3.2 **Types of Wind Power Plants (WPPs):**

- The wind has its kinetic energy as it nothing but the flow of atmospheric air. A wind turbine is a machine which utilizes the kinetic energy of wind to produce rotational mechanical energy in its shaft.
- The rotational motion of the shaft turns an electrical generator to generate electricity. There are mainly two types of wind turbine available one is the horizontal axis type another is vertical axis type.
- The turbines are also available in different sizes depending upon their mode of applications.

  In many places of the modern world, people use small-sized wind turbines to charge batteries for auxiliary power supply to boats, caravans etc.
- Many electric utility companies use medium-sized wind turbines to supply a portion of the domestic load when sufficient wind is available so that they can sale back the surplus demanded power to the electrical grid.
- The stock of fossil fuels on that planet is becoming nil day by day, so there is a significant need for renewable sources of energy to produce electricity to meet up the on-growing demand for electricity.
- The wind power generating station is one of the solutions for that. The wind power generating stations, use many giant wind turbines to produce required electricity.
- The wind turbines can have either horizon shaft or vertical shaft depending on their design criteria. The horizontal design is more common as it produces more power compared to a vertical one.

Wind turbines are broadly classified into two categories.

- When the axis of rotation is parallel to the air stream (i.e. horizontal), the turbine is said to be a Horizontal Axis Wind Turbine (HAWT), and
- When it is perpendicular to the air stream (i.e. vertical), it is said to be a Vertical Axis Wind Turbine (VAWT).
- The size of the rotor and its speed depends on rating of the turbine.

3.2.1 Horizontal Axis Wind Turbine (HAWT):

- ❖ HAWTs have emerged as the most successful type of turbines. These are being used for commercial energy generation in many parts of the world. Their theoretical basis is well researched and sufficient field experience is available with them.

3.2.1.1. Main Components

- ❖ The constructional details of most common, three-blade rotor, horizontal axis wind turbine are shown in Fig. Main parts are as follows:

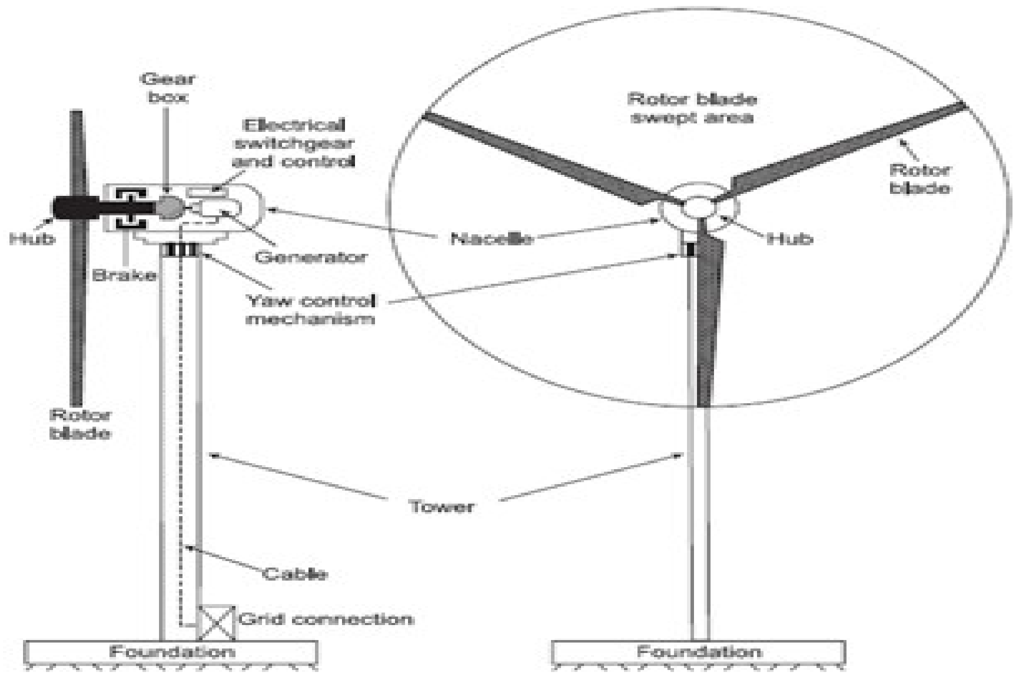

Figure: 3.2.1

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 175]

(a) Turbine Blades:

- ❖ Turbine blades are made of high-density wood or glass fiber and epoxy composites. They have airfoil type cross-section. The blades are slightly twisted from the outer tip to the root to reduce the tendency to stall.

- In addition to centrifugal force and fatigue due to continuous vibrations there are many extraneous forces arising from wind turbulence, gust, gravitational forces and directional changes in the wind, etc. All these factors are to be taken care off at the designing stage. Diameter of a typical, MW range, modern rotor may be of the order of 100 m.

- Modern wind turbines have two or three blades. Two/three blade rotor HAWT are also known as propeller type wind turbines owing to their similarity with propellers of old aero planes. However, the rotor rpm in case of wind turbine is very low as compared to that for propellers.

(b) Hub:

- The central solid portion of the rotor wheel is known as hub. All blades ate attached to the hub. Mechanism for pitch angle control is also provided inside the hub.

(c) Nacelle:

- The term nacelle is derived from the name for housing containing the engines of an aircraft. The rotor is attached to nacelle, mounted at the top of a tower.
- It contains rotor brakes, gearbox, generator and electrical switchgear and control.
- Brakes are used to stop the rotor when power generation is not desired. Gearbox steps up the shaft rpm to suit the generator. Protection and control functions are provided by switchgear and control block. The generated electrical power is conducted to ground terminals through a cable.

(d) Yaw Control Mechanism:

- The mechanism to adjust the nacelle around vertical axis to keep it facing the wind is provided at the base of nacelle.

(e) Tower:

- Tower supports nacelle and rotor. For medium and large sized turbines, the tower is slightly taller than the rotor diameter. In case of small sized turbine, the tower is much larger than the rotor diameter as the air is erratic at lower heights.

- Both steel and concrete towers are being used. The construction can be either tubular or lattice type.

- The tower vibrations and resulting fatigue cycles under wind speed fluctuations are avoided by careful design. This requires avoidance of all resonance frequencies of tower, the rotor and the nacelle from the wind fluctuation frequencies.

3.2.1.2. Types of Rotors:

- Depending on the number of blades, wind speed and nature of applications, rotors have been developed in various types of shapes and sizes. These are shown in Fig.2.2.The types of rotors shown in (a) to (e) are relatively high-speed ones, suitable for applications such as electrical power generation. Large HAWTs have been manufactured with two and three blades. A single-blade rotor, with a balancing counterweight is economical, has simple controls but it is noisier and produces unbalanced forces. It is used for low-power applications.
- Those given in Fig. (f) and (g) are low-speed rotors and most suited for water lifting applications, which require high starting torque. They can capture power even from very slow winds.

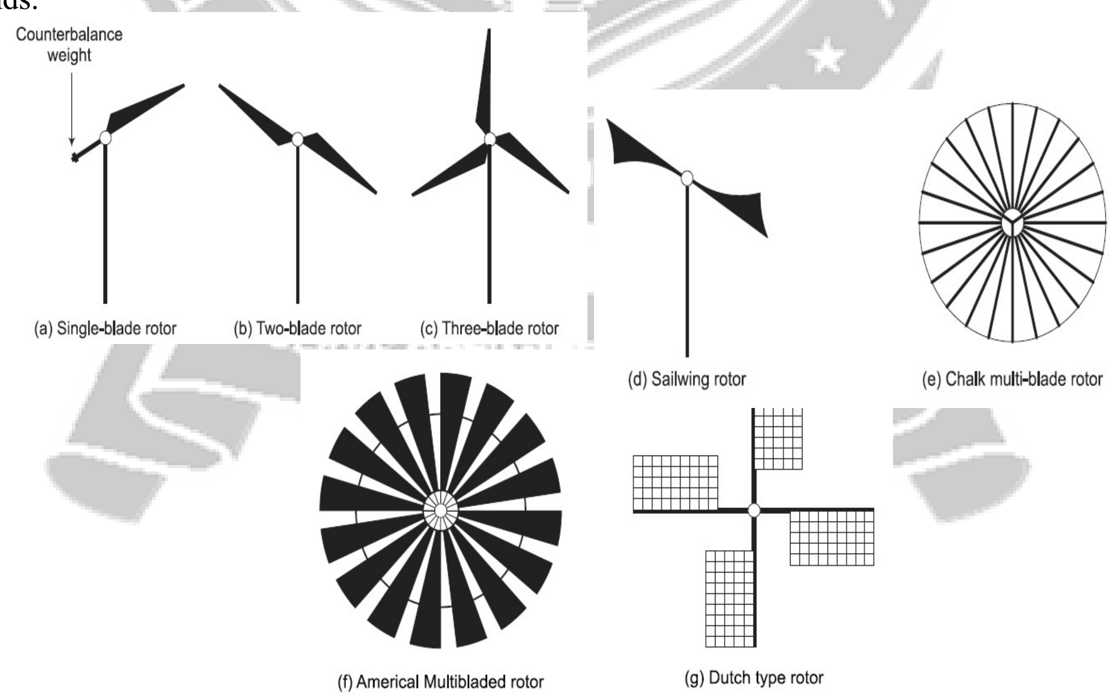

Figure: 3.2.2

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 177]

3.2.2. Vertical Axis Wind Turbine (VAWT):

- VAWTs are in the development stage and many models are undergoing field trial. Main attractions of a VAWT are:

(i) It can accept wind from any direction, eliminating the need of yaw control.

(ii) Gearbox, generator etc. are located at the ground, thus eliminating the heavy nacelle at the top of the tower. This simplifies the design and installation of the whole structure, including tower

iii) The inspection and maintenance also gets easier and

(iv) It also reduces the overall cost.

3.2.2.1. Main Components:

- The constructional details of a vertical axis wind turbine (Darrieus type rotor) are shown in fig. The details of main components are as follows,

(a) Tower (or Rotor Shaft):

- The tower is a hollow vertical rotor shaft, which rotates freely about vertical axis between top and bottom bearings. It is installed above a support structure. In the absence of any load at the top, a very strong tower is not required, which greatly simplifies its design. The upper part of the tower is supported by guy ropes. The height of the tower of a large turbine is around 100 m.

(b) Blades:

- It has two or three thin, curved blades shaped like an eggbeater in profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces-the so-called _Troposkien'profile.
- The blades have airfoil cross section with constant chord length. The pitch of the blades cannot be changed.

  The diameter of the rotor is slightly less than the tower height.
- The first large (3.8 MW), Darrieus type, Canadian machine has rotor height as 94 m and diameter as 65 m with a chord of 2.4 m.

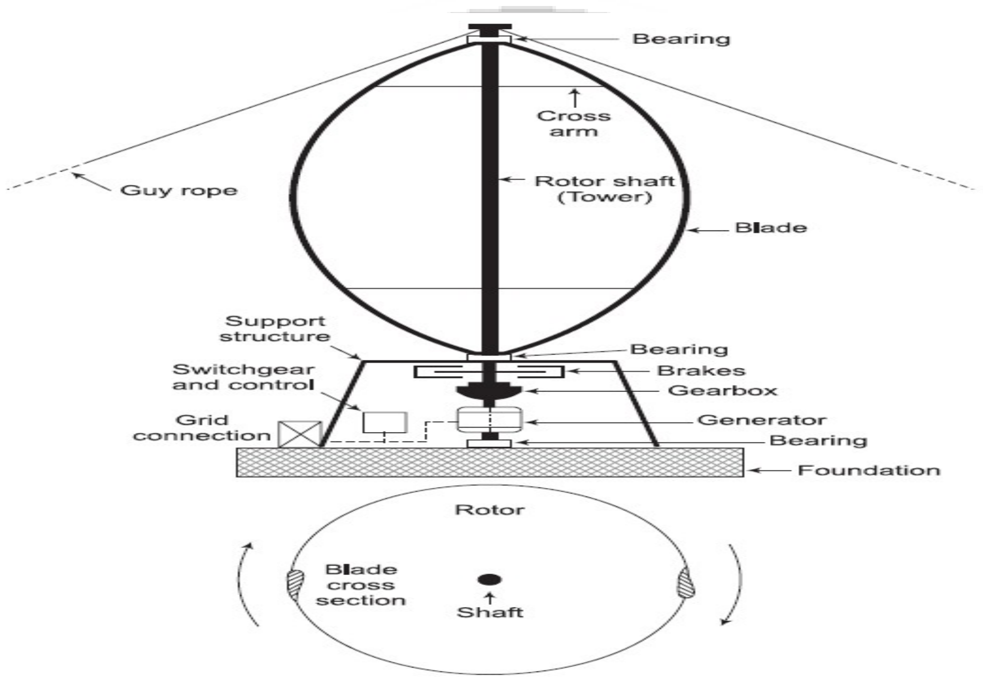

Figure: 3.2.3

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 178]

3.2.2.2. Types of Rotors:

Various types or rotors for VAWTs are shown in Fig.

- The simplest being three or four cups structure attached symmetrically to a vertical shaft.
- Drag force on concave surface of the cup facing the wind is more than that on convex surface.
- As a result, the structure starts rotating. Some lift force also helps rotation. However, it cannot carry a load and is, therefore, not used as power source.
- Main characteristic of this rotor is that its rotational frequency is linearly related to wind speed.

- Therefore, it is used as a transducer for measuring the wind speed and the apparatus is known as cup anemometer.

The Savonius or S-rotor:

- It consists of two half cylinders attached to a vertical axis and facing in opposite directions to form a two-vaned rotor. It has high starting torque, low speed and low efficiency.
- It can extract power even from very slow wind, making it working most of the time.

- These are used for low power applications. High starting torque particularly makes it suitable for pumping applications, using positive displacement pumps

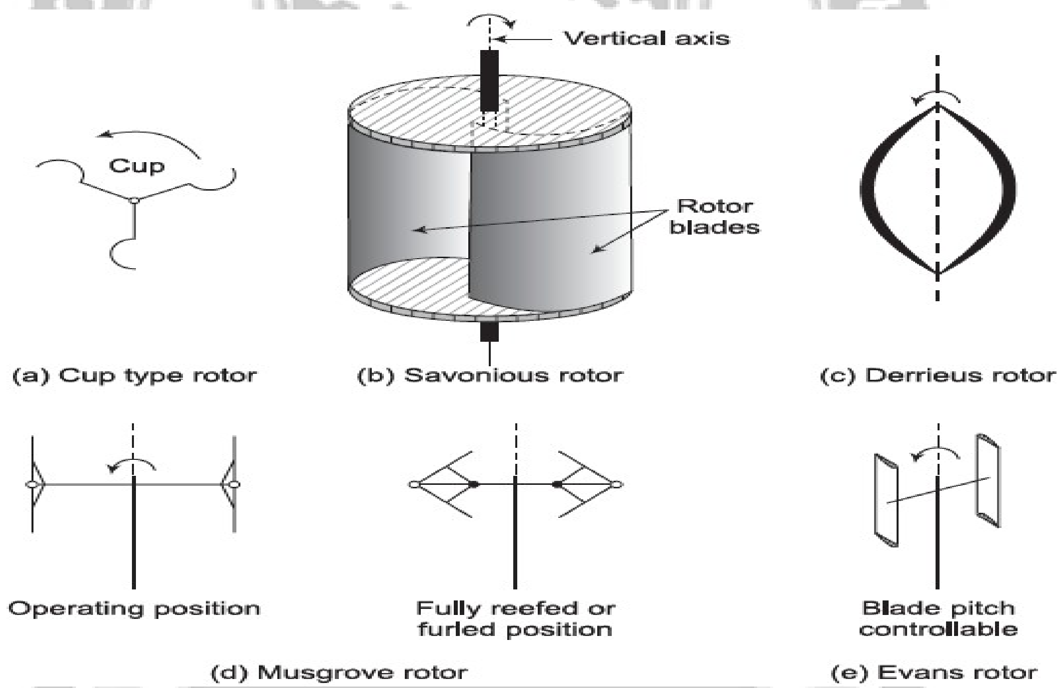

Figure: 3.2.4

[Source: "Solar Photovoltaics: Fundamentals,Technologies andApplications" by ChetanSingh Solanki, Page: 179]

Darrieus rotor:

- ✓ It is used for large-scale power generation. Power coefficient is considerably better than S-rotor. It runs at a large tip-speed ratio.
- ✓ The aerodynamic force on the blade reverses in every revolution causing fatigue. This along with centrifugal force complicates the design of the blade.
- ✓ One of the drawbacks of this rotor is that it is usually not self-starting. Movement may be initiated by using electrical generator as motor.
- ✓ As the pitch of the blade cannot change, the rotor frequency and thus the output power cannot be controlled. Rotor frequency increases with wind speed and power output keeps on increasing till the blades stall.
- ✓ Hence at high wind speed it becomes difficult to control the output. For better performance and safety of the blades, gearbox and generator, etc., it is desirable to limit the output to a level much below its maximum possible value.

Musgrove suggested H shaped rotor :

- ✓ where blades with fixed pitch are attached vertically to a horizontal cross arm.
- ✓ Power control is achieved by controlled folding of blades. Inclining the blades to the vertical provides an effective means of altering the blades angle of attack and hence controlling the power output.
- ✓ Evans rotor, also known as Gyromill is an improvement over H shaped rotor.
- ✓ Here, the rotor geometry remains fixed (blades remain straight), but the blades are hinged on a vertical axis and the blade pitch is varied cyclically (as the blade rotates about vertical axis) to regulate the power output.
- ✓ But the need to vary the pitch cyclically through every rotor revolution introduces considerable mechanical complexity. However, this enables it to self-start.