WIND ENERGY

Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern **wind turbines**, can be used to generate **electricity**.

Mathematical Expression of Available Power

The wind power is generated due to the movement of wind. The energy associated with such movement is the kinetic energy and is given by the following expression:

Energy = KE = $\frac{1}{2}mv^2$, where,

m = Air mass in kg = Volume (m^3) × Density (kg/m^3) = Q × ρ,

Q = Discharge

v = Velocity of air mass in m/s

Hence, the expression for power can be derived as follows:

$$\text{Power} = \frac{dE}{dt}$$

$$= \frac{1}{2} \times \frac{d(mv^2)}{dt}$$

$$= \frac{1}{2} \times \frac{d(\rho \times Q \times v^2)}{dt}$$

$$= \frac{1}{2} \times \rho \times v^2 \times \frac{d(Q)}{dt}$$

Here, $\frac{dQ}{dt}$ = Rate of discharge (m^3/s) = A (m^2) • v (m/s), where

A = Area of cross section of blade movement

$$\text{Power} = \frac{1}{2} \times \rho \times A \times v^3$$

Use: -Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to produce electrical power, windmills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships.

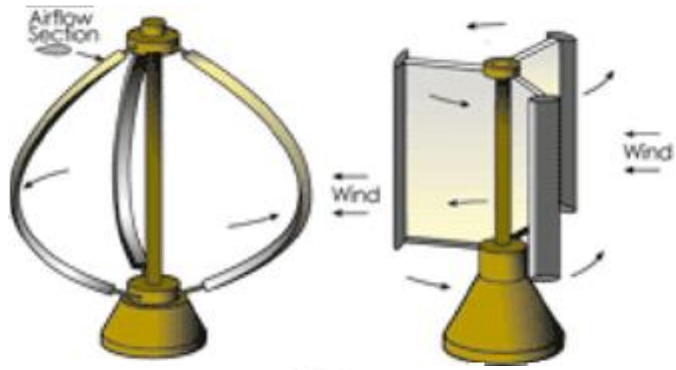
Advantage: -Wind is a clean source of renewable energy that produces no air or water pollution and since the wind is free, operational costs are nearly zero once a turbine is erected.

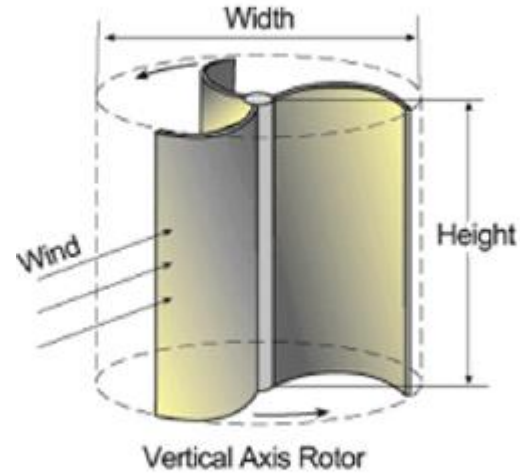
Classification of Wind-mills

Wind turbines are classified into two general types: Horizontal axis and Vertical axis. A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground. There are a number of available designs for both and each type has certain advantages and disadvantages. However, compared with the horizontal axis type, very few vertical axis machines are available commercially.

Horizontal Axis: This is the most common wind turbine design. In addition to being parallel to the ground, the axis of blade rotation is parallel to the wind flow. A tail vane is usually used to keep the blades facing into the wind. Some very large wind turbines use a motor-driven mechanism that turns the machine in response to a wind direction sensor mounted on the tower. Commonly found horizontal axis wind mills are aero-turbine mill with 35% efficiency and farm mills with 15% efficiency.

Vertical Axis: Although vertical axis wind turbines have existed for centuries, they are not as common as their horizontal counterparts. The main reason for this is that they do not take advantage of the higher wind speeds at higher elevations above the ground as well as horizontal axis turbines. The basic vertical axis designs are the Darrieus, which has curved blades and efficiency of 35%, the Giromill, which has straight blades, and efficiency of 35%, and the Savonius, which uses scoops to catch the wind and the efficiency of 30%. A vertical axis machine need not be oriented with respect to wind direction. Because the shaft is vertical, the transmission and generator can be mounted at ground level allowing easier servicing and a lighter weight, lower cost tower.





Main Components of a wind-mill

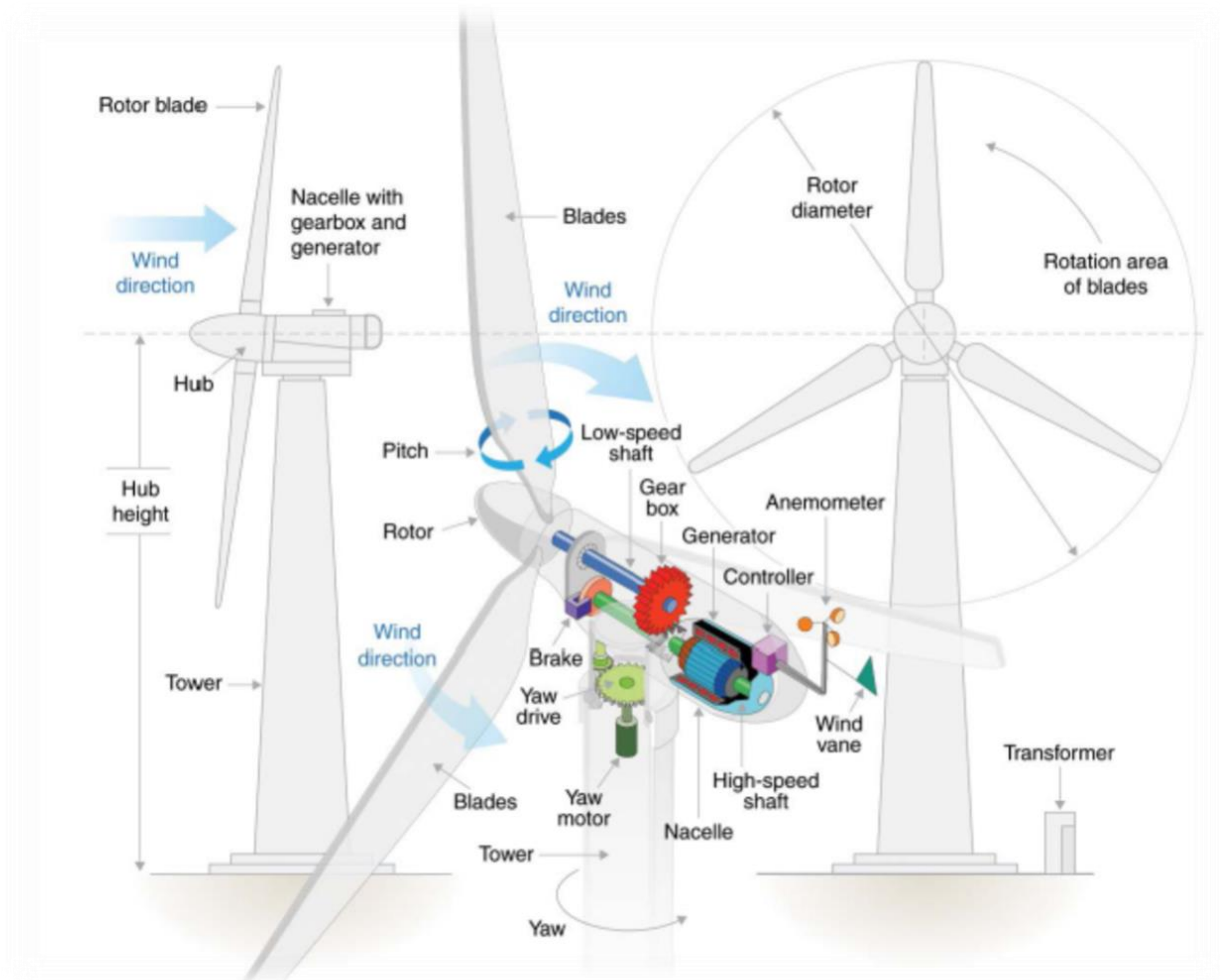
Rotor and Blades: The portion of the wind turbine that collects energy from the wind is called the rotor. The rotor usually consists of two or more wooden, fiberglass or metal blades which rotate about an axis (horizontal or vertical) at a rate determined by the wind speed.

Hub: The central solid portion of the rotor wheel is known as hub. All blades are attached to the hub. The mechanism of pitch angle control is also provided inside the hub.

Nacelle: The term nacelle is derived from the name for housing containing the engines of an aircraft. The rotor is attached to the nacelle, and mounted at the top of a tower. It contains rotor brake, high speed shaft, gear box, controller and generator.

- Brakes are used to stop the rotor when power generation is not desired. It can also be used for maintenance purpose.
- Gear box is used to step up the shaft speed (RPM) to desired speed.
- Controller is used to provide necessary control action.
- Generator is used to generate electrical energy.

Yaw Control Mechanism: The mechanism to adjust the nacelle around the vertical axis to keep it facing the wind is provided at the base of the nacelle. Yaw motor and Yaw drive are used for this purpose.



Tower: The tower on which a wind turbine is mounted is not just a support structure. It also raises the wind turbine so that its blades safely clear the ground and so it can reach the stronger winds at higher elevations. Maximum tower height is optional in most cases, except where zoning restrictions apply. The decision of what height tower to use will be based on the cost of taller towers versus the value of the increase in energy production resulting from their use. Studies have shown that the added cost of increasing tower height is often justified by the added power generated from the stronger winds.

Operating Characteristics of wind mills

All wind machines share certain operating characteristics, such as cut-in, rated and cut-out wind speeds.

Cut-in Speed: Cut-in speed is the minimum wind speed at which the blades will turn and generate usable power. This wind speed is typically between 10 and 16 km/h.

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

Cut-out Speed: At very high wind speeds, typically between 72 and 128 km/h, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed. Having a cut-out speed is a safety feature which protects the wind turbine from damage. Shut down may occur in one of several ways.

Betz Limit: It is the flow of air over the blades and through the rotor area that makes a wind turbine function. The wind turbine extracts energy by slowing the wind down. The theoretical maximum amount of energy in the wind that can be collected by a rotor is approximately 59%. This value is known as the Betz limit. If the blades were 100% efficient, a wind turbine would not work because the air, having given up all its energy, would entirely stop. In practice, the collection efficiency of a rotor is not as high as 59%.