Wind Energy

Wind results from air in motion. Air in motion arises from a pressure gradient. It has been estimated that 2% of the solar radiation falling on the face of the earth is converted to KE in the atmosphere and 30% of the KE occurs in the lowest 1000 m elevation. The energy available in the wind over the earth surface is 1.6 x 107 MW which is of the order of magnitude of present energy consumption on the earth. In India air speed values lies between 05-20 km/hr. Wind speed increase with height. They are measured at standard height of 10m where they are found to be 20- 25% greater than close to the ground surface.

- **Wind Power:**

Wind possesses kinetic energy by virtue of its motion. Factors that determine the output from wind mill

(1) Wind Speed

(2) Cross Section of wind swept by rotor

(3) Over all conversion efficiency of rotor, transmission system and generator/ pump. Wind mill works on the principle of converting KE of the wind into mechanical energy. Power is equal to energy per unit time

$$KE = ½\ mV2$$
$$= ½\ \rho\ AV.V2$$
$$= ½\ \rho\ AV3, \text{ watts}$$

Where m = ρ AV, ρ= Air density = 1.225 kg/m3 at sea level and changes by 10% with altitude

Area swept by the rotor, A = π /4 D2, V = wind velocity
Maximum available energy = ½ ρπ/4 D2 V3 = 1/8 ρπ D2 V3

✓ **From equation,**

1. The wind power available is directly proportional to the air density
2. By doubling the diameter of the rotor the power will increase 4 fold
3. By doubling wind speed the power available will increase 8 fold

- **Suitable places for erection of wind mill**
  1. Off shore and on the sea coast – wind energy availability is 2400 KWH/m2/year
  2. Mountains – 1600 KWH/m2/year
  3. Plains – 750 KWH/m2/year

- **Places unsuitable for wind mill**
  1. Humid equatorial region. In these area wind velocity is minimum
  2. Warm, windy countries where frequency of cyclones is more

Advantages of Wind Energy

1. It is renewable source of energy
2. Now polluting and no adverse influences on environment.
3. No fuel and no transportation is required
4. The cost of electricity production is comparatively low

Disadvantages

1. Wind energy is dilute and fluctuating in nature
2. It requires storage capacity
3. Machines operating on wind energy are noisy
4. Wind power machines are relatively have high overall weight (110 kg/kw)
5. large area is required for wind mill
6. Efficiency of operation is poor and maintenance costs are high

❖ Wind mills Types and Performance

A wind mill is a machine for wind energy conversion. A wind turbine converts the kinetic energy of the wind's motion to mechanical energy transmitted by the shaft. A generator further converts it to electrical energy, thereby generating electricity.

Wind mills are generally classified as

- Horizontal axis type, and
- Vertical axis type,

depending on their axis of rotation.

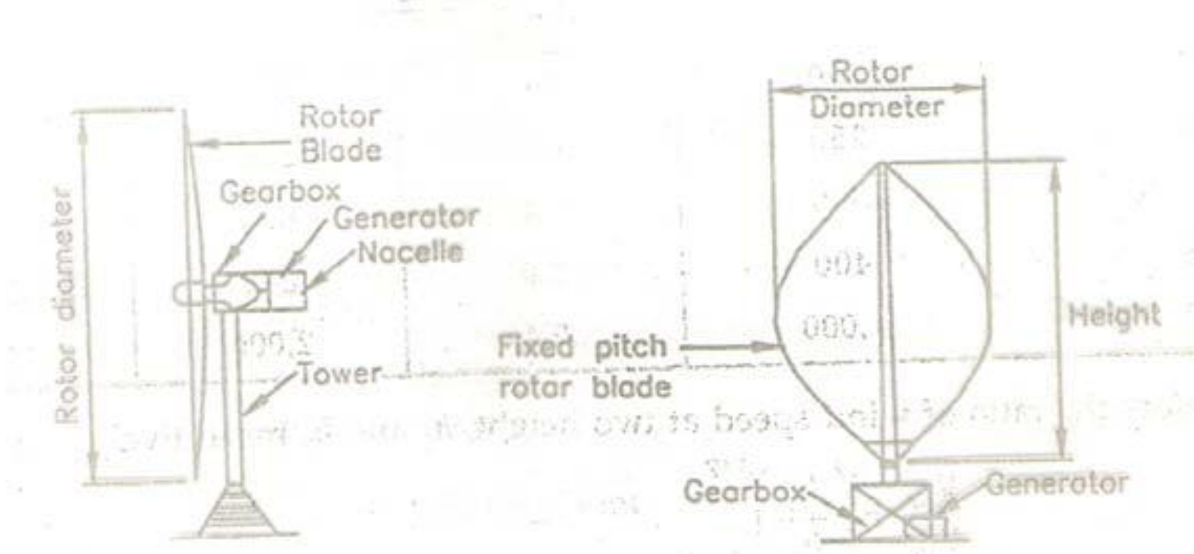
Horizontal axis wind mills further sub-classified as single bladed, double bladed, multiblade and bicycle multibladed type, sail, wing.

The vertical axis wind mill is again sub-divided into two major types:

(i) Savonius or 'S' type rotor mill (low velocity wind),

(ii) Darrieus type rotor mill (high velocity wind), based on the working speed of the machine and the velocity ranges required by the machine for operation.

Vertical axis machines are of simple design as compared to horizontal axis.



(a) Horizontal axis (b) Vertical axis

❖Vertical Axis Type Wind Mills

✓ **The Savonius Rotor:** The simplest of the modern types of wind energy conversion systems is the Savonius rotor which works like a cup anemometer. This type was invented by S.J. Savonius in the year 1920. This machine has become popular since it requires relatively low velocity winds for operation.

✓ **Constructional details and principle of operation.** It consists of two half-cylinders facing opposite directions in such a way as to have almost an S-shaped cross-section. The S shaped rotors are supported at top and bottom by two circular plates. These curved blades fixed on central pipe and free to rotate.

There two semi-circular drums are mounted on a vertical axis perpendicular to the wind direction with a gap at the axis between the two drums. Irrespective of the wind direction the rotor rotates such as to make the convex sides of the buckets head into the wind. However, instead of having two edges together to make an S-shape, they overlap to leave a wide space between the two inner edges, so that each of these edges is near the central axis of the opposite half cylinder, as shown in the figure. The main action of the wind is very simple; the force of the wind is greater on the cupped face than that on the rounded face. The wind curving around the back side of the cupped face exerts a reduced pressure much as the wind does over the top of an air- foil and this helps to drive the rotor. The wide slot between the two inner edges of the half cylinders, lets the air whip around inside the forward-moving cupped face and then around the inside of the backward moving face, thus pushing both in the direction of the rotation.

The ratio of height to the overall diameter of the machine can be varied, but it is generally less than 3 to 1. Power coefficient of S rotor is low, but it might possibly be improved by changes in the design number and arrangement of the vanes. It has low efficiency, low speed and self starting capacity. It is not good for generating electricity because of low rpm. The rpm above 1000 is generally best for generating electricity.

❑Advantages

1. Performs at low wind velocity ranges
2. It has its low cut in speed (Wind speed required for switching electric power into the line)
3. Generator can be mounted on ground
4. Low system cost
5. Simple structure, easy to manufacture
6. Since it has vertical axis energy conversion system, it eliminates expensive power transmission system from the rotor to the axis
7. Yaw and Pitch control are not required. A constant speed vertical axis wind turbine, automatically stalls at high wind speeds
8. Overall weight of the turbine may be substantially less than that of conventional systems.

❑ Disadvantages

1. This type of machine is too solid
2. It is not useful for a very tall installation because long drive shaft problems.

❖ Areas of Concern

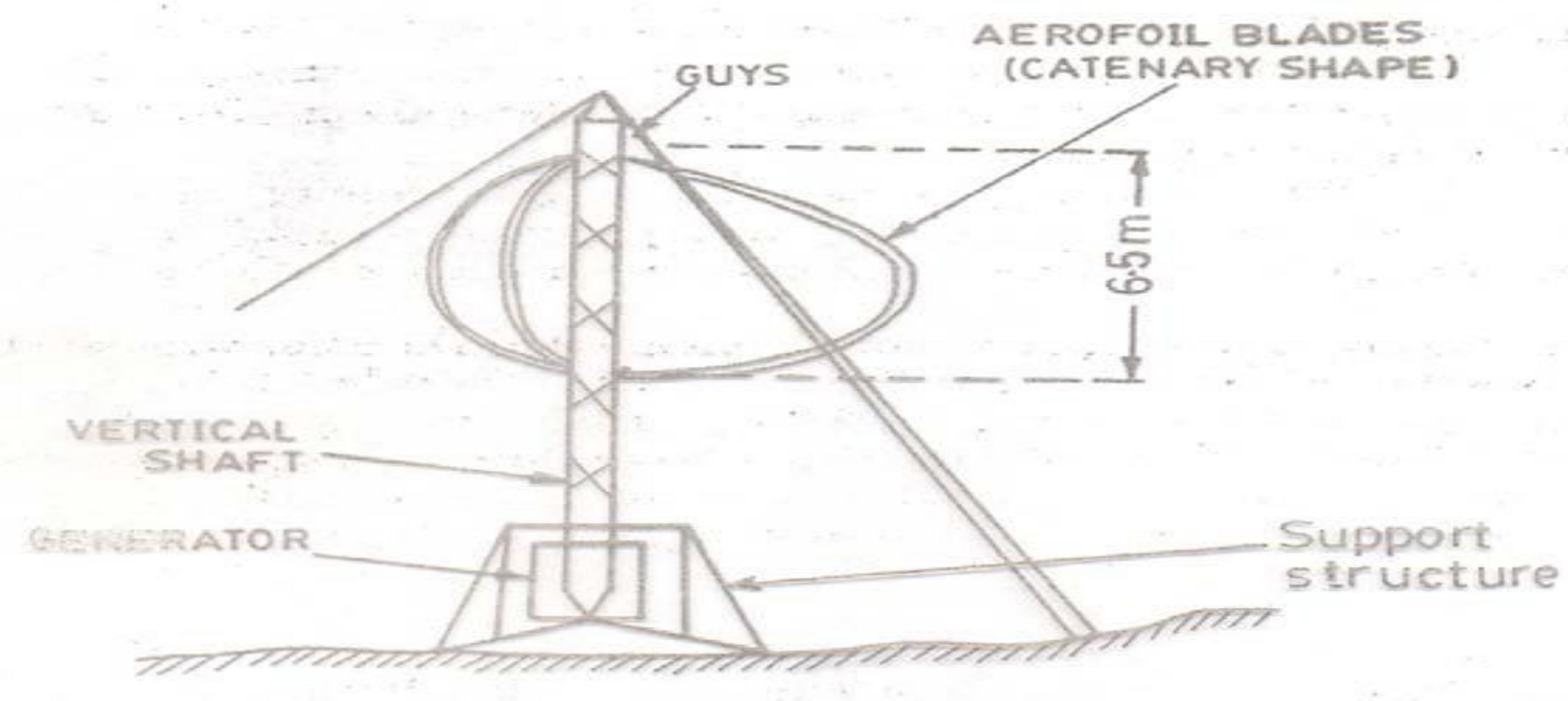
The Savonius rotor has moderately good efficiency and a satisfactory starting characteristics, the latter being particularly important for use with a positive displacement pumps. The rotor area requirement for getting the required amount of power is higher than any other systems. It is commonly used for pumping, and to operate small agricultural machines like winnowers, blowers, bird scarers, grinders etc. The another use of this type of wind energy conversion system is to use this machine along with Darrieus rotor for starting purposes.

❖ The Darrieus type machines (High velocity wind).

This machine was invented originally and patented in 1925 by G.J.M. Darrieus a French Engineer and this concept has recently been given serious consideration once again. This type of windmills is already in use in Canada. As noted, a modern rapidly rotating propeller type windmill, by use of an efficient air foil, effectively intercepts large area of wind with a small blade area. The Darrieus wind mill is a type of vertical axis machine that has the same advantage. An additional advantage is that it supports its blades in a way that minimizes bending stresses in normal operation.

❖ Constructional details and principle of operation.

In this type of machine, the blades are curved and attached to hubs on the vertical shaft at both ends to form a cage-like structure suggestive of an ordinary egg beater. The curved blade has the shape that a rope would take if subjected to centrifugal force in rapid rotation, some think like the shape of the rope in the exercise of skipping rope. Darrieus rotors have three symmetrical aerofoil blades, both ends of which are attached to a vertical shaft. Thus the force in the blade due to rotation is pure tension. This provides a stiffness to help withstand the wind forces it experience. The blades can thus be made lighter than in the propeller type. When rotating, these air foil blades provide a torque about the central shaft in response to a wind stream. This shaft torque is being transmitted to a generator at the base of the central shaft for power generation.



Vertical Axis Wind mill

- ✓ **Characteristics of Darrieus Rotor**
  - (i) Not self starting
  - (ii) High speed
  - (iii) High efficiency
  - (iv) Potentially low capital cost

❑ Advantages

1. The rotor blades can accept the wind from any compass.
2. The machine can be mounted on the ground eliminating tower structures and lifting of huge weight of machine assembly
3. It eliminates yaw control requirement for its rotor to capture wind energy
4. Airfoil rotor fabrication costs are expected to be reduced over conventional rotor blade costs.
5. The absence of pitch control requirements for 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.

❑ Disadvantages

1. It requires external mechanical aid for start up
2. Rotor power output efficiency of a Darrieus wind energy conversion system is also some what 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 and 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.
5. Finally since a Darrieus rotor cannot be yawed out of the wind or its blades feathered, special high torque breaking system must be incorporated

❖Horizontal Axis Type Wind Mills

The blade of the wind mill may have a thin cross-section or the more efficient thick cross section of an aerofoil. The motion causing the “wind due to motion” here is the rotation of the blades. At the tip of the blades of a modern wind turbine, the velocity is about six times the wind velocity. This means that the blades are set rather flat at a small angle with the plane of the rotation and almost at right angles to the direction of the wind so that the effective wind properly approach from ahead of the leading edge. At other parts of the blade, between the tip and the axle, the velocity and the ideal set of the aerofoil is at a greater angle to the plane of rotation. Ideally the blade should be twisted, but because of construction difficulties this is not always achieved.

(1) Horizontal axis using two aerodynamic blades

In this type of design, rotor drives a generator through a step-up gear box. The blade rotor is usually designed to be oriented downwind of the tower. The components are mounted on a bedplate which is attached on a pintle at the top of the tower. The rotor blades are continuously flexed by unsteady aerodynamic, gravitational and inertia loads, when the machine is in operation. If the blades are made of metal, flexing reduces their fatigue life. With rotor the tower is also subjected to above loads, which may cause serious damage. If the vibrational modes of the rotor happen to coincide with one of the natural mode of vibration of the tower, the system may shake itself to pieces. Because of the high cost of the blade rotors with more than two blades are not recommended. Rotors with more than two, say 3 or 4 blades would have slightly higher power coefficient.

(2) Horizontal axis propeller type using single blade.

In this arrangement, a long blade is mounted on a rigid hub induction generator and gear box. If extremely long blades (above say 6.0m) are mounted on rigid hub, large blade root bending moments may occur due to tower shadow, gravity and sudden shifts in wind directions. To reduce rotor cost, use of low cost counter weight is recommended which balances long blade centrifugally.

(3) Horizontal axis multiblade type.

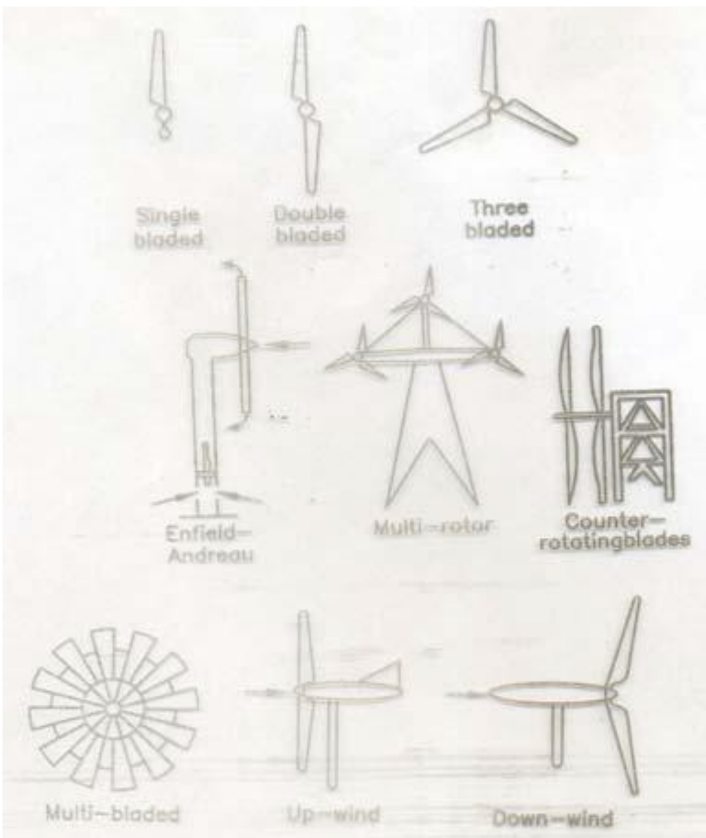
This type of design for multiblades as shown in fig are made from sheet metal or aluminium. The rotors have high strength to weight ratios and have been known to servive hours of freewheeling operation in 60 km/hr winds. They have good power coefficient, high starting torque and added advantage of simplicity and low cost.

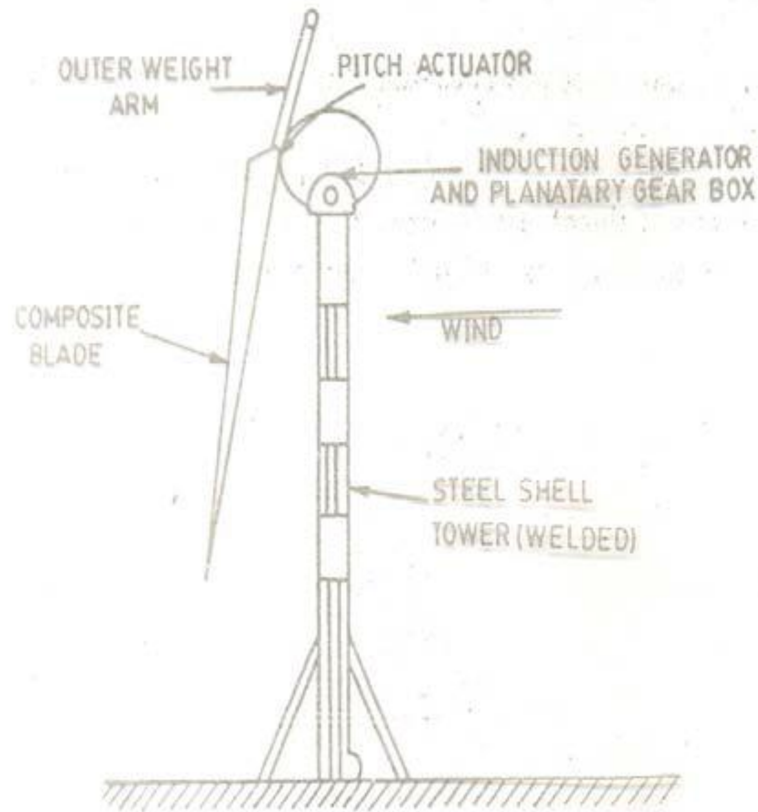
(4)Horizontal axis wind mill – Dutch Type.

It is one of the oldest designs. The blade surfaces are made from an array of wooden slats which ‘feather’ at high wind speeds.

(5) Sail type.

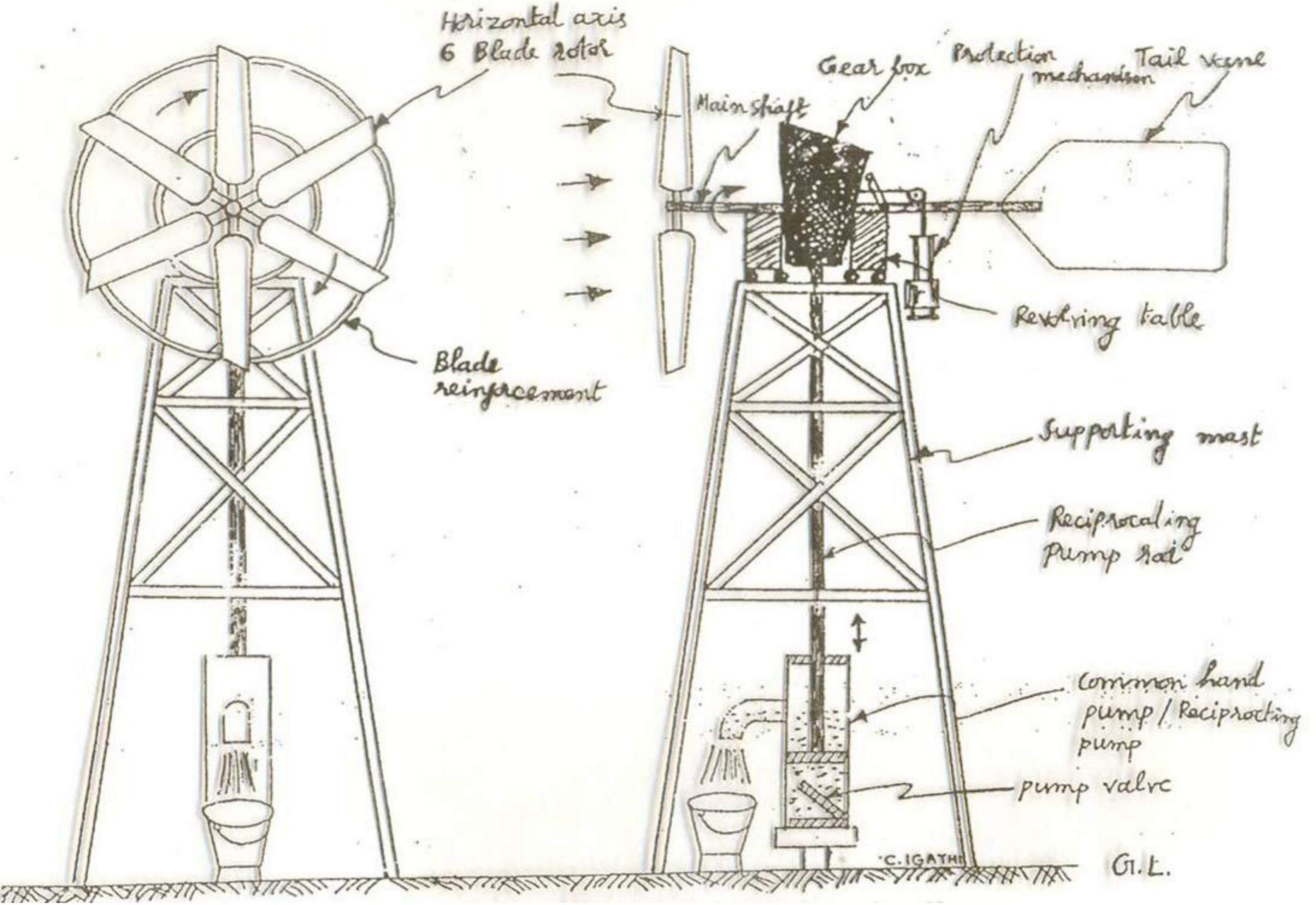
It is of recent origin. The blade surface is made from cloth, nylon or plastics arranged as mast and pole or sail wings. There is also variation in the number of sails used. The horizontal axis types generally have better performance. They have been used for various applications, but the two major areas of interest are electric power generation, and pumping water.



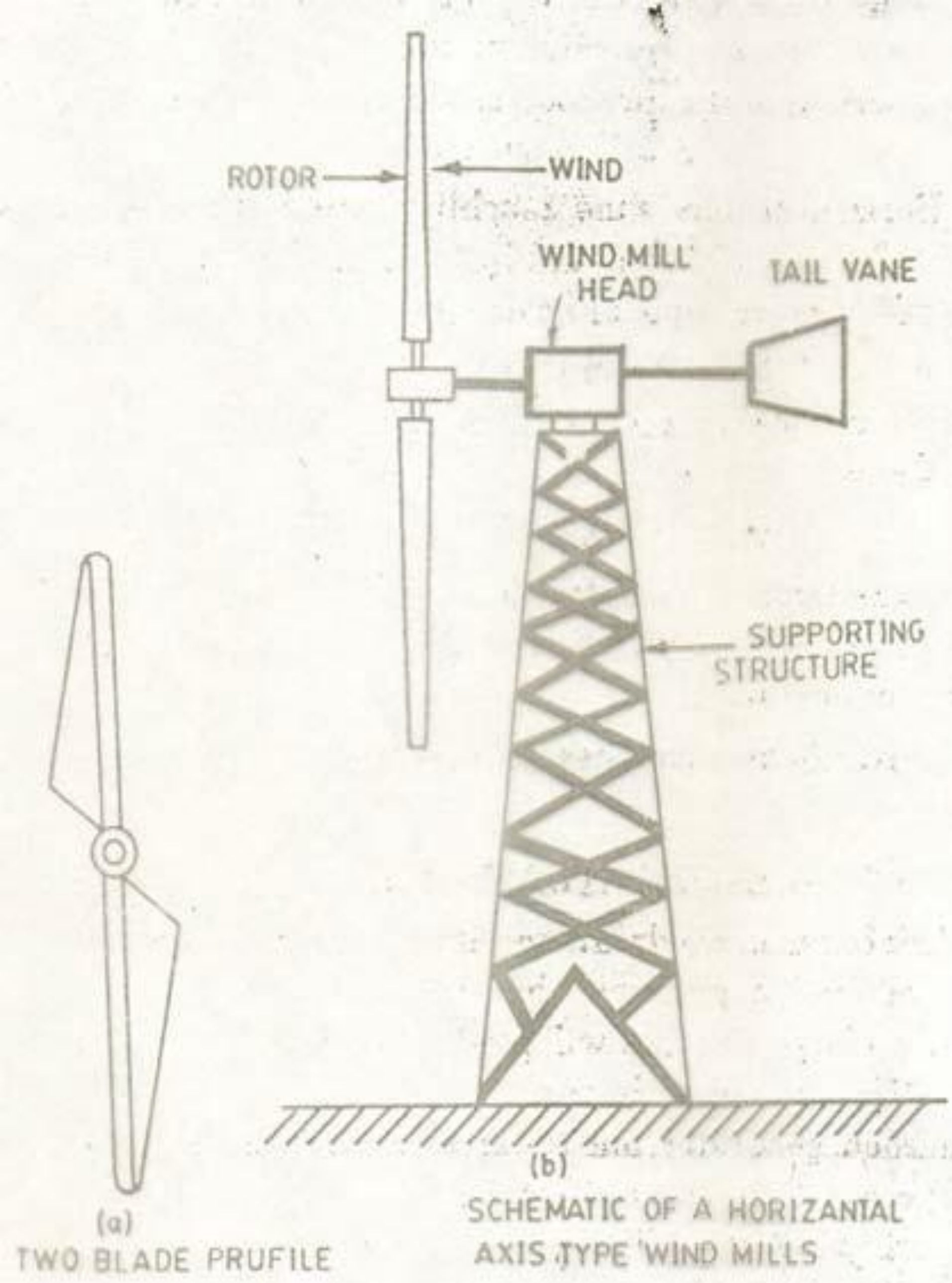


Different types of Horizontal Axis Wind mills

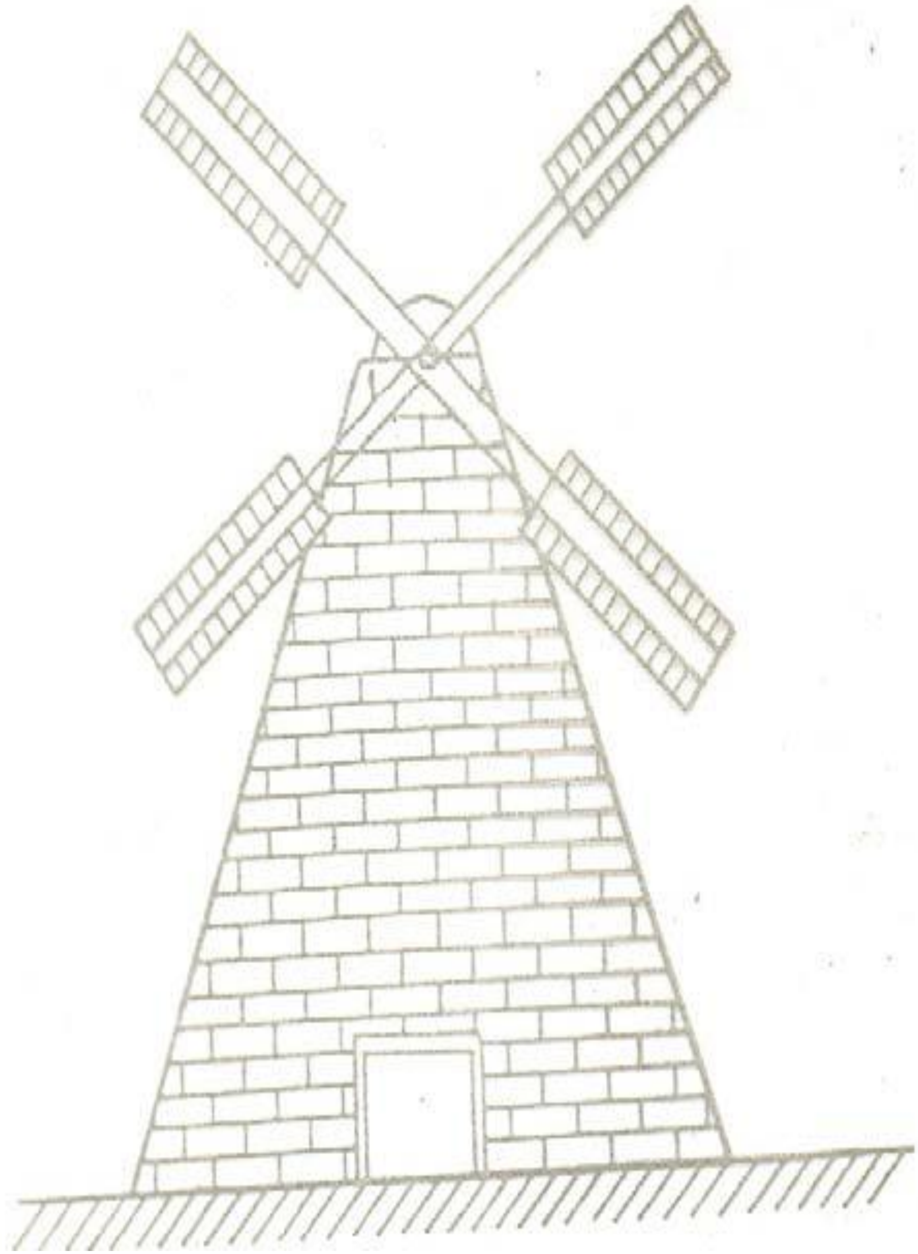
Single Blade Horizontal Axis Wind mill



Water pumping Wind mill



Horizontal axis using two aerodynamic blades



Horizontal axis wind mill – Dutch Type

- **Water Pumping Wind Mill**: Conversion of wind energy into mechanical power is the technology of wind mill.

The water pumping wind mill consists of a horizontal axis rotor with 10 – 12 blades. The pumps set consist of a piston with washer and valve arrangement. The rotor is mounted on the top of the tower to obtain sufficient wind velocity erected over a well at a height of about 10m and the pump is mounted in the well. A crank mechanism enclosed in the gear box fixed to the shaft of the rotors converts the rotary motion into a reciprocating motion of the piston inside the pump body. This action causes the piston – washer – Valve assembly to suck the water from the well and discharge through the delivery pipe. When blowing winds are allowed to strike a set fitted rotor blades arranged in the form of rotor, makes it to rotate and the rotation is utilized to run the mechanism. The rotor is always made to face wind direction automatically by a tail vane arranged at right angle to the rotor plane. At normal operating conditions the tail vane is locked up with rotor consisting of a rope, pulley and counter weight mechanism. The windmill starts rotating at certain velocity and is known as cutting speed. High velocity winds cause damage to the rotor assembly and the damage is prevented by resting the rotor using safety mechanism.

When the wind velocity exceeds the cut off limit, the relative shift between rotor and tail vane occurs and the safety mechanism automatically releases the connection between them. After the connection is broken, the rotor and tail vane come together and align in one plane parallel to the wind direction and resting of rotor takes place. To restore the operation of wind mill at normal wind speed, a man has to climb the tower and manually lock the tail vane with rotor. The wind speed at which the rotation occurs, ranges from 6-35 km/hr for pumping the water. Pump driving mechanism for piston rods are aligned in line of pump shaft so that a 3600 rotation of the entire rotor assembly is possible when the pump is in operation. Common hand operated bore well pump can also be attached to the wind mill with a min. modification. Pumped water can directly let in to the channel for irrigation or directed to over head storage tank.