



## Design, Analysis and Fabrication of Horizontal Turbine Type Domestic Windmill



### A Project Report

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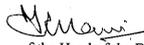
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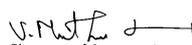
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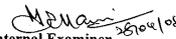
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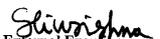
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### ABSTRACT

This millennium marks the start of renewable energy production. With the economic straitjacket the developing countries are going through, it becomes imperative that we rely upon alternate power sources that are not only supportive of the country's monetary resources but also its ecological balance. In this regard we have concentrated on one of the most common energy sources, wind power. Depending on the available wind pressure and velocity in various areas different types of wind mills can be erected and wind energy can be tapped usefully.

The capacity of a windmill to produce energy is directly proportional with wind velocity. The degree of conversion of kinetic energy of wind to the rotary mechanical energy is affected by this wind velocity. This in turn affects the electro-mechanical energy conversion to produce electrical power.

Gamma distribution is one of the most useful continuous distributions to estimate the mean wind power. The mean wind power of 18 stations in Tamil Nadu was estimated. An overall map of Gamma distribution for wind power was obtained. Based on the above data, a wind mill model which can be utilized for domestic purpose is decided on.

This project mainly concentrates on the design, analysis and fabrication of turbine elements, mainly profile and dimension of blade, to produce the required power (240 watts) in low velocity of wind, which is available in both rural and urban area atmosphere, by keeping other electro-mechanical component's design capable to produce 240 watts at an average wind velocity of 3 m/s.

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## CHAPTER I INTRODUCTION

Wind result from air in motion. Air in motion arises from a pressure gradient. On a global basis one primary forcing function causing surface winds from the poles toward the equator is convective circulation. Solar radiation heats the air near the equator, and this low density heated air is buoyed up. At the surface it is displaced by cooler more dense higher pressure air flowing from the poles. In the upper atmosphere near the equator the air thus tend to flow back toward the poles and away from the equator. The net result is a global convective circulation with surface winds from north to south in the northern hemisphere.

It is clear from the above over simplified model that the wind is basically caused by the solar energy irradiating the earth. This is why wind utilization is considered a part of solar technology. In actuality the wind is much more complex. The above model ignores the earth's rotation which causes a coriolis force resulting in an easterly wind velocity component in the northern hemisphere.

There is the further complication of boundary layer frictional effects between the moving air and the earth's rough surface. Mountains, trees, buildings, and similar obstructions impair stream line air flow. Turbulence results and the wind velocity in a horizontal direction markedly increase with altitude near the surface. Local winds are caused by two mechanisms. The first is differential heating of land and water. Solar isolation during the day is readily converted to sensible energy of the land surface but is partly absorbed in layers below the water surface and partly consumed in evaporating some of that water.

The land mass becomes hotter than the water, which causes the air above the land to heat up and become warmer than the air above water. The warmer lighter air above the land rises and the cooler heavier air above the water moves into replace it. This is the mechanism of shore breezes. At night, the direction of the breezes is reversed because the land mass cools to the sky more rapidly than

the water, assuming a sky. The second mechanism of local winds is caused by hills and mountain sides. The air above the slopes heats up during the day and cools down at night, more rapidly than the air above the low lands. This causes heated air the day to rise along the slopes and relatively cool heavy air to flow down at night.

Wind turbines produce rotational motion; wind energy is readily converted into electrical energy by connecting the turbine to an electric generator. The combination of wind turbine and generator is some times referred as an aero generator. A step-up transmission is usually required to match the relatively slow speed of the wind rotor to the higher speed of an electric generator.

In India the interest in the windmills was shown in the last fifties and early sixties. A part from importing a few from outside, new designs was also developed, but it was not sustained. It is only in the last few years that development work is going on in many institutions. An important reason for this lack of interest in wind energy must be that wind, in India area relatively low and vary appreciably with the seasons. Data quoted by some scientists that for India wind speed value lies between 5 km/hr to 15-20 km/hr. these low and seasonal winds imply a high cost of exploitation of wind energy. Calculations based on the performance of a typical windmill have indicated that a unit of energy derived from a windmill will be at least several times more expensive than energy derivable from electric distribution lines at the standard rates, provided such electrical energy is at all available at the windmill site.

The above argument is not fully applicable in rural areas for several reasons. First electric power is not and will not be available in many such areas due to the high cost of generation and distribution to small dispersed users. Secondly there is possibility of reducing the cost of the windmills by suitable design. Lastly, on small scales, the total first cost for serving a felt need and low maintenance costs are more important than the unit cost of energy. The last point is illustrated easily: dry cells provide energy at the astronomical cost of about Rs.300 per kWh and yet they are in common use in both rural and urban areas.

Wind energy offers another source for pumping as well as electric power generation. India has potential of over 20,000 MW for power generation and ranks as one of the promising countries for tapping this source. The cost of power generation from wind farms has now become lower than diesel power and comparable to thermal power in several areas of our country especially near the coasts. Wind power projects of aggregate capacity of 8 MW including 7 wind farms projects of capacity 6.85 MW have been established in different parts of the country of which 3 MW capacities has been completed in 1989 by DNES.

Wind farms are operating successfully and have already fed over 150 lakes units of electricity to the respective state grids. Over 25 MW of additional power capacity from wind is under implementation. Under demonstration programmer 271 wind pumps have been installed up to February 1989. Sixty small wind battery charges of capacities 300 watts to 4 kW are under installation. Likewise to stand-alone wind electric generators of 10 to 25 kW are under installation.

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## 2.2. POWER OF WIND:

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

- (i) The wind speed;
- (ii) The cross-section of wind swept by rotor; and
- (iii) 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 gearbox, transmission system and generator or pump could decrease overall wind turbine efficiency to 35% or less.

The power in the wind can be computed by using the concept of kinetics. The wind will work on the principle of converting kinetic energy of the wind to mechanical energy. 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  $1/2 m V^2$ . The amount of air passing in unit time, through an area A, with velocity V, is AV, and its mass m is equal to its volume multiplied by its density  $\rho$  of air, or

$$m = \rho AV$$

(m is the mass of air transverse the area A swept by the rotating blades of a wind mill type generator).

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## CHAPTER 2 BASIC PRINCIPLES OF WIND ENERGY CONVERSION

### 2.1 NATURE OF WIND:

The circulation of air in the atmosphere is caused by the non-uniform heating of the earth's surface by the sun. The air immediately above a warm area expands; it is forced upwards by cool, denser air which flows in from surrounding areas causing a wind. The nature of the terrain, the degree of cloud cover and the angle of the sun in the sky are all factors which influence this process. In general, during the day the air above the land mass tends to heat up more rapidly than the air over water. In coastal regions this manifests itself in a strong onshore wind. At night the process is reversed because the air cools down more rapidly over the land and the breeze therefore blows off shore.

The main planetary winds are caused in much the same way: Cool surface air sweeps down from the poles forcing the warm air over the tropics to rise. But the direction of these massive air movements is affected by the rotation of the earth and the net pressure areas in the countries-clockwise circulation of air around low pressure areas in the northern hemisphere, and clockwise circulation in the southern hemisphere. The strength and direction of these planetary winds change with the seasons as the solar input varies.

Despite the wind's intermittent nature, wind patterns at any particular site remains remarkably constant year by year. Average wind speeds are greater in hilly and coastal areas than they are well inland. The winds also tend to blow more consistently and with greater strength over the surface of the water where there is a less surface drag.

Wind speeds increase with height. They have traditionally been measured at a standard height of ten meters where they are found to be 20-25% greater than close to the surface. At a height of 60 m they may be 30-60% higher because of the reduction in the drag effect of the earth's surface.

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Substituting this value of the mass in the expression for the kinetic energy, we obtain, **kinetic energy =  $1/2 \rho AV \cdot V^2$  watts.**  
**=  $1/2 \rho AV^3$  watts**

Equation tells us that 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.

Equation also tells us that the power available is proportional to air density (1.225 kg/m<sup>3</sup> at sea level). It may vary 10-15 percent during the year because of pressure and temperature change. It changes negligibly with water content. Equation also tells us that the wind power is proportional to the intercept area. Thus an aero turbine with a large swept area has higher power than a smaller area machine; but there are added implications. Since the area is normally circular of diameter D in horizontal axis aero turbines, then  $A = \pi/4 D^2$  (sq.m), which when put in equation gives,

$$\text{Available wind power } P_a = \frac{1}{2} \rho \pi/4 D^3 V^3 \text{ watts} \\ = 1/8 \rho \pi D^3 V^3$$

The power extracted by the rotor is equal to the product of the wind speed as it passes through the rotor (i.e. V<sub>r</sub>) and the pressure drop  $\Delta p$ . In order to maximize the rotor power it would therefore be desirable to have both wind speed and pressure drop as large as possible. However, as V is increased for a given value of the free wind speed (and air density), increases at first, passes through a maximum, and then decreases. Hence for the specified free-wind speed, there is a maximum value of the rotor power.

The fraction of the free-flow wind power that can be extracted by a rotor is called the power-coefficient; thus

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$$\text{Power coefficient} = \frac{\text{Power of wind rotor}}{\text{Power available in the wind}}$$

Where power available is calculated from the air density, rotor diameter, and free wind speed as shown above. The maximum theoretical power coefficient is equal to  $16/27$  or  $0.593$ . This value cannot be exceeded by a rotor in a free-flow wind-stream.

### 2.3. MAXIMUM POWER:

The total power can not be converted to mechanical power. Consider a horizontal-axis, propeller-type windmill, henceforth to be called a wind turbine, which is the most common type used today. Assume that the wheel of such a turbine has thickness  $\alpha b$ . Let  $p_1$  and  $V_1$  be the wind pressure and velocity at the upstream of the turbine.  $V_2$  is less than  $V_1$  because the turbine extracts kinetic energy.

Considering the incoming air between 1 and 2 as a thermodynamic system, and assuming that the air density remains constant (since changes in pressure and temperature are very small compared to ambient), that the potential energy is zero, and no heat or work are added or removed between 1 and 2, the general energy equation reduces to the kinetic and flow energy-terms only:

### 2.4. WIND ENERGY CONVERSION:

Traditional windmills were used extensively in the Middle Ages to mill grain and lift water for land drainage and watering cattle. Wind energy converters are still used for these purposes today in some parts of the world, but the main focus of attention now lies with their use to generate electricity. There is also growing interest in generating heat from the wind for space and water heating and for glass-houses but the potential market is much smaller than for electricity generation.

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Power conditioning is readily achieved using an electronic black box called a 'synchronous' inverter, and although this is an expensive item of equipment, it does eliminate the need for batteries and for conversion of home appliances to run to DC.

Where there is no grid connection, electricity that is surplus to immediately requirements must be stored on site using heavy-duty batteries. It can be recovered later when the demand exceeds the supply. An alternative is to dump it (by generating and dissipating heat) or better, to convert it into heat that can be stored, for example as hot water in a well-insulated tank.

### 2.6. LARGE PRODUCERS:

Large and medium-sized wind generators are designed to give a stable and constant electrical output over a wide range of wind speeds and to feed current directly into the grid. They operate primarily as fuel savers, reducing the utility's total fuel burn.

The choice of generator type depends on the size of the local distribution grids and its associated generating capacity. An induction generator would normally be used where there is a significant amount of other generating capacity (which could provide the necessary reactive power for excitation). Induction generators are robust and reliable and require minimal control equipment. For isolated networks where other local generating capacity is limited, and where a high degree of autonomous control is required, a synchronous generator is more appropriate. Synchronous generators are more complex and therefore more expensive than induction machines.

### 2.7. LIFT AND DRAG:

Lift and drag are the basics for wind energy conversion. The extraction of power, and hence energy, from the wind depends on creating certain forces and

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The term "wind mill" is still widely used to describe wind energy conversion systems, however it is hardly adopted. Description any more. Modern wind energy conversion systems are more correctly referred to as 'WECS', 'aero generators', 'wind turbine generators', or simply 'wind turbines'.

The fact that the wind is variable and intermittent source of energy is immaterial of some applications such as pumping water for land drainage – provided, of course, that there is a broad match between the energy supplied over any critical period and the energy required. If the wind blows, the job gets done; if it does not, the job waits. However, for many of the uses to which electricity is put, the interruption of supply may be highly inconvenient. Operators or users of wind turbines must ensure that there is some form of back-up to cover periods when there is insufficient (or too much) wind available. For small producers, back-up can take the form of:

- (i) Battery storage,
- (ii) Connection with the local electricity distribution system; or

For utilities responsible for public supply, the integration of medium – sized and large wind turbines into their distribution network could require some additional plant which is capable of responding quickly to meet fluctuating demand.

### 2.5. SMALL PRODUCERS:

Private Citizens in several countries have won the right to operate wind generators and other renewable energy systems and to export power to the grid. For most small wind generators this requires that the output is 'conditioned' so that it conforms to the frequency and phase of the mains supply. Only a few small units are designed to maintain a constant rotational rate so that can be synchronized to the mains frequency and feed electricity directly into the grid. Most produce direct current (DC) or variable output alternating current (AC).

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applying them to rotate (or to translate) a mechanism. There are two primary mechanisms for producing forces from the wind; lift and drag.

By definition lift forces act perpendicular to the airflow, while drag forces act in the direction of flow. Lift forces are produced by changing the velocity of the air stream flowing over either side of the lifting surface: speeding up the air flow causes the pressure to drop, while slowing the air stream down leads to increase in pressure.

In other words, any change in velocity generates a pressure difference across the lifting surface. This pressure difference produces a force that begins to act on the high-pressure side of the lifting surface which is called an airfoil. A good airfoil has a high lift/drag ratio, in some cases it can generate lift forces perpendicular to the air stream direction that are 30 times as great as the drag force parallel to the flow. The lift increases as the angle formed at the junction of the airfoil and the air-stream (the angle of attack) becomes less and less acute, up to the point where the angle of the airflow on the low-pressure side becomes excessive.

When this happens, the airflow breaks away from the low pressure side. A lot of turbulence ensues, the lift decreases and the drag increases quite substantially, this phenomenon is known as stalling. For efficient operation, a wind turbine blade needs to function with as much lift and as little drag as possible because drag dissipates energy. As lift does not involve anything more complex than deflecting the airflow, it is usually an efficient process. The design of each wind turbine specifies the angle at which the airfoil should be set to achieve the maximum lift to drag ratio.

In addition to airfoils, there are two other mechanisms for creating lift. One is the so-called Magnus effect, caused by spinning a cylinder in an air stream at a high-speed of rotation. The spinning slows down the air speed on the side where the cylinder is moving into wind and increases it on the other side; the result is similar to an airfoil. This principle has been put to practical use in or two cases but is not generally employed. The second way is to blow air through

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narrow slots in a cylinder, so that it emerges tangentially; this is known as a Thwarts slot. This also creates a rotation (or circulation) of the air flow which in turn generates lift. Because the lift ratio of airfoils is generally much better than those of rotating or slotted cylinders, the latter techniques probably have little practical potential.

**Symbols**

- V - Free wind velocity
- $V_b$  - Velocity of airfoil element  
( $V_b I = \omega r$ ),
- $V_r$  - resultant wind as 'seen' by airfoil element
- $F_L$  - lift force (perpendicular to  $V_r$ )
- $F_D$  - drag force
- $\theta$  - angle of twist
- $\alpha$  - angle of incidence
- $\omega$  - angular speed of rotor
- r - Distance of airfoil element from its axis of rotation.

The windmill blades 'sees' the resultant vector  $V_r$ . The blades need to be twisted because r varies in proportion to radius.

interpreted in terms of boundary layer concept, keeping in mind the factors that influence its development. The wind velocity at a given height can be represented in terms of gradient height and velocity.

In as much as the height of the windmill rotor depends on the design wind velocity and cost of supporting structure. The above factors have a bearing on the design. Similarly, winds being an unsteady phenomenon, the scale of periods considered for this the temporal parameters (scale of our, month and year) is an important set of data required in the design. While the hourly mean velocity (for many years) provides the data for establishing the potential of the place for tapping the wind energy. The scale of the month is useful to indicate whether it is going to be useful during particular periods of the year and what storage if necessary is to be provided for as already mentioned above. The data based on scale of the hour is useful for mechanical aspects of design. In addition to the data on the hourly mean velocity, two other information's required are:

- Spells of low wind speeds, and
- Gusts

The site choice for a single or a spatial array of WECS (wind energy conversion system) is an important matter when wind electric is looked at from the systems points of view of aero turbine generators feeding power into a conventional electric grid. If the WECS sites are wrongly or poorly chosen the net wind electric generated energy per year may be sub optimal with resulting high capital cost for the WECS apparatus, high cost for wind generated electrical energy, and no returns on investment.

Even if the WECS is to the small generator not tied to the electric grid, the sitting must be carefully chosen if inordinately long break even times to the avoided. Technical, economic environmental, social, and other factors are examined before a decision is made to erect a generating plant on a specific site. Some of the main considerations are discussed below.

**CHAPTER 3  
WIND DATA AND ENERGY ESTIMATION**

The seasonal as well as instantaneous changes in wind both with regard to magnitude and direction need to be well understood to make the best use of them in windmill designs. Winds are known to fluctuate by a factor of 2 or more within seconds (and thus causing the power to fluctuate by a factor of 8 or more). This calls for a proper recording and analysis of the wind characteristics.

There are various ways the data on wind behavior is collected depending on the use it is intended to be put into. The hourly mean wind velocity as collected by the meteorological observations is the basic data used in a windmill designs. The hourly means is the one averaged over a particular hour of the day, over the day, month, year and years. The factors, which affect the nature of the wind close to the surface of the earth, they are:

- (i) Latitude of the place,
- (ii) Altitude of the place,
- (iii) Topography of the place,
- (iv) Scale of the hours, month or year.

Winds being an unsteady phenomenon, the scale of the periods considered are an important set of date required in the design. The hourly mean velocity (for many years) provides the data for establishing the potential of the place for tapping the wind energy. The scale of the month is useful to indicate whether it is going to be useful during particular periods of the year and what storage if necessary is to be provided for. The data based on scale of the hour is useful for mechanical aspects of design.

Since the winds near the surface of the earth are derived from large scale movements of atmospheric winds, the location height above ground level at which the wind is measured and the nature of the surface on earth have an influence on the velocity of wind at any given time. The winds near the surface of the earth are

(1) High annual average wind speed. A fundamental requirement of the successful use of WECS, obviously, is an adequate supply of wind has stated above. The wind velocity is the critical parameter. The power in the wind  $P_w$ , through a given cross sectional area for a uniform wind velocity V, is

$$P_w = KV^3$$

Where K is a constant. It is evident; because of the cubic dependence on wind velocity that small increases in V markedly affect the power in the wind, EX. Doubling V, increases  $P_w$  by a factor of 8. it is obviously desirable to select a site for WECS with high wind velocity. Thus a high average wind velocity is the principal fundamental parameter of concern in initially appraising a WECS site. For a more detailed estimate value, one would like to have the average of the velocity cubed. The average wind velocity is observed in 18 different areas in Tamil Nadu and these areas were segregated into 4 types, viz: high, medium, low and very low wind velocity areas, as given in the table below:

**Table: 3.1 Wind Velocity Data**

S.NO	Power Range(W/m2)	Place
1	51-82.4	Coimbatore
		Kanyakumari
		Tuticorin
2	29-50.99	Pamban
		Karaikal
		Nagapattinam
3	12-28.99	Pondicherry
		Palayamkottai
		Kodaikanal
		Madurai
		Tiruchirapalli
4	2-11.99	Cuddalore
		Meenampakkam
		Nungampakkam
		Vellore
		Mettur
		Ooty

Anemometer data is normally based on wind speed measurements from a height of 10m. For the most accurate assessment of wind power potential it is absolutely essential that anemometer data be obtained at the precise site and hub height for any proposed WECS.

Strategy for siting is generally recognized to consist of

1. Survey of historical wind data,
2. Contour maps of terrain and wind are consulted.
3. Potential sites are visited.
4. Best sites are instrumental for approximately one year.
5. Choose optimal site.

(2) Availability of anemometry data. It is another important siting factor. The principal object is to measure the wind speed, which basically determines the WECS output power, but there are many practical difficulties with the instrumentation and measurement methods. The anemometer height above ground, accuracy, linearity, location on the support tower, shadowing and inaccurate readings there from, icing inertia of rotor whether it measures the horizontal velocity component or vertical, and temperature effects are a few of the many difficulties encountered. The anemometry data should be available over some time period at the precise spot where any proposed WECS is to be built and that this should be accomplished before a siting decision is made.

(3) Availability of wind  $V_{(t)}$  curve at the proposed site. This important curve determines the maximum energy in the wind and hence is the principal initially controlling factor in predicting the electrical output and hence revenue returns of the WECS machines. It is desirable to have average wind speed  $V \geq 12-16 \text{ km/hr} (3.5-4.5 \text{ m/sec})$  which is about the lower limit at which present large scale WECS generators 'cut in' i.e. start turning. The  $V_{(t)}$  curve goes to zero there will be no generated power during that time. If there are long periods of calm the WECS reliability will be lower than if the calm periods are short. In making such reliability estimates it is desirable to have measured  $V_{(t)}$  curve over about a 5 year period for the highest confidence level in the reliability estimate.

(4) Wind structure at the proposed site. The ideal case for the WECS would be a site such that the  $V_{(t)}$  curve was flat, i.e. a smooth steady wind that blows all the time; but a typical site is always less than ideal. Wind especially

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(10) Nearness of site to local center/users. This obvious criterion minimizes transmission line length and hence losses and costs. After applying all the previous siting criteria, hope fully as one narrows the proposed WECS sites to one or two they would be relatively near to the users of the generated electric energy.

(11) Nature of ground. Ground condition should be such that the foundations for a WECS, destroying the foundations for a WECS are secured. Ground surface should be stable. Erosion problem should not be there, as it could possibly later wash out the foundations of a WECS, destroying the whole system.

(12) Favorable land cost. Land cost should be favorable as this along with other siting costs, enters into the total WECS system cost.

(13) Other conditions such as icing problem, salt spray or blowing dust should not present at the site, as they may affect aero turbine blades, or environmental is generally adverse to machinery and electrical apparatus.

The wind shear, and consequently the available wind power at a given altitude, is also affected by the roughness of the earth's surface in a given location. If the area contains buildings, trees, wind machines, or other obstacles, the variation of the wind speed with altitude above ground level is usually greater for these obstructed areas than for the case of open water and flat plains. The characteristics of a good wind power site may be summarized as follows:

1. A site should have a high annual wind speed.
2. There should be no tall obstructions for a radius of 3 km.
3. An open plain or an open shore line may be good location.
4. The top of a smooth, well rounded hill with gentle slopes lying on a flat plain or located on an island in a lake or sea is a good site.

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near the ground is turbulent and gusty, and changes rapidly in direction and in velocity. This departure from homogeneous flow is collectively referred to as "the structure of the wind".

(5) Altitude of the proposed site. It affects the air density and thus the power in the wind and hence the useful WECS electric power output. Also, as is well known, the winds tend to have higher velocities at higher altitudes. One must be careful to distinguish altitude from height above ground. They are not the same except for a sea level WECS site.

(6) Terrain and its aerodynamic. One should know about terrain of the site to be chosen. If the WECS is to be placed near the top but not on the top of a not too blunt hill facing the prevailing wind, then it may be possible to obtain a 'speed up' of the wind velocity over what it would otherwise be. Also the wind here may not flow horizontal making it necessary to tip the axis of the rotor so that the aero turbine is always perpendicular to the actual wind flow.

(7) Terrain and its aerodynamic. One should know about terrain of the site to be chosen. If the WECS is to be placed near the top but not on the top of a not too blunt hill facing the prevailing wind, then it may be possible to obtain a 'speed up' of the wind velocity over what it would otherwise be. Also the wind here may not flow horizontal making it necessary to tip the axis of the rotor so that the aero turbine is always perpendicular to the actual wind flow. It may be possible to make use of hills or mountains, which channel the prevailing winds into a pass region, thereby obtaining higher wind power.

(8) Local Ecology. If the surface is bare rock it may mean lower hub heights hence lower structure cost. If trees or grass or vegetation are present, all of which tend to restructure the wind, then higher hub heights will be needed resulting in large system costs than the bare ground case.

(9) Distance to Roads or Railways. This is another factor the system engineer must consider for heavy machinery, structures, materials, blades and other apparatus will have to be moved into any chosen WECS site.

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## CHAPTER 4 CLASSIFICATION OF WIND ENERGY CONVERSION SYSTEM

### 4.1. CLASSIFICATIONS:

#### 4.1.1. First, there are two broad classifications:

- (i) **Horizontal Axis Machines.** The axis of rotation is horizontal and the aero turbine plane is vertical facing the wind.
- (ii) **Vertical Axis Machines.** The axis of rotation is vertical. The sails or blades may also be vertical, as on the ancient Persian windmills, or nearly so, as on the modern Darrieus rotor machine.

#### 4.1.2. Then, they are classified according to size as determined by their useful electrical power output.

- (i) **Small Scale (up to 2 kW).** These might be used on farms, remote applications, and other places requiring relatively low power.
- (ii) **Medium Size Machines (2-100kW).** These wind turbines may be used to supply less than 100 kW rated capacity, to several residence or local use.
- (iii) **Large Scale or Large Size Machines (100 kW and up).** Large wind turbines are those of 100 kW rated capacity or greater. They are used to generate power for distribution in central power grids. There are two sub classes:

- (a) Single Generator at a single site.
- (b) Multiple Generators sited at several places over an area.

#### 4.1.3. As per the type of output power, wind aero generators are classified as:

- (i) DC output
  - (a) DC generator
  - (b) Alternator rectifier

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- (ii) AC output
  - (a) Variable frequency, variable or constant voltage AC.
  - (b) Constant frequency, variable or constant voltage AC.

**4.1.4. As per the rotational speed of the aero turbines, these are classified as:**

- (i) Constant Speed with variable pitch blades. This mode implies use of a synchronous generator with its constant frequency output.
- (ii) Nearly Constant Speed with fixed pitch blades. This mode implies an induction generator.
- (iii) Variable Speed with fixed pitch blades. This mode could imply, for constant frequency output:
  - (a) Field modulated system
  - (b) AC-DC-AC link
  - (c) Double output induction generator
  - (d) AC commutation generator
  - (e) Other variable speed constant frequency generating systems.

**4.1.5. Wind turbines are also classified as per how the utilization of output is made:**

- (i) Battery storage
- (ii) Direct connection to an electromagnetic energy converter
- (iii) Other forms (thermal potential etc.) of storage.
- (iv) Interconnection with conventional electric utility grids.

The system engineer seeking to integrate WECS will, naturally be most interested in the latter case but should be aware that WECS will, naturally be most interested in the latter case but should be aware that WECS offer other options as well.

**4.2. ADVANTAGE AND DISADVANTAGE OF WECS**

**4.2.1. Advantages of wind energy are:**

- (i) It is a renewable source of energy

**4.4. TURBINE TOWER SYSTEM:**

As stated earlier, the horizontal axis wind turbines are mounted on towers, and there are wind forces on the tower. Both upwind and downwind locations have been used so that tower design is an essential aspect of the overall system design.

**4.5. VERTICAL-AXIS MACHINES:**

Vertical - axis rotors can be either drag-or lift-based. The cup anemometer is an example of a drag-based, vertical axis wind device. The drag on a cup is greater when its concave side faces the wind which causes the device to rotate. Lift also plays a small part: the cups crossing the wind experience a small lift because their convex surfaces deflect the wind and causes a pressure reduction.

The main virtue of the cup anemometer is that it tends to rotate within a narrow range of TSRs under all conditions, so its rotational speed is closely proportional to wind speed. However, it can not carry a load with any efficiency; it has never been constructed on a large scale for use as a wind turbine. The Savonius rotor works on a principle similar to that of the cup anemometer but is adopted to produce shaft power. It also takes advantage of the lift generated as the curved outer surfaces of its scoops cross the air flow.

There are also a variety of so-called Panamones; there are pure drag devices, in which one side of the rotor carries blades or sails square to the wind, while other side produces reducing drag by shielding or furling the blades. Because drag devices tend to run at TSR below unity (since their tips can not readily travel faster than the wind), they are inevitably less efficient than lift-dependent devices. In addition, their high solidity makes them more material-intensive in relation to the wind area 'seen' by the rotor.

- (ii) Like all forms of solar energy, wind power systems are non-polluting, so it has no adverse influence on the environment.
- (iii) Wind energy systems avoid fuel provision and transport.
- (iv) On a small-scale up to a few kilowatt system is less costly. On a large-scale costs can be competitive with conventional electricity and lower costs could be achieved by mass production.

**4.2.2. Disadvantages of wind energy are:**

- (i) Wind energy available in dilute and fluctuating in nature.
- (ii) Unlike water energy wind energy needs storage capacity because of its irregularity.
- (iii) Wind energy systems are noisy in operation; a large unit can be heard may kilometers away.
- (iv) Wind power systems have a relatively high overall weight, because they involve the construction of a high tower and include also a gearbox, a hub and pitch changer, a generator coupling shaft etc. for large systems a weight of 110 kg/kW (rated) has been estimated.
- (v) Large areas are needed, typically, propellers 1 to 3 m in diameter, deliver power in the 30 to 300 W ranges.
- (vi) Present systems are neither maintenance-free nor practically reliable. However, the fact that highly reliable propeller engines are built for aircraft suggest that the present troubles could be overcome by industrial development work.

**4.3. HORIZONTAL - AXIAL MACHINES**

The common wind turbine with a horizontal (or almost horizontal) axis, is simple in principle, but the design of a complete system, especially a large one that will produce electric power economically, is complex. Not only must be individual components, such as the rotor, transmission, generator, and tower, be as efficient as possible, but these components must function effectively in combination.

Hence following are the three distinct advantages of vertical axis wind turbines over horizontal axis ones:

- (1) They will react to wind from any direction and therefore do not need yawing equipment to turn the rotor into the wind.
- (2) They can require less structural support because heavy components (like gear box and generator) can be located at ground level. This configuration also eases installation and maintenance.
- (3) Since the blades do not turn end over end, the rotor is not subjected to continuous cyclic gravity loads. (Fatigue induced by such action is a major consideration in the design of large horizontal axis machines).

Properly the single biggest disadvantage with vertical axis machines is that far less is known about them than horizontal axis ones. This handicap is rapidly being removed.

**4.6. ADVANTAGES OF SUCH WEC SYSTEM ARE:**

1. The major advantage of this design is that the rotor blades can accept the wind from any compass.
2. Another added advantage is that the machine can be mounted on the ground eliminating tower structures and lifting of huge weight of machine assembly, i.e. it can be operated close to the ground level.
3. Since this machine has vertical axis symmetry, it eliminates yaw control requirement for its rotor to capture wind energy. A dual purpose and relatively simple shaft axis support is anticipated as well as ground level power output delivery due to presence of vertical shaft. This may in turn, allow easier access and serviceability.
4. Airfoil rotor fabrication costs are expected to be reduced over conventional rotor blade costs.
5. The absence of pitch control requirements are synchronous operation may yield additional cost savings.

6. The tip speed ratio and power coefficient are considerably better than those of the S-rotor but are still below the values for a modern horizontal-axis, two-bladed propeller rotor.

#### 4.7. DISADVANTAGES:

(1) Although a Darrieus machine has many directional symmetry for wind energy capture, it require external mechanical aid for start up. Tests indicate that, with small machines, the problem can be solved by attaching S-rotors at the top and bottom of the vertical (rotational) axis. This approach does not appear to be feasible with larger machines, but if the wind power system connected to a utility grid, the generator can serve as a motor to start the turbine. The (alternating-current) load can also provide a means for controlling the speed of the rotor regardless of the wind speed, so that variable-pitch blades are not required. At very high speeds, stalling occurs and the rotation stops automatically.

(2) Rotor power output efficiency of a Darrieus wind energy conversion system is also somewhat lower than that of a conventional horizontal rotor.

(3) Because a Darrieus rotor is generally situated near ground proximity, it may also experience lower velocity wind compared to a tower mounted conventional wind energy conversion system of comparable projected rotor disc area. This may yield less energy output.

(4) Because a Darrieus rotor encounters greatly varied local flow conditions per revolution, greater vibratory stresses are encountered which will affect rotor system life? High tension cable tie down of tower-shaft may require large extensive bearing for support.

(5) Finally since a Darrieus rotor cannot be yawed out of the wind or its blades feathered, special high torque braking system must be incorporated.

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The electrical control strategy employed for any particular scheme can be designed to effect control of the generator, the power transmission link or the load.

#### 5.3. SCHEMES FOR ELECTRIC GENERATION:

Several schemes for electric generation have been developed. These schemes can be broadly classified under three categories:

- (i) Constant – speed constant frequency systems (CSCF)
- (ii) Variable speed constant frequency systems (VSCF)
- (iii) Variable speed variable frequency systems (VSVF)

##### 5.3.1. Constant speed constant frequency system (CSCF).

Constant speed drive has been used for large generators connected directly to the grid where constant frequency operation is essential.

###### (a) Synchronous Generator.

For such machines the requirement of constant speed is very rigid and only minor fluctuations about 1% for short durations (fraction of second) could be allowed. Synchronization of wind driven generator with power grid also will pose problems with gusty winds.

###### (b) Induction Generator.

If the stator of an induction machine is connected to the power grid and if the rotor is driven above synchronous speed  $N_s$  ( $N_s=120f/p$ ), the machine becomes a generator and delivers constant line frequency power to the grid. ( $f$ =line frequency – and  $p$ =number of poles for which the stator winding is made). Per unit slip is 0 and 0.05. The output power of wind drive n induction generator is uniquely determined by the operating speed. The pull out torque  $T^m$  condition

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## CHAPTER 5 POWER GENERATION

### 5.1 INTRODUCTION :

Aero turbines convert wind energy into rotary mechanical energy. A mechanical interface, consisting of a step-up gear and a suitable coupling transmits the energy to an electrical generator. The output of this generator is connected to the load or system grid. The controller senses the wind direction, wind speed, power output of the generator and other necessary performance quantities of the system and initiates appropriate control signals to take suitable corrective actions. The system should be protected from excessive temperature raise of the generator, electrical faults and extra wind conditions.

The choice of an electrical generator and control method to be employed (if any) can be decided by consideration of the following three factors:

- (i) The basis of operation i.e. either constant tip speed or constant tip speed ratio.
- (ii) The wind-power rating of the turbine and
- (iii) The type of load demand e.g. battery connection.

Wind power ratings can be divided into three convenient grouping, small to 1kW, medium to 50 kW and large 200 kW to megawatt frame size.

### 5.2. Electrical generators types applicable to these ratings:

- Small – permanent, magnet, D.C. generators.
- Medium-permanent magnet, D.C generator, induction generator, synchronous generator.
- Large – induction generator, synchronous generator.

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should not be exceeded. When this happens the speed continues to increase and the system may 'run away' the torque-speed characteristics of an induction machine in the motor and generating modes. Induction generators are basically simpler than synchronous generators. They are easier to operate, control and maintain, have no synchronization problems and are economical. However, they draw their excitation from the grid and hence impose reactive volt ampere burden. But static capacitors can be used to overcome this problem.

### 5.3.2. Variable speed constant frequency scheme. (VSCF scheme).

Variable-speed drive is typical for most small wind generators used in autonomous applications, generally producing variable frequency and variable voltage output. The variable speed operation of wind-electric system yield higher outputs for both low and high wind speeds. This results in higher annual energy yields per rated installed kW capacity. Both horizontal axis and vertical axis turbines will exhibit this gain under variable speed operation. The popular schemes to obtain constant frequency output are as follows:

#### (a) AC-DC-AC link.

With the advent of high powered thyristors and high voltage D.C. transmission systems, A.C. output of the 3-phase alternator is rectified using a bridge rectifier and then converted back to A.C. using line commutated inverters. They utilize an A.C. source (power lines) which periodically reverses polarity and causes the commutation to occur naturally. Since frequency is automatically fixed by the power line, they are also known as synchronous inverters. The block diagram of the system.

#### (b) Double Output Induction Generator.

In this system a slip-ring induction motor is used. Rotor power output at slip frequency is converted to line frequency power by rectification and inversion output power is obtained both from stator and rotor and hence this device is called double output induction generator. Rotor output power has the electrical

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equivalence of additional impedance in the rotor circuit. Therefore, increasing rotor outputs lead to increasing slips and higher speeds. Such an operation increases the operating speed range from  $N_3$  to  $2N_3$ , i.e. slip varying from 0 to 1.0.

**(c) A.C. Communication generator.**

This system is also known as Scherbius system employs two polyphase windings in the stator and a commutator winding on the rotor. Basic problems in employing this device for wind energy conversion are the cost and care required by the commutator and the brush gear.

**6.2. DISADVANTAGES OF WIND ENERGY CONVERSION SYSTEM**

- ✓ Rotor power output efficiency of a Darrieus wind energy conversion system is also somewhat lower than that of a conventional horizontal rotor.
- ✓ Because a Darrieus rotor is generally situated near ground proximity, it may also experience lower velocity wind compared to a tower mounted conventional wind energy conversion system of comparable projected rotor disc area. This may yield less energy output.

**CHAPTER 6**

**ADVANTAGE AND DISADVANTAGE OF WIND ENERGY CONVERSION SYSTEM:**

**6.1. ADVANTAGES OF WIND ENERGY CONVERSION SYSTEM**

- ✓ The major advantage of this design is that the rotor blades can accept the wind from any compass.
- ✓ Another added advantage is that the machine can be mounted on the ground eliminating tower structures and lifting of huge weight of machine assembly, i.e. it can be operated close to the ground level.
- ✓ Since this machine has vertical axis symmetry, it eliminates yaw control requirement for its rotor to capture wind energy. A dual purpose and relatively simple shaft axis support is anticipated as well as ground level power output delivery due to presence of vertical shaft. This may in turn, allow easier access and serviceability.
- ✓ Airfoil rotor fabrication costs are expected to be reduced over conventional rotor blade costs.
- ✓ The absence of pitch control requirements for synchronous operation may yield additional cost savings.
- ✓ The tip speed ratio and power coefficient are considerably better than those of the S-rotor but are still below the values for a modern horizontal-axis, two-bladed propeller rotor.

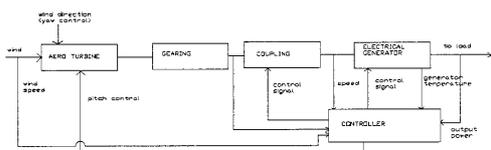
**DESIGN, ANALYSIS AND FABRICATION**

## CHAPTER 7 COMPONENTS AND DESCRIPTION

The main components of our "HORIZONTAL TURBINE TYPE DOMESTIC WIND MILL" as follows,

- Blade with Shaft
- Spur Gear Arrangement
- Battery
- Inverter
- D.C. Generator

Actual Working principle of wind mill with controller circuit is shown in fig.



**FIG 7.1 WORKING PRINCIPLE**

Aero turbines convert energy in moving air to rotary mechanical energy. In general, they require pitch control and yaw control (only in the case of horizontal or wind axis machines) for proper operation. A mechanical interface consisting of a step up gear and a suitable coupling transmits the rotary mechanical energy to an electrical generator. The out put of this generator is connected to the load or power grid as the application warrants. Yaw control. For localities with the prevailing wind in one direction, the design of the turbine can be greatly

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components. For an effective utilization, all the components need to be properly designed and matched with the rest of the components.

The windmill head supports the rotor, housing the rotor bearings. It also houses any control mechanism incorporated like changing the pitch of the blades for safety devices and tail vane to orient the rotor to face the wind. The latter is facilitated by mounting it on the top of the supporting structure on suitable bearings.

### 7.2. TRANSMISSION:

Varying the pitch of the rotor blades, conveniently controls the rate of rotation of large wind turbine generators operating at rated capacity or below, but it is low, about 40 to 50 revolutions per minute (rpm). Because optimum generator output requires much greater rates of rotation, such as 1800 rpm, it is necessary to increase greatly the low rotor of turning. Among the transmission options are mechanical systems involving fixed ratio gears, belts, and chains, singly or in combination or hydraulic systems involving fluid pumps and motors. Fixed ratio gears are recommended for top mounted equipment because of their high efficiency; know cost, and minimum system risk.

For bottom mounted equipment which requires a right-angle drive, transmission costs might be reduced substantially by using large diameter bearings with ring gears mounted on the hub to serve as a transmission to increase rotor speed to generator speed. Such a combination offers a high degree of design flexibility as well as large potential savings.

### 7.3. BLADE WITH SHAFT:-

The horizontal type wind mill is having multi-bladed (10-16 Blades) type. The blade surface is convex with the material of Mild steel. These blades are coupled to the shaft with the help of guide bush. The distances between the two blades are equivalently divided.

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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 turbine, 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 in to the wind. The area of the wind swept by the wind rotor is then a maximum. In a small turbine, yaw action is controlled by a tail van, similar to that in a typical windmill. In large 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 project the system from extreme conditions brought upon by strong winds electrical faults, and the like. The physical embodiment for such an aero-generator is shown in a generalized form. The sub-components of the windmill are:

- Wind turbine or rotor
- Wind mill head
- Transmission and control, and
- Supporting structure

Such a machine typically is a large impressive structure.

### 7.1. ROTORS:

7.1.1. Rotors are mainly of two types:

- (i) Horizontal axis rotor and
- (ii) Vertical axis rotor.

One advantage of vertical – axis machines is that they operate in all wind directions and thus need no yaw adjustment the rotor is only one of the important

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### 7.4. SPUR GEAR ARRANGEMENT:-

The spur gears, which are designed to transmit motion and power between parallel shafts, are the most economical gears in the power transmission industry. The vertical axis of the turbine is coupled with the generator by using spur gear arrangement with the gear ratio above 3 so that the generator generates maximum voltages.

### 7.5. BATTERY:

7.5.1. Introduction:

In isolated systems away from the grid, batteries are used for storage of excess solar energy converted into electrical energy. The only exceptions are isolated sunshine load such as irrigation pumps or drinking water supplies for storage. In fact for small units with output less than one kilowatt. Batteries seem to be the only technically and economically available storage means.

Since both the photo-voltaic system and batteries are high in capital costs. It is necessary that the overall system be optimized with respect to available energy and local demand pattern. To be economically attractive the storage of solar electricity requires a battery with a particular combination of properties:

- (1) Low cost
- (2) Long life
- (3) High reliability
- (4) High overall efficiency
- (5) Low discharge
- (6) Minimum maintenance
  - (A) Ampere hour efficiency
  - (B) Watt hour efficiency

We use lead acid battery for storing the electrical energy from the solar panel for lighting the street and so about the lead acid cells are explained below.

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### 7.5.2. Lead-acid wet cell:

Where high values of load current are necessary, the lead-acid cell is the type most commonly used. The electrolyte is a dilute solution of sulfuric acid ( $\text{H}_2\text{SO}_4$ ). In the application of battery power to start the engine in an auto mobile, for example, the load current to the starter motor is typically 200 to 400A. One cell has a nominal output of 2.1V, but lead-acid cells are often used in a series combination of three for a 6-V battery and six for a 12-V battery.

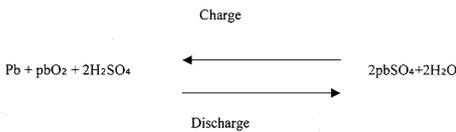
The lead acid cell type is a secondary cell or storage cell, which can be recharged. The charge and discharge cycle can be repeated many times to restore the output voltage, as long as the cell is in good physical condition. However, heat with excessive charge and discharge currents shortens the useful life to about 3 to 5 years for an automobile battery. Of the different types of secondary cells, the lead-acid type has the highest output voltage, which allows fewer cells for a specified battery voltage.

### 7.5.3. Construction:

Inside a lead-acid battery, the positive and negative electrodes consist of a group of plates welded to a connecting strap. The plates are immersed in the electrolyte, consisting of 8 parts of water to 3 parts of concentrated sulfuric acid. Each plate is a grid or framework, made of a lead-antimony alloy. This construction enables the active material, which is lead oxide, to be pasted into the grid. In manufacture of the cell, a forming charge produces the positive and negative electrodes. In the forming process, the active material in the positive plate is changed to lead peroxide ( $\text{PbO}_2$ ). The negative electrode is spongy lead ( $\text{Pb}$ ).

Automobile batteries are usually shipped dry from the manufacturer. The electrolyte is put in at the time of installation, and then the battery is charged to from the plates. With maintenance-free batteries, little or no water need be added

The chemical equation for the lead-acid cell is



On discharge, the  $\text{Pb}$  and  $\text{PbO}_2$  combine with the  $\text{SO}_4$  ions at the left side of the equation to form lead sulfate ( $\text{PbSO}_4$ ) and water ( $\text{H}_2\text{O}$ ) at the right side of the equation.

One battery consists of 6 cells, each have an output voltage of 2.1V, which are connected in series to get a voltage of 12V and the same 12V battery is connected in series, to get a 24 V battery. They are placed in the water proof iron casing box.

### 7.5.5. Caring for lead-acid batteries:

Always use extreme caution when handling batteries and electrolyte. Wear gloves, goggles and old clothes. "Battery acid" will burn skin and eyes and destroy cotton and wool clothing.

The quickest way of ruin lead-acid batteries is to discharge them deeply and leave them stand "dead" for an extended period of time. When they discharge, there is a chemical change in the positive plates of the battery. They change from lead oxide when charge out lead sulfate when discharged. If they remain in the lead Sulfate State for a few days, some part of the plate dose not returns to lead oxide when the battery is recharged. If the battery remains discharge longer, a greater amount of the positive plate will remain lead sulfate. The parts of the plates that become "sulfate" no longer store energy. Batteries that

in normal service. Some types are sealed, except for a pressure vent, without provision for adding water.

### 7.5.4. Chemical action:

Sulfuric acid is a combination of hydrogen and sulfate ions. When the cell discharges, lead peroxide from the positive electrode combines with hydrogen ions to form water and with sulfate ions to form lead sulfate. Combining lead on the negative plate with sulfate ions also produces he sulfate. There fore, the net result of discharge is to produce more water, which dilutes the electrolyte, and to form lead sulfate on the plates.

As the discharge continues, the sulfate fills the pores of the grids, retarding circulation of acid in the active material. Lead sulfate is the powder often seen on the outside terminals of old batteries. When the combination of weak electrolyte and sulfating on the plate lowers the output of the battery, charging is necessary.

On charge, the external D.C. source reverses the current in the battery. The reversed direction of ions flows in the electrolyte result in a reversal of the chemical reactions. Now the lead sulfates on the positive plate reactive with the water and sulfate ions to produce lead peroxide and sulfuric acid. This action reforms the positive plates and makes the electrolyte stronger by adding sulfuric acid.

At the same time, charging enables the lead sulfate on the negative plate to react with hydrogen ions; this also forms sulfuric acid while reforming lead on the negative plate to react with hydrogen ions; this also forms currents can restore the cell to full output, with lead peroxide on the positive plates, spongy lead on the negative plate, and the required concentration of sulfuric acid in the electrolyte.

are deeply discharged, and then charged partially on a regular basis can fail in less then one year.

Check your batteries on a regular basis to be sure they are getting charged. Use a hydrometer to check the specific gravity of your lead acid batteries. If batteries are cycled very deeply and then recharged quickly, the specific gravity reading will be lower than it should because the electrolyte at the top of the battery may not have mixed with the "charged" electrolyte. Check the electrolyte level in the wet-cell batteries at the least four times a year and top each cell of with distilled water. Do not add water to discharged batteries. Electrolyte is absorbed when batteries are much discharged. If you add water at this time, and then recharge the battery, electrolyte will overflow and make a mess. Keep the top of your batteries clean and check that cables are tight. Do not tighten or remove cables while charging or discharging. Any spark around batteries can cause a hydrogen explosion inside, and ruin one of the cells, and you.

On charge, with reverse current through the electrolyte, the chemical action is reversed. Then the  $\text{Pb}$  ions from the lead sulfate on the right side of the equation re-form the lead and lead peroxide electrodes. Also the  $\text{SO}_4$  ions combine with  $\text{H}_2$  ions from the water to produce more sulfuric acid at the left side of the equation.

### 7.5.6. Current ratings:

Lead-acid batteries are generally rated in terms of how much discharge currents they can supply for a specified period of time; the output voltage must be maintained above a minimum level, which is 1.5 to 1.8V per cell. A common rating is ampere-hours (A.h.) based on a specific discharge time, which is often 8h. Typical values for automobile batteries are 100 to 300 A.h.

As an example, a 200 A.h battery can supply a load current of 200/8 or 25A, used on 8h discharge. The battery can supply less current for a longer time or more current for a shorter time. Automobile batteries may be rated for "cold

cranking power", which is related to the job of starting the engine. A typical rating is 450A for 30s at a temperature of 0 degree F.

Note that the ampere-hour unit specifies coulombs of charge. For instance, 200 A.h. corresponds to  $200A \times 3600s$  ( $1h=3600s$ ). the equals 720,000 A.S, or coulombs. One ampere-second is equal to one coulomb. Then the charge equals 720,000 or  $7.2 \times 10^5 C$ . To put this much charge back into the battery would require 20 hours with a charging current of 10A. The ratings for lead-acid batteries are given for a temperature range of 77 to 80°F. Higher temperature increase the chemical reaction, but operation above 110°F shortens the battery life.

Low temperatures reduce the current capacity and voltage output. The ampere-hour capacity is reduced approximately 0.75% for each decreases of 1° F below normal temperature rating. At 0°F the available output is only 60 % of the ampere-hour battery rating. In cold weather, therefore, it is very important to have an automobile battery unto full charge. In addition, the electrolyte freezes more easily when diluted by water in the discharged condition.

**7.5.7. Specific gravity:**

Measuring the specific gravity of the electrolyte generally checks the state of discharge for a lead-acid cell. Specific gravity is a ratio comparing the weight of a substance with the weight of a substance with the weight of water. For instance, concentrated sulfuric acid is 1.835 times as heavy as water for the same volume. Therefore, its specific gravity equals 1.835. The specific gravity of water is 1, since it is the reference.

In a fully charged automotive cell, mixture of sulfuric acid and water results in a specific gravity of 1.280 at room temperatures of 70 to 80°F. As the cell discharges, more water is formed, lowering the specific gravity. When it is down to about 1.150, the cell is completely discharged.

Specific-gravity readings are taken with a battery hydrometer. Note that the calibrated float with the specific gravity marks will rest higher in an

It may be of interest to note that an automobile battery is in a floating-charge circuit. The battery charger is an AC generator or alternator with rectifier diodes, driven by a belt from the engine. When you start the car, the battery supplies the cranking power. Once the engine is running, the alternator charges the battery. It is not necessary for the car to be moving. A voltage regulator is used in this system to maintain the output at approximately 13 to 15 V.

The constant voltage of 24V comes from the solar panel controlled by the charge controller so for storing this energy we need a 24V battery so two 12V battery are connected in series. It is a good idea to do an equalizing charge when some cells show a variation of 0.05 specific gravity from each other. This is a long steady overcharge, bringing the battery to a gassing or bubbling state. Do not equalize sealed or gel type batteries.

With proper care, lead-acid batteries will have a long service life and work very well in almost any power system. Unfortunately, with poor treatment lead-acid battery life will be very short.

**7.6. INVERTERS:**

**7.6.1. Introduction:**

The process of converting D.C. into A.C. is known as INVERSION. In other words, we may define it as the reverse process of rectification. The device, which performs this process, is known as an INVERTOR. Inversion is, by no means, a recent process. In olden days gas-filled tubes and vacuum tubes were used to develop inverters. Thyristor inverter is popularly used as a large power device.

Vacuum tube inverters were generally used for high-frequency applications. Some of the main disadvantages of the tube as well as the mercury pool type inverters are:

1. They are very costly
2. They are very big in size and heavy in weight

electrolyte of higher specific gravity. The decimal point is often omitted for convenience. For example, the value of 1.220 is simply read "twelve twenty". A hydrometer reading of 1260 to 1280 indicates full charge, approximately 12.50 are half charge, and 1150 to 1200 indicates complete discharge.

The importance of the specific gravity can be seen from the fact that the open-circuit voltage of the lead-acid cell is approximately equal to

$$V = \text{Specific gravity} + 0.84$$

For the specific gravity of 1.280, the voltage is  $1.280 + 0.84 = 2.12V$ , as an example. These values are for a fully charged battery.

**7.5.8. Charging the lead-acid battery:**

The requirements are illustrated in figure. An external D.C. voltage source is necessary to produce current in one direction. Also, the charging voltage must be more than the battery e.m.f. Approximately 2.5 per cell are enough to over the cell e.m.f. so that the charging voltage can produce current opposite to the direction of discharge current.

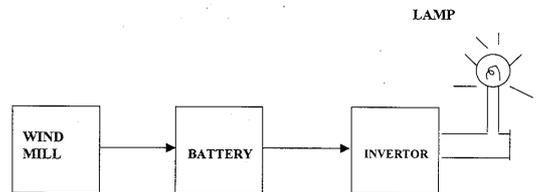
Note that the reversal of current is obtained just by connecting the battery VB and charging source VG with + to + and -to-, as shown in figure. The charging current is reversed because the battery effectively becomes a load resistance for VG when it higher than VB. In this example, the net voltage available to produce charging currents is  $15-12=3V$ . A commercial charger for automobile batteries is essentially a D.C. power supply, rectifying input from the AC power line to provide D.C. output for charging batteries.

Float charging refers to a method in which the charger and the battery are always connected to each other for supplying current to the load. In figure the charger provides current for the load and the current necessary to keep the battery fully charged. The battery here is an auxiliary source for D.C. power.

3. They have very poor efficiency
4. The voltage drop across these devices is very high
5. They are less accurate
6. They are very slow in response, etc.

The basic principle of an inverter can be explained with the help of a simple circuit shown in figure

The D.C. battery storage is given to an inverter and this inverter inverts 12V D.C. to input in to AC output. step upped in to 230V. The 230V AC supply is given to the lamp.



**FIG 7.2 ENERGY FLOW FROM ROTOR TO LOAD**

The basic principle of an inverter can be explained with the help of a simple circuit, as shown in figure. If switch S is connected alternately to position 1 and 2 at a rapid speed and if S is not kept closed to any of the two positions (1 and 2) for too long, and then an alternating voltage will appear across the primary winding. This can be explained by the direction of the current flow in the primary winding.

Although the voltage applied is D.C. in nature, the direction of current flow in the primary winding when S is connected to position 1 is from top to bottom whereas when S is connected at position 2, the current flows from bottom to top. This change in the direction of current flow in the primary winding gives

rise to an alternating voltage in it. The frequencies of this alternating voltage will depend on how rapidly the switch (S) positions are interchanged. This alternating voltage in the primary winding will induce an alternating emf in the secondary winding, which will act as the A.C. output.

With the development of semi-conductor devices, a lot of improvements to took place in the design of inverter circuits. Transistor being a fast-switching device was used as a switch for developing low and medium power inverters.

Later, with the arrival of SCRs, SCR inverters (in general, thyristor inverters) were developed. This usually have more power rating as compared to the thyristor inverters. SCRs are normally driven by means of gate pulses through the gates. Efficiency of an inverter increases as its input voltage is raised because the voltage drop in the device becomes insignificant when compared to the high input voltage.

For low voltage inversion, special transistors may be used. After the inversion, the output voltage may be raised to the required level by means suitable transformer. For very low voltage and high current requirement, tunnel diodes are used for developing the inverter.

In this project we use thyristor inverter for inverting the output 24V D.C. voltage from the storage battery with step up of voltage (using transformer) of 230 A.C. voltages. And this explained below.

#### 7.6.2. Working principle of inverters:

The basic principle of an inverter has been explained in the introduction, the block diagram representation for an inverter circuit is shown in figure (8). Resonance circuit or the Oscillator circuit is the heart of the inverter. This block is also known as the Tank circuit. It is built up by using a suitable power transistor and a combination of inductor and/or capacitor with resistors of required value. The resistor, capacitor, inductor, etc. are used for building up the oscillations are called the resonant elements.

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The magnetic field may be supplied by either a permanent magnet or an electromagnet. For now, we will use a permanent magnet to describe a basic DC generator.

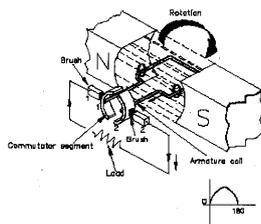


FIG 7.3 GENERATOR

**Basic Operation of a DC Generator** A single conductor, shaped in the form of a loop, is positioned between the magnetic poles. As long as the loop is stationary, the magnetic field has no effect (no relative motion). If we rotate the loop, the loop cuts through the magnetic field, and an EMF (voltage) is induced into the loop.

When we have relative motion between a magnetic field and a conductor in that magnetic field, and the direction of rotation is such that the conductor cuts the lines of flux, an EMF is induced into the conductor. The magnitude of the induced EMF depends on the field strength and the rate at which the flux lines are cut. The stronger the field or the more flux lines cut for a given period of time, the larger the induced EMF.

$$E = K\Phi N$$

Where, E = generated voltage

K = fixed constant

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The D.C. is fed to the oscillator from a D.C. source. The oscillator builds up oscillations the designed frequency at a low voltage. The frequency depends on the values and combinations of the resonant element. The basic formula for producing oscillations by the Tank circuit is that it should be under damped in nature. The mathematical condition for this nature is given by,

$$(R^2) < [(4L)/C]$$

In case a battery is used as a D.C. source rectified D.C. obtained from A.C. mains should change it.

The low voltage A.C. output from the oscillator is then fed to a step up transformer for raising the output A.C. voltage at the required level. A 2N 3055 transistor is commonly used for developing low power (50 to 70W) inverters. For medium and high power requirements, now a day, mostly thyristors inverters are used.

### 7.7. PERMANENT MAGNET D.C. GENERATOR:

#### 7.7.1. Voltage Production:

DC Circuits, that there are three conditions necessary to induce a voltage into a conductor.

1. A magnetic field
2. A conductor
3. Relative motion between the two.

A DC generator provides these three conditions to produce a DC voltage output.

#### 7.7.2. Theory of Operation:

A basic DC generator has four basic parts:

- (1) A magnetic field;
- (2) A single conductor, or loop;
- (3) A commutator; and
- (4) Brushes

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F = magnetic flux strength

N = speed in RPM

The direction of the induced current flow can be determined using the "left-hand rule" for generators. This rule states that if you point the index finger of your left hand in the direction of the magnetic field (from North to South) and point the thumb in the direction of motion of the conductor, the middle finger will point in the direction of current flow.

For example, the conductor closest to the N pole is traveling upward across the field; therefore, the current flow is to the right, lower corner. Applying the left-hand rule to both sides of the loop will show that current flows in a counter-clockwise direction in the loop.

#### 7.7.3. Dc generator construction :

**Output Voltage-vs-Load Current for Shunt-Wound DC Generator** the shunt-wound generator, running at a constant speed under varying load conditions, has a much more stable voltage output than does a series-wound generator. Some change in output voltage does take place. This change is caused by the fact that, as the load current increases, the voltage drop (IR) across the armature coil increases, causing output voltage to decrease.

As a result, the current through the field decreases, reducing the magnetic field and causing voltage to decrease even more. If load current is much higher than the design of the generator, the drop in output voltage is severe. For load current within the design range of the generator, the drop in output voltage is minimal.

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## CHAPTER 8

### DESIGN OF BLADE CONTOUR

The contour and shape of the blade determine the energy conversion and power extraction. There are different types of blade contours such as flat straight blade, flat angled blade, twisted blade, aerofoil, etc.,

There are some theories which explain the aerodynamics and design blades of turbine or propeller. Some of the theories are explained below with some common examples.

#### 8.1. AXIAL MOMENTUM THEORY:

The function of a propulsive system is to produce a thrust. This can be achieved only by imparting axial momentum to the fluid to force a backward motion. The energy associated to the fluid is an inevitable loss.

The original theory, as first formulated by Rankine and Froude, excluded the viscous effects, the rotation of the slipstream, and the uneven load distribution, with the scope of evaluating the ideal efficiency of such a propulsive system (also called *actuator disc*).

The rotor is degenerated into a disc perpendicular to the thrust, and is capable of sustaining a pressure difference between its two sides, and of generating/imparting linear momentum to the fluid that passes through it. The mechanism of thrust generation requires the evaluation of the mass flow through a stream tube bounded by the disc.

In a later refinement the load distribution on the disc was taken into account with the momentum equation, and led to the conclusion that the load, in fact, must be constant over the actuator disc to produce optimal thrust (e.g. with minimum energy losses).

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#### 8.4. COMBINED BLADE-ELEMENT AND MOMENTUM THEORY:

The combination of the blade element with the momentum theory makes it possible to evaluate a field of induced velocity around the propeller, and therefore correct the inflow conditions assumed in the primitive blade element theory. Also, the use of correction terms for  $C_D$  and  $C_L$  from the finite aspect-ratio wing theory yields more realistic terms for the forcing equations.

The induced velocities are not known until the propeller loads are computed. With the loading available one can recompute the field of induced velocities and thus iterate the process. Many problems have remained to this day: the theory holds for not too loaded propellers; stall cannot be predicted; hub and tip losses cannot be evaluated; unsteady and yawed operation are beyond the theory.

#### 8.5. VORTEX METHODS:

The description of the blade and its slipstream by vortex lines/surfaces removes some of the limitations of the BEM/momentum theory.

If the wake were to be known exactly, then the field of induced velocities and other relevant quantities could be computed more readily. This can be done, in fact, by appropriate manipulation of the Biot-Savart equation for the inviscid vortex line. The use of the *vortex theory* has opened the way to the solution of time-dependent flows.

The classical expression of a vortex-induced velocity is the Biot-Savart law, that is the fundamental relationship between a vortex, its shape, and the velocity that it induces. This method proves extremely valuable, because it can track the main pattern of the vortex system.

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#### 8.2. GENERAL MOMENTUM THEORY:

An important extension of the axial momentum theory is the introduction of an angular momentum balance equation for the slipstream, to take into account the rotation imparted to the fluid by the propulsive system.

The theory finds that the optimal load on the disc is constant, and a small efficiency loss for lightly loaded propellers (of the order of a few percent).

A basic result was that the efficiency increases with the propeller diameter, and decreases with the increasing disc loading.

The propeller should be as large and as lightly loaded as possible, because it is more efficient to move a given mass of fluid through a large stream tube at low speed, rather than through a small stream tube at high speed.

This is one of the reasons why marine propellers are so large and so slow (speeds lower than 100 rpm).

#### 8.3. BLADE-ELEMENT THEORY:

A more realistic interpretation of the propeller operation is the use of sectional airfoil data to derive integral quantities for the entire propeller. This theory was developed only when the airfoil theory was well understood and airfoil data were made available by systematic wind tunnel experiments.

The blade element, or strip theory, provides a means to determine forces and moments by assuming the blade as composed of a number of aerodynamically independent cross-sections, whose characteristics are the same as a blade at a proper angle of attack. Therefore the operation of a cross-section is indirectly related to that of a two-dimensional airfoil. Its main drawback is that experimental data are needed *a priori*.

Even when these data are available the correlation between airfoil in axial flow and a rotating airfoil is not straightforward, since it involves the prediction of the field of wake-induced velocities. This problem is usually solved by defining an equivalent angle of attack to be used in two-dimensional calculations.

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#### 8.6. LIFTING SURFACE METHODS:

Lagrangian vortex-lattice wake representations are practically the top-of-the-line models of long-term rotor free wakes. Moreover, a vortex-lattice wake can be directly attached to a rotor blade for a complete BEM solution. This strategy allows to overcome the problem of guessing the wake shape at the beginning of the time marching solution. The method is quite flexible, since it allows the computation of single- and multi-bladed rotors with arbitrary flight path, and free wake analysis in the time-stepping mode.

One of the problems with the method is that the computational time increases linearly (or exponentially) with the number of time steps (e.g. with the number of panels released in the wake). A solution past the transient state (three or four rounds) may easily require thousands of vortices.

#### 8.7. PANEL METHODS:

Large grid extensions are required by any field method, including the full potential equation. Other potential flow theories, such as the panel methods are not field methods, but the entire flow field can be resolved once the solution has been determined at appropriate boundaries.

The unsteady effects are formulated in a proper way, and the general method is nominally correct, although numerical solutions of complex flows with a free wake analysis are difficult (when not impossible) to obtain, due to some peculiar features of the vortical flows. Panel methods are of the same variety of the unsteady vortex lattice methods, but include the thickness effects in a more detailed description of the aerodynamic system.

#### 8.8. COMPUTATIONAL FLUID DYNAMICS:

CFD is the last word in rotor aerodynamics. Full potential, Euler and Navier-Stokes methods have been exploding in the last decade, thanks also to the progress in computer hardware. Virtually all problems have been attempted.

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Full potential methods have been left behind due to the difficulty of modeling the wake; Euler methods are limited by the lack of viscosity. Additional wake modeling is needed if the grid has not enough resolution, but this problem is just contingent, because limited by the current computer power.

The development of accurate CFD codes for a rotating blade is in itself a difficult task, that requires lengthy computer programming and debugging sessions.

#### 8.9. EULER METHODS:

Euler methods have been advanced as higher order schemes, requiring very fine grids, have been developed. In the most recent works it is proven that, along with fine resolution and high order integration schemes, multi-block grids are required to reduce the numerical diffusion of the vorticity. Typically, this occurs at the blade tips. However, if the main interest is to compute the blade loads, a multi-block grid is not needed, but the requirements on the resolution are still very high without assumptions on the wake evolution.

#### 8.10. NAVIER-STOKES:

In real flows the vortex system decays due to the presence of the viscosity. The diffusion process is further complicated by the onset of turbulence. Viscosity and turbulence are other important phenomena that limit and finally define the performance of a rotor blade. However, the diffusion process affects the rotor wake at a larger scale.

#### 8.11. STATE OF THE ART:

The complexity of most of the new CFD methods has led to a time lag in code development. The designers of large scale codes must consider the manageability of a new projects, which usually requires years of development, or dozens of scientist-years.



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State-of-the art numerical methods are likely to be fully exploited in the next generation of computer codes, especially if higher-level symbolic languages will become available.

Some Navier-Stokes solvers have been developed over the past ten years, but a mesh-independent solution still requires large computing costs. Even then there are some cases where the wake effects are simulated by changing the local angle of attack, after computing the downwash with the lifting line theory.

#### 8.12. SELECTED DESIGN AND ANALYSIS MODEL:

From these methods the COMPUTATIONAL FLUID DYNAMICS method is used for the design and analysis of blade shape. The software tool for the CFD used in this project is FLUENT. In the next chapter, the analysis for different types of blade is done.

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## CHAPTER 9

### SELECTION OF BLADE CONTOUR USING CFD

The blade contour is decided by using this CFD analysis. This is done by the software called FLUENT. It contains all the governing equations as in-built functions.

#### 9.1. ASSUMPTIONS:

- > The wind flow is assumed to be uniform steady laminar flow
- > Navier-stokes equation.
- > Turbine is assumed to be a impulse
- > Wind velocity of 3 m/s
- > No boundary layer formation

##### 9.1.1. Uniform Steady laminar flow:

This flow is assumed to be uniform steady laminar flow. If the flow is turbulent in nature then there may be chance of stalling effect. So this effect neglected for analysis purpose.

##### 9.1.2. Impulse Turbine:

Naturally all the wind turbines are acting as both impulse turbine and reaction turbine. The impulse turbine produces power by the momentum of the wind whereas the reaction turbine produces power by using the weight of the fluid. Since the effect due to reaction is very small it is neglected. Thus the turbine is considered to be shrouded impulse turbine as shown in fig.10.1

##### 9.1.3. Boundary layer formation:

Due to the friction between the fluid and wall there may be frictional loss in fluid velocity. For analysis purpose this effect is neglected.

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#### 9.2. BLADE ANALYSIS:

The FLUENT software is used to analyze the selected blades. In this project work the following blades were analyzed for their efficiency to convert the kinetic energy of the wind into useful electrical power output.

- > Flat straight blade
- > Flat angled blade(LEFT)
- > Flat angled blade(RIGHT)

The above blades are also easy to manufacture and also economic to buy.

##### 9.2.1. Flat straight blade:

The side view or cross section of the blade is shown in the fig 9.1 and 9.2. This shows the flow of wind on the flat and straight blade. Since blade is straight there is less chance of expansion. The whole velocity profile is obstructed by the blade. This leads to sudden loss of velocity of wind. In the fig the green arrows indicate the available wind velocity that is 3m/s. the red profile indicates the expanded velocity and the blue indicates the minimum velocity due to the loss of kinetic energy. In this type of blade profile, the back flow is very strong which tends to more power loss and also the expanded velocity also can't be reused. The power co-efficient of this contour is also very less.

##### 9.2.2. Flat angled blade (left):

In this profile the velocity of the wind is getting expansion on the wall of the blade. The power co-efficient is also higher than that of the flat blade. The power of back flow is less here which is shown in fig.9.3 and 9.4. The expanded velocity can be reused for next blade. Thus these types of contour give more power co-efficient.

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9.2.3. Flat angled blade (right):

These types of profile provide the path for expansion of wind velocity as shown in fig.9.5 and 9.6. Thus this expansion leads to recovery of velocity which is lost during the conversion of kinetic energy into mechanical power. The power of the back flow is also less thus these increases the power co-efficient of the turbine. This type of blade profile gives more power than that of the others. Thus this blade is efficient in energy conversion.

The analysis clearly shows that flat angled blade – right gives very good power co-efficient. The blades are curved for better performance as shown in fig 9.7 and 9.8. Thus the expanded velocity is reused by that blade itself. So this type is selected, designed and fabricated.

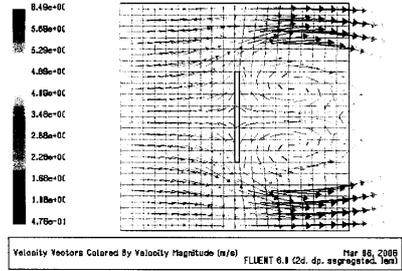


FIG 9.1 VELOCITY CONTOUR OF FLAT AND STRAIGHT BLADE

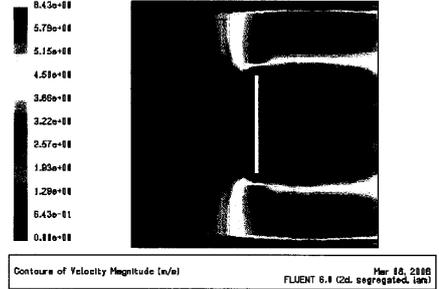


FIG 9.2 VELOCITY MAGNITUDE OF FLAT AND STRAIGHT BLADE

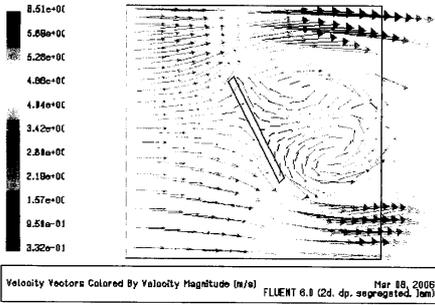


FIG 9.3 VELOCITY CONTOUR OF FLAT AND ANGLED BLADE (LEFT)

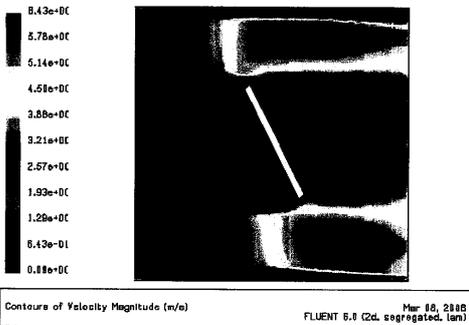


FIG 9.4 VELOCITY MAGNITUDE OF FLAT AND ANGLED BLADE (LEFT)

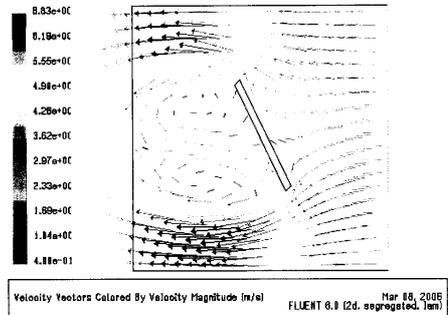


FIG 9.5 VELOCITY CONTOUR OF FLAT AND STRAIGHT BLADE (RIGHT)

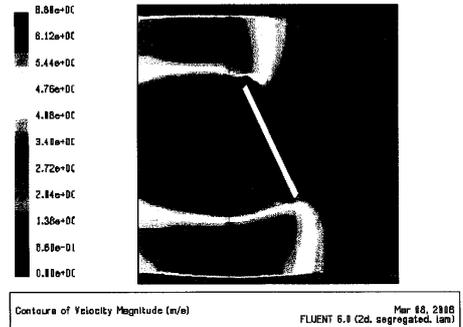


FIG 9.6 VELOCITY MAGNITUDE OF FLAT AND STRAIGHT BLADE (RIGHT)

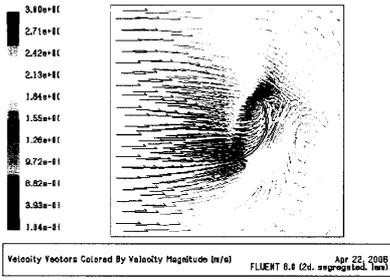


FIG 9.7 VELOCITY CONTOUR OF CURVED BLADE (RIGHT)

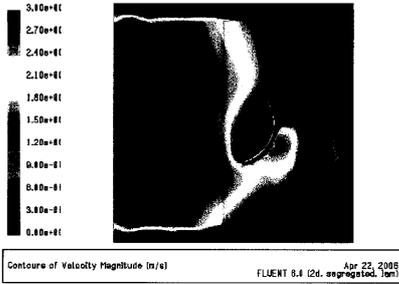


FIG 9.8 VELOCITY MAGNITUDE OF CURVED BLADE (RIGHT)

CHAPTER 10  
DRAFTING AND FIGURES

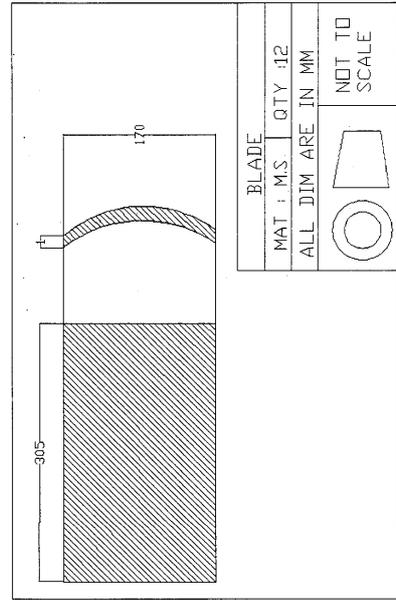


FIG 10.1 BLADE

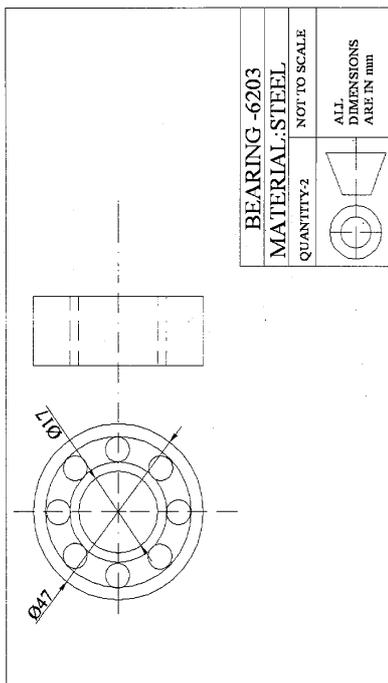


FIG 10.2 BEARING

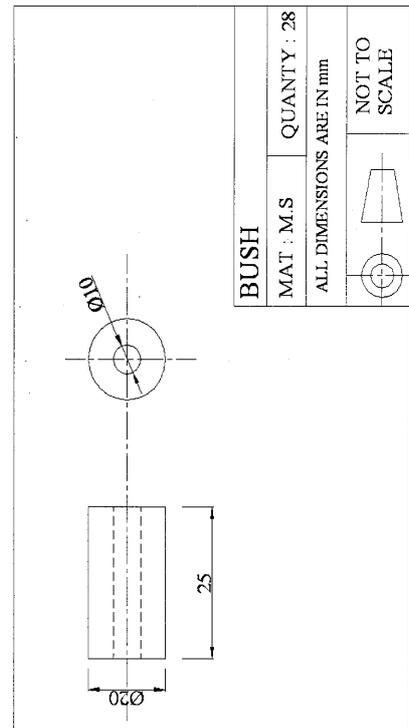


FIG 10.3 BUSH

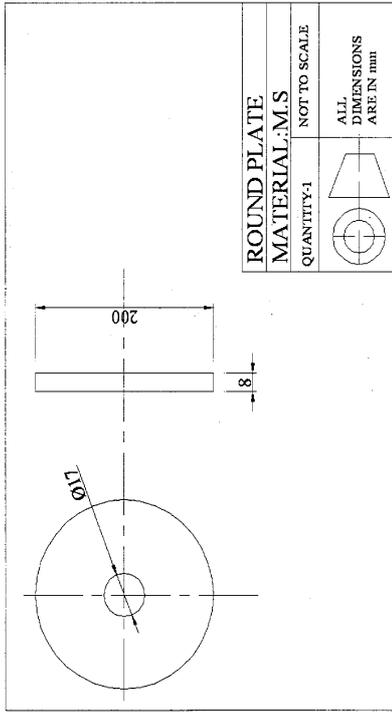


FIG 10.4 ROUND PLATE

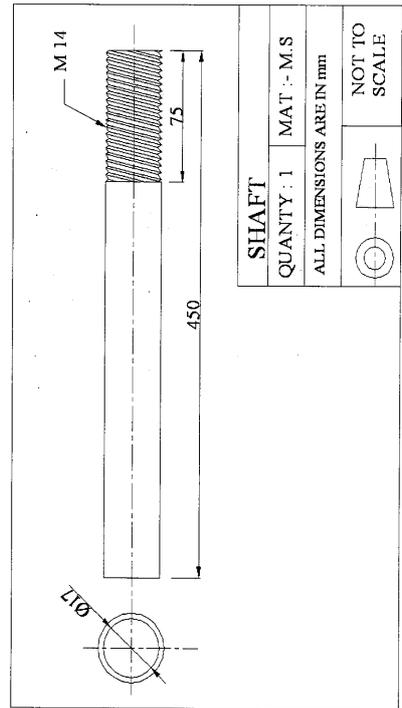


FIG 10.5 SHAFT

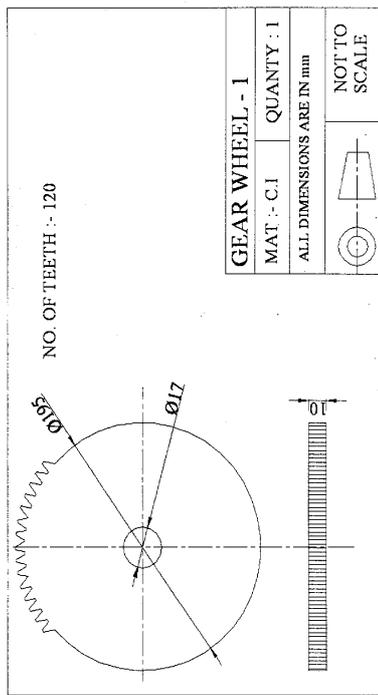


FIG 10.6 GEAR WHEEL I

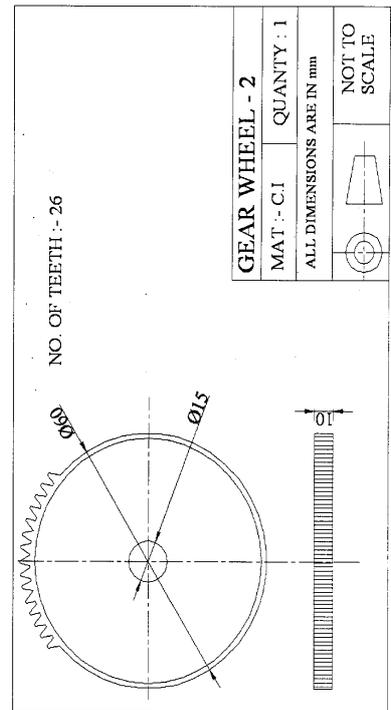


FIG 10.7 GEAR WHEEL II

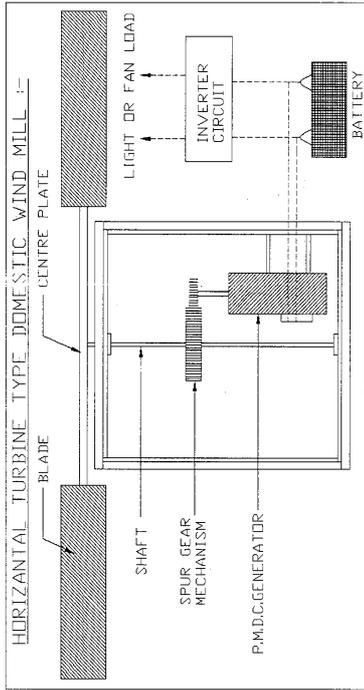


FIG 10.8 LAYOUT OF WINDMILL

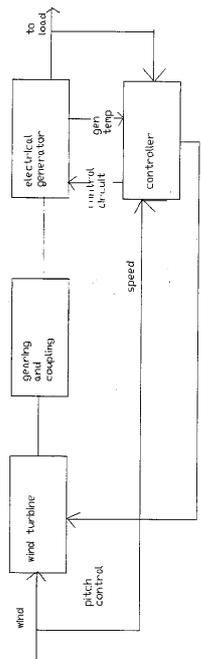


FIG 10.10 ELECTRICAL CIRCUIT WIND MILL

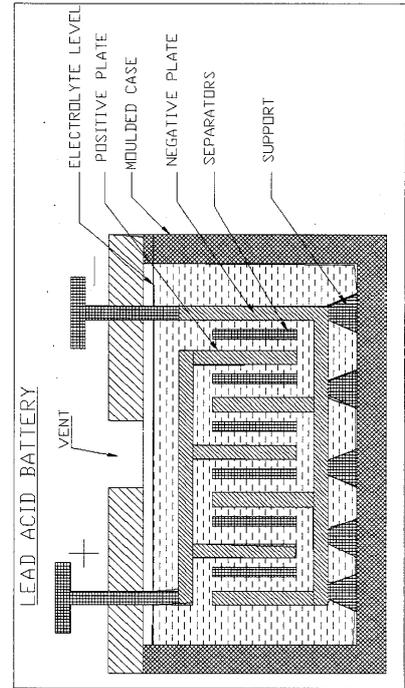


FIG 10.9 LEAD ACID BATTERY

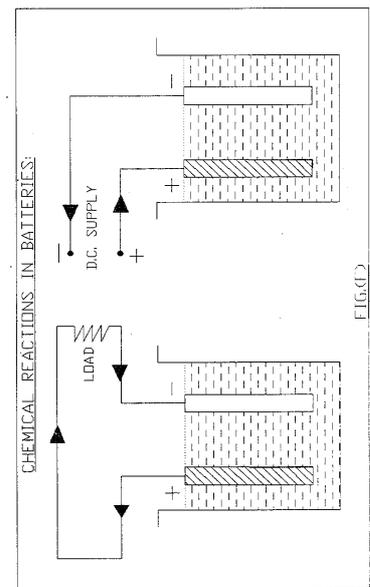


FIG 10.11 CHEMICAL REACTION IN BATTERY

FIG.(C)

**CHAPTER-11  
LIST OF MATERIALS**

**TABLE 11.1 BILL OF MATERIALS**

Sl. No.	Name of the Parts	Quantity	Materials
01.	Blades	14	M.S
02.	Frame structure	1	M.S
03.	Battery	1	Lead-acid
04.	Generator	1	Aluminium
05.	Bearing	2	Steel
06.	Connecting Wire	-	Cu
07.	Gear Wheel	2	C.I
08.	Inverter	1	Electronic
09.	Blade Shaft	14	M.S
10.	Bush	28	M.S
11.	Round Plate	1	M.S
12.	Main Shaft	1	M.S

Thus the parts were designed and fabricated separately. The designs of various blade profiles were done and they were analyzed for possible maximum efficiency i.e. straight flat profile, inclined flat (left and right) profile and inclined curved profile. The best performing profile was selected and manufactured. The wind mill was successfully assembled. Here the angle of the blades can be adjusted so as to get better performance. This manufactured windmill was mounted and power output was obtained for domestic consumption.

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$$\begin{aligned} \text{Manufacturing Cost} &= \text{Material Cost} + \text{Labour cost} \\ &= 9500+1500 \\ &= \text{Rs.11000/-} \end{aligned}$$

$$\begin{aligned} \text{Overhead Charges} &= 10\% \text{ of the manufacturing cost} \\ &= \text{Rs.1100/-} \end{aligned}$$

**12.4. TOTAL COST:**

$$\begin{aligned} \text{Total cost} &= \text{Material Cost} + \text{Labour cost} + \text{Overhead Charges} \\ &= 9500+1500+1100 \\ &= \text{Rs.12100/-} \end{aligned}$$

**Total cost for this project =Rs.12100/-**

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**CHAPTER-12  
COST ESTIMATION**

**12.1. MATERIAL COST:-**

**TABLE 12.1 MATERIAL LIST**

Sl. No.	Name of the Parts	Quantity	Materials
01.	Blades	14	M.S
02.	Frame structure	1	M.S
03.	Battery	1	Lead-acid
04.	Generator	1	Aluminium
05.	Bearing	2	Steel
06.	Connecting Wire	-	Cu
07.	Gear Wheel	2	C.I
08.	Inverter	1	Electronic
09.	Blade Shaft	14	M.S
10.	Bush	28	M.S
11.	Round Plate	1	M.S
12.	Main Shaft	1	M.S

**Material cost = Rs.9500/-**

**12.2. LABOUR COST:**

LATHE, DRILLING, WELDING, GRINDING, POWER HACKSAW, GAS CUTTING:

**Labour Cost = Rs.1500/-**

**12.3. OVERHEAD CHARGES:**

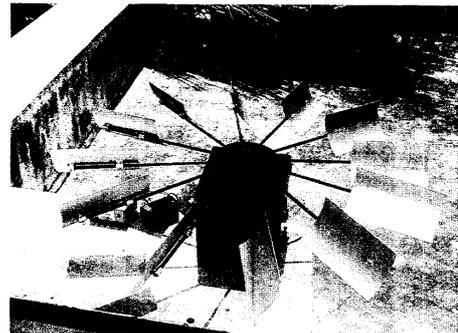
The overhead charges are arrived by "Manufacturing cost"

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**CHAPTER – 13  
TEST RUNNING**



**FIG 13.1 ASSEMBLED WIND MILL I**



**FIG 13.2 ASSEMBLED WIND MILL II**

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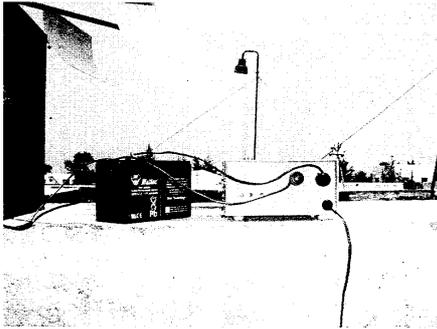


FIG 13.3 INVERTER AND BATTERY

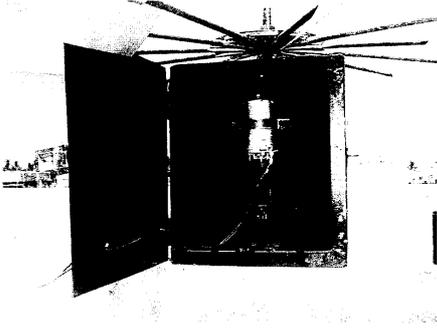


FIG 13.4 GEAR ASSEMBLY WITH GENERATOR I

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### CHAPTER-13 CONCLUSION

Through this project we have designed and manufactured a wind mill on a lower power scale which can be used domestically for day to day power consumption (240 Watts). Detailed flow analysis on various blade profiles has ensured maximum output because of proper utilization of the available energy.

In India the interest in the windmills was shown in the last fifties and early sixties. A part from importing a few from outside, new designs was also developed, but it was not sustained. It is only in the last few years that development work is going on in many institutions. An important reason for this lack of interest in wind energy must be that wind, in India area relatively low and vary appreciably with the seasons. Data quoted by some scientists that for India wind speed value lies between 3m/s to 7m/s. These low and seasonal winds imply a high cost of exploitation of wind energy. Calculations based on the performance of a typical windmill have indicated that a unit of energy derived from a windmill will be at least several times more expensive than energy derivable fro electric distribution lines at the standard rates, provided such electrical energy is at all available at the windmill site.

The above argument is not fully applicable in rural areas for several reasons. First electric power is not and will not be available in many such areas due to the high cost of generation and distribution to small dispersed users. Then there is possibility of reducing the cost of the windmills by suitable design. This project has aimed at offsetting the disadvantage and thereby facilitating electrical power even to the economically backward sector. Further more, the usage of renewable wind energy indicates very low investment with high profit margins creating independent power units even in rural villages and other developing sectors.

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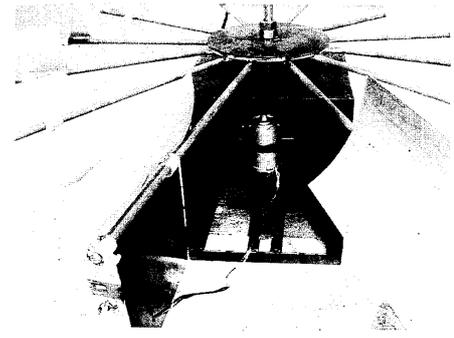


FIG 13.5 GEAR ASSEMBLY WITH GENERATOR II

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