenty percent more power is added to the wind turbine.

Disadvantages of vertical wind turbines

- The environmental impact upon migratory bids. The large surface area can easily suck birds and other objects into the wind turbine, due to a vortex effect that can be attributed to the vertical position of the rotor blades.
- There is a height limitation to how big a vertical wind turbine can be built.
- Instability due to its main center of gravity being in the airfoil. Strong support at the base is required.
- Must be located in an area with steady prevailing winds,
- Installing a vertical wind turbine is expensive, because they are not as widely used as horizontal wind turbines.

2.6 Wind energy system:

- A wind energy system transforms the kinetic energy of the wind into mechanical or electrical energy that can be harnessed for practical use.
- Wind turbines extract the kinetic energy of the wind to produce electricity or into mechanical energy that can be harnessed for practical use, using a rotor fitted with aerodynamic blades.

Electric Power Generation

- Electric power generation using non-conventional sources is receiving considerable attention throughout the world due to exhaustion of fossil fuels, and environmental issue. Wind energy, which is the clean energy source and infinite natural resources, is one of the available non-conventional energy sources. Wind Energy is an renewable energy source used in commercial and industrial applications.

Types of power generation

Power generation using wind energy is possible in two ways,

- Constant Speed operation and
- Variable Speed operation using power electronic converters.

Variable Speed Operation

- Variable speed generation for wind generator is attractive because of its characteristic to achieve maximum efficiency at all wind velocities. Therefore, variable speed control of permanent magnet generator which applied vector control is needed. The need of rotor speed sensor in vector control, a new sensor-less control of PMSG based on flux linkage is determined.

2.7 Design Specifications:

1. **System**
   i. Generator Power : 500Watts
   ii. Type : Stand alone system

2. **Performance parameter**
   i. Rated electrical power : 500Watts
   ii. Rated wind speed : 2 m/sec.
   iii. Operating speed range : 2-5 m/sec.
   iv. Cut in wind speed : 1.5 m/sec and below
   v. Cut out wind speed : 10 m/sec and above

3. **Rotor**
   i. Type of Hub : Fixed pitch
   ii. Hub diameter : 214 mm
   iii. Rotor diameter : 784 mm
   iv. Rotor speed at rated
   Wind speed : 300 rpm.

4. Blade

i.	Height	: 285 mm
ii.	Material	: Normal plastic
iii.	Maximum chord	: 93 mm
iv.	Chord length at outer Periphery	: 40 mm
v.	Blade edge	: sharp
vi.	Number of blades	: 6

5. Generator

i.	Type	: PMDC shunt generator
ii.	Rated speed	: 1500 rpm
iii.	Current	: 12 A
iv.	Output	: 500 Watts
v.	Insulation	: Class B

6. Braking System : Electro magnetic Braking

2.8 Wind velocity analysis:

Wind energy systems as other energy systems have to be planned carefully to achieve reliability and low cost. They are by their nature very sensitive to meteorological phenomena because these do not only influence normal operation but can disrupt the service, augment demands or require consideration for environmental reasons. From the system analysis and investigation, the design steps are fixed for low power wind turbine system.

Meteorological information for wind energy use should contain high resolution spatial maps of regional wind climatology's derived by special algorithms. As a prerequisite, models for transforming measured wind data into objective scale representative values must be used, because measured meteorological data are very often representative. Furthermore short term forecasts of wind speed for scheduling and dispatching may be a favorable method to optimize wind energy buying and selling by the wind farm operators. These forecasts have to be highly accurate local forecasts with an uncertainty of less than fifteen percent and should be based on a numerical weather prediction. Basically, for sitting and yield estimation the following data and information must be finding from measuring devices and representative ness of the data. Measurements are time series of wind speed and wind direction, maximum winds or gustiness and lightning frequencies.

Site selection is typically worth the additional time and effort to locate the proper size to maximize energy production and maintain the wind turbine expected life. Site selection may have a significant effect on annual energy production. For the site selection wind velocity should have to analyze in installing area. Before the wind turbine erection in a particular area, we have to measure and record the speed of wind using anemometer. So we first started with analyzing the wind velocity in our area by using PC interfaced recordable anemometer. The velocity of the wind is analyzed and found to be varying with seasons, days and hours.

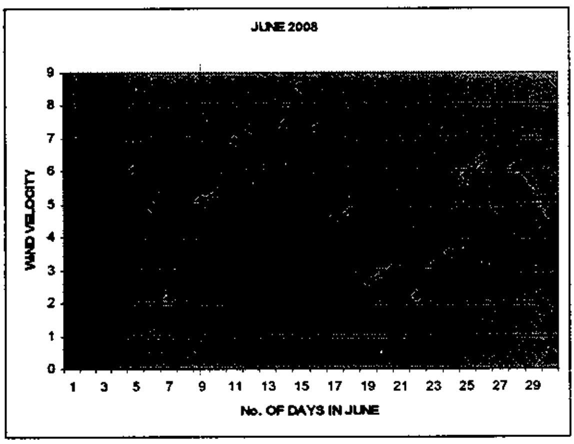


Fig 1

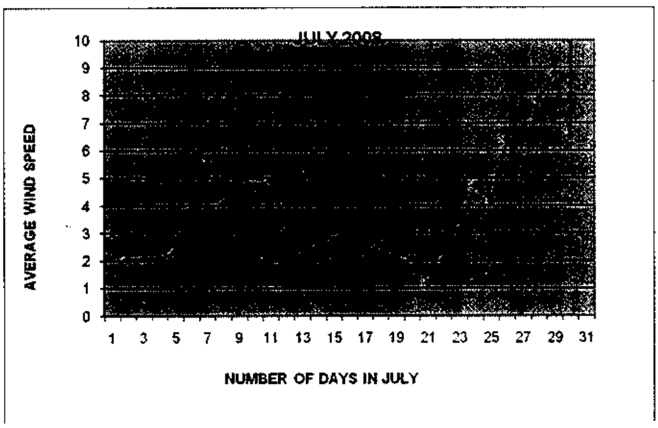
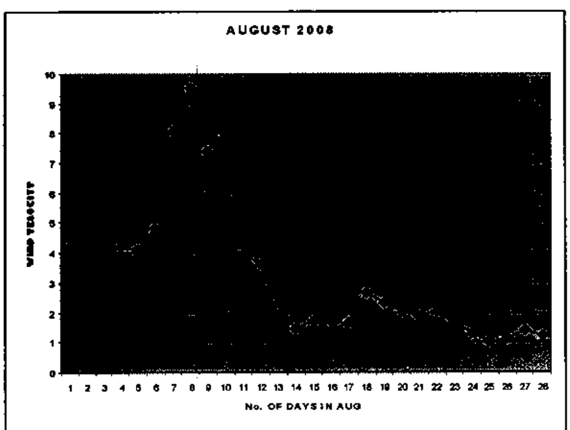
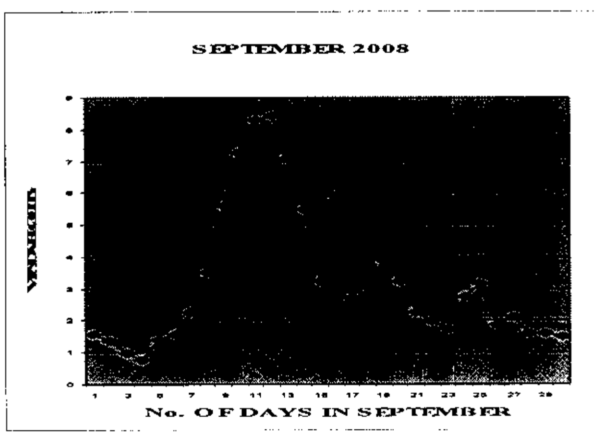


Fig 2





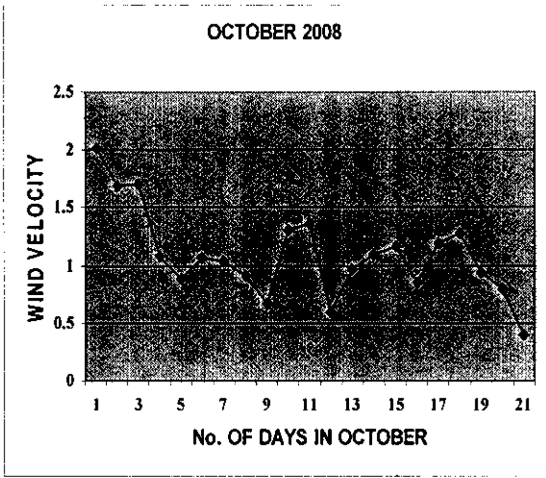


Fig 5

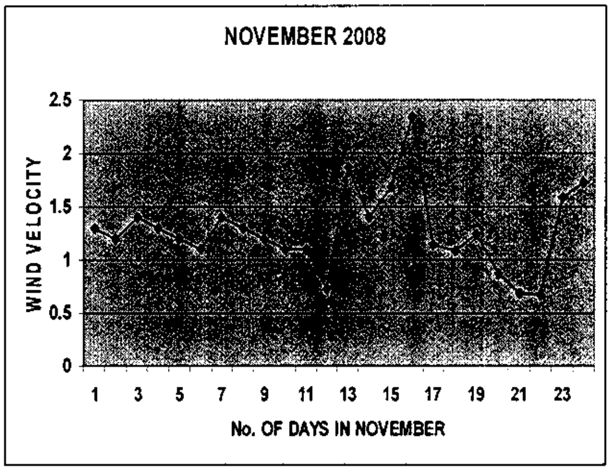


Fig 6

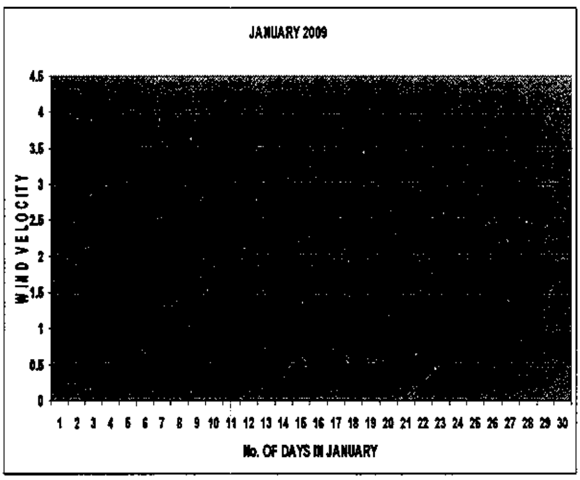


Fig 7

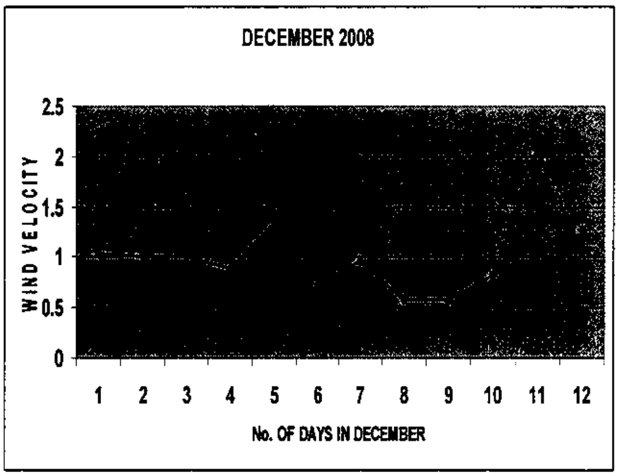
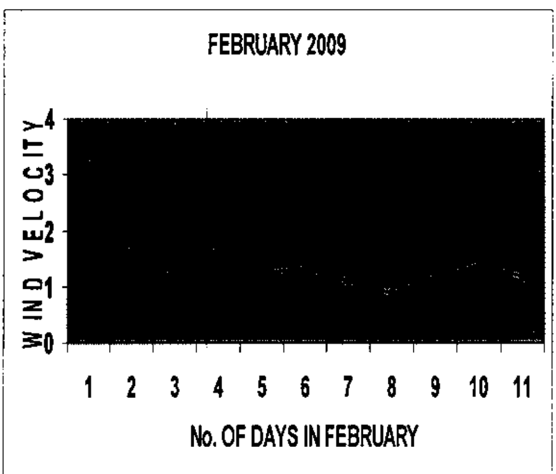
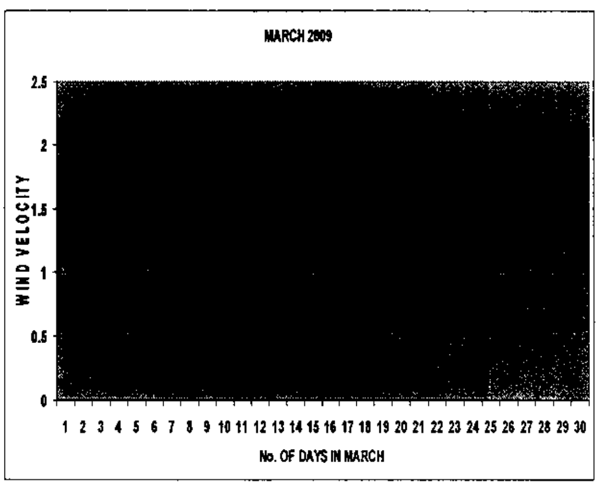


Fig 8





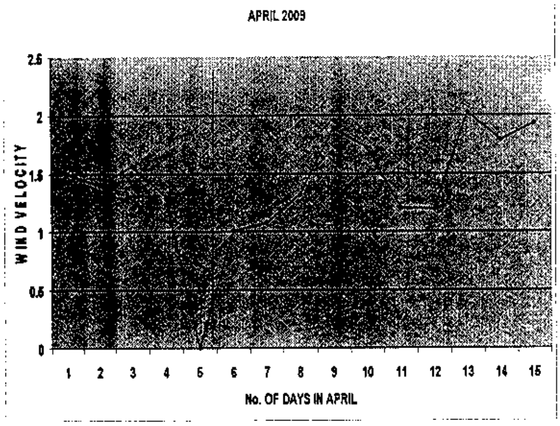


Fig 11

Months	Maximum average wind velocity(m/s)
June 2008	8.5
July 2008	9
August 2008	9.5
September 2008	8.5
October 2008	2
November 2008	2.25
December 2009	2.1
January 2009	4
February 2009	3.5
March 2009	2
April 2009	2

Here the wind velocity is expressed in m/s. The above table shows the average wind velocity for the corresponding months. The wind velocities were found to be maximum from June to august. The average wind velocity is obtained for a period of one year between June 2008 to April 2009.The average wind velocity varies from 2 m/s to 10 m/s.so to overcome this situation and make use of this low wind for throughout year production we planned to design the braking as per the aero dynamics principles.

2.9 Components of wind turbine system:

2.9.1 The Hub:

The blades on all wind turbines are bolted to the hub. wind turbines with Aerostar blades, have a flange joint, where the glass fiber is molded out in a ring with steel bushes for the bolts. The newer wind turbines have threaded bushes glued into the blade root itself. In both cases bolts from the blade pass through a flange on the cast hub. The flange bolt-holes are elongated, enabling the blade tip angle to be adjusted.

The hub is cast in a special type of strong iron alloy, called cast iron. Because of the complicated hub shape which is difficult to make in any other way, it is convenient to use cast iron. In addition the hub must be highly resistant to metal fatigue, and this is difficult to achieve in a welded construction.

2.9.2 Main Shaft:

The main shaft of a wind turbine is usually forged from hardened and tempered steel. Hardening and tempering is a result of forging the axle after it has been heated until it is white-hot at about 1000 degrees centigrade. By hammering or rolling the blank is formed with an integral flange, to which the hub is later bolted. The shaft is reheated a final time to a glowing red, following the forging process, and then plunged into a basin of oil or water. This treatment gives a very hard, but at the same time rather brittle surface. Therefore the axle is once again reheated to about 500 degrees centigrade,tempering the metal and thereby enabling the metal to regain some of its former strength.

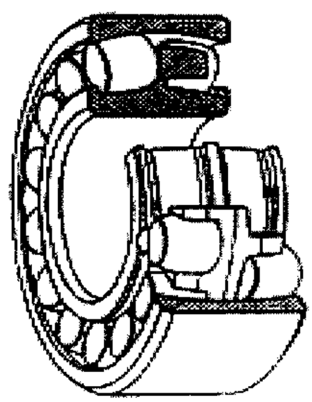


figure 2.2 Main shaft

2.9.3 Main Bearings:

All modern wind turbines have spherical roller bearings as main bearings. The term spherical means that the inside of the bearing's outer ring is shaped like a cross section of a ball. This has the advantage of allowing the bearing's inner and outer ring to be slightly slanted and out-off-track in relation to each other without damaging the bearing while running. The maximum allowable oblique angle is normally 1/2 degree, not so large, but large enough to ensure that any possible small errors in alignment between the wind turbine shaft and the bearing housing will not give excessive edge loads, resulting in possible damage to the bearing. The spherical bearing has two sets of rollers, allowing both absorption of radial loads (across the shaft) from the weight of the rotor, shaft, etc. and the large axial forces (along the shaft) resulting from the wind pressure on the rotor. The main bearings are mounted in the bearing housings bolted to the main frame. The quantity of bearings and bearing seats vary among the different types of wind turbines: Small wind turbines up to and including 150 kW have two bearings, each with its own flanged bearing housing.

2.9.4 The Clamping unit:

By the means of a clamping unit the main shaft of the wind turbine is coupled to the gearbox. The gear has a hollow shaft that fits over the rear end of the main shaft. Torque between the two components is transferred by friction between the two. A clamping unit, normally composed of an inner ring and two outer rings with conical facings, is placed on the outside of the gear's hollow shaft. When the main shaft is placed inside the hollow shaft during the assembly of the wind turbine, the conical facings of the clamping unit are loosely positioned on the hollow shaft. Following control of the correct alignment of the gear and the main shaft, the rings are tightened by the means of a large number of bolts.

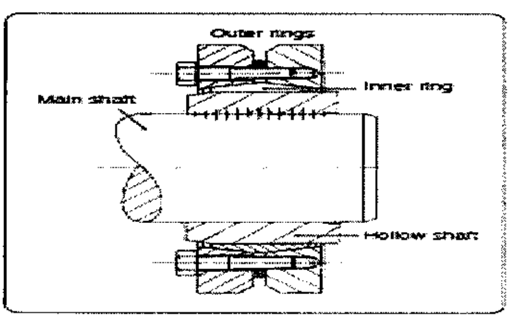


Figure 2.3 Clamping unit

2.9.5 The Coupling:

Figure 2.4 Coupling

The coupling is placed between the gearbox and the generator. Once again it is not possible to consider the coupling as the same as a clutch in a normal car. One cannot engage or disengage the transmission between the gearbox and the generator by pressing a pedal, or in some other such way. The transmission is a permanent union and the expression coupling should be understood as a junction made by a separate machine component. The coupling is always a flexible unit, made from built-in pieces of rubber, normally allowing variations of a few millimeters only. This flexibility allows for some slight differences in alignment between the generator and the gearbox. This can be of importance under assembly and also during running operation, when both gearbox and generator can have tendencies for slight movement in relation to each other.

2.9.6 Braking system:

The Braking System works in the principle of centrifugal action that controls the rotor speed through governors. The rotor can be stopped under abrupt conditions by mechanical braking systems. In modern windmills electrical braking system is used instead of mechanical braking system because frequent use of mechanical braking system creates heat stress in the Generator.

2.9.7 Generator:

The generator is the unit of the wind turbine that transforms mechanical energy into electrical energy. The blades transfer the kinetic energy from the wind into rotational energy in the transmission system, and the generator is the next step in the supply of energy from into electricity. Inside this component, coils of wire are rotated in a magnetic field to produce electricity. Different generator designs produce either alternating current or direct current and they are available from low range of output power rating. The generator's rating or size is dependent on the length of the wind turbines blades because longer blades capture more energy.

The modern wind turbine generator requires a versatile and a reliable control system to perform the following functions:

1. The orientation of the rotor into the wind
2. Start up and cut-in of the equipment
3. Power control of the rotor by varying the pitch of the blades
4. Generator output monitoring – status , data computation and storage
5. Shut down and cut – out owing to malfunction or high winds
6. Protection for the generator, the utility accepting the power and the prime mover
7. Auxiliary and/or emergency power and
8. Maintenance mode

2.9.8 Lift:

Lift is primary due to the physical phenomena known as Bernoulli's law. This physical law states that when the speed of an air flow over a surface is increased the pressure will then drop. This law is counter to what most people experience from walking or cycling in a head wind, where normally one feels that the pressure increases when the wind also increases. This is also true when one sees an air flow blowing directly against a surface, but it is not the case when air is flowing over a surface.

2.9.9 Blade Design:

Wind turbine blades have an airfoil type cross section and a variable pitch. They are slightly twisted from the outer tip to the root to reduce the tendency for the rotor to stall. In a few devices, the blades had a constant chord length, however better performance is obtained with blades that are narrower at the tip than at the root.

A fundamental problem in wind turbine design is to allow for the many forces to which the blades are subjected during normal operation. In addition to vibration stresses resulting from rotation, there are several extraneous forces. There arises from wind turbulence, directional changes in the wind, variations of wind speed with height, wind gusts, gravitational forces, the pressure of the tower etc. The blades must be constructed and attached to the hub in such a manner as to withstand these forces. Consequently, aerodynamic performance is sacrificed to sum extent in the design of a rotor with adequate strength. Although the wind power of a rotor increases with the square of the swept diameter, there is a practical limit to the size. In the first place, the mass of a blade increases rapidly with its dimensions. As a result, the wind power available per unit mass decreases as the dimensions of the rotor are increased; the tip speed ratio tends to decrease correspondingly.

2.9.10 Gearbox:

The Gear box is placed between the main shaft and the Generator. Its function is to increase the slow rotational speed of the rotor blades to the generator rotation speed of 1000 or 1500 rpm. The Gear box has a constant tip speed ratio.

2.9.11 Yaw Control:

For localities with the prevailing wind in one direction, the design of a turbine can be greatly simplified. The rotor can be in a fixed orientation with the swept area perpendicular to the predominant wind direction. Such a machine is said to be yaw fixed. Most wind turbines, however, are yaw active, that is to say, as the wind direction changes, a motor rotates the turbine slowly about the vertical (or yaw) axis so as to face the blades into the wind. The area of the wind stream swept by the wind rotor is then a maximum.

In the small turbines, yaw action is controlled by a tail vane, similar to that in a typical pumping windmill. In larger machines, a servomechanism operated by a wind-direction sensor controls the yaw motor that keeps the turbine properly oriented.

The purpose of the controller is to sense wind speed, wind direction, shafts speeds and torques at one or more points, output power and generator temperature as necessary and appropriate control signals for matching the electrical output to the wind energy input and protect the system from extreme conditions brought upon by strong winds electrical faults, and the like.

2.9.12 Towers:

Four types of supporting towers deserve consideration, these are :

1. the reinforced concrete tower
2. the pole tower
3. the built up shell tube tower
4. the truss tower

Among these, the truss tower is favoured because it is proved and widely adaptable, cost is low, parts are readily available, it is readily transported, and it is potentially stiff. Shell tube towers also have attractive features and may prove to be competitive with truss towers.

The type of the supporting structure and its height is related to cost and the transmission system incorporated. It is designed to withstand the wind load during gusts (even if they occur frequently and for very short periods). Horizontal axis wind turbines are mounted on towers so as to be above the level of turbulence and other ground related effects. The maximum tower height for a small WECS is about 10m, and the maximum height is estimated to be roughly 60 m.

The turbine may be located either un wind or down wind of the tower. In the un wind location (that is the wind encounters the turbine before reaching the tower), the wake of the passing rotor blades causes repeated changes in the wind forces on the tower. As the result, the tower will tend to vibrate and may eventually be damaged. On the other hand if the turbine is downwind from the tower,the tower vibrations are less but the blades are now subjected to severe alternating forces as they pass through the tower wake.

Both unwind and downwind locations have been used in WEC devices. Downwind rotors are generally preferred for the large aerogenerators.Although other forces acting on the blades of these large machines are significant,tower effects are still important and tower design is an essential aspect of the overall system design.

CHAPTER 3
BRAKING SYSTEM

3.1 Introduction:

The Braking System works in the principle of centrifugal action that controls the rotor speed through governors. The rotor can be stopped under abrupt conditions by mechanical braking systems. In modern windmills electrical braking system is used instead of mechanical braking system because frequent use of mechanical braking system creates heat stress in the Generator.

The desirable requirements of a braking system are,

1. The braking system should be simple, robust, quick, and reliable in action.
2. Maintenance needs should be minimum and braking system must be easy for the driver to control and operate.
3. The system should be inexhaustible.
4. The system should not cause damage to other parts of the wind turbine.

3.2 Introduction to magnetic materials

Magnetic materials are those materials in which a state of magnetization can be induced. Such materials when materials when magnetized create a magnetic field in the surrounding space. In a material all the molecules contain electrons which orbit around the nucleus; these orbits are therefore, equivalent to circulating currents and so develop an m.m.f due to an individual orbit, in most molecules, is neutralized by an opposite one. But in magnetic materials such as iron and steel there are a number of unneutralised orbits, such that a resultant axis of m.m.f exists which produces a magnetic dipole. In unmagnetised specimens, because of mutual attraction and repulsion among the dipoles, the molecular m.m.f axes lie along continuous closed paths, and no external magnetic effect can be deleted. In magnetized specimens, the dipoles line up parallel with the exciting m.m.f and when the exiciting m.m.f is removed, a number of dipoles may remain aligned in the direction of the external field and thus exihibit permanent magnetism.

3.3 Definitions related to magnetic materials:

Magnetic force: It is the force exerted by one magnet on another either to attract it or repel it.

Unit pole strength: It is the defined as the strength of that pole which when placed in vacuum at a distance of one metre from a similar and equal pole, repels it with a force of one newton.

Magnetic flux density: It is usually represented by letter B and is defined as the flux or lines of forces passing per unit area through any substance through a plane at right angles to the direction of magnetic flux; it is measured in wb/m^2.

Magnetic field strength: It is defined as the field strength at any point within a magnetic field is the force exerted by a unit north pole at that point.

Relative permeability: It is the ratio of the flux density produced in that material to the flux density produced in the vacuum by the same magnetizing force.

Magnetic potential: The magnetic potential at any point within the magnetic field is measured by the workdone in carrying a unit north pole from infinity to that point against the force of magnetic field.

Intensity of magnetization: It is defined as the pole strength per unit area of the bar or magnetic moment per unit volume of the bar. It is denoted by I

Magnetomotive force: It is that force which drives or tends to drive the flux through the magnetic circuit.

Magnetic reluctance: It is the property of the material which opposes the production of magnetic flux in it.

Magnetic field of induction: A state of a region such that a conductor carrying a current in the region would be subjected to mechanical force and an e.m.f would be induced in an elementary loop rotated with respect to the field in such a manner as to change the flux linkages.

Magnetic ageing: The change in magnetic properties of a material resulting from metallurgical change. This term applies whether the change results from a continued normal or specified accelerated ageing condition.

3.4 Magnetisation:

It has been found that all materials are affected by the presence of a magnetic field, in that they are found experimentally to acquire magnetic moments. The magnitude of this moment per **unit** volume is called the magnetization of the medium and is described by the magnetic dipole moment p_m by

$$M = N\, p_m$$

N is the number of magnetic dipoles per unit volume.

For a magnetic material : $\mathbf{B} = \mu_0(\mathbf{M}+\mathbf{H})$

Consider a solenoid,

Let, l=Length of the solenoid,

A=Area of cross-section of the solenoid,

N=Number of turns, and

I=Current through the solenoid.

If the solenoid is placed in vacuum the flux density will be :

$$B_0 = \mu_0 H$$

(where H = NI/l, H being magnetizing force)

If the vacuum is replaced by a homogeneous magnetic medium the flux density will increase to

$$B = \mu_0\mu_r H$$

Thus, there will be an increase in flux density of

$$B - B_0 = \mu_0 (\mu_r - 1) H = \mu_0 H`$$

Now this increase in flux density can be thought of due to an increase in H by H' rather than due to the change in the medium. If I' is the corresponding increase in current then we have

$$H` = NI`/l = NI`A/ l A$$

The right hand side of eqn represents the total magnetic dipole moment per unit volume and is the magnetization of the medium denoted by the letter M. Hence

$$H` = (\mu_r - 1) H = M$$

Or, $$M/H = \chi = \mu_r - 1$$

Where χ is a dimensionless quantity defined as the magnetic susceptibility of the medium. Under this condition

$$B = B_0 + \mu_0 H = \mu_0 (1 + \chi) H$$

$$= \mu_0 (1 + M/H) H$$

i.e., $$B = \mu_0 (M + H)$$

3.5 Classification of Magnetic Materials:

All materials possess magnetic properties to a greater or lesser degree and these are determined by the facts that

(i) a magnetic field exerts forces and torques on the bodies,

(ii) a body placed in a magnetic field distorts the field. The magnetic properties of the materials are characterized by their relative permeability. In accordance with the value of relative permeability the materials may be classified in the following three ways :

1.Ferromagnetic materials :

The relative permeability of these materials are much greater than unity and are dependent on the field strengths. They attract the lines of forces strongly. The principal ferromagnetic elements are iron, cobalt, nickel. Gadolinium however, also comes under this classification. These have high susceptibility.

2.Paramagnetic materials :

These have relative permeability slightly greater than unity and are magnetized slightly. They attract the lines of forces weakly. Aluminium, platinum and oxygen belong to this category.

3.Diamagnetic materials :

The relative permeability of these materials is slightly less than unity. They repel the lines of force slightly. The examples are bismuth, silver, copper and hydrogen.

FERROMAGNETIC ELEMENTS

1. **Iron :**

    - It has the highest susceptibility comparatively. This property added with low cost makes suitable for commercial purposes.

    - Its magnetic properties are considerably affected by the presence of traces of carbon, oxygen and nitrogen, therefore, these undesirable elements should be reduced to the possible attainable limits. High purity means high permeability and reduced hysteresis loss. Its permeability is to the tune of 2000.

2. **Nickel :**

- It is also one of the important ferromagnetic elements. When it is heated, it remains ferromagnetic upto 395 c and beyond that it gets converted to paramagnetic.

- Its properties as ferromagnetic material are considerably improved when alloyed with iron and cobalt.

3. **Cobalt :**

- Its permeability is 250 and increases with the temperature upto 300 C. it loses its magnetic properties at about 1130 C.

- When in pure state it does not prove to be an important ferromagnetic material.

- Its cost is adequately high.

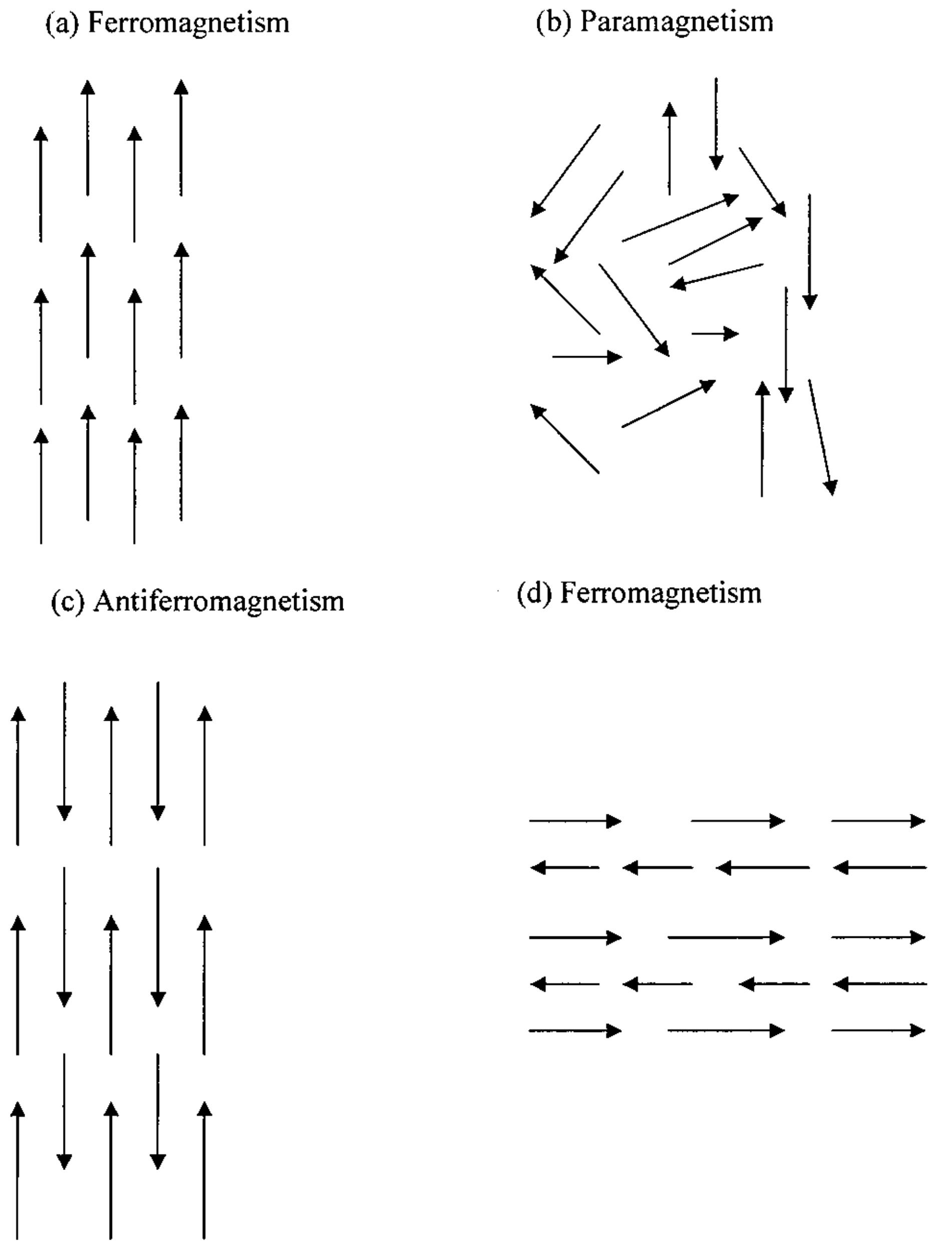


Figure 3.1 Types of magnetism

3.6 Types of tests:

The study of magnetic measurements has been divided into three categories :

1. **D.C. tests : These tests are often termed as " ballistic tests".**

    - These are used for determination of B.H curves and hysteresis loops of ferromagnetic materials.
    - These tests provide an adjustable m.m.f on the magnetic circuits and a ballistic galvanometer or flux meter for measurement of flux density.

2. **A.C. tests : These tests may be carried at power, audio or radio frequencies.**

    - A.C tests are used to determine iron ;losses or core losses in strip material when it is subjected to alternating field.
    - These loses can be separated into hysteresis losses and eddy current losses by a separate method involving variation of frequency and form factor.

3. **Steady state tests: These are used to measure the steady state value of flux in the airgap of magnetic circuit.**

    - The above tests are normally carried out on ring specimens of the ferromagnetic materials although bar specimens are easier to construct. However , some difficulties and accuracies arise in performing the test on bar specimens; " permeaters" overcome these difficulties and inaccuracies in testing bar specimens of magnetic material.

Measurements of Flux/Flux Density:

- The ring specimen is wound with a magnetizing winding which carries a current I.
- A search coil (known as "B coil") of convenient number of turns is wound on the specimen and connected through a resistance and calibrating coil, to a ballistic galvanometer as shown.

- The current through the magnetizing coil is reversed and therefore the flux linkages of the search coil change inducing an e.m.f, e in it. This e.m.f. sends a current through the ballistic galvanometer causing it to deflect.

Let, ϕ = Flux linking with search coil,

R = Resistance of the ballistic galvanometer circuit,

N = Number of turns in the search coil, and

t = Time taken to reverse the flux.

Therefore, Average e.m.f. induced in the search coil,

$$\mathbf{e = N.\, d\phi/dt = 2N\phi/t}$$

3.7 Correction of air gap flux:

In the above calculations have assumed that the flux is uniform throughout the specimen,and that the effective area of cross-section of the search coil is equal to the cross-sectional area of the specimen. However, usually the area of the search coil is larger than that of the specimen and thus the flux linking with the search coil is the sum of the flux existing in the specimen and the flux which is present in the air space between the specimen and the search coil.

Therefore, The value of the flux observed = True value of flux in the specimens + flux in the air space between specimen and search coil

Or,
$$\mathbf{B`A_{sp} = B\, A_{sp} + \mu_0 H\, (A_{sc} - A_{sp})}$$

Therefore, True value of flux density,

$$\mathbf{B = B` - \mu 0H\, ((A_{sc} / A_{sp}) - 1)}$$

Where, B' = Observed or apparent value of flux densit, Wb/m^2

B = True value of flux density in specimen, Wb/m^2

A_{sp} = Cross-sectional area of specimen, m^2 and

A_{sc} = Cross-sectional area of search coil, m^2.

Consider a solenoid 50cm long and 2.2 cm in diameter is uniformly wound with 500 turns of insulated wire.

(i) Finding the magnetic field strength at the centre of the solenoid when carrying a current of 1.8 amperes.

(ii) If a secondary coil is wound round the central part of the solenoid, calculate the flux passing through it.

Solution:

Given : $l = 50$ cm ; $d = 2.2$cm

$N = 500$; $I = 1.8$ A

(i) Magnetic field strength at the centre, H:

$$H = NI / l = (500 \times 1.8)/0.5$$

$$\mathbf{H = 1800\ AT/m} \text{ (Ans.)}$$

(ii) Flux passing through the secondary coil, Φ :

$$\Phi = \mu_0 \mu_r HA \text{ (assuming air-cored solenoid i.e., } \mu_r = 1)$$

$$= 4\Pi \times 10^{-7} \times 1\ 1800 \times ((\Pi/4) \times 0.022^2)$$

$$\mathbf{\Phi = 85.98 \times 10^{-8}\ Wb} \text{ (Ans.)}$$

3.8 Testing of Permanent Magnets:

The method of testing permanent magnet depends upon the shape of the magnet which in turn varies greatly according to the purpose for which the magnet is to be used.

Because of the self-demagnetizing force in permanent magnets, it is necessary, in testing such magnets, to measure H by means of coils give the value of the air flux density at the magnet surface at different points, and thus measure H for these points. The flux density B is measured by search coils in the ordinary way.

- In this method of magnet testing, the magnet to be tested is placed with its straight ends inside two magnetizing coils and so that its ends press against two poles pieces, in the air gap between which a thin iron disc, plated with copper is mounted.
- The disc is mounted in ball bearings and clearances between it and the pole pieces are small. It is driven round at constant speed by small motor, and has two small brushes making contact with its spindle and its rim.

Working: When a current flow in the magnetizing windings, flux crosses the gap between the poles pieces and the flux density in the gap will be proportional to that in the magnet. An e.m.f. will be induced in the revolving disc, this e.m.f. being proportional to the gap flux density and being measured by the mille voltmeter V. Thus the voltmeter reading gives a measure of the flux density in the specimen, while H is obtained by the usual formula from the constants of magnetizing coils and from the current in these coils.

Some leakage exists between the two arms of the magnet, but with proper design of apparatus its effect upon the results is small.

3.9 Precautions in Magnetic Testing:

- Where the inductance is measured by means of a stationary test coil surrounding the specimen, the space between the coil and the test specimen should be as small as possible. However, this space cannot be reduced to zero, and for precision work the necessary correction must be made. The test coil area A can be determined by noting the deflection of a ballistic galvanometer when the test coil is placed in a standard solenoid and the current in the solenoid is reversed.
- Before induction measured measurements are made, the specimen should be carefully demagnetized. This is best done by first magnetizing to a value well above the maximum at which measurements will be made; the current is then gradually reduced to zero, being rapidly reversed meanwhile. Alternating current of 25 Hz frequency is convenient where much work is to be done.
- In loss measurements, the temperature of the specimen should be carefully noted, because this affects the eddy current loss. The exciting winding should therefore, the sufficiently large to avoid heating of the specimen. In tests of sheet materials, the strips should not be too narrow, because of the hardening at the edges due to cutting. This effect is negligible with the width of 5 cm. care should be taken that the burrs are removed from the edges and that the only insulation between sheets is the natural scale or oxide. The test specimen should be composed of strips cut from the sheets in both directions.
- The readings of a ballistic galvanometer should be kept at about the same magnitude by varying the resistance in series with it. The observational error is thus kept constant.

3.10 Methods of measurement of air gap flux and field strength:

- Measurement of air gap flux

Some of the suitable methods for the measurement of air gap flux are:

1. Deflection of a pivoted magnetic needle – The classical magnetometer method.
2. The rapid rotation of search coil through 180. – e.g the classical magnetometer method.
3. Continuous rotation of search coil fitted with a commutator to give a D.C. output.
4. Continuous rotation of search coil with slip rings to give an A.C. output.
5. The force on a current carrying conductor in the field.
6. The effect of the field on the magnetization of a small piece of soft iron excited by A.C in a magnetizing field.

- Measurement of field strength
  1. By withdrawal of search coil.
  2. By nuclesr magnetic resonance.
  3. Use of bismuth spiral.
  4. Use of mumetal wires.
  5. Use of hall effect devices.
- By withdrawal of search coil
  1. In this method a search coil is placed in a magnetic field. The terminals of the search coil are connected to a ballistic galvanometer.
  2. This search coil is suddenly withdrawn from the magnetic field, as a consequence the flux linking the search coil changes. This induces an emf in the search coil which causes the galvanometer to deflect. The flux density in the field may be known from the throw of the galvanometer.
- By nuclear magnetic resonance
  1. when a high frequency alternating magnetic field is superimposed on atomic nuclei located in a constant magnetic field is liable to occur at a specific ratio of the constant field strength H to frequency f of the alternating field.
  2. according to laws of quantum mechanics the magnetic moment of say the hydrogen nucleus may be oriented either in the same direction as that of the external magnetic field or in a opposition to it.

3. the orientation of the proton magnetic moment can be changed by application of an energy quantum hf, where h is planck's constant and f is the frequency. The difference between these two energy states of the proton amounts to $2m_pH$ where m_p is the proton magnetic moment.

$$hf = 2m_pH$$
$$f = 2m_p H / h$$
$$H = 2\pi f / \gamma p$$

The value of γp of a number of substances is known to the nearest thousandth of a percent.

According to this method the magnetic strength of a constant field is determined by measuring the frequency at which nuclear resonance occurs.

- A proton sample, say, an aqueous solution of ferric nitrate contained in a glass ampule is surrounded by a small coil and is inserted in the magnetic field to be measured, the axis of the coil being at right angles to the field.
- The coil and capacitor constitute an oscillatory circuit, which is connected to a high frequency oscillator.
- Resonance is detected by a sharp change in the amplitude of the resonance curve traced on the screen of CRO at a change in the oscillator frequency. The resonance frequency is measured by means of a frequency meter or wave meter.
- This method is more suitable for the measurement of fields.

Let us consider an example if an iron cored coil and a standard 2.5 ohm resistor are connected in series and the potential difference is measured across each on an A.C potentiometer of coordinate type. The readings are $3.5 \pm j\ 1.1$ V for the coil and $4.6 - j\ 1.8$ V for the resistor. Let us calculate the magnetizing component and loss coefficient of current through the coil.

Current through the coil, $I = 4.6 - j\ 1.8 / 2.5$

$= 1.84 - J\ 0.72$

Voltage across the coil, $v = 3.5 \pm j\ 1.1$

Angle between v and I is = 38.35

Loss component of current, $I_e = I \cos \delta = 1.54$ A

Magnetising component of current, $I_m = I \sin \delta$

The commonly used types of braking system are

1.Rheostatic Braking

2.Regenerative Braking

3.Electromagnetic Braking

3.11 Rheostatic Braking:

In this method, the motor is disconnected from the supply and operated as a generator driven by the momentum, supplying current to the resistance across the motor, thus dissipating away the energy and coming to a quick stop.

During the braking period the motors are driven as a generator owing to the kinetic energy and electrical energy so generated is dissipated in the form of heat in the resistances connected across them.

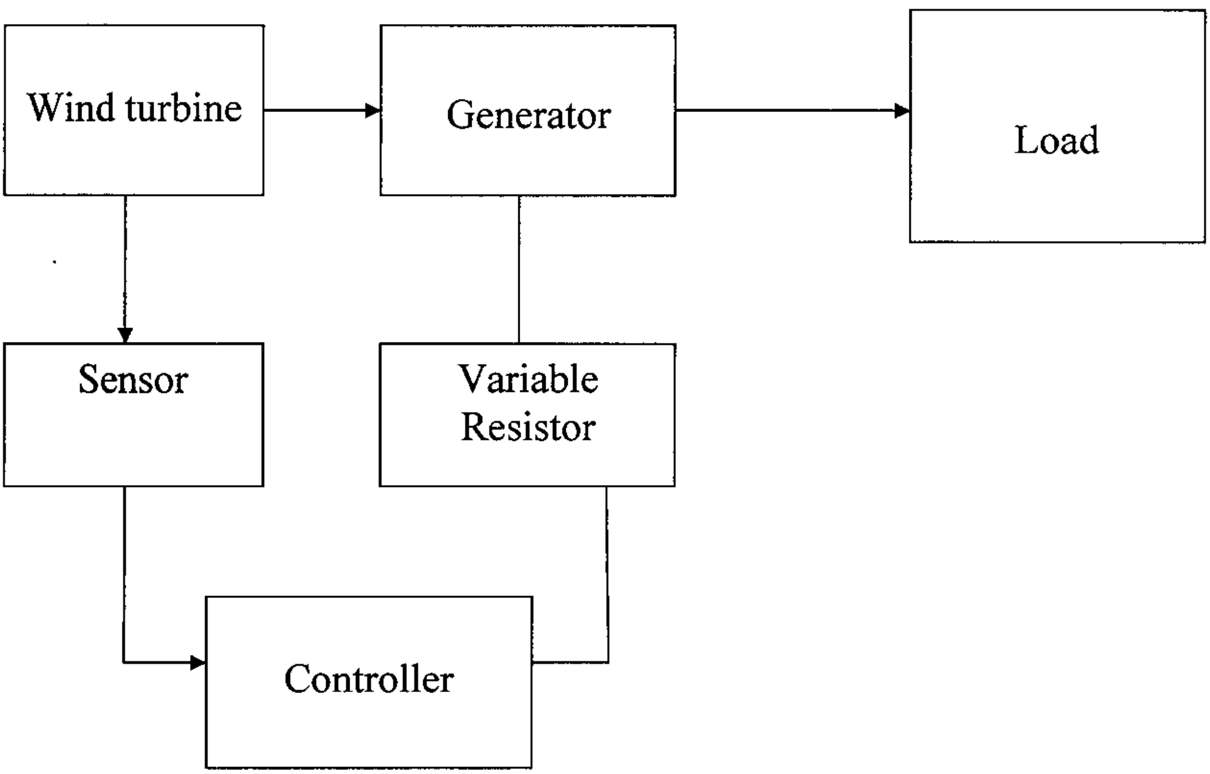


Figure 3.2 Block diagram of rheostatic braking

The block diagram explains the working principle of rheostatic braking, where in the wind turbine blades is coupled with the generator, which in turn is connected to the load, the sensor senses the wind velocity and is fed to the controller. Variable resistors are used to minimize the speed when it exceeds the rated speed. As it involves large numbers of resistive elements are used, which makes the circuit more complex and expensive. As the circuit involves more number of resistive elements, large amount of heat is dissipated and which in turn reduces the effectiveness of the system. And also the stored energy of the rotating parts of the motor and the driven machine is wasted.

3.12 Regenerative Braking:

In Regenerative braking the motors remain connected to the supply and return the braking energy to the supply. For regenerative braking it is essential that traction motors must generate power at a voltage higher than the supply voltage and at a reasonable constant voltage. Regenerative braking is an inherent characteristic of a shunt motor and does not require any change in connection. The main advantage of this type is that with no extra resistance in the rotor circuit the speed during braking remains almost constant and independent of the gradient and the weight of the wind turbine system. The principle involved is, before bringing the motor to rest, the field excitation is increased to the permissible maximum value, as a result of which the speed of the motor is reduced to the minimum value and the kinetic energy released from the motor is fed back to the supply. If the above condition is satisfied, the motor is required to operate with a weak field at rated condition, the armature has to be designed to carry a large current to produce a rated torque and hence motor will be of large size, poor efficiency and costlier. Further there is a possibility that the blades get blended away, the rotor may cause damage due to high voltage and the circuit is more complex.

3.13 Electromagnetic Braking:

Electromagnetic brakes have been used as supplementary retardation equipment in addition to the regular friction brakes on heavy vehicles. Further this method overcomes the problems faced in the other methods and hence provides an effective result compared with the other methods

3.13.1 General Principle of Brake System

The principle of braking in road vehicles involves the conversion of kinetic energy into thermal energy (heat). When stepping on the brakes, the driver commands a stopping force several times as powerful as the force that puts the car in motion and dissipates the associated kinetic energy as heat. Brakes must be able to arrest the speed of a vehicle in short periods of time regardless how fast the speed is. As a result, the brakes are required to have the ability to generating high torque and absorbing energy at extremely high Rates for short periods of time. Brakes may be applied for a prolonged periods of time in some applications such as a heavy vehicle descending a long gradient at high speed. Brakes have to have the mechanism to keep the heat absorption capability for prolonged periods of time.

3.13.2 Block Diagram

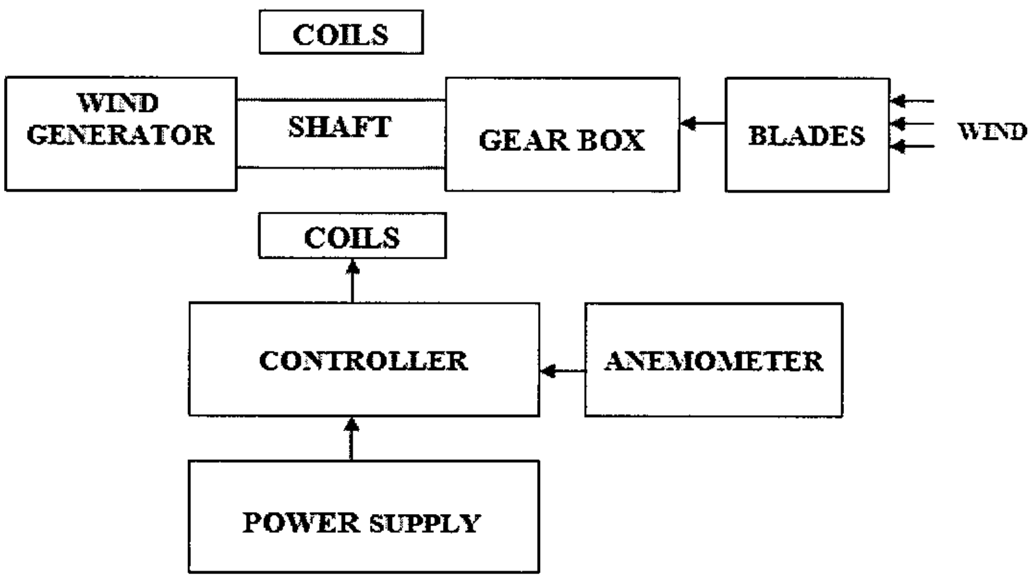


Figure 3.3 Block diagram of electromagnetic braking

Description :

The above block diagram explains the principle of operation of an electromagnetic braking where in the wind generator is connected to the shaft of the blades and magnetic coils are kept around the shaft. The controller unit is used to sense the speed at which the motor rotates, anemometer measures the wind velocity. If it exceeds the rated speed, the coils get magnetized and hence the reduction in speed is noted.

3.13.3 Brake Fading Effect

The conventional friction brake can absorb and convert enormous energy values, but only if the temperature rise of the friction contacts materials is controlled. This high energy conversion therefore demands an appropriate rate of heat dissipation if a reasonable temperature and performance stability are to be maintained. Unfortunately, design, construction, and location features all severely limit the heat dissipation function of the friction brake to short and intermittent periods of application. This could lead to a 'brake fade' problem (reduction of the coefficient of friction, less friction force generated) due to the high temperature caused by heavy brake demands. The main reasons why conventional friction brakes fail to dissipate heat rapidly are as follows:

- Poor ventilation due to encapsulation in the road wheels,
- Diameter restriction due to tire dimensions,
- Width restrictions imposed by the vehicle spring designer;
- Problems of drum distortion at widely varying temperatures.

when subject to heavy braking demands, and at temperatures of this order, a
reduction in the coefficient of friction ('brake fade') suddenly occurs .The potential hazard of tire deterioration and bursts is perhaps also serious due to the close proximity of overheated brake drums to the inner diameter of the tire.

3. 13.4 General Principle

The working principle of the electric retarder is based on the creation of eddy currents within a metal disc rotating between two electromagnets, which sets up a force opposing the rotation of the disc .If the electromagnet is not energized, the rotation of the disc is free and accelerates uniformly under the action of the weight to which its shaft is connected. When the electromagnet is energized, the rotation of the disc is retarded and the energy absorbed appears as heating of the disc. If the current exciting the electromagnet is varied by a rheostat, the braking torque varies in direct proportion to the value of the current. A typical retarder consists of stator and rotor. The stator holds 16 induction coils, energized separately in groups of four.

The coils are made up of varnished aluminum wire mounded in epoxy resin. The stator assembly is 9 supported resiliently through anti-vibration mountings on the chassis frame of the vehicle. The rotor is made up of two discs, which provide the braking force when subject to the electromagnetic influence when the coils are excited.

3.13.5 Characteristics of Electromagnetic Braking :

It was found that electromagnetic brakes can develop a negative power which represents nearly twice the maximum power output of a typical engine,and at least three times the braking power of an exhaust brake .These performance of electromagnetic brakes make them much more competitive candidate for alternative retardation equipments compared with other retarders. By using the electromagnetic brake as supplementary retardation equipment, the friction brakes can be used less frequently, and therefore practically never reach high temperatures. The brake linings would last considerably longer before requiring maintenance, and the potentially "brake fade" problem could be avoided.In research conducted by a truck manufacturer, it was proved that the electromagnetic brake assumed 80 percent of the duty which would otherwise have been demanded of the regular service brake . Furthermore, the electromagnetic brake prevents the dangers that can arise from the prolonged use of brakes beyond their capability to dissipate heat.

The electromagnetic brake is well suited to such conditions since it will independently absorb more than 300 H.p . It therefore can exceed the requirements of continuous uninterrupted braking, leaving the friction brakes cool and ready for emergency braking in total safety. The installation of an electromagnetic brake is not very difficult if there is enough space between the gearbox and the rear axle. It does not need a subsidiary cooling system. It does not rely on the efficiency of engine components for its use, as do exhaust and hydrokinetic brakes. The electromagnetic brake also has better controllability. The exhaust brake is an on/off device and hydrokinetic brakes have very complex control system. The electromagnetic brake control system is an electric switching system which gives it superior controllability. From the foregoing, it is apparent that the electromagnetic brake is an attractive complement to the safe braking of systems.

3.14 Practical Tests:

TEST 1:

Circuit Diagram:

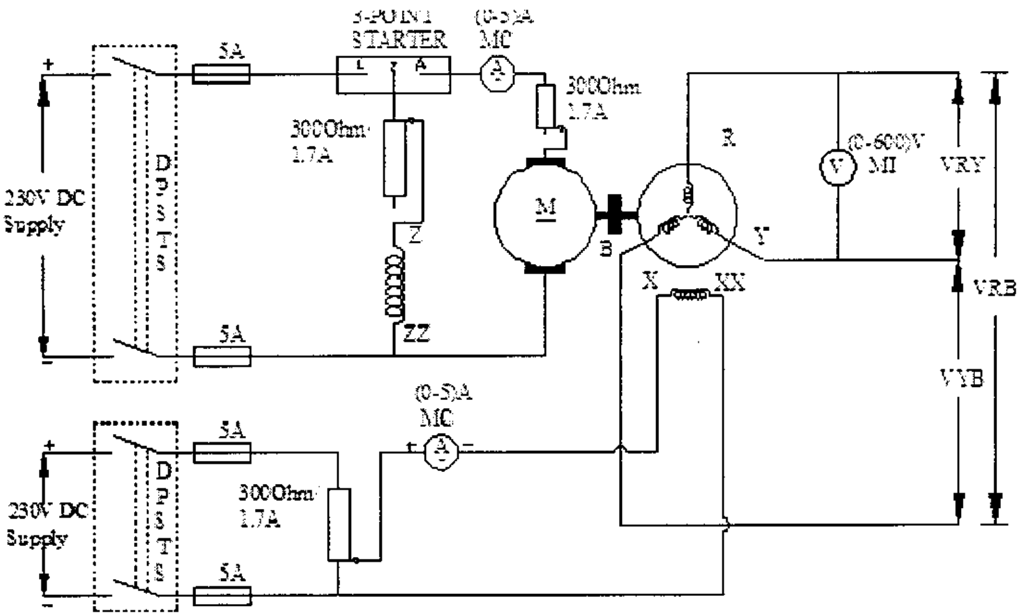


Figure 3.4 Circuit diagram of Electromagnetic braking – Test 1

Name Plate Details:

Motor	Alternator
Voltage: 230 V	Voltage: 400 V
Current: 1.9 A	Current: 4.3 A
Speed: 1500 rpm	Speed: 1500 rpm
Output Power: 0.7 KW	Output Power: 3 KVA
Excitation: 0.7 A	Excitation: 0.75 A

3.15 Test Results:

Table 3.1 – Test 1 :RATED SPEED = 1600 RPM

FIELD CURRENT (amp)	% SPEED REDUCTION	OUTPUT VOLTAGE (V)
0 (Normal condition)	0	14 (Residual voltage)
0.1	0.00125	76
0.2	0.0025	134
0.4	0.005	210
0.6	0.0069	244

Table 3.2 – Test 2: RATED SPEED = 1500 RPM

FIELD CURRENT (amp)	% SPEED REDUCTION	OUTPUT VOLTAGE (v)
0 (Normal condition)	0	16 (Residual voltage)
0.1	0.0013	68
0.2	0.0027	126
0.3	0.00533	170
0.4	0.00733	192
0.5	0.00866	210

TEST 2:

Coupling a DC motor with a Steel coupler

Test Results:

Circuit Diagram:

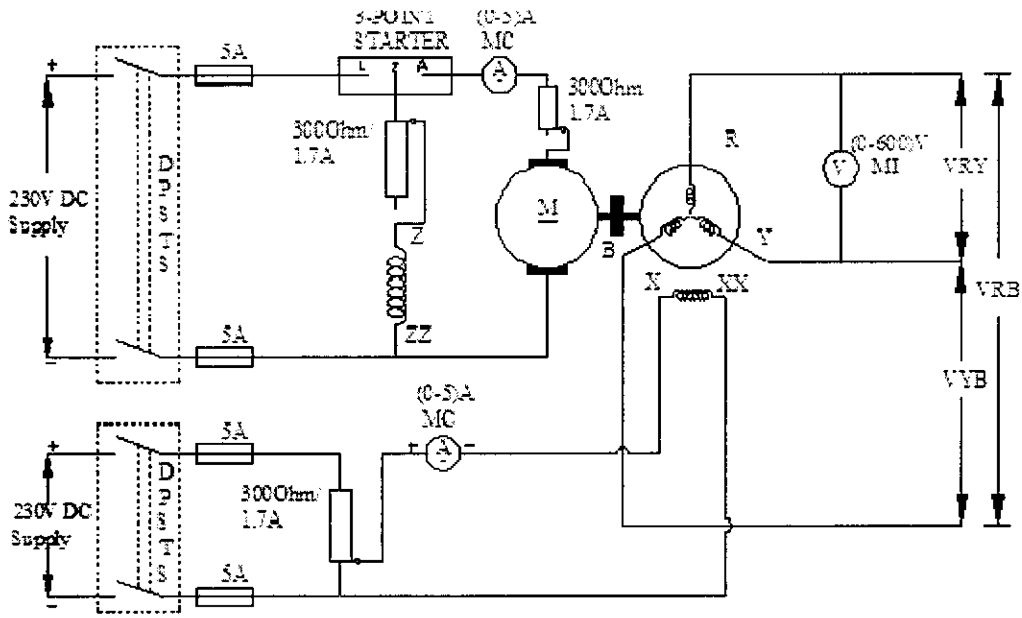


Figure 3.5 Circuit diagram of Electromagnetic braking – Test 2

Table 3.3 –Test 3: Air gap = 20 mm

RATED SPEED (rpm)	% REDUCTION IN SPEED
1000	10
800	11.23
600	12.33
500	13.43
350	14.57
150	73.33

The table 3 shows the readings of electromagnetic braking, the PM dc motor used is coupled with the steel coupler. In this method two rheostats are used, one for varying the field current and the other for the speed. This experiment is carried out keeping the air gap as 20 mm. The rated speed is set and the fixed current is varied from minimum to maximum value and the corresponding reduction in speed is noted down. For example if rated if the rated speed is set as 150 rpm, when the field current is varied from minimum to maximum value, the reduction in speed is upto 40 rpm that is nearly 73.33 % is obtained. The experiment is repeated keeping the rated speed at various values.

3.16 Inferences from the practical analysis:

- Initially the magnetic ability of the motor was tested by applying field to the motor.
- A steel coupling was coupled with the shaft of the motor, A Speed reduction was observed.
- When the field coils of the motor are connected in series, Reduction in speed was between (5 – 10) RPM.
- When the field coils of the motor are connected in parallel, Reduction in speed between (30 – 35) RPM is observed.
- When the field coils are paired up and connected in parallel the speed reduction was between (50 – 100) RPM, it depends on the rated speed of the motor.
- At low rated speeds the motor started to Brake.
- All these inferences are made keeping the Air gap as 20 mm.
- With further reducing the air gap, further more reduction is speed is noted.

Table 3.4 –Test 4: Air gap = 2 mm

VOLTAGE (VOLTS)	SPEED (RPM)
0	710
12	687
15	663
18	633
22	594
28	557
33	541
45	544
49	535
54	492
59	478
62	473
65	451
72	432
76	421
80	406
83	392
87	386
89	368
90	342
92	328
94	316
96	282
98	272
99	264
100	249

The readings in table 4 are obtained by conducting the same experiment but with minimized value of air gap of 2mm. With the minimized air gap, further more reduction in speed is noted down. The table 4 shows the variation in field current and the corresponding speed reduction. By comparing the results obtained in this table with the tables 3.1 to 3.3 , more accurate results are obtained.

CHAPTER 4
CONTROL SYSTEM

4.1 Microcontroller:

Introduction to microcontroller

Microcontrollers are destined to play an increasingly important role in revolutionizing various industries and influencing our day to day life more strongly than one can imagine. Since its emergence in the early 1980's the microcontroller has been recognized as a general purpose building block for intelligent digital systems. It is finding using diverse area, starting from simple children's toys to highly complex spacecraft. Because of its versatility and many advantages, the application domain has spread in all conceivable directions, making it ubiquitous. As a consequence, it has generate a great deal of interest and enthusiasm among students, teachers and practicing engineers, creating an acute education need for imparting the knowledge of microcontroller based system design and development. It identifies the vital features responsible for their tremendous impact, the acute educational need created by them and provides a glimpse of the major application area.

Microcontroller

A microcontroller is a complete microprocessor system built on a single IC. Microcontrollers were developed to meet a need for microprocessors to be put into low cost products. Building a complete microprocessor system on a single chip substantially reduces the cost of building simple products, which use the microprocessor's power to implement their function, because the microprocessor is a natural way to implement many products. This means the idea of using a microprocessor for low cost products comes up often. But the typical 8-bit microprocessor based system, such as one using a Z80 and 8085 is expensive. Both 8085 and Z80 system need some additional circuits to make a microprocessor system. Each part carries costs of money. Even though a product design may require only very simple system, the parts needed to make this system as a low cost product.

To solve this problem microprocessor system is implemented with a single chip microcontroller. This could be called microcomputer, as all the major parts are in the IC. Most frequently they are called microcontroller because they are used they are used to perform control functions.

The microcontroller contains full implementation of a standard MICROPROCESSOR, ROM, RAM, I/0, CLOCK, TIMERS, and also SERIAL PORTS. Microcontroller also called "system on a chip" or "single chip microprocessor system" or "computer on a chip".

A microcontroller is a Computer-On-A-Chip, or, if you prefer, a single-chip computer. Micro suggests that the device is small, and controller tells you that the device' might be used to control objects, processes, or events. Another term to describe a microcontroller is embedded controller, because the microcontroller and its support circuits are often built into, or embedded in, the devices they control.

Today microcontrollers are very commonly used in wide variety of intelligent products. For example most personal computers keyboards and implemented with a microcontroller. It replaces Scanning, Debounce, Matrix Decoding, and Serial transmission circuits. Many low cost products, such as Toys, Electric Drills, Microwave Ovens, VCR and a host of other consumer and industrial products are based on microcontrollers.

4.1.1 Evolution of microcontroller

Markets for microcontrollers can run into millions of units per application. At these volumes of the microcontrollers is a commodity items and must be optimized so that cost is at a minimum. .Semiconductor manufacturers have produced a mind-numbing array of designs that would seem to meet almost any need. Some of the chips listed in this section are no longer regular production, most are current, and a few are best termed as "smoke ware": the dreams of an aggressive marketing department.

4.1.2 Use of Microcontrollers - Today

A microcontroller is a kind of miniature computer that you can find in all kinds of Gizmos. Some examples of common, every-day products that have microcontrollers are built-in. If it has buttons and a digital display, chances are it also has a programmable microcontroller brain.

Every-Day the devices used by ourselves that contain Microcontrollers. Try to make a list and counting how many devices and the events with microcontrollers you use in a typical day. Here are some examples: if your clock radio goes off, and you hit the snooze button a few times in the morning, the first thing you do in your day is interact with a microcontroller. Heating up some food in the microwave oven and making a call on a cell phone also involve operating microcontrollers. That's just the beginning. Here are a few more examples: Turning on the Television with a handheld remote, playing a hand held game, Using a calculator, and Checking your digital wrist watch. All those devices have microcontrollers inside them, that interact with you. Consumer appliances aren't the only things that contain microcontrollers. Robots, machinery, aerospace designs and other high-tech devices are also built with microcontrollers.

4.1.3 Applications

Microcontrollers are designed for use in sophisticated real time applications such as

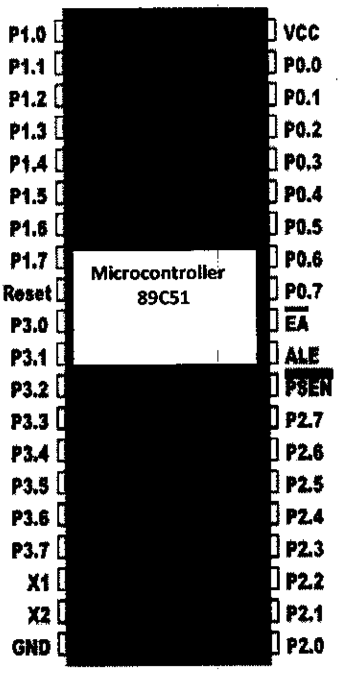
1. Industrial Control
2. Instrumentation and
3. Intelligent computer peripherals

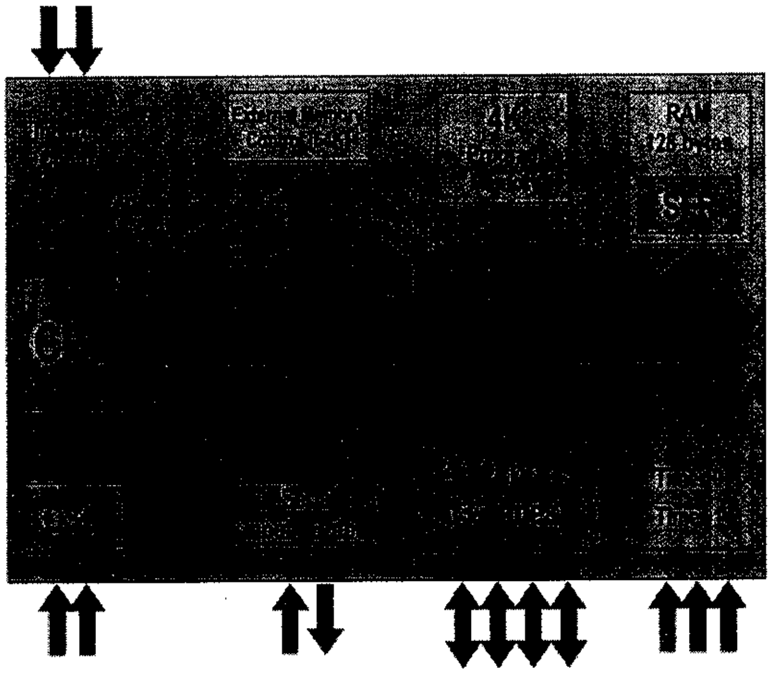
They are used in industrial applications to control

- Motor
- Robotics
- Discrete and continuous process control
- In missile guidance and control
- In medical instrumentation
- Oscilloscopes
- Telecommunication
- Automobiles
- For Scanning a keyboard
- Driving an LCD

- For Frequency measurements
- Period Measurements

4.2 Block Diagram of Microcontroller:





MPLAB

MPLAB IDE is an integrated development environment that provides development engineers with the flexibility to develop and debug firmware for various Microchip devices. MPLAB IDE is a Windows-based Integrated Development Environment for the Microchip Technology Incorporated PICmicrocontroller (MCU) and dsPIC digital signal controller (DSC) families. In the MPLAB IDE, you can:

- Create source code using the built-in editor.
- Assemble, compile and link source code using various language tools. An assembler, linker and librarian come with MPLAB IDE. C compilers are available from Microchip and other third party vendors.

- Debug the executable logic by watching program flow with a simulator, such as MPLAB SIM, or in real time with an emulator, such as MPLAB ICE. Third party emulators that work with MPLAB IDE are also available.
- Make timing measurements.
- View variables in Watch windows.
- Program firmware into devices with programmers such as PICSTART Plus or PRO MATE II.
- Find quick answers to questions from the MPLAB IDE on-line Help.

MPLAB Simulator

MPLAB SIM is a discrete-event simulator for the PIC microcontroller (MCU) families. It is integrated into MPLAB IDE integrated development environment. The MPLAB SIM debugging tool is designed to model operation of Microchip Technology's PIC microcontrollers to assist users in debugging software for these devices.

IC PROG

The PRO MATE II is a Microchip microcontroller device programmer. Through interchangeable programming socket modules, PRO MATE II enables you to quickly and easily program the entire line of Microchip PIC microcontroller devices and many of the Microchip memory parts.PRO MATE II may be used with MPLAB IDE running under supported Windows OS's (see Read me for PRO MATE II.txt for support list), with the command-line controller PROCMD or as a stand-alone programmer.

4.3 TMOD (Timer mode) register:

Both timers 0 and 1 use the same register, called TMOD, to set the various timer operation modes. TMOD is an 8-bit register in which the lower 4 bits are set aside for timer 0 and the upper 4 bits are aside for timer 1. In each case, the lower 2 bits are used to set the timer mode and the upper 2 bits to specify the operation. These options are discussed next.

GATE	C/T	M1	M0	GATE	C/T	M1	M0
TIMER 1				TIMER 2			

Gate: Gating control when set. Timer/Counter is enabled only while the INTx pin is high and the TRx control pin is set. When cleared, the timer is enabled whenever the TRx control bit is set.

C/T: Timer or counter selected cleared for timer operation (input from internal system clock). Set for counter operation (input from Tx input pin).

M1: Mode bit 1
M0: Mode bit 0

M1	**M0**	**Mode**	**Operting Mode**
0	0	0	13-bit timer mode 8-bit timer/counter THx with TLx as 5-bit prescaler
0	1	1	16-bit timer mode 16 bit timer/counters THx and TLx are cascaded ; there is no prescaler
1	0	2	8-bit auto reload 8-bit auto reload timer/counter; THx holds a value which is to be reloaded into TLx each time it overflows.
1	1	3	Split timer mode.

M1, M0:

M0 and M1 select the timer mode. There are three modes: 0,1 and 2. Mode 0 is a 13-bit timer, mode 1 is a 16-bit timer, and mode 2 is an 8-bit timer. We will mainly concentrate on modes 1 and 2 since they are the ones used most widely. We will soon describe the characteristics of these modes, after describing the rest of the TMOD register.

C/T (clock timer):

This bit in the TMOD register is used to decide whether the timer is used as a delay generator or an event counter. If C/T=0, it is used as a timer for time delay generation. The clock source for the time delay is the crystal frequency of the 89C51 . This section is concerned with this choice. The timer's use as a event counter is discussed in the next section.

Clock source for timer:

As we know, every timer needs a clock pulse to tick. If C/T=0, the crystal frequency attached to the 89C51 is the source of the clock for the timer. This means that the size of the crystal frequency attached to the 89C51 also decides the speed at which the 89C51 timer ticks. The frequency for the timer is always $1/12^{th}$ the frequency of the crystal attached to the 89C51.

Gate:

The other bit of the TMOD register is the GATE bit. Notice in the TMOD register that both timers 0 and 1 have the GATE bit. The purpose is that every timer has a means of starting and stopping. Some timers do this by software, some by hardware, and some have both software and hardware controls. The timers in the 89C51 have both. The start and stop of the timer are controlled by the way of software by the TR (timer start) bits TR0 and TR1. This is achieved by the instructions "SETB TR" and "CLR TR1" for timer 1, and "SETB TR0" and CLR TR0" for timer 0. The SETB instruction starts it, and it is stopped by the CLR instruction. These instructions start and stop the timers as long as GATE=0 in the TMOD register. The hardware way of starting and stopping the timer by an external source is achieved by making GATE=1 in the TMOD register. However, to avoid further confusion for now, we will make GATE=0, meaning that no external hardware is needed to start and stop the timers. In using software to start and stop the timer where GATE=0, all we need are the instructions “SETB TRx” and “CLR TRx”.

4.4 Liquid Crystal Display(LCD):

Liquid crystal displays (LCDs) have materials, which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal.

An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.

One each polarizes are pasted outside the two glass panels. These polarizes would rotate the light rays passing through them to a definite angle, in a particular direction. When the LCD is in the off state, light rays are rotated by the two polarizes and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent.

When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarizes, which would result in activating / highlighting the desired characters. The LCD’s are lightweight with only a few millimeters thickness. Since the LCD’s consume less power, they are compatible with low power electronic circuits, and can be powered for long durations.

The LCD does not generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD’s have long life and a wide operating temperature range. Changing the display size or the layout size is relatively simple which makes the LCD’s more customers friendly.

The LCDs used exclusively in watches, calculators and measuring instruments are the simple seven-segment displays, having a limited amount of numeric data. The recent advances in technology have resulted in better legibility, more information displaying capability and a wider temperature range. These have resulted in the LCDs being extensively used in telecommunications and entertainment electronics. The LCDs have even started replacing the cathode ray tubes (CRTs) used for the display of text and graphics, and also in small TV applications.

Crystalonics dot–matrix (alphanumeric) liquid crystal displays are available in TN, STN types, with or without backlight. The use of C-MOS LCD controller and driver ICs result in low power consumption. These modules can be interfaced with a 4-bit or 8-bit microprocessor /Micro controller.

- The built-in controller IC has the following features:
- Correspond to high speed MPU interface (2MHz)
- 80 x 8 bit display RAM (80 Characters max)
- 9,920-bit character generator ROM for a total of 240 character fonts. 208 character fonts (5 x 8 dots) 32 character fonts (5 x 10 dots)
- 64 x 8 bit character generator RAM 8 character generator RAM 8 character fonts (5 x 8 dots) 4 characters fonts (5 x 10 dots)
- Programmable duty cycles
- 1/8 – for one line of 5 x 8 dots with cursor
- 1/11 – for one line of 5 x 10 dots with cursor
- 1/16 – for one line of 5 x 8 dots with cursor
- Wide range of instruction functions display clear, cursor home, display on/off, cursor on/off, display character blink, cursor shift, display shift.
- Automatic reset circuit, which initializes the controller / driver ICs after power on.

4.5 Power supply:

Herewith the operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an ac voltage, a steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level, and finally, regulating to obtain a desired fixed dc voltage. The regulation is usually obtained from an IC voltage regulator unit, which takes a dc voltage and provides a somewhat lower dc voltage, which remains the same even if the input dc voltage varies, or the output load connected to the dc voltage changes.

A block diagram containing the parts of a typical power supply and the voltage at various points in the unit is shown in fig 19.1. The ac voltage, typically 120 V rms, is connected to a transformer, which steps that ac voltage down to the level for the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit can use this dc input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value even if the input dc voltage varies somewhat, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units.

4.5.1 Block diagram

The ac voltage, typically 220V rms, is connected to a transformer, which steps that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation.

A regulator circuit removes the ripples and also remains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units.

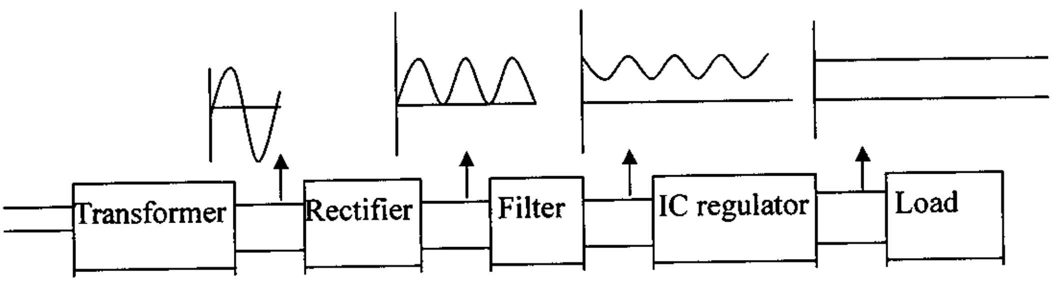


Figure 4.1 Block diagram of Power supply

4.5.2 Working principle

Transformer

The potential transformer will step down the power supply voltage (0-230V) to (0-6V) level. Then the secondary of the potential transformer will be connected to the precision rectifier, which is constructed with the help of op–amp. The advantages of using precision rectifier are it will give peak voltage output as DC, rest of the circuits will give only RMS output.

Bridge rectifier

When four diodes are connected as shown in figure, the circuit is called as bridge rectifier. The input to the circuit is applied to the diagonally opposite corners of the network, and the output is taken from the remaining two corners.

Let us assume that the transformer is working properly and there is a positive potential, at point A and a negative potential at point B. the positive potential at point A will forward bias D3 and reverse bias D4.

The negative potential at point B will forward bias D1 and reverse D2. At this time D3 and D1 are forward biased and will allow current flow to pass through them; D4 and D2 are reverse biased and will block current flow.

The path for current flow is from point B through D1, up through RL, through D3, through the secondary of the transformer back to point B. this path is indicated by the solid arrows. Waveforms (1) and (2) can be observed across D1 and D3.

One-half cycle later the polarity across the secondary of the transformer reverse, forward biasing D2 and D4 and reverse biasing D1 and D3. Current flow will now be from point A through D4, up through RL, through D2, through the secondary of T1, and back to point A. This path is indicated by the broken arrows. Waveforms (3) and (4) can be observed across D2 and D4. The current flow through RL is always in the same direction. In flowing through RL this current develops a voltage corresponding to that shown waveform (5). Since current flows through the load (RL) during both half cycles of the applied voltage, this bridge rectifier is a full-wave rectifier.

One advantage of a bridge rectifier over a conventional full-wave rectifier is that with a given transformer the bridge rectifier produces a voltage output that is nearly twice that of the conventional full-wave circuit.

This may be shown by assigning values to some of the components shown in views A and B. assume that the same transformer is used in both circuits. The peak voltage developed between points X and y is 1000 volts in both circuits. In the conventional full-wave circuit shown—in view A, the peak voltage from the center tap to either X or Y is 500 volts. Since only one diode can conduct at any instant, the maximum voltage that can be rectified at any instant is 500 volts.

The maximum voltage that appears across the load resistor is nearly-but never exceeds-500 vOlts, as result of the small voltage drop across the diode. In the bridge rectifier shown in view B, the maximum voltage that can be rectified is the full secondary voltage, which is 1000 volts. Therefore, the peak output voltage across the load resistor is nearly 1000 volts. With both circuits using the same transformer, the bridge rectifier circuit produces a higher output voltage than the conventional full-wave rectifier circuit.

IC voltage regulators

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustably set voltage. The regulators can be selected for operation with load currents from hundreds of milli amperes to tens of amperes, corresponding to power ratings from milli watts to tens of watts.

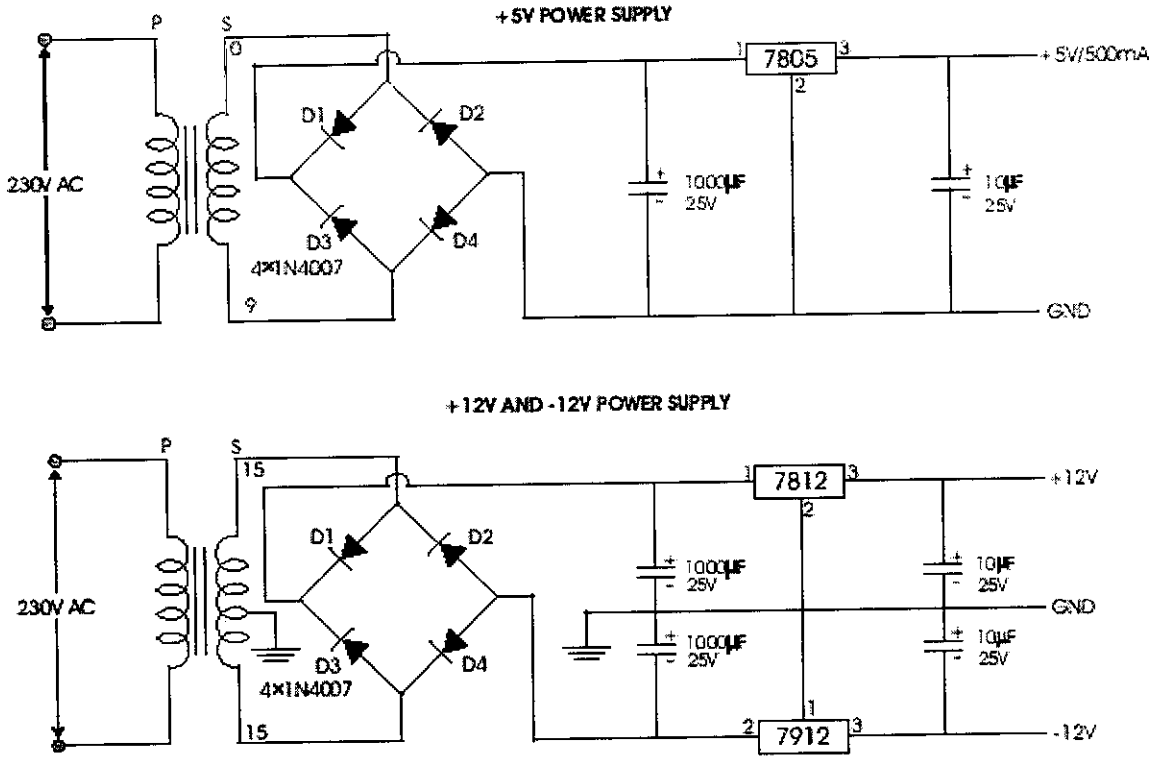


Figure 4.2 Circuit diagram of Power supply

A fixed three-terminal voltage regulator has an unregulated dc input voltage, Vi, applied to one input terminal, a regulated dc output voltage, Vo, from a second terminal, with the third terminal connected to ground.

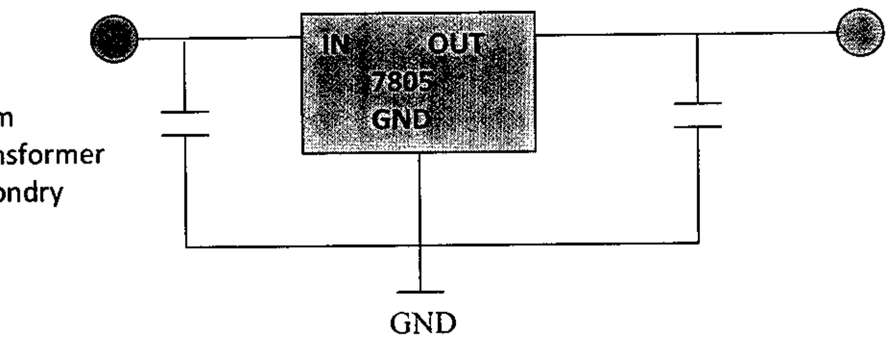
The series 78 regulators provide fixed positive regulated voltages from 5 to 24 volts. Similarly, the series 79 regulators provide fixed negative regulated voltages from 5 to 24 volts.

- For ICs, microcontroller, LCD --------- 5 volts
- For alarm circuit, op-amp, relay circuits ---------- 12 volts

Three terminal voltage regulators:

Fig shows the basic connection of a three-terminal voltage regulator IC to a load. The fixed voltage regulator has an unregulated dc input voltage, Vi, applied to one input terminal, a regulated output dc voltage, Vo, from a second terminal, with the third terminal connected to ground. For a selected regulator, IC device specifications list a voltage range over which the input voltage can vary to maintain a regulated output voltage over a range of load current. The specifications also list the amount of output voltage change resulting from a change in load current (load regulation) or in input voltage (line regulation).

Fixed Positive Voltage Regulators:



The series 78 regulators provide fixed regulated voltages from 5 to 24 V. A 7812, is connected to provide voltage regulation with output from this unit of +12V dc. An unregulated input voltage Vi is filtered by capacitor C1 and connected to the IC's IN terminal. The IC's OUT terminal provides a regulated + 12V which is filtered by capacitor C2 (mostly for any high-frequency noise). The third IC terminal is connected to ground (GND). While the input voltage may vary over some permissible voltage range, and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. These limitations are spelled out in the manufacturer's specification sheets.

4.6 Speed sensor:

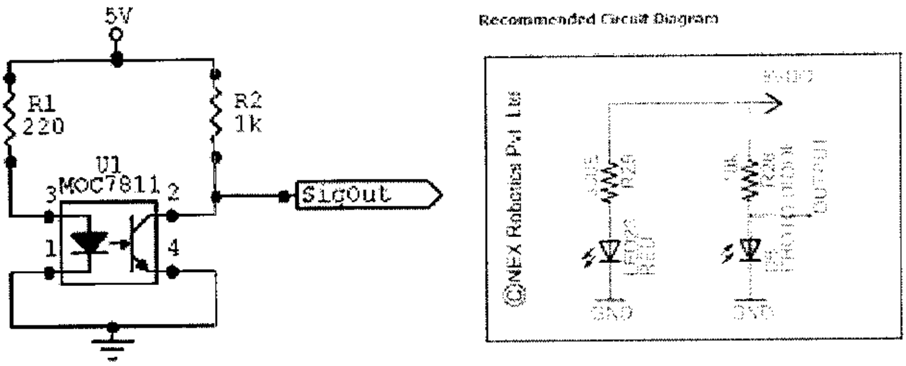


Figure 4.3 circuit diagram of speed sensor

This circuit is designed to monitor the speed of the motor. The holes type pulley is attached in the motor shaft. The pulley is rotated across the USLOT. The USLOT consists of IR transmitter and receiver.

Infrared transmitter is one type of LED which emits infrared rays generally called as IR Transmitter. Similarly IR Receiver is used to receive the IR rays transmitted by the IR transmitter. One important point is both IR transmitter and receiver should be placed straight line to each other.

When supply is ON, the IR transmitter LED is conducting it passes the IR rays to the receiver. The IR receiver is connected to base of the BC 547 switching transistor through resistors. When motor is not rotating the IR transmitter passes the rays to the receiver. The IR receiver LED is conducting due to that less than 0.7V is given to transistor base so that transistor is not conducting. Now the VCC +5V is given to the input of the inverter (IC7404) and zero taken as output. When motor is rotating, the pulley attached in the shaft also rotating, so it interprets the IR rays between transmitter and receiver. Hence IR receiver LED is not conducting due to that more than 0.7V is given to base of the transistor. Now the transistor is conducting so it shorts the collector and emitter terminal. The zero voltage is given to inverter input and +5v is taken in the output. Hence depends on the motor speed the zero to 5v square pulse is generating at the output which is given to microcontroller in order to count the pulse. This pulse rate is equal to the speed of the motor.

4.6.1 Circuit Diagram of Speed Control

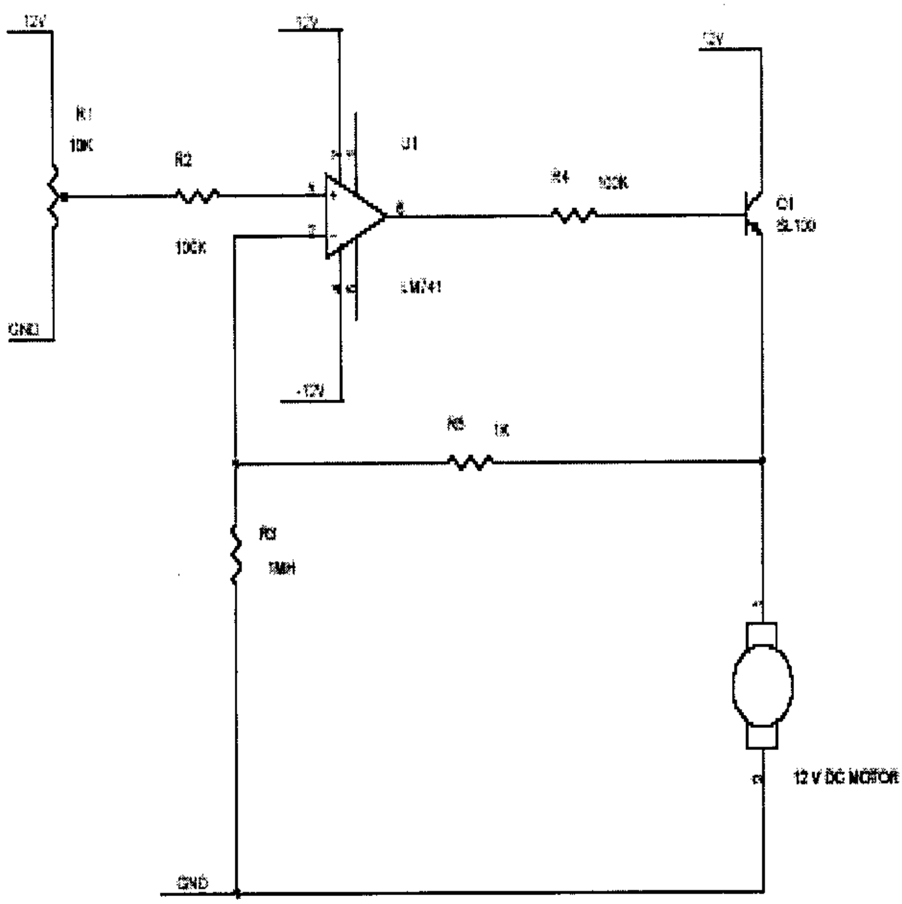


Figure 4.4 circuit diagram of motor speed control

4.6.2 Working principle

This circuit is designed to control the speed of the 12v motor. Here the Variable resistor is used to give the different voltage signal to amplifier circuit. The amplifier circuit is constructed by the LM 741 operational amplifier. The variable voltage is given to non inverting input terminal. Then the amplified signal is given to SL 100 power transistor. The 12v motor is connected in the transistor side. Depending on the amplified signal current through the transistor is controlled due to that the motor speed is controlled.

4.7 Block Diagram of Control system:

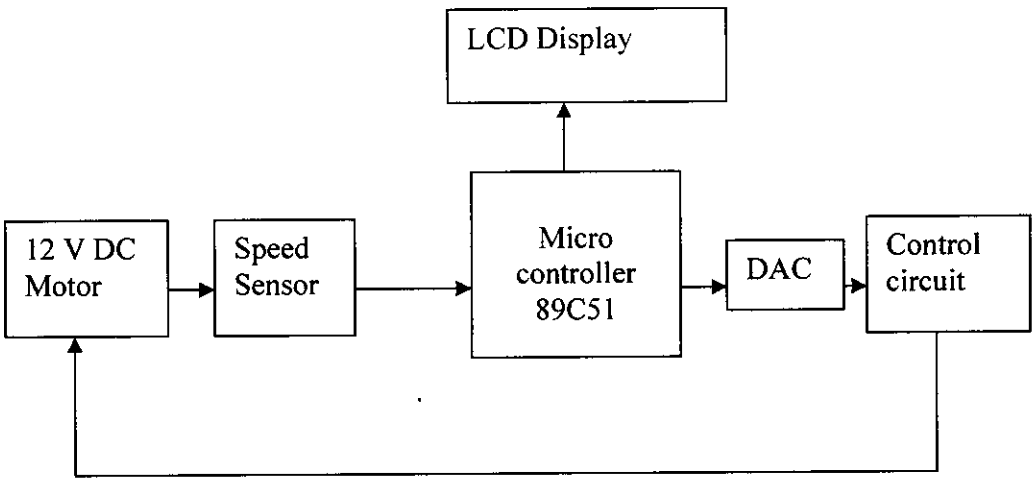


Figure 4.5 Block diagram of control system

4.8 Coding for control system :

```
        ORG 0000H
Main  : SETB P3.5
        MOV TMOD, #60H
        MOV TH1, #00H
        SETB TR1
        LCALL delay
        MOV A, TL1
        CJNE A, #19H
        SETB P1.4
        SJMP main
Check:  JC clear
        SETB P1.4
```

```
        SJMP main
Delay : MOV R3, #32H
        MOV R2, #32H
Loop  : MOV R1, #32H
Back  : DJNZ R1, back
        DJNZ R2, loop
        DJNZ R3, loop
        RET
```

Description :

The above coding is designed to brake the wind turbine blades when it exceeds the rated wind velocity. The micro controller 89C51 is used to perform the braking operation and the delay is designed for a period of one second. For each second, the speed of the motor is displayed. If the speed is above the rated speed, the micro controller 89C51 is set high else it is at low state.

4.9 Time delay calculation:

Crystal oscillator frequency = 12 MHz

Clock divider constant = 12

$$\text{Frequency for executing instruction} = \frac{\text{Crystal oscillator frequency}}{\text{Clock divider constant}}$$

$$= \frac{12}{12}$$

$$= 1 \text{ MHz}$$

$$1 \text{ Machine cycle} = \frac{1}{1 \text{ MHz}}$$

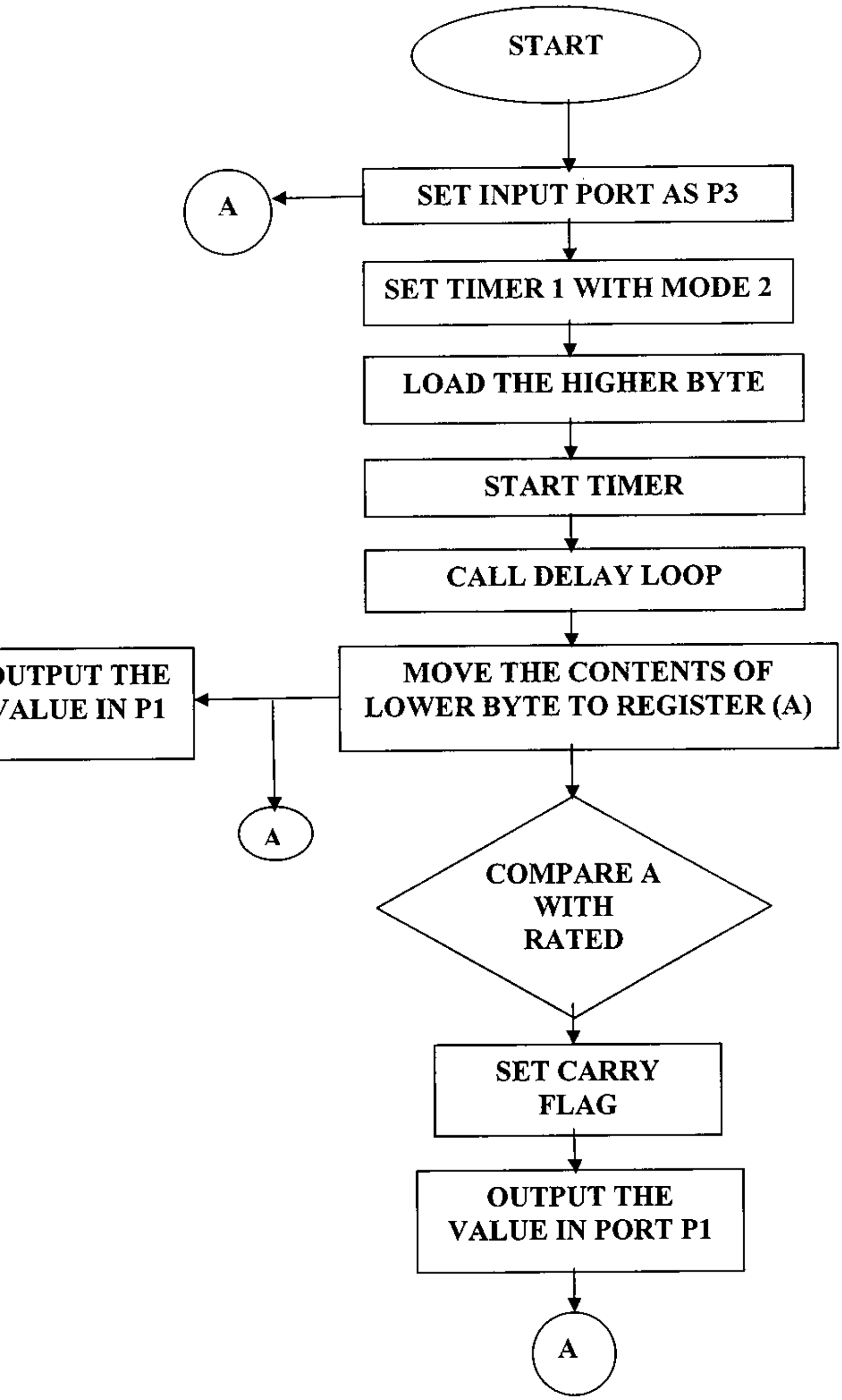
$$= \mathbf{1\ \mu\ sec}$$

	Machine cycle
Delay : MOV R3, #32H	1
MOV R2, #32H	1
Loop : MOV R1, #32H	1
Back : DJNZ R1, back	2
DJNZ R2, loop	2
DJNZ R3, loop	2
RET	2

Time delay = [(50*2)(50*2)(50*2)+3+2] * $1*10^{-6}$

= **1.000005 sec**

4.10 Flow chart for control system:



CHAPTER 5
CONCLUSION

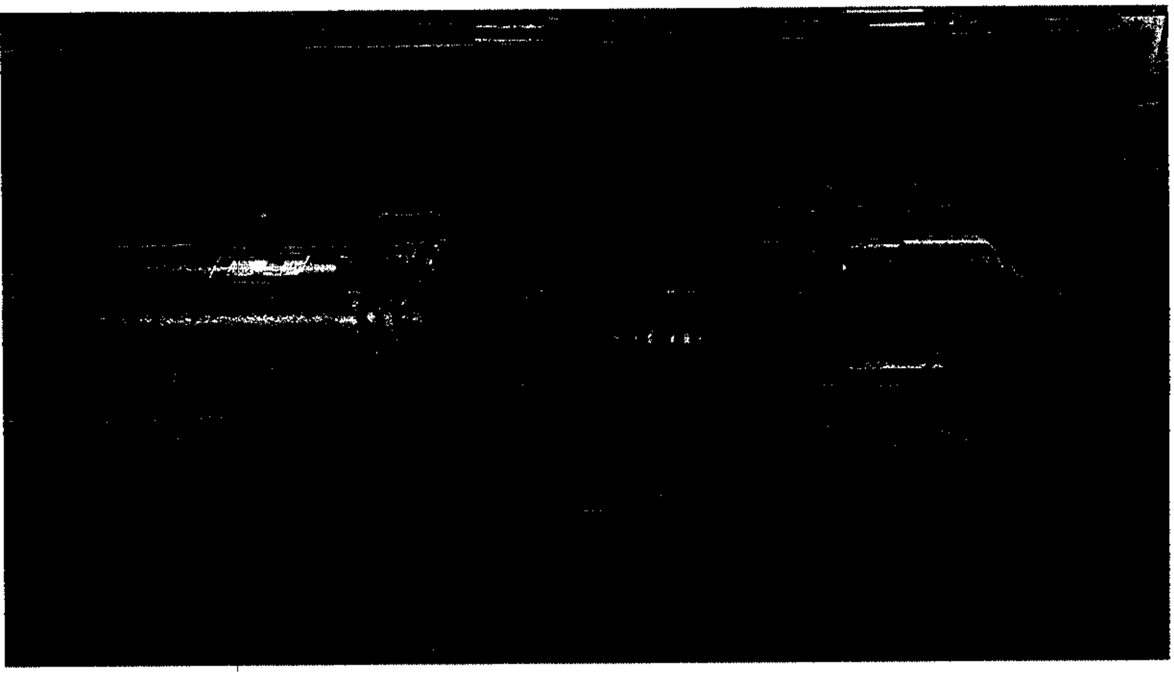
In this project of constructing a suitable braking system, a novel technique has been proposed for the design and fabrication of braking system. It can be used for low power aero generators, where the braking system is designed according to the aero dynamic principles. Furthermore this system provides more accurate results to brake the wind speed when it exceeds the rated speed.

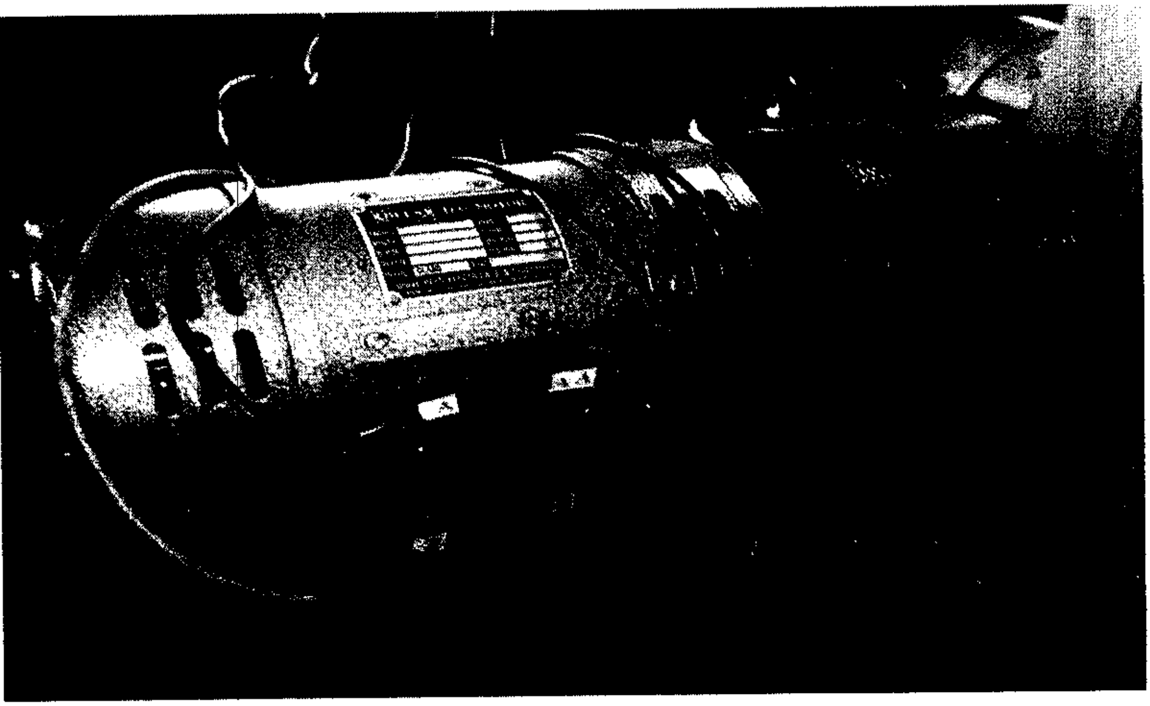
Practical experiments were undergone in the laboratory for analyzing the electromagnetic capability of the motor using a steel coupling. A suitable hardware is also designed using a 89C51 micro controller to demonstrate the phenomenon of electromagnetic braking. This system of electromagnetic braking is mainly designed in order to prevent the damage caused to the blades of the wind turbine, when the wind velocity is very high. It further prevents the damage caused to the neighboring materials, environment and human beings. Thus the method of electromagnetic braking produces more accurate results when compared with other techniques.

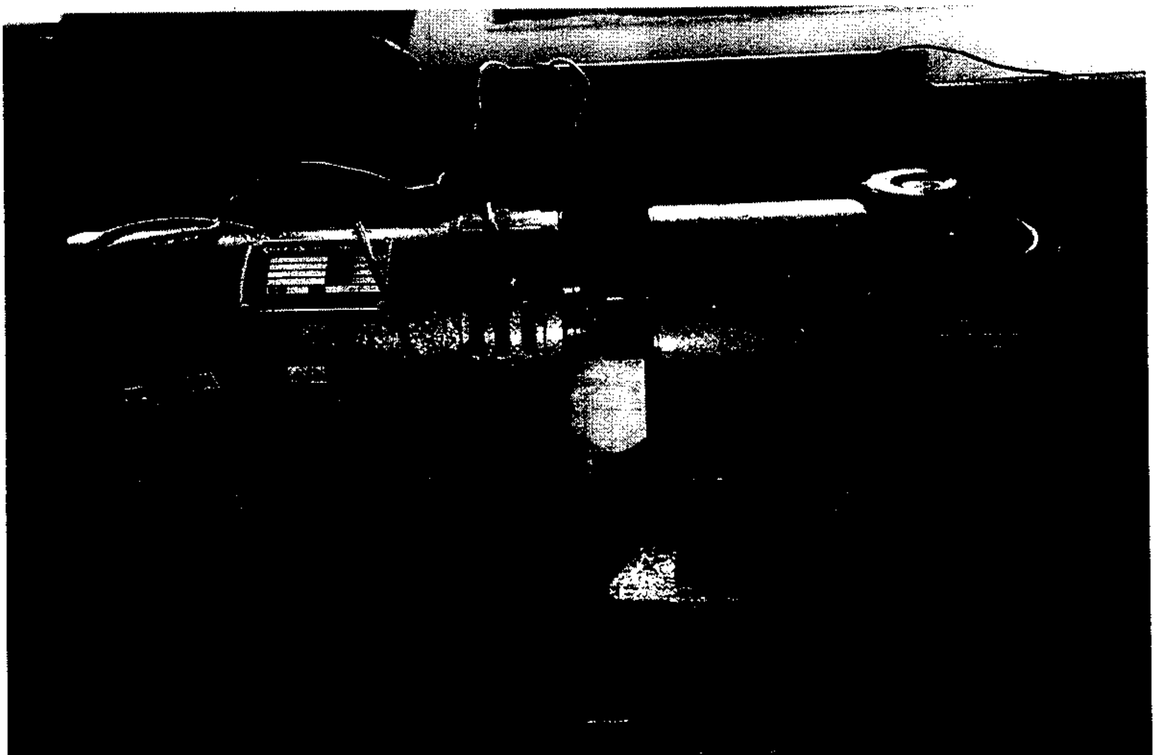
Further, wind velocity analysis is also done considering the parameters like wind velocity, time and area for a period of one year.

PHOTOGRAPHS

ELECTROMAGNETIC BRAKING







REFERENCES

'Wind turbine braking system design"-Discussion with S.Sasikumar, Managing ctor,Green Power Tech(P) LTD,Coimbatore.

3.H Khan "Non conventional Energy Resources" ; Tata McGraw-Hill Publishers,Edition .

B Gupta "Utilization of Electric Power and Electric Traction"; Katson Books, 9th Edition .

Auhammed Ali Mazidi ; Janice Gillispie Mazidi ; Rolin D.McKinley; " The 8051 ocontroller and Embedded Systems using assembly and c language" Pearson Prentice Hall, nd Edition.

tegration of wind turbines on weak rural networks Craig, L.M; Davidson; Jenkins;Vaudin A; ortunities and advances in International Electric power Generation, International Conference onf.publ.No.419) 1997.

aul Gipe : Wind energy Basics, a guide to small and micro wind systems, Chelsea Green ishing company, 1997.

iguere, P., Selig, M.S., "New Airfoils for Small Horizontal Axis Wind Turbines". Journal of r Energy Engineering Vol.120, May 1998.

angler, J.L., "Influence of pitch, Twist, and Taper on a Blade's Performance Loss due to ughness". Journal of Solar Energy Engineering Vol. 119, August 1997.

Giguere, P., Selig, M.S., "Desirable Airfoil Characteristics for Large Variable-Speed izontal Axis Wind Turbines". Journal of Solar Energy Engineering, Vol.119, August 1997.

Eggleston, D.M., Starcher, K., "A Comparative Study of the Aerodynamics of Several Wind bines Using Flow Visualization" Journal of Solar Energy Engineering Vol.112, Nov.90.

Iqbal, M.T., Coonick, A., "Dynamic control of a stand alone wind turbine," BWEA-16 ual conference, 1994.

Web sites:

www.windpower.org

www.wikipedia.org

www.iwea.org

www.ewea.org