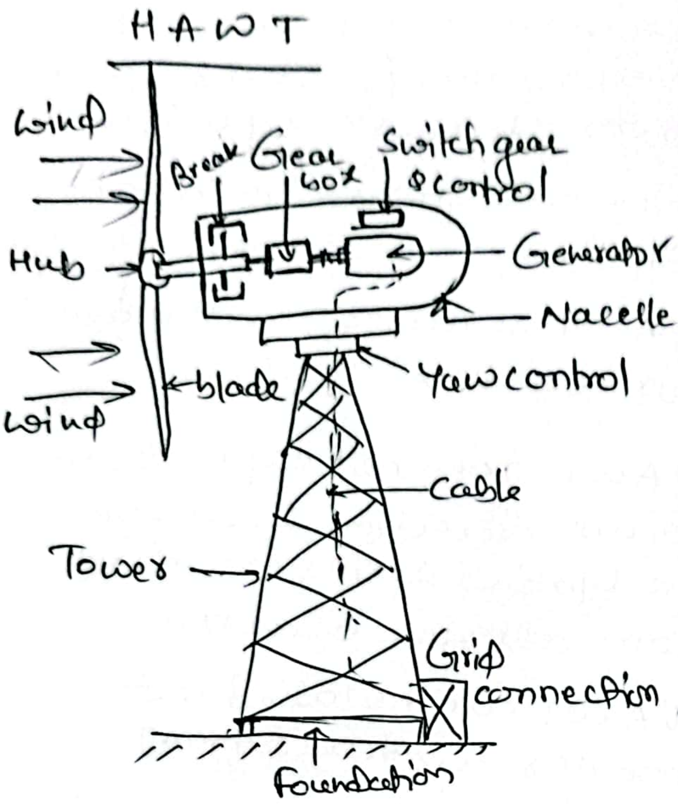
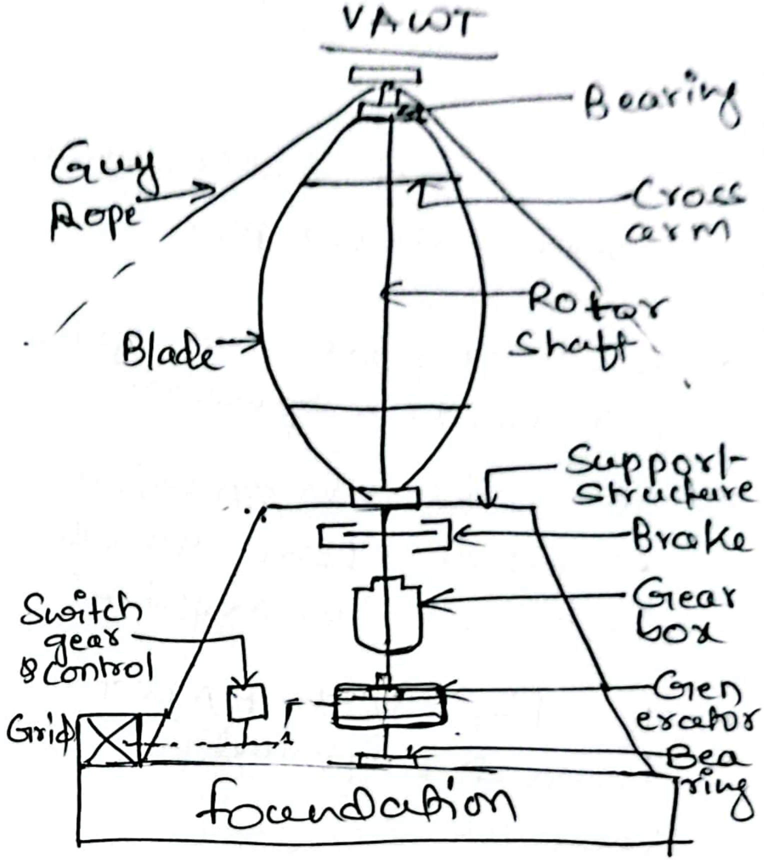
Module 3 WIND ENERGY

Difference between HAWT & VAWT





HAWT	VAWT
*) Horizontal Axis Wind Turbine is the one whose axis of rotation is horizontal with respect to the wind stream	*) Vertical Axis wind turbine axis of rotation is vertical with respect to the wind stream.
*) All the equipments like Gear box, Generator are placed in the nacelle at the top of the tower	*) All the equipments are ~~placed~~ like gear box, generator switch gear and control etc are placed on the ground.
*) In HAWT Yaw mechanism is required to orient the turbine in the direction of wind	*) VAWT does not require yaw mechanism because it recieves wind from all direction.
*) The direction of wind should be perpendicular to the blades	*) VAWT recieves wind from all direction.

HAWT	VAWT
*) HAWT is self starting	*) It's not self starting. It requires some starting mechanism to start VAWT from stationary position.
*) The design and installation of HAWT is complex	*) The design and installation of VAWT is simple
*) HAWT requires large space for blade's operation	*) VAWT requires small space for blade's opⁿ.
*) HAWT depends on wind direction hence yaw & pitch control is required.	*) VAWT does not depends on wind direction because the blades recieves wind from all the direction.
*) The hight of the HAWT from the ground is very large.	*) VAWT are installed at smaller distance from the ground.
*) HAWT uses a heavy nacelle to provide housing to the equipments & it is placed at the top of the tower	*) No need of nacelle. all equipments are placed on ground.
*) HAWT has high power coefficient	*) VAWT has low power coefficient.
*) HAWT has high tip speed ratio	*) VAWT has low tip speed ratio.
*) operation is very noisy	*) Comparatively less noise
*) Ideal efficiency of HAWT is around 50-60%.	*) Ideal efficiency of VAWT is alway >70%.
*) Cause high obstruction for birds	*) Cause less obstruction for birds.
*) More expensive due to complex design	*) less expensive due to simple design.

7.7.1 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.

A. *Main Components*

The constructional details of the most common, three-blade rotor, horizontal axis wind turbine is shown in Fig. 7.14. The main parts are as follows:

Turbine Blades Turbine blades are made of high-density wood or glass fibre and epoxy composites. They have an airfoil type of 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. All these factors are to be taken care off at the designing stage. The diameter of a typical, MW range, modern rotor may be of the order of 100 m.

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

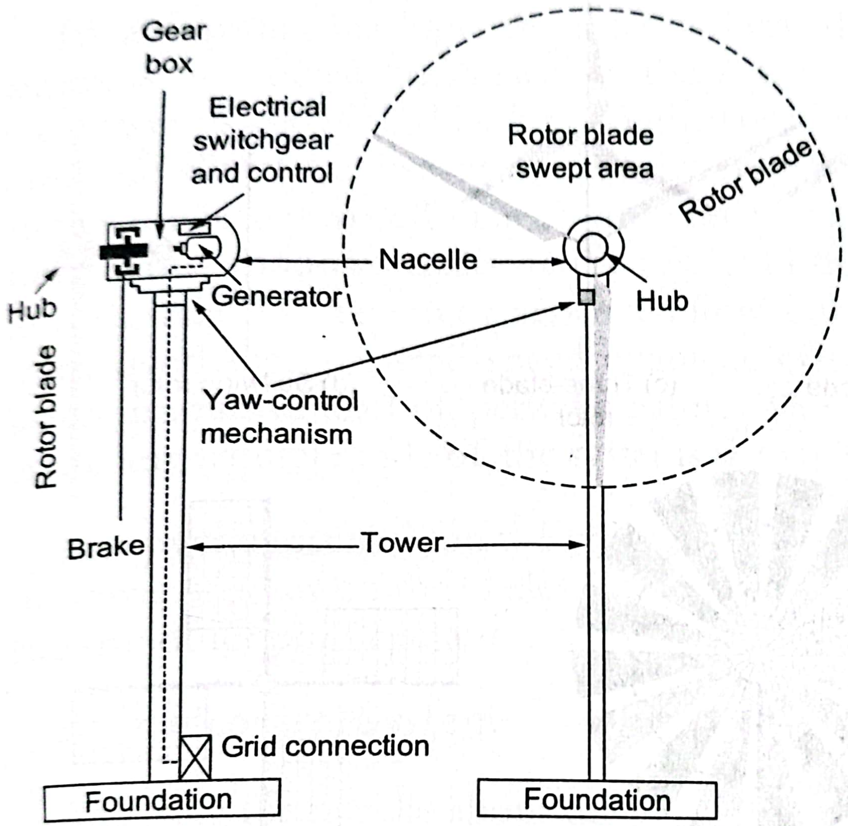


Fig. 7.14 *Horizontal axis wind turbine*

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 brakes, gearbox, generator and electrical switchgear and control. Brakes are used to stop the rotor when power generation is not desired. The 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.

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.

Tower The tower supports the nacelle and rotor. For medium and large sized turbines, the tower is slightly taller than the rotor diameter. In case of a 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.

7.7.2 Vertical Axis Wind Turbine (VAWT)

VAWTs are in the development stage and many models are undergoing field trial. The main attractions of a VAWT are

(i) it can accept wind from any direction, eliminating the need of yaw control,
(ii) the gearbox, generator, etc., are located at the ground, thus eliminating the heavy nacelle at the top of the tower, thus simplifying the design and installation of the whole structure, including the tower,
(iii) the inspection and maintenance also gets easier, and
(iv) it also reduces the overall cost.

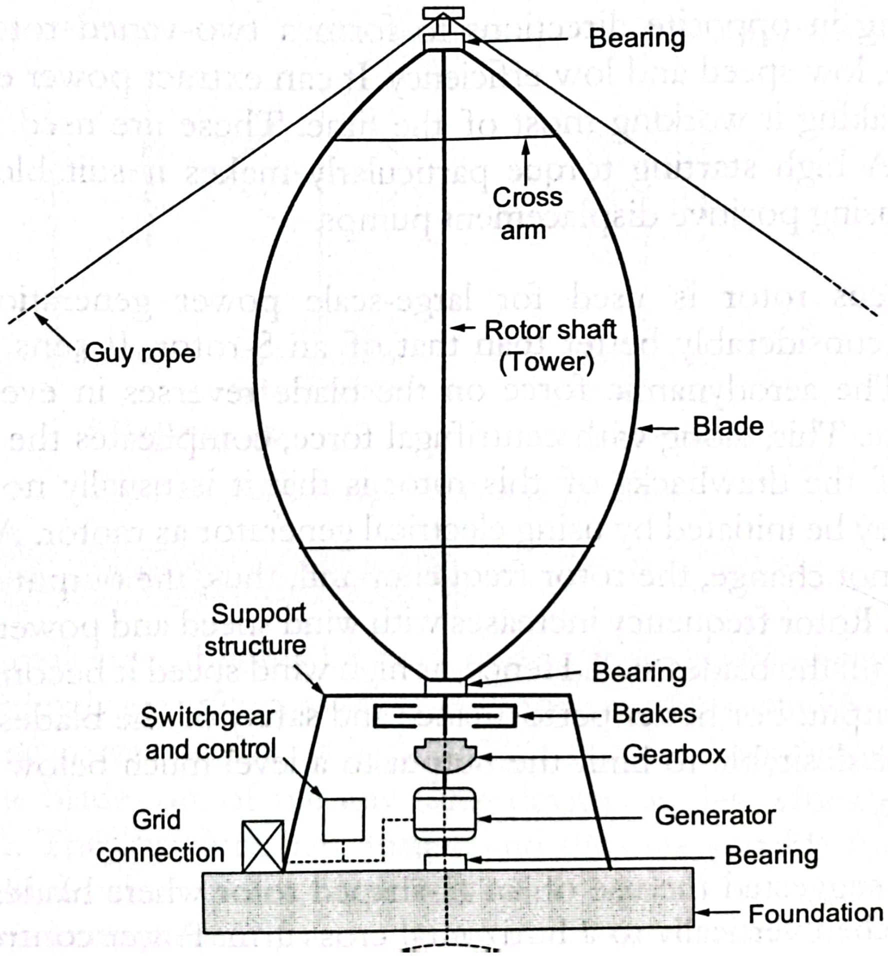
A. *Main Components*

The constructional details of a vertical axis wind turbine (Darrieus-type rotor) are shown in Fig. 7.19. The details of the main components are as follows:

Tower (or Rotor Shaft) The tower is a hollow vertical rotor shaft, which rotates freely about the vertical axis between the 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.

Blades It has two or three thin, curved blades shaped like an eggbeater in a profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces—the so called 'Troposkien' profile. The blades have an 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 a rotor height as 94 m and the diameter as 65 m with a chord of 2.4 m.

Support Structure The support structure is provided at the ground to support the weight of the rotor. Gearbox, generator, brakes, electrical switchgear and controls are housed within this structure.

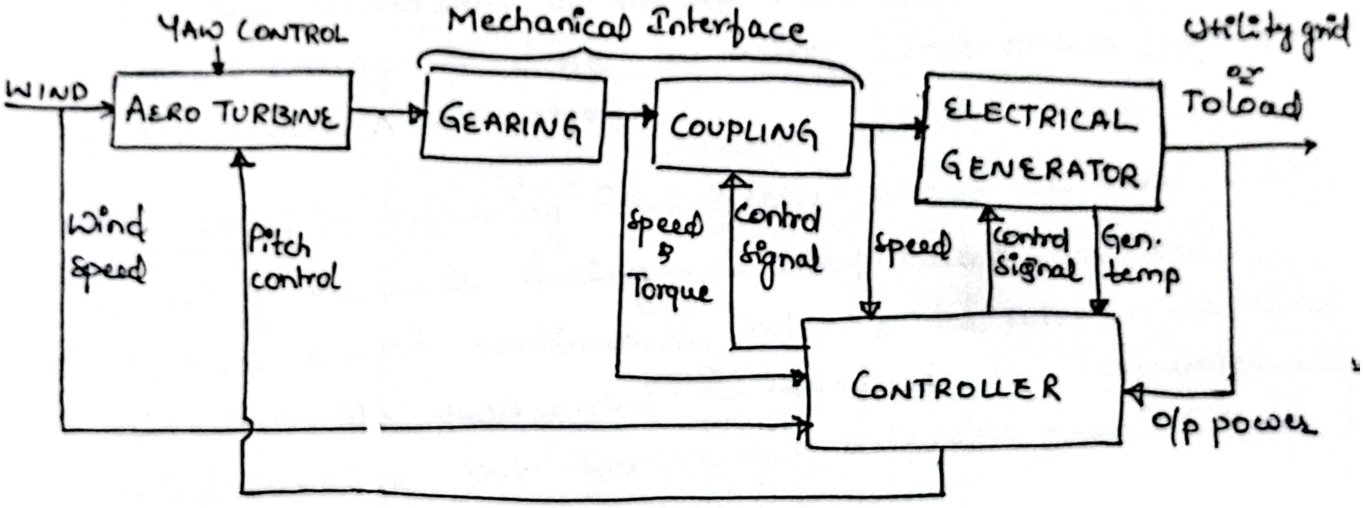


Wind Energy Conversion System (WECS)

Windmills & wind energy converters convert wind power to electrical power.

Most of wind turbines designed for production of electricity have consisted of a two- & three bladed propeller (rotor) rotating around a horizontal axis.

Typical WEC systems range from 30KW for individual units to 5.0 MW for wind farms of multiple units. Hub heights of around 80 mts and rotor diamts are around 65 mts.



fig① Block diagram of WECS with its Basic Components

AERO TURBINE :- It converts energy in moving air to rotary mechanical energy. In general, they require pitch control and yaw control (only in horizontal axis wind turbine) for proper opn. Basically Aero turbines are of two types, one is horizontal axis wind turbine and another is verti'le axis wind turbine.

Horizontal axis wind turbines are the most successful type of turbines. These are being used for commercial energy generation. These turbines have two & three blades. HAWT (Horizontal Axis Wind Turbines) are also known as propeller type wind turbines

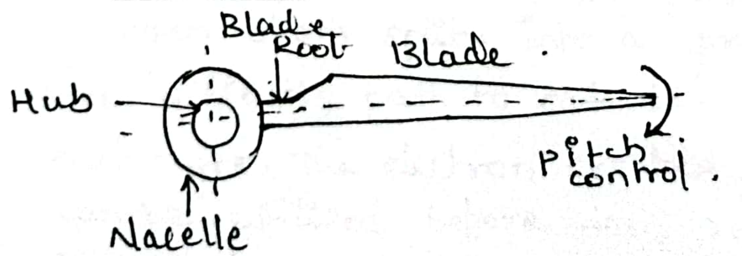
VAWT (Vertical Axis Wind Turbines) are in the development stage. and The main advantage of VAWT is it can accept wind from any direction, eliminating the need of yaw control & reduces overall cost.

MECHANICAL INTERFACING:- It consist of a step up gear and a suitable coupling transmits the rotary mechanical energy to an electrical generator. The turbine shaft speed is stepped up with the help of gears, with a fixed gear ratio, to suit the electrical generator and fine-tuning of speed is incorporated by pitch control.

Generator:- It converts mechanical energy to electrical energy. The o/p of this generator is connected to the load & power grid. This conversion of rotary mechanical energy to electrical energy is done by using synchronous generator or by induction generator.

Yaw control:- Adjusting the nacelle about the vertical axis to bring the blade facing the wind called yaw control. ie; yaw control continuously orients the rotor in the wind direction. The yaw control is required for horizontal axis wind turbine but for vertical axis wind turbine Yaw control mechanism is not required.

Pitch control:-



The pitch of the blade is controlled by rotating it from its root where it is connected to the hub

Controller:- It sense wind speed, direction, shafts speed and torque at one or more points. It senses Generator temperature, o/p power and gives control signals for matching the o/p to the i/p.

Wind Energy

Wind is the motion of air in the atmosphere. Movement means that the air has macroscopic kinetic energy (in addition to the microscopic thermal energy that comes from the air being at a particular temperature), which can be harnessed by a wind turbine and turned into electricity. This is often referred to as wind power and wind is therefore considered as a primary energy flow. This is often considered a form of naturally occurring convection.

Generally, movement in the horizontal direction is much stronger than in the vertical direction. However, both the vertical and horizontal components of wind have a significant impact on weather. Rising air cools and condenses to form clouds and sinking air warms and dissipates cloud cover. Wind is generally described in terms of horizontal speed and direction. Wind speed can be measured by an anemometer and wind direction by a weather vane. The force of friction and the Coriolis Effect both influence wind direction and speed. Wind is formed due to uneven heating of the Earth's surface. These surfaces absorb heat at different rates; for example sand on a beach can be too hot to walk on while nearby grass feels cool. As these surfaces absorb heat at different rates, the air just above the surface warms and begins to rise. The rising hot air creates a change in pressure in the area.[1] Air naturally moves from the areas of high pressure to low pressure, which causes the horizontal movement of air.

A practical example is the ocean breeze. The air above land warms faster than air over water. As the hot air over land rises, the cool air over the ocean rushes in to fill the space. The result is a cool ocean breeze.

Advantages and Disadvantages of wind energy

Advantages

- Wind power has a remarkably small impact upon the carbon footprint.
- There are zero carbon emissions associated with the operation of wind turbines.

- Wind energy has one of the lowest water consumption footprints, unlike fossil fuels and nuclear power plants.
- Wind turbines reduce a nation's demand for imported fuel sources.
- Wind turbines are a great resource to help generate energy in remote locations such as mountain communities or the countryside.
- Wind power can be combined with Solar Energy in order to generate a sustainable energy source in developing countries.

Disadvantages

- Wind turbines depend on a suitable wind speed in order to generate electricity.
- If wind speed is below a certain threshold, turbines depend on other forms of electricity generation in order to operate.
- The visual impact of the turbines.
- The complexity of manufacturing offshore wind farms makes it a much more costly method than onshore wind farms.
- Wind turbines generate a lot less power than the average fossil fuelled power station, requiring multiple wind turbines to be built in order to make an impact.

Potential of Wind Energy in India

Wind is an intermittent and site-specific resource of energy and therefore, an extensive Wind Resource Assessment is essential for the selection of potential sites. The Government, through National Institute of Wind Energy (NIWE), has installed over 800 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m, 100m and 120m above ground level. The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 meter and 695.50 GW at 120 meter above ground level. Most of this potential exists in seven windy States as given below:-

Properties of Wind

S. No.	State	Wind Potential at 100 m (GW)	Wind Potential at 120 m (GW)
1	Gujarat	84.43	142.56
2	Rajasthan	18.77	127.75
3	Maharashtra	45.39	98.21
4	Tamil Nadu	33.79	68.75
5	Madhya Pradesh	10.48	15.40
6	Karnataka	55.85	124.15
7	Andhra Pradesh	44.22	74.90
8	Total 7 windy states	292.97	651.72
9	Others	9.28	43.78
	Total	302.25	695.50

Wind speed

Wind speed is one of the most critical characteristics in wind power generation. In fact, wind speed varies in both time and space, determined by many factors such as geographic and weather conditions.

Wind speed Distribution

1. Diurnal pattern caused by different temperatures at day and night. This effect is more distinct at coastal sites the off shore
2. Depressions and Anti cyclones usually occur with periods of about 4 days. This phenomenon is more distinct in oceanic than continental regions.
3. Annual pattern varies with the degree of latitude and vanishes in close proximity to the equator

Wind Turbulence

The turbulence of the wind is the fluctuation of the wind speed in short time scale which acts as a dynamic load in wind turbines. Thus, wind turbine components can be influenced by fatigue loads, particularly on the rotor blades, due to the large turbulence when the speed of wind is high.

Wind gust

Wind gust refers to a phenomenon that a wind blasts with a sudden increase in wind speed in a relatively small interval of time. In case of sudden turbulent gusts, wind speed, turbulence, and wind shear may change drastically. Reducing rotor imbalance while maintaining the power output of wind turbine generator constant during such sudden turbulent gusts calls for relatively rapid changes of the pitch angle of the blades.

Wind shear

Wind shear is meteorological phenomenon which describes the changes in wind speed as a function of height. The velocity of wind around the ground surface is theoretically considered to be zero due to the frictional resistance of the airflow around the ground. Thus, the rate of wind velocity increases with the height which is an important factor in designing of wind energy plant.

Long term Fluctuations

The annual energy yield form wind can also vary from year to year, caused by many variations in solar intensity and other large scale effects. Evidence shows that varioation in wind are much more pronounced thatn in solar irradiance and can vary much as 30% year to year

Power from wind:

The power in the wind can be computed by using concept of kinetics. The wind mill works on 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 of its mass times the square of the velocity $(1/2)mv^2$. The amount of air passing in unit time, A area through which air is allowed to pass, with velocity V, and its mass m is equal to its volume multiplied by it's density ρ of air

$$m = \rho AV$$

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

$$\text{Kinetic energy} = (1/2)mV^2 = (1/2)mV^2 \text{ watts}$$

The power available is proportional to air density. It may vary 10 to 15 percent during year because of pressure and temperature change. The power is proportional to the intercept area. The aero turbine with large swept area has higher power than smaller area machine. Thus

$A = (1/4)\pi D^2$, where D is swept area (circular in shape)

Available power in wind, $P_a = (1/2)mv^2 = (1/2)\rho AV * V^2$

$$= (1/2)\rho((1/4\pi)D^2)V * V^2$$

$$= (1/8)\pi\rho D^2 * V^3$$

Hence, by increasing by doubling the diameter of the rotor will result in four fold increase in power available in wind.

Problems associated with wind energy

Environmental impacts

Modern wind farms today may contain a large number of large-size wind turbines. Therefore, their impacts on the environment cannot be ignored. One of the impacts is that poorly sited wind energy facilities may block bird migration routes and hurtor kill birds.

Building wind farms will change the character of local landscape. Modern large wind turbines are more than 100 m tall and thus can be seen at a far distance. In practice, the visual effect for local residents is a significant consideration and is always scrutinized for wind projects. To minimize the visual effect, wind turbinesusually use neutral colors such as light grey or off-white. [

Wind turbine noise

Wind turbine noise consists of aerodynamic noise from rotating blades and mechanical vibration noise from gearboxes and generators. For a modern large wind turbine, aerodynamic noise from the blades is considered to be the dominant noise source.

There are two components in aerodynamic noise: (1) airfoil self noise, that is, the noise produced by the blade in an undisturbed inflow and is caused by the interaction in the boundary layer with the blade trailing edge; and (2) inflow turbulence noise which is caused by the interaction of upstream atmospheric turbulence with the blade and depends on the atmospheric conditions.

Integration of wind power into grid

Wind is a highly intermittent energy source for causing overall fluctuation in wind power generation. Electricity generated from wind turbines strongly depends on the local weather and geographic conditions that can fluctuate a great deal more than with some renewable energy sources such as hydropower.

Thermal management of wind turbines

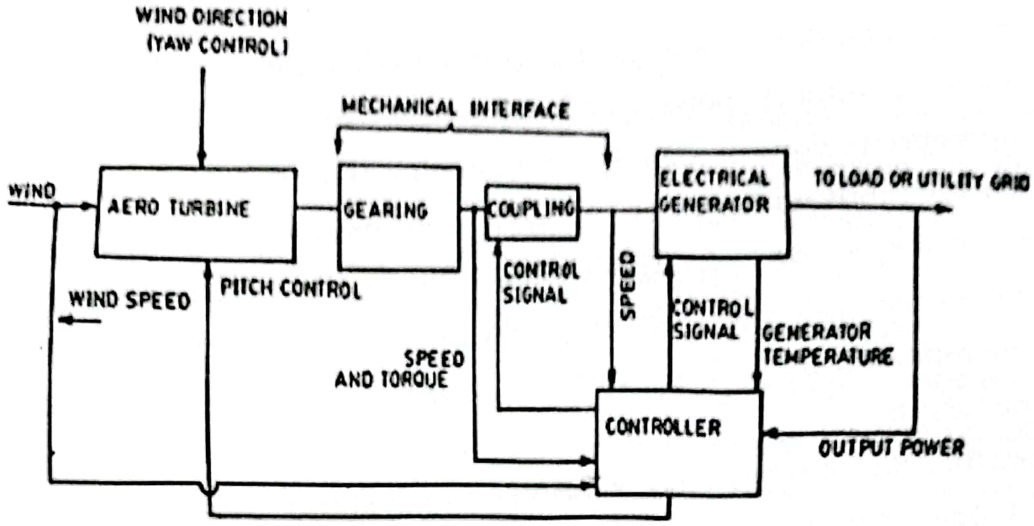
Large wind turbines are usually installed far away from urban areas and often operate under severe climate conditions, thus experiencing large variations in environmental temperatures. As a consequence, there is a need for a wind turbine to have a robust thermal control system for maintaining temperature levels inside the nacelle within specified limits.

During turbine operation, heat is generated from electric/electronic devices and rotating mechanical components (e.g. gearboxes and bearings) as a result of various power losses.

In cold climates, heating may be required for

- Warming up the lubrication oil in gearboxes
- Heating blades and hub to prevent them from icing over

Basic components of wind energy conversion system (WECS)



An apparatus for converting the kinetic energy available in the wind to mechanical energy that can be used to power machinery (grain mills, water pumps, etc). **The major components of a typical wind energy conversion system include a wind turbine, a generator, interconnection apparatus, and control systems.**

The aero turbines convert energy in moving air to rotary mechanical energy. In general, they require pitch control and yaw control 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 output of this generator is connected to the load or power grid as the application warrants.

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

42.1.
26.1.
18.1.
Gujrat
MP
MH

1949 Twh
1407 Twh

G 1375 Kwh
C 1255 Kwh

426132

maximum.

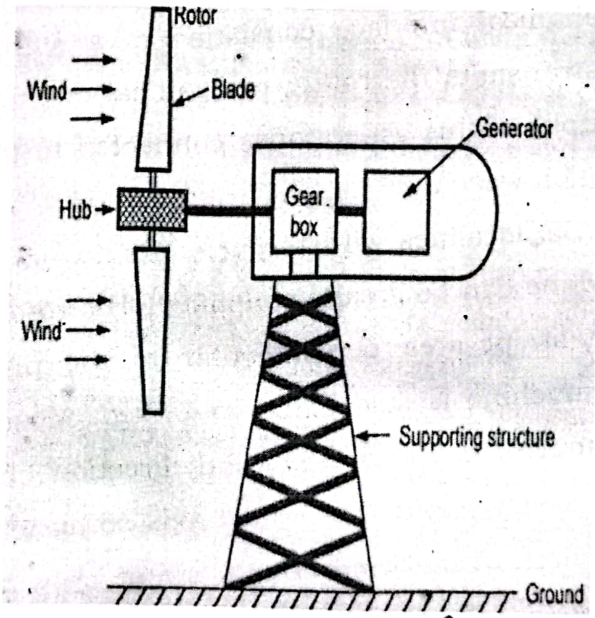
The Controller: it senses the wind speed, wind direction, shaft speed and torques, output power and generator temperature as necessary and appropriate control signals for matching the electrical output to the wind energy input and protect the system for extreme conditions brought upon by strong winds , electrical faults.. the control system consists of various sensors and decision elements like relays, logic modules, analog circuits, microprocessor and actuators which can be hydraulic, electric or pneumatic.

Classification of wind energy conversion systems

1. According to the axis of rotation

When considering the configuration of the rotating axis of rotor blades, modern wind turbines can be classified into the horizontal-axis and vertical-axis turbines

Horizontal Axis Machines:. Most commercial wind turbines today belong to the horizontal-axis type, in which the rotating axis of blades is parallel to the wind stream. The advantages of this type of wind turbines include the high turbine efficiency, high power density, low cut-in wind speeds, and low cost per unit power output.



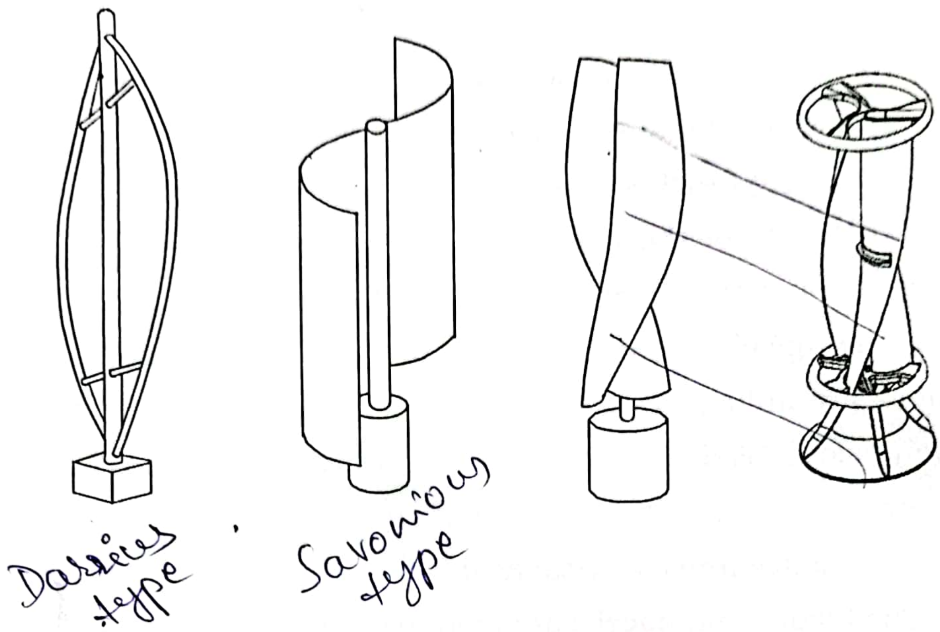
Modern wind turbines consist of several main components:

Rotor Blades - The rotor blades of a wind turbine operate under the same principle as aircraft wings. One side of the blade is curved while the other is flat. The wind flows more quickly along the curved edge, creating a difference in pressure on either side of the blade. The blades are "pushed" by the air in order to equalize the pressure difference, causing the blades to turn.

- **Nacelle** – The nacelle contains a set of gears and a generator. The turning blades are linked to the generator by the gears. The gears convert the relatively slow blade rotation to the generator rotation speed of approximately 1500 rpm. The generator then converts the rotational energy from the blades into electrical energy.
- **Tower** – The blades and nacelle are mounted on top of a tower. The tower is constructed to hold the rotor blades off the ground and at an ideal wind speed. Towers are usually between 50-100 m above the surface of the ground or water. Offshore towers are generally fixed to the bottom of the water body, although research is ongoing to develop a tower that floats on the surface.

Vertical-axis wind turbines: The blades of the vertical-axis wind turbines rotate with respect to their vertical axes that are perpendicular to the ground. A significant advantage of vertical-axis wind turbine is that the turbine can accept wind from any direction and thus no yaw control is needed. Since the wind generator, gearbox, and other main turbine components can be set up on the ground, it greatly simplifies the wind tower design and construction, and consequently reduces the turbine cost. Because the axis of the wind turbine is supported only on one end at the ground, its maximum practical height is thus limited. As the rotor surface in this turbine moves in the same direction as of the wind, they are also called cross wind axis rotors.

In addition, the unstable flow field may result in more aerodynamic losses and introduce more fatigue loads on the turbine. Furthermore, the blades in a downwind wind turbine may produce higher impulsive or thumping noise.

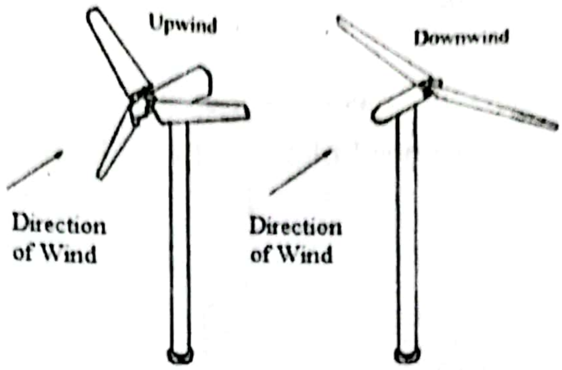


2. Based on the configuration of the wind rotor with respect to the wind flowing direction

Upwind and downwind wind turbines:

Based on the configuration of the wind rotor with respect to the wind flowing direction, the horizontal-axis wind turbines can be further classified as upwind and downwind wind turbines. The majority of horizontal-axis wind turbines being used today are upwind turbines, in which the wind rotors face the wind. The main advantage of upwind designs is to avoid the distortion of the flow field as the wind passes though the wind tower and nacelle.

For a downwind turbine, wind blows first through the nacelle and tower and then the rotor blades. This configuration enables the rotor blades to be made more flexible without considering tower strike. However, because of the influence of the distorted unstable wakes behind the tower and nacelle, the wind power output



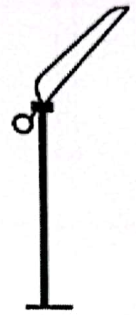
Types of Horizontal Axis Wind Turbines

3. **According to size:**
   - i. Small scale (up to 2 kW)
   - ii. Medium size Machines (2 kW to 100 kW)
   - iii. Large size Machines (100 kW and above)
4. **According to output power:**
   - i. DC output (D. C. Generator and alternator with rectifiers)
   - ii. AC output
     - a. Variable frequency, variable or constant voltage AC
     - b. Constant frequency, variable or constant voltage AC
5. **According to rotational speed:**
   - a. Constant Speed with variable pitch blades.
   - b. Nearly Constant Speed with fixed pitch blades
   - c. Variable Speed with fixed pitch blades
6. **According to utilization of output made:**
   - a. Battery storage
   - b. Direct connection an electromagnet energy convertor
   - c. Interconnection with conventional electric utility grids

Construction of various wind mills

1. **Horizontal axis propeller type using single blade:** In this type, a long blade is mounted on a rigid hub with induction motor and gear box as shown in figure. If extremely long blades are mounted on rigid hub, large

blade root bending moment may occur due to tower shadow, gravity and sudden shifts in wind directions. To reduce the rotor cost, use of low cost counter weight is recommended which balances the long blade centrifugally. These need high wind speeds to produce same power



Single bladed.

Advantages

1. Simple blade controls
2. Lower blade weight and cost, lower gear box cost
3. Counter weight costs less than second blade
4. Pitch bearing do not carry centrifugal forces
5. Blade root spar can be large diameter

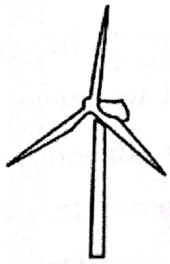
Disadvantages

1. Vibration produced due to aerodynamic torque
2. Unconventional appearance
3. Large blade root bending moment
4. Starting torque reduced by ground boundary layer

2. **Horizontal axis propeller type using two blades:** In this type of wind mill, the rotor has two blades and it drives the generator thought a step up gear box. The rotor blades are continuously flexed by unsteady aerodynamic, gravitational and inertial load. When the machine is in operation. If the blades are made of metals, flexing reduces their fatigue life with rotor and tower is also subjected to above loads, which may

cause serious damage.

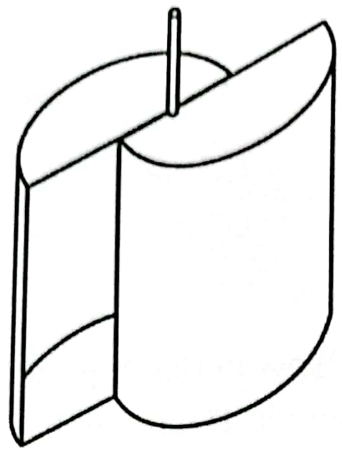
3. **Horizontal axis multi bladed type:** In this Type of design for multi blade made from sheet steel or aluminum. The rotors have high strength to weight ratio and have been know to service hours of freewheeling operation in 60 kmph winds. They have good power coefficient, high starting torque and added advantages of simplicity and low cost.



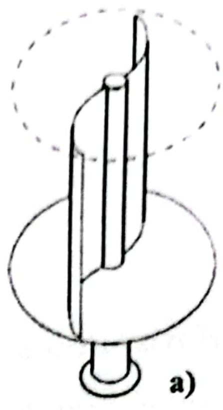
Vertical Axis Wind mills

Vertical-axis wind turbine (VAWT) is a type of wind turbine where the main rotor shaft is set transverse to the wind while the main components are located at the base of the turbine. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair. VAWTs do not need to be pointed into the wind, which removes the need for wind-sensing and orientation mechanisms.

Savonius Wind Turbine



Savonius



a)

Schematic drawing of a two-scoop Savonius turbine.

The Savonius wind turbine (SWT) is a drag-type Vertical Axis Wind Turbine (VAWT). The common design includes a rotating shaft with two or three scoops that catch the incoming wind. Due to its simplistic and robust design and its relatively low efficiency it is used whenever reliability is more important than efficiency. One reason for the low efficiency of a Savonius wind turbine is that roughly only half of the turbine generates positive torque, while the other side moves against the wind and thus produces negative torque. A variant of SWT is the Harmony wind turbine with helix-shaped blades and an automatic furling mechanism during high-speed wind conditions.

Advantages

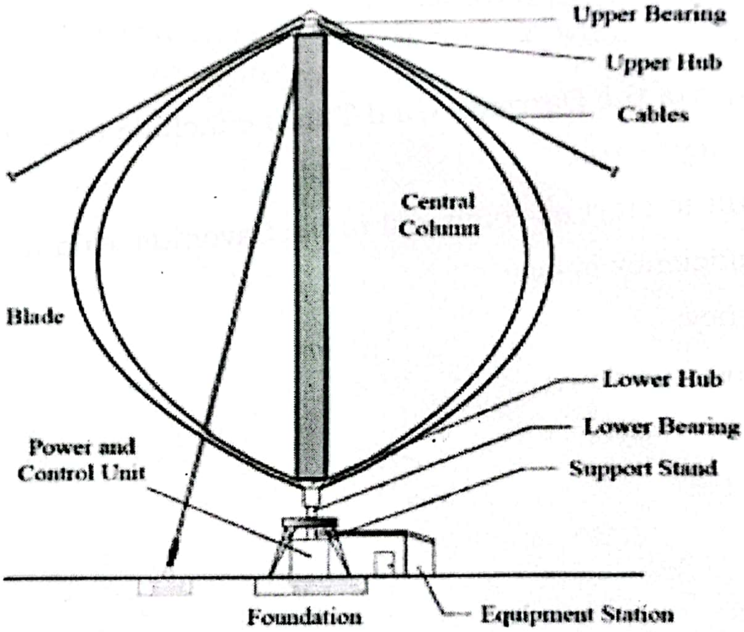
- Having a vertical axis, the Savonius turbine continues to work effectively even if the wind changesdirection.
- Because the Savonius design works well even at low wind speeds, there's no need for a tower orother expensive structure to hold it in place, greatly reducing the initial setup cost.
- The device is quiet, easy to build, and relatively small.
- Because the turbine is close to the ground, maintenance is easy.

Disadvantages

The scoop system used to capture the wind's energy is half as efficient as a conventional turbine,resulting in less power generation.

Darrieus Wind Turbine Design

The design of the Darrieus wind turbine can be done using a number of curved aerofoil blades which are arranged on a rotary framework or shaft. The Darrieus wind turbine is a type of vertical axis wind turbine, used to produce electricity using wind energy. The blade curve of this turbine allows being stressed only in anxiety at high rotary speeds.



Darrieus Wind Turbine Working Principle

These turbines are not self-starting but it requires a motor which is small powered to begin the revolution. Once it has sufficient speed then the wind flows across the aerofoils starts to produce torque & the rotor can be driven in the region of the wind. In the Darrieus turbine, two mini Savonius rotors are placed on the shaft to start a revolution. These reduce the Darrieus turbine once it gets going but they make the complete device very simpler as well as easier to keep.

Advantages

The advantages of the Darrieus Wind Turbine include the following.

- The rotor receives the wind from each direction.
- Easily arranged in the buildings
- Safety for workers
- Very easy to operate, so they don't upset people in housing neighborhoods.
- Portable from one place to another.
- Includes low-speed blades so that it reduces the risk to birds & people.
- It works in severe weather through uneven winds as well as mountain conditions.

Disadvantages

The disadvantages of the Darrieus Wind Turbine include the following.

- Low efficiency
- It is difficult to start as compared to the Savonius wind turbine
- Rotation efficiency is low
- Low efficiency
- Component wear-down

Question bank

1. With a neat block diagram, construction of wind energy conversion system.
2. Explain classification of wind mills
3. With a neat sketch explain construction and working of horizontal axis wind mill.
4. With neat sketch explain working of vertical axis wind mill which uses the drag force for generating power.
5. Discuss with a neat sketch a wind mill which not a self starting machine.
6. Compare horizontal and vertical axis wind mills.
7. Derive an expression for power available in wind.
8. Discuss various wind properties.

Classification of WECS

1) According to Axis of Rotation
   - i) Horizontal Axis Wind Turbine (HWAT)
   - ii) Vertical Axis Wind Turbine (VAWT)

2) Based on the configuration of wind rotor with respect to the wind flowing direction,
   - i) Up wind turbine
   - ii) Down wind turbine.

3) According to size
   - i) Small scale (up to 2kW)
   - ii) Medium size machine (2kW to 100kW)
   - iii) Large size machine (> 100kW

4) According to output power
   - i) DC output
   - ii) AC output

5) According to ~~rotational speed~~ Utilization
   - i) Battery storage
   - ii) Direct connection
   - iii) Interconnection with Grid.

6> According to rotational speed

→ i> constant speed with variable pitch blade

→ ii> Variable speed with fixed pitch blade.