UNIT IV

Wind, Solar Energy and DG Technologies

Wind Energy scenario:

History of wind-mills:

The wind is a by-product of solar energy. Approximately 2% of the sun's energy reaching the earth is converted into wind energy. The surface of the earth heats and cools unevenly, creating atmospheric pressure zones that make air flow from high- to low-pressure areas.

The wind has played an important role in the history of human civilization. The first known use of wind dates back 5,000 years to Egypt, where boats used sails to travel from shore to shore. The first true windmill, a machine with vanes attached to an axis to produce circular motion, may have been built as early as 2000 B.C. in ancient Babylon. By the 10th century A.D., windmills with wind-catching surfaces having 16 feet length and 30 feet height were grinding grain in the areas in eastern Iran and Afghanistan.

The earliest written references to working wind machines in western world date from the 12th century. These too were used for milling grain. It was not until a few hundred years later that windmills were modified to pump water and reclaim much of Holland from the sea.

The multi-vane "farm windmill" of the American Midwest and West was invented in the United States during the latter half of the l9th century. In 1889 there were 77 windmill factories in the United States, and by the turn of the century, windmills had become a major American export. Until the diesel engine came along, many transcontinental rail routes in the U.S. depended on large multi-vane windmills to pump water for steam locomotives.

Farm windmills are still being produced and used, though in reduced numbers. They are best suited for pumping ground water in small quantities to livestock water tanks. In the 1930s and 1940s, hundreds of thousands of electricity producing wind turbines were built in the U.S.

They had two or three thin blades which rotated at high speeds to drive electrical generators. These wind turbines provided electricity to farms beyond the reach of power lines and were typically used to charge storage batteries, operate radio receivers and power a light bulb. By the early 1950s, however, the extension of the central power grid to nearly every American household, via the Rural Electrification Administration, eliminated the market for these machines. Wind turbine development lay nearly dormant for the next 20 years.

A typical modern windmill looks as shown in the following figure. The wind-mill contains three blades about a horizontal axis installed on a tower. A turbine connected to a generator is fixed about the horizontal axis.

Like the weather in general, the wind can be unpredictable. It varies from place to place, and from moment to moment. Because it is invisible, it is not easily measured without special instruments. Wind velocity is affected by the trees, buildings, hills and valleys around us. Wind is a diffuse energy source that cannot be contained or stored for use elsewhere or at another time.

Wind turbine generators **(April/May 2014)**

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 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.

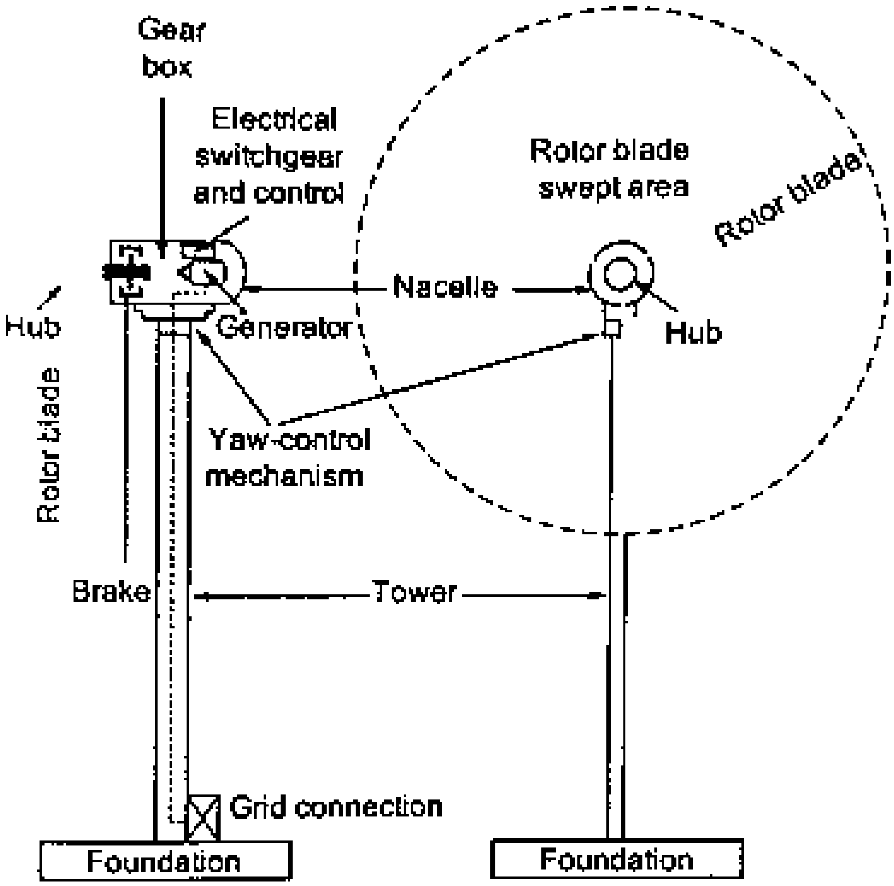


Fig. 7.14 Horizontal axis wind turbine

Main Components:

The constructional details of the most common, three-blade rotor, horizontal axis wind turbine is shown in figure. 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 is typical, MW range, modern rotor may be of the order of 100m.

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 aeroplanes. However, the rotor rpm in case of wind turbine is very low as compared to that for propellers. The relative merits and demerits of two-blades and three-blade rotors are as follows:

- Compared to the two-blade design, the three-blade machine has smoother power output and balanced gyroscopic force.
- There is no need to teeter (to be discussed later in this section) the rotor, allowing the use of a simple rigid hub. The blades may be cross-linked for greater rigidity.
- Adding a third blade increases the power output by about 5% only, while the weight and cost of a rotor increases by 50%, thus giving a diminished rate of return for additional 50% weight and cost.
- The two-blade rotor is also simpler to erect, since it can be assembled on the ground and lifted to the shaft without complicated maneuvers during the lift.

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.

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.

(ii) 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. Although vertical axis wind turbines have these advantages, their designs are not as efficient at collecting energy from the wind as are the horizontal machine designs.

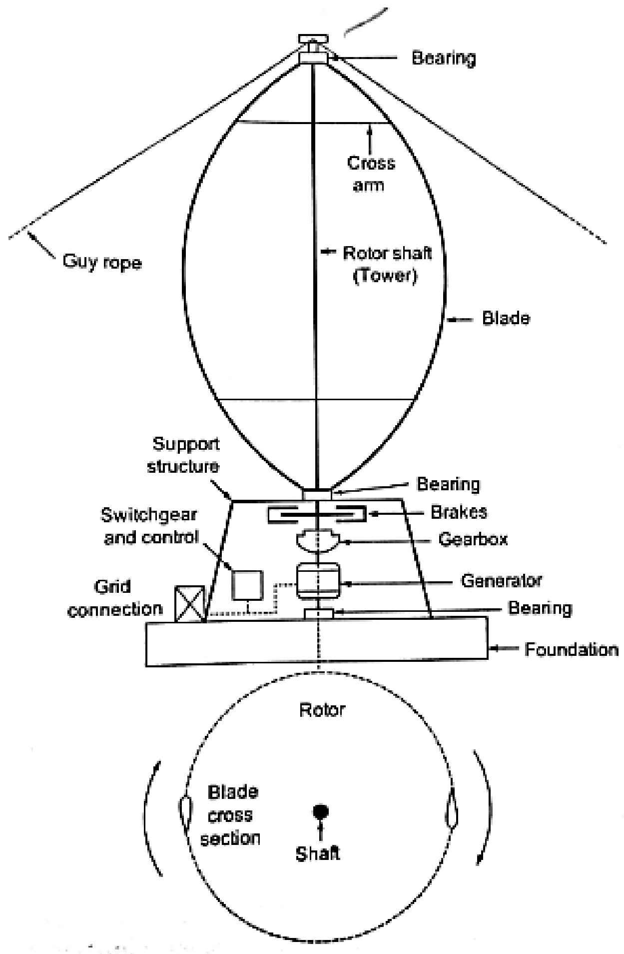
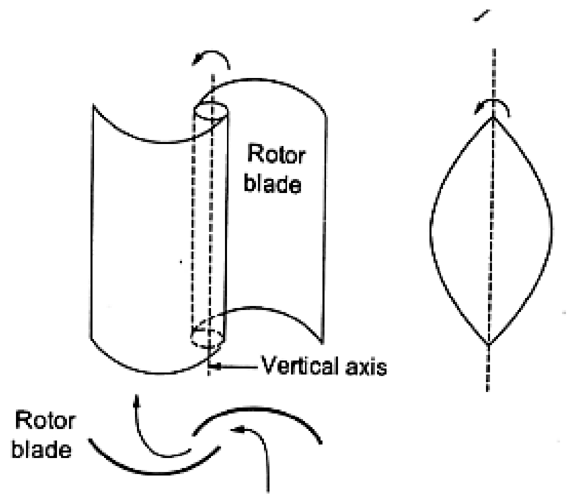


Fig. 7.19 *Vertical axis wind (Darrieus) turbine*



(b) Savonious rotor (c) Darrieus rotor

There is one more type of wind-mill called Cyclo-gyro wind-mill with very high efficiency of about 60%. However, it is not very stable and is very sensitive to wind direction. It is also very complex to build.

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 locate at the ground, thus eliminating th4e 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.

Main components:

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

Tower (or rotor shaft):

The tower is a hollow vertical rotor shaft, which rotated 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 100m.

Blades:

It has two or three thin, curved blades 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 94m and the diameter as 65m with a chord of 2.4m.

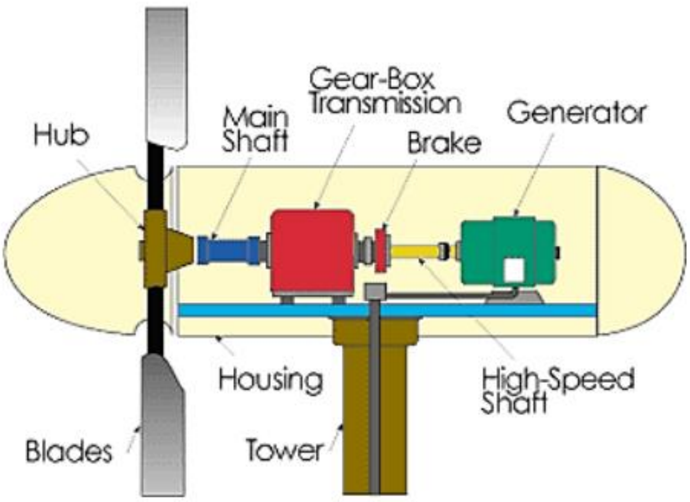
Support Structure:

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.

Function of wind power generation system. **(Nov 2012) (Nov 2013)(April 2015)**

Main components of a wind-mill:

Fig. below shows typical components of a horizontal axis wind mill.



Rotor:

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 and the shape of the blades. The blades are attached to the hub, which in turn is attached to the main shaft.

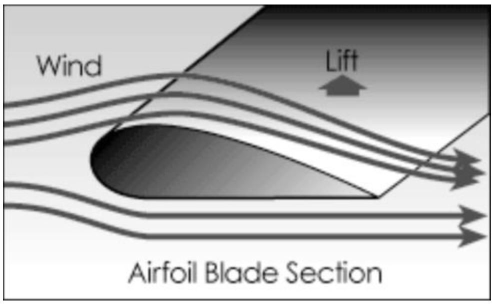
Drag design:

Blade designs operate on either the principle of drag or lift. For the drag design, the wind literally pushes the blades out of the way. Drag powered wind turbines are characterized by slower rotational speeds and high torque capabilities. They are useful for the pumping, sawing or grinding work. For example, a farm-type windmill must develop high torque at start-up in order to pump, or lift, water from a deep well.

Lift design:

The lift blade design employs the same principle that enables airplanes, kites and birds to fly. The blade is essentially an airfoil, or wing. When air flows past the blade, a wind speed and pressure differential is created between the upper and lower blade surfaces. The pressure at the lower surface is greater and thus acts to "lift" the blade. When blades are attached to a central axis, like a wind turbine rotor, the lift is translated into rotational motion. Lift-powered wind turbines have much higher rotational speeds than drag types and therefore well suited for electricity generation.

Fig. below gives an idea about the drag and lift principle.



Tip Speed Ratio:

The tip-speed is the ratio of the rotational speed of the blade to the wind speed. The larger this ratio, the faster the rotation of the wind turbine rotor at a given wind speed. Electricity generation requires high rotational speeds. Lift-type wind turbines have maximum tip-speed ratios of around 10, while drag-type ratios are approximately 1. Given the high rotational speed requirements of electrical generators, it is clear that the lift-type wind turbine is most practical for this application.

The number of blades that make up a rotor and the total area they cover affect wind turbine performance. For a lift-type rotor to function effectively, the wind must flow smoothly over the blades. To avoid turbulence, spacing between blades should be great enough so that one blade will not encounter the disturbed, weaker air flow caused by the blade which passed before it. It is because of this requirement that most wind turbines have only two or three blades on their rotors.

Generator:

The generator is what converts the turning motion of a wind turbine's blades into electricity. Inside this component, coils of wire are rotated in a magnetic field to produce electricity. Different generator designs produce either alternating current (AC) or direct current (DC), and they are available in a large range of output power ratings. The generator's rating, or size, is dependent on the length of the wind turbine's blades because more energy is captured by longer blades.

It is important to select the right type of generator to match intended use. Most home and office appliances operate on 240 volt, 50 cycles AC. Some appliances can operate on either AC or DC, such as light bulbs and resistance heaters, and many others can be adapted to run on DC. Storage systems using batteries store DC and usually are configured at voltages of between 12 volts and 120 volts.

Generators that produce AC are generally equipped with features to produce the correct voltage of 240 V and constant frequency 50 cycles of electricity, even when the wind speed is fluctuating.

DC generators are normally used in battery charging applications and for operating DC appliances and machinery. They also can be used to produce AC electricity with the use of an inverter, which converts DC to AC.

Transmission:

The number of revolutions per minute (rpm) of a wind turbine rotor can range between 40 rpm and 400 rpm, depending on the model and the wind speed. Generators typically require rpm's of 1,200 to 1,800. As a result, most wind turbines require a gear-box transmission to increase the rotation of the generator to the speeds necessary for efficient electricity production. Some DC-type wind turbines do not use transmissions. Instead, they have a direct link between the rotor and generator. These are known as direct drive systems. Without a transmission, wind turbine complexity and maintenance requirements are reduced, but a much larger generator is required to deliver the same power output as the AC-type wind turbines.

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. Larger wind turbines are usually mounted on towers ranging from 40 to 70 meters tall.

Towers for small wind systems are generally "guyed" designs. This means that there are guy wires anchored to the ground on three or four sides of the tower to hold it erect. These towers cost less than freestanding towers, but require more land area to anchor the guy wires. Some of these guyed towers are erected by tilting them up. This operation can be quickly accomplished using only a winch, with the turbine already mounted to the tower top. This simplifies not only installation, but maintenance as well. Towers can be constructed of a simple tube, a wooden pole or a lattice of tubes, rods, and angle iron. Large wind turbines may be mounted on lattice towers, tube towers or guyed tilt-up towers.

Towers must be strong enough to support the wind turbine and to sustain vibration, wind loading and the overall weather elements for the lifetime of the wind turbine. Their costs will vary widely as a function of design and height.

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 kmph.

Rated speed:

The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power. For example, a "10 kilowatt" wind turbine may not generate 10 kilowatts until wind speeds reach 40 kmph. Rated speed for most machines is in the range of 40 to 55 kmph. At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called "power curves," showing how their wind turbine output varies with wind speed.

Cut-out speed:

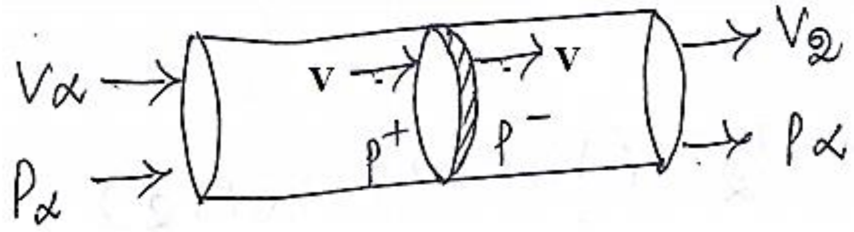
At very high wind speeds, typically between 72 and 128 kmph, most wind turbines cease power generation and shut down. The wind speed at which shut down occurs is called the cut-out speed. Having a cut-out speed is a safety feature which protects the wind turbine from damage. Shut down may occur in one of several ways. In some machines an automatic brake is activated by a wind speed sensor. Some machines twistor "pitch" the blades to spill the wind. Still others use "spoilers," drag flaps mounted on the blades or the hub which are automatically activated by high rotor rpm's, or mechanically activated by a spring loaded device which turns the machine sideways to the wind stream. Normal wind turbine operation usually resumes when the wind drops back to a safe level.

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 wind turbine's 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%. A more typical efficiency is 35% to 45%. A complete wind energy system, including rotor, transmission, generator, storage and other devices, which all have less than perfect efficiencies, will deliver between 10% and 30% of the original energy available in the wind.

Mathematical expression governing wind 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:



According to Bernoulli's principle

Energy per unit volume before = Energy per unit volume after

Power extraction = Loss in kinetic energy

Energy per unit volume before = Energy per unit volume after.

$\frac{1}{2}\rho V_{\propto}^2 + P_{\propto} = \frac{1}{2}\rho v^2 + P^+$…..(1)

$\frac{1}{2}\rho V_2^2 + P_{\propto} = \frac{1}{2}\rho v^2 + P^-$……(2)

From eqn 1 and eqn 2,

$\frac{1}{2}\rho(V_{\propto}^2 - V_2^2) = P^+ - P^-$……(3)

This equation is pressure difference.

Thrust (Force) = $(P^+ - P^-)\,A$ ……(4)

Thrust = $\frac{1}{2}\rho(V_{\propto}^2 - V_2^2)\,A$ …….(5)

Thrust F= mA

F= m $(V_\alpha - V_2)$ ………..(6)

$\frac{1}{2}\rho(V_{\propto}^2 - V_2^2) =$ m $(V_\alpha - V_2)$ ………….(7)

$$\frac{1}{2}\rho(V_{\propto}^2 - V_2^2)A = \rho A v(V_\alpha - V_2)$$

$$\frac{1}{2}\left(\frac{V_{\propto}^2 - V_2^2}{(V_\alpha - V_2)}\right) = v$$

$$v = \frac{1}{2}\left(\frac{(V_\alpha + V_2)(V_\alpha - V_2)}{(V_\alpha - V_2)}\right)$$

$v = \frac{1}{2}(V_\alpha + V_2)$ ……….(8)

Considering the axial interference factor a,

$v = V_\alpha(1-a)$ ……….(9)

When, a=0 (fully open)

$v = V_\alpha$

When, a=1 (fully closed)

v=0

Equate eqn 8 and eqn 9

$$v = \frac{1}{2}(V_\alpha + V_2) = V_\alpha(1-a)$$

$(V_\alpha + V_2) = 2V_\alpha(1-a)$

$(V_\alpha + V_2) = 2V_\alpha - 2V_\alpha a)$

$V_2 = V_\alpha - 2V_\alpha a$

$V_2 = V_\alpha(1-2a)$

Power extracted form wind turbine,

$P = \frac{1}{2}\rho \mathrm{Av}(V_\propto^2 - V_2^2)$

Sub $v = V_\alpha(1-a)$

$$V_2 = V_\alpha(1-2a)$$

$P = \frac{1}{2}\rho A V_\alpha(1-a)(V_\propto^2 - (V_\alpha(1-2a))^2$

$P = \frac{1}{2}\rho A V_\alpha(1-a)(V_\propto^2 - (V_\propto^2(1-2a)^2)$

$P = \frac{1}{2}\rho A V_\propto^3(1-a)(1- 1+4a^2-4a)$

$P = \frac{1}{2}\rho A V_\propto^3(4a-8a^2+4a^3)$ This is the power extraction

Condition for maximum power

$\frac{dp}{da} = 0$

$0 = \frac{1}{2}\rho A V_\propto^3(4-16a+12a^2)$

$= 4-16a+12a^2$

$= 12a^2-16a+4$

$a = 12a^2-12a-4a+4$

$= 12a(1-a)+a(-a+1)$

$a = 1, a = \frac{1}{3}$

Sub $a = \frac{1}{3}$ in power extraction equation,

$P = \frac{1}{2}\rho A V_\propto^3 \times \frac{16}{17}$is the power extraction of wind.

Wind energy conversion systems(WECS) :

A wind energy conversion system converts wind energy into some form of electrical energy. In practical, medium and large scale WECS are designed to operate in parallel with a public or local ac grid. This is known as a ***grid-connectedsystem***. A small system, isolated from the grid, feeding only to a local load is known as ***autonomous***, remote, decentralized, stand-alone or isolated power system. A general block diagram of a grid-connected WECS is shown in figure. 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. This block acts as a drive for the generator. Use of variable gear ratio has been considered in the past and was found to add more problems than benefits. Hence dc, synchronous or induction generators are used for mechanical to electrical power conversion depending on the design of the system. The interface conditions the generated power grid-quality power. It may consist of a power electronic converter, transformer and filter, etc. The control unit monitors and controls the interaction among various blocks. It derives the reference voltage and frequency signals from the grid and receives wind speed, wind direction, wind turbine speed signals, etc., processes them and accordingly controls various blocks for optimal energy balance.

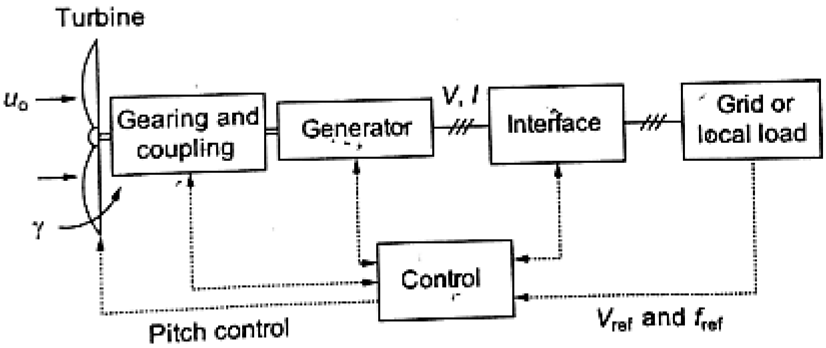


Fig. 7.23 *General block diagram of a WECS*

The main features of various types of generators and their suitability in wind power generation are discussed below:

i) DC Generator:

Conventional dc generators are not favoured due to their high cost, weight and maintenance problems of the commutator. However, permanent-magnet (brushless and commutator-less) dc machines are considered in small-rating (below hundred kW) isolated systems.

ii) Synchronous Generator:

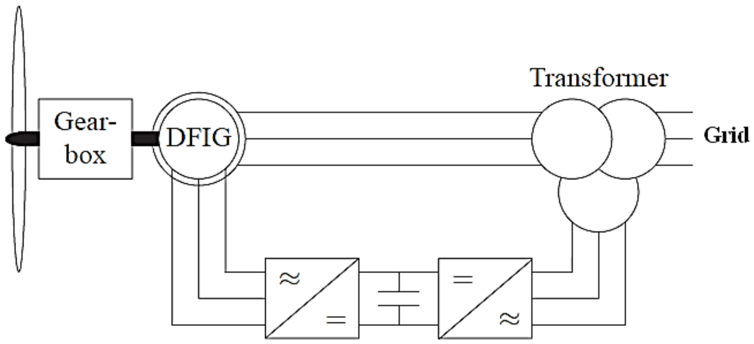
Synchronous generators produce high-quality output and are universally used for power generation in conventional plants. However, they have very rigid requirement of maintaining constant shaft speed and any deviation from synchronous value immediately reflects in the generated frequency. Also, precise rotor speed control is required for synchronization. Due to this reason, a synchronous machine is not well suited to wind power generation. Requirement of dc current to excite rotor field, which needs sliding carbon brushes on the slip rings also poses limitations on its use. The need of a dc field current and brushes can be eliminated by using reluctance rotor. The reliability is greatly improved while reducing the cost. The machine rating, however, is limited to tens of kW. Synchronization of a wind-driven generator with the power grid also poses problems especially during gusty winds. The main advantage is that it generates both active as well as reactive powers.

iii) Induction Generators:

The primary advantages of an induction machine are the rugged, brushless construction, no need of separate dc field power and tolerance of slight variation of shaft speed (±10%) as these variations are absorbed in the slip. Compared to dc and synchronous machines, they have low capital cost, low maintenance and better transient performance. For these reasons, induction generators are extensively used in wind and micro-hydroelectric plants. The machine is available from very low to several megawatt ratings.

The induction machine requires ac excitation current, which is mainly reactive. In case of a grid-connected system, the excitation current is drawn from the grid and therefore, the network must be capable of supplying this reactive power. The voltage and frequency are determined by the grid. In a standalone system, the induction generator is self-excited by shunt capacitors.

A more detailed picture of the DFIG system with a back-to-back converter can be seen in fig. below. The back-to-back converter consists of two converters, i.e., machine-side converter and grid-side converter that are connected "back-to-back." Between the two converters a dc-link capacitor is placed, as energy storage, in order to keep the voltage variations (or ripple) in the dc-link voltage small. With the machine-side converter it is possible to control the torque or the speed of the DFIG and also the power factor at the stator terminals, while the main objective for the grid-side converter is to keep the dc-link voltage constant. The speed–torque characteristics of the DFIG system can be seen in fig. below As also seen in the figure, the DFIG can operate both in motor and generator operation with a rotor-speed range of $\Delta\omega_{maxr}$ around the synchronous speed, ω_1.



A typical application, as mentioned earlier, for DFIG is wind turbines, since they operate in a limited speed range of approximately 30%. Other applications, besides wind turbines, for the DFIG systems are, for example, flywheel energy storage system, stand-alone diesel systems, pumped storage power plants, or rotating converters feeding a railway grid from a constant frequency public grid

Environmental aspects of wind:

(i) Audible noise:

The wind turbine is generally quiet. It poses no objectionable noise disturbance in the surrounding area. The wind turbine manufacturers generally supply the machine noise level data in dB versus the distance from the tower. This machine produces 55 dB noise at a 50-meter distance from the turbine and 40 dB at a 250-meter distance. The Table compares the turbine noise level with other generally known noise levels. The table indicates that the turbine at a 50-meter distance produces noise no higher than the average factory. This noise, however, is a steady noise. The turbine makes loud noise while yawing under the changing wind direction. The local noise ordinance must be complied with. There have been cases of noise complaints reported by the nearby communities.

Noise Level of Some Commonly Known Sources Compared with Wind Turbine

Source	Noise level
Elevated train	100 dB
Noisy factory	90 dB
Average street	70 dB
Average factory	60 dB
Average office	50 dB
Quiet conversation	30 dB

(ii) Electro Magnetic Interference (EMI):

Any stationary or moving structure in the proximity of a radio or TV tower interferes with the signals. The wind turbine towers, being large structures, can cause objectionable electromagnetic interference on the performance of the nearby transmitters or receivers. Additionally, rotor blades of an operating wind turbine may reflect impinging signals so that the electromagnetic signals in the neighbourhood may experience interference at the blade passage frequency. The exact nature and magnitude of such EMI depend on a number of parameters. The primary parameters are the location of the wind turbine tower relative to the radio or TV tower, physical and electrical properties of the rotor blades, the signal frequency modulation scheme, and the high frequency electromagnetic wave propagation characteristics in the local atmosphere.

(iii). Visual Impacts

Because they must generally be sited in exposed places, wind turbines are often highly visible; however, being visible is not necessarily the same as being intrusive. Aesthetic issues are by their nature highly subjective. Proper siting decisions can help to avoid any aesthetic impacts to the landscape. One strategy being used to partially offset visual impacts is to site fewer turbines in an y one location by using multiplelocations and by using today's larger and more efficient models of wind turbines.

(iv). Bird life

Bird and bat deaths are one of the most controversial biological issues related to wind turbines. The deaths of birds and bats at wind farm sites have raised concerns by fish and wildlife agencies and conservation groups. On the other hand, several large wind facilities have operated for years with only minor impacts on these animals.

To try to address this issue, the wind industry and government agencies have sponsored research into collisions, relevant bird and bat behaviour, mitigation measures, and appropriate study design protocols. In addition, project developers are required to collect data through monitoring efforts at existing and proposed wind energy sites. Careful site selection is needed to minimize fatalities and in some cases additional research may be needed to address bird and bat impact issues.

(v). Other Concerns

Unlike most other generation technologies, wind turbines do not use combustion to generate electricity, and hence don't produce air emissions. The only potentially toxic or hazardous materials are relatively small amounts of lubricating oils and hydraulic and insulating fluids. Therefore, contamination of surface or ground water or soils is highly unlikely. The primary health and safety considerations are related to blade movement and the presence of industrial equipment in areas potentially accessible to the public.

SOLAR ENERGY:

The photovoltaic effect is the electrical potential developed between two dissimilar materials when their common junction is illuminated with radiation of photons. The photovoltaic cell, thus, converts light directly into electricity. The pv effect was discovered in 1839 by French physicist Becquerel. It remained in the laboratory until 1954, when Bell Laboratories produced the first silicon solar cell. It soon found application in the U.S. space programs for its high power capacity per unit weight. Since then it has been an important source of power for satellites. Having developed maturity in the space applications, the pv technology is now spreading into the terrestrial applications ranging from powering remote sites to feeding the utility lines.

Energy from the sun:

The physics of the PV cell is very similar to the classical p-n junction diode. When light is absorbed by the junction, the energy of the absorbed photons is transferred to the electron system of the material, resulting in the creation of charge carriers that are separated at the junction. The charge carriers may be electron-ion pairs in a liquid electrolyte or electron hole pairs in a solid semiconducting material. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field and circulate as the current through an external circuit. The current squared times the resistance of the circuit is the power converted into electricity.

The remaining power of the photon elevates the temperature of the cell. The origin of the photovoltaic potential is the difference in the chemical potential, called the Fermi level, of the electrons in the two isolated materials. When they are joined, the junction approaches a new thermodynamic equilibrium. Such equilibrium can be achieved only when the Fermi level is equal in the two materials. This occurs by the flow of electrons from one material to the other until a voltage difference is established between the two materials which have the potential just equal to the initial difference of the Fermi level. This potential drives the photocurrent.

Solar constant:

The solar constant is the rate at which the energy is received upon a unit surface, perpendicular to the sun’s direction, in free space at the earth’s mean distance from the sun. It is generally expressed in calories per square centimetre per minute and in these units has usually been considered to lie in the range of 1.89 to 1.95.

Solar Spectrum:

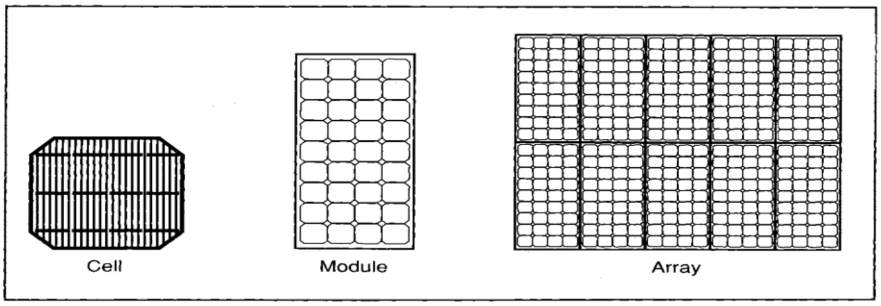
The energy irradiation comes in the form of electromagnetic waves of a wide spectrum. Longer wavelengths have less energy (for instance infrared) than shorter ones such as visible light or UV. The spectrum can be depicted in a graph, the spectral distribution, which shows the relative weight of individual wavelength plotted over all wavelengths, measure in W/m (wavelength).

Clarity index:

The ratio of the solar radiation arriving at the earth's surface to extra-terrestrial radiation. The monthly average clearness index is the ratio of monthly average daily solar radiation at the surface of the monthly average daily extra-terrestrial radiation. K_T varies from place to place from about 0.3 for very overcast climates to 0.8 for very sunny places.

Solar module:

The solar cell described above is the basic building block of the pv power system. Typically, it is a few square inches in size and produces about one watt of power. For obtaining high power, numerous such cells are connected in series and parallel circuits on a panel (module) area of several square feet fig. below.



The solar array or panel is defined as a group of several modules electrically connected in series-parallel combinations to generate the required current and voltage. Fig shows the actual construction of a module in a frame that can be mounted on a structure. Mounting of the modules can be in various configurations as seen in Fig. In the roof mounting, the modules are in the form that can be laid directly on the roof. In the newly developed amorphous silicon technology, the PV sheets are made in shingles that can replace the traditional roof shingles on one-to-one basis, providing a better economy in the material and labour.

VI characteristics of a solar cell. **(Nov/Dec 2014)**

The wll known characteristic of an ordinary silicon pn junction is shown in figure below as a dark characteristic with the junction not illuminated. Mathematically this is given by

$$I = I_o\{\exp\left(\frac{V}{V_T}\right) - 1\}$$

Where I_o is the reverse saturation current,

$V_T = \frac{kT}{q}$

where k is Boltzman's constant

T is temperature in ^oK and

q is charge of an electron

When the pn junction is illuminated, the characteristic gets modified in shape and shifts downwards as the photon generated component is added with reverse leakage current a shown in figure. The above diode equation is modified as

$$I = -I_{sc} + I_o\{\exp\left(\frac{V}{V_T}\right) - 1\}$$

When the junction is short circuited at its terminals, V becomes zero and a finite current $I=-I_{sc}$ flows through the external path emerging from the p side. I_{sc} is known as short circuit current and its magnitude will depend on solar radiation. Now, a voltage source is inserted in the external path with positive polarity on the p side. As the magnitude of this external voltage is increased from zero, the current tarts decreasing. The value $V_{oc}$of this voltage at which the current becomes zero is known as open circuit voltage.

$$\text{Thus } V_{oc} = V_T ln\left\{\left(\frac{I_{sc}}{I_o}\right) + 1\right\}$$

Mathematically, the I-V characteristic of a solar cell may be written as;

$$I = I_{sc} - I_o\{\exp\left(\frac{V}{V_T}\right) - 1\}$$

In order to obtain asmuch energy as possible from the rather costly PV cell, it is desirable to operate the cell to produce maximum power. The maximum power (P_m) point can be obtained by plotting the hyperbola defined by VxI= constant, such that it is tangential to the I-V characteristic. The voltage and current corresponding to this point are peak point voltage, V_m and peak point current I_m respectively. Thus, there is only one point on the characteristic at which it will produce the maximum electrical power under the incident illumination level. Operating at other than the maximum power it will mean that the cell will produce a lesser electrical power and more thermal power. The maximum power point is also readily found by simply plotting cell power versus sell voltage as shown in figure. If a rectangle of maximum possible area is inscribed in the area defined by the I-V characteristics and I-V axes, it meets the characteristics at the peak point as shown in figure. Closeness of the characteristics to the rectangular shape is a measure of the quality of the cell. An idea cell would have a perfect rectangular characteristic. Therefore, the 'fill factor',FF which indicates the quality of a cell, is defined as the ratio of the peak power to the product of open circuit voltage and short circuit current i.e.

$$FF = \frac{V_m I_m}{V_{oc} I_{sc}}$$

An ideal cell will have a fill factor of unity. In order to maximize the fill factor, the ratio of the photocurrent to reverse saturation current should be maximized while minimizing internal series resistance and maximizing the shunt resistance. Typically, its value for a commercial silicon cell is in the range of 0.5 to 0.83.

The conversion efficiency

$$\eta = \frac{V_m I_m}{solarpower} = \frac{FFV_{OC} I_{SC}}{solarpower}$$

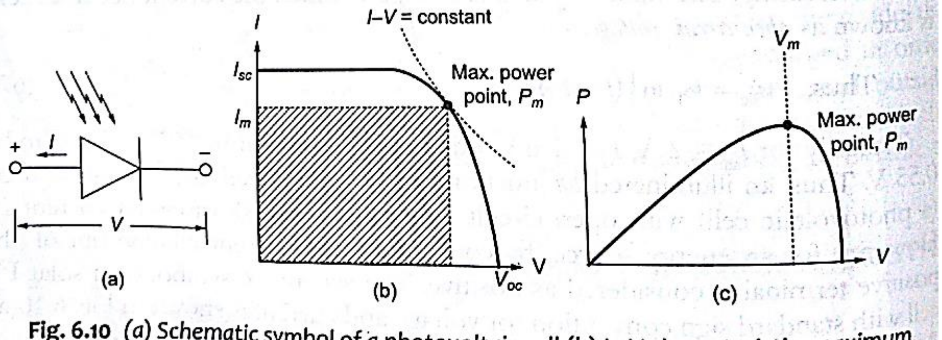


Fig. 6.10 *(a) Schematic symbol of a photovoltaic cell (b) I– V characteristic, maximum power point (c) P–V characteristic*

Solar PV plant and construction, working of solar cell. (April 2013)(April/May 2012)(Nov 2012)(April/May 2014)

The solar thermal power system collects the thermal energy from solar radiation and uses at high or low temperature. The low temperature applications include water and space heating for commercial and residential buildings. Producing electricity using the steam-turbine-driven electrical generator is example for a high temperature application. The technology of generating electrical power using the solar thermal energy has been demonstrated at commercial scale.

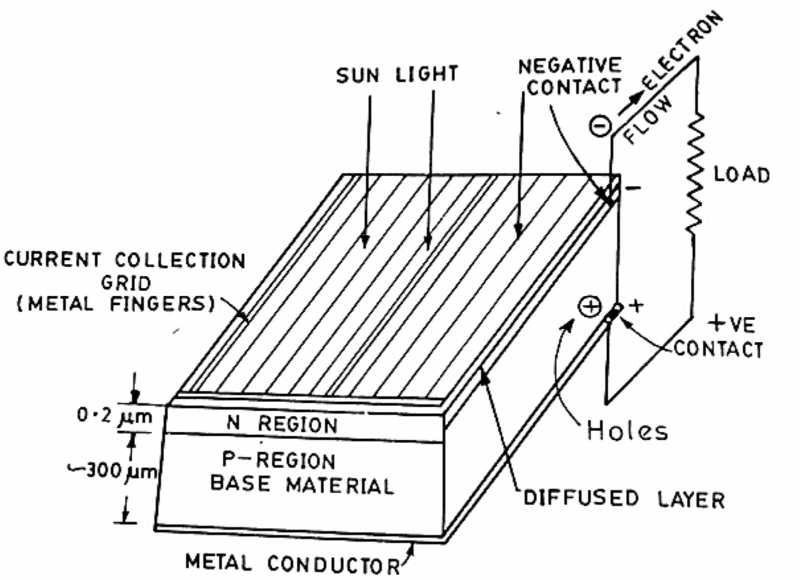


Fig. 5.6.1. Schematic view of a typical solar cell.

Fig. above shows the basic cell construction. For collecting the photocurrent, the metallic contacts are provided on both sides of the junction to collect electrical current induced by the impinging photons on one side. Conducting foil (solder) contact is provided over the bottom (dark) surface and on one edge of the top (illuminated) surface. Thin conducting mesh on the remaining top surface collects the current and lets the light through. The spacing of the conducting fibers in the mesh is a matter of compromise between maximizing the electrical conductance and minimizing the blockage of the light. In addition to the basic elements, several enhancement features are also included in the construction. For example, the front face of the cell has anti-reflective coating to absorb as much light as possible by minimizing the reflection. The mechanical protection is provided by the cover glass applied with a transparent adhesive.

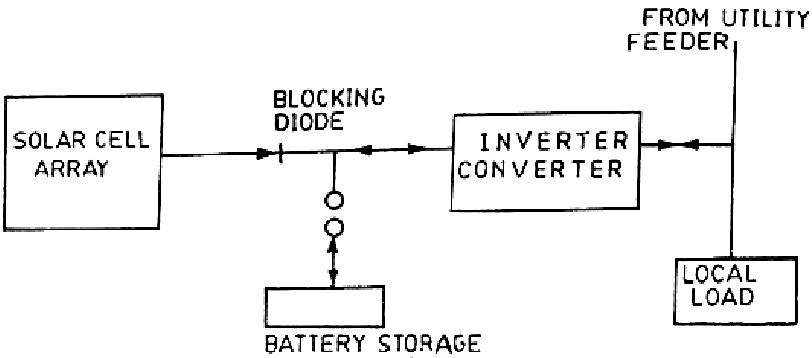


Fig. 5.6.5. Basic photovoltaic system integrated with power grid.

Fig. above shows the schematic of a large-scale solar thermal power station developed, designed, built, tested, and operated with the U.S. Department of Energy funding. In this plant, the solar energy is collected by thousands of sun-tracking mirrors called heliostats that reflect the sun's energy to a single receiver a top a centrally located tower. The enormous amount of energy focused on the receiver is used to generate high temperature to melt a salt. The hot molten salt is stored in a storage tank, and is used, when needed, to generate steam and drive the turbine generator. After generating the steam, the used molten salt at low temperature is returned to the cold salt storage tank. From here it is pumped to the receiver tower to get heated again for the next thermal cycle.

The usable energy extracted during such a thermal cycle depends on the working temperatures. The maximum thermodynamic conversion efficiency that can be theoretically achieved with the hot side temperature T_{Hot} and the cold side temperature T_{cold} is given by the Carnot cycle efficiency, which is as follows, where the temperatures are in absolute scale. The higher the hot side working temperature and lower the cold side exhaust temperature, the higher the plant efficiency of converting the captured solar energy into electricity. The hot side temperature T_{Hot} , however, is limited by the properties of the working medium. The cold side temperature T_{cold} is largely determined by the cooling method and the environment available to dissipate the exhaust heat.

A major benefit of this scheme is that it incorporates the thermal energy storage for duration in hours with no degradation in performance, or longer with some degradation. This feature makes the technology capable of producing high-value electricity for meeting peak demands. Moreover, compared to the solar photovoltaic, the solar thermal system is economical, as it eliminates the costly semiconductor cells.

Distributed Generation

Distributed generation (or DG) generally refers to small-scale (typically 1 kW – 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system. Distributed generators include, but are not limited to synchronous generators, induction generators, reciprocating engines, micro turbines (combustion turbines that run on high-energy fossil fuels such as oil, propane, natural gas, gasoline or diesel), combustion gas turbines, fuel cells, solar photo voltaics, and wind turbines.

Applications of Distributed Generating Systems

There are many reasons a customer may choose to install a distributed generator. DG can be used to generate a customer's entire electricity supply; for peak shaving (generating a portion of a customer's electricity onsite to reduce the amount of electricity purchased during peak price periods); for standby or emergency generation (as a backup to Wires Owner's power supply); as a green power source (using renewable technology); or for increased reliability. In some remote locations, DG can be less costly as it eliminates the need for expensive construction of distribution and/or transmission lines.

Benefits of Distributed Generating Systems

Distributed Generation:

It has a lower capital cost because of the small size of the DG (although the investment cost per kVA of a DG can be much higher than that of a large power plant). It may reduce the need for large infrastructure construction or upgrades because the DG can be constructed at the load location. If the DG provides power for local use, it may reduce pressure on distribution and transmission lines.

With some technologies, it produces zero or near-zero pollutant emissions over its useful life (not taking into consideration pollutant emissions over the entire product lifecycle ie. pollution produced during the manufacturing or after decommissioning of the DG system).

It can increase power reliability as back-up or stand-by power to customers and offers customers a choice in meeting their energy needs and challenges associated with Distributed Generating Systems. There are no uniform national interconnection standards addressing safety, power quality and reliability for small distributed generation systems.

Solar- Wind hybrid system : (Nov'2016)

The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fuelling them is increasingly becoming difficult if they are to be used for commercial purposes. There is a growing awareness that renewable energy such as photovoltaic system and Wind power have an important role to play in order to save the situation. Figure 1 is the schematic layout of Solar-Wind Hybrid system that can supply either dc or ac energy or both.

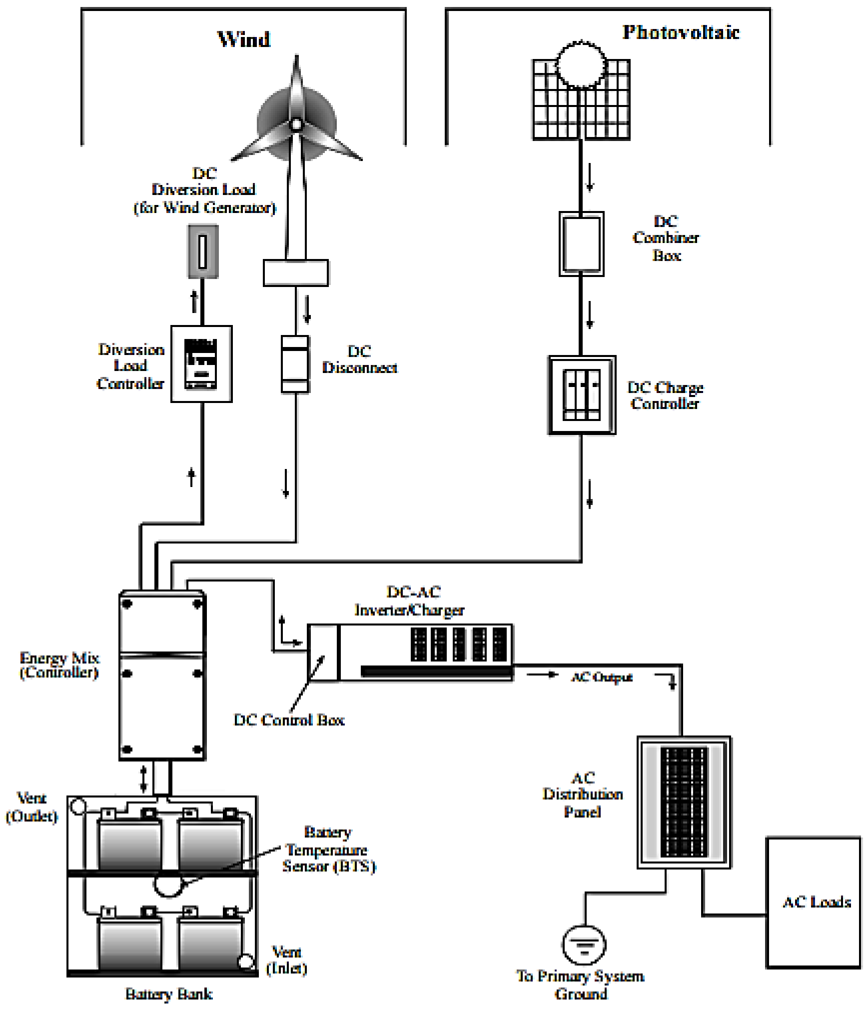
SOLAR ENERGY

Solar energy is energy from the Sun. It is renewable, inexhaustible and environmental pollution free. Nigeria, like most other countries is blessed with large amount of sunshine all the year with an average sun power of 490W/m2 /day . Solar charged battery systems provide power supply for complete 24hours a day irrespective of bad weather. Moreso, power failures or power fluctuations due to service part of repair as the case may be is non-existent.

Solar Systems There are two types of solar systems; those that convert solar energy to D.C power, and those that convert solar energy to heat.

Solar-generated Electricity – Photovoltaic The Solar-generated electricity is called Photovoltaic (or PV). Photovoltaics are solar cells that convert sunlight to D.C electricity. These solar cells in PV module are made from semiconductor materials. When light energy strikes the cell, electrons are emitted. The electrical conductor attached to the positive and negative scales of the material allow the electrons to be captured in the form of a D.C current. The generated electricity can be used to power a load or can be stored in a battery.

Photovoltaic system is classified into two major types: the off-grid (stand alone) systems and inter-tied system. The off-grid (stand alone) system are mostly used where there is no utility grid service. It is very economical in providing electricity at remote locations especially rural banking, hospital and ICT in rural environments. PV systems generally can be much cheaper than installing power lines and step-down transformers especially to remote areas. Solar modules produce electricity devoid of pollution, without odour, combustion, noise and vibration. Hence, unwanted nuisance is completely eliminated. Also, unlike the other power supply systems which require professional training for installation expertise, there are no moving parts or special repairs that require such expertise.



The major components include P.V modules, battery and inverter. The most efficient way to determine the capacities of these components is to estimate the load to be supplied. The size of the battery bank required will depend on the storage required, the maximum discharge rate, and the minimum temperature at which the batteries will be used. When designing a solar power system, all of these factors are to be taken into consideration when battery size is to be chosen. Lead-acid batteries are the most common in P.V systems because their initial cost is lower and also they are readily available nearly everywhere in the world. Deep cycle batteries are designed to be repeatedly discharged as much as 80 percent of their capacity and so they are a good choice for power systems

WIND POWER

Wind Power is energy extracted from the wind, passing through a machine known as the windmill. Electrical energy can be generated from the wind energy. This is done by using the energy from wind to run a windmill, which in turn drives a generator to produce electricity [6]. The windmill in this case is usually called a wind turbine. This turbine transforms the wind energy to mechanical energy, which in a generator is converted to electrical power. An integration of wind generator, wind turbine, aero generators is known as a wind energy conversion system

Component of a wind energy project

Modern wind energy systems consist of the following components: • A tower on which the wind turbine is mounted; • A rotor that is turned by the wind; •The nacelle which houses the equipment, including the generator that converts the mechanical energy in the spinning rotor into electricity.

The tower supporting the rotor and generator must be strong. Rotor blades need to be light and strong in order to be aerodynamically efficient and to withstand prolonged used in high winds[8]. In addition to these, the wind speed data, air density, air temperature need to be known amongst others. 3.2 Wind Turbine A wind turbine is a machine for converting the kinetic energy in wind into mechanical energy. Wind turbines can be separated into two basic types based on the axis about which the turbine rotates. Turbines that rotate around a horizontal axis are more common. Vertical-axis turbines are less frequently used [8,9]. Wind turbines can also be classified by the location in which they are used as Onshore, Offshore, and aerial wind turbines [9] 3.3 Wind Power Modeling The block diagram in figure 3 shows the conversion process of wind energy to electrical energy.

There is the need for the provision of an alternative sustainable electric power supply system to provide electricity to rural and the unreached communities. The importance of Information Communication Technology for e-service to rural communities are inevitable in order to achieve the MDGs objective. Also there is the need for rural banking and hospitals if the social and economic lives of rural citizens in Nigeria are to be improved. The provision of hybrid solar -wind energy system to power ICT infrastructures, banking and hospitals in rural and the unreached communities that are not connected to National Grid Power supply system is very important so as to maintain a continuous electricity supply. When considering the cost and overall efficiency, it is advisable for all the stakeholders who have concern for the rural community development to embrace solar and wind power.

Solar PV plant & construction and working of solar cell.
(April 2013)(April/May 2012)(Nov 2012)(April/May 2014)

Introduction: Solar energy is an important, clean, cheap and abundantly available renewable energy. It is received on Earth in cyclic, intermittent and dilute form with very low power density 0 to 1 kW/m2.Solar energy received on the ground level is affected by atmospheric clarity, degree of latitude, etc. For design purpose, the variation of available solar power, the optimum tilt angle of solar flat plate collectors, the location and orientation of the heliostats should be calculated.

Definition :

The solar PV cells convert the incident light energy directly to electrical energy in DC form.In solar PV system the intermediate thermal energy stage is omitted and the energy is converted directly from solar energy form to electrical form.

Units of solar power and solar energy:

In SI units, energy is expressed in Joule. Other units are angley and Calorie where

1 angley = 1 Cal/cm2.day

1 Cal = 4.186 J

For solar energy calculations, the energy is measured as an hourly or monthly or yearly average and is expressed in terms of kJ/m2/day or kJ/m2/hour. Solar power is expressed in terms of W/m2 or kW/m2.

Essential subsystems in a solar energy plant:

1. **Solar collector or concentrator**: It receives solar rays and collects the energy. It may be of following types:

a) Flat plate type without focusing

b) Parabolic trough type with line focusing

c) Paraboloid dish with central focusing

d) Fresnel lens with centre focusing

e) Heliostats with centre receiver focusing

2. **Energy transport medium**: Substances such as water/ steam, liquid metal or gas are used to transport the thermal energy from the collector to the heat exchanger or thermal storage. In solar PV systems energy transport occurs in electrical form.

3. **Energy storage**: Solar energy is not available continuously. So we need an energy storage medium for maintaining power supply during nights or cloudy periods. There are three major types of energy storage: a) Thermal energy storage; b) Battery storage; c) Pumped storage hydro electric plant.

4. **Energy conversion plant**: Thermal energy collected by solar collectors is used for producing steam, hot water, etc. Solar energy converted to thermal energy is fed to steam thermal or gas thermal power plant.

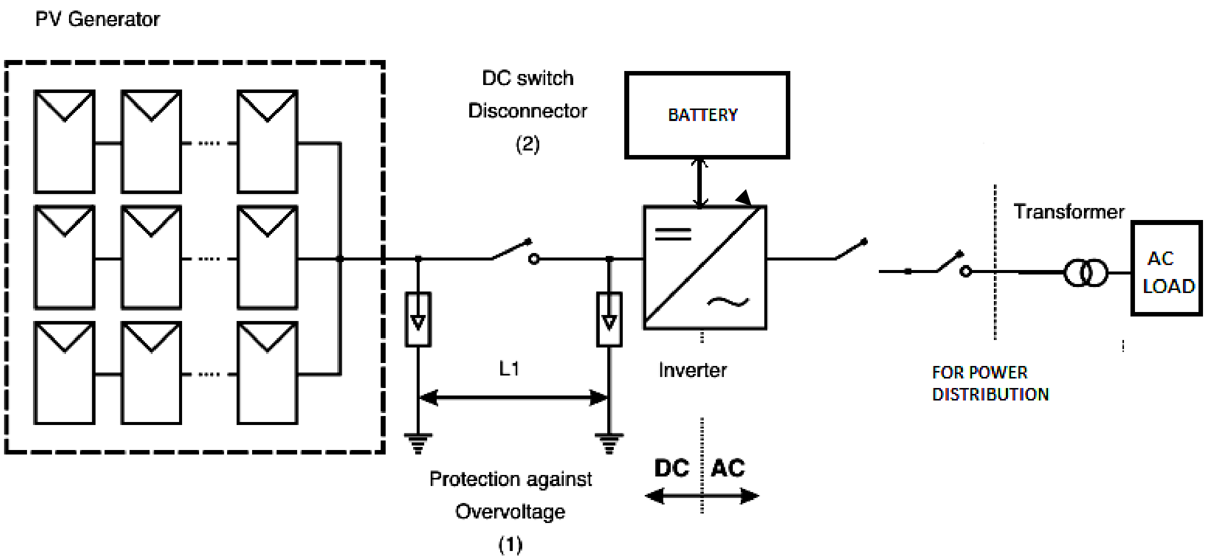
5. **Power conditioning, control and protection system**: Load requirements of electrical energy vary with time. The energy supply has certain specifications like voltage, current, frequency, power etc. The power conditioning unit performs several functions such as control, regulation, conditioning, protection, automation, etc.

6. **Alternative or standby power supply**: The backup may be obtained as power from electrical network or standby diesel generator.

SOLAR COLLECTORS

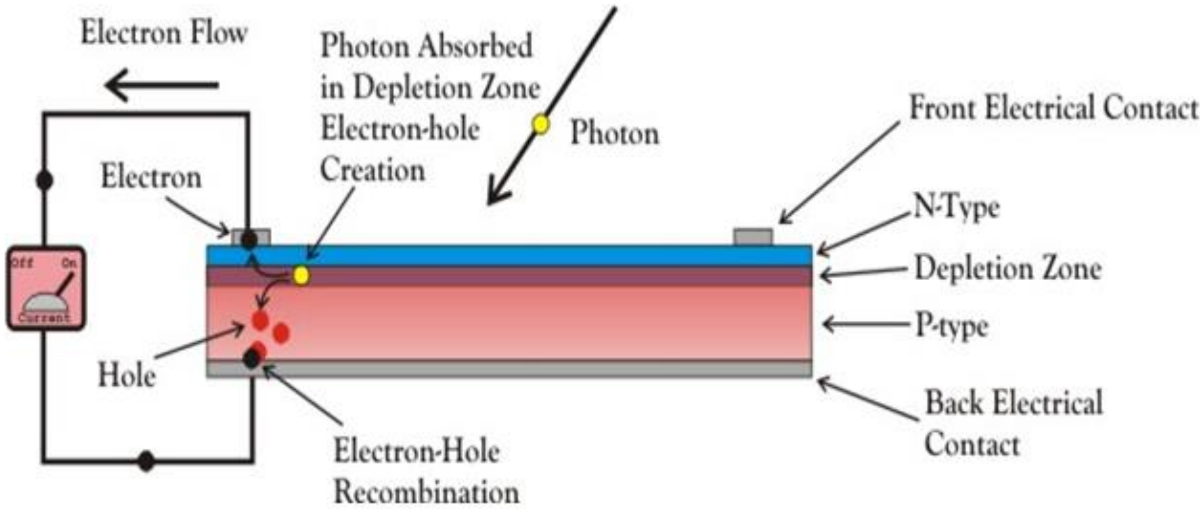
Solar thermal energy is the most readily available source of energy. The Solar energy is most important kind of non-conventional source of energy which has been used since ancient times, but in a most primitive manner. The abundant solar energy available is suitable for harnessing for a number of applications. The application of solar thermal energy system ranges from solar cooker of 1 kw to power plant of 200MW. These systems are grouped into low temperature (<150^{o}C), medium temperature (150-300oC) applications.

SCHEMATIC OF SOLAR PV SYSTEM:



Construction of Solar Cell

It this is basically a junction diode, but constructional it is little bit different form conventional p - n junction diode. A very thin layer of p - type semiconductor is grown on a relatively thicken. We provide few finer electrodes on the top of the p - type semiconductor layer. These electrodes do not obstruct light to reach the thin p - type layer. Just below the p - type layer there is a p - n junction. We also provide a current collecting electrode at the bottom of the n - type layer. We encapsulate the entire assembly by thin glass to protect the **solar cell** from any mechanical shock.



PHOTOVOLTAIC EFFECT

The **photovoltaic effect** is the creation of voltage or electric current in a material upon exposure to light and is a physical and chemical property/phenomenon. The**photovoltaic effect** is closely related to the **photoelectric effect**.

WORKING OF SOLAR CELL:

Solar is the basic unit of solar energy generation system where electrical energy is extracted directly from light energy without any intermediate process. The working of a solar cell solely depends upon its photovoltaic effect hence a solar cell also known as photovoltaic cell. A solar cell is basically a semiconductor device. The solar cell produce electricity while light strikes on it and the voltage or potential difference established across the terminals of the cell is fixed to 0.5 volt and it is nearly independent of intensity of incident light whereas the current capacity of cell is nearly proportional to the intensity of incident light as well as the area that exposed to the light. Each of the solar cells has one positive and one negative terminal like all other type of battery cells. Typically a solar or photovoltaic cell has negative front contact and positive back contact.A semiconductor p-n junction is in the middle of these two contacts.

While sunlight falling on the cell the some photons of the light are absorbed by solar cell. Some of the absorbed photons will have energy greater than the energy gap between valence band and conduction band in the semiconductor crystal. Hence, one valence electron gets energy from one photon and becomes excited and jumps out from the bond and creates one electron-hole pair. These electrons and holes of e-h pairs are called light-generated electrons and holes. The light-generated electrons near the p-n junction are migrated to n-type side of the junction due to electrostatic force of the field across the junction. Similarly the light-generated holes created near the junction are migrated to p – type side of the junction due to same electrostatic force. In this way a potential difference is established between two sides of the cell and if these two sides are connected by an external circuit current will start flowing from positive to negative terminal of the solar cell. This was basic working principle of a solar cell now we will discuss about different parameters of a solar or photovoltaic cell upon which the rating of a solar panel depends. During choosing a particular solar cell for specific project it is essential to know the ratings of a solar panel. These parameters tell us how efficiently a solar cell can convert the light to electricity.

Short Circuit Current of Solar Cell

The maximum current that a solar cell can deliver without harming its own constriction. It is measured by short circuiting the terminals of the cell at most optimized condition of the cell for producing maximum output. The term optimized condition I used because for fixed exposed cell surface the rate of production of current in a solar cell also depends upon the intensity of light and the angle at which the light falls on the cell. As the current production also depends upon the surface area of the cell exposed to light, it is better to express maximum current density instead maximum current. Maximum current density or short circuit current density rating is nothing but ration of maximum or short circuit current to exposed surface area of the cell.

$$J_{sc} = \frac{I_{sc}}{A}$$

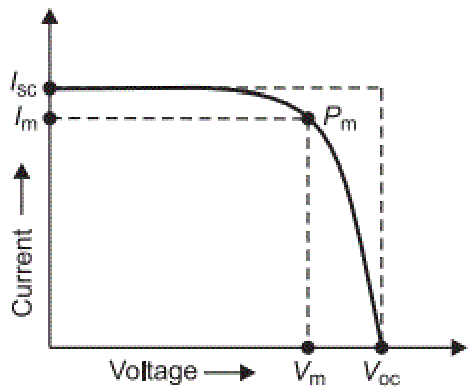
Where, I_{sc} is short circuit current, J_{sc} maximum current density and A is the area of solar cell.

Open Circuit Voltage of Solar Cell

It is measured by measuring voltage across the terminals of the cell when no load is connected to the cell. This voltage depends upon the techniques of manufacturing and temperature but not fairly on the intensity of light and area of exposed surface. Normally open circuit voltage of solar cell nearly equal to 0.5 to 0.6 volt. It is normally denoted by V_{oc}.

Maximum Power Point of Solar Cell

The maximum electrical power one solar cell can deliver at its standard test condition. If we draw the v-i characteristics of a solar cell maximum power will occur at the bend point of the characteristic curve. It is shown in the v-i characteristics of solar cell by P_m.



Current at Maximum Power Point

The current at which maximum power occurs. Current at Maximum Power Point is shown in the v-i characteristics of solar cell by I_m.

Voltage at Maximum Power Point

The voltage at which maximum power occurs. Voltage at Maximum Power Pointis shown in the v-i characteristics of solar cell by V_m.

Fill Factor of Solar Cell

The ratio between product of current and voltage at maximum power point to the product of short circuit current and open circuit voltage of the solar cell.

$$Fill\ Factor = \frac{P_m}{I_{sc} \times V_{oc}}$$

Efficiency of Solar Cell

It is defined as the ratio of maximum electrical power output to the radiation power input to the cell and it is expressed in percentage. It is considered that the radiation power on the earth is about 1000 watt/square metre hence if the exposed surface area of the cell is A then total radiation power on the cell will be 1000 A watts. Hence the efficiency of a solar cell may be expressed as

$$Efficiency(\eta) = \frac{P_m}{P_{in}} \approx \frac{P_m}{1000A}$$

Advantages

- Electricity produced by solar cells is clean and silent. Because they do not use fuel other than sunshine, PV systems do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health.
- Photovoltaic systems are quiet and visually unobtrusive.
- Small-scale solar plants can take advantage of unused space on rooftops of existing buildings.

- It operates reliably for long periods of time with virtually no maintenance.
- Solar energy is a locally available renewable resource
- A PV system can be constructed to any size based on energy requirements.

Disadvantages

- Some toxic chemicals, like cadmium and arsenic, are used in the PV production process. These environmental impacts are minor and can be easily controlled through recycling and proper disposal.
- Solar energy is somewhat more expensive to produce than conventional sources of energy
- Solar power is a variable energy source, with energy production dependent on the sun. Solar facilities may produce no power at all some of the time, which could lead to an energy shortage if too much of a region's power comes from solar power.

Solar- Wind hybrid system: (Nov'2016)

The global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas. Generators which are often used as an alternative to conventional power supply systems are known to be run only during certain hours of the day, and the cost of fuelling them is increasingly becoming difficult if they are to be used for commercial purposes. There is a growing awareness that renewable energy such as photovoltaic system and Wind power have an important role to play in order to save the situation. Figure 1 is the schematic layout of Solar-Wind Hybrid system that can supply either dc or ac energy or both.

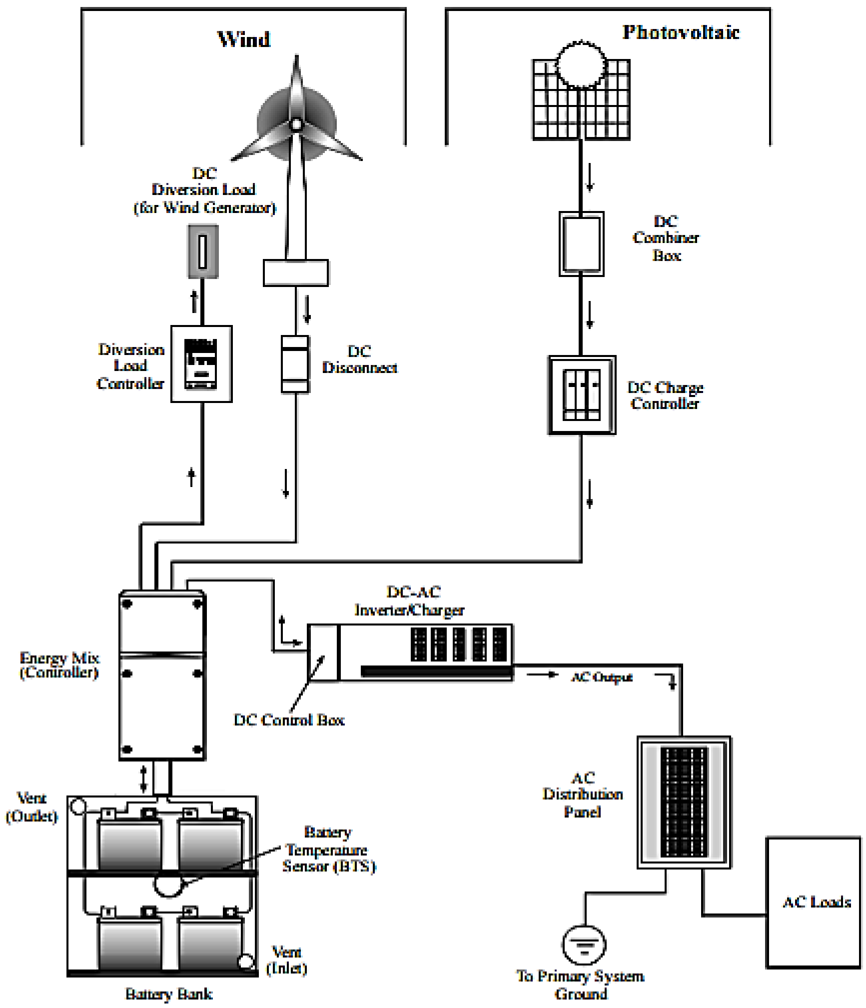
SOLAR ENERGY

Solar energy is energy from the Sun. It is renewable, inexhaustible and environmental pollution free. Nigeria, like most other countries is blessed with large amount of sunshine all the year with an average sun power of 490W/m2 /day . Solar charged battery systems provide power supply for complete 24hours a day irrespective of bad weather. More so, power failures or power fluctuations due to service part of repair as the case may be is non-existent.

Solar Systems There are two types of solar systems; those that convert solar energy to D.C power, and those that convert solar energy to heat.

Solar-generated Electricity – Photovoltaic The Solar-generated electricity is called Photovoltaic (or PV). Photovoltaics are solar cells that convert sunlight to D.C electricity. These solar cells in PV module are made from semiconductor materials. When light energy strikes the cell, electrons are emitted. The electrical conductor attached to the positive and negative scales of the material allow the electrons to be captured in the form of a D.C current. The generated electricity can be used to power a load or can be stored in a battery.

Photovoltaic system is classified into two major types: the off-grid (stand alone) systems and inter-tied system. The off-grid (stand alone) system are mostly used where there is no utility grid service. It is very economical in providing electricity at remote locations especially rural banking, hospital and ICT in rural environments. PV systems generally can be much cheaper than installing power lines and step-down transformers especially to remote areas. Solar modules produce electricity devoid of pollution, without odour, combustion, noise and vibration. Hence, unwanted nuisance is completely eliminated. Also, unlike the other power supply systems which require professional training for installation expertise, there are no moving parts or special repairs that require such expertise.



The major components include P.V modules, battery and inverter. The most efficient way to determine the capacities of these components is to estimate the load to be supplied. The size of the battery bank required will depend on the storage required, the maximum discharge rate, and the minimum temperature at which the batteries will be used. When designing a solar power system, all of these factors are to be taken into consideration when battery size is to be chosen. Lead-acid batteries are the most common in P.V systems because their initial cost is lower and also they are readily available nearly everywhere in the world. Deep cycle batteries are designed to be repeatedly discharged as much as 80 percent of their capacity and so they are a good choice for power systems

WIND POWER

Wind Power is energy extracted from the wind, passing through a machine known as the windmill. Electrical energy can be generated from the wind energy. This is done by using the energy from wind to run a windmill, which in turn drives a generator to produce electricity [6]. The windmill in this case is usually called a wind turbine. This turbine transforms the wind energy to mechanical energy, which in a generator is converted to electrical power. An integration of wind generator, wind turbine, aero generators is known as a wind energy conversion system

Component of a wind energy project

Modern wind energy systems consist of the following components: • A tower on which the wind turbine is mounted; • A rotor that is turned by the wind; • The nacelle which houses the equipment, including the generator that converts the mechanical energy in the spinning rotor into electricity.

The tower supporting the rotor and generator must be strong. Rotor blades need to be light and strong in order to be aerodynamically efficient and to withstand prolonged used in high winds[8]. In addition to these, the wind speed data, air density, air temperature need to be known amongst others. 3.2 Wind Turbine A wind turbine is a machine for converting the kinetic energy in wind into mechanical energy. Wind turbines can be separated into two basic types based on the axis about which the turbine rotates. Turbines that rotate around a horizontal axis are more common. Vertical-axis turbines are less frequently used [8,9]. Wind turbines can also be classified by the location in which they are used as Onshore, Offshore, and aerial wind turbines [9] 3.3 Wind Power Modeling The block diagram in figure 3 shows the conversion process of wind energy to electrical energy.

There is the need for the provision of an alternative sustainable electric power supply system to provide electricity to rural and the unreached communities. The importance of Information Communication Technology for e-service to rural communities are inevitable in order to achieve the MDGs objective. Also there is the need for rural banking and hospitals if the social and economic lives of rural citizens in Nigeria are to be improved. The provision of hybrid solar -wind energy system to power ICT infrastructures, banking and hospitals in rural and the unreached communities that are not connected to National Grid Power supply system is very important so as to maintain a continuous electricity supply. When considering the cost and overall efficiency, it is advisable for all the stakeholders who have concern for the rural community development to embrace solar and wind power.

2- MARKS

1. What is the principle of wind power generation?

Principle of wind energy generation is to convert kinetic energy of moving air (wind) into electrical energy. If mechanical energy is directly used it is called a windmill. e.g. Pump. If mechanical energy is used to generate electrical energy and then used it is a wind energy converter and clusters of wind mills are called a wind form.

2. What are the main components of WECS? **(Nov 2012)(April 2013)**

1. Rotor
2. Gearbox
3. Enclosure
4. Generator

3. What are the two basic designs of turbines? **(April/May 2012)**

1. Vertical axis (or) Egg beater style
2. Horizontal axis (propeller style) machines

4. Write down the various types of wind power plants.

1. Remote
2. Hybrid
3. Grid connected

5. How are wind energy conversions systems classified?

a. According the axis of rotation
   i. Vertical axis wind turbine
   ii. Horizontal axis wind turbine
b. According the range of output power
   i. Small scale
   ii. Medium scale
   iii. Large scale
c. According to the no of generator used
   i. Single generator system
   ii. Multiple generator system
d. According to the types of output power
   i. AC and DC

6. What are the disadvantages of wind power generation system? **(Nov 2013)**

1. Low energy production
2. Expensive maintenance
3. Noise Disturbances
4. Wind can never be predicted
5. Threat to wild life

7. List any four advantages of wind turbine.

1. Inexhaustible fuel source
2. No pollution
3. Excellent supplement to other renewable source
4. Its free

8. What are the components of solar energy?(April 2014)

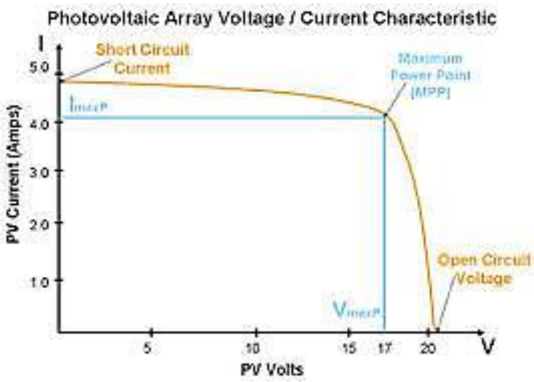
Classify the methods of solar energy storage.

a. Solar pond
b. Rock bed storage
c. Solar energy is stored in Battery in the form of chemical energy.

9. Define solar constant? (April 2015)(Nov 2013)(November 2012)

- It is the rate at which solar energy arrives at the top of atmosphere.
- This is the amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun.
- According to NASA the solar constant is expressed in following three ways:
  – 1.353 Kilowatts per square meter or 1353 watts per square meter
  – 429.2 Btu per square foot per hour
  – 1164 kcal per square meter per hour

10. Draw the VI characteristics of Solar PV cell. (April/May 2012)



11. Define solar energy.(November 2011)

Solar energy in the form of solar radiation that penetrates the earth the earth's atmosphere and reaches the surface differs in amount. Solar radiation radiations that has absorbed or scattered and reaches the ground directly from the sun is called "Direct Radiation" or "Beam Radiation". Diffuse Radiation is that solar radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere

12. What is concentration ratio?

Concentration ratio is defined as the ratio between the aperture area and the receiver absorber area of the collector.

13. What are the types of collectors used in solar power generation?

Types of collectors

- Flat plate collectors(60°C)
- Focusing or concentrating collectors
- Cylindrical parabolic concentrator (100-200°C)
- Paraboloids, Mirror Arrays(<200°C)

14. List any four applications of solar collectors.(November 2012)

1. Solar water heating
2. Solar space heating systems
3. Solar refrigeration
4. Industrial process heat systems

15. List the four important solar systems.

1. Low temperature cycles using flat plat collector or solar pond
2. Power tower or central receiver system
3. Distributed collector system
4. Concentrating collectors for medium and high temperature cycle

16. List the advantages of solar Energy.

1. Solar energy is free from pollution
2. They collect solar energy optically and transfer it to a single receiver, thus minimizing thermal-energy transport requirements
3. They typically achieve concentration ratios of 300 to 1500 and so are highly efficient both in collecting energy and converting it to electricity.
4. The plant requires little maintenance or help after setup
5. It is economical

17. List any four disadvantages of solar energy.

1. Available in day time only
2. Need storage facilities
3. It needs a backup power plant
4. Keeping back up plants hot includes an energy cost which includes coal burning

18. What is the principle of solar generation?

Solar energy the energy produced in the sun and collected on the earth. Energy from sun in the form of heat and light is harnessed. Solar heating system uses the heat energy and solar electric system uses light energy (photo voltaic cell) to generate electrical energy.

19. What is solar cell?

The solar cells operate on the principle of photo voltaic effect, which is a process of generating an emf as a result of the absorption of ionizing radiation. It is possible to convert solar energy directly into electrical energy by means of silicon wafer photo-voltaic cells, also called the solar cells, without any intermediate thermodynamic cycle. Thus a solar cell is a transducer, which converts the sun's radiant energy directly into electrical energy and is basically a semi-conductor diode capable of developing a voltage of 0.5-1volts and a current density of 20-40 mA/sq.cm depending on the materials used and the conditions of sunlight.

20. What is solar collector? (April 2013)

Solar energy is the energy produced in the sun and collected on the earth. Energy from sun in the form of heat and light is harnessed. Solar heating system uses the heat energy and solar electric system uses light energy (photo voltaic cell) to generate electrical energy.

21. Name few applications of solar energy. (Nov 2012)

1. Solar water heating
2. Solar space heating systems
3. Solar refrigeration

4. Industrial process heat systems

22. What are the applications of solar water heater?(November 2012)

1. **Domestic:** Flats, Bungalows and Apartments.
2. **Commercial:** Hotels, Hospitals, Hostels and Dormitories.
3. **Industrial:** Process Industries, Preheating boiler feed water. In domestic sector, hot water is used for bathing, washing of clothes & utensils.

23. What are the issues in grid connection for wind energy Nov' 2015

Conventional power stations are usually connected to the high voltage or extra-high voltage system. While Wind turbines may be connected to ac system at various voltage levels, including the low voltage, medium voltage, high voltage as well as to the extra high voltage system. The suitable voltage level depends on the amount of power generated.

24. Give short note on cut-out speed April 2016

As the speed increases above the rate output wind speed, the forces on the turbine structure continue to rise and, at some point, there is a risk of damage to the rotor. As a result, a braking system is employed to bring the rotor to a standstill. This is called the cut-out speed and is usually around 25 metres per second.

25. Give short note on cut-in speed

At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate. However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed and is typically between 3 and 4 metres per second.

26. How the distribution generation is superior to conventional centralized generation April 2016

Distributed generation (DG) technology choices. Several clarifications are necessary:

- Distributed generation is any electric generating plant located next to users.
- DG is not a new concept. Edison built his first commercial electric plant near Wall Street in lower Manhattan, and he recycled energy to heat surrounding buildings.
- DG plants employ all of the technologies that are used in central generation.
- DG plant capacities range from a few kilowatts to several hundred megawatts, depending on the users' needs. We have installed 40-kilowatt backpressure steam turbines in office buildings that recycle steam pressure drop, and managed a 200-megawatt coal-fired CHP plant serving Kodak's world headquarters in Rochester, New York.
- DG can use renewable energy, but not every renewable energy plant is DG. Solar photovoltaic panels on individual buildings or local windmills are distributed generation, while large hydro and wind farms are central generation requiring transmission and distribution (T&D).
- DG uses all fuels, including nuclear. Modern naval vessels generate power with nuclear reactors and then recycle waste heat to displace boiler fuel.

PONDICHERRY UNIVERSITY QUESTIONS

2 MARKS

1. Define solar constant? **(April 2015)(Nov 2013)**
2. Draw the VI characteristics of Solar PV cell. **(April/May 2012/ Nov'2015)**
3. What is solar collector? **(April 2013)**
4. Name few applications of solar energy. **(Nov 2012)**
5. What are the components of solar energy? **(April 2014)**
6. Define solar energy**.** **(November 2011)**
7. Define solar constant in solar energy. **(November 2012)**
8. List any four applications of solar collectors. **(November 2012)**
9. What are the applications of solar water heater? **(November 2012)**
10. What are the main components of WECS? **(Nov 2012)(April 2013)**
11. What are the two basic designs of turbines? **(April/May 2012)**
12. What are the disadvantages of wind power generation system? **(Nov 2013)**
13. How are biogas plants classified **April 2015**
14. What are the issues in grid connection for wind energy Nov' 2015
15. Give short note on cut-out speed April 2016
16. How the distribution generation is superior to conventional centralized generation April 2016

11 MARKS

1. Explain the types of wind turbine generators **(April/May 2014)**

2. With neat sketch explain the function of wind power generation system.

(Nov 2012) (Nov 2013)(April 2015)

3. Explain the basic components of wind energy conversion system**. (April 2015)**

4. Explain the operating principle of wind energy conversion systems with doubly fed induction generator. (May 2016)

5. Explain wind energy conversion system for a horizontal axis wind turbine with a suitable diagram. (Nov' 2015)

6. Explain the block diagram and working of solar power generation. Draw the schematic diagram of a solar PV plant and explain. Describe construction and working of solar cell.

(April 2013)(April/May 2012)(Nov 2012)(April/May 2014)

7. Explain about VI characteristics of a solar cell. **(Nov/Dec 2014)**

8. Give a detailed note on " Environmental impacts of solar power generation system" (May 2016)

9. Explain solar- wind hybrid system in detail with a neat sketch. (Nov'2016)