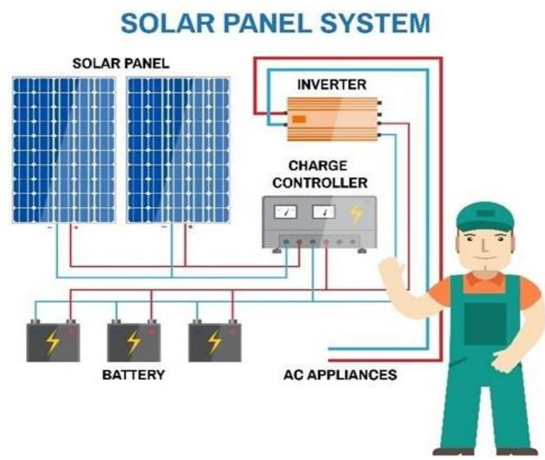
ELECTRICAL ENGINEERING DEPARTMENT

SOLAR PANEL INSTALLTION AND MAINTENACE



CHAPTER 1

CHECK SITE CONDITIONS, COLLECT TOOLS AND RAW MATERIALS

1.1 BASICS ON SOLAR ENERGY:

Solar energy is energy that comes from the sun. Every day the sun radiates, or sends out, an enormous amount of energy. Like other stars, the sun is a big gas ball made up mostly of hydrogen and helium. The sun generates energy in its core in a process called **nuclear fusion.** Solar power is energy from the sun that is converted into thermal or electrical energy. Solar energy is the cleanest and most abundant renewable energy source available.

Solar technologies can harness this energy for a variety of uses, including generating electricity, providing light or a comfortable interior environment, and heating water for domestic, commercial, or industrial use.

1.1.1 Photo Voltaic effect

Electricity can be generated directly from sunlight, by a process called photovoltaic effect, which is defined as the generation of an electromotive force as a result of the absorption of ionizing radiation. The photo voltaic effect can be observed in almost any junction of material that have different electrical characteristics, but the best performance to date has been from solar cells made of Silicon.

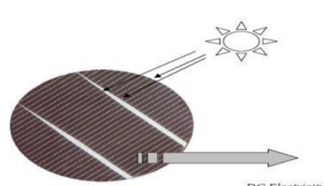


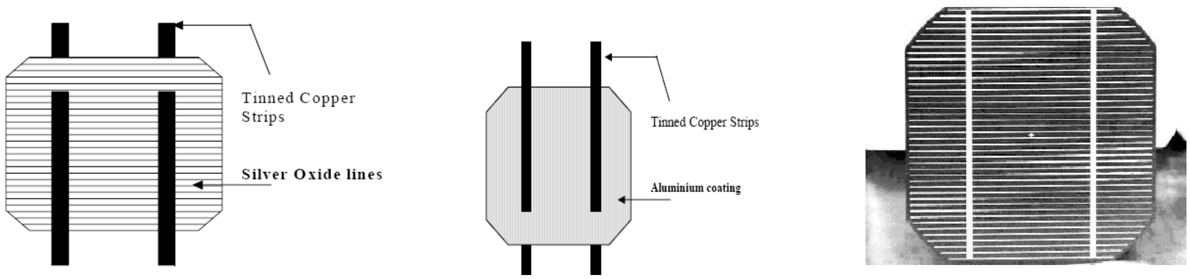
Fig 1.1 Photovoltaic effect

1.1.2 Solar Cell: construction and working

The basic building block of a photovoltaic system is the Solar Cell, a semiconductor device having a simple p-n junction and which when exposed to sunlight produces DC electricity. The solar cell is made up of “Semi-Conductor” materials that are processed to make the device photovoltaic. The solar cell is made of single crystal silicon, polycrystalline and amorphous . A thin p type silicon wafer is taken through phosphorus diffusion process and by screen-printing technology electrodes are made. The P-N junction of the solar cell gives rise to diode characteristics. Hence a solar cell is a PN junction device on which front and back electrical contacts are screen-printed.). The side, which has negative polarity, is taken as front side and that which has positive polarity is taken as backside. The front or Negative side is exposed to sunlight for conduction to take place. Two Tinned copper strips work as terminal leads for interconnection to other cells. For collection of charge from the cell and conduction to terminal leads on negative side, Silver Oxide lines are screen printed horizontally and these are joined to terminal leads at close spacing (refer Fig 1.2a). These lines cover only 5% of the total area of the cell, so that these do not pose any hindrance to the exposure of Sunrays. The back or Positive side is not exposed to sunlight; hence Aluminium is coated on whole surface for better conductivity (refer Fig 1.2b). Aluminium is coated instead of Silver Oxide as latter is expensive hence not economical. The operation of solar cells involves these major processes:

- ✓ Absorption of sunlight into semiconductor materials .
- ✓ Generation of charge carriers.

- ✓ Separation of +ve & -ve charges to different regions of the cell to produce e.m.f.



(a) (b) ©

Figure:1.2 (a) solar cell front view (b) solar cell rear view © solar cell actual view

1.1.2.1 Working of Photovolatic cell :

Photovoltaic directly convert **solar energy into electricity**. They work on the principle of the photovoltaic effect. Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed. Only the absorbed photons provide energy to generate electricity. When enough sunlight (energy) is absorbed by the material (a semiconductor), electrons are dislodged from the material's atoms. When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, electricity flows.

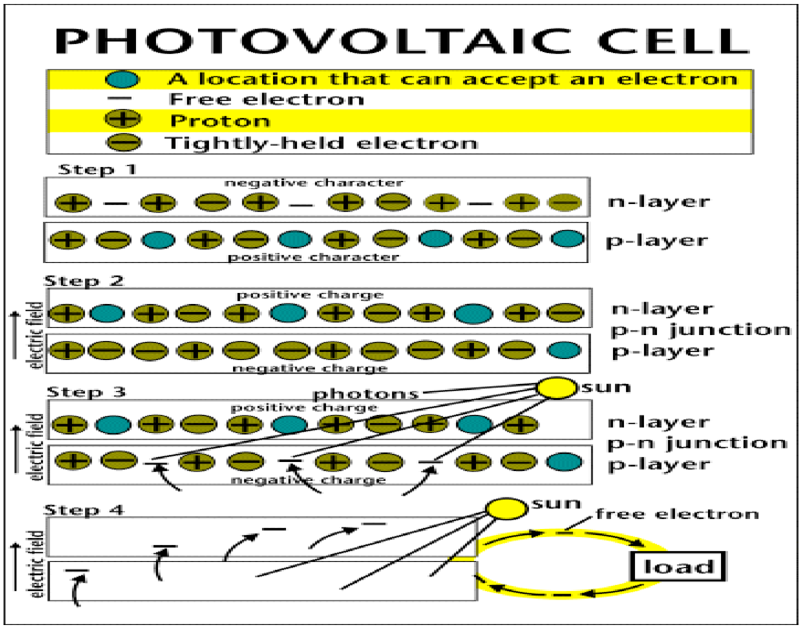


Fig 1.3: Working of photovoltaic cell

1.1.3 BASIC TERMS:

i. The watt measures the rate of energy conversion and it is the main unit of power used in photovoltaic.

1 kilowatt (kW)	1000W
1 megawatt (MW)	1000 kW or 1000000 watts
1 gig watt (GW)	1000 MW or 1000000000 watts
1 Terawatt (TW)	1000 GW or 1000000000000 watts
PW	P = peak (peak-performance of a module)

ii. ENERGY = POWER x TIME

1 Kilowatt Hour = 1KWH = 1000 watts

Electrical energy is generally measured in kilowatt-hours (kWh). If a solar panel produces 100 watts for 1 hour, it has produced 100 watt-hours or 0.1 kWh.

iii. What is a solar rating?

The solar rating is a measure of the average solar energy (also called "Solar Irradiance") available at a location in an average year. Radiant power is expressed in power per unit area: usually Watts/sq-meter, or kW/sq-meter. The total daily Irradiation (Wh/sq-meter) is calculated by the integration of the irradiance values (W/sq-meter).

iv. Solar Cell:

The basic photovoltaic device, which generates electricity when exposed to sunlight, shall be called a "Solar Cell".

v. Solar Module:

The smallest complete environmentally protected assembly of interconnected solar cells shall be called "Module".

vi. Solar Panel:

A group of modules fastened together, pre-assembled and interconnected, designed to serve as an installable unit in an Array shall be called "Panel".

vii. Solar Array:

A mechanically integrated assembly of modules or panels together with support structure, but exclusive of foundation, tracking, thermal control and other components, as required to form a dc power producing unit shall be called an "Array".

viii. Solar irradiation:

The total solar radiant power incident upon unit area of an inclined surface (Watt/m^2) is called total solar irradiance.

On any given day the solar radiation varies continuously from sunrise to sunset and depends on cloud cover, sun position and content and turbidity of the atmosphere. The maximum irradiance is available at **solar noon** which is defined as the midpoint, in time, between sunrise and sunset.

ix. Insolation:

Insolation differs from irradiance because of the inclusion of time. Insolation is the amount of solar energy received on a given area over time measured in kilowatt-hours per square meter squared (kW-hrs/m^2) - this value is equivalent to "**peak sun hours**".

x. Peak Sun Hours:

Peak sun hours is defined as the equivalent number of hours per day, with solar irradiance equaling 1,000 W/m^2, that gives the same energy received from sunrise to sunset. A peak sun hour is of significance because PV panel power output is rated with a radiation level of 1,000W/m^2 .

xi. Conversion Efficiency

The ratio of the maximum power to the product of area and irradiance expressed as a percentage.

n = (Maximum power / Area x irradiance) x 100 %

1.1.4 V-I Curve of Solar cell:

The total electrical output (wattage) of a photovoltaic module is equal to its output voltage multiplied by its operating current. The output characteristics of any given module are characterized by a performance curve, called an I-V curve that shows the relationship between current and voltage.

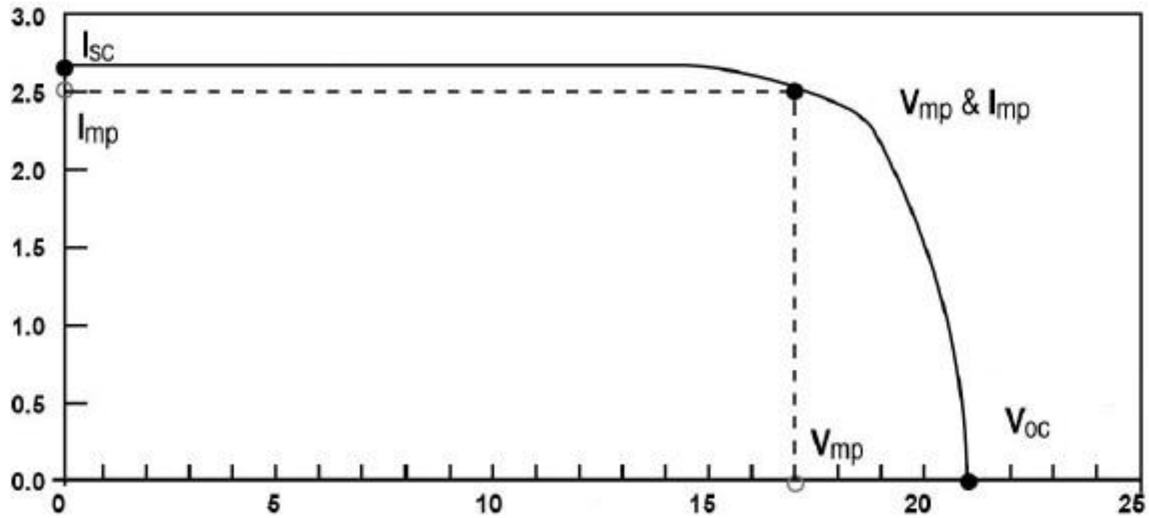


Figure 1.4: ***Module I-V curve (12VDC nominal)***

Figure shows a typical I-V curve. Voltage (V) is plotted along the horizontal axis. Current (I) is plotted along the vertical axis. I-V curve contains three significant points: Maximum Power Point (representing both Vmp and Imp), the Open Circuit Voltage (Voc), and the Short Circuit Current (Isc).

- **Maximum Power Point :**

This point, labelled Vmp and Imp, is the operating point at which the maximum output will be produced by the module at operating conditions indicated for that curve.

- **Open Circuit Voltage :**

This point, labelled Voc, is the maximum voltage achieved when no current is being drawn from the module. Since no current is flowing, the module experiences maximum electrical potential. The example in Figure 1.4

displays an open circuit voltage of approximately 21.4 volts. The power output at Voc is zero watts since there is no current.

- **Short Circuit Current :**

This point, labelled Isc, is the maximum current output that can be reached by the module under the conditions of a circuit with zero resistance or a short circuit. The example in Figure1.4 displays a current of approximately 2.65 amps. The power output at Isc is zero watts since the voltage is zero.

1.1.5 Advantages and Disadvantages of Solar Panel

Advantages

- Fuel source for Solar Panel is direct and endless so no external fuels required.
- Sunlight - free of cost.
- Unlimited life of Solar Modules, fast response and high reliability.
- Pollution free.
- Minimum Maintenance
- Independent working
- Operation is simple and no electrochemical reaction and no liquid medium.
- Noise-free as there are no moving parts.
- No AC to DC conversion losses as DC is produced directly.
- No transmission losses as installed in the vicinity of the load.
- Suitable for remote, isolated and hilly places.
- Since it is in modular form, provision of future expansion of capacity is available.
- It can generate powers from milli-watts to several mega watts.

- It can be used almost everywhere from small electronic device to large scale MW power
- It can be installed and mounted easily with minimum cost.

Disadvantages

- Initial cost is high
- Dependent on sunlight
- Additional cost for storage battery.
- Climatic condition, location, latitude, longitude, altitude, tilt angle, ageing, dent, bird
- It has no self-storage capacity.
- Manufacturing is very complicated process.
- To install solar panel large area is required.

1.1.6 Components of Solar power Generation systems:

The solar power system consists of the following components:

i. Solar array
ii. Battery Bank
iii. Solar Charge Controller
iv. Field Junction Box
v. Inverter
vi. Net meter
vii. Solar Module Mounting Structure
viii. Earthing kit
ix. Cables.

i. PV Module, panel and array :

It is the heart of the solar power plant. Actually a single solar PV cell generates very tiny amount that is around 0.1 watt to 2 watts. But it is not practical to use such low power unit as building block of a system. So required number of such cells are combined together to form a practical commercially available solar unit which is known as **solar module or PV module**.

Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. In a solar module the solar cells are connected in same fashion as the battery cell units in a battery bank system. That means positive terminals of one cell connected to negative terminal voltage of solar module is simple sum of the voltage of individual cells connected in series in the module. The normal output voltage of a solar cell is approximately 0.5 V hence if 6 such cells are connected in series then the output voltage of the cell would be 0.5 × 6 = 3 Volt.

Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit.

A **photovoltaic array** is the complete power-generating unit, consisting of any number of PV modules and panels. **Fig 1.5** below shows the picture of PV cell, panel, module and array.

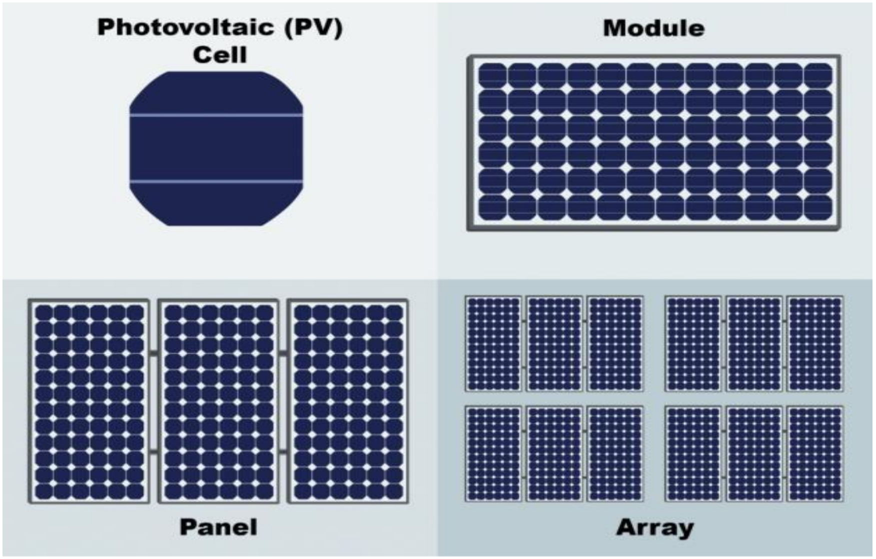


Fig 1.5: PV Module, panel and array

ii. Battery:

It is used to produce the power back or store the excess energy produced during day, to be supplied during night.

iii. Charge Controller:

Charge controllers regulate the DC from the solar panels to **make sure that the batteries don't overcharge**. A charge controller can measure whether the batteries are fully charged, and can stop the current from flowing in order to prevent the batteries from permanent damage.

iv. Field Junction Box (FJB):

FJB is the interface between Solar panels and the Charge Controller. All the incoming/outgoing cables/wires from Solar panel to Charge Controller are terminated at FJB. Fig 1.6 below shows the picture of FJB.

Fig 1.6: Field Junction Box (FJB)

v. **Inverters** (or Converters):

Solar panels produce direct current which is required to be converted into alternating current to be supplied to home or power grid.

vi. **Net Meter:**

A net meter is a key component of solar systems that are connected to the grid if your utility offers net metering.

If your utility company offers net metering and you have grid-connected solar, with or without a battery, any solar electricity that you produce that you don't use (or store in your battery) is sent to the grid. With net metering, your utility will pay you for that electricity you send, which lowers your electric bill. To keep track of how much electricity your solar panels produce versus how much electricity you use from the utility, a special electric meter, called a 'net meter', is required.

Since they aren't connected to the utility, off-grid solar systems do not need a net meter.

vii. **Solar Module Mounting Structure:**

This is made up of galvanized iron frames and angles. In this structure flexibility is provided to change the module-mounting angle seasonally. This structure is grouted by small civil work and modules are mounted subsequently. Also, this mounting structure should be earthed suitably at several places if voltage of the array is more than 50 Volts.

viii. **Earthing kit:**

Earthing kit is provided to earth the mounting structure. The installation shall have proper earth terminals and shall be properly earthed. The earth resistance shall not be more than 2 ohm. Earth provided shall preferably be maintenance free using earth resistance improvement material.

ix. **Cables:**

We require different types of cables to connect module to module, modules to charge controller, charge controller to battery, or connect battery to load as required. The cable size used for interconnection of SPV module, Charge Controller and battery shall be minimum 2 X 2.5 sq. mm Cu. Cable. As far as some hardware is concerned the screws and bolts/nuts are of Chrome plated, stainless steel and brass so that rusting should not be take place.

1.1.6 Types of Solar power Generation system:

According to the requirement of power, multiple photovoltaic modules are electrically connected together to form a PV array and to achieve more power. There are different types of PV systems according to their implementation.

i. **PV direct systems:** These systems supply the load only when the Sun is shining. There is no storage of power generated and, hence, batteries are absent. An inverter may or may not be used depending on the type of load.

ii. **Off-grid systems:** This type of system is commonly used at locations where power from the grid is not available or not reliable. An off-grid solar power system is not connected to any electric grid. It consists solar panel arrays, storage batteries and inverter circuits. Fig 1.7 and 1.8 shows the Off-grid PV system.

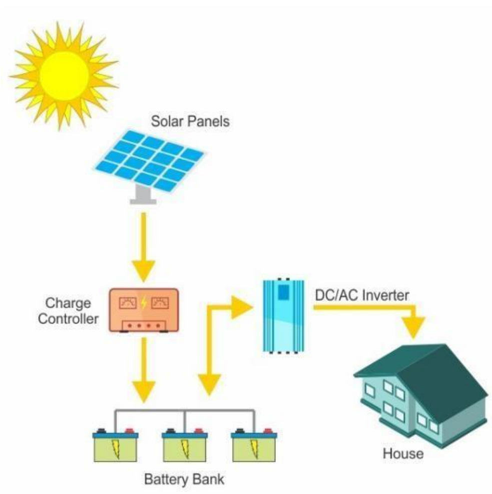


Fig 1.7:Simple Off-grid PV systems

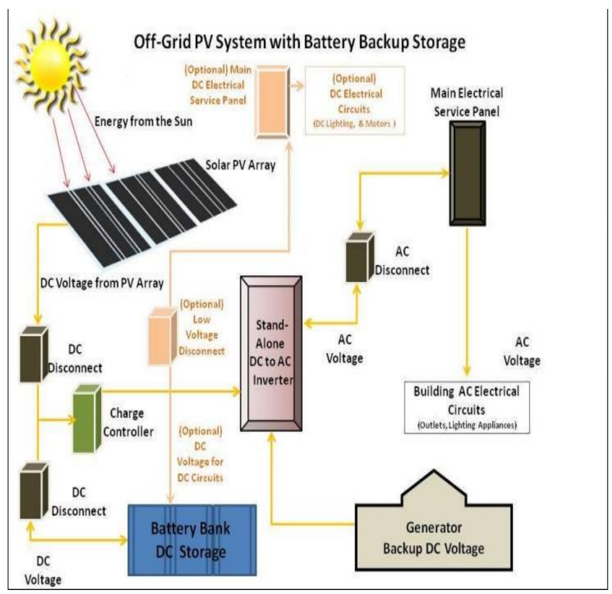


Fig 1.8 : Typical Off-grid PV system

Merits:

a. Independent from the power provided by the utility company.

b. Cheaper alternative than extending grid in remote areas.

c. A solution to regular power cuts.

d. Purchase battery as per your requirement

Demerits:

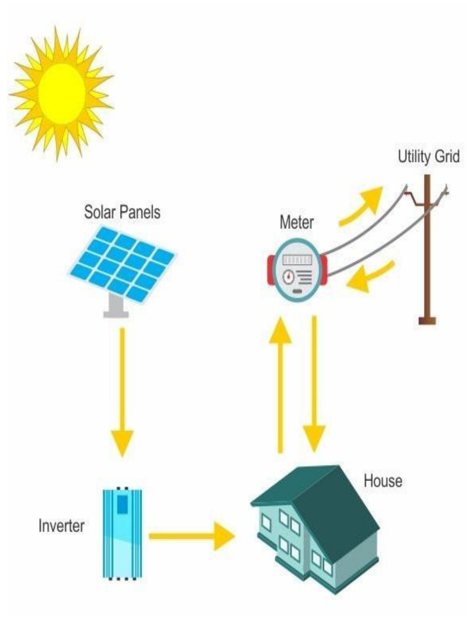
a. It is more expensive than On-Grid systems as batteries are expensive to replace.

b. Batteries have limited life and require maintenance.

c. Requires more components than On-Grid systems

iii. On-Grid Systems

This is the most popular Solar PV system mainly installed in residential, industrial and business areas that have regular power supply from the utility grid. Excess energy is sent to the utility grid for which you either get credited to your electricity bill or paid depending on the state laws. Fig 1.9 and 1.10 shows the On-grid PV system.



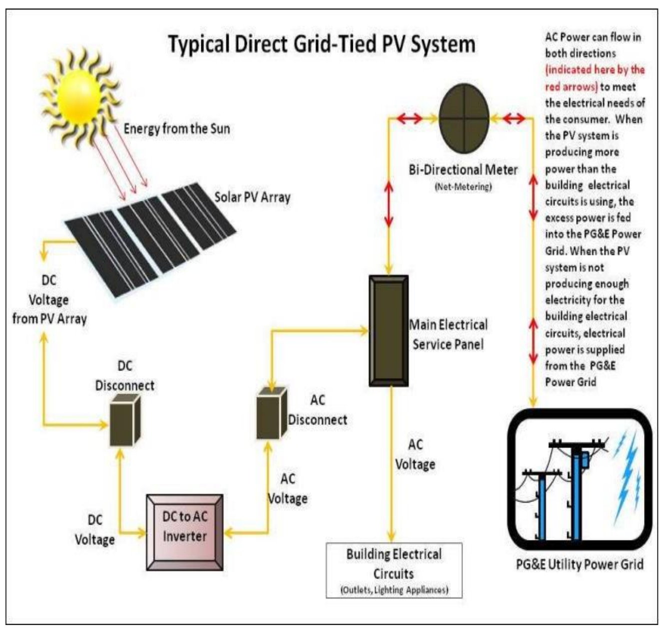


Fig 1.9 :simple On-grid PV systems **Fig 1.10 : Typical On-grid PV system**

Merits:

a. Cheapest Solar PV system, since it requires the lowest no of components for setup.

b. Lowest maintenance costs.

c. Exchange excess energy with the utility grid.

d. Reduce the burden of high tariff electricity bills, year on year tariff increase (avg. 2%).

e. Can be upgraded to a Hybrid Solar PV system.

f. Higher efficiency than Off-Grid systems since it is grid dependent

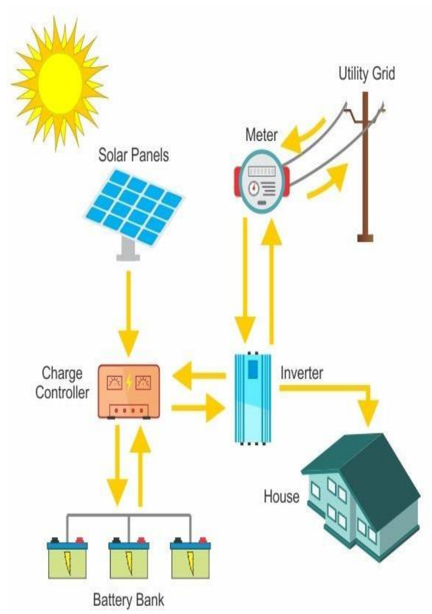
Demerits:

a. Does not have a backup for electricity outage.

b. Since it is dependent on the utility grid there is no power during an outage

iv. Hybrid Systems:

As the name suggests, this type of system is a combination of both on-grid and off-grid systems where the system is connected to the grid and also has a battery backup. It is installed in areas that cannot depend on their electricity providers and require a backup during inconsistent power cuts. Fig 1.11 and 1.12 shows the Hybrid PV system.



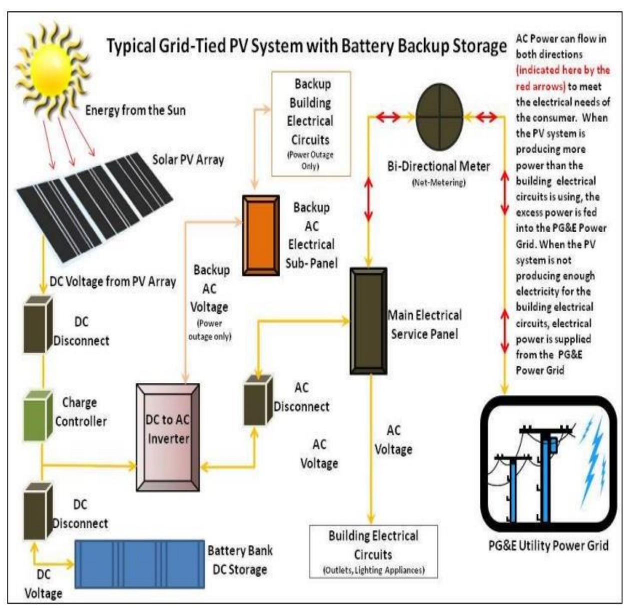


Fig 1.11 :simple On-grid PV systems

Fig 1.12: Typical On-grid PV system

Merits:

a. Eliminates the possibility of having no power.

b. Extra energy is exchanged with the utility company.

c. Battery setup is based on requirements

Demerits:

a. More expensive than on-grid Solar PV Systems.

b. Batteries will require maintenance as they have a limited life

1.2 Use of Solar Panels:

i. Solar panel used for electricity generation:

We use solar panels to generate electricity. This process can take place either in domestic or industrial purposes. The domestic solar panels can be used in generating electricity at home. And in the industrial panel we use to generate electricity in mass. For this, engineers need to install an array of solar panels from a solar power station. Solar panels can be used to generate large amounts of electricity, and this process can take place both at domestic and industrial scale. A key benefit of solar panels is that they can be used in providing electricity in the remote areas as well, provided there is enough solar energy at that place. This will help the people living there.

ii. Solar panel used for cooking:

It can be used for cooking by using solar oven (solar cooker) instead of cooking in conventional oven.

iii. **Solar panel used for Battery charging:**

It can be used to charge a battery bank in the sunlight throughout the day and use this battery bank in the nighttime or when required.

iv. **Solar panel used for Water heaters:**

It can be used for water heaters known as solar water heater. Nowadays solar water heater replaces the traditional water heaters.

v. **Solar panel used for Transports:**

It can also be used in solar powered vehicles in future.

1.2.1 Handling Procedure of Solar Panels:

Solar panels are heavy and awkward to lift and carry. Loading and unloading panels from trucks and on the roofs can cause strains, muscle pulls and back injuries .The panels can also heat up quickly when exposed to sunlight, causing burns if not handled safely. Therefore, following precaution and procedure should be carried out during handling of solar panels.

i. **Always stop working in bad weather:**

The first safety rule to keep in mind is to **stop working in bad weather**. In a storm, the wind can blow these panels around resulting in damage to the PV system. You should never work in **conditions of snow or high wind**, when these conditions are expected, due to the increased chance of slipping or losing your balance as a basic rule, do not install a solar PV system on your own, **have a least one other person with you** in case of accident or emergency.

ii. Electrical risks:

Solar panels **should be covered with an opaque sheet** when un-packaged, to prevent heat or energy buildup. Also, keep your photovoltaic solar panels **covered with an opaque material during wiring** to stop or prevent electricity production. **Wear insulated gloves** when working with solar panels as they may have an electric charge.

iii Lifting , moving solar panels and accessing the roof:

Always use safe lifting techniques and lift each solar panel with at least **two people**. If possible, it is advisable to use a forklift to move the solar panels. **Never climb ladders while carrying solar panels**, hoist solar panels onto rooftops, use cranes, hoists or ladder-based winch systems, make sure that they were properly inspected. Solar panels can be very heavy, make sure that the roof is strong enough to support the weight of the solar panels before mounting your solar panels.

When working on rooftops, always ensure that extreme safety precautions are taken **(including harnesses, lifelines and safety nets)** to prevent slipping, falling and causing injury or death. It is advisable **to use insulated tools when working on a photovoltaic system.** Use rubber latter mats to prevent the ladder from slipping and get a second person to securely hold ladders as you climb. An elevating work platform (EWP) may also be a suitable means of access.

Fig 1.13 to 1.16 shows the technique, how to Lifting , moving solar panels and accessing the roof

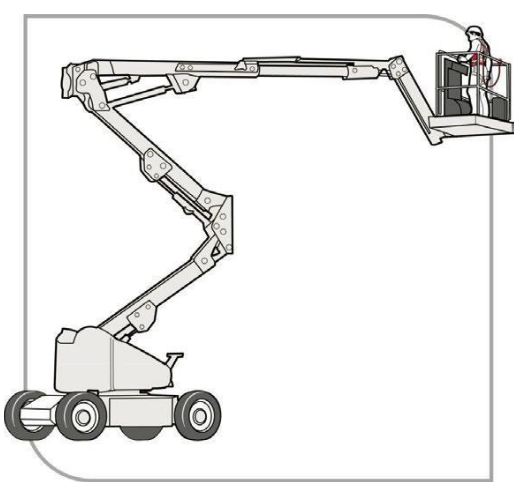


Figure 1.13: Boom-type elevating work platform

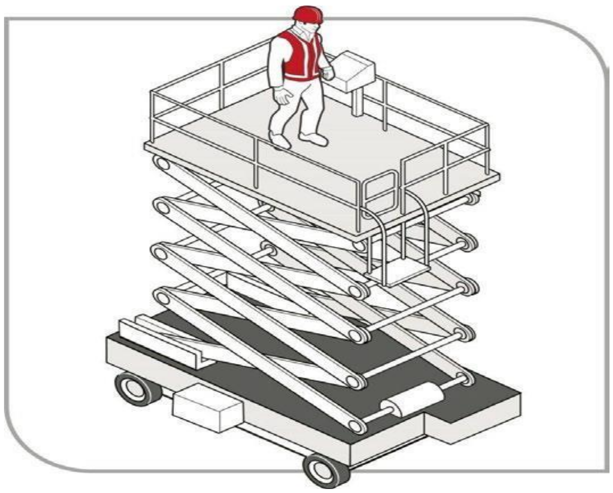


Figure 1.14: Scissor-lift elevating work platform

Fig 1.15: Example of a panel lifter

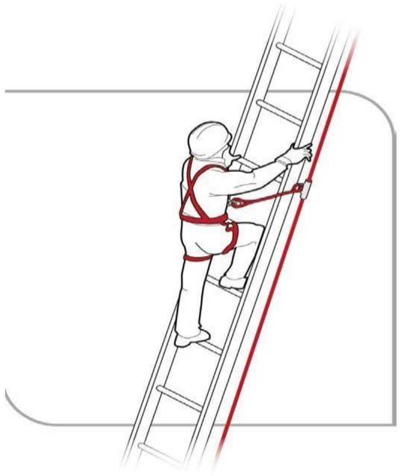


Fig. 1.16: Example of acceptable ladder use

iv **Do not drop** anything on the solar panels, for it can damage or break them. Make sure the area underneath your solar panels is **clean, clear and free of foreign objects**. Be very careful of falling objects and do: not ever throw objects up or down when installing a PV system.

1.3 Energy Storage, control and conversion:

1.3.1 Energy storage:

Batteries store and produce energy as needed. In PV systems, they capture surplus energy generated by your PV system to allow you to store energy for use later in the day. Like technologies such as **fuel cells**, a battery converts chemical energy to electrical energy. There are many types of batteries that can be used in PV systems. The lead-acid type of the most common, but lithium-ion batteries are becoming more popular.

Lithium -ion batteries	**Lead-acid batteries**
Becoming more common in domestic grid-connected solar PV storage systems	Used for off-grid storage systems where additional storage is required
More expensive	Less expensive
Lighter and smaller	Heavier and larger
Requires integrated controller to manage charging and discharging	Requires good charging and discharging process to maintain battery health
More efficient	Less efficient
Longer expected lifetime	Shorter expected lifetime

Table 1.1: Two Most Common Types of Batteries for PV System Storage

1.3.1.1 Battery Capacity:

Battery storage systems often have power ratings in kilo Watts (kW) and are typically between 1 – 7 kW. The power rating is the capability of the battery to provide power. The measurement for battery storage capacity is in ampere-hours (Ah) or kilowatt-hours (kWh). A 12-volt battery rated at 480Ah stores 2.25 kWh of energy. This is usually larger than the batteries actual capacity because:

- ✓ Batteries lose some energy during charging and discharging
- ✓ Batteries cannot be fully discharged

Figure 1.17: An example of a gel battery, rated at 12 volts and 58 amp-hours.

1.3.1.2 Battery Banks :

When the total voltage needs is greater than what one battery can provide, a number of batteries are connected together to form a bank. For example, two 12-volt batteries wired in series (positive terminal to negative terminal), produces a battery bank capable of providing up to 24 volts of DC energy, and four batteries wired in series produces 48 volts. Fig 1.18 shows the battery bank of 2 strings of 2 volt batteries wired in series.Each string is 12 volts, so the total capacity of battery bank is 24 volt.

Battery banks are sized to allow loads to operate for multiple days during cloudy weather conditions when the array is not able to charge the battery bank. Batteries have a limited life cycle. A cycle consists of discharging a battery and recharging it to full capacity. The life cycle of a battery can be lengthened if the battery is not discharged all the way to 0% charge. A reasonable design is to have batteries discharge to 50% then recharge full.However, this design may require having more batteries in the bank. Batteries used in solar systems are classified as deep-cycle batteries and may be discharged up to 80% of its storage capacity

Figure 1.18: A bank of two strings of 2 volt batteries wired in series. Each string is 12 volts

1.3.2 Solar Charge Controller:

Charge controller is the interface between Array and battery bank. It protects the battery from overcharging and moderate charging at finishing end of charge of battery bank. Therefore it enhances the life of the battery bank. It also indicates the charging status of batteries like battery undercharged, overcharged or deep discharged through LEDs indications. Some switches and MCBs are also provided for manual or accidental cut-off of charging. In some charge controllers load terminals are also provided through a low battery charge cut-off device so that it can protect the battery bank from deep discharge. The front view of a typical Charge controller is shown in Fig 1.19 and connection is shown in fig 1.20

Fig1.19: front view of Solar Charge Controller

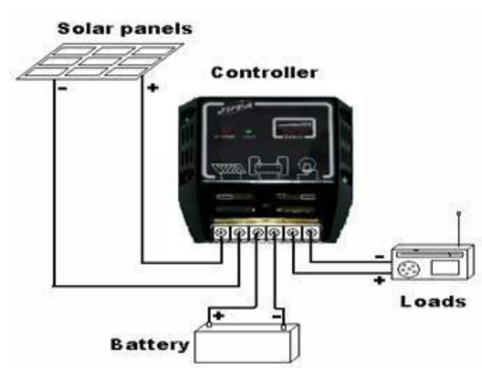


Fig 1.20: connection diagram of Solar Controller

First the controller is connected to battery bank and then it is connected to Solar Array/Solar module for sensing the voltage from the module. When the system is put into operation, the SPV modules start charging the battery bank.

The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.

A set of operational amplifiers are used to monitor panel voltage and load current continuously. If the battery is fully charged, an indication will be provided by a green LED. To indicate undercharging, overloading, and deep discharge condition a set of LEDs are used.

Care should be taken that in no case the battery connections are removed from the controller terminals when the system is in operation, otherwise SPV voltage may damage the Charge controller, since the solar voltage is always higher than the battery voltage.

1.3.2.1 Types of Solar Charger Controller:

The two major types of solar charge controllers are:

a) Pulse Width Modulation (PWM) controllers
b) Maximum Power Point Tracking (MPPT) controllers

a) Pulse Width Modulation (PWM) controllers:

PWM stands for Pulse Width Modulation. PWM charge control devices can be used as an electrical switch between batteries. The switch can be quickly switch on and switch off. Therefore, desired voltage can be obtained to charge the batteries. The charge current will be slowly decreased as the batteries charged.

b) Maximum Power Point Tracking (MPPT) controllers:

MPPT stands for Maximum Power Point Tracking. MPPT is a technique to observe and regulates the energy going from solar panel to the battery. Solar panels show changeable outputs according to weather conditions. MPPT charge control devices can match the solar panel voltage with battery voltage to maximize the charge efficiency.

1.3.2.2 Comparison between MPPT and PWM:

MPPT devices are more efficient than PWM. MPPT charge control devices have 30% more efficient in charging efficiency according to PWM type. On the other hand, MPPT controllers are more expensive than PWM controllers. Because of that, in small systems where the efficiency is not critical, are still using PWM charge controller.

1.3.3 Conversion:

a) **PV cell :** As we know that the sun energy is converted to electricity(DC) through Photovoltaic cell.

b) **DC to AC converter(Inverter)**: DC is converted into ac through inverter.

1.4 BASIC ELECTRICAL SYSTEM AND FUNCTIONING:

i. Inverter:

As SPV array produce direct current electricity, it is necessary to convert this direct current into alternating current and adjust the voltage levels to match the grid voltage. Conversion shall be achieved using an electronic Inverter and the associated control and protection devices. All these components of the system are termed the “Power Conditioning Unit (PCU)”. In addition, the PCU shall also house MPPT (Maximum Power

Point Tracker), an interface between Solar PV array & the Inverter.. Inverter output should be compatible with the grid frequency.

ii. Combiner Box :

A PV system array with multiple strings of modules will have a positive lead and a negative lead on the end of each string. The positive leads will be connected to individual fuses and the negative leads will be connected to a negative busbar in an enclosure. This is called the source circuit. The combiner box serves to "combine" multiple series strings into one parallel circuit. For example, an array with three strings of 10 modules wired in series would produce 300 volts (10 modules x 30 volts) per string and 4 amps per string. When the leads are landed in the combiner box, the circuit would produce 300 volts at 12 amps (3 strings x 4 amps/string). Once the circuits are combined, leaving the box it is referred to as the "output circuit".

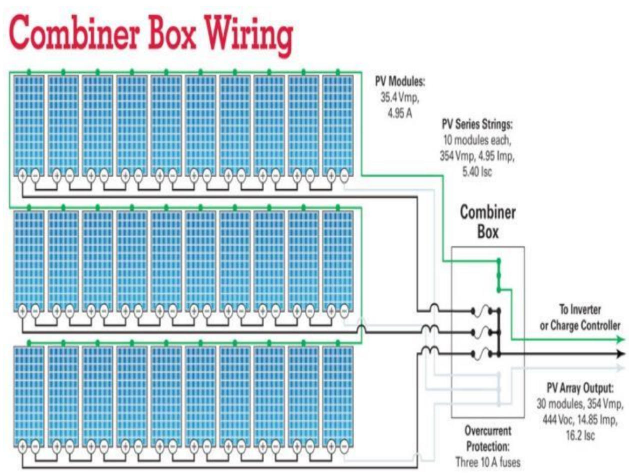


Fig 1.21: junction box

iii. PV (DC)Disconnect :

A direct current (DC) disconnect switch is installed between the inverter load and the solar array. The disconnect switch is used to safely de-energize the array and isolate the inverter from the power source

Figure 1.22 :Examples of DC safety disconnect switch boxes.

iv. AC Disconnect Switch :

Safety disconnect switch are required on the AC-side of the inverter to safely disconnect and isolate the inverter from the AC circuit.

Figure 1.22. Examples of AC safety disconnect switch boxes.

v. Net meter:

Net metering is an electric billing tool that uses the electric grid to store excess energy produced by your solar panel system. Under net metering, energy your solar panels produce and you don't use is credited back to you.On a cloudy or rainy day when your panel's aren't producing enough energy, the utility grid will feed your home energy, and count that energy against the credits you've banked over time.

1.5 MECHANICAL EQUIPMENT AND ITS FUNCTIOING:

i. Racking:

Racking refers to the mounting apparatus which fixes the solar array to the ground or rooftop. Typically constructed from steel or aluminum, these apparatuses mechanically fix the solar panels in place with a high level of precision. Racking systems should be designed to withstand extreme weather events such as hurricane or tornado level wind speeds and/or high accumulations of snow.

Rooftop racking systems typically come in two variations including flat roof systems and pitched roof systems. For flat rooftops it is common for the racking system to include weighted ballast to hold the array to the roof using gravity. On pitched rooftops, the racking system must be mechanically anchored to the roof structure. Ground mounted PV systems, as shown in figure 1.23, can also use either ballast or mechanical anchors to fix the array to the ground. Some ground mounted racking systems also incorporate tracking systems which use motors and sensors to track the Sun through the sky, increasing the amount of energy generated at a higher equipment and maintenance cost.

Fig 1.23: solar inverter (yellow) mounted to the solar racking converts DC electricity from the solar array to useful AC electricity

ii. Interconnector:

Interconnectors help solar panels connect with one another as shown in fig 1.24. These should be extremely weather-resistant and should enable secure connections.

Fig 1.24: Interconnector

1.6 MAINTENANCE PROCEDURE OF EQUIPMENT:

Once a corporate or state is ready to go solar, the next step is to identify the checkpoints in maintenance of solar power plant which is one of the major concerns plant heads have while deciding to go for on-site solar.

Who will take care of the solar power plant maintenance? How will it be done? How will the maximum output be ensured? These are some of the questions that come up.

Maintenance of solar power plant is handled by the solar developer. This ensures equipment life is maximized, and incentives are perfectly aligned with both the parties. Solar power plants require very little maintenance as there are no moving parts. Preventative maintenance is performed on major components of a solar PV system is given below:

1. Solar modules and Solar mounting structures:

The regular maintenance activity for a solar array (some solar modules connected in series), in India especially, is to keep the surface (glass) dust free. Occasional inspection and checks of the solar module ensure the performance efficiency at optimal levels.

a. **Cleaning:** To remove a layer of dust, panels are simply washed with soft water. If the module has thick dirt or grime and bird droppings, which are harder to remove, cold water is used, and the panel surface is cleaned with a sponge. Sometimes, soft detergents are also used along with water for easier cleaning. Metal brushes should be avoided to prevent wearing of the panel surface.

Fig 1.25: Picture of Cleaning PV panel

Note: Many people question, do solar panels need cleaning? - the answer is yes. Depending on the type of panel you have, **you might be weekly or monthly in cleaning solar panels**. Your solar panel manufacturer should be able to advise you on this for solar panel cleaning.

b. **Defect Checking:** A visual inspection of the modules is done periodically to look for possible defects such as cracks, chips, de-lamination, fogged glazing, water leaks and discolouration. If any obvious defects are found, their location is noted down in the system logbook so that they can be monitored for generation output. If the damage causes the modules to perform lower than the rated value, they should be replaced.

c. **Structure Stability**: Solar module mounting frames are examined to make certain that the frames and modules are firmly secured, and mounting bolts are rust free. Junction boxes are inspected to ensure that the wires are not chewed by rodents or insects.

2. Inverter / charge controller:

This component is maintained by minimizing dust accumulation. A dry cloth is used to wipe away any accumulated dirt/dust. After which a visual inspection ensures that all the indicators such as LED lights are working and the wires leading to and from this device are not loose. If self-checks are done, note that the charge controller should indicate that the system is charging when the sun is shining.

3. Wiring and connections:

Inspect all wiring installations, conductors, terminators, conduit, junction box etc regularly for any cracks, breaks or deterioration in the insulation.. Moreover, the connections are inspected for corrosion and/or burning.

1.7 SITE SURVEY, DESIGN AND EVALUTION OF VARIOUS PARAMETERS:

1.7.1 SITE SURVEY

An ideal site survey should contain the following parameters:

i. **Climate condition of site:**

The solar irradiation level, temperature and variation in wind speed at the site provide an estimate of the potential for the solar PV installation and the specific components required. For instance, at low solar irradiation level sites an efficient solar panel is required as compared to high solar irradiation sites. Similarly solar panels work more efficiently in colder regions as compared to hotter regions. Also installation design of solar system should consider the worst wind load on the panels and the structure they are placed on.

ii. **Type of property and its roof:**

Defining the type of property as residential, commercial, industrial or institutional is essential as the structure of the property and its roof type determines the design of solar system. The type of roof is also important as there can be various types such as RCC, Metal sheet, Aluminum sheet and Asbestos.. A roof can be flat or sloping with a specific potential to carry weight of panels so this helps determine many other factors dependent on this information.

iii. **Location of solar PV array:**

It is important to determine the ideal solar PV array during the site survey. South, south-east and south-west are three directions of the property where solar PV array can be installed.

iv. **Shade analysis:**

Ideally, the location where solar PV array is to be installed should be shadow free. During site survey, any obstructions such as adjacent buildings, trees, water tanks, dish antennas, parapet walls, etc should be noted as any obstacles can cause shade which can impact electricity generation. Shadow analysis is done to ensure maximum sunlight is captured throughout the year during the time frame of 9:00am to 3:00pm.

v. **Space availability:**

The space needed for a 1kW solar system is 80sqft. So for a 10kW system the space needed is 800sqft. During site survey, the potential area is measured on the roof or the ground and on this basis the solar PV system is designed. The structure and type of roof (flat or slope), its direction, nearby obstructions and its accessibility impact the location where solar PV array is to be installed.

vi. **Size and location of existing electrical connection:**

To get the correct information on the size and location of the connection it is necessary to answer a few questions. Is it a single phase or a three phase electrical connection? At what voltage and frequency electricity is supplied to the property? Where is the main connection of the property to the electricity grid? These questions will help analyse the site survey better.

vii. **Location for mounting solar system components:**

Once the ideal location of the PV installation is decided, , the location and diagram of mounting other components is to be specified in site survey. Factors such as distribution box, the inverter and the wiring route of the whole system should be determined as well. If the installation is off-grid, the placement of the battery is also necessary.

1.7.2 Designing and evaluation of an SPV system parameter:

Solar energy system consists of four major components:

i. Solar panel

ii. Inverter
iii. Energy storage: charge controller and battery
iv. Loads

Design step:

Following steps are followed on the basis of above components for designing and evaluation of SPV system parameter.

- **i. Load calculation:**Determine the energy consumption of targeted load.
- **ii. Sizing of Inverter:** Estimate the inverter rating.
- **iii. Battery selection:** Calculate the battery size as per inverter rating.
- **iv. Size of pv module:** finally estimate the solar module size.

Theses steps are explained below:-

Step 1: Load calculation

a. Identify all the AC and DC loads that you want to target. For DC loads we don't need an inverter although a charge controller is required, as the solar generated DC power can be directly fed to the DC loads.

b. Once you have targeted the loads, calculate the energy rating for each load as follows:-

- ✓ Note the power rating specified on the loads (device likes Tv, fan , CFL etc) in watts.
- ✓ Note the running time of each loads in hours.
- ✓ Calculate the energy consumption (consider approximately 25% as energy loss factor).

Step 2: Size of Module:

Solar panel/module is the base of our solar energy system. To find out the sizing of PV module, the total peak watt produced needs. The peak watt(Wp) produced depends on the size of the PV module and climate of site location .According to the thumb rule, 1kW panel generation 4kWh . To determine the sizing of PV modules, calculate as follow:-

a. **Calculate total Watt-hours per day for each appliance used:**

   Divide the total watt-hours per day needed from the Pv modules from the step 1(b) by 4 to get the total watt-peak rating needed for the PV panels needed to operate the appliances.

b. **Calculate the number of PV panels for the system:**

   Divide the answer obtained from step 2(a) by the rated output Watt-peak of PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

Step 3: Sizing of Inverter

a. Once we have estimated the energy requirement, the next task is to calculate the inverter rating for the same.
b. Consider an inverter with fair efficiency , we have considered an inverter with 85% efficiency.
c. The total power wattage consumed by the loads as per calculated in step 1 is considered as an output of the inverter .Will add 25% as a safety factor in the required power wattage. It means

Total power wattage required (Output) = total power consumed by load+ total `
power consumed by load×0.25

d. Calculate the inverter input capacity rating :-

   Input(VA)= output(watt)/efficiency ×100

e. Estimate the energy input required by the inverter:-

Input energy(Watt-hour)=Output (watt-hour) /efficiency × 100

f. Now , once we have determined the inverter capacity, the next task is to check the inverter available in market.

g. Now , it is necessary to see the inverter specification data sheet to determine the system voltage. For 1kw inverter we can choose 24V system voltage.

Step 4: Battery Selection:-

For a standalone rooftop solar , a battery is required so as to store energy during a sunny day and retrieve it during the evening or cloudy weather. For selecting a battery system one needs to define the below terms:-

a) **Type of Battery:** select types of battery for small residential system lead acid batteries are preferred due to low cost and for industrial applications lithium ion batteries are preferred .

b) **System voltage ampere -hour rating:-**

Estimated Capacity(Ampere-hour)= energy output(watt-hour)/system volt(v)

c) **Depth of discharge (DOD):-**

It indicates the charging capacity of the battery . for lead acid batteries,DOD is 50% and for litinum ion batteries DOD is 80%. also consider battery loss factor is 0.85

Actual battery capacity=Estimated capacity(Ah)/DoD × battery loss factor

d) **Days of autonomy:**

It means how many number of days battery can furnish power in case of non -sunny days.

Required battery capacity= Actual battery capacity(Ah)× No. of autonomy days

e) The final steps is the calculation of the number of batteries required to supply the amount of energy estimated . Available lead acid batteries are 40Ah, 100Ah, 150Ah, 200Ah and the voltage level of the battery is 12V. we must ensure that the battery bank voltage must be equal to the inverter system voltage. Batteries can be connected in series connection to attain the voltage level and parallel connection to attain the required Ah to form a battery bank.

Step 5: Solar charge controller using:

The solar charge controller is typically rated against amperage and voltage capacities.Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application.Make sure that solar charge controller has enough capacity to handle the current from PV array.According the standard practice , the sizing of solar charge controller is to take the short circuit current(Isc) of the PV array and multiply it by 1.25.

Solar charge controller rating = no. Of module ×Total short circuit current $(I_{sc}) \times 1.25$

(Remarks: MPPT charge controller sizing will be different.)

Note: Depending on the above system design, fuse wire, junction box and other components are also to be chosen , keeping in mind the maximum current and voltage rating.

Example: A house has following electrical appliances usage.we consider all AC load for calculation:-

- ✓ One 10Watt LED used 7 hours
- ✓ One fan 50 Watt used 10 hours
- ✓ One TV 120 watt used 5 hours
- ✓ One computer 200Watt used 5 hours

The system will be powered by 24volt, 330 Wp solar module rating.

Step 1: Determine energy consumption demand:

Total energy consumed = (10W ×7 h)+(50W×10 h)+(120W × 5 h)+(200W ×5 h)

= 2170 watt-hour

Total energy needed(add 25% as energy loss factor)= 2170 × 1.25

= 2712.5 W-h

Step 2: Size the PV panel/module:

Consider 1 Kw panel generate 4Kwp, therefore, Total

Wp of PV panel capacity needed = 2712.5/4

= 678.12 Wp

Number of PV panels needed = 678.12/330

= 2.05= 3modules

Step 3: sizing of Inverter:

Total watt of all appliances=10+50+120+200=380W inverter should be considered25% safety factor

Total power wattage required (Output) = total power consumed by load+ total ` power consumed by load×0.25

= 380 + 380×0.25

= 475 W

Now, inverter input capacity rating;

Input(VA) = output(watt)/efficiency ×100

= 475(watt)/85 × 100

= 559 VA=560VA

The required input power for the inverter is estimated as 560VA, now we need to estimate the energy input required by the inverter

Input energy(Watt-hour)=Output (watt-hour) /efficiency × 100

= 2712.5/85 × 100

= 3191.1 watt-hour

Step 4: Battery selection:

Estimated Capacity(Ampere-hour)= energy output(watt-hour)/system volt(v)

= 2170 Wh/24V

= 90 Ampere-hour(Ah)

Actual battery capacity=Estimated capacity(Ah)/DoD × battery loss factor

= **90(Ah)**/0.5× 0.85

=212 Ah

Required battery capacity= Actual battery capacity(Ah)× No. of autonomy days

= 212 Ah× 2= 424 Ah

So the battery should be rated 12 V, 424 Ah(500 Ah) for 2 days autonomy.

Step 5: Solar charge controller using:

Solar charge controller rating = no. Of module ×Total short circuit current (I_{sc})× 1.25

= 3×7.5 A×1.25

= 28.125 A= 30 A

So the solar charge controller should be rated 30A at 12 V or greater.

1.8 TOOLS INVOLVED IN INSTALLATION OF SYSTEM:

Below are several lists that describe many of the tools needed for an installation.

i. **Tape measure:** measuring tapes to obtain accurate plot dimensions,

Fig 1.26: Measuring Tape

ii. **Solar Pathfinder :**

The Solar Pathfinder takes a 360-degree view of the location. The Solar Pathfinder uses a highly polished, transparent, convex plastic dome to give a panoramic view of the entire site. All the trees, buildings or other obstacles to the sun are plainly visible as reflections on the surface of the dome. The sun path diagram can be seen through the transparent dome at the same time.

Because the Solar Pathfinder works on a reflective principle rather than actually showing shadows, it can be used anytime of the day, anytime of the year, in either cloudy or clear weather. The actual position of the sun at the time of the solar site analysis is irrelevant. In fact, the unit is easier to use in the absence of direct sunlight. It could even be used on a moonlit night.

Figure 1.27: Solar pathfinder

iii. **Compass** :a compass for finding the azimuth. It is not needed if you’re using a Solar Pathfinder

Figure1.28 : compass

iv. Another useful item to carry around is a notepad/sketchpad to roughly plot the site and surrounding areas.

v. Angle finder:

Setting the solar module at the optimum tilt angle increases the power output. Depending on the time of year the sun may be higher or lower in the sky. Adjusting the tilt angle by 15 degrees (latitude) can result in an increase in the energy output of the solar module.

Fig 1.29 : Angle finder

The angle finder is an expensive tool used to check the tilt angle of the module. The finder is set on the frame of the module and the angle in degrees can be read on tool.

vi. Torpedo level:

Figure1.30 : **Torpedo level**

vii. Hand tools: The hand tool required for installation of solar structure and modules are drill machine with assorted bits, cutter machine, spanner set, hammer, cutting plier, slip joint plier, nose plier, screw drivers of different sizes, utility knife, wire stripper, crimping tool, neon tester, hole punch etc. It's better either to carry an extension board with you or all the power machines should be battery operated. Figure shows a spanner set of assorted size, cutting plier, wire stripper, screw driver, neon tester, nose plier and hammer used for solar PV installation.

Figure1.31: Different Hand tools

viii. Fish tape:

A **fish tape** (also known as a *draw wire* or *draw tape* or an "electricians snake") is a tool used by electricians to route new wiring through walls and electrical conduit

Figure 1.32: Fish Tape

ix. Cordless drill : if you're doing a pitched roof or tilt-leg installation, you're going to need a cordless drill and impact driver, along with their accessories.

Figure 1.33: Cordless drill with different size of bit

x. Digital Multi-meter:

One of the most versatile and ultimately a "must-have" tool is the digital multimeter. To check the energy output of a PV module, a digital multimeter with both alternating current (AC) and direct current (DC) capabilities is an important tool to have on hand. Direct current voltage can be measured using the multi meter. This tool can be used to measure circuit voltage, continuity, and resistance.

Figure 1.34. A digital multimeter with leads connected.

xi. Digital clamp on meter:

Solar modules produce direct current (DC) electricity. A digital clamp-on ammeter can be used to measure circuit voltage (as with the digital multi-meter) as well as circuit amperage. Circuit amperage (or current) is safely checked with a clamp-on ammeter. The ammeter is used to measure direct current (DC) amperage moving through the circuit while wired to a load. Set the meter to a setting higher than the expected current level of the circuit to be measured to prevent damaging the meter

Figure 1.35 : digital clamp-on ammeter with leads is used to perform the circuit measurements.

xii. non-contact thermometer :

To check the cell temperature, use a non-contact thermometer and point to the white back sheet of the module. This tool is relatively inexpensive and easy to use. Set the temperature to Celsius or Fahrenheit .Point the meter to the back side of the module and pull the trigger. Locate the red laser dot. Read the thermometer. Check at various locations on the module, and at various times of the day to observe how the temperature of the solar cell increases with very little sun.

Figure 1.36: non-contact thermometer

1.9 QUALITY AND PROCESS STANDARDS:

The modules should be tested and certified by a Govt. of India authorized test centres or should conform to relevant International Electrotechnical Commission (IEC) standard as per MNRE guidelines. Offered module shall have a power output warranty of 90% of the rated power for 10 years. The rated output power and Efficiency of each supplied & installed module shall not be less than the specified power rating and Efficiency of the modules, in any case. Every module should have suitable by-pass diode at its terminal box. The SPV Modules must be installed in such a way so as to deliver proper voltage and current to ensure desired power output as per specifications of CREDA for the size of SPVPP ordered.

The PV modules should be made in India; The PV modules used must qualify to the latest edition of IEC PV module qualification test or equivalent BIS standards Crystalline Silicon Solar Cell Modules IEC 61215/IS14286. The PCU/ inverters should be tested from the MNRE approved test centres/ NABL/ BIS/IEC accredited testing- calibration laboratories. In case of imported power conditioning units, these should be approved by international test houses.

Each PV module must use a RF identification tag (RFID), which must contain the following information:

(i) Name of the manufacturer of PV Modules (should be made in India).

(ii) Name of the Manufacturer of Solar cells.

(iii) Month and year of the manufacture (separately for solar cells and module).

(iv) Country of origin (separately for solar cells and module).

(v) I-V curve for the module.

(vi) Peak Wattage, Im, Vm and FF for the module.

(vii) Unique Serial No and Model No of the module.

(viii) Date and year of obtaining IEC PV module qualification certificate.

(ix) Name of the test lab issuing IEC certificate.

(x) Other relevant information on traceability of solar cells and module should be as per ISO 9000 series. The RFID must be inside of module lamination. The module laminate, but must be able to MNRE. withstand harsh environmental conditions.

(n) Inter connections of solar modules should be through good quality male female joint. Name of manufacturer, S. No. of Module & manufacturing year should be clearly fixed inside the glass lamination of every module. Thermal sticker should be affixed behind every module which should clearly state the specifications & capacity of the module.

(o) Every module should have PID Test report as per the prevailing norms of MNRE.

1.9.1 Quality certification and standards for grid-connected rooftop solar PV systems :

All components of grid-connected rooftop solar PV system/ plant must conform to the relevant standards and certifications given below:

Solar PV Modules/Panels	
IEC 61215/ IS14286	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61701	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1/ IS 16170: Part 1	Photovoltaic (PV) module performance testing and energy rating –: Irradiance and temperature performance measurements, and power rating
IEC 62716	Photovoltaic (PV) Modules – Ammonia (NH3) Corrosion Testing (As per the site condition like dairies, toilets)
IEC 61730-1,2	Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction, Part 2: Requirements for Testing
IEC 62804	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation. IEC TS 62804-1: Part 1: Crystalline silicon (mandatory for applications where the system voltage is > 600 VDC and advisory for installations where the system voltage is < 600 VDC)
IEC 62759-1	Photovoltaic (PV) modules – Transportation

	testing, Part 1: Transportation and shipping of module package units
Solar PV Inverters	
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems – Part 1: General requirements, and Safety of power converters for use in photovoltaic power systems Part 2: Particular requirements for inverters. Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC/IS 61683 (as applicable)	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions)
BS EN 50530 (as applicable)	Overall efficiency of grid-connected photovoltaic inverters: This European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid- connected photovoltaic systems. In that case the inverter energizes a low voltage grid of stable AC voltage and constant frequency. Both the static and dynamic MPPT efficiency is considered.
IEC 62116/ UL 1741/ IEEE 1547 (as applicable)	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures
IEC 60255-27	Measuring relays and protection equipment – Part 27: Product safety requirements
IEC 60068-2 (1, 2, 14, 27, 30 & 64)	Environmental Testing of PV System – Power Conditioners and Inverters a) IEC 60068-2-1: Environmental testing - Part 2-1: Tests – Test A: Cold b) IEC 60068-2-2: Environmental testing - Part 2-2: Tests - Test B: Dry heat c) IEC 60068-2-14: Environmental testing - Part

	2-14: Tests – Test N: Change of temperature d) IEC 60068-2-27: Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock e) IEC 60068-2-30: Environmental testing - Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle) f) IEC 60068-2-64: Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance
IEC 61000 – 2,3,5 (as applicable)	Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) testing of PV Inverters
Fuses	
IS/IEC 60947 (Part 1, 2 & 3), EN 50521	General safety requirements for connectors, switches, circuit breakers (AC/DC): a) Low-voltage Switchgear and Control-gear, Part 1: General rules b) Low-Voltage Switchgear and Control-gear, Part 2: Circuit Breakers c) Low-voltage switchgear and Control-gear, Part 3: Switches, disconnections, switch-disconnectors and fuse-combination units d) EN 50521: Connectors for photovoltaic systems – Safety requirements and tests
IEC 60269-6	Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems

Surge Arrestors	
IEC 62305-4	Lightening Protection Standard
IEC 60364-5-53/ IS 15086-5 (SPD)	Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control
IEC 61643- 11:2011	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods
Cables	
IEC 60227/IS 694, IEC 60502/IS 1554 (Part 1 & 2)/ IEC69947	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation)
BS EN 50618	Electric cables for photovoltaic systems (BT(DE/NOT)258), mainly for DC Cables
Earthing /Lightning	
IEC 62561	Series (Chemical earthing)
IEC 62561-1	Lightning protection system components (LPSC) - Part 1: Requirements for connection components
IEC 62561-2	Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes
IEC 62561-7	Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds
Junction Boxes	
IEC 60529	Junction boxes and solar panel terminal boxes shall be of the thermo-plastic type with IP 65

	protection for outdoor use, and IP 54 protection for indoor use
Energy Meter	
IS 16444 or as specified by the DISCOMs	A.C. Static direct connected watt-hour Smart Meter Class 1 and 2 — Specification (with Import & Export/Net energy measurements)
Solar PV Roof Mounting Structure	
IS 2062/IS 4759	Material for the structure mounting Note- Equivalent standards may be used for different system components of the plants. In case of clarification following person/agencies may be contacted.

1.10 OCCUPATIONAL HEALTH AND SAFETY STANDARDS:

While the PV industry has a good safety record to date, workers not properly prepared or trained to work with hazards such as electricity, or working at heights, working in ceiling spaces, or with energy storage batteries), place themselves at risk of serious injury or death.

i. management plan:

The principal contractor for a construction project must prepare a written management plan for the workplace before work commences.The management plan must contain:

- ✓ names, positions and health and safety responsibilities of workers at the workplace whose positions or roles involve specific health and safety responsibilities, for example site supervisors, project managers, first aid officers.

- ✓ site-specific health and safety rules and how workers will be informed of the rules .
- ✓ arrangements to collect, assess, monitor and review safe work method statements.
- ✓ the provision and maintenance of a hazardous chemicals register, safety data sheets and hazardous chemicals storage .

ii. **Qualifications and licencing:**

Make sure you and your workers only carry out work you are qualified and competent to do and that any electrical work is undertaken by an appropriately licensed and competent person.The electrical risk associated with making incorrect connections, such as with panel-to-panel connectors, may result in serious shock or injury, or significant property damage.

iii. **Training :**

Workers and other people who may be exposed to health and safety risks during the construction and operation of solar farms must be provided with information and training related to the workplace and work to be performed. This may include site induction training, supervisor and management training, work-specific training and ongoing or refresher training.Workplace specific training should include information on:

- ✓ hazards and control measures relevant to the site .
- ✓ manufacturer or designer instructions on how the solar farm is to be constructed, installed, used, altered or dismantled .

- ✓ site safety requirements and documentation including safe work procedures, safe work method statements, safety management systems and traffic management plans .
- ✓ how to use and maintain equipment, including any conditions and prohibitions on the use of equipment and reference to operator manuals .
- ✓ safety procedures for working in certain conditions (e.g. in remote locations, at night, or in high temperatures) .
- ✓ how to ensure electrical equipment has been de-energised to enable electrical work to be undertaken and not inadvertently re-energise the equipment .
- ✓ personal protective equipment requirements, including instruction on fitting, use, cleaning, maintaining and storing equipment .
- ✓ workplace facilities, including their location, use and maintenance .
- ✓ first aid procedures, location of facilities and who to contact .
- ✓ emergency procedures, including who to contact in an emergency.

iv. Safety for Non-electrical risks :

Non-electrical risks that must be managed with safety standards used that include:

- ✓ falling from heights : minimising the risk of falls by providing a fall prevention device, work positioning system or a fall arrest system etc.

- ✓ falling structures, loads or objects (e.g. during lifting operations) : use personal protective equipment such as hard hats , enclosing areas where loads are being lifted and use of tool lanyards etc.
- ✓ on-site traffic management :Planning can help minimise vehicle movement around a workplace. To limit the number of vehicles at a workplace. designated travel paths for vehicles including entry and exit points, haul routes for debris or plant and materials, or traffic crossing other streams of traffic .Designated delivery and loading and unloading areas etc.
- ✓ exposure to sun, heat, noise and vibration :Personal hearing protection must also be provided to protect workers for risk.

These risks must be managed through all stages of construction including during site establishment, site clearing, materials delivery, construction and installation of frames and modules, construction of transmission infrastructure and grid connection, and commissioning.

CHAPTER-2
INSTALLATIONOF SOLAR PANEL

2.1 Solar energy system components such as panels , batteries , charge controllers, inverters:

Solar panels can be used to generate electricity for both commercial and home use. In both cases, the Photovoltaic Panel are installed on Roof Top to get maximum possible sunlight and generate maximum electricity from the system.

Following are the steps involved in the installation process:

Step-1: Mount Installation

The first step is to fix the mounts that will support he Solar Panels. It can be Roof-ground mounts or flush mounts depending on the requirement. This base structure provides support and sturdiness. Care is taken on direction in which the PV panels (monocrystalline or polycrystalline) will be installed. For countries in the Northern Hemisphere, the best direction to face solar panels is south because it gets maximum sunlight. East and West directions will also do. For countries in the Southern Hemisphere, the best direction is North.

Again, the mounting structure must be slightly tilted. Angle of the tilt could be between 18 to 36 Degree. Many companies use a solar tracker to increase the conversion efficiency.

Step-2: Install the Solar Panels

Next step is to fix the solar panels with the mounting structure. This is done by tightening nuts and bolts. Care is taken to secure the whole structure properly so that it is sturdy and lasts long.

Step-3: Do Electrical Wiring

Next step is to do the electrical wiring. Universal Connectors like MC4 are used during wiring because these connectors can be connected with all type of solar panels. These panels can be electrically connected with each other in following series:

1. **Series Connection**: In this case, the Positive (+) Wire is of one PV module is connected to the Negative (–) Wire of another module. This type of wiring increases the voltage match with the battery bank.
2. **Parallel Connection**: In this case, Positive (+) to Positive (+) and Negative (–) to Negative (–) connection is done. This type of wiring voltage of each panel remains same.

Step-4: Connect the System to Solar Inverter

Next step is to connect the system to a solar inverter. The Positive wire from the solar panel is connected to the Positive terminal of the inverter and the Negative wire is connected to the Negative terminal of the inverter.

The solar inverter is then connected to the Solar Battery and Grid input to produce electricity.

Step-5: Connect Solar Inverter and Solar Battery

Next step is to connect the solar inverter and the solar battery. The positive terminal of the battery is connected with the positive terminal of the inverter and negative to negative. Battery is needed in off grid solar system to store electricity backup.

Step-6: Connect Solar Inverter to the Grid

Next step is to connect the inverter to the grid. To make this connection, a normal plug is used to connect to the main power switch board. An output wire is connected with electric board that supplies electricity to the home.

Step: 7: Start Solar Inverter

Now when all the electrical wiring and connections are done, it is time to start the inverter switch ON the Main Switch of the Home. Most solar inverters will have digital display to show you stats regarding generation and usage of solar unit.

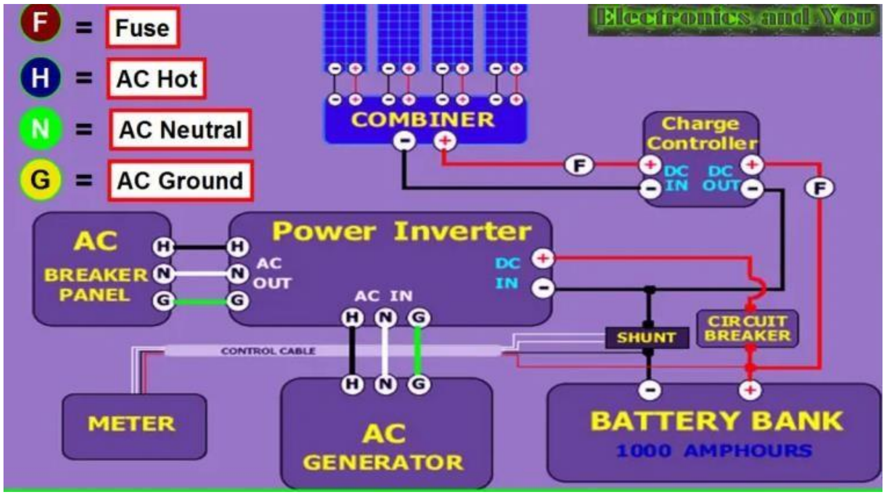


Fig 2.1 Solar installation diagram

2.2 Significance of volts, amps and watts: series and parallel connection:

2.2.1 Significance of volts, amp and watts:

i. Solar Cell Voltage:

An single photovoltaic solar cell can produce an "Open Circuit Voltage" (VOC) of about 0.5 to 0.6 volts at 25oC (typically around 0.58V) no matter how large they are.This cell voltage remains fairly constant just as long as there is sufficient irradiance light from dull to bright sunlight. Open circuit voltage means that the PV cell is not connected to any external load and is therefore not producing any current flow.

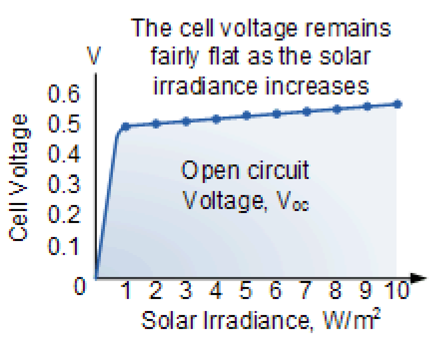


Fig 2.2 Solar cell voltage

When connected to an external load, such as a light, the output voltage of the individual cell drops to about 0.46 volts or 460 mV (460 millivolts) as the electrical current begins to flow, and will remain around this voltage level regardless on the sun's intensity. This decrease in output voltage is caused by resistance and power losses within the cells structure as well as the metallic conductors deposited on the cells surface.

Temperature also affects a photovoltaics output voltage. The higher the temperature is, the lower the cell's output voltage becomes as the cell degrades under the hot conditions. So in full sun the output voltage reduces by about 5% for every 25°C increase in cell temperature. Then solar panels and modules with more photovoltaic cells are recommended for very hot climates than would be used in colder ones in order to offset power output losses due to high temperatures.

ii. Solar Cell Current:

Unlike a photovoltaic cells voltage, the output DC current (I) however, does vary in direct relationship to the amount or intensity of the sunlight (photon energy) falling onto the face of the PV cell.

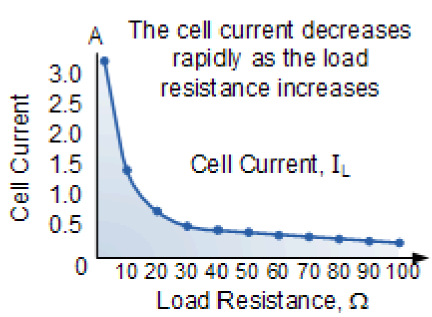


Fig 2.3 Solar cell current

Also the output current is directly proportional to the cells surface area as the larger the cell the more light energy enters the cell. Then the more sunlight entering the cell, the more current it produces. Photovoltaic cells with high current outputs are generally more desirable, but the higher the current output, the more they will cost.

iii. PV Panel Power Output

We have said previously that the power output of a photovoltaic solar cell is given in watts and is equal to the product of voltage times the current (V x I) and this is true. The optimum operating voltage of a PV cell under load is about 0.46 volts at the normal operating temperatures, generating a current in full sunlight of about three amperes.

Thus the power output of a typical photovoltaic solar cell can be calculated as: power (P) equals voltage times current = V x I = 0.46 x 3 = 1.38 watts.

2.2.2 Solar Panels in Series:

When a solar installer wires your solar panels in a series, each panel is connected to the next in a "string." The total voltage of each solar panel is summed together, but the amps of electrical current stay the same.Therefore,

Power = sum voltage * amps = watts

➢ Solar Panels in series of Same Characteristics

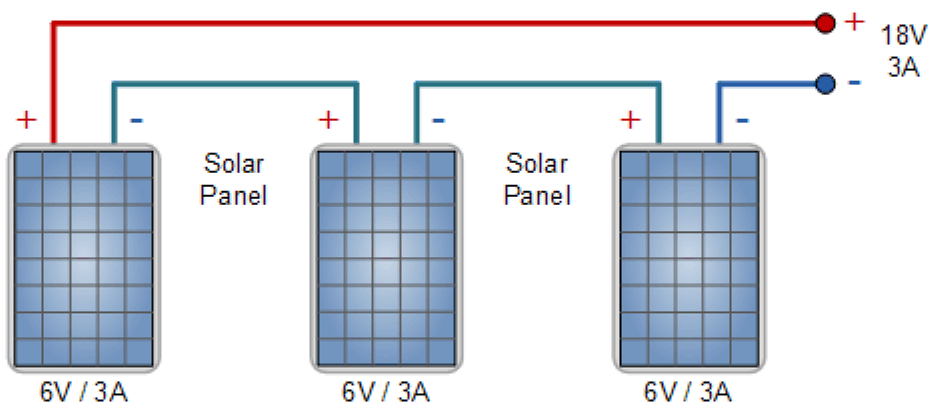


Fig 2.4 connection of solar panel of same rating in series

In this method all the solar panels are of the same type and power rating. The total voltage output becomes the sum of the voltage output of each panel. Using the same three 6 volt, 3.0 amp panels from above, we can see that when these pv panels are connected together in series, the array will produce an ouput voltage of 18 Volts (6 + 6 + 6) at 3.0 Amperes, giving 54 Watts (volts x amps) at full sun.

Now lets look at connecting solar panels in series with different nominal voltages but with identical current ratings.

➢ Solar Panels in Series of Different Voltages

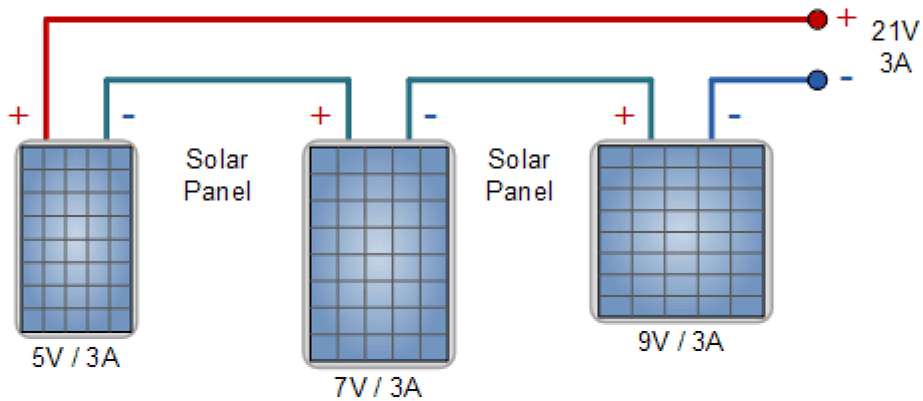


Fig 2.5 connection of solar panel of different voltage rating in series

In this method all the solar panels are of different types and power rating but have a common current rating. When they are connected together in series, the array produces 21 volts at 3.0 amps, or 63 watts. Again the output amperage will remain the same as before at 3.0 amps but the voltage output jumps to 21 volts (5 + 7 + 9) .

Finally, lets look at connecting solar panels in series with completely different nominal voltages and different current ratings.

- **Solar Panels in Series of Different Currents:**

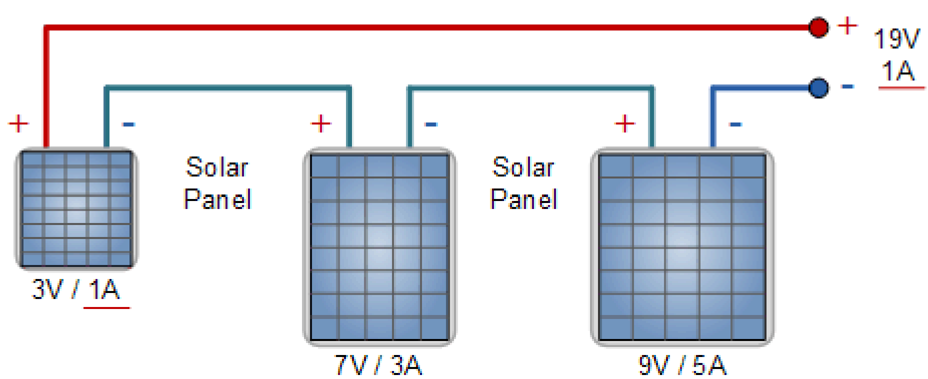


Fig 2.6 connection of solar panel of different current rating in series

In this method all the solar panels are of different types and power rating. The individual panel voltages will add together as before, but this time the amperage will be limited to the value of the lowest panel in the series string, in this case 1 Ampere. Then the array will produce 19 Volts (3 + 7 + 9) at 1.0 Ampere only, or only 19 watts out of a possible 69 watts available reducing the arrays efficiency.

We can see that the solar panel rated at 9 volts, 5 amps, will only use one fifth or 20% of its maximum current potential reducing its efficiency and wasting money on the purchase of this solar panel. Connecting solar panels in series with different current ratings should only be used provisionally, as the solar panel with the lowest rated current determines the current output of the whole array.

2.2.2 Solar Panels in Parallel:

The next method we will look at of connecting solar panels together is what's known as "**Parallel Wiring**". Connecting solar panels together in parallel is used to boost the total system current and is the reverse of the series connection. For parallel connected solar panels you connect all the positive terminals together (positive to positive) and all of the negative terminals together (negative to negative) until you are left with a single positive and negative connection to attach to your regulator and batteries.

When you connect solar panels together in parallel, the total voltage output remains the same as it would for a single panel, but the output current becomes the sum of the output of each panel as shown.

Therefore,

Power = voltage * sum current = watts

➢ Solar Panels in Parallel of Same Characteristic:

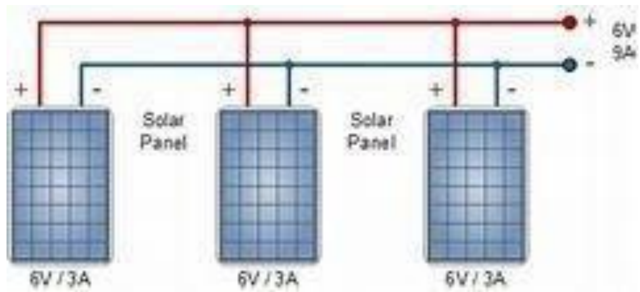


Fig 2.7 connection of solar panel of same rating in parallel

In this method ALL the solar panels are of the same type and power rating. Using the same three 6 Volt, 3.0 Amp panels as above, the total output of the panels, when connected together in parallel, the output voltage still remains at the same value of 6 volts, but the total amperage has now increased to 9.0 Amperes (3 + 3 + 3), producing 54 watts at full sun.

But what if our newly acquired solar panels are non-identical, how will this affect the other panels. We have seen that the currents add together, so no real problem there, just as long as the panel voltages are the same and the output voltage remains constant. Lets look at connecting solar panels in parallel with different nominal voltages and different current ratings.

➢ **Solar Panels in Parallel with Different Voltages and Currents:**

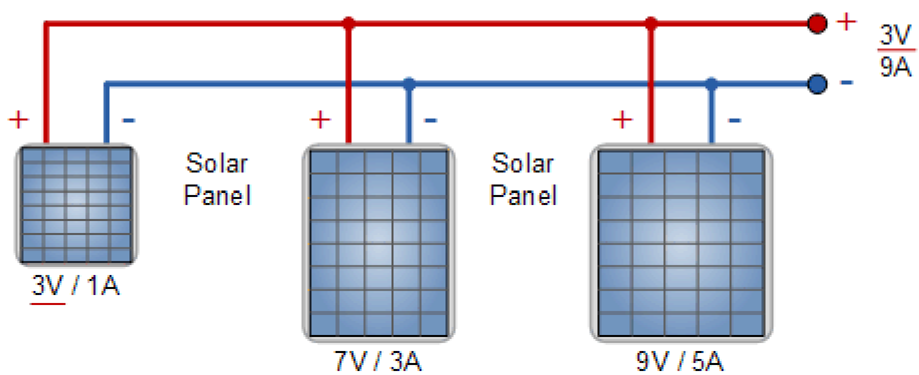


Fig 2.8 connection of solar panel of different rating in parallel

Here the parallel currents add up as before but the voltage adjusts to the lowest value, in this case 3 volts. Solar panels must have the same output voltage to be useful in parallel. If one panel has a higher voltage it will supply the load current to the degree that its output voltage drops to that of the lower voltage panel.

We can see that the solar panel rated at 9 volts, 5 amps, will only operate at a maximum voltage of 3 volts as its operation is being influenced by the smaller panel, reducing its efficiency and wasting money on the purchase of this higher power solar panel. Connecting solar panels in parallel with different voltage ratings is not recommended as the solar panel with the lowest rated voltage determines the voltage output of the whole array.

Then when connecting solar panels together in parallel it is important that they ALL have the same nominal voltage value, but it is not necessary that they have the same ampere value.

2.2.3 : Series – Parallel Connection of Modules

When we need to generate large power in a range of Giga-watts for large PV system plants we need to connect modules in series and parallel. In large PV plants first, the modules are connected in series known as "PV module string" to obtain the required voltage level.

Then many such strings are connected in parallel to obtain the required current level for the system. The following figures shows the connection of modules in series and parallel. To simplify this, take a look at right in the following figure

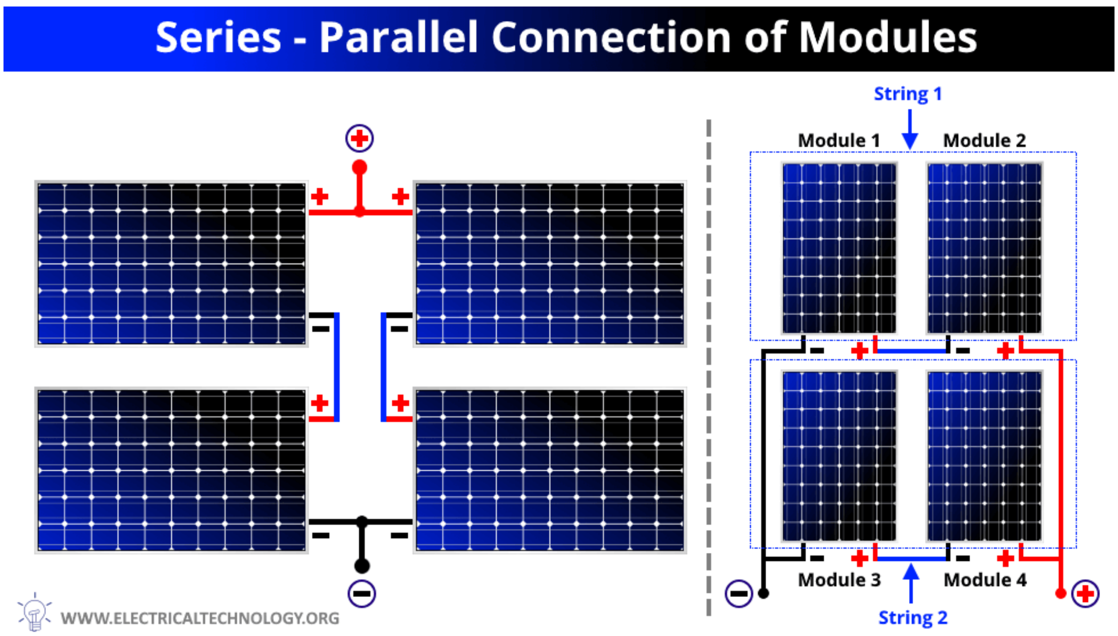


Fig 2.9 connection of solar panel series, parallel and series-parallel connection

2.4 Solar Panel Mounting:

Solar Panel Mounts are used to install photovoltaic panels. These mounts are available in 3 main types:

1. Pole mounts

2. Roof-ground mounts; and
3. Flush mounts.

With the help of these mounts, you can install your solar panel onto an RV, on rooftop or against the side of a pole, on your roof. You can even install them as a free-standing unit.

Fig 2.10 Different mounting structure

Mounting systems are essential for the appropriate design and function of a solar photovoltaic system. They provide the structural support needed to sustain solar panels at the optimum tilt, and can even affect the overall temperature of the system.

2.4.1 Inclination and angle of tilt:

The solar panel angle of your solar system is different depending on which part of the world you are. Solar panels give the highest energy output when they are **directly facing the sun**. The sun moves across the sky and will be low or high depending on the time of the day and the season. For that reason the ideal angle is never fixed. To get the most sun reaching the panel throughout the day, you need to determine what direction the panels should face and calculate an optimal tilt angle. This will depend on:

- **Where you live**
- What **time of the year** you need the most solar energy

In the northern hemisphere, the general rule for solar panel placement is, solar panels should face true south. Usually this is the best direction because solar panels will receive direct light throughout the day.

By the same reasoning, if the solar panel is located in the southern hemisphere, the panel should instead face in the direction of true north.

- **Orientation:** The sun's apparent location east and west of true south is called azimuth, which is measured in degrees east or west of true south

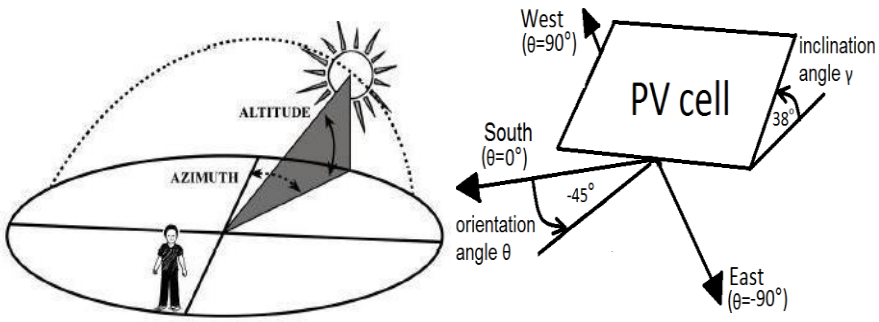


Fig 2.11 orientation and inclination angle

- **Angle or tilt of solar panel:**

Tilt angle of solar module is defined as angle between the horizontal ground and the solar module.

The angle that a solar panel should be set at to produce the most energy in a given year is determined by the geographical latitude. A general rule for optimal annual energy production is to set the solar panel tilt angle equal to the geographical latitude. For example, if the location of the solar array is at 50^o latitude, the optimal tilt angle is also 50^o.

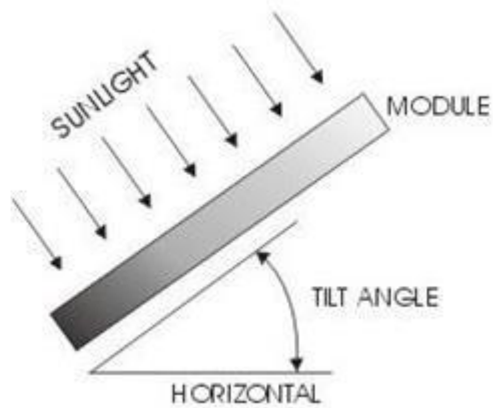


Fig2.12: tilt angle of solar panel

- **Effect of Tilt Angle:**

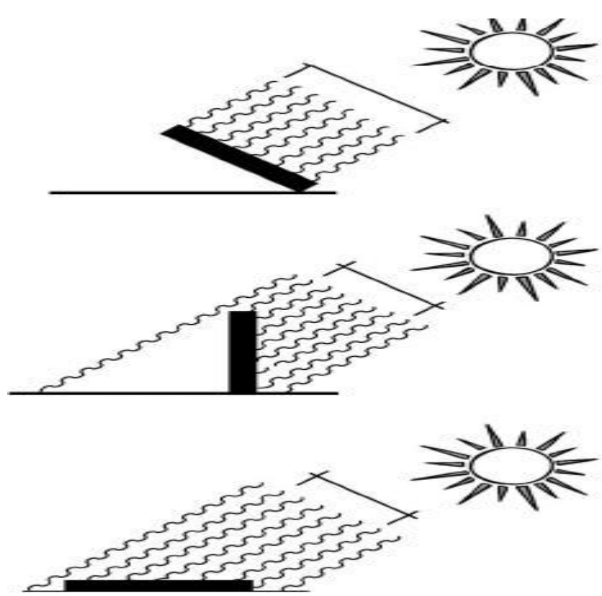


Fig 2.13: Effect of tilt angle

2.5 Placement of solar panel mounting:

i. Solar panel on Roof:

Step1: choose the right location:

Start by surveying your house to find the best location to fix the solar panels. Don't forget that just because the sun targets a specific area within the rooftop doesn't mean it's the right place to place the panels. The direction and the pitch of your roof affect the efficiency of the solar modules. Therefore , be sure to use a location that will offer the panels proper exposure t the sun.

Step 2: Mount Installation:

The next thing to do is fixing the roof mount that will hold the solar panels.it can be flush mounts or roof-ground mounts, but this depend on the installation requirement.

Additionally , the mounting structure should be titled slightly at an angle of between 18-36 degree Celsius. solar tracker mechanism will boost the efficiency of the system.Make mounting strong to sustain extreme weather conditions

Step3: Ground the mounting system:

Mounting system is made of metal that's why you must earth it.

ii. Ground-Mounted structure:

Step1: Build a strong foundation:

Ground mounting is different from roof mounting.Build a sturdy foundation under which you will fix the racking rails by pouring concrete and setting piers.

Step2: Install the racking rails:

The racking report specifics the spacing for the system plus the rail size. Start by spacing the rails to match the mounting holes measurement at the back of the panel.When you start a new row, create some space to accommodate the panel overhang on both sides.

Step3: Ground the mounting system:

Mounting system is made of metal that's why you must earth it.

2.6 Sunlight and direction assessment :

i. Assessing a site for sun

When assessing a site for sun, consider:

- the time during the day that the site receives sunlight
- the sun's path at different times of the day and year
- how the site's shape, slope and orientation affect solar access
- how obstructions such as adjacent buildings, trees and landforms will impact on the site and the potential design

- the owners' lifestyle – for example, when they want to have sun or shade.

Ideally a site should have excellent solar access for most of the day and be of a shape/size to allow a home to be built with the living areas facing north, requiring minimal purchased energy for space heating. By contrast, a house on a site that sees little sun, or where living areas cannot face north, will typically require higher amounts of purchased energy, and therefore have a bigger carbon footprint.

ii. Sun paths

Assessing the passage of sun across a site is important. There are a number of locally-produced tools that can help, but a site visit is still necessary to identify site-specific conditions such as the impact of a large tree.

Sun path diagrams provide a broader overview of sun on a site as they map the path of the sun across the sky at different times during the day throughout the year. They can help establish the position of the sun relative to a site and can be used to determine the effect of shadows cast by buildings, trees and landforms on and around the site.

iii. Altitude and azimuth

The position of the sun with respect to an observer is commonly represented by two angles – altitude and azimuth.

Altitude is the angle of the sun’s rays compared with the horizon. At sunrise and sunset, the altitude is zero, and in the southern hemisphere, the maximum altitude of the sun at any specific location occurs at solar noon on 21/22 December (longest days of the year).

iv. Solar radiation

Solar or ultraviolet (UV) radiation is the energy from the sun. The amount of solar radiation available on a site depends on the latitude and the sunlight hours received.

2.7 Site surveying methods and evaluation parameter:

Already done in chapter 1 , topic 1.7

2.8 Tools involved in installation of system:

Already done in chapter 1 , topic 1.8

CHAPTER 3

COORDINATE COLLEAGUES AT WORK

3.1 Company's policies on incentives, delivery standards and personel management:-

3.1 Policies on incentives:

A incentive scheme is a plan to motivate individual or group performance .An incentive scheme basically involves monetary rewards.e incentives pay but also includes non -monetary rewards (in which no direct money is given to employee).

Many companies have come out with compensation program that offer additional benefit based on individual, group or organizational performance. So every employee has to work hard , deliver results on a daily .

Example of monetary rewards:-

i. Annual incentive

ii. Spot incentive

iii. Profit sharing

iv. Bonus

v. Giving free vacations

Example of non- monetary rewards:-

i. Flexible working

ii. Extra leave

iii. Allow time to do volunteer work

iv. Say thank u

v. Recognize you employees on social media

3.1.2 Delivery standards:

Delivering products on time and efficiently is not always easy, but if done properly, it can help a business stand out from the competition.

i. Get It Right The First Time:

Don't allow any room for error. If the wrong product is delivered it will take time to return and re-send, and your customer will be upset. They might never buy from you again.

ii. Keep The Item Safe:

Whenever possible, ensure fragile items are well packed. There is nothing worse for a customer than receiving an item damaged in transit.

iii. Be Quick:

One hour deliveries might be impossible, but the faster you can process the order, and send it out, the happier your customers will be buying from you. They might receive an item before they expect it too.

iv. Offer Options

A good courier service will offer its customers a range of delivery options, such as next day, several weeks, and other time frames.

3.1.3 Personnel Management:

Personnel management involves **the administrative tasks that address the hiring and compensation of a company's employees**. it aims to recruit and retain the quality workforce necessary for an organization to meet its goals. Following are the four functions of Personnel Management:

1. **Manpower Planning**

   Manpower Planning which is also called as Human Resource Planning consists of putting right number of people, right kind of people at the right place, right time, doing the right things for which they are suited for the achievement of goals of the organization

2. **Recruitment:** Recruitment is of 2 types

   a. **Internal Recruitment -** is a recruitment which takes place within the concern or organization. Internal sources of recruitment are readily available to an organization. Internal sources are primarily three - Transfers, promotions and Re-employment of ex-employees.

   Internal recruitment may lead to increase in employee's productivity as their motivation level increases. It also saves time, money and efforts. But a drawback of internal recruitment is that it refrains the organization from new blood. Also, not all the manpower requirements can be met through internal recruitment. Hiring from outside has to be done.

b. **External Recruitment -** External sources of recruitment have to be solicited from outside the organization. External sources are external to a concern. But it involves lot of time and money. The external sources of recruitment include - Employment at factory gate, advertisements, employment exchanges, employment agencies, educational institutes, labour contractors, recommendations etc.

3. Selection process:

a. Application call

b. Written test

c. Interview

d. Medical examination

e. Appointment letter

4. Training and Development:

Training of employees takes place after orientation takes place. Training is the process of enhancing the skills, capabilities and knowledge of employees for doing a particular job. Training process moulds the thinking of employees and leads to quality performance of employees. It is continuous and never ending in nature.Training is generally imparted in two ways:

a. **On the job training-** On the job training methods are those which are given to the employees within the everyday working of a concern. It is a simple and cost-effective training method. The inproficient as well as semi- proficient employees can be well trained by using such training method.

b. **Off the job training-** Off the job training methods are those in which training is provided away from the actual working condition. It is generally used in case of new employees. Instances of off the job training methods are workshops, seminars, conferences, etc. Such method is costly and is effective .

3.2 Importance of the individual's role in the workflow.

A business workflow is a repeatable process that consists of a series of tasks that generally need to be completed in a specific sequence.

The workflow improve the individual employee efficiency,quickly respond to issues or problem,established the responsibility and improve the quality of product /services etc. Therefore this turn ,dramatically streamline and automate improve business , minimizing room for errors and increasing overall efficiency .

3.3 Reporting Structure:

A reporting structure refers to the interrelationship between various authorities in a company. This is a hierarchal chain of command that clarifies who reports to whom. Some reporting structures are self-evident in small businesses that only have a few employees. These businesses may have the employer as the sole senior authority and all employees report to them. The case is different in large corporations where many activities take place simultaneously. Large businesses require formal reporting hierarchies. Companies set up reporting structures to identify which employees are in charge of various functions, departments and the entire organization. Their structure depends on several factors, including the size of the company, type of business, products and services produced, current projects, geographic locations and the employee's individual expertise.

i. Hierarchical org structure

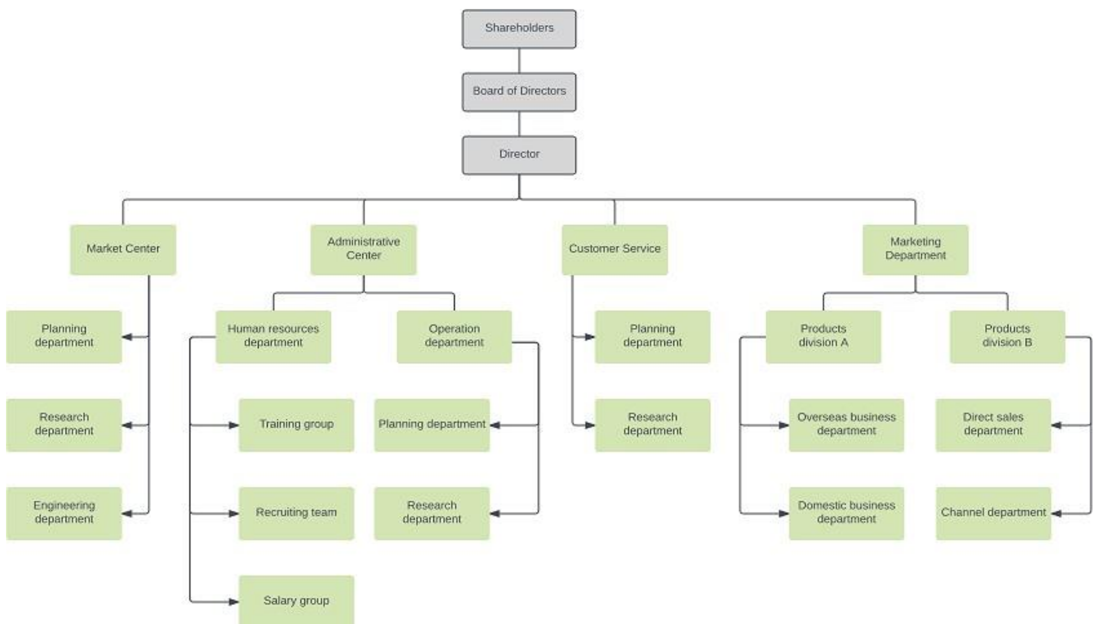


Figure 3.1 Hierarchical org structure

The pyramid-shaped organizational chart we referred to earlier is known as a hierarchical org chart. It’s the most common type of organizational structure—the chain of command goes from the top (e.g., the CEO or manager) down (e.g., entry-level and low-level employees) and each employee has a supervisor.

Pros

- Better defines levels of authority and responsibility

- Shows who each person reports to or who to talk to about specific projects
- Motivates employees with clear career paths and chances for promotion
- Gives each employee a specialty
- Creates camaraderie between employees within the same department

Cons

- Can slow down innovation or important changes due to increased bureaucracy
- Can cause employees to act in interest of the department instead of the company as a whole
- Can make lower-level employees feel like they have less ownership and can’t express their ideas for the company

3. Functional org structure

Similar to a hierarchical organizational structure, a functional org structure starts with positions with the highest levels of responsibility at the top and goes down from there. Primarily, though, employees are organized according to their specific skills and their corresponding function in the company. Each separate department is managed independently.

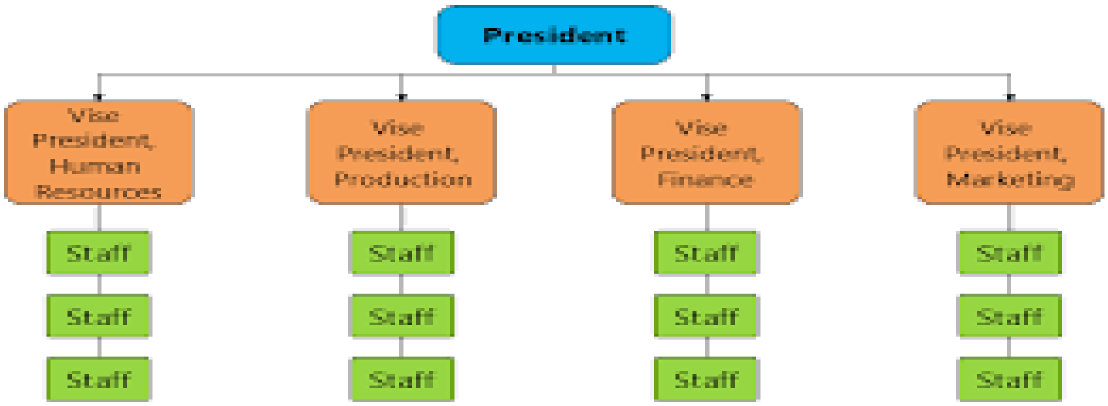


Fig 3.2 Functional org structure

Pros

- Allows employees to focus on their role
- Encourages specialization
- Help teams and departments feel self-determined
- Is easily scalable in any sized company

Cons

- Can create silos within an organization
- Hampers interdepartmental communication
- Obscures processes and strategies for different markets or products in a company

3**. Horizontal or flat org structure**

A horizontal or flat organizational structure fits companies with few levels between upper management and staff-level employees. Many start-up businesses use a horizontal org structure before they grow large enough to build out different departments, but some organizations maintain this structure since it encourages less supervision and more involvement from all employees.

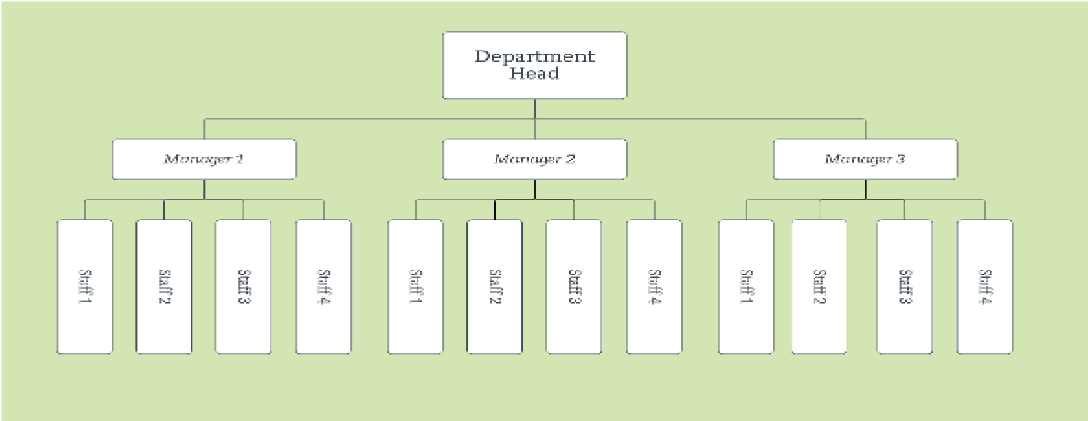


Fig 3.3 Horizontal or flat org structure

Pros

- Gives employees more responsibility
- Fosters more open communication
- Improves coordination and speed of implementing new ideas

Cons

- Can create confusion since employees do not have a clear supervisor to report to.
- Can produce employees with more generalized skills and knowledge.
- Can be difficult to maintain once the company grows beyond start-up status.

4. Divisional org structure:

In divisional organizational structures, a company's divisions have control over their own resources, essentially operating like their own company within the larger organization. Each division can have its own marketing team, sales team, IT team, etc. This structure works well for large companies as it empowers the various divisions to make decisions without everyone having to report to just a few executives.

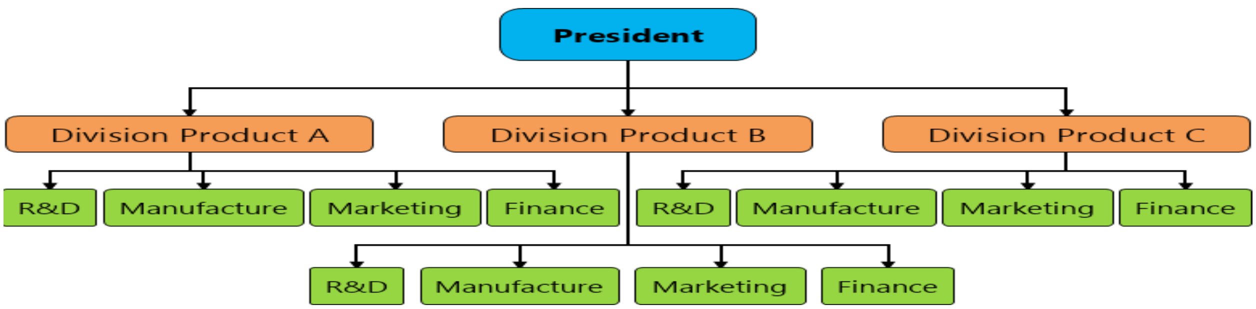


Figure 3.4 **Divisional org structure**

Pros

- Helps large companies stay flexible
- Allows for a quicker response to industry changes or customer needs
- Promotes independence, autonomy, and a customized approach

Cons

- Can easily lead to duplicate resources
- Can mean muddled or insufficient communication between the headquarters and its divisions
- Can result in a company competing with itself

5. Matrix org structure

A matrix organizational chart looks like a grid, and it shows cross-functional teams that form for special projects. For example, an engineer may regularly belong to the engineering department (led by an engineering director) but work on a temporary project (led by a project manager). The matrix org chart accounts for both of these roles and reporting relationships.

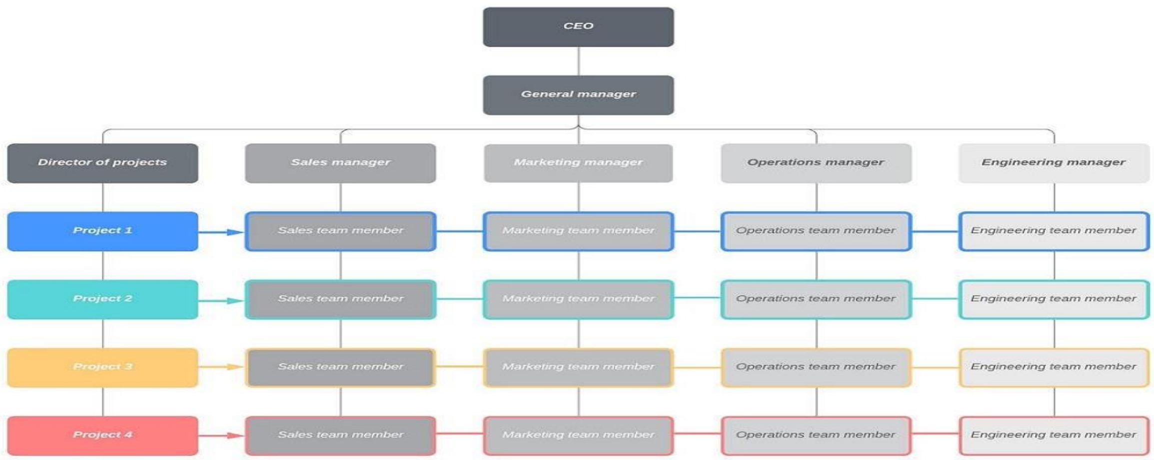


Figure 3.5 :Matrix org structure

Pros

- Allows supervisors to easily choose individuals by the needs of a project
- Gives a more dynamic view of the organization
- Encourages employees to use their skills in various capacities aside from their original roles

Cons

- Presents a conflict between department managers and project managers
- Can change more frequently than other organizational chart types

6. Team-based org structure

It'll come as no surprise that a team-based organizational structure groups employees according to (what else?) teams—think scrum teams or tiger teams. A team organizational structure is meant to disrupt the traditional hierarchy, focusing more on problem solving, cooperation, and giving employees more control.

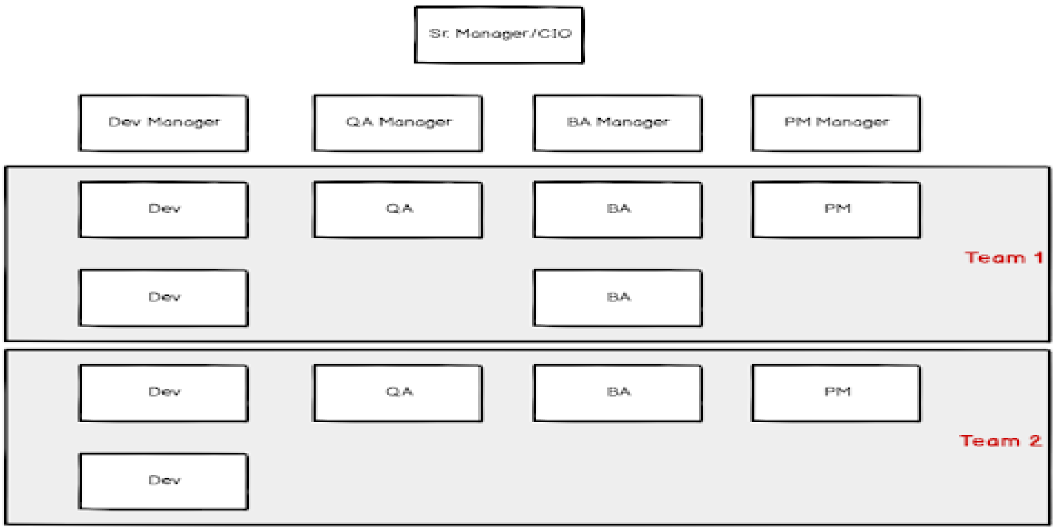


Figure 3.6: Team-based org structure

Pros

- Increases productivity, performance, and transparency by breaking down silos
- Promotes a growth mindset
- Changes the traditional career models by getting people to move laterally
- Values experience rather than seniority
- Requires minimal management
- Fits well with agile companies with scrum or tiger teams

Cons

- Goes against many companies' natural inclination of a purely hierarchical structure
- Might make promotional paths less clear for employees

7. Network org structure

These days, few businesses have all their services under one roof, and juggling the multitudes of vendors, subcontractors, freelancers, offsite locations, and satellite offices can get confusing. A network organizational structure makes sense of the spread of resources. It can also describe an internal structure that focuses more on open communication and relationships rather than hierarchy.

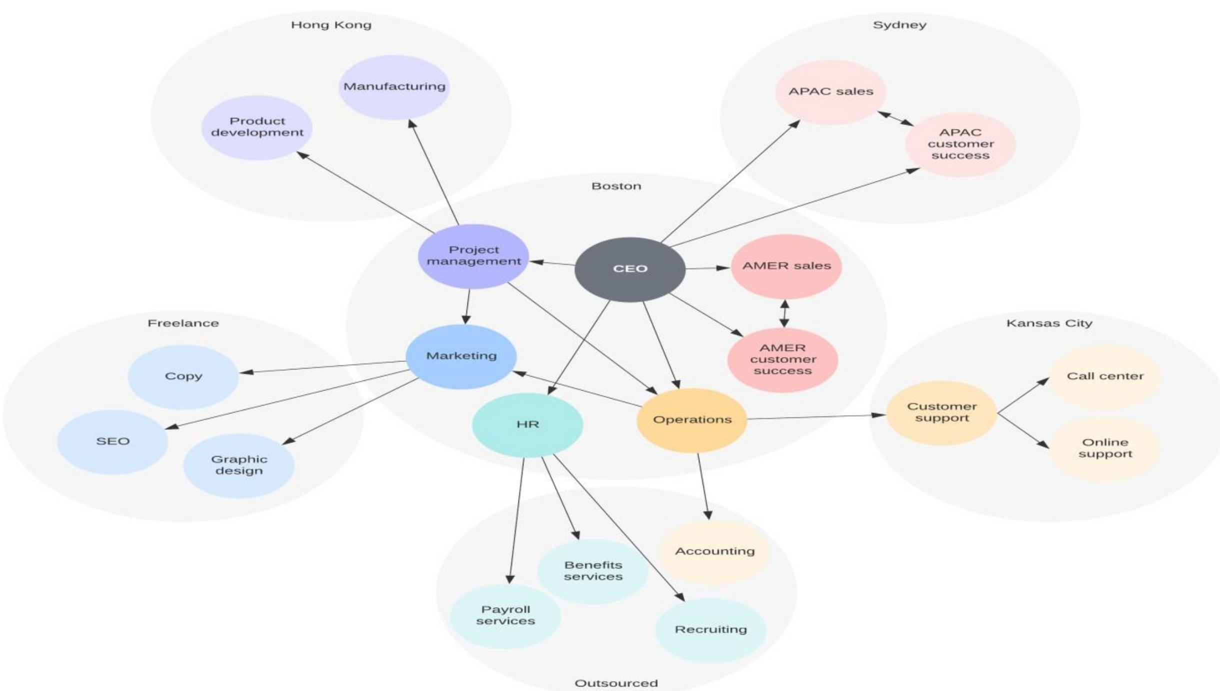


Figure 3.7 Network org structure

Pros

- Visualizes the complex web of onsite and offsite relationships in companies
- Allows companies to be more flexible and agile
- Give more power to all employees to collaborate, take initiative, and make decisions
- Helps employees and stakeholders understand workflows and processes

Cons

- Can quickly become overly complex when dealing with lots of offsite processes
- Can make it more difficult for employees to know who has final say

Consider the needs of your organization, including the company culture that you want to develop, and choose one of these organizational structures.

3.4 Communicating effectively:

Effective Communication is defined as the ability to convey information to another effectively and efficiently. Business managers with good verbal, nonverbal and written communication skills help facilitate the sharing of information between people within a company for its commercial benefit.

In other words, communication is said to be effective when all the parties (sender and receiver) in the communication, assign similar meanings to the message and listen carefully to what all have been said and make the sender feel heard and understood.

In a business organization, communication is said to be effective when the information or data shared among the employees effectively contribute towards organization's commercial success.

Benefits:

i. Effective communication facilitates innovations in a business organization by allowing employees and management to come up with innovative ideas that might further help in the overall development of the organization.

ii. A work environment enriched with effective or open communication helps in building a cohesive and effective team. Effective communication always boosts the morale of employees.

iii. When there is hassle-free and open communication between the management and the employees, it leads to a steady rise in the pace of progress of the organization.

3.5 Building Team coordination:

For a team to work productively there must be good communication, positive engagement, and a universal sense of trust and respect between all members. Achieving and maintaining an encouraging community normally requires team building. There are given below few steps to improve the team building coordinations.

i. Roadmap Of The Team's Goals:

Teams often underperform due to lack of coordination. If team goals are not well defined or communicated clearly, it becomes difficult for the team to work as a unit. Thus, for a manager or a team leader handling an overseas team, it is essential to establish a concrete roadmap. Having a roadmap not only helps enhance productivity, but also ensures completion of targets within the stipulated timeline.

ii. Define Individual Roles Within The Team:

For managers of geographically dispersed teams, it is a must to spell out individual roles within the team. Clearly defining individual roles as per proficiency and aptitude helps a team to perform better. Defining the responsibilities according to one's skill sets also ensures that the task completed will be thorough and error free.

iii. Planning & Communication:

Behind every successful project lies great communication. However, this doesn't mean having too many calls or Skype chats on a daily basis. Instead, it is important to communicate with the right teams at the right time. Sharing notes and regular feedback is a great way to enhance a team's productivity.

A good manager communicates clearly about the targets or objectives in a transparent, clear and empathetic manner. The team leader must also have great communication skills to keep the team motivated and coordinated.

iv. Make Work More Fun:

Team happiness not only spurs productivity, but it also makes the work environment a happy place. For managers, who are handling overseas teams, it is important to make work more fun. It has been observed that workplace happiness impacts productivity the most.

Depending on the budget, you may want to get your team together once a year or more for dinners and team-building activities. If budgets are tight, you could set up an intranet team page with photographs of team members.

v. Give Feedback & Rewards:

For the manager of a geographically dispersed team, it's important to maintain the team's morale, and feedback and rewards go a long way in achieving that. Schedule regular telephonic calls, or video calls to share feedback with your team. Make sure you are fair and consistent while providing feedback to overseas teams. Also, ensure that your team is equally rewarded so that they do not feel demotivated or isolated

CHAPTER 4

SAFETY AT WORKPLACE

4.1 Maintaining the work area safe and secure:

It is important to ensure that work happens safely and effectively to prolong the life of the system and ensure the well-being of the workers operating the system.

1. Safety begins with personnel:

During any solar power installation, the first step is to ensure the personnel are properly trained. It is not enough for staff to know how to carry out their operations safely, they must also be trained to handle emergency situations in a timely and effective manner.

Other personnel considerations:

- ✓ Regular monitoring of the physical fitness of the staff for the strenuous tasks they are expected to perform.
- ✓ Ensure they have valid medical certification suitable for the job on hand.
- ✓ A stern policy on the use of inebriants on the job.
- ✓ Personal Protective Equipment (PPE) such as safety shoes, safety helmets, reflecting jackets, gloves and safety belt, full body harnesses with permanent lifelines should be strictly mandatory for all workers and all jobs

2. Solar installation checklist

i. Surveying rooftop for plot points

- ✓ High quality and well maintained Personal Protective Equipment (PPE) to be used during the solar power installation.
- ✓ While the installation is in progress, use of mobiles and other electrical devices is prohibited to avoid all distractions

ii. **Unloading of modules, clamps, electrical panels and cables**

- ✓ The attachment of modules to the crane or forklift has to be secured by a qualified person.
- ✓ While unloading the modules, crane speed should be maintained below 10 km per hour.

iii. **Lifting of modules by lifting operators**

- ✓ To avoid accidents, lifting equipment is maintained at a safe pace from installation personnel.
- ✓ The jack or boom of the lifting equipment should be oiled and serviced regularly to ensure smooth operations.

iv. **Lifting modules manually by stairs**

- ✓ If the modules are lifted manually onto the rooftop, the path is sanitised and cleared of any physical obstacles.
- ✓ Adequately sized project teams are formed for easy handling of modules.

v. **Module installation**

- ✓ During the solar power plant installation, instructions are laid out and to be followed diligently by one and all.
- ✓ The entire installation staff is regularly trained to avoid any damage to the modules.

vi. **Routing of cable**

- ✓ During the routing of the cable, a thorough check is done to ensure the cable is not damaged.
- ✓ The entire process should be carried out under stringent supervision of qualified engineers.

vii. **Electrical solar panel installation**

- ✓ Cut resistant quality hand gloves are used as and when modules are physically installed.
- ✓ Utmost care is taken to not overload the panels

viii. Routing the AC cable

- ✓ When the AC cable is routed, the tray is secured for any wear and tear.
- ✓ Once the tray is clear of any damage, it is carefully positioned to keep it moisture free.

ix. **Clamp fixing**

- ✓ The monkey ladder, which is used for installation, comes with a provision for attachment of safety lanyard.
- ✓ The ropes are also customised to suit individual projects

x. **Earthing**

- ✓ During the process, the speed of the boring machine is always maintained below 10 km per hour.
- ✓ The team strictly adheres to the use of cotton, PVC, and leather gloves while fixing electrodes, handling backfilling compound and connecting the electrical panel.
- ✓ Welding goggles, face shields, and aprons are also used during the welding of the system

4.2 Handling hazardous material:

The impact and handling of hazardous materials are summarized on the basis of manufacturing of solar panel and their installation process.

1. HAZARDS IN PV MANUFACTURE:

During the manufacturing process with solar panels may be exposed to many chemicals such as telluride, cadmium telluride, gallium and germanium. Hydrofluoric acid as well as other acids and alkails that are used in the cleaning process, each presents its individual hazard. Solar panels also pose carcinogenic risks, so it is vital to protect workers from exposure to these dangers. Care during handling of the hazards materials during manufacturing are:-

- ✓ Employees who work in an environment where toxic materials is present during making PV cell should shower daily and wash their hands and faces prior to eating, smoking and drinking.
- ✓ employees should use personal protective equipment to avoid all potential skin contact, including where appropriate, gloves and a laboratory coat.
- ✓ Maintenance workers tasked with the routine clean-up of reactors and clean-up of accidental spills may be at special risk.After clean-up operations have been completed, these workers should be required to shower and change their clothing.

2. HAZARDS IN PV INSTALLATION :

During system installation process does not require toxic chemicals . The site is mechanically cleared of large vegetation, fences are constructed, and the land is surveyed to layout exact installation locations. Trenches for underground wiring are dug and support posts are driven into the ground. The solar panels are bolted to steel and aluminum support structures and wired together. Inverter pads are installed, and an inverter and transformer are installed on each pad. Once everything is connected, the system is tested, and only then turned on.

Care during handling of the hazards materials during installation are

- ✓ Solar panels easily injure the worker .Solar panels can get hot quickly in the sun, and their sharp edges and heavy clunky nature can lead to injuries that include cuts, bruises, scrapes, pulled muscles, burns, strains, sprains and broken bones.

- ✓ Solar panels begin to heat up as soon as they are uncovered, and then they bake in the sun all day long.That means that they are often very hot during the installation process and maintenance tasks. Installers should look at safety gear to protect against burns .

4.3 Operating hazardous tools and equipment :-

1. Personal Protective Equipment (PPE):

Safety must be the foremost issue and hence the tools for personnel safety are of prime importance. The tools for personnel safety are helmet, safety belt or rope, hand gloves, boots, safety glasses, ladder etc. Each installer must have these tools, also called Personal Protective Equipment (PPE), and should be familiar with their use.

Fig4.1: Personal Protective Equipment (PPE)

i. Safety for Head:-

Wearing a **helmet** offers protection and can prevent head injuries. Select a sturdy helmet that is adapted to the working conditions. These days you can find many elegant designs and you can choose extra options such as an adjustable interior harness and comfortable sweatbands.

Fig4.2: Helmet

ii. Safety for Eyes and face:-

The eyes are the most complex and fragile parts of our body. Each day, more than 600 people worldwide sustain eye injuries during their work. Eye and face protection is done by following equipment:-

- Safety glasses()required for most PV installation tasks)
- Goggles
- Face shield

(a)

(b)

(c)

Fig 4.3 (a) Safety Glasses (b) Goggles © Face shield

iii Safety for Hearing:

An **earplug** is a device that is inserted in the ear canal to protect the user's ears from loud noises, intrusion of water, foreign bodies, dust or excessive wind. Since they reduce the sound volume, earplugs are often used to help prevent hearing loss and tinnitus (ringing of the ears).

Fig4.4: Different types of earplug

iv. Safety for respiration:

Respirators serve to protect the user from breathing in contaminants in the air, thus preserving the health of their respiratory tract. Dust masks offer protection against fine dust and other dangerous particles. If the materials are truly toxic, use a full-face mask . This adheres tightly to the face, to protect the nose and mouth against harmful pollution.

Fig4.5: Mask and respirator

v. Safety for Hand:

Hands and fingers are often injured, so it is vital to protect them properly. Depending on the sector you work in, you can choose from gloves for **different applications**:

- ✓ protection against vibrations
- ✓ protection against cuts by sharp materials
- ✓ protection against cold or heat
- ✓ protection against bacteriological risks
- ✓ protection against splashes from diluted chemicals.

vi. Safety for Feet:

Even your feet need solid protection. **Safety shoes** a**nd boots** are the ideal solution to protect the feet against heavy weights. An **anti-skid sole** is useful when working in a damp environment, definitely if you know that 16,2% of all industrial accidents are caused by tripping or sliding. On slippery surfaces, such as snow and ice, **shoe claws** are recommended. Special socks can provide extra comfort.

Fig4.6: Protective Footwear

Each employee uses protective footwear when working in areas when there is a danger of foot injuries due to falling or rolling objects, and where such employee's feet are exposed to electrical hazards.

vii. Safety for Body:

Preventing accidents is crucial in a crowded workshop. That is why a good visibility at work is a must: a **high-visibility jacket and pants made of a strong fabric** can help prevent accidents.

Fig 4.7 Clothes for body safety

viii. PPE for Arc Flash

When a risk of arc flash exists, the selection of PPE and its characteristics can be done as a consequence of the calculation of the incident arc energy or consulting a hazard category. Protective equipment for arc flash, as shown in Figure

Fig4.9: PPE for arc flash

2. Fall protection tools:

Many PV arrays are installed on rooftops or elevated structure , so each employee on a walking/working surfaces with an unprotected side or edge 6 feet or more above or a lower level shall be protected from the falling by use of guardrail system, safety net system or personal fall arrest system(includes anchorage,lifeline and body harness).

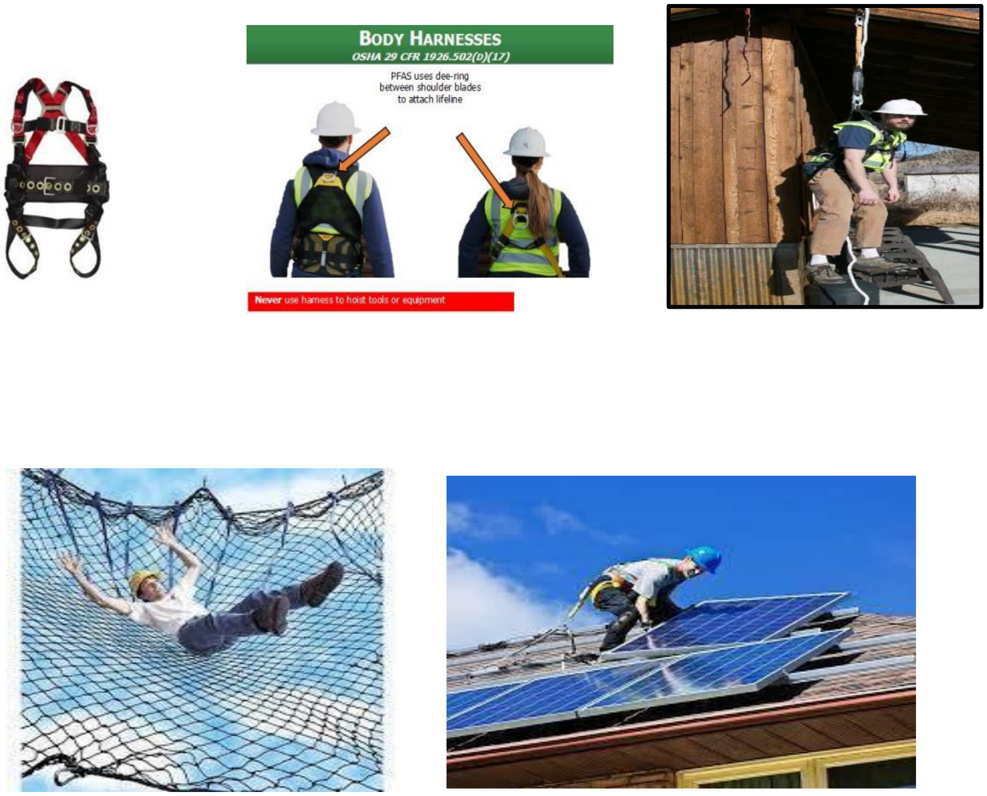


Fig 4.10: Fall protection tools

3. Fire protection equipment:

Firefighting equipment shall be conspicuously located and access all the times without any delay. Firefighting equipment periodically inspect ted and maintain .Defective equipment shall be replaced immediately.

4.4 Emergency procedures to be followed such as fire accidents, etc:

All electrical installations, by their nature, will carry some degree of fire risk. Although fires caused by PV panels are rare, any fire involving a building with a PV array can present an increased risk to occupants and fire-fighters. If a fire damages the DC cables from the PV array, for example by burning off insulation, then there will be risk of electric shock from the exposed DC conductors, in particular to fire-fighters. In the PV systems the fire may be caused due to:-

- ✓ **Installation mistake**: poor installation or the use of wrongly specified, incorrect or faulty equipment. Some time seen that AC isolator switches being used mistakenly in DC circuits resulting in a build-up of heat within the switch enclosure and leading to a fire.

- ✓ **Product failures**: use of faulty inverters or faulty DC switches or the absence of isolator switches.

- ✓ **External influence**: animals, lightning etc.
- ✓ **Planning failure**: poor mechanical and electrical design (e.g. incorrect selection of DC isolators, cabling). Any switching or connection faults on the DC side of a system can result in the generation of a high temperature arc or high resistance fault which could start a fire. DC arcs can be difficult to extinguish and pose a risk to fire-fighters attempting to suppress the fire.
- ✓ Many PV systems feed energy into the electricity grid at times when it is not required by the building. When such feed in is occurring from a number of distributed sources, this can cause voltage fluctuations in the grid. Fluctuations are known to have the potential to cause fires in sensitive equipment, such as television sets

Thus fire and/or electric shock risks, although these can be minimised by good system design, product selection and installation practices.

4.4.1 Emergency Procedure during fire:

Following safety rules should be adopted during fire by firefighter:-

a) **Complete a 360 to locate ESS:**

The-first arriving member should complete a 360 walk around of the building, if possible, to locate any solar panels and or energy storage systems (ESS) present.

b) **Turn off all systems:**

As a general safety rule for securing PV systems at an emergency or fire scene, Firefighters should shutoff and secure all switches/disconnects that are visible and accessible and all circuit breakers at the Main Electrical Service Panel.

c) **Commence the fire attack- from distance:**

If the solar panels on the roof of a residential structure are burning, firefighters need to understand that PV modules or components, or the adjacent areas around the modules or components, the aluminum frame can become deformed or melt, exposing the hazardous chemicals to direct flame and/or significant heat.

Firefighters can safely extinguish the fire by applying a straight stream from a minimum of 20 feet away or use a fog pattern from 5 feet away.Grid utility electricity coming from the local power company to the house has not changed and the firefighters need to recognize this and follow their standard operating procedures for working with existing residential utility electrical services.Foam is not needed to extinguish a solar panel or battery fire.In fact, testing has shown that plain water is most effective tool.

The exposure to flame and heat will cause the materials to dissipate in the smoke plume, constituting an inhalation hazard to Firefighters without breathing apparatus, as well as people standing near the fire building and in the path of the plume. The inhalation hazard from these chemicals can be mitigated for Firefighters by ensuring the constant use of breathing apparatus and all PPE during fire attack and overhaul operations.

d) **Strategies for Battery fire :**

Firefighters should be familiar with how to isolate the bank of batteries from the PV system, if needed. If the PV system is disconnected from the batteries, the bank of batteries themselves still has potential for electrical shock. Firefighter should never attempt to cut into or attempt to damage the batteries under any circumstance. If the batteries are punctured by a conductive object, such as halligan tool, the object may become energized. Firefighters working around or adjacent to the battery storage areas should only use flashlights and must utilize proper PPE, including breathing apparatus, during fire attack and overhaul operations.

CHAPTER-5

SOLAR TRACKING SYSTEM

5.1 Solar Tracker:

It is a device that solar panels can move easily from one side to another side with moving sun.

The most-common applications for solar trackers are positioning photovoltaic (PV) panels (solar panels) so that they remain perpendicular to the Sun's rays and positioning space telescopes so that they can determine the Sun's direction. By keeping the panel perpendicular to the Sun, more sunlight strikes the solar panel, less light is reflected, and more energy is absorbed.

It is kept in mind that the Sun angle changes north to south seasonally and east to west daily. As a result, although tracking east to west is important, north to south tracking has a less-significant impact.

5.1 Types of Solar Tracking Systems

1. Based on the Rotation:

There are two types of solar tracking systems on the basis of rotation:-

a) Single-axis solar tracker
b) Dual-axis.Solar tracker

These are discussed one by one

a) Single-axis solar tracker :

It moves your panels on one axis of movement, usually aligned with north and south. These setups allow your panels to arc from east to west and track the sun as it rises and sets. Single-axis photovoltaic tracking systems are divided into three different types. These include

i. horizontal single-axis tracking system, (HSAT)
ii. vertical single-axis tracking system, and
iii. tilted single-axis tracking system

i. horizontal single-axis tracking system, (HSAT):

The rotating axis of the HSAT is horizontal with the ground as shown in Fig 5.1(a) .

ii. Vertical single-axis tracking system (VSAT):

The rotating axis of the VSAT is vertical with the ground as shown in fig 5.1(b). These tracking systems rotate from east to west during the day.

iii. Tilted single-axis tracking system (TSAT):

All tracking systems with a horizontal and vertically rotating axis are considered to be tilted single-axis tracking systems as shown in fig 5.1(c). The tilt angles of tracking systems are often limited to decrease the elevated end's height off the ground and reduce the wind profile.

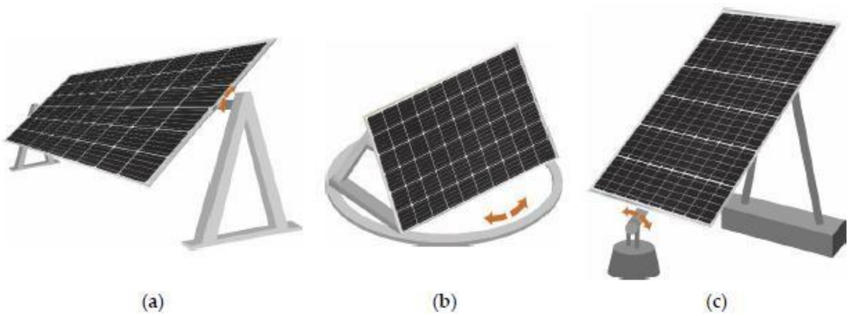
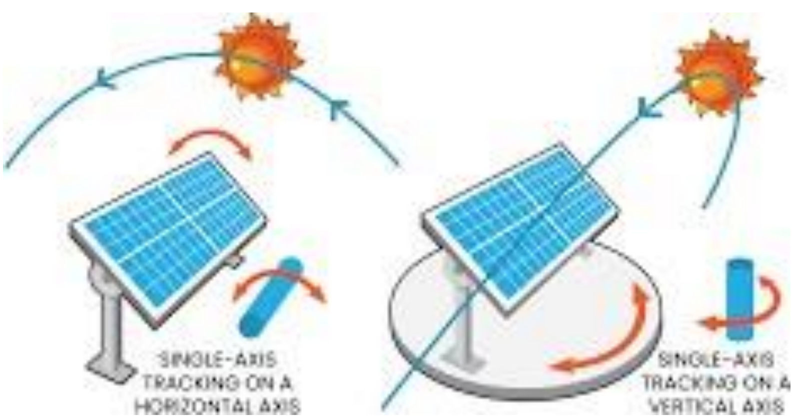


Figure 5.1: Single axis solar tracking system: (a) HSAT (b) VSAT (c) TSAT



b) Dual-axis solar tracker :

It allows your panels to move on two axes, aligned both north-south and an east-west. This type of system is designed to maximize your solar energy collection throughout the year. It can track seasonal variations in the height of the sun in addition to normal daily motion.

Dual-axis photovoltaic tracking systems are divided into two different types, which are classified by the azimuth of their primary axes with respect to the ground. Two common types are azimuth-altitude tracking system and tip-tilt tracking system.

i. Tip-tilt dual-axis tracking system (TTDAT) :

A tip-tilt dual-axis tracking system (TTDAT) has its primary axis horizontal to the ground, while the secondary axis is normal to the primary axis. It is shown in fig 5.2(a).

ii. Azimuth-altitude dual-axis tracking system :

An azimuth-altitude dual-axis tracking system (AADAT) has its primary axis vertical to the ground, while the secondary axis is normal to the primary axis.It is shown in fig 5.2(b).

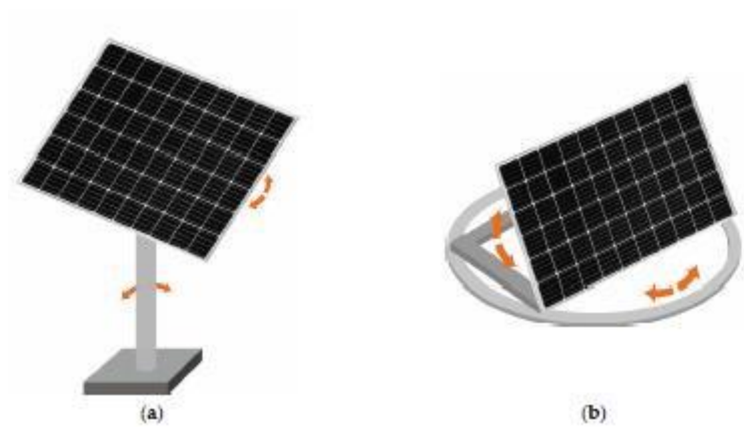


Figure 5.2. Dual-axis photovoltaic tracking systems: (a) TTDAT and (b) AADAT.

Disadvantage:

The annual power consumption of dual-axis solar tracker is 72% over single-axis solar tracker. The dual axis solar tracker is more complicated, costly, and requires high maintenance as compared with one axis solar tracker

2. Based on the Drive:

There are two main types of solar tracker exist active (electrical) and passive (mechanical).

a) Passive tracker:

The passive solar tracker is the system in which the solar panel is fixed with a face upwards to the sky. Passive tracking systems use the pressure difference of special liquids or gases with a low boiling point or springs from material with formed memory to move the axes of the tracking system. The pressure difference is created by the thermal differences of the shaded and illuminated sides of the tracking system. The tracking system moves until the pressure difference is in balance, which allows stretching and thus tracking in clear weather. Passive systems are used very rarely and do not need additional power supply to operate.

b) Active solar tracker :

Active systems are those that use electrical drives and mechanical assemblies to operate. The main components are a microprocessor, an electric motor, gearboxes, and sensors. Most of the active trackers use the sensor for moving the panel with sunlight

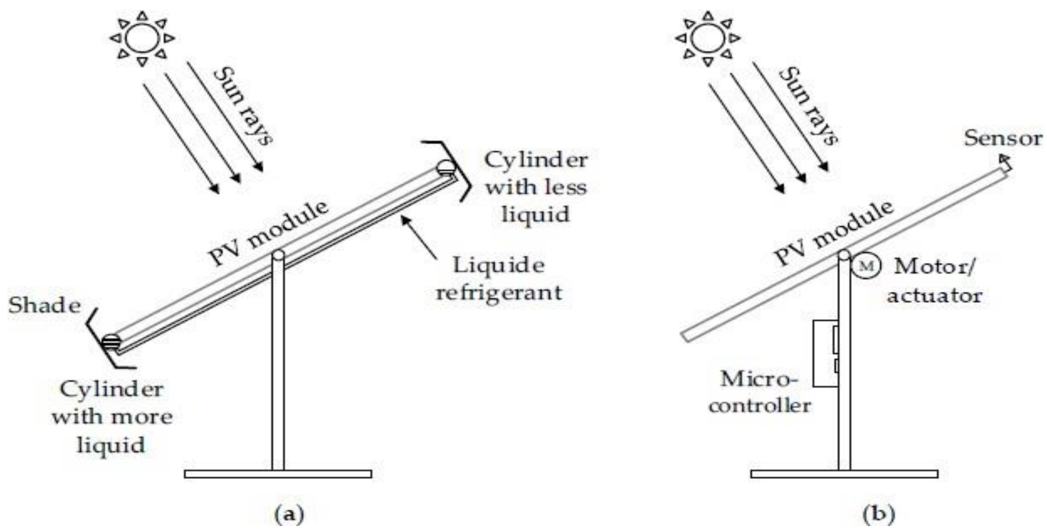


Figure 5.3. Driving system: (a) passive tracking system (b) Active tracking system

5.2 Advantages and disadvantages of solar tracking system:

➢ Advantages of solar tracking system:

With solar tracking, power output can be increased by about 30 to 40 percent.

➢ Disadvantages of solar tracking system:

A static solar panel may have a warranty that spans decades and may require little to no maintenance. Solar trackers, on the other hand, have much shorter warranties and require one or more actuators to move the panel. These moving parts increase installation costs and reduce reliability; active tracking systems may also use a small amount of energy (passive systems do not require additional energy).

Computer-based algorithm solar trackers are more expensive, require additional maintenance, and become obsolete much faster than static solar panels, since they use fast-evolving electronic components with parts that may be difficult to replace in relatively short periods of time.

PRINCIPLES OF ELECTRICAL ENGG.

Electrical Engg. Department.
1^{st} Sem/1^{st} Year

Electrical Fundamentals

DIFFERENT FORMS OF ENERGY

- Energy exists in many forms.
- Energy can be moved from one object to another.
- Energy can be changed from one form to another.
- Energy cannot be created or destroyed.

Potential Energy : The energy in matter due to its position or the arrangement of its parts. Energy that can be stored for a long period of time in its present form.

Kinetic Energy: Energy of a moving object. Energy in motion, energy doing work.

SIX FORMS OF ENERGY

- Mechanical Energy
- Electrical energy
- Heat Energy
- Nuclear Energy
- Solar Energy
- Wind Energy
- Chemical Energy

MECHANICAL ENERGY

- Energy that moves objects from place to place
- You use mechanical energy when you kick a ball or turn the pedals of a bicycle
- Other examples include water flowing in a stream, tires rolling down a road and sound waves from your iPod.

CHEMICAL ENERGY

- Energy released by a chemical reaction
- The food you eat contains chemical energy that is released when you digest your meal
- Wood, coal, gasoline, and natural gas are fuels that contain chemical energy

Examples of Chemical Energy

- **The chemical bonds in a matchstick store energy that is transformed into thermal energy when the match is**

ELECTRICAL ENERGY

- Energy that comes from the electrons within atoms
- It can be generated at a power plant or inside a battery and can power everything from remote-controlled cars to refrigerators
- Lightning and static electricity are also forms of electrical energy

HEAT (THERMAL) ENERGY

- Energy created by the motion of atoms and molecules that occurs within an object
- Thermal energy exists when you heat a pot of water on a stove

Nuclear Energy

- **Energy contained in the nucleus of an atom**
- **Nuclear energy is released when nuclei are split apart into several pieces, or when they are combined to form a single, larger nucleus.**

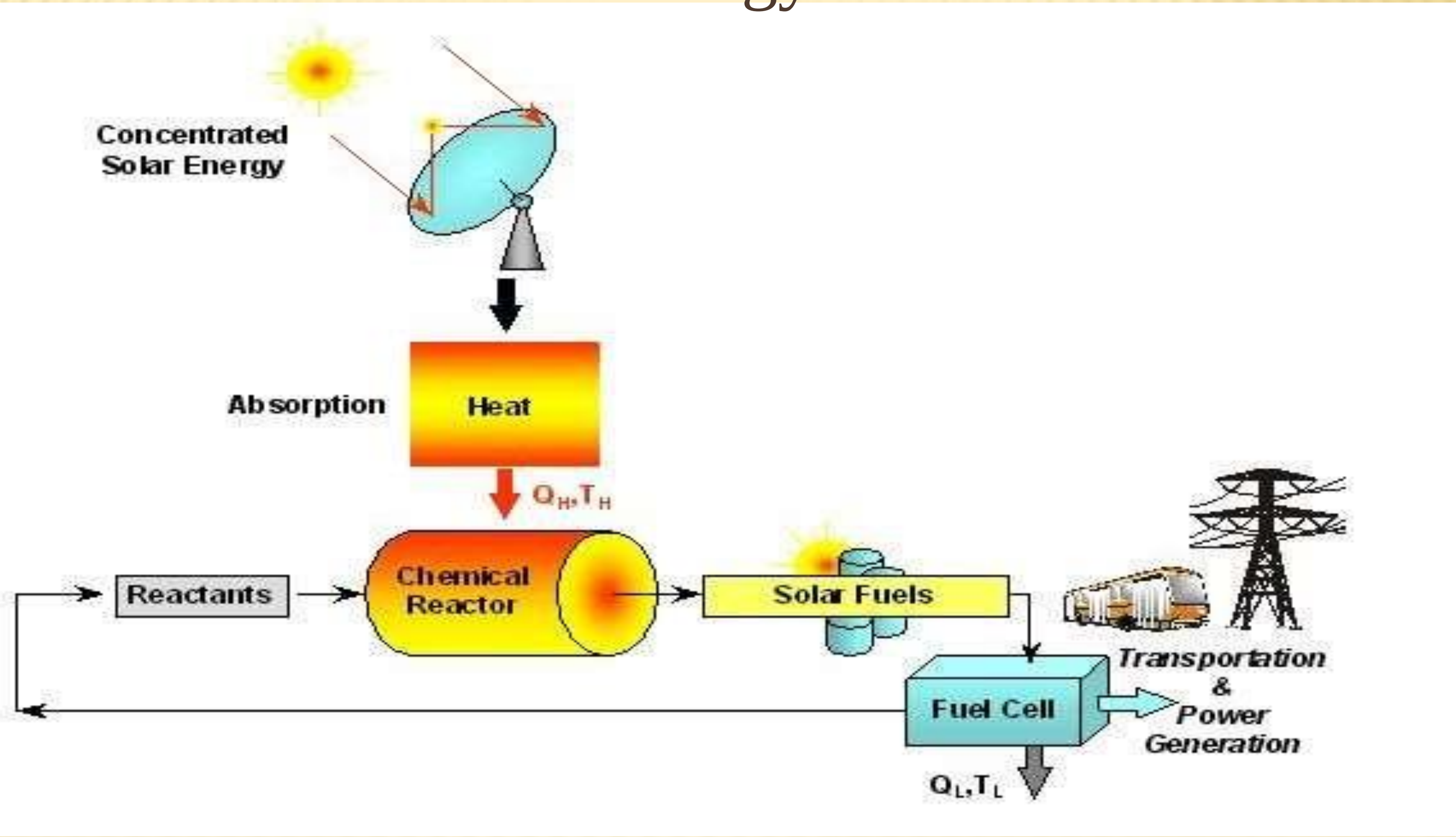
- ***Uranium is the example of nuclear energy.***

LIGHT (RADIANT) ENERGY

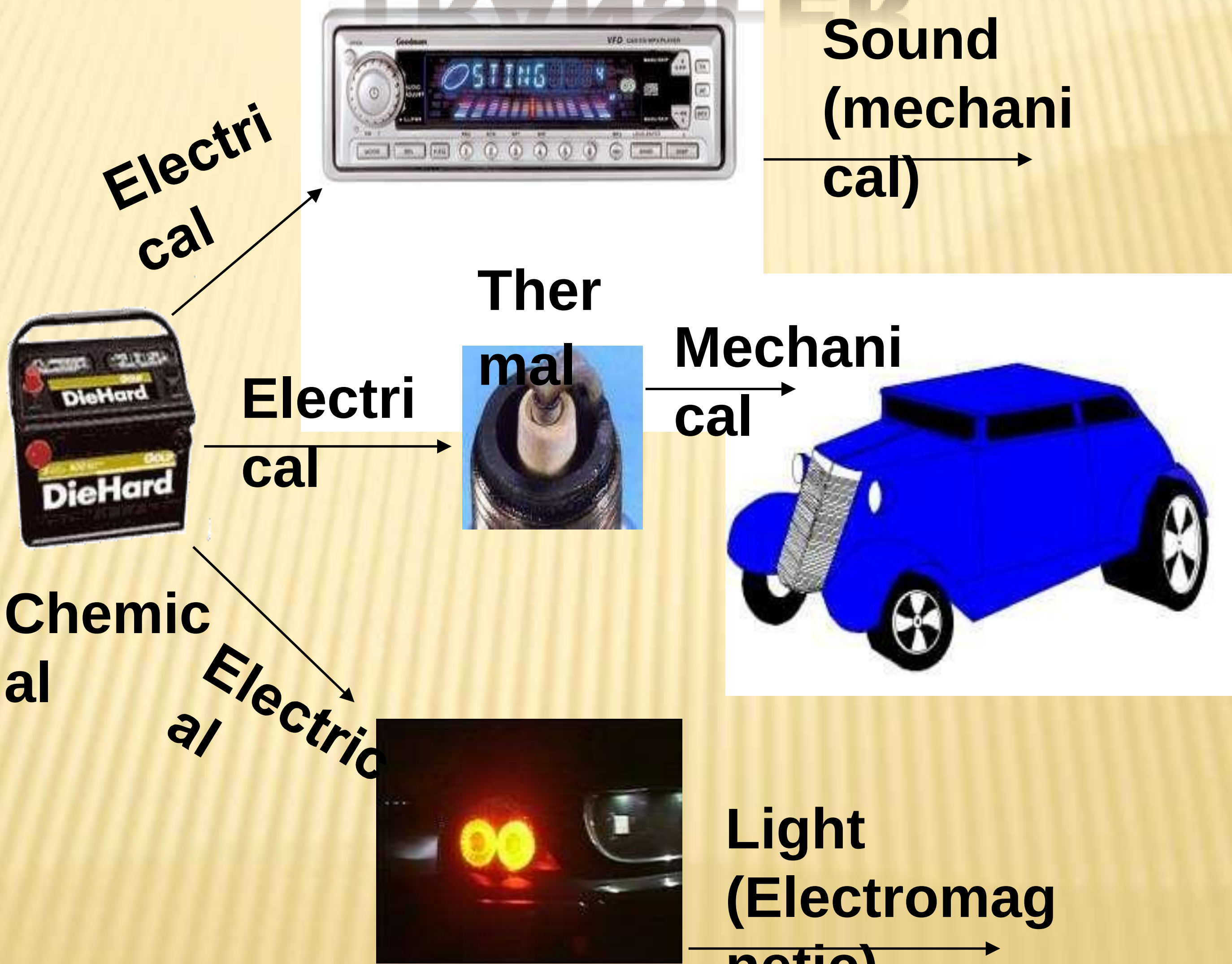
- Energy that can move through empty space
- The sun and stars are powerful sources of radiant energy
- The light given off by light bulbs and campfires are also forms of radiant energy

ENERGY CONVERSION ONE FORM TO ANOTHER FORM :

All forms of energy can be converted into other forms of energy.



ENERGY TRANSFER



Advantages of electrical energy over other type of energy :

1. Electric power is very easy to distribute and transport.

2.Its called "Clean and Green energy" . Clean because it doesn' have any byproducts and green because it doesn't cause an kind of pollution neither any of the resources of mothe earth are exhausted when we use this form of energy.

3. It can be easily converted to other form of energy.

4. It is much cheaper than other forms of energy.

5. It can be easily transmitted to various location ver

USE OF ELECTRICAL ENERGY

1. It is used for lighting purpose in home , industries and hospital etc.
2. it is used for heating domestic and industries.

    Domestic= Heaters ,electrical irons.

    Industries = Boiler , heating o- one.

3. It is used in welding . It is used for metal piece joining.
4. It is used in communication purpose with the help of T.v ,computer, telephone and radio etc.
5. In a car battery, the chemical reaction creates an electron which has the energy to move in an electric current. These moving charges provide electrical energy to the circuits in the car.
6. A stove plugged into a wall outlet takes the moving electric charges, electrical energy and changes them into thermal energy by causing the heating coils to get very hot for cooking

THE INTERNATIONAL SYSTEM OF UNITS (SI)

The SI units are based on seven *defined* quantities:

Quantity	Basic Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	degree kelvin	K
Amount of substance	mole	mol
Luminous	candela	cd

Defined quantities are combines to form **derived units.**

Quantity	Unit Name (Symbol)	Formula
Frequency	hertz (Hz)	s^{-1}
Force	newton (N)	$kg.m/\ s^2$
Energy of work	joule (J)	n.m
Power	watt (W)	J/s
Electric charge	coulomb (C)	A.s
Electric potential	volt (V)	J/C
Electric resistance	ohm ( )	V/A
Electric conductance	siemen (S)	A/V
Electric	farad (F)	C/V

The International System of Units (SI)

Advantage: uses prefixed based on the power of 10:

Prefix	Symbol	Power
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	d	10^{-2}
deci	d	10^{-1}
deka	da	10
hecto	h	10^{2}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}

BASIC CONCEPT OF CHARGE:

- The basic quantity in an electric circuit is the

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

- The charge on an electron is *negative* and equal in magnitude

Note:

1. *The Coulomb is a large unit for charges. In 1 C of charge, there are $1/(1.602 \times 10^{-19}) = 6.24 \times 10^{18}$ electrons.*
2. *The law of conservation charge states that charge can be neither be creat•ed nor destroyed, only transferred.*

Base unit = coulomb

Symbol = Q

Abbreviation = C

BASIC CONCEPT OF ELECTRICAL CURRENT:

- ***Flow of charge in a electric circuit is known as electric current . It unites is ampere. It is mea*** 1 ampere= 1 coulomb/ second **.**

$$I = \frac{\text{charge}}{\text{time}} = \frac{\text{coulombs}}{\text{seconds}}$$

$$I = \frac{Q}{t} \text{ amperes}$$

- Two types of current:

1. *An alternating current (ac) is a current that varies sinusoidally with time (i).*
2. *A direct current (dc) is a current that remains constant with time (I)*

BASIC CONCEPT OF *ELECTRICAL POTENTIAL (VOLTAGE)* :

- Electric pressure that causes current flow

- To move the electron in a conductor in a particular direction requires some work or energy transfer.. It is performed by an *external electromotive force (emf).*

- It is also known as *voltage* or *potential difference*.

Electrical potential = work done \ charge
units = J / C = volt
It is measured by voltmeter

Potential difference : **Difference between two bodies have different electrical potential than a potential difference will be exist between them.**

POWER:

The rate at which work is done is an electric current is called electric power. It is measured in watt

$$P = \frac{W}{t} = \frac{\text{joules}}{\text{second}} = \text{watt}$$

$$P = IV$$

A **watt** results when **1 joule of energy** is converted or used in **1 second**

power is the product of voltage and current

- + sign power →power is being delivered to/ absorbed by the element
- - sign power →power is being supplied by the element.
- To determine polarity, use passive sign convention.

ENERGY:

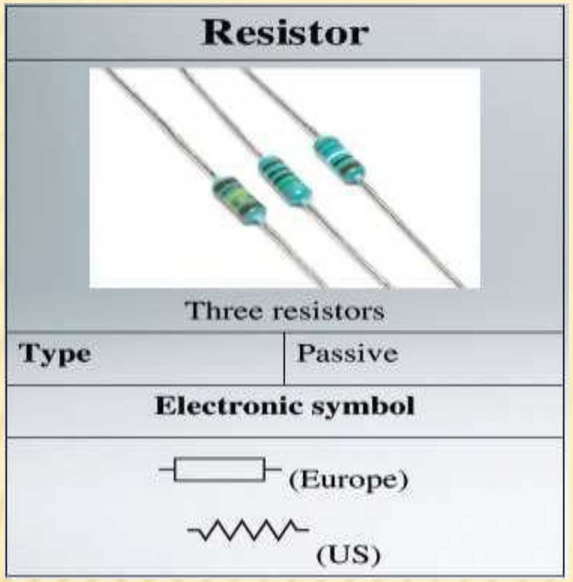
Total amount of work done is an electrical circuit is known as electrical energy.

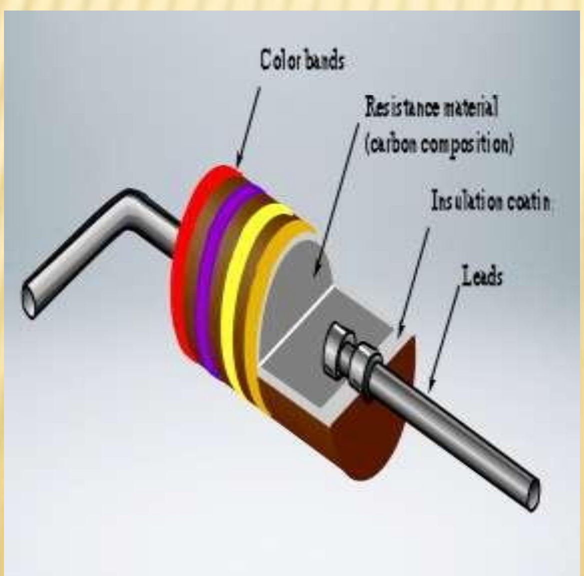
E = electrical power * time

units of electrical energy = joule and Kwh.

It is measured by kwh meter or energy meter.

Resistance:





Resistance (R) is the physical property of an element that impedes the flow of current . The units of resistance are **Ohms (Ω)**

Resistivity (ρ) is the ability of a material to resist current flow. The units of resistivity are **Ohm-meters (Ω-m)**

Example:

Resistivity of copper 1.68×10^{-8} Ω·m

Resistivity of glass 10^{10} to 10^{14} Ω·m

Factors upon which Resistance of a cunductor depends :

1. Resistance of conductor is directly proportional to length of the conductor. Greater the length , greater the resistance .

   i.e R a l

2. Area of cross section of the cunductor is inversly proportional to the resistance of the cunductor.greater the area of cross section , lesser the resistance and vice-versa.

   i.e. R a l/a

3. Resistance offered by cunductors vary as per the nature of the material of cunductor vary.

4. Resistance of conductor increase with temperature and vice-versa.

   we can write:

   R a l/a

   $R=\rho L/a$

CONVERSION OF UNITS OF WORK, POWER & ENERGY

- 1 watt = 1 Joule/second
  = 1 N-m/s
  = 10^7 ergs/S
  = $\frac{1}{1.36}$ ft. Lbs/S
- 1 KW = 1000 watt
  = 1000 J/S
  = 1000 N-m/s
  = 10^{10} ergs/S
  = 735 ft. Lbs/ S
  = 1.34 h.p. (British)
  = 1.36 h.p. (Metric)
- 1 B.H.P = 746 watts
- 1 H.P. = 75 Kg-wt m/s = 75x9.81
  = 735.5 watts or joules or Nm/S

  or 1 H.P. = 735.5 kW
- 1 kWh = 1000 watt-hours
  = 3,600,000 watt-sec or joule
  = 36 x 10^{12} ergs = 2.654 x 10^6 ft-Lbs.
- 1 Calorie = 4.18 x 10^7 ergs.
  = 4.18 joule or watt-sec.
- 1 Kcal = 4.18 x 10^7 ergs.
  = 4200 J or watt-sec
  = 1.166 x 10^{-3} kWh
- 1 kWh = 3600000 watt-sec or joules
  = 860 K. cal

RELATION BETWEEN H.P AND TORQUE

If a rotor of radius r metre rotates at a speed of N r.p.m. The force acting on the rotor tangential to its radius is F newtons, then

Work done in one revolution = Force x distance covered

= F x 2πr = 2πT Nm or J

where T is the torque i.e. moment acting on the rotor.

Work done per minute = 2πNT (since revolution made per minute is N)

Work done/sec or power = 2πNT/60 J/sec or watts

DC CIRCUITS

Electrical circuit : The close path flows by the electric circuit is known as electrical circuit.

DC circuits : The close path which DC current is flow is known as DC circuits.

Ohm's law : The current flowing between the end of the conductor is directly proportional to the potential difference across the end of the conductor with the physical condition, temp. pressure etc. don't change.

Mathematically,

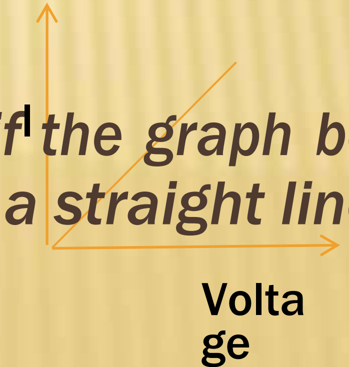
I a V

or V /I =constant

This constant is called the resistance of the conductor.

V / I = R

The ohm's law is verified , if the graph between V&I at different values is a straight line as shown in fig,.



- ***Limitations of Ohm's Law :***

I. It does not apply on the unilateral networks.
II. It does not apply on the non-linear networks , the parameter of the network is vary with the voltage and current. Their parameters like resistance, inductance, capacitance and frequency etc. do not remain constant with time. So, ohm's law is not applicable to the non-linear networks.

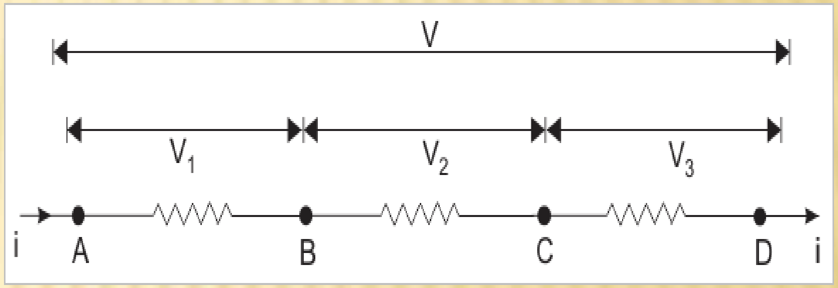
- ***Applications of Ohm' s Law:***

1. It can be applied to D.C as well as A. C circuit.
2. To find out the value resistance of the circuit and also for knowing the voltage and current of the circuit.

Resistance in series:

The circuit in which resistance are connected end to end so that they connected from one path for the flow of current than resistance are called connected in series and such circuit is called series circuit .

As shown in fig below resistance between point A and D is equal to the sum of three individual resistances. The current enters in to the point A of the combination, will also leave from point D as there is no other parallel path provided in the circuit. Now say this current is I. So this current I will pass through the resistance R_1, R_2 and R_3.



voltage drop across R1 , V1 = IR1

R2 , V2= IR2

R3 , V3= IR3

Since, sum of voltage drops across the individual resistance is nothing but the equal to applied voltage across the combination

Total voltage V = V1+V2+V3

V = IR1+IR2+IR3

V/ I = R1+R2+R3 then according to Ohm's law, V = IR

R = R1+R2+R3

So, the above proof shows that equivalent resistance of a combination of resistances in series is equal to the sum of individual resistance. If there were n number of resistances instead of three resistances, the equivalent resistan $R = R_1 + R_2 + R_3 + \ldots\ldots\ldots R_n$

Resistances in Parallel:

The circuit in which one end of each resistor is collected to common point and the other end of each resistor is connected to another common point so that they are many path for current flow then resistor are said to be connected in parallel and such circuit is called parallel circuit

As this current will get three parallel paths through these three electrical resistances, the current will be divided into three parts. Say currents I_1, I_1 and I_1 pass through resistor R_1, R_2 and R_3 respectively.

Acc to ohm's law

Current in resistance *R1 , I1 = V / R1*

R2 , I2 = V / R2

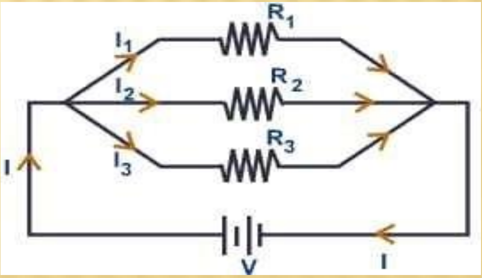
R3 , I3 = V / R3

Total current I = I1 + I2 + I3

I = V / R1 +V / R2 + V / R3

I = V[1 / R1 + 1 / R2 + 1 / R3

1 / R = 1 / R 1 + 1 / R2 + 1 / R3



The above expression represents equivalent resistance of resistor in parallel. If there were n number of resistances connected in parallel, instead of three resistances, the expression of equivalent resistance would be written as

$$\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\cdots\cdots+\frac{1}{R_n}\right)^{-1}$$

Hence, the number of resistor are connected in parallel reciprocal of total resistance is equal to the reciprocal sum of individual resistors.

i. *Voltage across each resistances of the parallel combinations is same.*
ii. *Current in each branch is given by the ohm law and total current is equal to the sum of branch current.*
iii. *Different resistance have individual current.*
iv. *Reciprocal of the total resistance is equal to the same of the reciprocal sum of the individual resistors.*

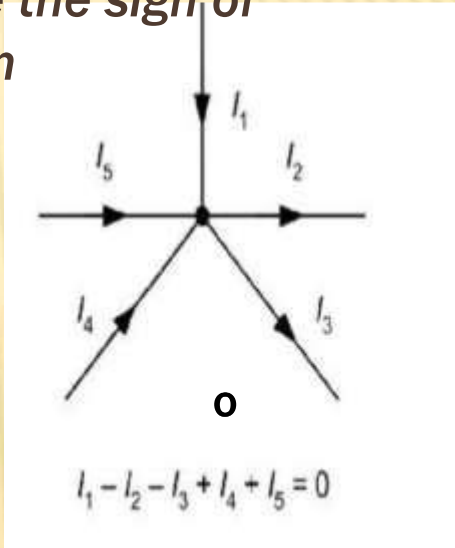
Application of parallel circuit : *In the domestic installation all the electrical appliances are connected in parallel across the supply so that voltage across each appliance is same . The reason for connecting the appliances in parallel are due to*

i. *Electrical appliances are rated for same voltage and operate efficiently when supplied with this rated voltage.*

ii. When appliances are connected in parallel each operate independently of

Kirchhoff's current law(KCL) : *The algebraic sum of all the current meeting at any junction in an electric circuit is zero. This is called the Kirchhoff's current law . If we take the sign of current following towards point O is taken as +ve an*

following away from the point O is taken as the –ve



+ I1 + I2 + (- I3) + I4 + (- I5) = 0

I1 + I2 + I4 = I3 + I5

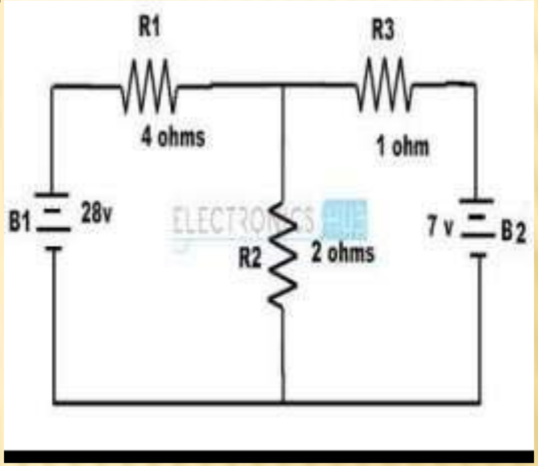
Incoming current = Outgoing current

$$\sum_{n=1}^{N} i_n = 0$$

Where N is the total number of branches

$$\sum_{\text{node}} i_{enter} = \sum_{\text{node}} i_{leave}$$ connected to a node.

Kirchhoff's voltage law (KVL) : *In any closed circuit the algebraic sum of the product of current and re plus the algebraic sum of all the e.m.f in that zero is called Kirchhoff's voltage law.*



i. ***Sign of e.m.f :*** *A rise in a potential is considered as +ve while fall in potential is considered as negative.*

ii. ***Sign of voltage drop*** *: There is voltage drop in resistance due to the flow of current through it . If we go with the current then voltage drop should be taken as –ve where as ,if we go against the current flow, then voltage drop should be taken as positive.*

Consider closed circuit ABCFA

Voltage drop in $R_1 = -(I_1+I_2)R_1$

By applying KVL to this loop

$$-(I_1+I_2)R_1+E_1=0$$

Or $E_1=(I_1+I_2)R_1$

Now consider loop CDEFC

Voltage drop in $R_2 = +I_2R_2$

By applying KVL to this loop

$$I_2R_2+(I_1+I_2)R_1-E_2=0$$

Or $E_2= I_2R_2+(I_1+I_2)R_1$

THEVENIN'S THEOREM:

- Thevenin's theorem simplifies the process of solving for the unknown values of voltage and current in a network by reducing the network to an equivalent series circuit connected to any pair of network terminals.
- Any network with two open terminals can be replaced by a **single voltage source** (V_{TH}) and a **series resistance** (R_{TH}) connected to the open terminals. A component can be removed to produce the open terminals.

Vth = open circuit voltage between two terminals (known's as the Thevenin's equivalent voltage source. This is obtained by removing load resistance (RL)and find out the potential difference across the open terminal of RL. V_{TH} is determined by calculating the voltage between open terminals A and B.

Rth =It is the Thevenin's equivalent resistance which can be obtained by shorting the voltage source and calculating the circuit's total resistance as seen from open terminals A and B

THEVENIN'S THEOREM:

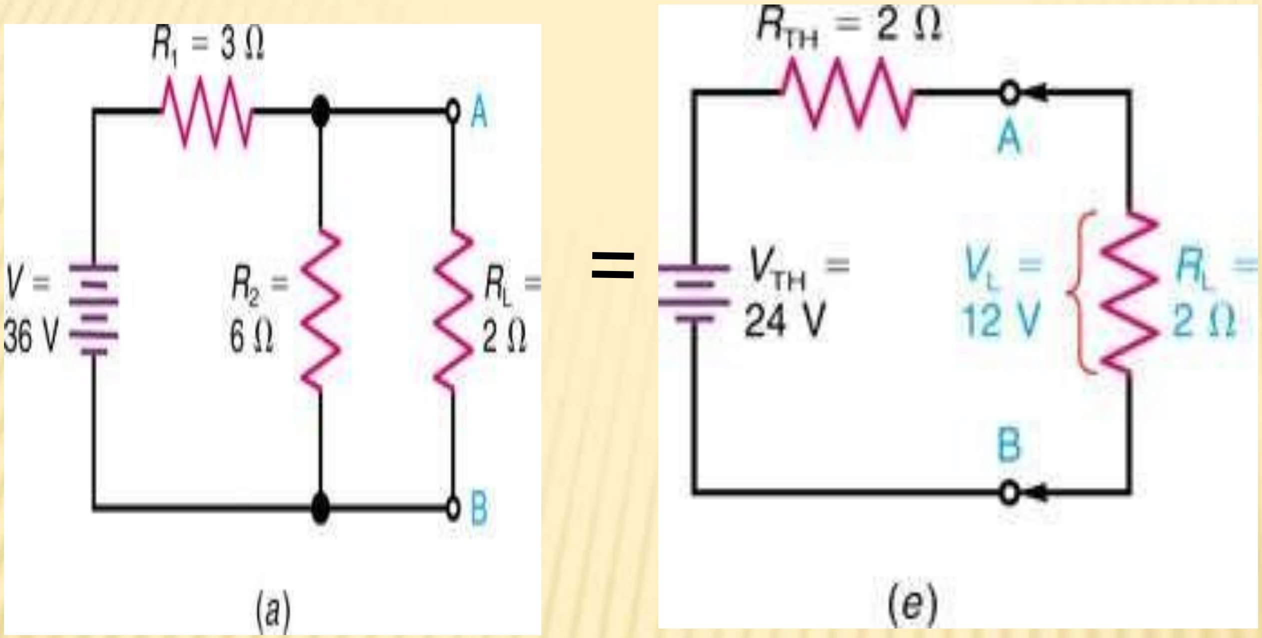
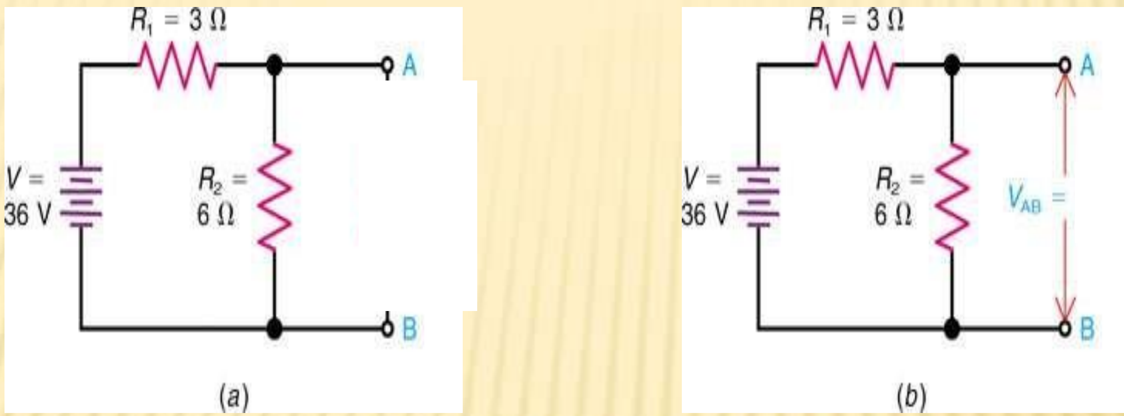


Fig. 1 Application of Thevenin's theorem. (*a*) Actual circuit with terminals A and B across R_L. (*b*) Disconnect R_L to find that V_{AB} is 24V. (*c*) Short-circuit V to find that R_{AB} is 2Ω.

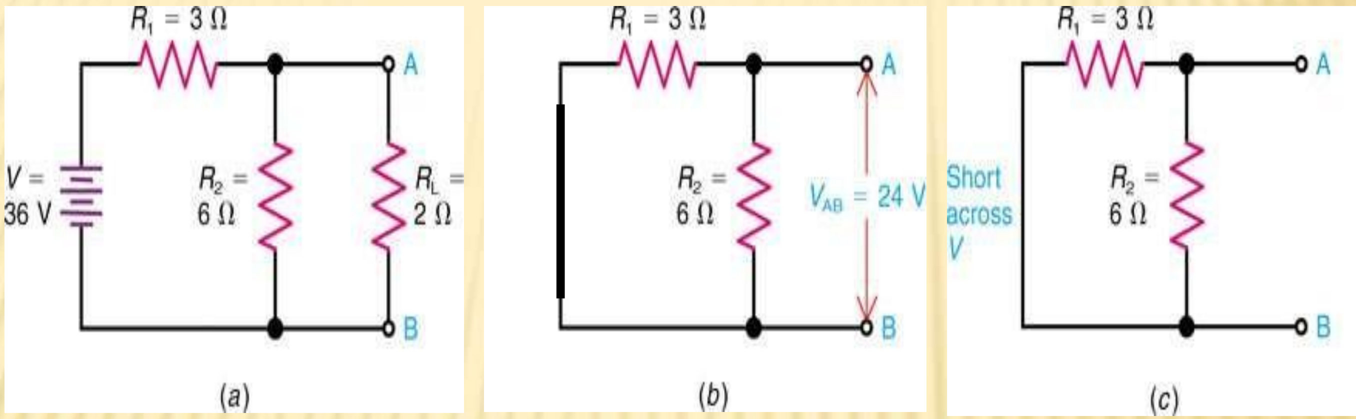
THEVENIN'S THEOREM



$$V_{R2} := 36V \cdot \frac{6\Omega}{3\Omega + 6\Omega} \qquad V_{R2} = 24\,V \qquad V_{AB} := V_{R2}$$

Fig. 2 Application of Thevenin's theorem. (*a*) Actual circuit with terminals A and B across R_L. (*b*) Disconnect R_L to find that V_{AB} is 24V. (*c*) Short-circuit *V* to find that R_{AB} is 2Ω.

THEVENIN'S THEOREM



$$R_{TH} := \frac{3\Omega \cdot 6\Omega}{3\Omega + 6\Omega} \qquad R_{TH} = 2\Omega$$

Fig. 3: Application of Thevenin's theorem. (*a*) Actual circuit with terminals A and B across R_L. (*b*) Disconnect R_L to find that V_{AB} is 24V. (*c*) Short-circuit V to find that R_{AB} is 2Ω.

THEVENIN'S THEOREM

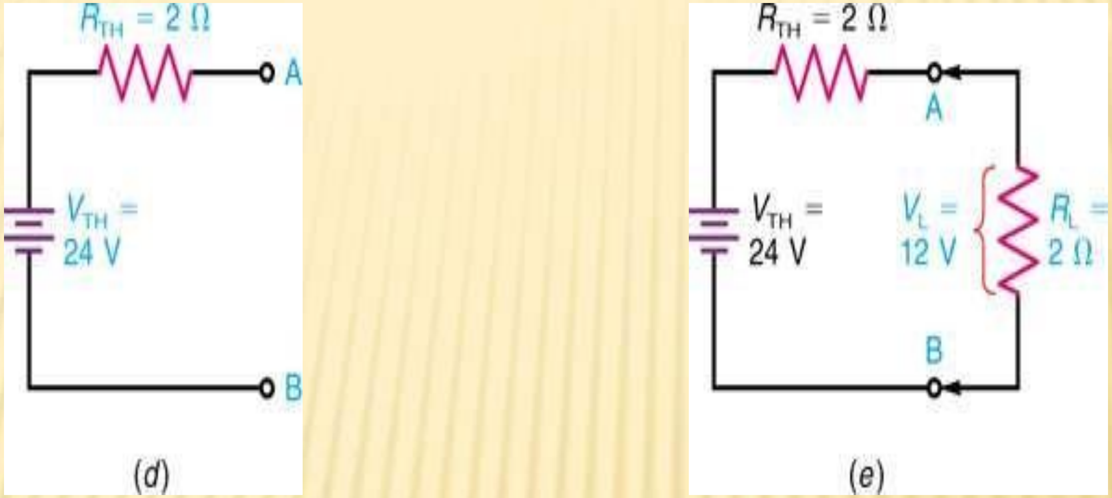
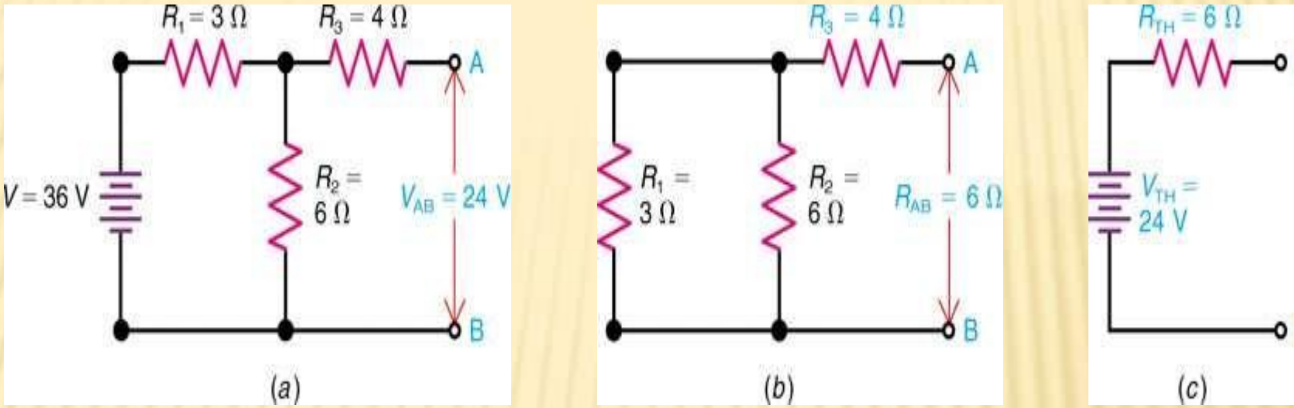


Fig.4 (*d*) Thevenin equivalent circuit. (*e*) Reconnect R_L at terminals A and B to find that V_L is 12V.

THEVENIN'S THEOREM



Note that **R_3** does not change the value of V_{AB} produced by the source V, but R_3 does increase the value of R_{TH}.

$$R_{TH} := \frac{3\Omega \cdot 6\Omega}{3\Omega + 6\Omega} + 4\Omega \qquad R_{TH} = 6\Omega$$

Fig. :5 Thevenizing the circuit of Fig. 3 but with a 4-Ω R_3 in series with the A terminal. (*a*) V_{AB} is still 24V. (*b*) Now the R_{AB} is 2 + 4 = 6 Ω. (*c*) Thevenin equivalent circuit.

NORTON'S THEOREM:

- Norton's theorem is used to simplify a network in terms of currents instead of voltages.
- It reduces a network to a simple parallel circuit with a current source (comparable to a voltage source).
- Norton's theorem states that any network with two terminals can be replaced by a single current source and parallel resistance connected across the terminals.

Thevenin-Norton Conversions:

•**Thevenin's theorem** says that any network can be represented by a voltage source and series resistance.

•**Norton's theorem** says that the same network can be represented by a current source and shunt resistance.

•Therefore, it is possible to convert directly from a Thevenin form to a a Norton form and vice versa.

•Thevenin-Norton conversions are often useful.

MAXIMUM POWER TRANSFER

- For any power source, the maximum power transferred from the power source to the load is when the resistance of the load R_L is equal to the equivalent or input resistance of the power source ($R_{in} = R_{Th}$ or R_N).
  - The process used to make $R_L = R_{in}$ is called impedance matching.

FIND THE VALUE OF R_{LOAD} THAT MAXIMIZES POWER

$$\frac{dp}{dR_L} = V_{Th}^2 \left(\frac{(R_{Th} + R_L)^2 - 2R_L(R_{Th} + R_L)}{(R_{Th} + R_L)^4} \right) = 0$$

$$(R_{Th} + R_L)^2 = 2R_{load}(R_{Th} + R_L)$$

$$R_L = R_{Th}$$

THE MAXIMUM POWER DELIVERED TO THE LOAD

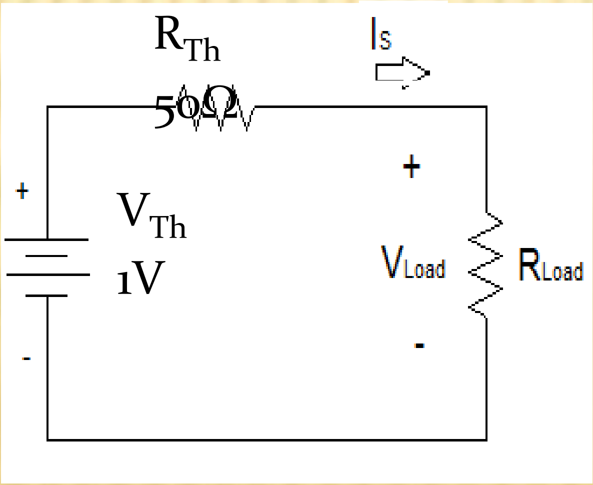
$$p_{max} = I^2 R_L = \frac{V_{Th}^2}{(2R_L)^2} R_L$$

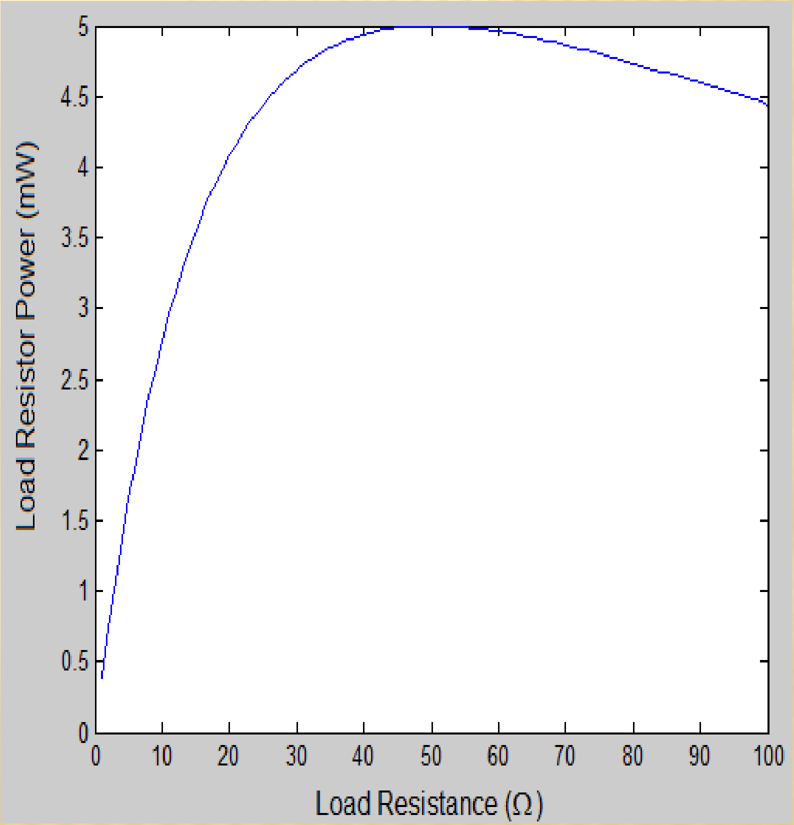
$$p_{max} = \frac{V_{Th}^2}{4R_L}$$

POWER TRANSFER CALCULATION

$$P_L = V_L^{\,2} / R_L$$

$$P_L = \frac{\left[\dfrac{R_L}{R_L + R_{Th}} V_{Th}\right]^2}{R_L}$$

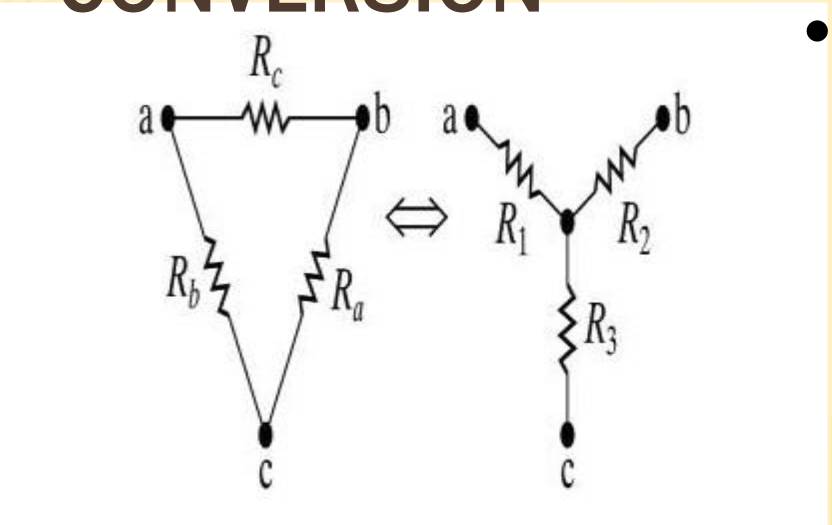




APPLICATION

- When developing new circuits for a known application, optimize the power transfer by designing the circuit to have an input resistance close to the load resistance.
- When selecting a source to power a circuit, one of the selection criteria is to match the input impedance to the load resistance.

Δ – Y CONVERSION



- The resistance between the terminal pairs must be the same for both circuits

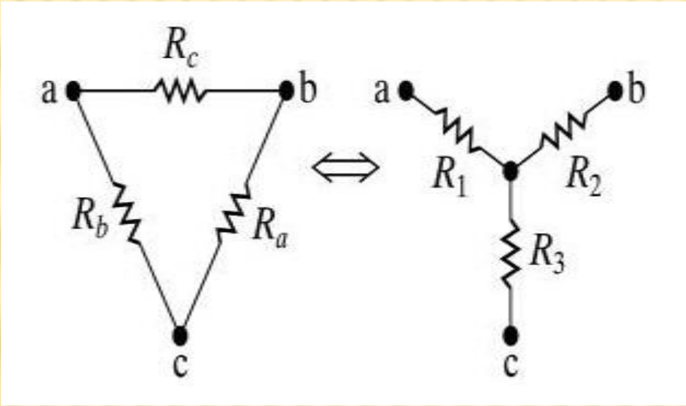
$$R_{ab} = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} = R_1 + R_2$$

$$R_{bc} = \frac{R_a(R_b + R_c)}{R_a + R_b + R_c} = R_2 + R_3$$

$$R_{ca} = \frac{R_b(R_c + R_a)}{R_a + R_b + R_c} = R_1 + R_3$$

Y – Δ CONVERSION

- After some algebraic manipulation



$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$

CELL AND BATTERIES

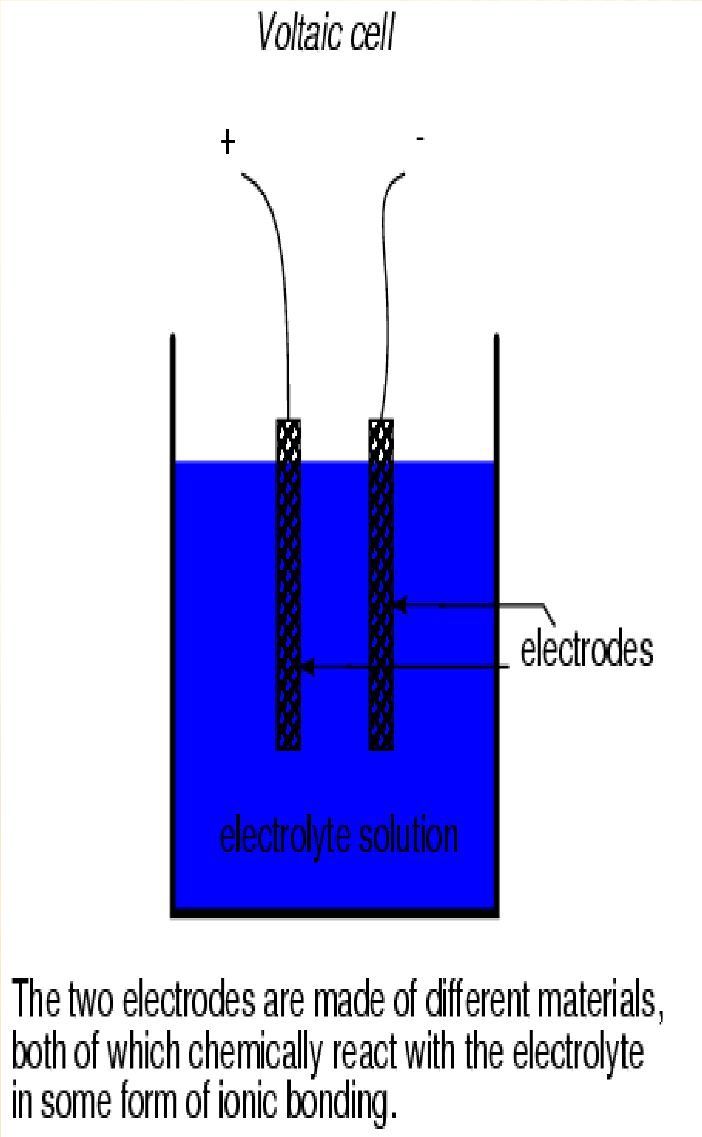
DefinitionofCell:

- A primary cell cannot be recharged because the internal chemical reaction cannot be restored. Example: **ZINC CARBON (1.5V),ALKALINE (1.5V)**

- A secondary cell, or storage cell, can be recharged because its chemical reacti sible. Example: LEAD **ACID (2.0 DMIUM (1.2V),NICKEL - METAL HYDRIDE – ION (3.3V)**

THE VOLTAIC CELL

- Motion of electrons in ionic bonding can be used to generate an electric current
- A device constructed to do just this is called a **voltaic cell**, or **cell** for short



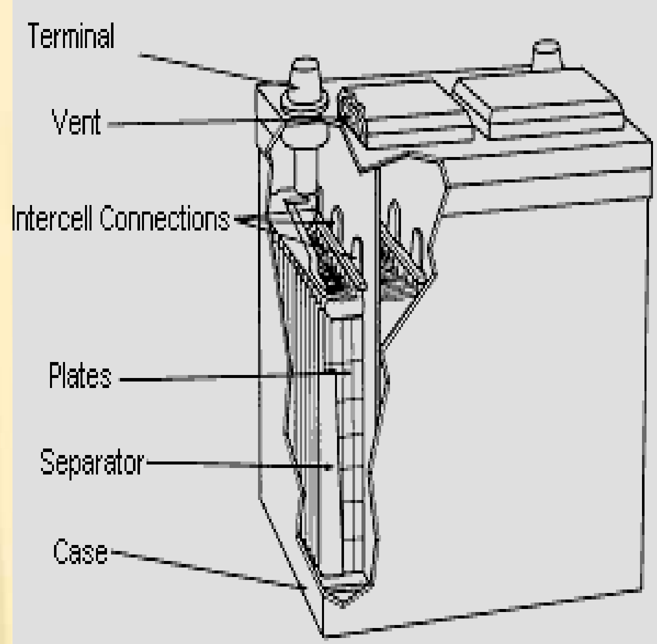
LEAD ACID BATTERY:

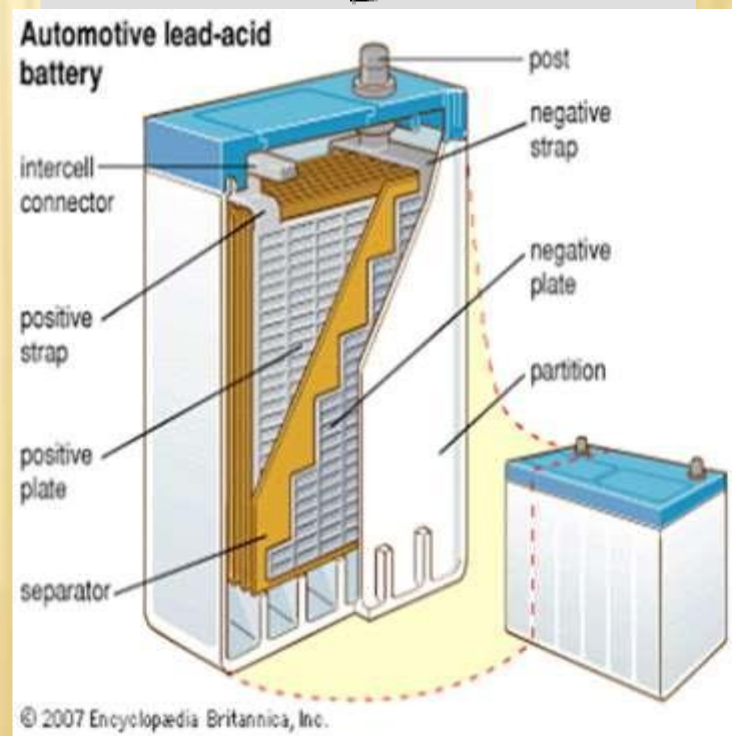
- Electrolyte for the most part distilled (pure) water, with some sulfuric acid mixed with the water.
- Electrodes must be of dissimilar metals.

Constructi on:

1.Separator: It is most important part of lead acid battery. Which separate the positive and negative plates from each other and prevents the short circuit? The separators must be porous so that the electrolyte may circulate between the plates . The separators must have higher insulating resistance and mechanical strength. The material used for separators are wood, rubber, glass wood mate, pvc.

2. Electrolyte:in lead acid battery dilute sulphuric acid (H_2SO_4)is used as an electrolyte. For this purpose one part concentrated sulphuric acid is mixed with three parts of distilled water.





3. Container: Container is a box of vulcanized rubber, molded rubber, molded plastic, glass or ceramic , on the base of this box there are supports block on which the positive and negative plates are established. Thus between this supports there are grooves which works like a mud box. The active material separated from the plates get collected in this mud box and it cannot make the contact with the plates thus the internal faults due to the mud are avoided.

4. Cover of cell: In lead acid battery it is also made of the same material which is used is used for making container. It is used to cover the complete cell after the installation of the

plates in it . it protects the cell from the dust as well as other external impurities.

5. **Vent plug**: The vent plug are provide in the cover plate of the cell which are used to fill up the electrolyte in the cell or the inspection of internal condition of the cell the vent plugs are aslo use for to exhaust the gases generated in the cell to the atmosphere.

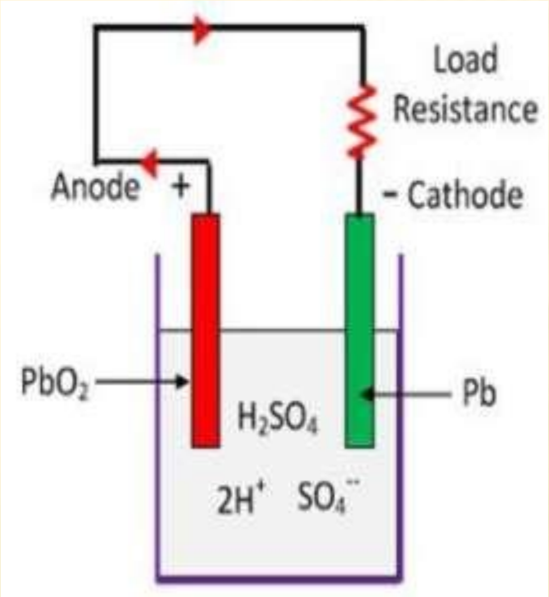
6. **Connecting bar:**It works like a link and used to connect the two cells in series. Terminal of one cell and negative terminal of another cell.

7 terminal posts: There are the terminals of the battery which are connected to charging circuit as well as the load. For identification the diameter of the positive terminal is design more as compared to the negative terminal.

working of lead acid battery:

•Dilute sulfuric acid used for lead acid battery has ration of acid: water = 1:3. This lead acid storage battery is formed by dipping lead peroxide plate and sponge lead plate in dilute sulfuric acid. A load is connected externally between these plates.

•**During Discharging:** In diluted sulfuric acid the molecules of the acid split into positive hydrogen ions and negative sulfate ions . The hydrogen ions when reach at PbO_2 plate, they receive electrons from it and become hydrogen atom which again attack PbO_2 and form



Positive plate reaction

$PbO_2(s) + 2H^{+} \rightarrow PbO + H_2O$

$PbO + H_2SO_4 \rightarrow PbSo_4 + H_2O$

The total reaction can be written as

$Pbo_2 + H_2SO_4 + 2H^{+} \longrightarrow PbSo_4 + 2H_2O$

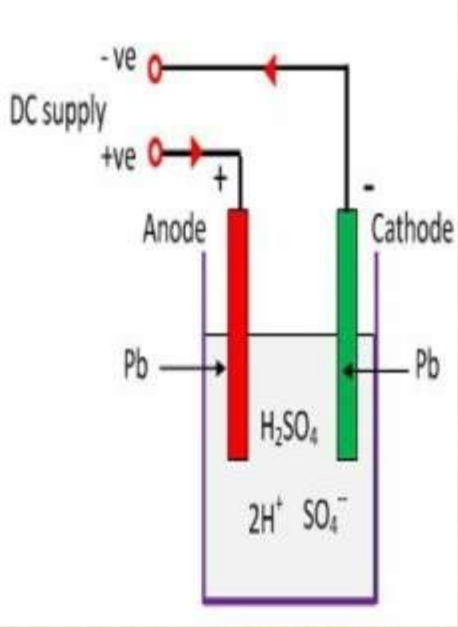
Negative plate reaction

$Pb + So_4 \rightarrow PbSO_4$

As H+ ions take electron from PbO_2 plate and SO_4 ions give electrons to Pb plate, there would be an inequality of electrons between these two plate. Hence there would be flow of current through the external load between these plates for balancing this inequality of electron. This process is called discharging of lead acid battery.

During Charging: During discharging , the density of sulfuric acid falls but there still sulfuric acid exist in the solution. In this case Hydrogen ions being positive charged move to the cathode connected with –ve terminal of DC source. Here each hydrogen ions take one electron from that and become hydrogen atom. These hydrogen atom then attack $PbSO_4$ and form lead and sulfuric acid.

$$PbSO_4 + 2H \rightarrow H_2SO_4 + Pb$$



Sulfate ions moves towards the anode connected with +ve terminal of Dc source where they will give up their extra electrons and become SO_4 and form lead peroxide and sulfuric acid.

$$PbSO_4 + 2H_2 + So_4 \rightarrow PbO_2 + 2H_2SO_4$$

Nickle cadmium battery

Nickel-cadmium batteries, generally referred to as NiCad batteries, are in wide use in the aviation industry. With proper maintenance, they can provide years of trouble-free service.

Positive plate- Nickel hydroxide($Ni(OH)_4$)

Negative plate- Cadmium(Cd)

Electrolyte- potassium hydroxide(KOH) with a small addition of lithium hydrate.

Discharging :

At cathode: $Cd+2OH \rightarrow Cd(OH)_2$

At anode: $Ni(OH)_4 + 2K \rightarrow 2KOH+Ni(OH)_2$

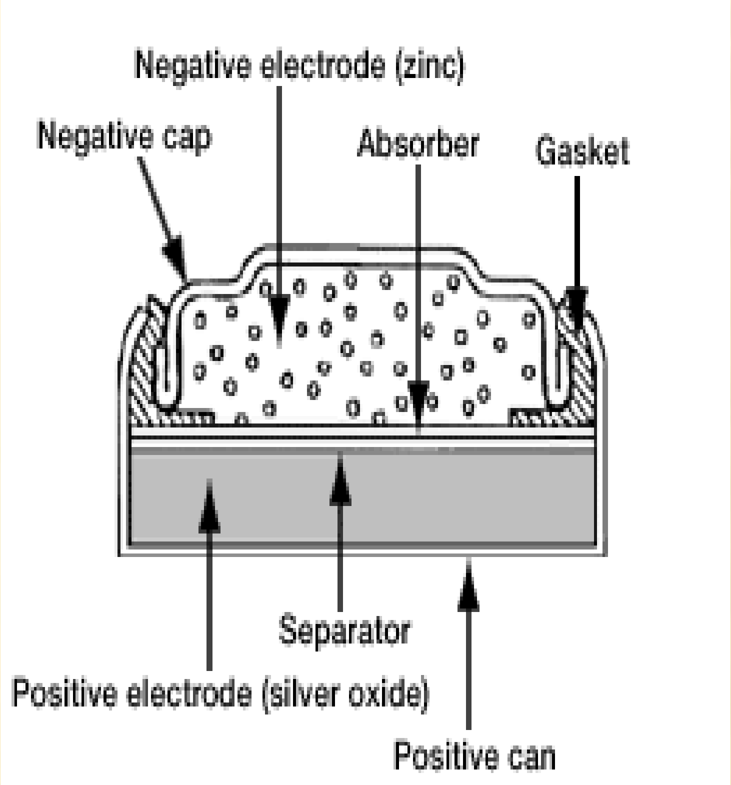
Charging:

At anode: $Ni(OH)_2 + 2OH \rightarrow Ni(OH)_4$

At cathode: $Cd(OH)_2+2K \rightarrow Cd+2KOH$

Silver oxide cell:

A silver-oxide battery is a primary cell with a very high energy-to-weight ratio. Available either in small sizes as button cells, where the amount of silver used is minimal and not a significant contributor to the product cost, or in large custom-designed batteries, where the superior performance of the silver-oxide chemistry outweighs cost considerations. These larger cells are mostly found in applications for the military In recent years they have become important as reserve batteries for manned and unmanned spacecraft. Spent batteries can be processed to recover their silver content.



Principle and reaction

The button-type silver oxide battery uses silver oxide (Ag2O) as its positive active material and zinc (Zn) as its negative active material. Potassium hydroxide (KOH) (W-type) or sodium hydroxide (NaOH) (SW-type) is used as an electrolyte

Battery Reactions	
Positive reaction :	$Ag_2O+H_2O+2e^- \rightarrow 2Ag+2OH^-$
Negative reaction :	$Zn+2OH^- \rightarrow ZnO+H_2O+2e^-$
Total reaction :	$Ag_2O+Zn \rightarrow 2Ag+ZnO$

Methods of charging :

1. constant-current method,
2. constant-voltage method,
3. modified constant-voltage method,
4. float charging method, and trickle charging method.

1. Constant-current charging method :

In the constant-current method, a fixed current is applied for a certain time to the battery to recharge it. The charging current is set to a low value to avoid the voltage across the battery from exceeding the gassing voltage as the battery charge approaches 100%. Consequently, this results in long charge times (usually 12 hours or longer). Though it is used for charging some small lead-acid batteries, the constant current charging method is not widely used for lead-acid batteries, because of the gassing which is likely to occur when charging a battery too long. The risk of gassing is more important when charging a battery which is only partially discharged.

2. Constant-voltage charging method :

In the constant-voltage charging method, a fixed-voltage is applied to the battery to recharge it. The initial charging current (current at the beginning of the battery charge) is at its maximum and can even reach higher values (even exceeding the maximum charge current prescribed by the battery manufacturer) when the battery depth of discharge is high. For this reason, purely constant-voltage charging is seldom used to charge lead-acid batteries that are used in cyclic charge-discharge applications (e.g., battery in an electric vehicle). However, constant-voltage charging is often used to maintain the charge of lead-acid batteries used in standby applications (e.g., as in uninterruptable power supplies), in which case the charge process is referred to as float charging

3. Float charging method:

In the float charging method, a constant voltage, set to a value just sufficient to finish the battery charge or to maintain the full charge is applied to the battery. Typical float charging voltage values range from about 2.15 V to 2.3 V per battery cell. The float charging method is commonly used to maintain the charge of lead acid batteries used in stationary applications, such as in uninterruptable power supplies and SLI batteries (when the battery is charged from the motor alternator). Note that to achieve a full recharge with a low constant voltage requires the proper selection of the starting current, which is based on the manufacturer's specifications.

4. Trickle charging method:

In the trickle charging method, a low-value constant current is applied to the battery. This small current is sufficient to maintain the full charge of a battery or to restore the charge of a battery that is used intermittently for short periods of time. The trickle charging method, also called the compensating charge, is used to maintain the charge of batteries used for stationary applications and SLI batteries. During trickle charging, the battery is disconnected from the load.

Installation of Lead Acid Batteries:

1. Before removing old battery, mark the positive (+) and negative (–) cables for proper connection to the new battery.
2. Always disconnect the ground cable first [usually negative (–)] to avoid any sparking around battery. Then disconnect the positive (+) cable and carefully remove the old battery.
3. Clean and inspect. If necessary, repaint or replace the tray, hold-down and/or battery cables. Cable ends must be clean and corrosion free. Cable must not be frayed or bare.
4. Put corrosion protection washers on battery terminals. Install new battery in same position as old one and tighten hold-down. Be sure terminals will clear hood, fender, box lid, etc. to avoid vehicle damage and/or explosion.
5. Connect positive (+) cable first. Connect ground cable last. If side terminal connection, use a special side terminal torque tool to tighten side terminal cables to

Care and Maintenance of Lead Acid Batteries:

1. As soon as the voltage of the cell reaches from 1.8 volt, the specific gravity of the electrolyte goes down to discharge level
2. The discharged battery should be put on charge without delay otherwise the lead sulphate on the plates settle down which may damage the battery.
3. The battery should not be overcharged.
4. All connections should be tight.
5. The battery room should e free from dust.
6. These should be placed in a ventilated room to prevent the gases evolved from the battery.
7. Charging rate should not be high as this may cause the plates to buckle.
8. The level of the electrolyte should be proper.
9. Check the vent holes and see that these are open and blo9cked by dust and air.
10. While preparing the electrolyte for the battery, it is acid that is to be added to the water.
11. The battery terminals should never be short circuited.

APPLICATIONS OF LEAD ACID BATTERY

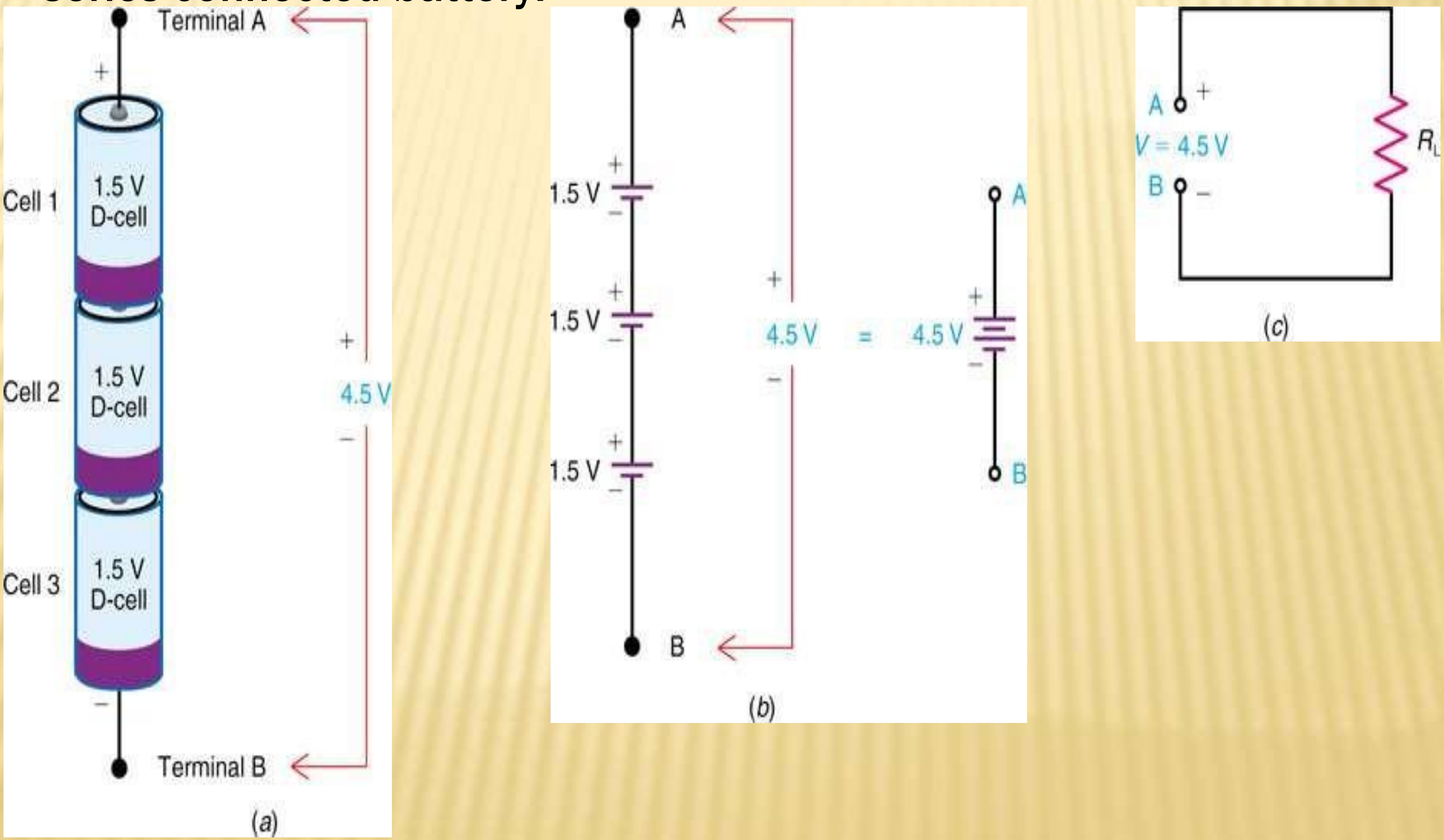
- These are used in automobiles for lighting and starting the vehicles. In some cases, these batteries supply current to music system etc. fitted into automobiles.
- These are used to deliver power to the lighting system in steam fed and diesel railway trains.
- These are used at generating stations and sub station to operate the controlling equipment.
- These are used in telephone exchanges.
- These are used to operate loudspeakers etc.
- These are used to provide emergency lights erc.

TESTING OF A FULLY CHARGED BATTERY:

- Voltage: The voltage of a fully charged cell is abut 2.2 volts, but quickly comes to 2.0 V when put on load
- Gassing: During discharging free gasses is an indication that battery has been charged.
- Specific gravity: During charging process, the specific gravity of the electrolyte increases and provides an important indication to the state of charge of the cell. The specific gravity of a fully charged cell is 1.28 and can be measured with hygrometer.
- Color of plate: The color of positive plate turns chocolate brown and that of negative plate is grey

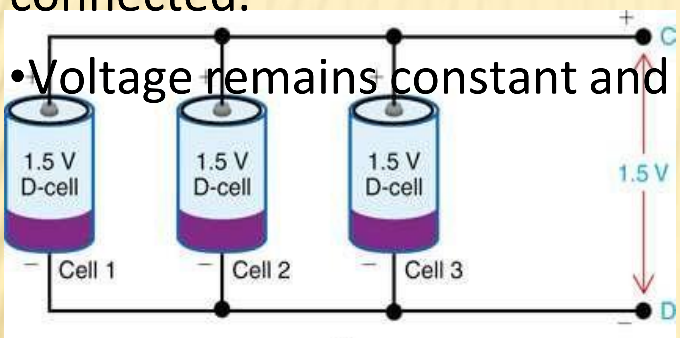
GROUPING OF CELL:

- **Grouping of cell in Series**: The current capacity of a battery with cells in <u>series</u> is the same as that for one cell because the same current flows through all series cells. **Positive terminal of one cell is connected to the negative terminal of the next, is called a series connected battery.**

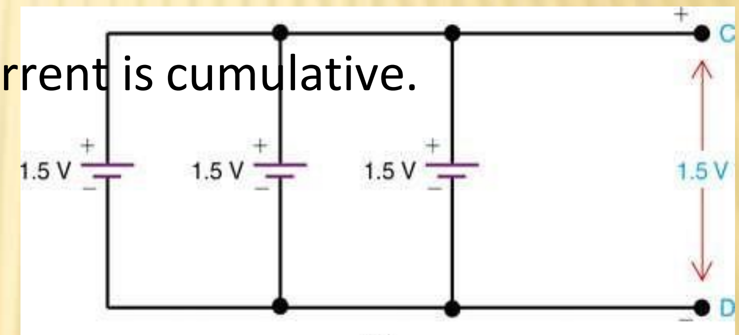


GROPING OF CELL IN PARALLEL:

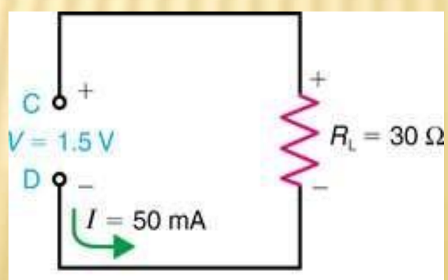
- **The <u>parallel</u> connection is equivalent to increasing the size of the electrodes and electrolyte, which increases the current capacity.**
- Connect the negative terminal from one cell to the negative of the next cell
- Connect the positive terminal to the positive terminal, is parallel connected.
- Voltage remains constant and the current is cumulative.



(a)



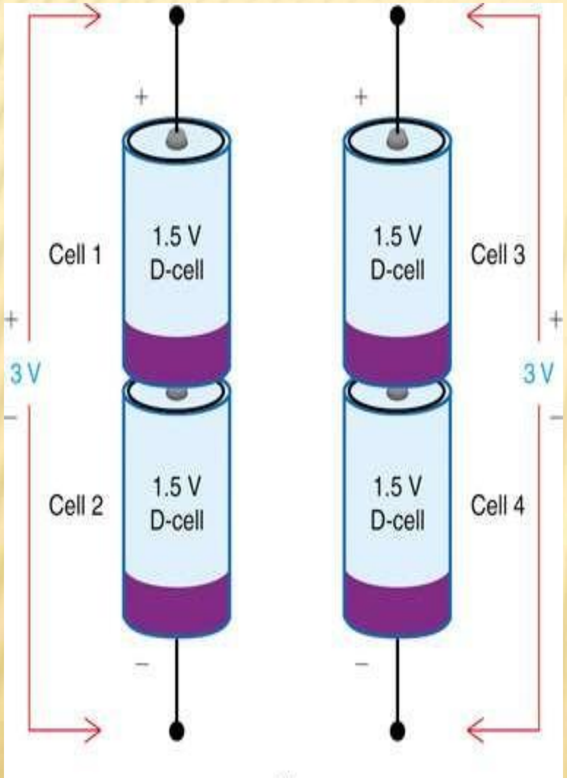
(b)



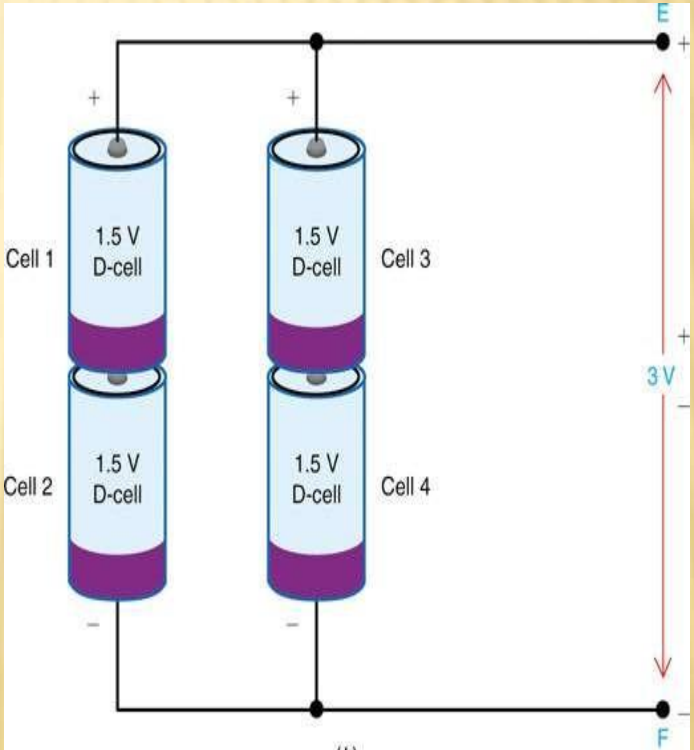
(c)

GROUPING OF CELL IN SERIES – PARALLEL COMBINATION:

To provide a higher output voltage and more current capacity, cells can be connected in <u>series-parallel</u> combination.



(a)



(b)

Magnetism and Electromagnetism

INTRODUCTION TO MAGNETS:

- It is the substance having properties of attracting iron and alloys. The phenomenon by which this attraction takes place is called magnetism.
- Not all objects are affected by the force of magnetism .example. *wood*, *glass*, *paper*, *plastic.*
- common metals affected by magnetism are *iron*, *nickel*, and *cobalt*
- Every magnet has two poles
  - north (N) pole
  - south (S) pole

  even if you break a magnet in half, each half will have a north pole and a south pole
- Properties of Magnet: like magnetic poles repel each other.unlike magnetic poles attract each other

  - *Magnet are of two types*
  - *Natural Magnets:*
  - *Artificial Magnets:*

Magnetic Field –

Area around a magnet where magnetic forces can act.

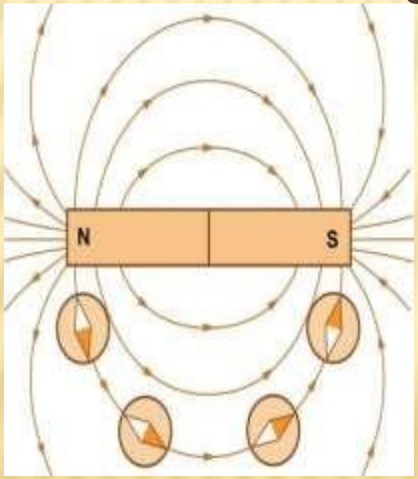
A magnetic field is made up of magnetic lines of force.

Magnetic Lines of Force –

Lines that show the shape of a magnetic field.

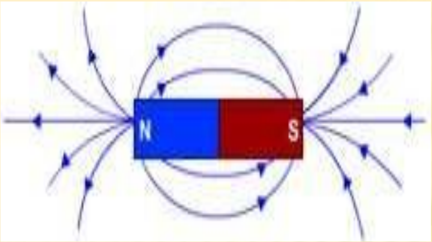
The magnetic lines of force are closest together at

agnet.



Bar magnet

MAGNETIC EFFECT OF ELECTRIC CURRENT



Electric Current is the flow of electric charge (a physical property of the matter that experiences a force when placed around an electromagnetic field)

•Magnetic field is the area around a magnet where the magnetic force is experienced. The imaginary lines of magnetic field around a magnet is called Magnetic Field Lines.

MAGNETIC FIELD LINES

•An Electromagnetic field (EM Field) is a combination of electric field and magnetic field. An EM field is produced when electrically charged particles, such as electrons are accelerated. Electrically charged particles are surrounded by electric fields and these charged particles when in motion generate magnetic field

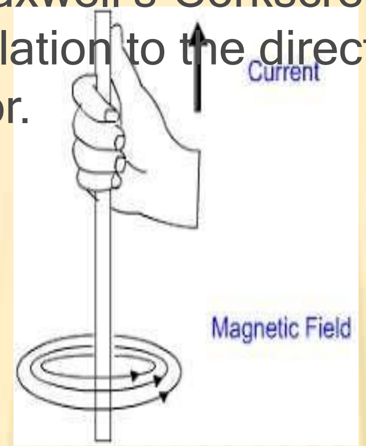
•Thus, the magnetic effect of electric current is defined as

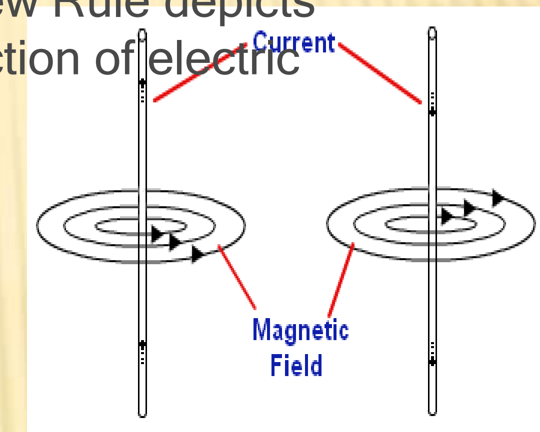
Direction of Magnetic lines of force:

The Right-Hand Thumb Rule or Maxwell's Corkscrew Rule depicts the direction of magnetic field in relation to the direction of electric current through a straight conductor.

RIGHT HAND THUMB RULE:

As per this rule suppose if a current carrying conductor is held by right hand with the thumbs up straight and the electric current flowing in the direction of the thumb then the direction of the magnetic field can be depicted by the direction of wrapping of the other fingers.

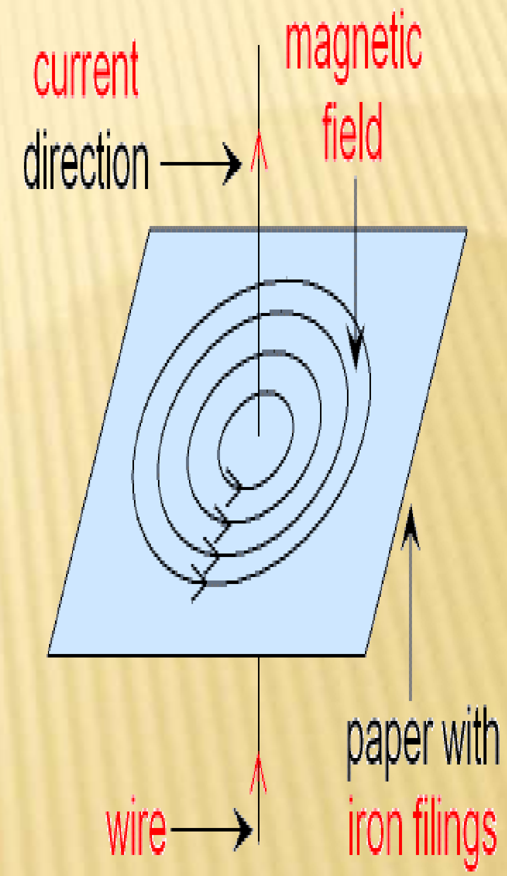




This means that in a vertically suspended current carrying conductor if the direction of the current is from south to north then the magnetic field will be in an anticlockwise direction. But if the direction of the current is flowing from north to south then the magnetic field will be in clockwise direction. In this rule, it should be noted that when current is flowing in an anticlockwise direction, then the magnetic field will be in a clockwise direction at the top of the loop and when it is vice versa then the magnetic field will be at the bottom of the loop.

Magnetic field around a straight Current Carrying conductor :

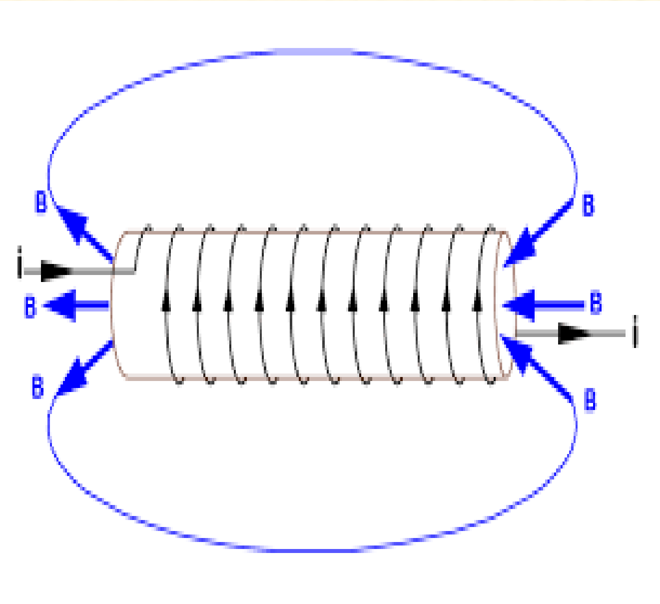
- A current carrying straight conductor has magnetic field in the form of concentric circles; around it. Magnetic field of current carrying straight conductor can be shown by magnetic field lines.
- The direction of magnetic field through a current carrying conductor depends upon the direction of flow of electric current. The direction of magnetic field gets reversed in case of a change in the direction of electric current.
- Let a current carrying conductor be suspended vertically and the electric current is flowing from south to north. In this case, the direction of magnetic field will be anticlockwise. If the current is flowing from north to south, the direction of magnetic field will be clockwise.



When current is flowing through a straight conductor, magnetic lines of forces are set up around the conductor in concentric circles. The red Arrow indicates the direction of current where as the black arrow indicates the magnetic field.

Magnetic Field due to a current in a Solenoid:

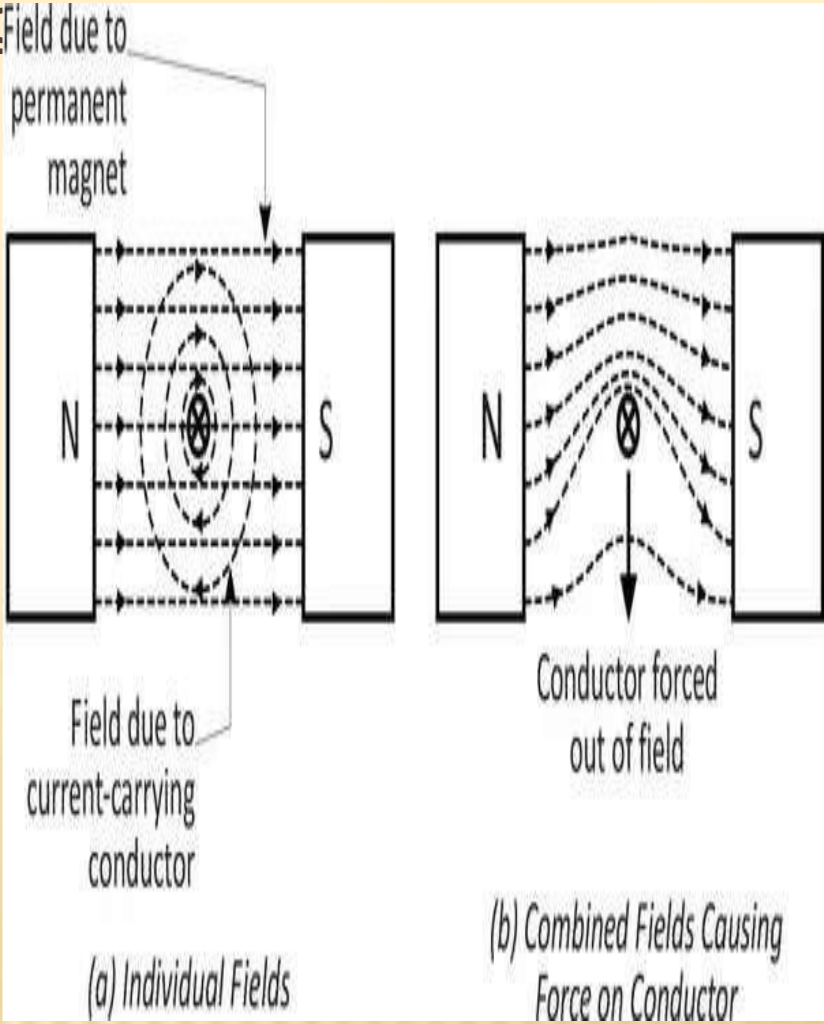
- Solenoid is the coil with many circular turns of insulated copper wire wrapped closely in the shape of cylinder.
- A current carrying solenoid produces similar pattern of magnetic field as a bar magnet. One end of solenoid behaves as the north pole and another end behaves as the south pole. Magnetic field lines are parallel inside the solenoid; similar to a bar magnet; which shows that magnetic field is same at all points inside the solenoid.
- By producing a stro solenoid, magnetic materials can be magnetize cing magnetic field inside a solenoid is called el



FORCE ON A CONDUCTOR PLACED IN A MAGNETIC FIELD When a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force which acts in a direction perpendicular to both the direction of current and the field.

Let us consider a current carrying conductor is placed in a uniform magnetic field as shown in figure By applying Right Hand Thumb Rule, It is seen that the direction of field around the conductor is found to be clockwise.

The magnetic field due to N and S pole and conductor are shown. The line of forces due to current carrying conductor and you two poles are in same direction at top. As shown to field at the top of conductor are helping each other (means magnetic lines due to pole and conductor are in same direction) whereas, at the bottom of the conductor, field due to poles is in opposite direction to the field due to current (means to field are in opposite direction). The result is that the lines of forces are crowded at the top of conductor and thinned at the bottom as shown.



FIELD INTENSITY (*H*) OR MAGNETIZING FORCE :

- The magneto motive force per unit length is called the magnetizing force (*H*)..
- Equation: *H* = mmf/length
- Units: AT/m
  ampere-turns per meter
- Shorter magnetic circuits produce a greater field intensity

Permeability (*μ*) :

•**Permeability** is a measure of the ability to concentrate magnetic fields. Materials with high permeability can concentrate flux, and produce large values of flux density *B* for a specified *H*.

The amount of flux produced by *H* depends on the material in the field.

These factors are reflected in the formulas:

$$B = \mu \times H$$

$$\mu = B / H$$

The ratio of the permeability of the material to that of air is called the **relative permeability.**

AMPERE-TURNS OF MAGNETO MOTIVE FORCE (MMF):

- The strength of a coil’s magnetic field is proportional to the amount of current flowing through the coil and the number of turns per given length of coil.
- Ampere-turns = $I \times N$ = mmf
- I is the amount of current flowing through N turns of wire.
- This formula specifies the amount of magnetizing force or magnetic potential (mmf).

flux density :

$$B = \frac{\Phi}{A}$$

$B = \text{Wb/m}^2 = \text{teslas (T)}$

$\Phi = \text{webers (Wb)}$

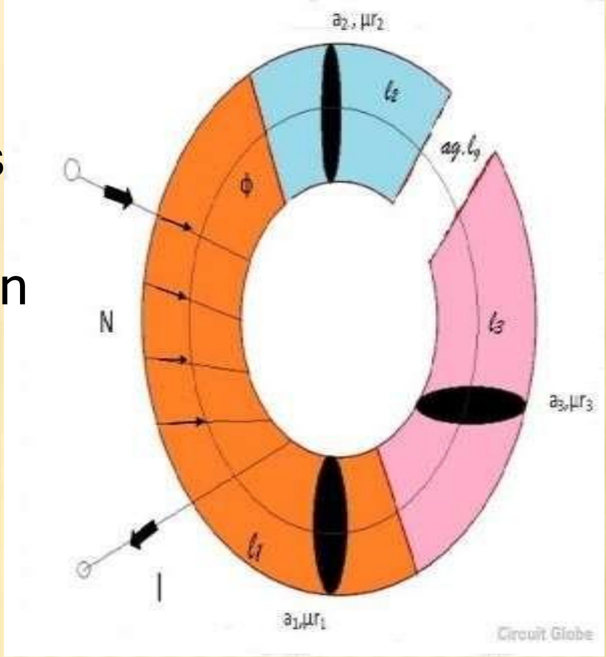
$A = \text{m}^2$

SERIES MAGNETIC CIRCUITS: DETERMINING NI

- We are now in a position to solve a few magnetic circuit problems, which are basically of two types.
- *In one type, Φ is given, and the impressed mmf NI must be computed.*
- This is the type of problem encountered in the design of motors, generators, and transformers.
- *In the other type, NI is given, and the flux Φ of the magnetic circuit must be found.*
- This type of problem is encountered primarily in the design of magnetic amplifiers and is more difficult since the approach is "hit or miss."

Series Magnetic Circuit

Definition: The **Series Magnetic Circuit** is defined as the magnetic circuit having a number of parts of different dimensions and materials carrying the same magnetic field. Consider a circular coil or solenoid having differen
the figure below



Current I is passed through the solenoid having N number of turns wound on the one section of the circular coil. Φ is the flux, sets up in the core of the coil.

a_1, a_2, a_3 are the cross-sectional area of the solenoid.
l_1, l_2, l_3 are the length of the three different coils having different dimension joined together in series.
μr_1, μr_2, μr_3 are the relative permeability of the material of the circular coil.
a_g and are the area and the length of the air gap.
The total reluctance (S) of the magnetic circuit is

$$S = S_1 + S_2 + S_3 + S_g$$

$$S = \frac{l_1}{a_1 \mu_0 \mu_{r1}} + \frac{l_2}{a_2 \mu_0 \mu_{r2}} + \frac{l_3}{a_3 \mu_0 \mu_{r3}} + \frac{l_g}{a_g \mu_0}$$

Total MMF = φ x S ....(1)

Putting the value of S in equation (1) we get

$$\text{Total mmf} = \varphi \ x \ \frac{l_1}{a_1 \mu_0 \mu_{r1}} + \frac{l_2}{a_2 \mu_0 \mu_{r2}} + \frac{l_3}{a_3 \mu_0 \mu_{r3}} + \frac{l_g}{a_g \mu_0} \ldots\ldots\ldots(2)$$

As B = φ/a) putting the valve of B in the equation (2) we obtain the following equation for the total MMF

$$\text{Total mmf} = \frac{B_1 l_1}{\mu_0 \mu_{r1}} + \frac{B_2 l_2}{\mu_0 \mu_{r2}} + \frac{B_3 l_3}{\mu_0 \mu_{r3}} + \frac{B_g l_g}{\mu_0}$$

$$(\text{As } H = B/\mu_0 \mu_r)$$

$$\text{Total mmf} = H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g$$

Magnetic Circuit

The closed path followed by magnetic lines of forces or we can say magnetic flux is called magnetic circuit. A magnetic circuit is made up of magnetic materials having high permeability such as iron, soft steel, etc. Magnetic circuits are used in various devices like electric motor, transformers, relays, generators galvanometer, etc.

Electric Circuit

The rearrangement by which various electrical sources like AC source or DC source, resistances, capacitance and another electrical parameter are connected is called electric circuit or electrical network.

DIFFERENCE BETWEEN ELECTRIC CIRCUIT AND MAGNETIC CIRCUIT :

BASIS	MAGNETIC CIRCUIT	ELECTRIC CIRCUIT
Definition	The closed path for magnetic flux is called magnetic circuit.	The closed path for electric current is called electric circuit.
Relation Between Flux and Current	Flux = mmf/reluctance	Current = emf/ resistance
Units	Flux φ is measured in weber (wb)	Current I is measured in amperes
MMF and EMF	Magnetomotive force is the driving force and is measured in Ampere turns (AT) Mmf =∫ H.dl	Electromotive force is the driving force and measured in volts (V) Emf = ∫ E.dl
Reluctance and Resistance	Reluctance opposes the flow of magnetic flux S = l/aμ and measured in	Resistance opposes the flow of current R = ρ. l/a and measured in

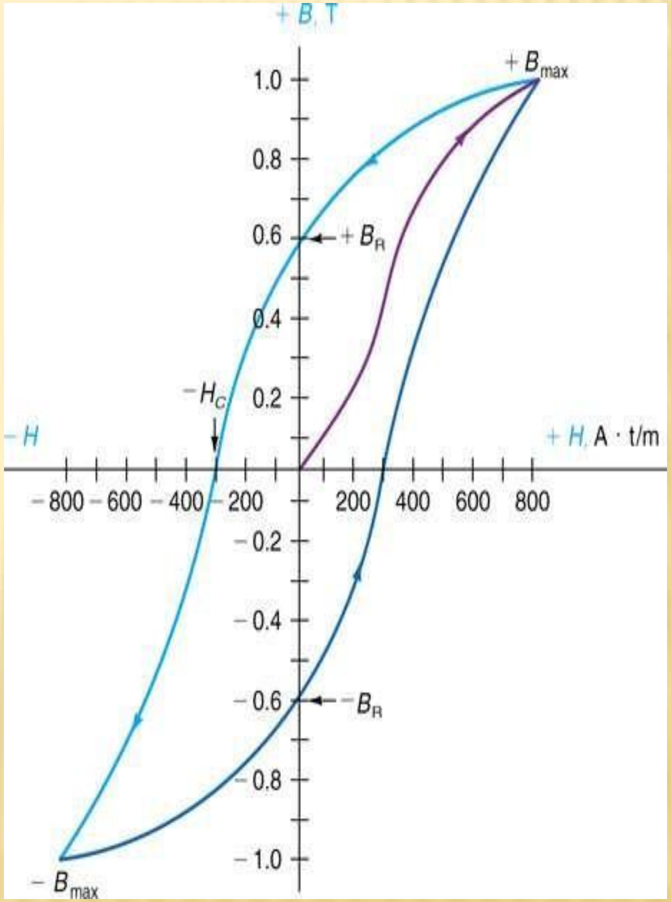
Relation between Permeance and Conduction	Permeance = 1/reluctance	Conduction = 1/ resistance
Analogy	Permeability	Conductivity
Analogy	Reluctivity	Resistivity
Density	Flux density B = φ/a (wb/m2)	Current density J = I/a (A/m2)
Intensity	Magnetic intensity H = NI/l	Electric density E = V/d
Drops	Mmf drop = φS	Voltage drop = IR
Flux and Electrons	In magnetic circuit molecular poles are aligned. The flux does not flow, but sets up in the magnetic circuit.	In electric circuit electric current flows in the form of electrons.
Examples	For magnetic flux, there is no perfect insulator. It can set up even in the non magnetic materials like air, rubber, glass etc.	For electric circuit there are a large number of perfect insulators like glass, air, rubber, PVC and synthetic resin which do not allow it to flow through them.

Applicable Laws	Khirchhoff flux and mmf law is followed	Khirchhoff voltage and current law is followed.

Variation of Reluctance and Resistance	The reluctance (S) of a magnetic circuit is not constant rather it varies with the value of B.	The resistance (R) of an electric circuit is almost constant as its value depends upon the value of ρ. The value of ρ and R can change slightly if the change in temperature takes place
Energy in the circuit	Once the magnetic flux sets up in a magnetic circuit, no energy is expanded. Only a small amount of energy is required at the initial stage to create flux in the circuit.	Energy is expanding continuously, as long as the current flows through the electrical circuit. This energy is dissipated in the form of heat.

MAGNETIC HYSTERESIS: HYSTERESIS REFERS TO A SITUATION WHERE THE MAGNETIC FLUX LAGS THE INCREASES OR DECREASES IN MAGNETIZING FORCE.

- Hysteresis Loop
  - B_R is due to **retentivity**, which is the flux density remaining after the magnetizing force is reduced to zero.
  - Note that $H = 0$ but $B > 0$.
  - H_C is the coercive force (needed to make $B = 0$)



Demagnetization :

To demagnetize a magnetic material completely, the retentivity B_R must be reduced to zero.

The practical way to do so is to magnetize and demagnetize the material with a decreasing hysteresis loop:

MAGNETIC HYSTERESIS LOSS

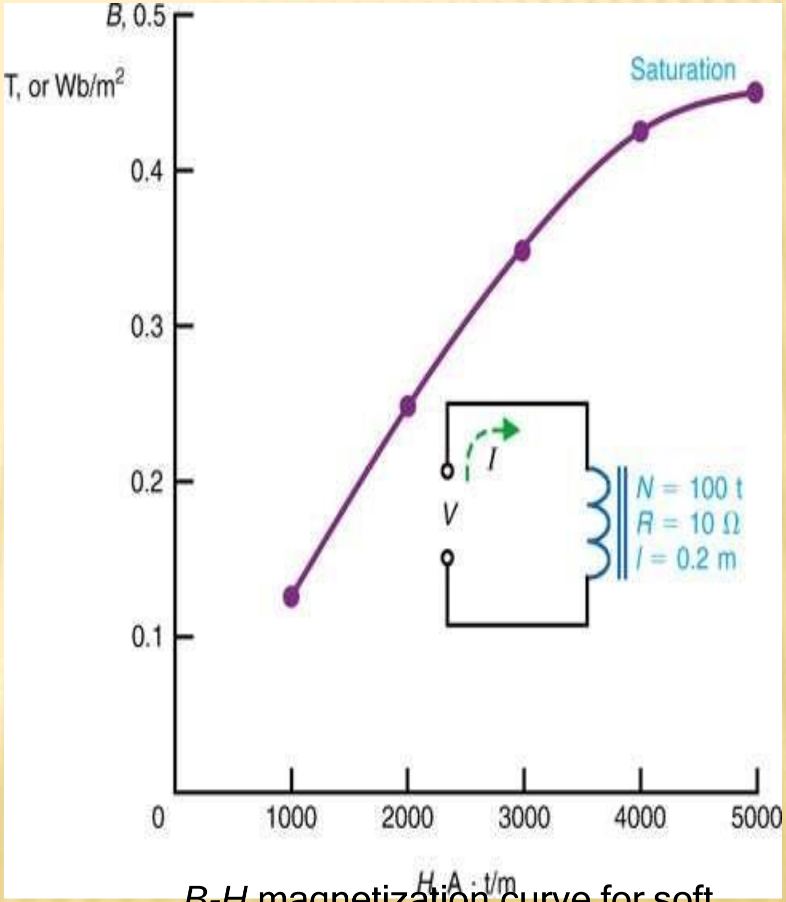
Hysteresis loss is energy wasted in the form of heat when alternating current reverses rapidly and molecular dipoles lag the magnetizing force.

For steel and other hard magnetic materials, **hysteresis losses** are much higher than in soft magnetic materials like iron.

- $P_h = (k_h)(f)(B_{max})^n$ where
  - P_h = hysteresis loss (W/unit mass)
  - f = frequency of the flux (Hz)
  - B_{max} = maximum value of the flux
  - k_h = constant
  - n = Steinmetz exponent
    - Value of 1.6 for silicon steel sheets

B-H MAGNETIZATION CURVE

- The *B-H* magnetization curve shows how much flux density *B* results from increasing field intensity *H*.
- Saturation is the effect of little change in flux density when the field intensity increases.



B-H magnetization curve for soft iron. No values are shown near zero, where μ may vary with previous magnetization.

Electromagnetic Induction

ELECTROMAGNETIC INDUCTION

Electromagnetic or **magnetic induction** is the production of an electromotive force (i.e., voltage) across an electrical conductor in a changing magnetic field

- Electromagnetic induction can be generated in two ways, namely when the electric conductor is kept in a moving magnetic field and when the electric conductor is constantly moving within a static magnetic field. The phenomenon of electromagnetic induction was first discovered by Michael Faraday when he moved a bar magnet through an electric coil. He noticed a change in voltage of the circuit. He later deduced the factors that could influence the electromagnetic induction as the number of coils, the strength of the magnet, the changing magnetic fields and the speed of relative motion between coil & magnet.
- The number of turns in the coils/wire is directly proportional to induced voltage. In other words, greater voltage is generated when the number of turns is higher. The changing magnetic field also influences the voltage which is induced. The speed of the relative motion between the coil and magnet was also found to affect the induced voltage or electromagnetic induction as rise in velocity cuts the lines of flux at a faster rate. This results in more induced electromagnetic force or voltage.
- The induced voltage in an electromagnetic induction is described by the following equation as:
- $e = N \times d\Phi dt$
- Where
- e = voltage induced (measured in volts)
- t = time (measured in seconds)
- N = number of turns found in the coil
- Φ = magnetic flux (measured in Webers)
- Many types of electrical equipment such as motors, generators and transformers function based on the principle of the electromagnetic induction.

FARADY'S FIRST LAW :

When a conductor cuts across the magnetic field, an e.m.f is induced in the conductor.

Or

When the magnetic flux linking with any circuit or coil changes , an e.m.f is induced in the circuit.

Faraday's second law:

It states that the magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil.

$$E = -N\frac{d\phi}{dt}$$

Lenz's law

Lenz's law states that when an emf is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such, that it produces an current that's magnetic field opposes the change which produces it. The negative sign used in Faraday's law of electromagnetic induction, indicates that the induced emf (ε) and the change in magnetic flux ($\delta\Phi_B$) have opposite signs.

$$\epsilon = -N\frac{\partial\Phi_B}{\partial t}$$

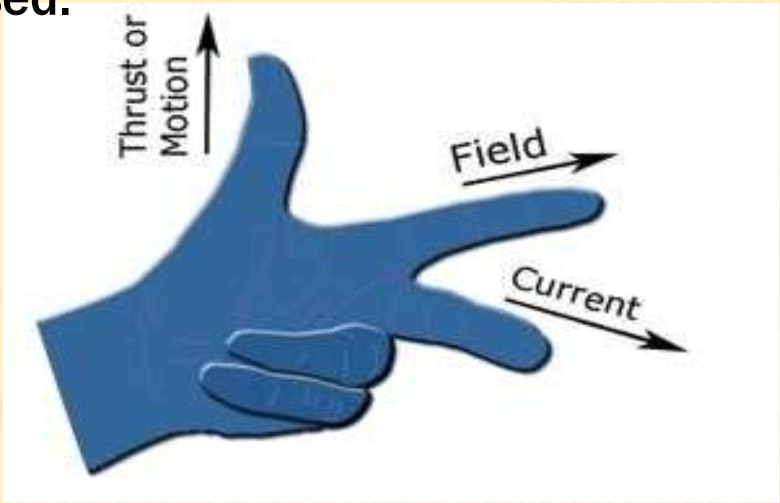
Where, ε = Induced emf

$\delta\Phi_B$ = change in magnetic flux

N = No of turns in coil

FLEMING'S LEFT HAND RULE

To find the direction of the force on a current carrying conductor, Fleming's left hand rule can be used.



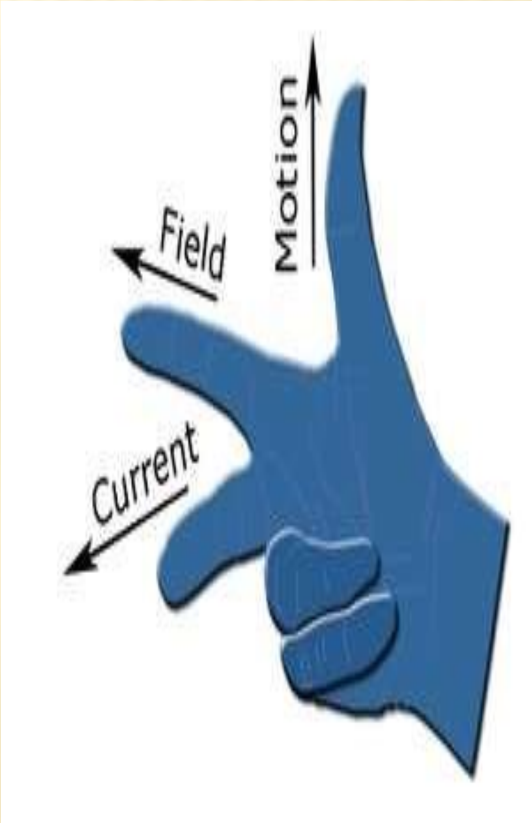
When current flows through a conducting wire, and an external magnetic field is applied across that flow, the conducting wire experiences a force perpendicular both to that field and to the direction of the current flow (i.e they are mutually perpendicular) . A left hand can be held, as shown in the illustration, so as to represent three mutually orthogonal axes on the thumb, fore finger and middle finger. Each finger is then assigned to a quantity (mechanical force, magnetic field and electric current). The right and left hand are used for generators and motors respectively.

FLEMING'S RIGHT-HAND RULE

Fleming's Right-hand Rule shows the direction of induced current when a conductor attached to a circuit moves in a magnetic field. It can be used to determine the direction of current in a generator's windings.

When a conductor such as a wire attached to a circuit moves through a magnetic field, an electric current is induced in the wire due to Faraday's law of induction. The current in the wire can have two possible directions. Fleming's right-hand rule gives which direction the current flows.

The right hand is held with the thumb, index finger and middle finger mutually perpendicular to each other (at right angles), as shown in the diagram.



- **The thumb is pointed in the direction of the motion of the conductor relative to the magnetic field.**
- **The first finger is pointed in the direction of the magnetic field. (north to south)**
- **Then the second finger represents the direction of the induced or generated current within the conductor (from the terminal with lower electric potential to the terminal with higher electric potential, as in a voltage**

TYPES OF INDUCED EMF

- Whenever a conductor is placed in a varying magnetic field, EMF is induced in the conductor and this EMF is called induced EMF.

Induced EMF is of two types

I. Dynamically induced EMF

When the conductor is in motion and the field is in stationary so the EMF is induced in the conductor, this type of EMF is called dynamically induced EMF.

II. Statically induced EMF

When the conductor is in stationary and the field is changing (varying) then in this case EMF is also induced in the conductor, which is called statically induced EMF.

Statically induced EMF is of two types-

Self induced EMF

Self-induced EMF is that EMF which is induced in the conductor by changing in its own. When current is changing the magnetic field is also changing around the coil and hence Faraday law is applied here and EMF are induced in the coil to it self which called self induced EMF.

Mutually induced EMF-When an alternating voltage or current is applied to the coil 'a' alternating current will flow in the coil' a' and is a result of which a

PRINCIPLE OF SELF INDUCTION

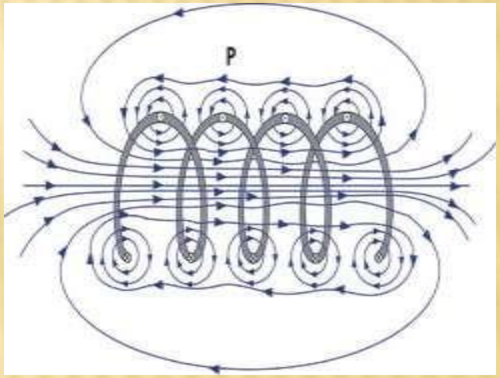
The property of a circuit by which an EMF is induced in the circuit whenever the current is flowing through it changes, is termed as self inductance.

Consider of coil of N turns (Air core) carrying a current of I amps. Let The Flux linking with the coil be Φ webers. then flux linkages = N I.

The lines of flux linking the coil will change with the change in current. This will induce an EMF according to Faraday's law. The EMF to induce is called self induced EMF.

Φ

COEFFICIENT OF SELF INDUCTANCE



NΦ /I i.e, flux linking for ampere is called the coefficient of self induction or inductance denoted by L.

If the current through the coil changes at the rate of one amp/second and the EMF induced and it is one volt, then self inductance is 1 Henry.

Mathematically

EMF of self inductance e_L =-L x rate of change of current in ampere/Sec.

FACTORS ON WHICH INDUCTANCE DEPENDS

The factor on which inductance depends are:

1. Number of turns in the coil.
2. Length of the coil.
3. Area of cross section of the coil.
4. Permeability of Core.

Self-inductance or in other words inductance of the coil is defined as the property of the coil due to which it opposes the change of current flowing through it. Inductance is attained by a coil due to the self-induced emf produced in the coil itself by changing the current flowing through it.

If the current in the coil is increasing, the self-induced emf produced in the coil will oppose the rise of current, that means the direction of the induced emf is opposite to the applied voltage.

Self-inductance does not prevent the change of current, but it delays the change of current flowing through it.

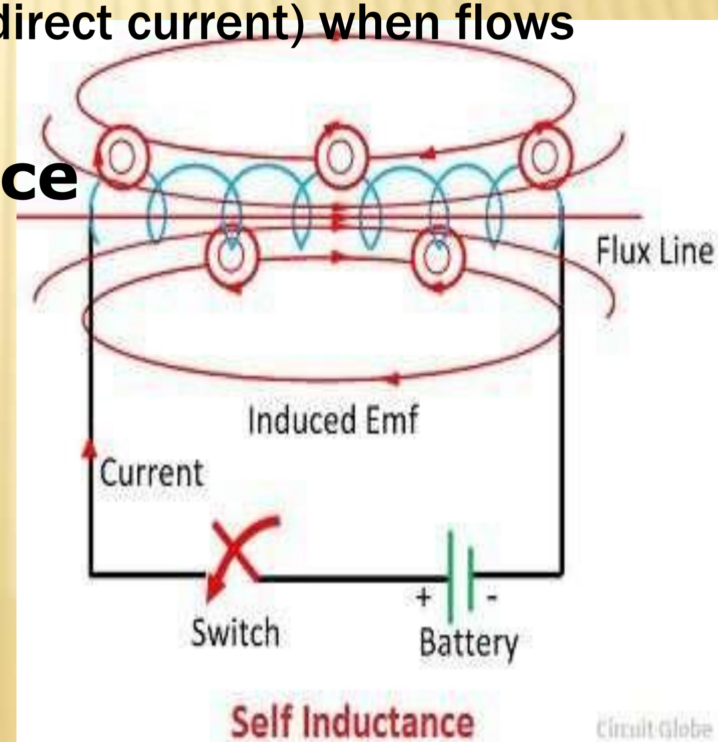
This property of the coil only opposes the changing current (alternating current) and does not affect the steady current that is (direct current) when flows through it. The unit of inductance is Henry (H).

Expression For Self Inductance

$$e = L \frac{dI}{dt}$$

Or

$$L = \frac{e}{dI/dt}$$



- The above expression is used when the magnitude of self-induced emf (e) in the coil and the rate of change of current (dI/dt) is known.
- Putting the following values in the above equations as e = 1 V, and dI/dt = 1 A/s then the value of Inductance will be L = 1 H.
- Hence, from the above derivation, a statement can be given that a coil is said to have an inductance of 1 Henry if an emf of 1 volts is induced in it when the current flowing through it changes at the rate of 1 Ampere/second.

The expression for Self Inductance can also be given as

$$e = L\frac{dI}{dt} = \frac{d}{dt}(LI) \text{ also } e = N\frac{d\varphi}{dt} = \frac{d}{dt}(N\varphi)$$

$$LI = N\varphi \text{ or } L = \frac{N\varphi}{I} \text{ Henry}$$

where,
N – number of turns in the coil
Φ – magnetic flux
I – current flowing through the coil

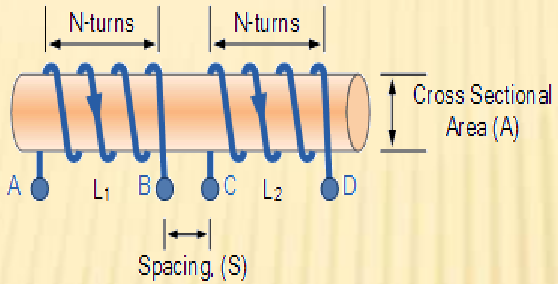
From the above discussion, the following points can be drawn about Self Inductance

- The value of the inductance will be high if the magnetic flux is stronger for the given value of current.
- The value of the Inductance also depends upon the material of the core and the number of turns in the coil or solenoid.
- The higher will be the value of the inductance in Henry, the rate of change of current will be lower.
- 1 Henry is also equal to 1 Weber/ampere

The solenoid has large self-inductance.

Principle of mutual induction

The property of one coil due to which it opposes the change of current in the other coil is called mutual induction between two coils.



Here the current flowing in coil one, L_1 sets up a magnetic field around itself with some of these magnetic field lines passing through coil two, L_2 giving us mutual inductance.

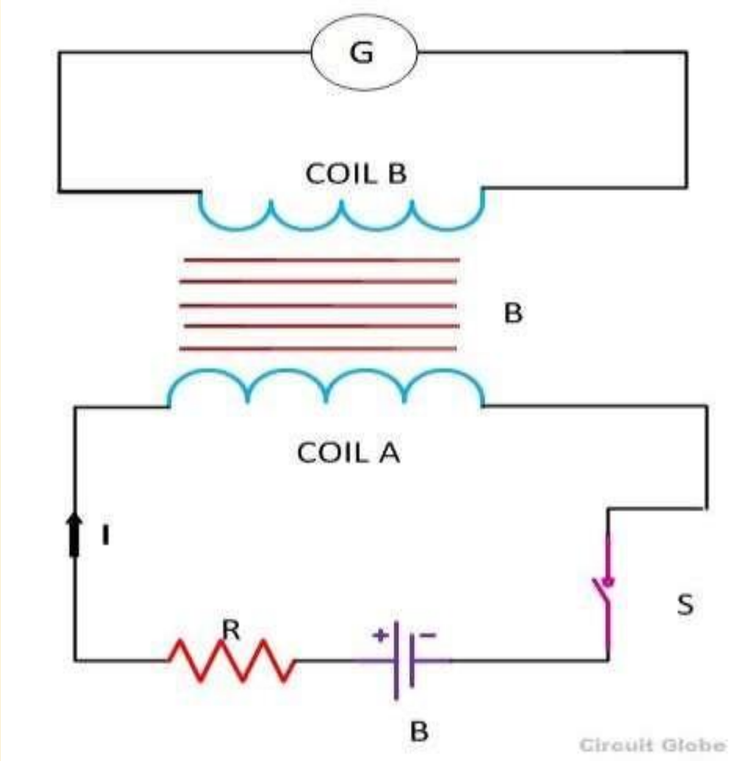
Coil one has a current of I_1 and N_1 turns while, coil two has N_2 turns.

Therefore, the mutual inductance, M_{12} of coil two that exists with respect to coil one depends on their position with respect to each other and is given as:

$$M_{12} = \frac{N_2 \Phi_{12}}{I_1}$$

MUTUAL INDUCED EMF

- **Definition: Mutual Inductance** between the two coils is defined as the property of the coil due to which it opposes the change of current in the other coil, or you can say in the neighboring coil. When the current in the neighboring coil is changing, the flux sets up in the coil and because of this changing flux emf is induced in the coil called Mutually Induced emf and the phenomenon is known as Mutual Inductance.



Let us understand the phenomenon of Mutual Inductance by considering an example as shown in the above figure.

Two coils namely coil A and coil B is placed nearer to each other. When the switch S is closed, and the current flows in the coil it sets up the flux φ in the coil A and emf is induced in the coil and if the value of the current is changed by varying the value of the resistance (R), the flux linking with the coil B also changes because of this changing current. Thus this phenomenon of the linking flux of the coil A with the other coil, B is called Mutual Inductance.

- For de uctance between the two coils, the follow

$$e_m = M \frac{dI_1}{dt}$$

or

$$M = \frac{e_m}{dI_1/dt} \text{ ....(1)}$$

This expression is used when the magnitude of mutually induced emf in the coil and the rate of change of current in the neighboring coil is known.

Hence, from the above statement, you can define Mutual Inductance as "the two coils are said to have a mutual inductance of one Henry if an emf of 1 volt is induced in one coil or say primary coil when the current f neighboring coil or secondary coil is changing at the rate

$$e_m = M \frac{dI_1}{dt} = \frac{d}{dt}(MI_1) \text{ .... (2) also}$$

$$e_m = N_2 \frac{d\varphi_{12}}{dt} = \frac{d}{dt}(N_2 \varphi_{12}) \text{ ....(3)}$$

Mutual inductance can also be expressed in another way as shown below equating equation (2) and (3) you will get

$$MI_1 = N_2\varphi_{12} \text{ Or } M = \frac{N_2\varphi_{12}}{I_1} \text{ Henry}$$

The above expression is used when the flux linkage ($N_2\varphi_{12}$) of one coil due to the current (I_1) flowing through the other coil are known.

The value of Mutual Inductance (M) depends upon the following factors

- Number of turns in the secondary or neighboring coil
- Cross-sectional area
- Closeness of the two coils

Mutual Coupling In the Magnetic Circuit

When on a magnetic core, two or more than two coils are wound the coils are said to be mutually coupled. The current, when passed in any of the coils wound around the magnetic core, produces flux which links all the coils together and also the one in which current is passed. Hence, there will be both self-induced emf and mutual induced emf in each of the coils.

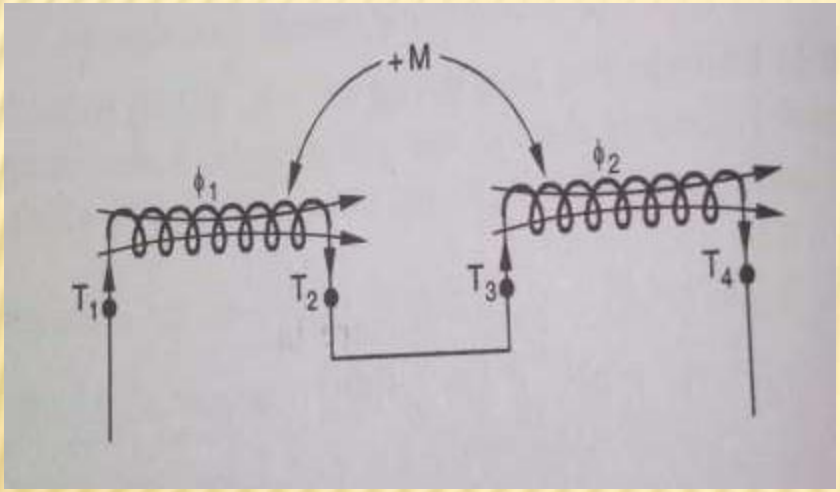
The best example of the mutual inductance is transformer, which works on the principle of Faraday’s Law of Electromagnetic Induction.

Faraday’s law of electromagnetic induction states that “ the magnitude of voltage is directly proportional to the rate of change of flux.” which is explained in the topic Faraday’s Law of Electromagnetic Induction.

INDUCTANCE IN SERIES

The two coils may be connected in series in the following ways or methods:

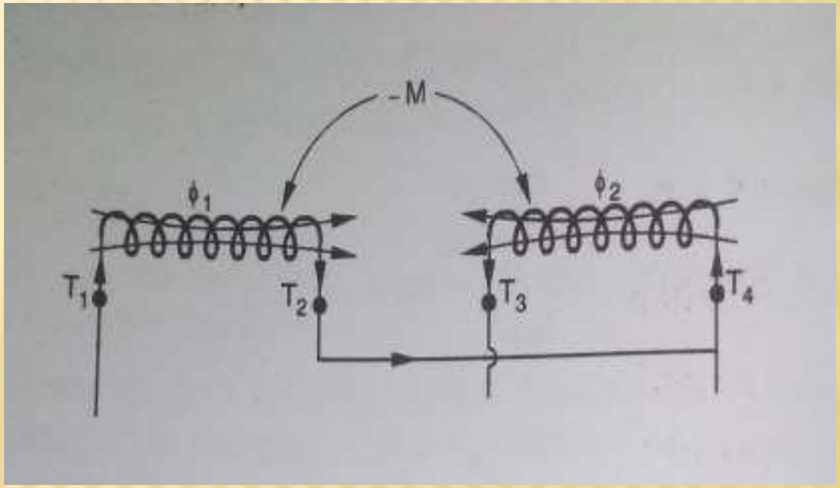
1. When their fluxes are additive (i.e. their fluxes are in the same direction as shown in figure). In this case, the inductance of a coil is increased by M.



Therefore, Total Inductance,

$$LT = (L_1 + M) + (L_2 + M)$$
$$= L_1 + L_2 + 2M.$$

2. When their fluxes are subtracted (i.E. Their classes are set up in the opposite direction as shown in figure). in this case, the inductance of each coil is decreased by M.



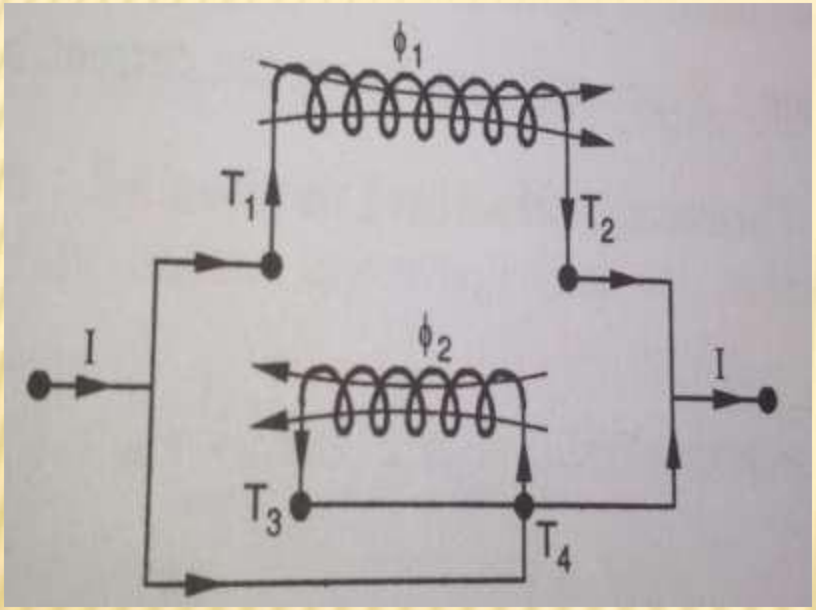
Therefore, Total Inductance,

$$LT = (L_1 - M) + (L_2 - M)$$
$$= L_1 + L_2 - 2M.$$

INDUCTANCE IN PARALLEL

The two coils may be connected in series in the following ways or methods:

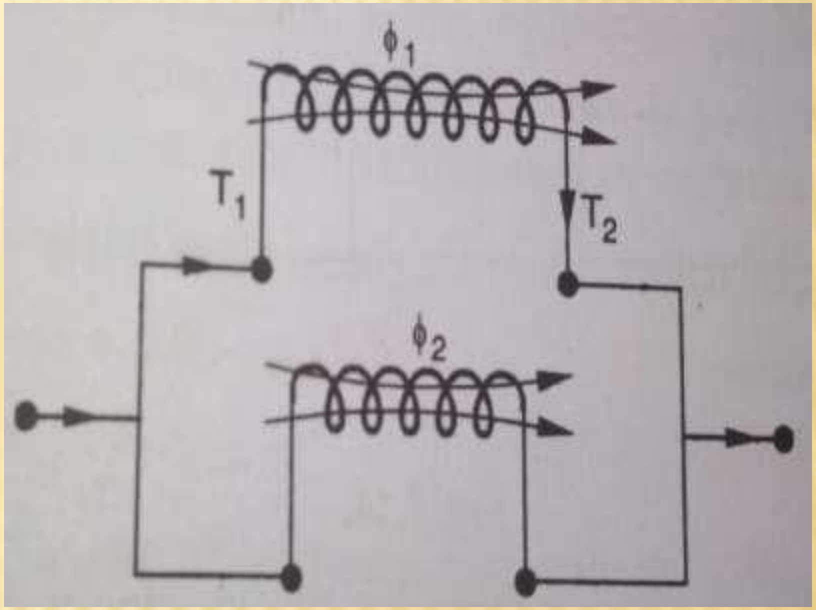
1. When the two field produced by them are in the direction as shown in figure.



Total inductance,

$$LT = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}$$

2. When the two fields produced by them are in opposite direction as shown in figure



Total inductance,

$$LT = \frac{L_1 L_2}{L_1 + L_2}$$

Energy Stored in a Magnetic Field

It takes energy to establish a current in an inductor; this energy is stored in the inductor's magnetic field.

Considering the emf needed to establish a particular current, and the power involved, we find:

Energy Stored in an Inductor

$$U = \frac{1}{2}LI^2$$

SI unit: joule, J

CONCEPT OF EDDY CURRENT, EDDY CURRENT LOSS

Whenever the magnetic flux linkages within close electric circuit changes, an EMF is induced in the circuit, this induced EMF circulate current within the body of material this circulating current is known as Eddy current the current in each part is directly proportional to the induced EMF and inversely proportional to the square of current in it and owing to the heat energy developed (I2R), the material quickly become hot. This energy loss is called Eddy current loss. Due to Eddy current loss, rise in temperature of material takes place.

Eddy current loss : Power loss due to Eddy current is called Eddy current loss.

Mathematically,

$$\text{Eddy current loss} = K_e . B_m^2 . t^2 . f^2 . v \text{ watt}$$

Where,

K_e = coefficient of Eddy current and its value depends upon the nature of magnetic material.

B_m = maximum value of flux density in Wb/m^2.

t = thickness of lamination in metre.

f = frequency of reversal of magnetic field in Hz.

v = volume of magnetic materials in m^3.

FACTORS AFFECTING EDDY CURRENT LOSS

The following are the main factors responsible for Eddy current loss:

(a) **Lamination Thickness** : Eddy current loss is proportional to the square of thickness of lamination. Therefore, the Eddy current losses will keep on increasing with the thickness of lamination.

(b) **Volume of Material** : Eddy current loss is directly proportional to the volume of magnetic material.

(c) **Frequency**: Eddy current loss is directly proportional to the square of frequency. Therefore, Eddy current loss increases with the increase in frequency.

(d) **Maximum Flux Density** : Eddy current loss is directly proportional to the square of maximum value of flux density.

METHODS OF REDUCING EDDY CURRENT LOSS

Eddy current losses can be reduced by taking following steps:

1. Eddy current is reduced by using very thin laminations of the core. Usual thickness of lamination is about 0.5 mm.
2. Each lamination is insulated from each other by thin layer of varnish or oxide film.
3. Eddy current losses are reduced by using high specific resistance materials like Silicon, Steel etc.

Magnetic field	A force field radiating from the north pole to the south pole of a magnet.
Magnetic flux	The lines of force between the north pole and south pole of a permanent magnet or an electromagnet.
Weber (Wb)	The SI unit of magnetic flux, which represents 10^8 lines.
Permeability	The measure of ease with which a magnetic field can be established in a material.
Reluctance	The opposition to the establishment of a magnetic field in a material.

Magnetomotive force (mmf)

The cause of a magnetic field, measured in ampere-turns.

Solenoid

An electromagnetically controlled device in which the mechanical movement of a shaft or plunger is activated by a magnetizing current.

Hysteresis

A characteristic of a magnetic material whereby a change in magnetism lags the application of the magnetic field intensity.

Retentivity

The ability of a material, once magnetized, to maintain a magnetized state without the presence of a magnetizing current.

Induced voltage (v_{ind})

Voltage produced as a result of a changing magnetic field.

Faraday's law

A law stating that the voltage induced across a coil of wire equals the number of turns in the coil times the rate of change of the magnetic flux.

Lenz's law

A law stating that when the current through a coil changes, the polarity of the induced voltage created by the changing magnetic field is such that it always opposes the change in the current that caused it. The current cannot change instantaneously.

GENERATION OF POWER

POWER GEBNERATION

- **Conventional Energy Resources**:

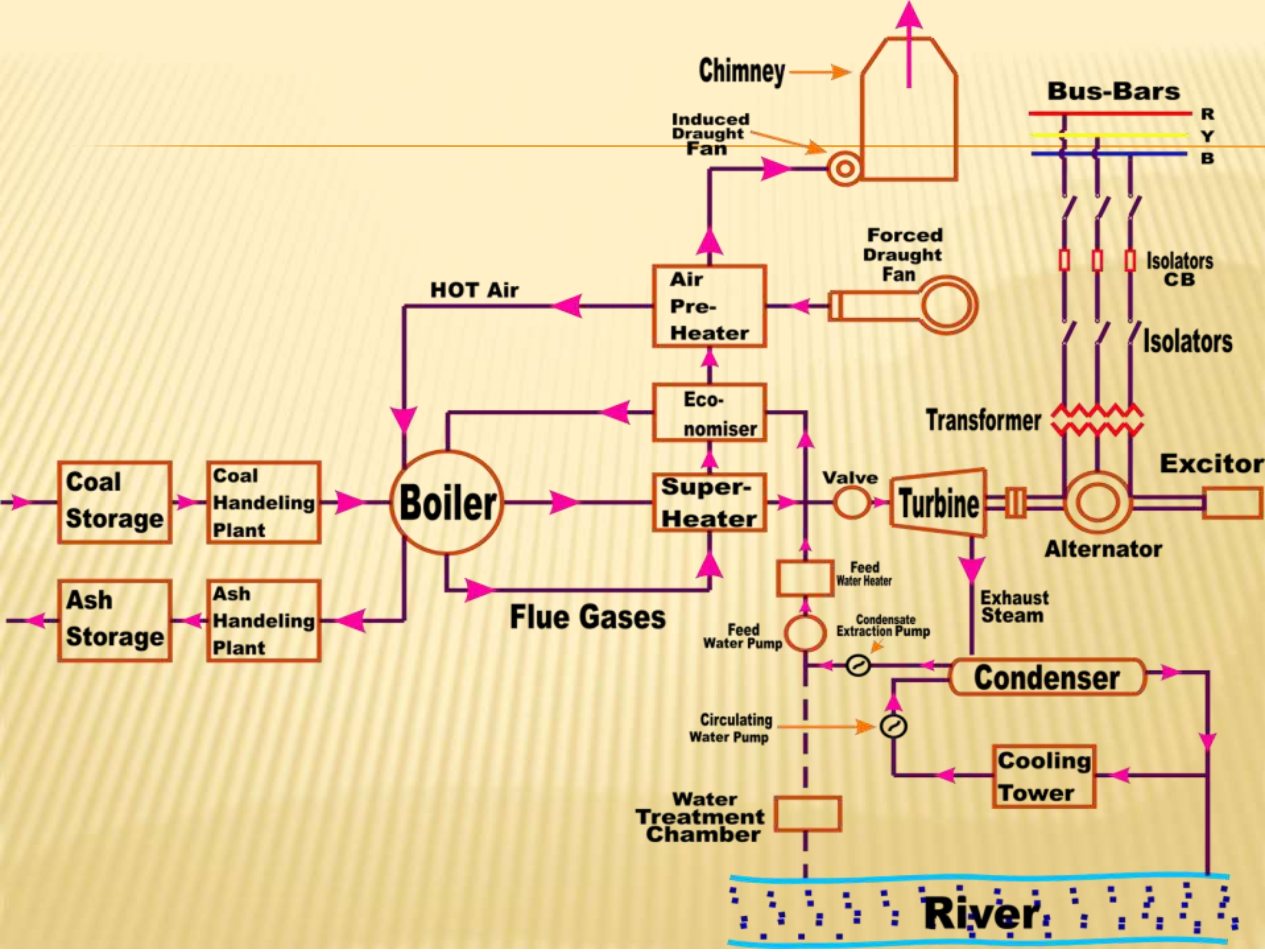
  Convection energy sources are naturally present and have been in use for years. The use of conventional sources is done for heating, lighting, cooking, running machinery, and provision of electricity. The examples for which include firewood, fossil fuels, and others.

- **Nonconventional Energy resources**:

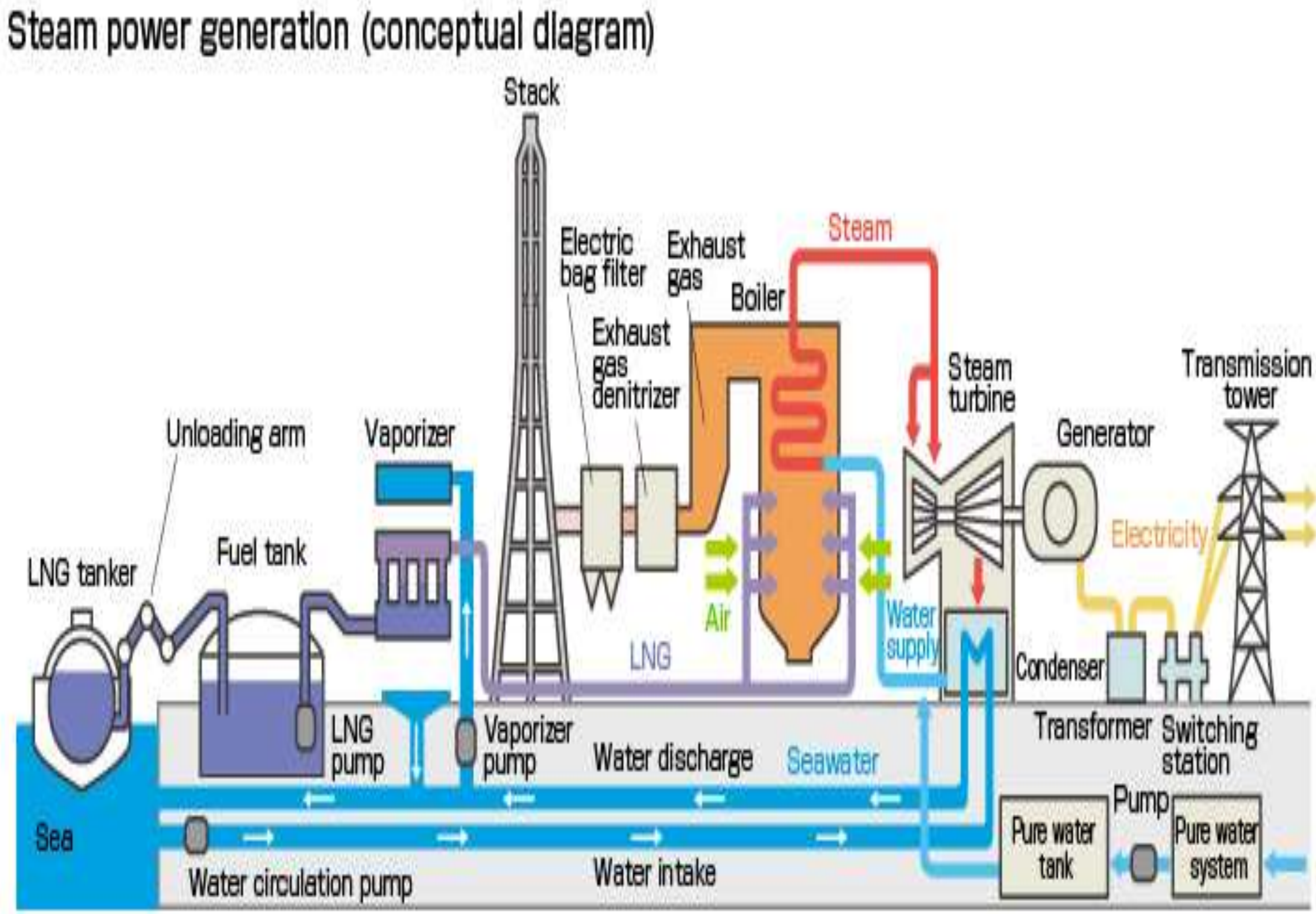
  Non- Conventional energy sources are the best alternatives to conventional sources while also non- polluting. Non-conventional sources could be obtained from sun, wind , Bio-mass, hot springs etc.

THERMAL POWER STATION

- Thermal power generation consists of **using steam power created by burning oil, liquid natural gas (LNG), coal, and other substances to rotate generators and create electricity.**
- Almost all **coal-fired power stations, petroleum, nuclear, geothermal, solar thermal electric, and waste incineration plants, as well as all natural gas power stations** are thermal.
- The block diagram wit energy flow is shown below:



Chimney
Bus-Bars
R
Y
B
Induced Draught Fan
Forced Draught Fan
Isolators CB
HOT Air
Air Pre-Heater
Isolators
Eco-nomiser
Transformer
Excitor
Valve
Coal Storage
Coal Handeling Plant
Boiler
Super-Heater
Turbine
Alternator
Feed Water Heater
Exhaust Steam
Ash Storage
Ash Handeling Plant
Flue Gases
Feed Water Pump
Condensate Extraction Pump
Condenser
Circulating Water Pump
Cooling Tower
Water Treatment Chamber
River



Steam power generation (conceptual diagram)
Stack
Electric bag filter
Exhaust gas
Steam
Boiler
Exhaust gas denitrizer
Steam turbine
Transmission tower
Unloading arm
Vaporizer
Generator
Electricity
Fuel tank
LNG tanker
Air
Water supply
LNG
Condenser
LNG pump
Vaporizer pump
Water discharge
Seawater
Transformer
Switching station
Pump
Sea
Pure water tank
Pure water system
Water circulation pump
Water intake

- **Coal:** In a coal based thermal power plant, coal is transported from coal mines to the generating station. Generally, bituminous coal or brown coal is used as fuel. The coal is stored in either 'dead storage' or in 'live storage'. Dead storage is generally 40 days backup coal storage which is used when coal supply is unavailable. Live storage is a raw coal bunker in boiler house. The coal is cleaned in a magnetic cleaner to filter out if any iron particles are present which may cause wear and tear in the equipment. The coal from live storage is first crushed in small particles and then taken into pulverizer to make it in powdered form. Fine powdered coal undergoes complete combustion, and thus pulverized coal improves efficiency of the boiler. The ash produced after the combustion of coal is taken out of the boiler furnace and then properly disposed. Periodic removal of ash from the boiler furnace is necessary for the proper combustion.

  Boiler: The mixture of pulverized coal and air (usually preheated air) is taken into boiler and then burnt in the combustion zone. On ignition of fuel a large fireball is formed at the center of the boiler and large amount of heat energy is radiated from it. The heat energy is utilized to convert the water into steam at high temperature and pressure. Steel tubes run along the boiler walls in which water is converted in steam. The flue gases from the boiler make their way through superheater, economizer, air preheater and finally get exhausted to the atmosphere from the chimney.

- **Superheater:** The superheater tubes are hanged at the hottest part of the boiler. The saturated steam produced in the boiler tubes is superheated to about 540 °C in the superheater. The superheated high pressure steam is then fed to the steam turbine.
- **Economizer:** An economizer is essentially a feed water heater which heats the water before supplying to the boiler.
- **Air pre-heater:** The primary air fan takes air from the atmosphere and it is then warmed in the air pre-heater. Pre-heated air is injected with coal in the boiler. The advantage of pre-heating the air is that it improves the coal combustion.

- **Steam turbine:** High pressure super heated steam is fed to the steam turbine which causes turbine blades to rotate. Energy in the steam is converted into mechanical energy in the steam turbine which acts as the prime mover. The pressure and temperature of the steam falls to a lower value and it expands in volume as it passes through the turbine. The expanded low pressure steam is exhausted in the condenser.

- **Condenser**: The exhausted steam is condensed in the condenser by means of cold water circulation. Here, the steam loses it's pressure as well as temperature and it is converted back into water. Condensing is essential because, compressing a fluid which is in gaseous state requires a huge amount of energy with respect to the energy required in compressing liquid. Thus, condensing increases efficiency of the cycle.

- **Alternator**: The steam turbine is coupled to an alternator. When the turbine rotates the alternator, electrical energy is generated. This generated electrical voltage is then stepped up with the help of a transformer and then transmitted where it is to be utilized.

ADVANTAGES AND DISADVANTAGES OF A THERMAL POWER PLANT

- **Advantages:**
- Less initial cost as compared to other generating stations.
- It requires less land as compared to hydro power plant.
- The fuel (i.e. coal) is cheaper.
- The cost of generation is lesser than that of diesel power plants.
- **Disadvantages:**
- It pollutes the atmosphere due to the production of large amount of smoke. This is one of the causes of global warming.
- The overall efficiency of a thermal power station is low (less than 30%)

HYDRO-ELECTRIC POWER PLANT

- A conventional dam holds water in a man-made lake, or reservoir, behind it. **When water is released through the dam, it spins a turbine connected to a generator that produces electricity.** The water returns to the river on the downstream side of the dam

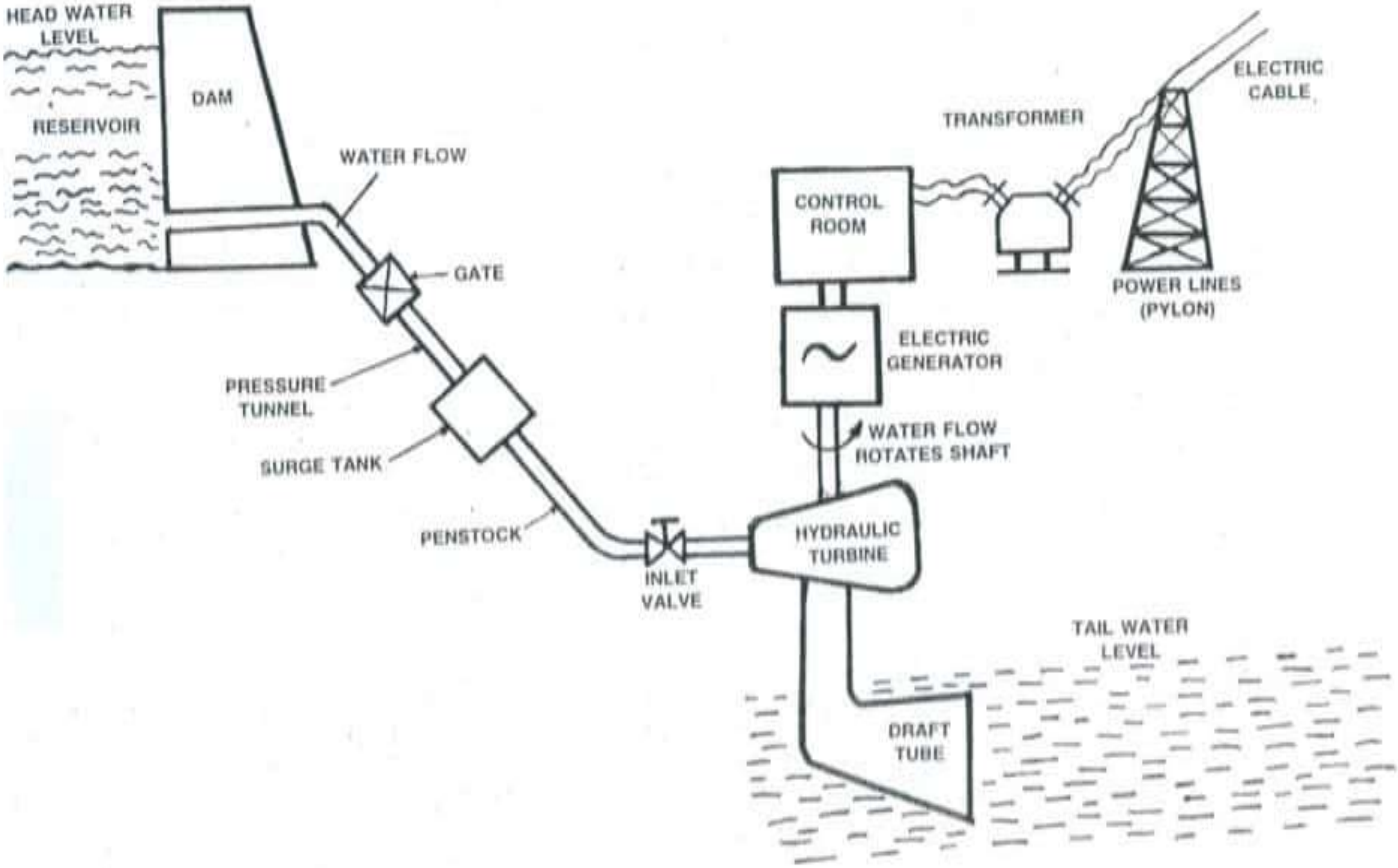
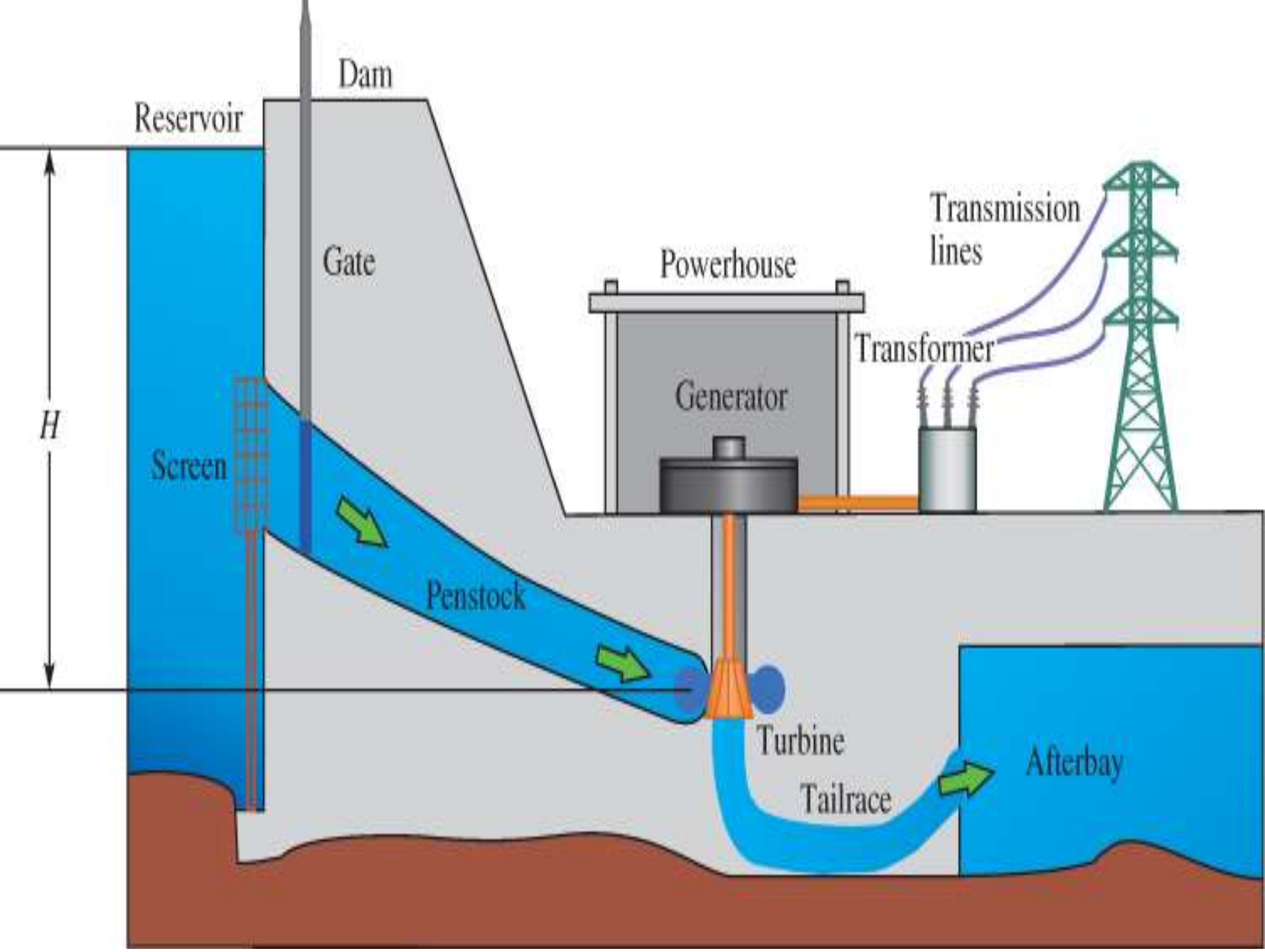


Fig.Layout of Hydro electric Power plant


Dam
Reservoir
Gate
Powerhouse
Transmission
lines
Transformer
Generator
H
Screen
Penstock
Turbine
Afterbay
Tailrace

PARTS OF HYDROELECTRIC POWER PLANT

- A hydroelectric power plant has the following parts:
- Dam or weir: it contains the river water, forming a reservoir behind it and thus creating a water drop that is used to produce energy. Dams can be made of earth or concrete (the latter is the most common one).
- Spillways: They release part of the impounded water without passing through the turbines; water can then be used for irrigation purposes. They are located on the main wall of the dam and can be at the top or at the bottom. Most of the water goes into a plunge pool at the toe of the dam, to prevent scour damage by the falling water.
- Water intakes: they let in the impounded water towards the turbines through a penstock. Water intakes have gates to control the amount of water that reaches the turbines and grids to filter out any debris such as trunks, branches, etc.

- <u>Powerhouse</u>: it houses the hydraulic and electrical equipment (turbines, generators, transformers) and the service area with control and testing rooms. It has inlet and outlet gates to ensure the equipment area can be dry in case of repairs or disassembling equipment.
- <u>Turbines</u>: they harness the energy of the water that goes through them to rotate around a shaft. There are three main types of turbines: Pelton, Francis and Kaplan turbines (propeller type).
- <u>Transformers</u>: electrical devices to increase or decrease the voltage in an alternating current circuit, while maintaining the electric power.
- <u>Electrical power transmission lines</u>: cables to transmit the electricity generated.

ADVANTAGES AND DISADVANTAGES OF HYDROPOWER PLANTS

Here are a few advantages of hydropower plants :

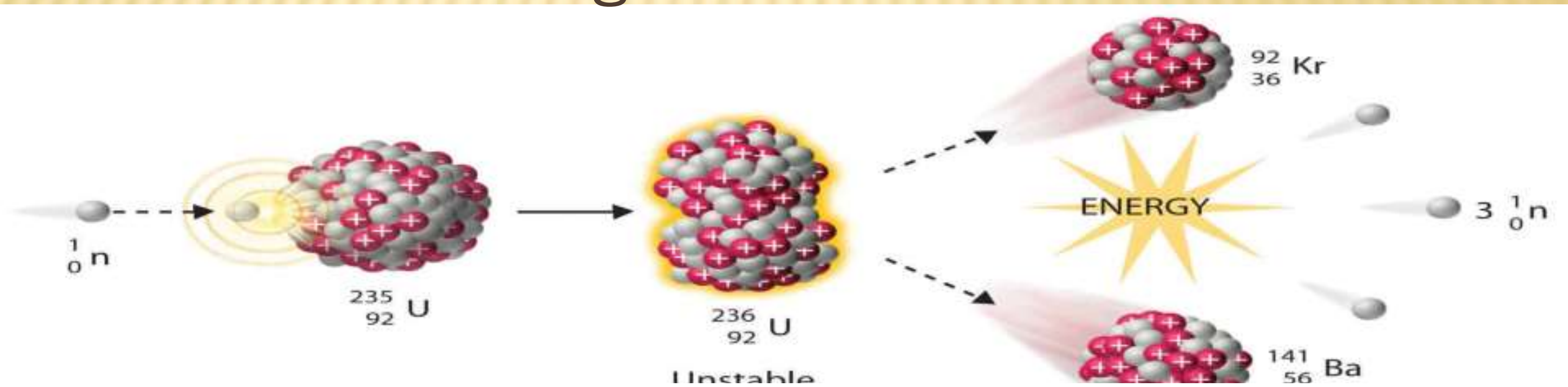
- Water is available throughout the year
- Operational and maintenance cost is lower than other power plants
- The cost of fuel is nil
- Hydro Plants are made for multiple purposes
- The requirement of working staff is less. The cost of expenses is lower as compared to other plants.

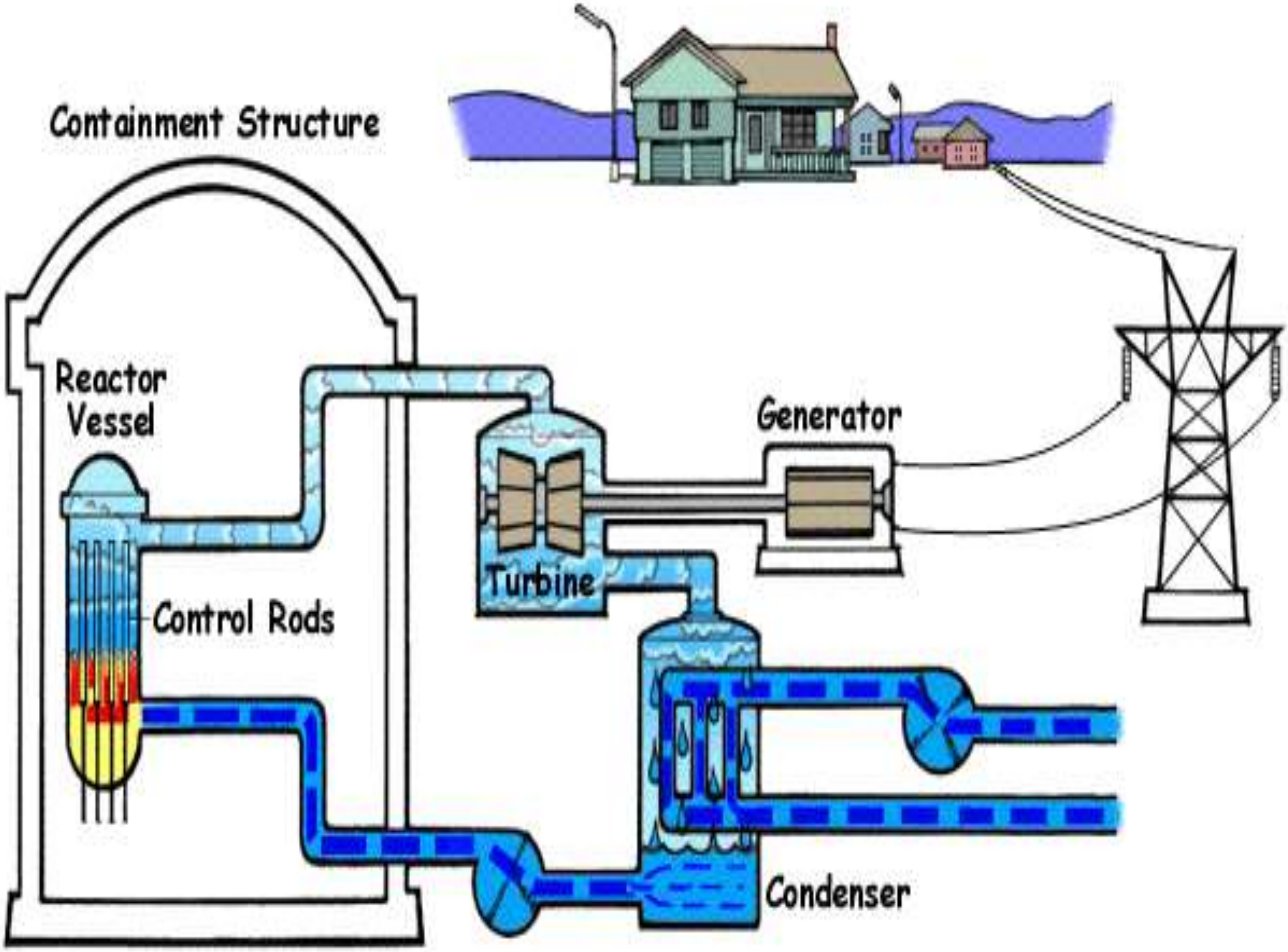
Listed are a few Disadvantages of Hydropower Plants.

- Embankment construction cost is high
- Land space requirement for set up is large
- Water must be abundant to continue the process
- Aquatic life is effected
- Embankment areas need to be evacuated for flood plains

NUCLEAR POWER PLANTS

- Nuclear power plants are **a type of power plant that use the process of nuclear fission in order to generate electricity.** They do this by using nuclear reactors in combination with the Rankine cycle, where the heat generated by the reactor converts water into steam, which spins a turbine and a generator.




Containment Structure
Reactor Vessel
Control Rods
Turbine
Generator
Condenser

BASIC COMPONENTS OF A NUCLEAR POWER PLANT

Nuclear Reactor

- A nuclear reactor is a special apparatus used to perform nuclear fission. Since the nuclear fission is radioactive, the reactor is covered by a protective shield. Splitting up of nuclei of heavy atoms is called as nuclear fission, during which huge amount of energy is released. Nuclear fission is done by bombarding slow moving neutrons on the nuclei of heavy element. As the nuclei break up, it releases energy as well as more neutrons which further cause fission of neighboring atoms. Hence, it is a chain reaction and it must be controlled, otherwise it may result in explosion. A nuclear reactor consists of fuel rods, control rods and moderator. A fuel rod contains small round fuel pallets (uranium pallets). Control rods are of cadmium which absorb neutrons. They are inserted into reactor and can be moved in or out to control the reaction. The moderator can be graphite rods or the coolant itself. Moderator slows down the neutrons before they bombard on the fuel rods.

- **Two types of nuclear reactors that are widely used -**
  Pressurised Water Reactor (PWR) -
  This type of reactor uses regular water as coolant. The coolant (water) is kept at very high pressure so that it does not boil. The heated water is transferred through heat exchanger where water from secondary coolant loop is converted into steam. Thus the secondary loop is completely free from radioactive stuff. In a PWR, the coolant water itself acts as a moderator. Due to these advantages, pressurised water reactors are most commonly used.

- **Boiling Water Reactor (BWR)** -
  In this type of reactor only one coolant loop is present. The water is allowed to boil in the reactor. The steam is generated as it heads out of the reactor and then flows through the steam turbine. One major disadvantage of a BWR is that, the coolant water comes in direct contact with fuel rods as well as the turbine. So, there is a possibility that radioactive material could be placed on the turbine.

Heat Exchanger

- In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water). Thus water from the secondary loop is converted into steam. The primary system and secondary system are closed loop, and they are never allowed to mix up with each other. Thus, heat exchanger helps in keeping secondary system free from radioactive stuff. Heat exchanger is absent in boiling water reactors.

Steam Turbine

- Generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft.

Alternator

- The steam turbine rotates the shaft of an alternator thus generating electrical energy. Electrical output of the alternator is the delivered to a step up transformer to transfer it over distances.
- The steam coming out of the turbine, after it has done its work, is then converted back into water in a condenser. The steam is cooled by passing it through a third cold water loop.

COMPARISION OF VARIOUS POWER PLANTS

S.No.	Item	Steam Power Station	Hydro-electric Power Plant	Diesel Power Plant	Nuclear power Plant
7.	*Overall efficiency*	Least efficient. Overall efficiency is about 25%.	Most efficient. Overall efficiency is about 85%.	More efficient than steam power station. Efficiency is about 35%.	More efficient than steam power station.
8.	*Starting*	Requires a lot of time for starting.	Can be started instantly.	Can be started quickly.	Can be started easily.
9.	*Space required*	These plants need sufficient space because of boilers and other auxiliaries.	Require very large area because of the reservoir.	Require less space.	These require minimum space as compared to any other plant of equivalent capacity.
10.	*Maintenance cost*	Quite high as skilled operating staff is required.	Quite low.	Less	Very high as highly trained personnel are required to handle the plant.
11.	*Transmission and distribution cost*	Quite low as these are generally located near the load centres.	Quite high as these are located quite away from the load centres.	Least as they are generally located at the centre of gravity of the load.	Quite low as these are located near load centres.
12.	*Standby losses*	Maximum as the boiler remains in operation even when the turbine is not working.	No standby losses.	Less standby losses.	Less.

ECONOMICS OF GENERATION

Fixed Cost

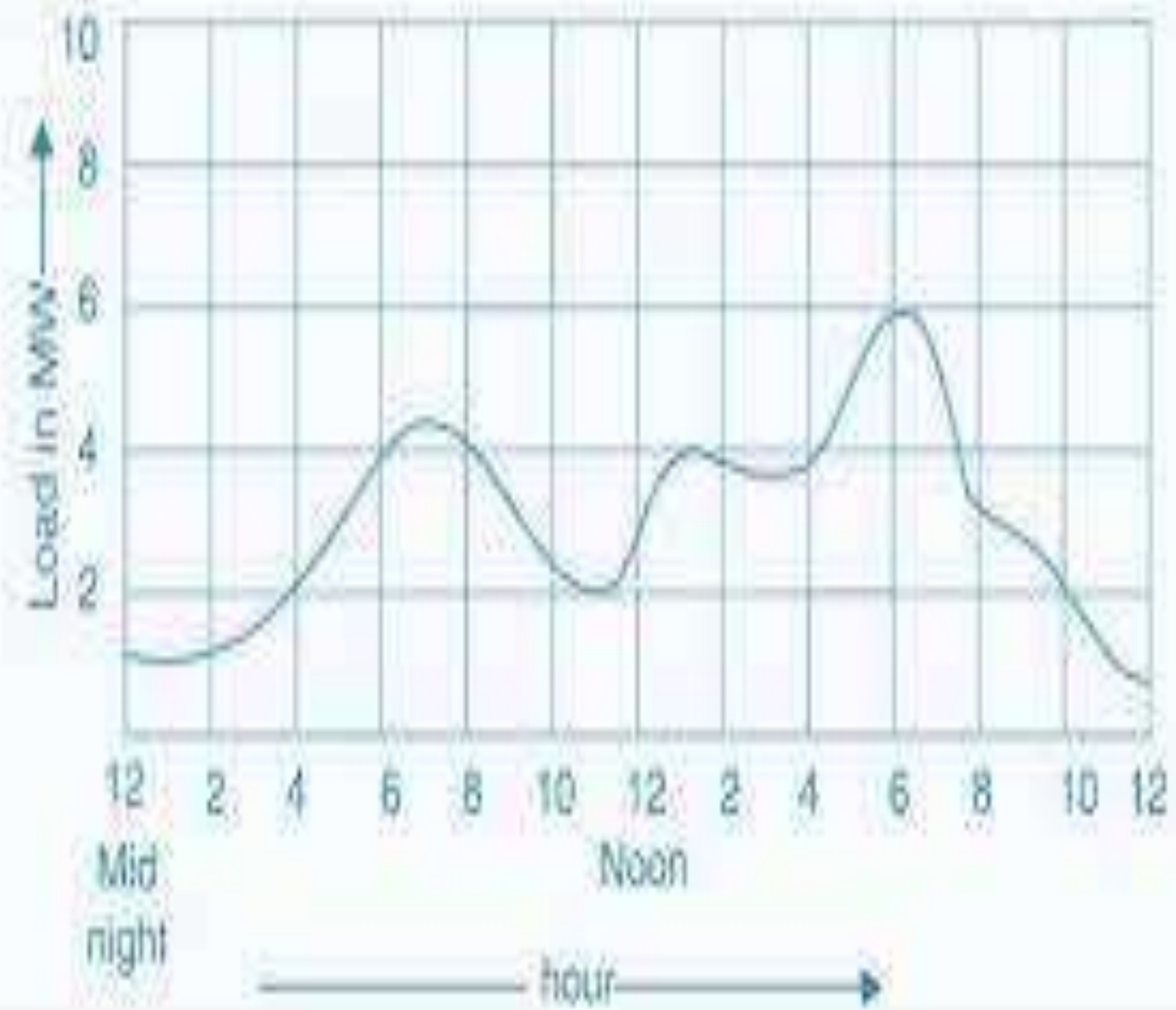
- As the name implies, such cost remains constant. It is independent of the maximum demand, the plant capacity and the energy generated.
  Fixed cost includes:
  Annual charges of the central organization management
- Salary of the employees (usually higher officials)
- Interest on the land costs
- All of these costs are fixed, and hence, fixed cost remains constant under all conditions.

Semi-Fixed Cost

- Such charges are independent of the energy (kWh) generated but depend upon the maximum demand.Higher the max demand, the greater the semi-fixed costs.
  Semi-fixed cost includes:
  Interest and depreciation on the capital costs (investment and insurance) on the land, the buildings (construction costs) and the costs of the equipment needed for generation, transmission and distribution of the electricity.
- The capital investment of the plant is huge and usually loaned.
- The interest of this loaned amount is considered in the cost of production.
- Such interest may range up to 8% depending upon the market conditions.
- The depreciation mentioned above relates to the reduction in value of the equipment that are used constantly.
- Due to wear and tear, the depreciation occurs and such depreciation costs are also included in the fixed and semi-fixed charges.
- Semi-fixed charges will also include the salaries of the management and other (clerical) staff, since these depend upon the size (and cost) of installation which again depends on the max demand.

LOAD CURVE

- A graphical plot showing the variation in demand for energy of the consumers on a source of supply with respect to time is known as the **load curve.**
- If this curve is plotted over a time period of 24 hours, it is known as **daily load curve.** If its plotted for a week, month, or a year, then its named as the **weekly, monthly or yearly load curve** respectively. The **load duration curve** reflects the activity of a population quite accurately with respect to electrical power consumption over a given period of time. To understand the concept better its important that we take the real life example of load distribution for an industrial load and a residential load, and have a case study on them, to be able to appreciate its utility from the perspective of an electrical engineering


10
8
6
4
2
Load in MW
12
2
4
6
8
10
12
2
4
6
8
10
12
Mid
night
Noon
hour

DEMAND FACTOR

- The demand factor of an electric power station is defined as the ratio of maximum demand on the power station to its connected load, i.e.,

DemandFactor=MaximumDemand/ConnectedLoad

- Generally, the value of demand factor is less than 1. It is because the maximum demand on the power station is usually less than the connected load to the power station. The knowledge of demand factor is important in determining the capacity of equipment of the power plant.

LOADFACTOR

- The load factor of a power station is defined as the ratio of average load to the maximum demand on the power station during a given period. he load factor can be *daily load factor, monthly load factor* or annual load factor if the time period (T) considered is a day or a month or a year respectively. The load factor of a power station is always less than 1. It is because the average load on the power station is smaller than the maximum demand. The load factor is very important because it is used to determine the overall cost per unit generated, i.e., if the load factor of the power station is higher, then the cost per unit generated will be lesser.

DIVERSITY FACTOR

- The diversity factor of the power station is defined as the ratio of sum of individual maximum demands to the maximum demand on the power station.
- The diversity factor of a power station is always greater than 1. The diversity factor plays a vital role in the determination of cost of generation of power. The greater is the diversity factor, the lesser is the cost of generation of power.

PLANT USE FACTOR AND RESERVE CAPACITY

- It is **the ratio of units generated to the product of plant capacity and the number of hours for which the plant was in operation.**
- is **a backup energy generation capacity that is used by the electric grid in the occurrence of unexpected fault such as the unavailability of a power plant.** Energy storage systems have the ability to provide this service and are used to offset or reduce costs incurred for generation of reserve capacity.

IMPORTANCE OF LOAD FACTOR

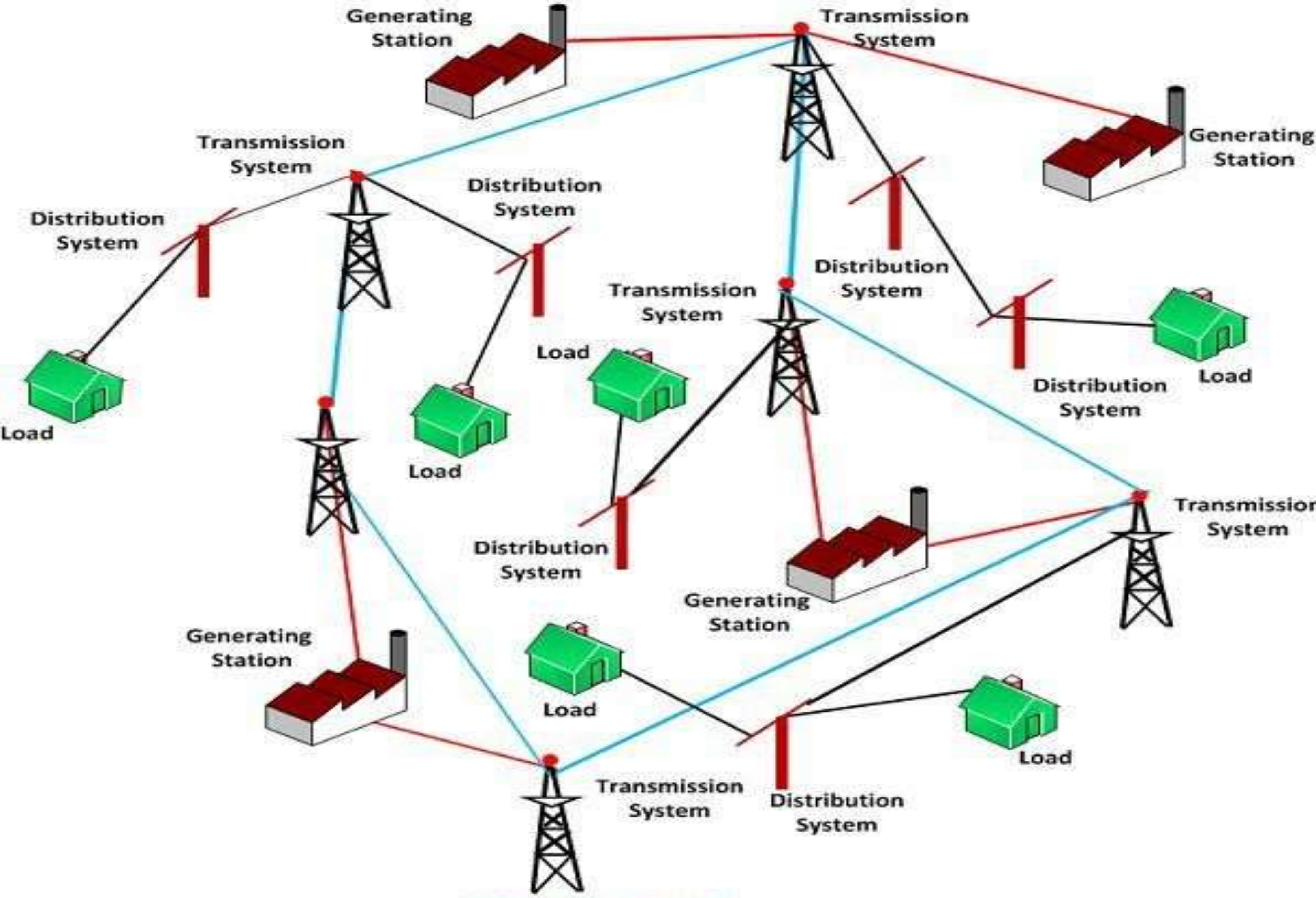
- Higher value of load factor means lower will be cost per unit generated and vice versa it is desirable that the value of load factor always higher.
- Higher the load factor means lower maximum demand or higher average demand (or higher number of unit generation for a given time)
- As tariff charges depends upon fixed part-maximum demand and variable part number of units consumption.
- Lower value maximum demand, resulting lower fixed charges of tariff which is distributed among large number of units generated therefore overall cost per unit generation is reduced.
- As the number of unit generation for a given time increases, the load factor also increases.
- Greater number of unit generation for a given plant, means cost per unit decreases.

IMPORTANCE OF DIVERSITY FACTOR

- Lower the value of maximum demand, higher the diversity factor as vice versa.
- The capital cost of power station depends upon capacity of the power station.
- Lower the maximum demand, lower the capital required for the power station.
- For a given number of consumers, higher the diversity factor of load, smaller will be capacity of the plant therefore fixed charges for the plant will be reduced.
- Therefore the utility company always tries to increases load factor as well as diversity factor.

TYPES OF ELECTRICAL GRID

- The power station of the grid is located near the fuel source which reduces the transportation cost of the system. But it is located far away from the populated areas. The power which is generated at high voltage is stepped down by the help of step down transformer in the substation and then supply to the consumers.The electrical grid is mainly classified into two types. They are
- **Regional Grid** – The Regional grid is formed by interconnecting the different transmission system of a particular area through the transmission line.
- **National Grid** – It is formed by interconnecting the different regional grid.



Electrical Grid

ADVANTAGES OF INTERCONNECTED POWER SYSTEM

- 1) Use of older plants
- 2) Economical operation
- 3) Increase reliability of power supply
- 4) Exchange of peak load
- 5) Increase diversity factor
- 6) Reduce plant reserve capacity
- 7) Reduce capital and operating cost

TRANSSMISSION SYSTEM

- Transmission lines **carry electric energy from one point to another in an electric power system**. They can carry alternating current or direct current or a system can be a combination of both.

Different types of transmission systems

- Single phase AC system. single phase, two wires. single phase, two wires with midpoint earthed. ...
- Two phase AC system. two-phase, three wires. two-phase, four wires.
- Three phase AC system. three-phase, three wires. three-phase, four wires.
- DC system. DC two wires.

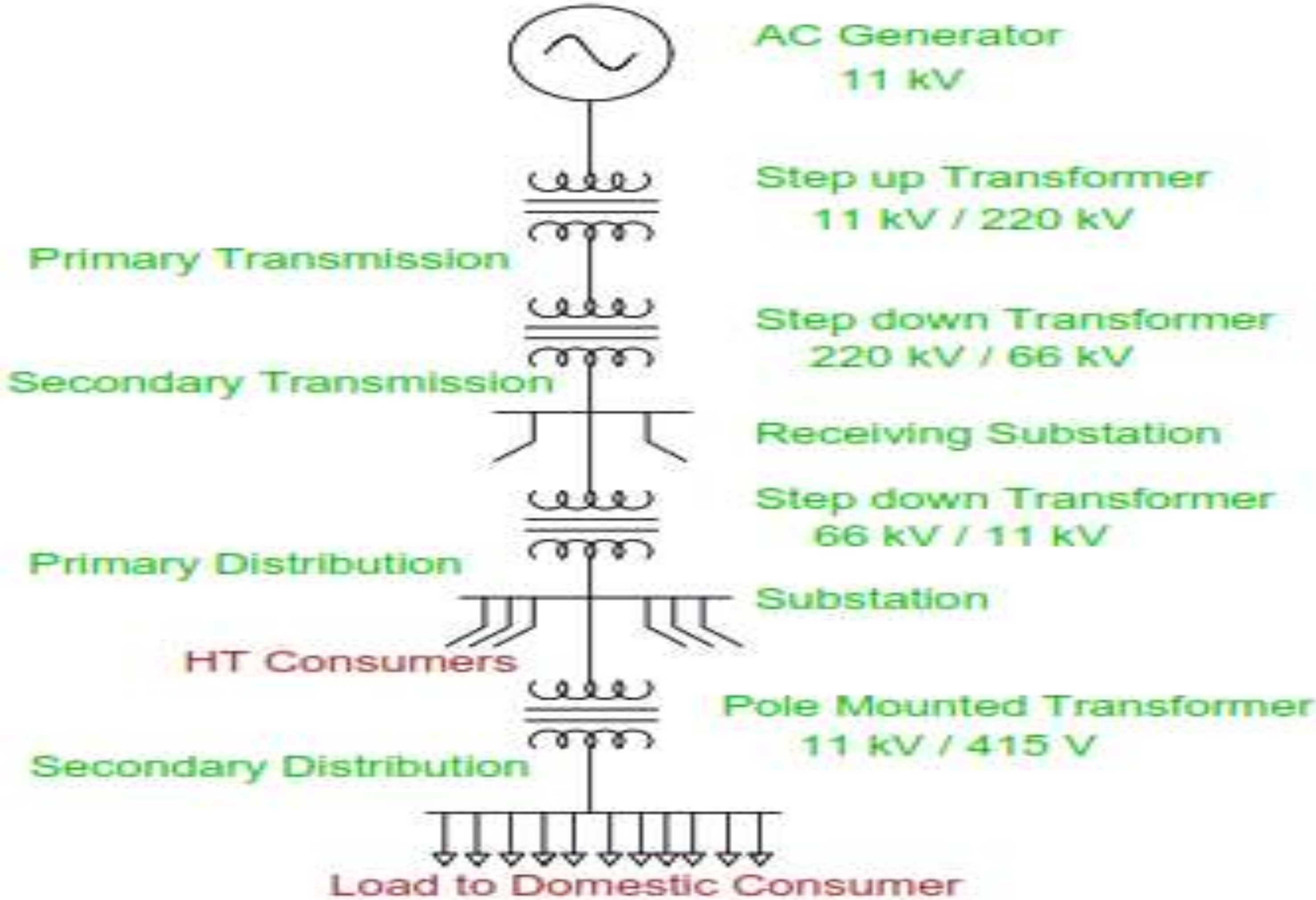


FIG : Single Line Diagram of Power Supply System

ADVANTAGES OF DC TRANSMISSION

- There are two conductors are used in DC transmission while three conductors are required in AC transmission.
- There are no inductance and surges (High Voltage waves for very short time) in DC transmission.
- Due to the absence of inductance, there are very low voltage drop in DC transmission lines as compare to the AC (if both Load and Sending end Voltage is same)
- There is no concept of Skin effect in DC transmission lines. Therefore, conductor having small cross sectional area is required in DC transmission line.
- A DC System has a less potential stress over AC system for same Voltage level. Therefore, a DC line requires less insulation.
- In DC System, there is no interference with other communication lines and systems.
- In DC Line, Corona losses are very low as compared to the AC transmission lines.
- In High Voltage DC (HVDC) Transmission lines, there are no dielectric losses.
- In DC Transmission system, there are no difficulties in synchronizing and related stability problems.
- DC system is more efficient than AC, therefore, the rate of price of Towers, Poles, Insulators, and conductor are low so the system is economical.
- In DC System, the speed control range is greater than AC System.
- There is low insulation needed in the DC system (about 70%).
- The price of DC cables is low (due to low insulation).
- In DC Supply System, the Sheath losses in underground cables are low.
- DC system is suitable for High Power Transmission based on High Current transmission.
- In DC System, The Value of charging current is quite low, therefore, the length of the DC Transmission lines is greater than AC lines.

DISADVANTAGES OF DC TRANSMISSION:

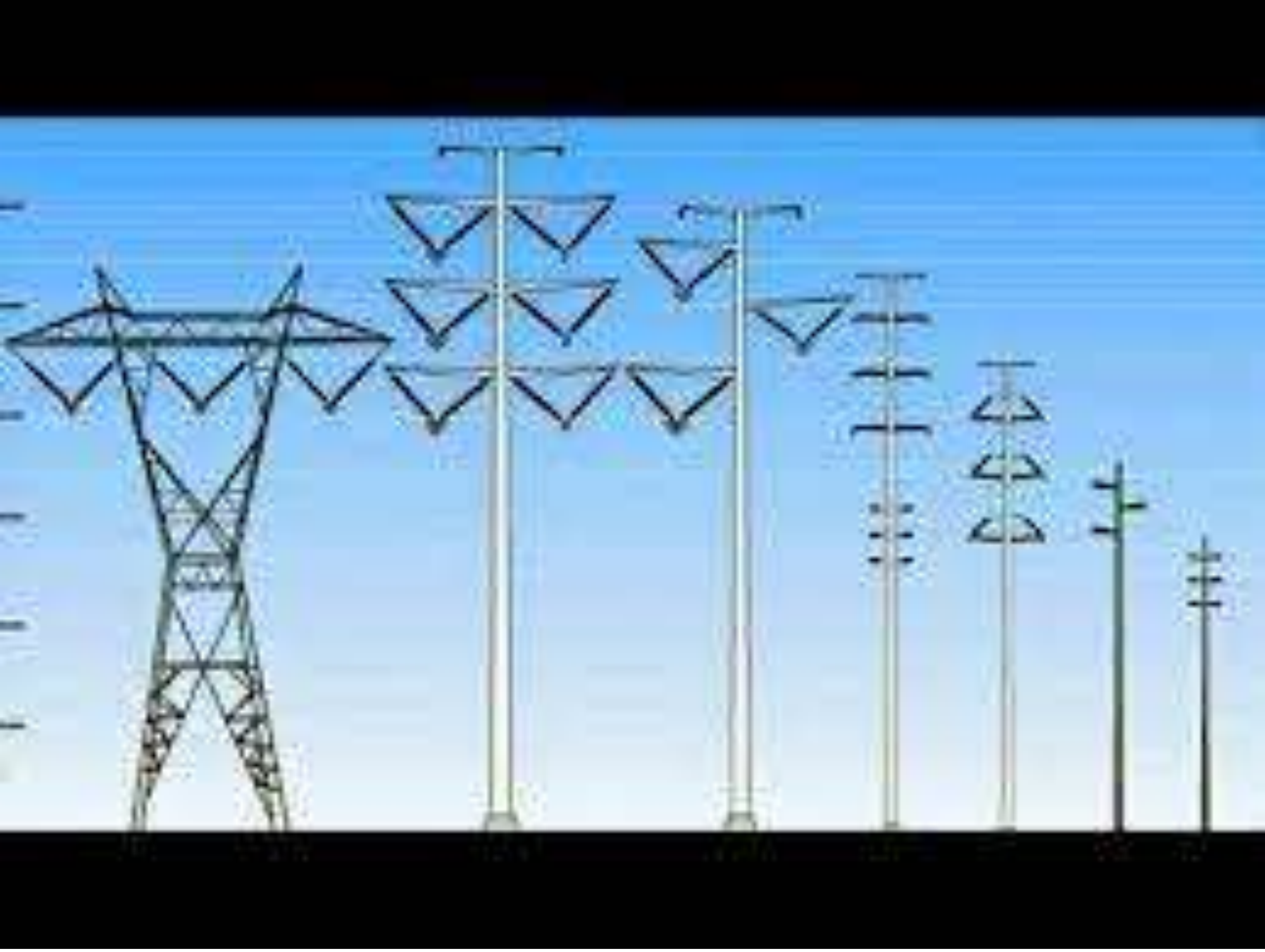
- Due to commutation problem, electric power can't be produced at High (DC) Voltage.
- In High Voltage transmission, we cant step-up the level of DC Voltage (As Transformer won't work on DC).
- There is a limitation of DC switches and circuit breakers (and they are costly too).
- The motor generator set is used to step down the level of DC voltage and the efficiency of Motor-generator set is lower than a transformer.
- DC transmission system is more complex and costly as compared to the AC transmission system..
- The level of DC Voltage can not be changed (step-up or step-down) easily. So we can not get desire voltage for electrical and electronics appliances (such as 5 Volts, 9 Volts 15 Volts, 20 and 22 Volts etc) directly from the transmission and distribution lines.

CONSTRUCTION FEATURES OF A TRANSMISSION LINE

- These transmission lines will use **a combination of lattice towers and support poles**. The materials for construction needed for each tower are brought to site and distributed along the right-of-way where the towers will be built. Smaller poles are placed between the towers to support the transmission cables

SUPPORTING STRUCTURES

- The supporting structures used for overhead transmission line conductors, such as **poles and towers**, are called the transmission line supports. The line supports should have high mechanical strength so that it can withstand the weight of conductors and wind loads.



INSULATOR

- A material that does not let electricity and heat travel through it is known as an insulator. The electrical insulator is a protector or protective device that finds a use for connecting many electrical components. It plays a notable role in the making of various electrical and electronic circuits and overhead power systems.
- The overhead line conductors on the poles are supported by an Insulator, which prevents current flow toward the ground. The transmission lines must function properly. Different materials, such as rubber, wood, plastic, mica, and others, can be used to create an insulator

- **Insulator properties**
- Insulators have some specific properties that make them different from other electrical devices. These are some features of insulators:
- High resistivity
- Good mechanical strength for the conductor load
- The high relative permittivity of insulator material
- Good dielectric strength
- Waterproof or non-porous
- Types of insulator materials
- Insulators consist of different types of insulator materials like plastic, rubber, mica, wood, glass, etc. In the electrical system, specific insulating materials are used like porcelain, glass, steatite, polymer, ceramic, PVC.

- **The importance of insulators**
- Help to protect from heat, noise, and electricity
- Support the overhead conductor
- Insulate the live parts of equipment or conductor from the earth
- Help to save switchgear, transformer, and other systems in a substation
- **Types of insulator**
- 4 Main Types of Insulator are:
- **Pin insulator**
- **Post insulator**
- **Suspension insulator**
- **Shackle insulator**

PIN TYPE INSULATOR

An insulator that isolates a wire from physical support, such as a pin on a utility pole or tower, is known as pin type insulator. It is the first developed insulators and being used for overhead lines. As the name suggests, the pin insulator is secured to the cross-arm on the pole. A pin insulator consists of nonconducting material such as porcelain, glass, plastic, polymer, or wood. Pin type insulators find a use for transmission and distribution of electric power at voltages up to 33 kV. Beyond operating voltage of 33 kV, the pin type insulators become too bulky and hence uneconomical.

- Pin insulator specifications
- It has high mechanical strength.
- It requires less maintenance as compared to other insulator types.
- Pin insulator pros
- Good creepage distance
- Simple in construction and cheap in cost
- Easy maintenance
- Can be used both vertically & horizontally
- Applicable to a high voltage transmission line.
- The mechanical strength of this insulator is high.

SUSPENSION TYPE INSULATORS

These insulators **consist of a number of porcelain discs connected in series by metal links in the form of a string.** The line conductor is suspended at the bottom end of this string and the other end of the string is fixed to the cross-arm of the steel tower

ADVANTAGES OF SUSPENSION INSULATORS:

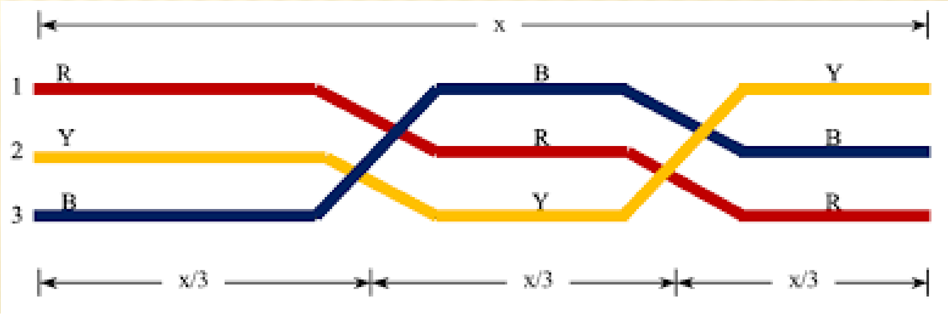
- Suspension insulators are cheaper in cost compared to pin type insulators for operating voltage above 50kV
- Each unit of suspension insulators (insulator disc) is designed for comparatively low voltage (11kV) and can be increase the insulation strength by connecting these insulator disc modules in series. The number of insulator discs require depends on the operating voltage
- Suspension type insulators give more flexibility to the line and mechanical stresses due to wind and other factors are reduced in this suspension type insulator arrangement. The connection at the cross arm is such a way that the insulator string is free to swing in any direction and thus takes up a position where it experiences only a pure tensile stress
- The suspension type insulators when used in conjunction with steel supporting structure has the advantage of rendering the conductor less liable to the affected by cross-arm thus enabling the tower to function as lightning ro

SHACKLE INSULATOR

- An insulator that is used in distribution networks that works with low voltage is known as a shackle insulator. This insulator is also known as a spool insulator. These insulators can be worked in two positions like horizontal otherwise vertical. At present, the usage of this insulator has decreased because of the underground cable used in distribution purposes.

TRANSPOSITION OF CONDUCTORS

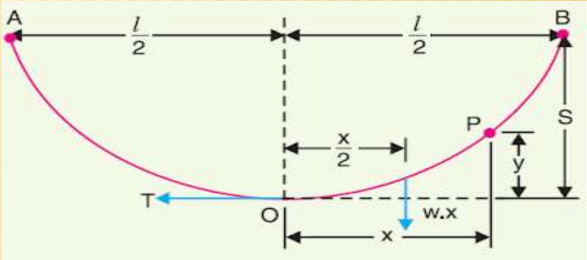
- Transposition is **the periodic swapping of positions of the conductors of a transmission line, in order to reduce crosstalk and otherwise improve transmission**. In telecommunications this applies to balanced pairs whilst in power transmission lines three conductors are periodically transposed.



SAG

- In a transmission line, **sag** is defined as the vertical difference in level between points of support (most commonly transmission towers) and the lowest point of the conductor. The calculation of sag and tension in a transmission line depends on the span of the overhead conductor.
- Span having equal level supports (i.e. towers of the same height) is called **level span**. Conversely, when the span has unequal levels of support, this is known as **unequal level span**.

- Let us consider an overhead line supported at two different towers which are at same level from ground. The point of support are A and B as shown in figure below. O in the figure shows the lowest point on the conductor. This lowest point O lies in between the two towers i.e. point O bisects the span equally.



Let,

L = Horizontal distance between the towers i.e. Span

W = Weight per unit length of conductor

T = Tension in the conductor

Let us take any point P on the conductor.

Assuming O as origin, the coordinate of point P will be (x,y).

Therefore, weight of section OP = Wx acting at distance of x/2 from origin O.

As this section OP is in equilibrium, hence net torque w.r.t point P shall be zero.

Torque due to Tension T = Torque due to weight Wx

$Ty = Wx(x/2)$

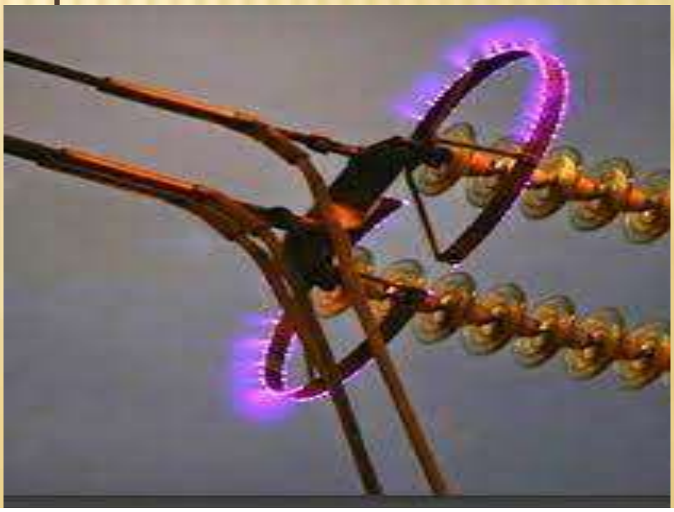
Therefore, **$y = Wx^2 / 2T$ ....(1)**

For getting Sag, put x = L/2 in equation (1)

Sag = $WL^2/8T$

CORONA

- **This phenomenon occurs when the electrostatic field across the transmission line conductors produces the condition of potential gradient.** The air gets ionized when the potential gradient at the conductor surface reaches the value of 30kV/cm at normal pressure and temperature



- **Factors Affecting Corona Discharge:**
- Supply Voltage: As the electrical corona discharge mainly depends upon the electric field intensity produced by the applied system voltage. ...
- Conductor Surface: The corona effect depends upon the shape, material and conditions of the conductors

METHODS OF REDUCING CORONA EFFECT:

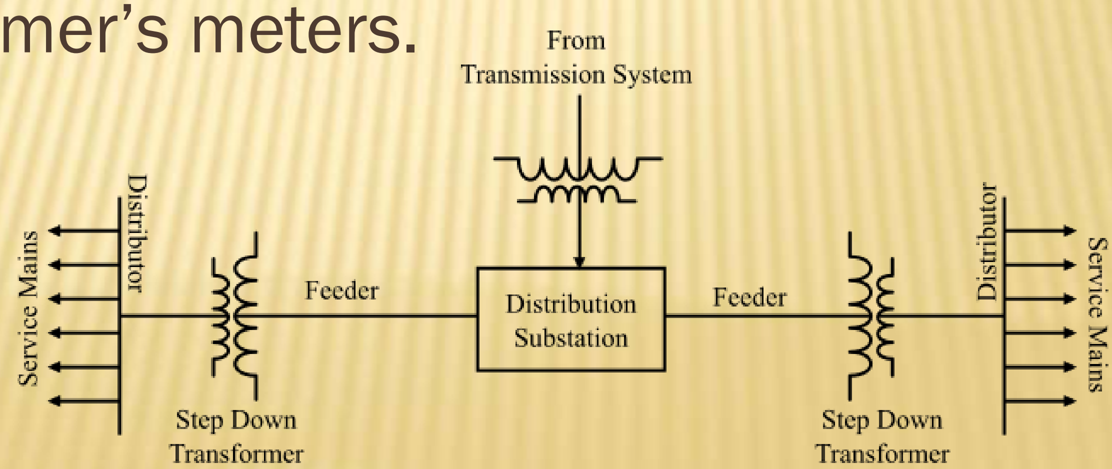
It has been seen that intense **corona effects** are observed at a working voltage of 33 kV or above.Therefore, careful design should be made to avoid corona on the sub-stations or bus-bars rated for 33kV and higher voltages otherwise highly ionised air may cause flash-over in the insulators or between the phases, causing considerable damage to the equipment. The following are the **methods of reducing corona effect** :

(i) By increasing conductor size : By increasing conductor size, the voltage at which corona occurs is raised and hence corona effects are considerably reduced.This is one of the reasons that ACSR conductors which have a larger cross-sectional area are used in transmission lines.

(ii) By increasing conductor spacing : By increasing the spacing between conductors, the voltage at which corona occurs is raised and hence **corona effects** can be eliminated.However, spacing cannot be increased too much otherwise the cost of supporting structure (e.g., bigger cross arms and supports) may increase to a considerable extent.

DISTRIBUTION SYSTEM

- The part of the power system that distributes electric power for local use is called as *distribution system*. Generally, a distribution system is the electrical system between the substation fed by transmission system and the consumer's meters.



COMPONENTS OF DISTRIBUTION SYSTEM

- **Distribution Sub-Station** – A distribution sub-station is the electrical system which transfers power from transmission system to the distribution system of an area.
- **Feeders** – A feeder is a conductor which connects the distribution sub-station to the area where power is to be distributed. The current in a feeder remains the same throughout its length because no tapings are taken from it. The main consideration in the design of a feeder being its current carrying capacity.
- **Distribution Transformers** – The distribution transformer is a step-down transformer in which primary and secondary are delta and star connected respectively. It is also termed as *service transformer*. The output voltage of distribution transformer is 440 V in 3-phase system whereas 230 V in 1-phase system in India.
- **Distributor** – A distributor is a conductor from which tapings are taken for supply to the consumers. Due to the taping is done at various places in a distributor, the current being not same throughout its length. The main design consideration of a distributor is the voltage drop across its length because the statutory limit of voltage variations is ± 6 % of rated voltage at the consumer's terminals.
- **Service Mains** – Service Mains is a small cable which connects the distributor to the consumer's meter.

CLASSIFICATION OF DISTRIBUTION SYSTEM

- **Classification based on the *nature of current*** –
- DC distribution system
- AC distribution system
- **Classification based on the *type of construction*** –
- Over-head system
- Under-ground system
- **Classification based on the *scheme of connection*** –
- Radial system
- Ring main system
- Inter-connected system
- Types of AC Distribution System
- Primary Distribution System
- The primary distribution system is the part of AC distribution system which operates at voltages slightly higher than general utilization. The voltage used for primary distribution depends upon the amount power to be transferred and distance of substation required to be fed. The commonly used primary distribution voltages are 11 kV, 6.6 kV and 3.3 kV. The primary distribution is done by 3-phase 3-wire system because of economic considerations.
- Secondary Distribution System
- The secondary distribution system includes those ranges of voltage at which consumer utilises the electrical energy. In India, the secondary distribution employs 440V (3-phase) & 230V (1-phase), 3-phase 4-wire system.

REQUIREMENTS OF A DISTRIBUTION SYSTEM

Some of the requirements of a good distribution system are –

- **Proper Voltage** – The voltage variations at consumer's terminals should be as low as possible. The statutory limit of voltage variations is ± 6 % (India) of the rated voltage at consumer's terminals.
- **Availability of Power on Demand** – The electric power must be available to the consumers in any amount that they may require from time to time.
- **Reliability** – The modern industry is almost dependent on electric power for its operation. This calls for reliable service as much possible.

REFRENCES

- https://www.tutorialspoint.com/
- https://en.wikipedia.org ›
- https://www.electricaltechnology.org
- www.electrical engineering.com
- www.electrical4u.com
- www.electrical engineering dost.com
- https://www.electricaleasy.com/

ELECTRICAL MEASURING INSTRUMENTS AND INSTRUMENTATION

TABLE OF CONTENTS

TABLE OF CONTENTS

- *Diploma holders in Electrical Engineering have to work on various jobs in the field as well as in testing laboratories and on control panels, where be performs the duties of installation, operation, maintenance and testing by measuring instruments.*
- *Instruments used to read and observe the general electrical quantities like current, voltage, power, energy, frequency, resistance etc and their wave shapes, have been incorporated in this subject. So the technician will know the construction and use of various types of electrical instruments.*

TABLE OF CONTENTS

DETAILED CONTENTS

TABLE OF CONTENTS

2. Ammeters and Voltmeters (Moving coil and moving iron type): (08 Periods)

- *2.1 Concept of ammeter and voltmeters and difference between them*
- *2.2 Construction and working principles of moving Iron and moving coil instruments*
- *2.3 Merits and demerits, sources of error and application of these instruments*

3. Wattmeters (DynamometerType) (04 Periods)

- *Construction, working principle, merits and demerits of dynamometer type wattmeter, Digital wattmeters.*

TABLE OF CONTENTS

4. Energymeter (06 Periods)

a) Induction Type

Construction, working principle, merits and demerits of single-phase and three-phase energy meters

- *Errors and their compensation*
- *Simple numerical problems*
- *Construction and working principle of maximum demand indicators*

b) Digital energy meter (diagram, construction and application)

TABLE OF CONTENTS

5. Miscellaneous Measuring Instruments:
(12 Periods)

- *Construction, working principle and application of Meggar, Earth tester(analog and digital) Multimeter, Frequency meter (dynamometer type) single phase power factor meter (Electrodynamometer type). Working principle of synchroscope and phase sequence indicator, tong tester (Clamp-on meter)*
- *Instrument Transformers: Construction, working and applications*

- *CT*
- *PT*

TABLE OF CONTENTS

6. *Electronic Instruments:* *(06 Periods)*

6.1 Cathode Ray Oscilloscope: Block diagram, working principle of CRO and its various controls. Applications of CRO.

- *Digital multi-meter (only block diagram) and Applications*

7. LCR meters.
(04 Periods)

- *Study of LCR meters and their applications*

TABLE OF CONTENTS

8. Power Measurements in 3-phase circuits by (06 Periods)

- *Two wattmeter method in balanced and unbalanced circuits and simple problems*
- *Three wattmeter method*

9. Transducers :- (04 Periods)

- *Introduction, Types of Transducers (1 phase,3 phase)*
- *Basic concept of pressure measurement, flow measurement, level measurement, displacement measurement using transducers*

10. Measurement of Temperature (04 Periods)

- *Different types of thermometers, thermocouple, resistance temperature detector and their construction, principle and working. Thermal Imager Camera (Concept)*

TABLE OF CONTENTS

TABLE OF CONTENTS

- ***Absolute Measuring Instruments***

These instruments give output in terms of physical constant of the instruments. For example Rayleigh's current balance and Tangent galvanometer are absolute instruments.

Secondary Measuring Instruments

- *These instruments are constructed with the help of absolute instruments. Secondary instruments are calibrated by comparison with absolute instruments. These are more frequently used in measurement of the quantities as compared to absolute instruments, as working with absolute instruments is time consuming.*

TABLE OF CONTENTS

TABLE OF CONTENTS

- The **electrical instrument** is used for measuring **electrical** quantities likes current, voltage, power, etc. The ammeter, voltmeter, wattmeter are the examples of the **electrical** measuring **instrument**. The ammeter measures the current in amps; voltmeter measures voltage and Wattmeter are used for measuring the power.

TABLE OF CONTENTS

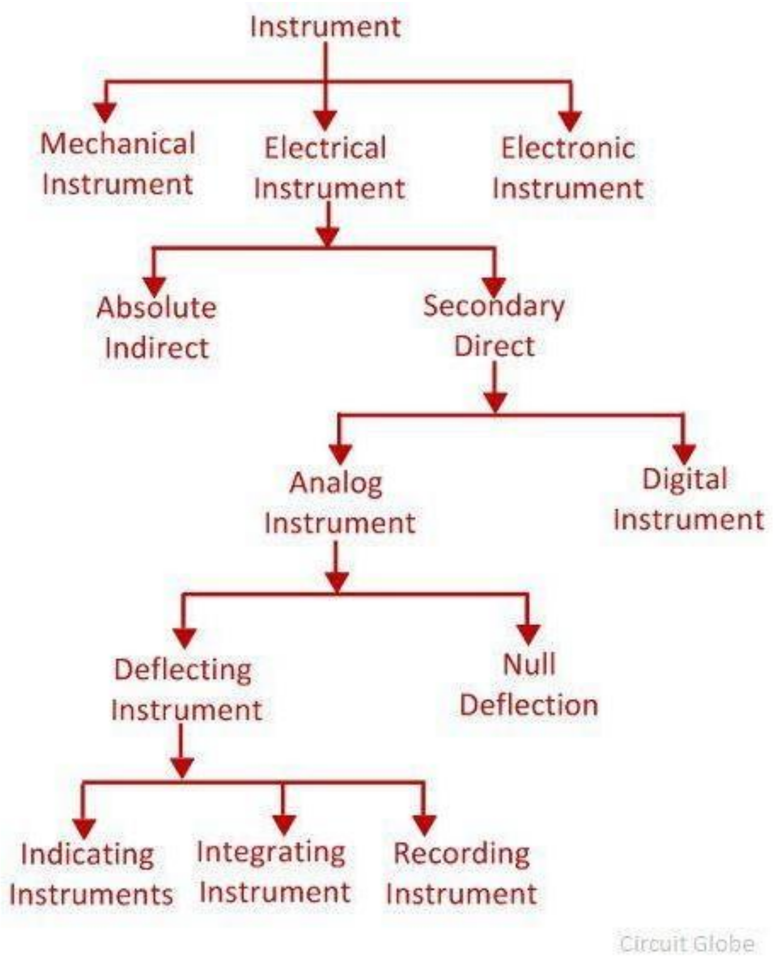


TABLE OF CONTENTS

TABLE OF CONTENTS

- *In these* ***types of instruments****, pointer of the* ***electrical measuring instrument*** *deflects to measure the quantity. The value of the quantity can be measured by measuring the net deflection of the pointer from its initial position*

TABLE OF CONTENTS

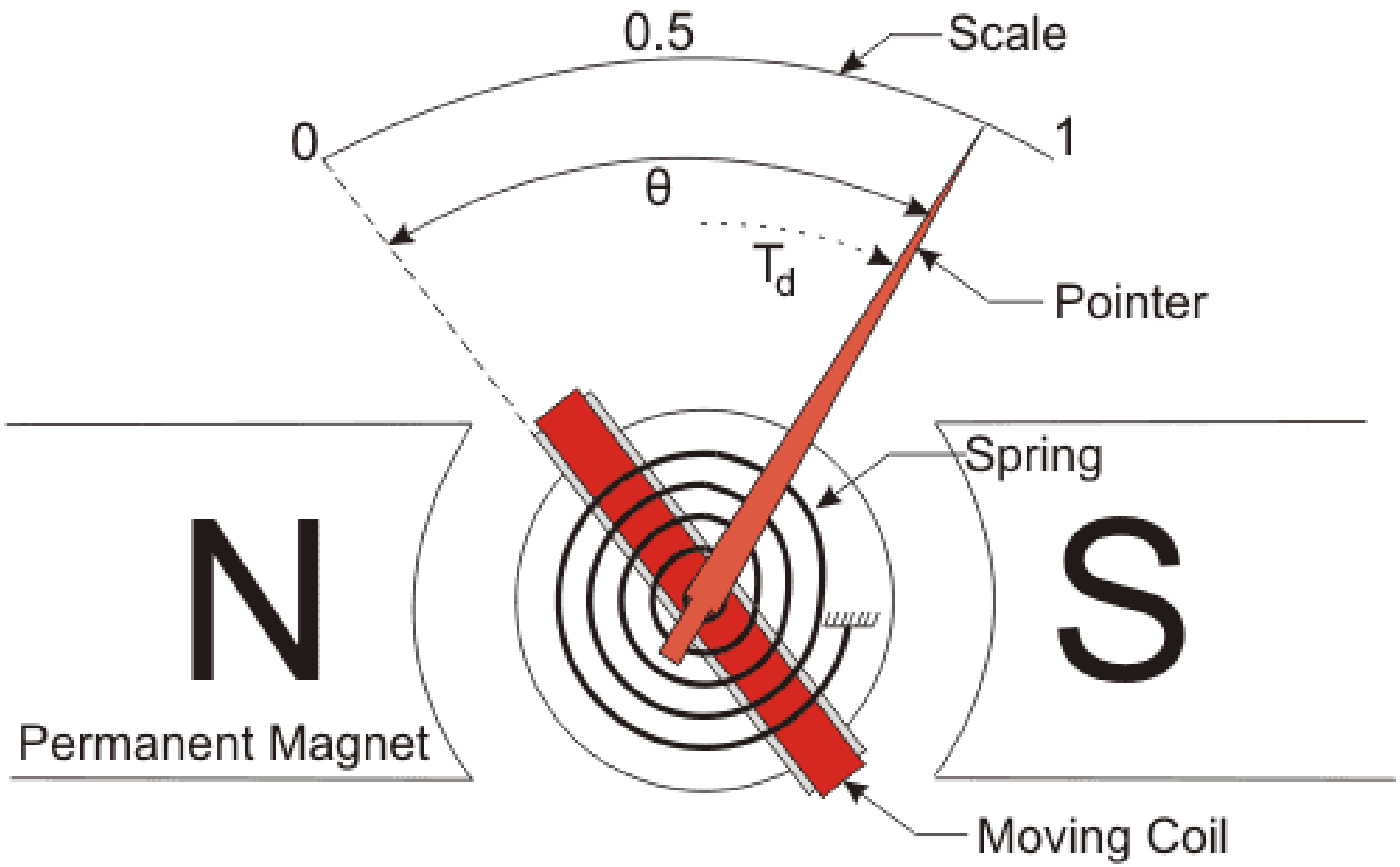


TABLE OF CONTENTS

The diagram shown has two permanent magnets which are called the stationary part of the instrument and the moving part which is between the two permanent magnets that consists of pointer. The deflection of the moving coil is directly proportion to the current.

Thus the torque is proportional to the current which is given by the expression $T_d = K.I$, where T_d is the deflecting torque. K is proportionality constant which depends upon the strength of the magnetic field and the number of turns in the coil. The pointer deflects between the two opposite forces produced by the spring and the magnets.

TABLE OF CONTENTS

In these type of characteristics measurement of quantities are either constant or vary slowly with the time. Few main static characteristics are written below:

- ***Accuracy**:*
  It is desirable quality in measurement. It is defined as the degree of the closeness with which instrument reading approaches the true value of the quantity being measured. Accuracy can be expressed in three ways
  - *Point accuracy*
  - *Accuracy as the percentage of scale of range*
  - *Accuracy as percentage of true value.*

TABLE OF CONTENTS

Sensitivity*:*

It is also desirable quality in the measurement. It is defined as the ratio of the magnitude response of the output signal to the magnitude response of the input signal.

Reproducibility*:*

It is again a desirable quality. It is defined as the degree of the closeness with which a given quantity may be repeatedly measured. High value of reproducibility means low value of drift. Drift are of three types

- *Zero drift*
- *Span drift*
- *Zonal drift*

Dynamic Characteristics

These characteristics are related with the rapidly changing quantities therefore in order to understand these types of characteristics we are required to study the dynamic relations between the input and the output.

TABLE OF CONTENTS

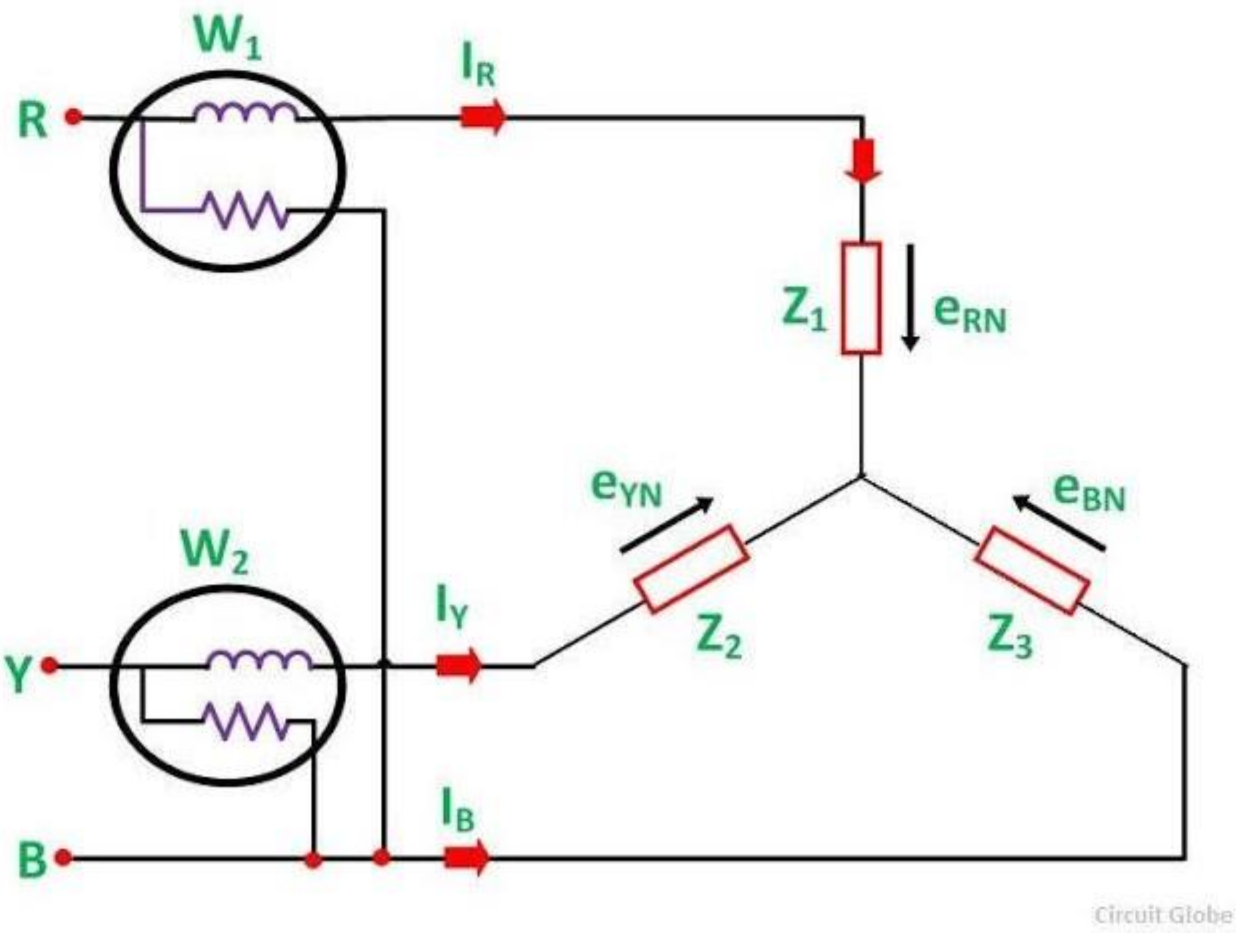


TABLE OF CONTENTS

- *Assignments and quiz/class tests, mid-term and end-term written tests, model/prototype making*
- *Actual laboratory and practical work, model/prototype making, assembly and disassembly exercises and viva-voce*

TABLE OF CONTENTS

RECOMMENDED BOOKS

- *Electrical Measurements and Measuring Instruments by Golding and Widdis; Wheeler Publishing House, New Delhi*
- *Electrical Measurements and Measuring Instruments by SK Sahdev, Uneek International Publications, Jalandhar*
- *A Course in Electrical Measurement and Measuring Instruments by AK Sawhney and PL Bhatia; Dhanpat Rai and Sons, New Delhi*
- *Electric Instruments by D. Cooper*
- *Experiments in Basic Electrical Engineering by SK Bhattacharya and KM Rastogi, New Age International (P) Ltd., Publishers, New Delhi*
- *Electronics Instrumentation by Umesh Sinha, Satya Publication, New Delhi*
- *Basic Electrical Measurements by Melville B. Staut.*
- *Electrical Measurement and Measuring Instruments by JB Gupta, SK Kataria and Sons, New Delhi*
- *Electrical Measurement and Measuring Instruments by ML Anand, SK Kataria and Sons, New Delhi*
- *e-books/e-tools/relevant software to be used as recommended by AICTE/HSBTE/NITTTR.*