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Wind Energy

7- Wind Turbine

A wind turbine is a machine that converts the kinetic energy from the wind into mechanical energy. If the mechanical energy is used directly by machinery, such as a pump or grinding stones; the machine is usually called a windmill. If the mechanical energy is then converted into electricity; the machine is called a wind generator. In general, the size of turbine ranges from a few Watts (small wind turbine) to several Million Watts (large wind turbine). Small wind turbines (small scale) are typically used to power houses, and schools that usually consume less than 50 KW of total capacity. The small turbines can be used in conjunction with solar photovoltaic. Large wind turbines (large scale) are typically installed in large arrays (wind farms); power ranges from 100 KW up to 5000 KW.

7-1Wind Turbines are usually classified into two categories:

a - Vertical - Axis Wind Turbine (VAWT).

b - Horizontal - Axis Wind Turbine (HAWT).

a-Vertical-Axis Wind Turbine (VAWT):

The first wind turbine was built based on the vertical-axis structure. This type has only been incorporated in small scale installations. Typical VAWT include the Darrius rotor, as shown in figure (7.1).

The advantages of the (VAWT) are:

1. It is easy to install and maintain for ground mounted generator and gearbox
2. It receives wind from any direction (no yaw control is required) and less sensitive to turbulence.
3. Simple blade design and low cost of fabrication.

Whereas, the disadvantages of a vertical-axis wind turbine are:

1. It is not a self-starting; thus, it requires a generator to run in motor mode at start where wind speeds are very slow close to the ground level.
2. It has lower efficiency; VAWT produces energy at only 50% of the efficiency of HAWT.
3. Difficulty in controlling blade over speed

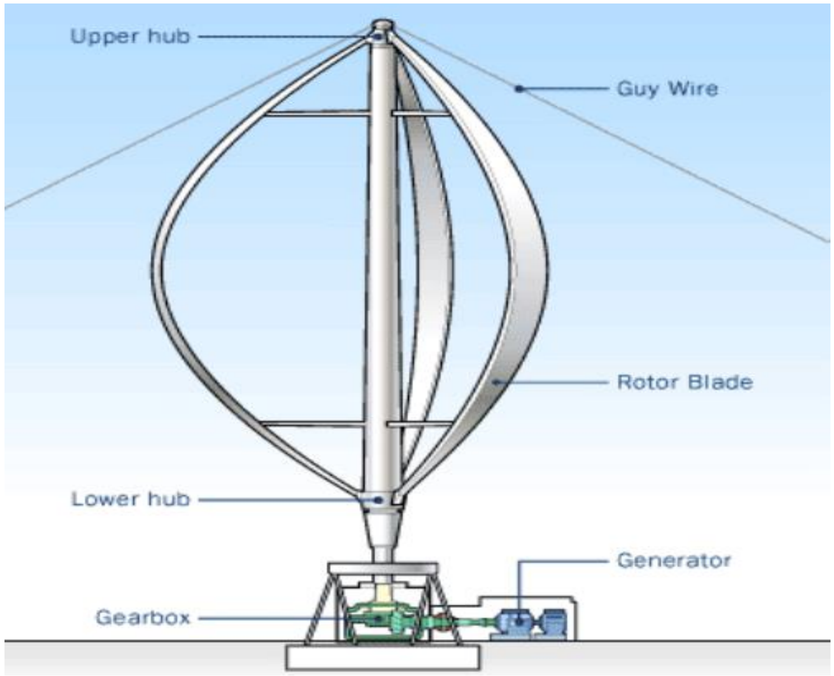

Figure 7.1: A typical vertical-axis turbine (the Darrius rotor).

b-Horizontal-Axis Wind Turbine (HAWT):

The most common design of modern turbine is based on the horizontal-axis structure. Horizontal-axis wind turbine is mounted on tower as shown in figure (7.2). The tower role is to raise the wind turbine above the ground to intercept stronger winds in order to harness more energy.

The advantages of the HAWT are:

1. HAWT: has the ability to collect maximum amount of wind energy, in addition it is most economic and widely used.
2. It has the ability to pitch the rotor blades in high wind storm to avoid damages.
3. Tall tower allows placement turbine on uneven land or in offshore locations

The disadvantages of the horizontal-axis turbine are:

1. The generator and gearbox should be mounted on a tower, thus restricting servicing.
2. Tall HAWTs are difficult to install and need very tall and expensive cranes and skilled operators.
3. Height turbine can be a hazard for low altitude aircraft

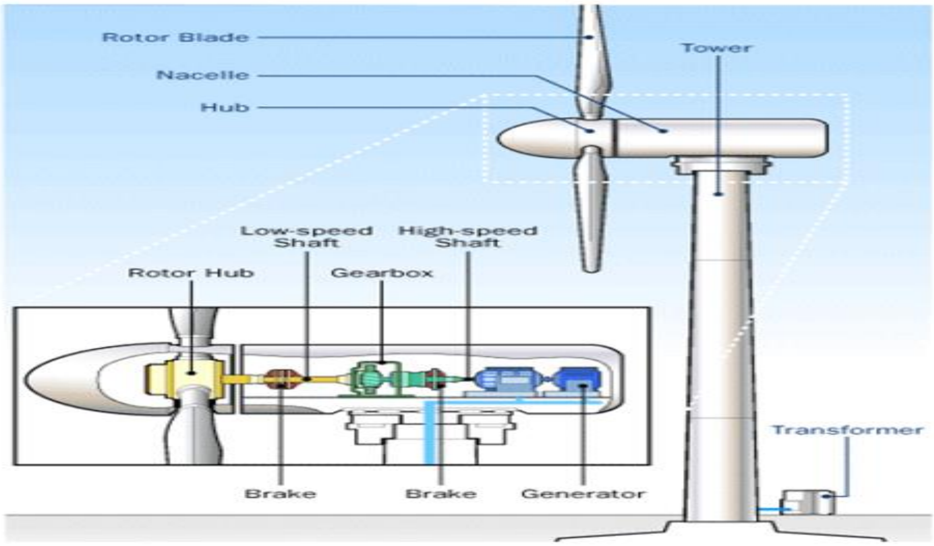

Figure 7.2: A typical horizontal-axis wind turbine

7-2 Structure of a Wind Turbine Generator (WTG):

Wind Turbine Generator: is the system that converts kinetic energy in the wind into electrical energy. Figure 7-3

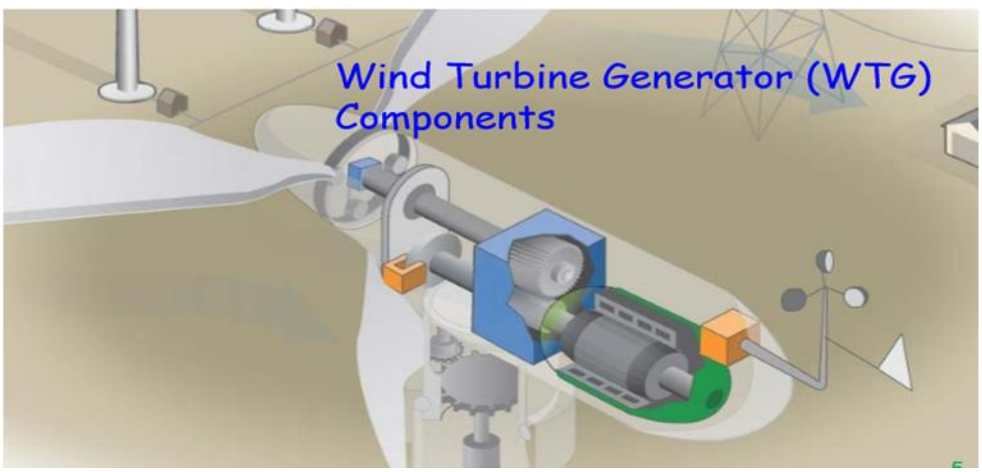

Figure7-3 Structure of a Wind Turbine Generator

7-2.1 Hub Height

It is the height that represents the center of the swept area of the wind turbine rotor above the ground surface.

7-2-2 Gear Box

It connects the low-speed shaft to the high-speed shaft and increases the rotational speed to the required level by the generator to produce electricity. The gear box is the costly and heavy part of the wind turbine.

7-2-3 Rotor Size

The size of the turbine blades is related to the amount of power that a turbine can produce, so the larger blades, the more wind that can be harvested. A doubling rotor diameter would increase the power output.

7-2-4 Blades

Blade is a rotating component aerodynamically designed to work on the principle of lift and drag to convert the kinetic energy of wind into mechanical energy which is transferred through shaft and then converted to electrical energy using generator. Most turbines have either two or three blades. Blade length is a key factor that determines power generation capacity of a wind turbine. The blades are usually made of glass fiber reinforced polyester or epoxy, which are less expensive than Kevlar reinforced models, and less susceptible to metal fatigue.

7-2-5 Yawing

The yaw is used to keep the rotor facing the wind, so it works according to the wind directions, as shown in figure (7-4).

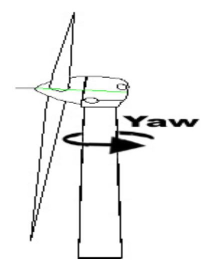

Figure 7-4: Yawing

7-2-6 Capacity Factor (CF)

The capacity factor of a power plant is the ratio of the actual annual energy production to the maximum possible energy production if it operates at its full capacity, as shown in equation (1.1).

$$CF = \frac{actual\ energy\ production}{maximum\ possible\ energy\ production} \quad \text{---------7-1}$$

7-2-7 Life Time

Modern wind turbine is generally designed to work for around 120 000 hours of operation. However, the actual lifetime of a wind turbine depends on both the quality of the turbine and the local climatic conditions, e.g., the amount of turbulence at site.

7-2-8 Fatigue Loads

Wind turbines are subjected to fluctuating winds, and fluctuating forces. This is particularly the case if they are located in a very turbulent wind climate. Components, which are subjected to repeat bending, such as rotor blades, may eventually develop cracks, which ultimately may cause the component break.

7-3 Wind Turbine Power Curve

The power curve of a wind turbine is its power output as a function of the wind speed. The power output largely depends on the wind speed, but it is also affected by wind shear, turbulence intensity, wind direction, and other factors. Wind turbine power curve for (ENERCON E-53) is shown in figure (7-5).

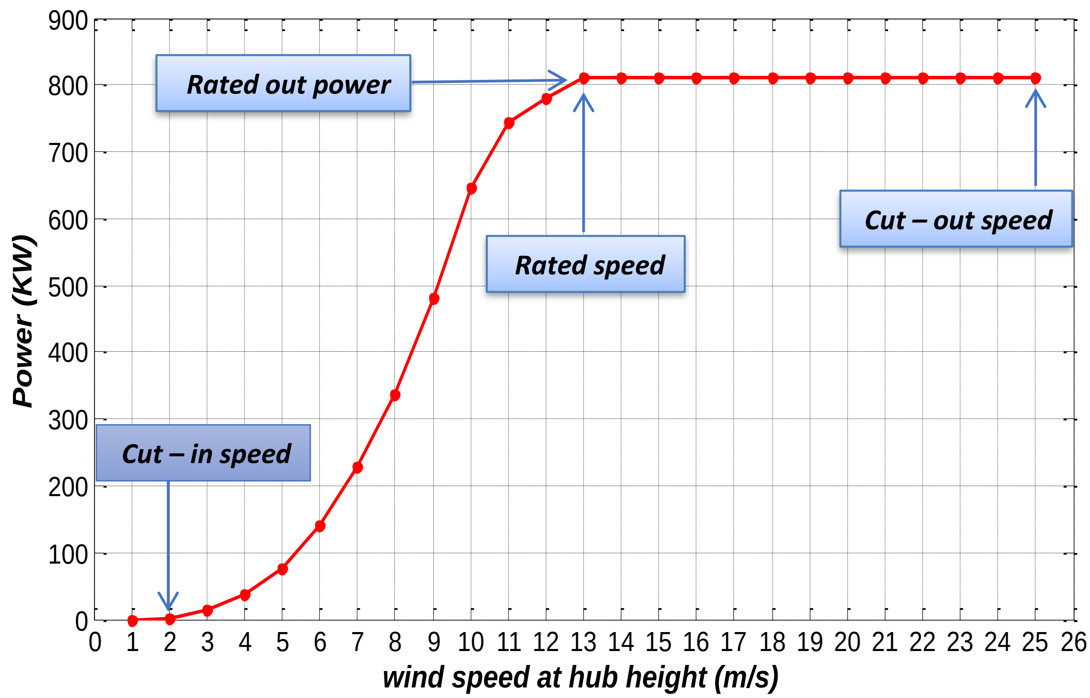

Figure 7-5: Power curve for E 53 -800KW

The cut-in wind speed is the minimum wind speed for the start of the turbine rotation. The cut-out speed is the maximum speed when the turbine has to stop due to the safety reasons and to prevent structural damage from the heavy loads. The rated output power is the maximum output of the turbine. Rated wind speed is the wind speed at which the maximum power output is reached.

Wind–solar hybrid system:

Both wind and solar energy are highly intermittent electricity generation sources. Time intervals within which fluctuations occur span multiple temporal scales, from seconds to years. These fluctuations can be subdivided into periodic fluctuations (diurnal or annual fluctuations) and non-periodic fluctuations related to the weather change.

Wind and solar energy are complementary to each other in time sequence and regions. In the summer, sunlight is intensive and the sunshine duration is long but there is less wind. In the winter, when less sunlight is available, wind becomes strong. During a day, the sunshine is strong while wind is weak. After sunset, the wind is strengthened due to large temperature changes near the earth's surface. For all load demands, the leveled energy cost for the wind–solar hybrid system is always lower than that of standalone solar or wind system. Because the major operating time for wind and solar systems occurs at different periods of time, wind–solar hybrid power systems can ensure the reliability of electricity supply. The applications of wind–solar hybrid systems range extensively from residential houses to municipal and industrial facilities, either grid connected or standalone. As in figure 7-6

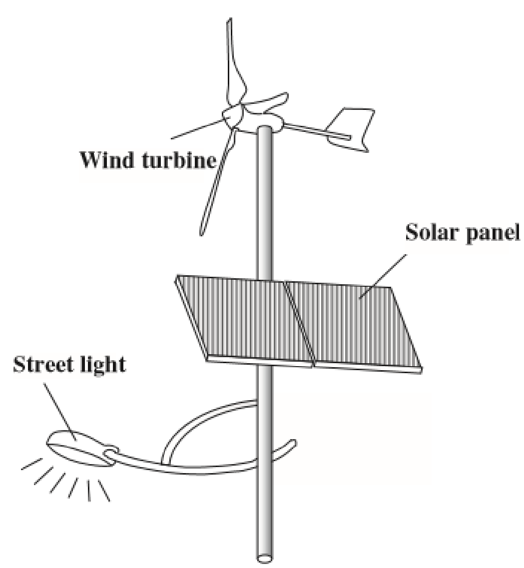

Figure 7-6 Wind–solar hybrid system for street lights

Wind–hydro hybrid system:

Hydropower generation is to convert potential energy in water into electrical energy by means of hydropower generators. As a renewable and clean energy source, hydropower accounts for the dominant portion of electricity generated from all renewable sources. In many locations of the world, hydropower is complementary with wind power, while the seasonal wind power distribution is higher in winter and spring but lower in summer and fall, hydropower is lower in the dry seasons (winter and spring) but higher in the wet seasons (summer and fall). Thus, the integration of wind and hydropower systems can provide significant technical, economic, and systematic benefits for both systems. Taking a reservoir as a means of energy regulation, “green” electricity can be produced with wind–hydro hybrid systems.