29/07/2022 10.0 am -11. 10 am

session 2

Wind Energy Conversion

- The fact that the wind is variable and intermittent source of energy is immaterial for some application 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 from of back-up can take the form of

(1) Battery storage

(2) Connection with the local electricity distribution systems, or

(3) A stand by generator powered by liquid or gaseous fuels

- For utility 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.

1. Small Producers

- Private citizens in several countries have won right to operate wind generator 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 in the frequency and phase of the mains supply will be maintained.

- Only 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 current (DC) or variable output Alternating current (AC).

- 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 on 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. 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 grid 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, a synchronous generator is more appropriate. Synchronous generator are more complex and therefore more expensive than induction machines.

3. Lift and Drag Force

- The extraction of power, and hence energy, from the wind depends on creating certain forces and 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 of Lift forces act perpendicular to the air flow, 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 and moves towards the low 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, upon the point where

the angle of the airflow on the low pressure side becomes excessive. When this happens, the air flow 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 involves anything more complex than deflecting the air flow, it is usually an efficient process. The design of each wind turbine specfies 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 spinnings 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 one or two cases but is not generally employed. The second way is to blow air through narrow slots in a cylinder, so that it emerges tangentially; this is known as a **Thwaits Slot**.

- Thwaits Slots also creates a rotation (or circulation) of airflow, which in turn generate lift. Because the lift drag ratio of airfoils is generally much better than those of rotating or slotted cylinders, the latter techniques probably have little practical potential.

- Fig. 5.6 and Fig. 5.7 shows the forces acting on the blade and cross section across A-A. The wind mill balde ‘sees’ the resultant vector ‘Vf’. The blades need to be twisted because ‘r’ varies in proportion to radius.

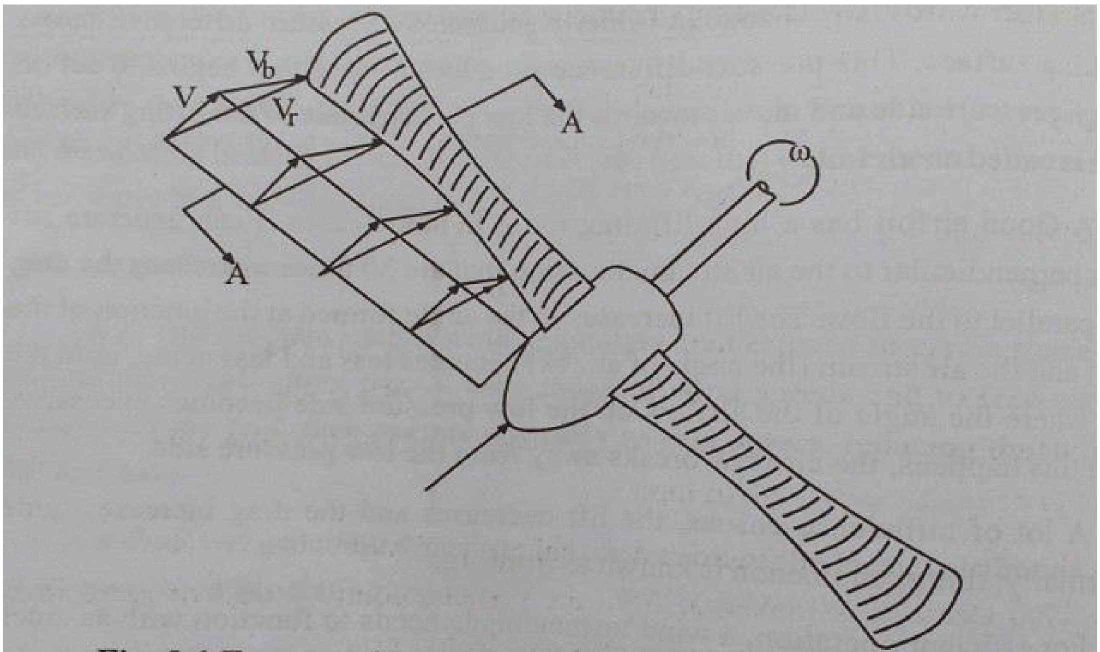
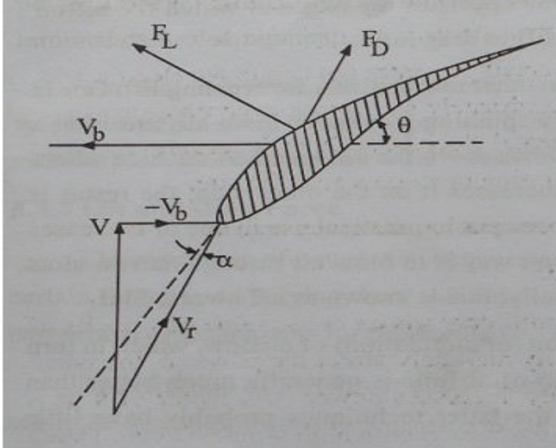


Fig. 5.6 Forces acting on the blade and cross-section across A–A.



Symbols

V	Free wind velocity
V_b	Velocity of airfoil element $[\lvert V_b \rvert = \omega_r]$
V_r	Resultant wind as ‘seen’ by airfoil element.
F_L	Lift force (perpendicular to V_r)
F_D	Drag Force
θ	Angle of Twist
α	Angle of Incidence
ω	Angular speed of rotor
r	Distance of airfoil element from its axis of rotation.

Fig. 5.7 Forces acting on the blade and cross - section across A–A.

TYPES OF WIND TURBINES

- Wind turbines can be separated into two basic types determined by which way the turbine spins. Wind turbines that rotate around a horizontal axis are more common (like a wind mill), while vertical axis wind turbines are less frequently used (Savonius and Darrieus are the most common in the group).

So we have ;

1) Horizontal Axis Wind Turbines (HAWT)

2) Vertical Axis Wind Turbines(VAWT)

Horizontal Axis Wind Turbines (HAWT): Schematic Structure, Advantage, Disadvantages

Horizontal Axis Wind Turbines (HAWT)

- Horizontal axis wind turbines, also shortened to HAWT, are the common style that most of us think of a wind turbine. A HAWT has a similar design to a windmill, it has blades that look like a propeller that spin on the horizontal axis as shown in figure.

- Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind.
- Small turbine are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor to turn the turbine into the wind.
- Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator.

- Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds.

- Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount.

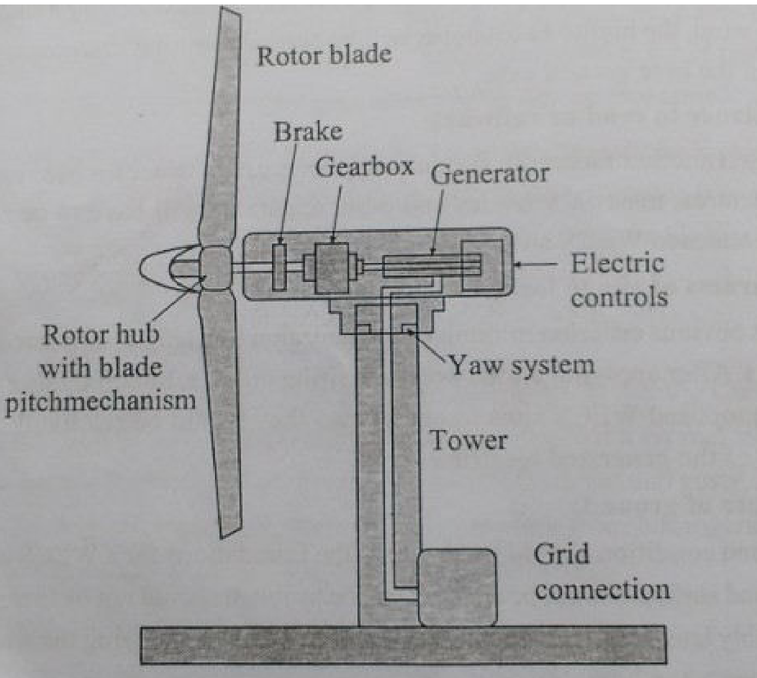


Fig. 5.8 Schematic Structure ofHorizontal Axis Wind Turbines

- Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind.
- Additionally, in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since turbulence leads to fatigue failures, and reliability is so important, most HAWTs are upwind machines.

Important point to remember regarding HAWT:

(1)Lift is the main force

(2)Much lower cyclic stress

(3)95% of the existing turbines are HAWTs

(4)Nacelle is placed at the top of the tower

(5)Yaw mechanism is required

HAWT Advantage

1. The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up the wind speed can increase by 20% and the power output by 34%.

2. High efficiency, since the blades always move perpendicular to the wind, receiving power through the whole rotation. In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to the wind leads to inherently lower efficiency.

HAWT Disadvantages

1. Massive tower construction is required to support the heavy blades, gearbox, and generator.

2.Components of horizontal axis wind turbine (gearbox, rotor shaft and brake assembly) being lifted into position.

3. Their height makes them obtrusively visible across large areas, disrupting the appearance of the landscape and sometimes creating local opposition.

- Download variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower).

5. HAWTs require an additional yaw control mechanism to turn the blades toward the wind.

6. HAWTs generally require a braking or yawing device in high winds to stop the turbine from spinning and destroying or damaging itself.

Vertical Axis Wind Turbines(VAWT): Schematic Structure, Advantage, Disadvantages

Vertical Axis Wind Turbines(VAWT)

- Vertical wind turbines, as shortened to VAWTs, have the main rotor shaft arranged vertically as shown in Fig 5.9.

- The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on site where the wind direction is highly variable or has turbulent winds.

- With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT generally create drag when rotating into the wind.

- It is difficult to mount vertical-axis turbines on towers, meaning they are often installed nearer to the base on which they rest, such as the ground or a building rooftop.
- The wind speed is slower at a lower altitude, so less wind energy is available for a given size turbine. Air flow near the ground and other objects can create turbulent flow, which can introduce issues of vibration, including noise and bearing wear which may increase the maintenance or shorten its service life.

- However, when a turbine is mounted on a rooftop, the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence.

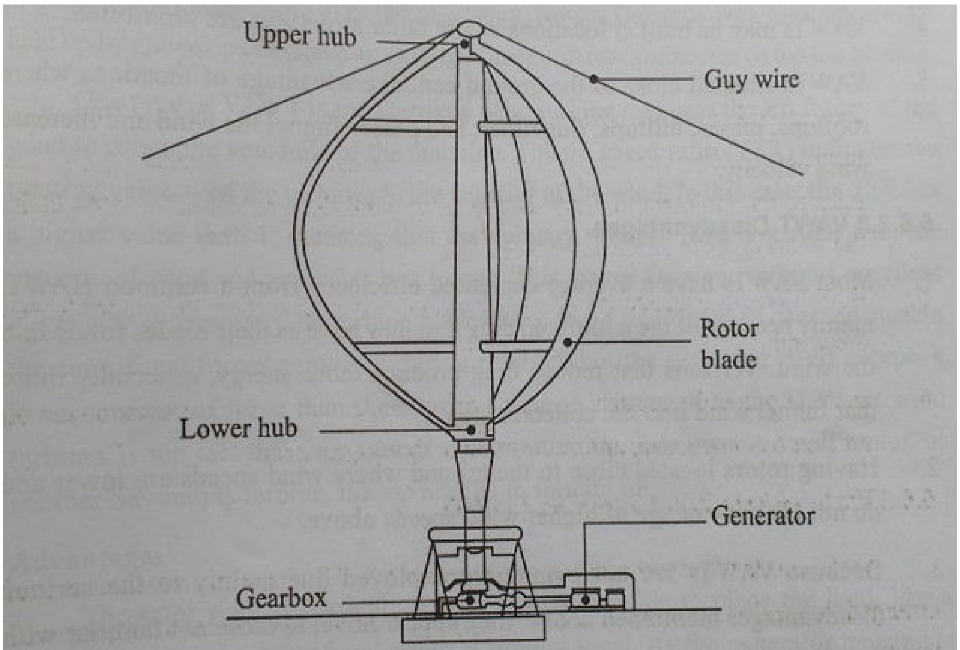


Fig. 5.9 Schematic Structure of Vertical Axis Wind Turbines (Darrieus wind turbine)

Important points to remember recording VAWT:

1. Nacelle is placed at the bottom.
2. Drag is the main force
3. Yaw mechanism is not required
4. Lower starting torque
5. Difficulty in mounting the turbine
6. Unwanted fluctuations in the power output

VAWT Advantages

1. No yaw mechanisms is needed

2. A VAWT can be located nearer the ground, making it easier to maintain the moving parts.

3. VAWTs have lower wind startup speeds than the typical the HAWTs.

4. VAWTs may be built at locations where taller structures are prohibited.

5. VAWTs situated close to the ground can take advantage of locations where rooftops, means hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

VAWT Disadvantage

- 1. Most VAWTs have a average decreased efficiency from a common HAWT, mainly because of the additional drag that they have as their blades rotate into the wind. Versions that reduce drag produce more energy, especially those that funnel wind into the collector area.

- 2. Having rotors located close to the ground where wind speeds are lower and do not take advantage of higher wind speeds above.

- 3. Because VAWTs are not commonly deployed due mainly to the serious disadvantage mentioned above, they appear novel to those not familiar with the wind industry. This has often made them the subject of wild claims and investment scams over the last 50 years.

****