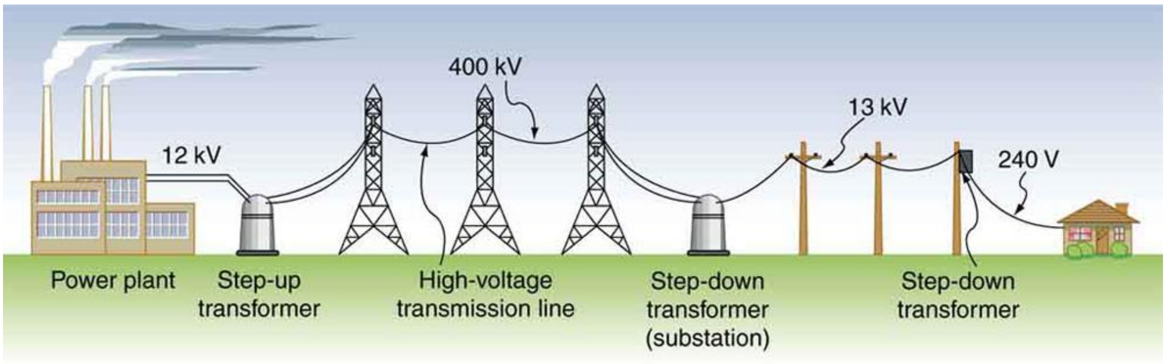
Electrical power transmission and Distribution

Electrical energy, after being produced at generating stations (TPS, HPS, NPS, etc.) is transmitted to the consumers for utilization. This is due to the fact that generating stations are usually situated away from the load centers. The network that transmits and delivers power from the producers to the consumers is called the transmission system. Electric power transmission can also be carried out using underground cables. But, construction of an underground transmission line generally costs 4 to 10 times than an equivalent distance overhead line. However, it is to be noted that, the cost of constructing underground transmission lines highly depends upon the local environment. Also, the cost of conductor material required is one of the most considerable charges in a transmission system. Since conductor cost is a major part of the total cost, it has to be taken into consideration while designing.



Main Elements of a Transmission Line

Due to the economic considerations, three-phase three-wire overhead system is widely used for electric power transmission. Following are the main elements of a typical power system.

Conductors: three for a single circuit line and six for a double circuit line. Conductors must be of proper size. This depends upon its current capacity. Usually, ACSR (Aluminium-core Steel-reinforced) conductors are used.

Transformers: Step-up transformers are used for stepping up the voltage level and step-down transformers are used for stepping it down. Transformers permit power to be transmitted at higher efficiency.

Line insulators: to mechanically support the line conductors while electrically isolating them from the support towers.

Support towers: to support the line conductors suspending in the air overhead.

Protective devices: to protect the transmission system and to ensure reliable operation. These include ground wires, lightening arrestors, circuit breakers, relays etc.

Voltage regulators: to keep the voltage within permissible limits at the receiving end.

Power Distribution System

A distribution substation is located near or inside city/town/village/industrial area. It receives power from a transmission network. The high voltage from the transmission line is then stepped down by a step-down transformer to the primary distribution level voltage. Primary distribution voltage is usually 11 kV, but can range between 2.4 kV to 33 kV depending upon region or consumer.

A typical power distribution system consists of -

- Distribution substation
- Feeders
- Distribution Transformers
- Distributor conductors

Service mains conductors

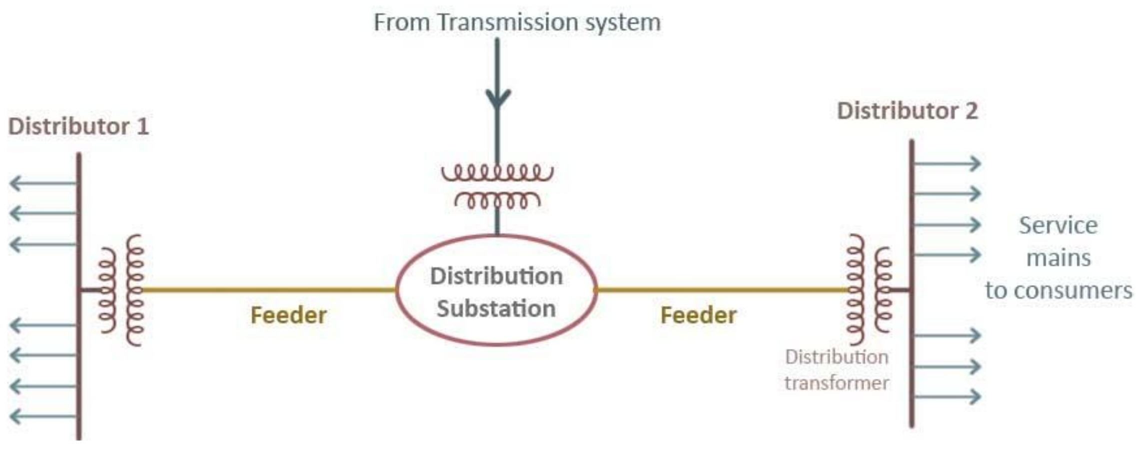
Along with these, a distribution system also consists of switches, protection equipment, measurement equipment etc.

Distribution feeders: The stepped-down voltage from the substation is carried to distribution transformers via feeder conductors. Generally, no tappings are taken from the feeders so that the current remains same throughout. The main consideration in designing of a feeder conductor is its current carrying capacity.

Distribution transformer: A distribution transformer, also called as service transformer, provides final transformation in the electric power distribution system. It is basically a step-down 3-phase transformer. Distribution transformer steps down the voltage to 400Y/230 volts. Here it means, voltage between any one phase and the neutral is 230 volts and phase to phase voltage is 400 volts. However, in USA and some other countries, 120/240 volts split-phase system is used; where voltage between a phase and neutral is 120 volts.

Distributors: Output from a distribution transformer is carried by distributor conductor. Tappings are taken from a distributor conductor for power supply to the end consumers. The current through a distributor is not constant as tappings are taken at various places throughout its length. So, voltage drop along the length is the main consideration while designing a distributor conductor.

Service mains: It is a small cable which connects the distributor conductor at the nearest pole to the consumer's end.



Single Line Diagram of AC Power Transmission

Generating station

- The electrical power is generated in the thermal / hydro / nuclear power station.
- The generation of 11 kV is done by alternator.
- The generated power is transmitted to different areas which are far away from generating station.
- The generated voltage is step up for transmission due to following reasons. As the generating voltage increases
    - ❖ Conductor volume (weight) decreases
    - ❖ Efficiency of transmission line increases
    - ❖ Percentage voltage drop decreases.

Primary transmission

- The step up transmission step up the generating voltage from 11 kV to 132 kV / 220 kV.
- It is transmitted by three phase, three wire supply system.

Secondary transmission

- The primary transmission line terminates at the receiving substation.
- The transmission line voltage steps down from 132 kV / 220 kV to 66 kV at the receiving end substation.
- The electrical power is transmitted at voltage level of 66 kV to different substation.
- This is called as secondary transmission.

Primary distribution

- The secondary transmission line terminates at the substation where the voltage is reduced from 66 kV / 11 kV by step down transformer.
- The 11 kV voltage is transmitted to different area of city by transmission line.

- The primary transmission is done through 3 – phase, 3 – wire system which supply power to HT consumers.

Secondary distribution

- The electrical power from primary distribution line is delivered to pole mounted distribution transformer.
- The pole mounted delta / star transformer step down the 11 kV to 440 V.
- The secondary of transformer star connected with neutral which supplies three phase four wire.
- The residential consumer gets single and three phase supply.

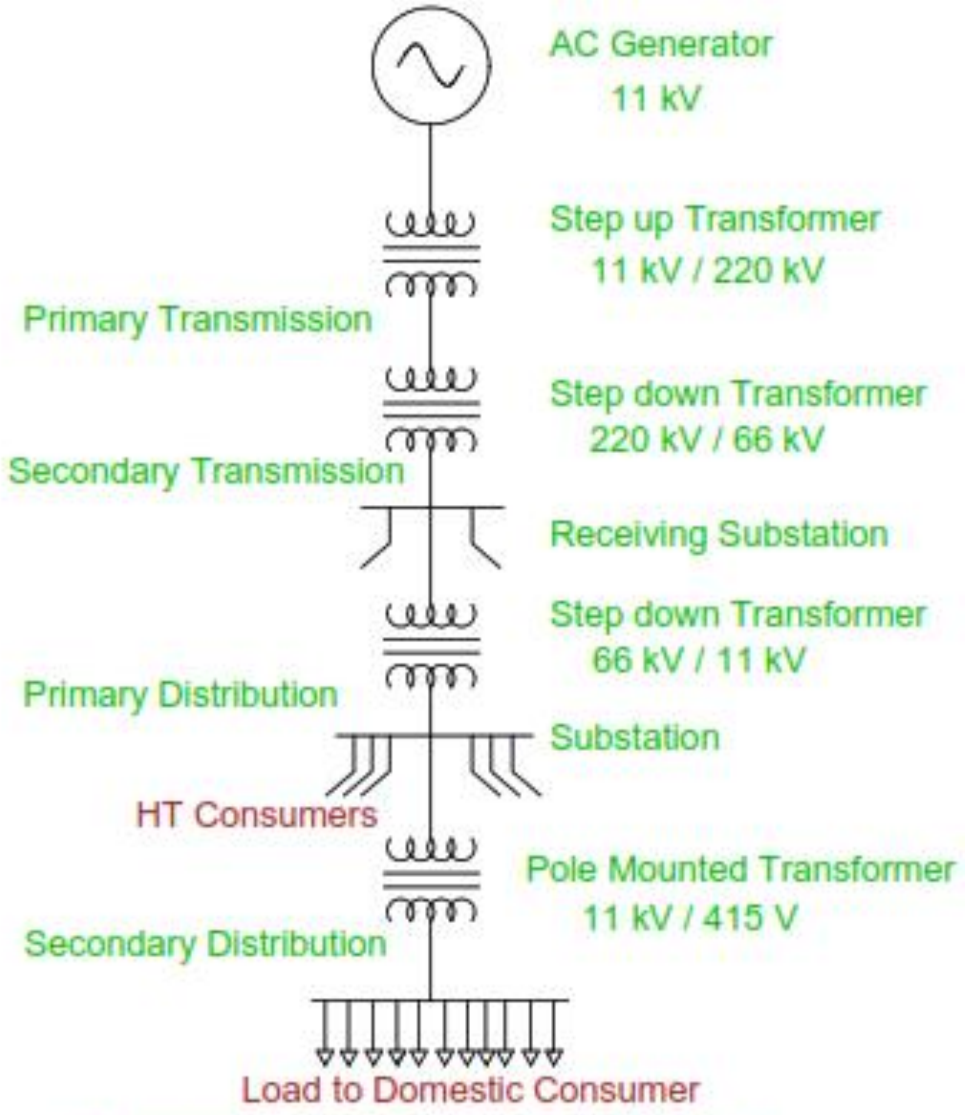
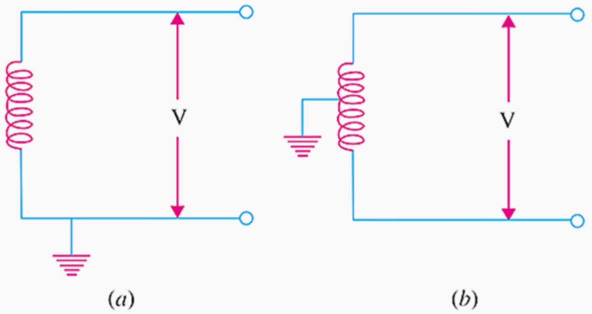


FIG : Single Line Diagram of Power Supply System

AC Power Supply Schemes-Based on Phase

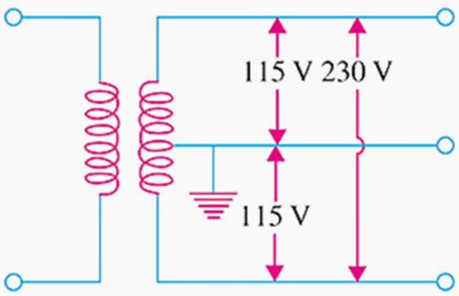
I. Single-phase, 2-wire System

It is shown in Figure 1 (a) and (b). In Figure 1 (a), one of the two wires is earthed whereas in Figure 1 (b) **mid-point of the phase winding is earthed**.



Single Phase 3-Wire System:

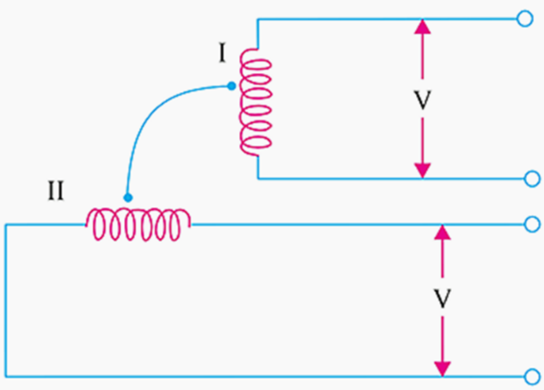
The 1-phase, 3-wire system is identical in principle with the **3-wire DC system**. As shown in Figure 2, the third wire or neutral is connected to the centre of the transformer secondary and earthed for protecting personnel from electric shock should the transformer insulation break down or the secondary main contact high voltage wire.



Two Phase 4-Wire System

As shown in Figure 4, the four wires are taken from the ends of the two-phase windings and the mid-points of the windings are connected together.

As before, the voltage of the two windings are in quadrature with each other and the junction point may or may not be earthed. If voltage between the two wires of a phase winding be V , then the voltage between one wire of phase I and one wire of phase II is **0.707 V**.



Three Phase 3-Wire System

Three-phase systems are used extensively. The 3-wire system may be delta-connected or star-connected whose star point **is usually earthed**.

The voltage between lines is **V** in delta-connection and √**3 V** in case of star connection where V is the voltage of each phase as shown in Figure 5 (a) and (b) respectively.

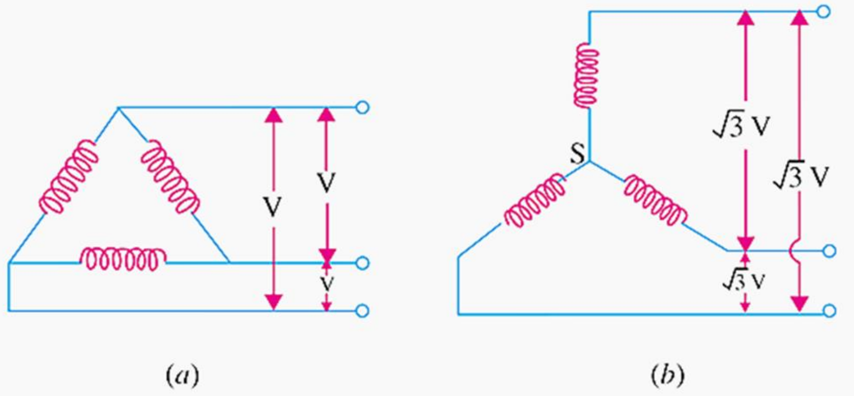


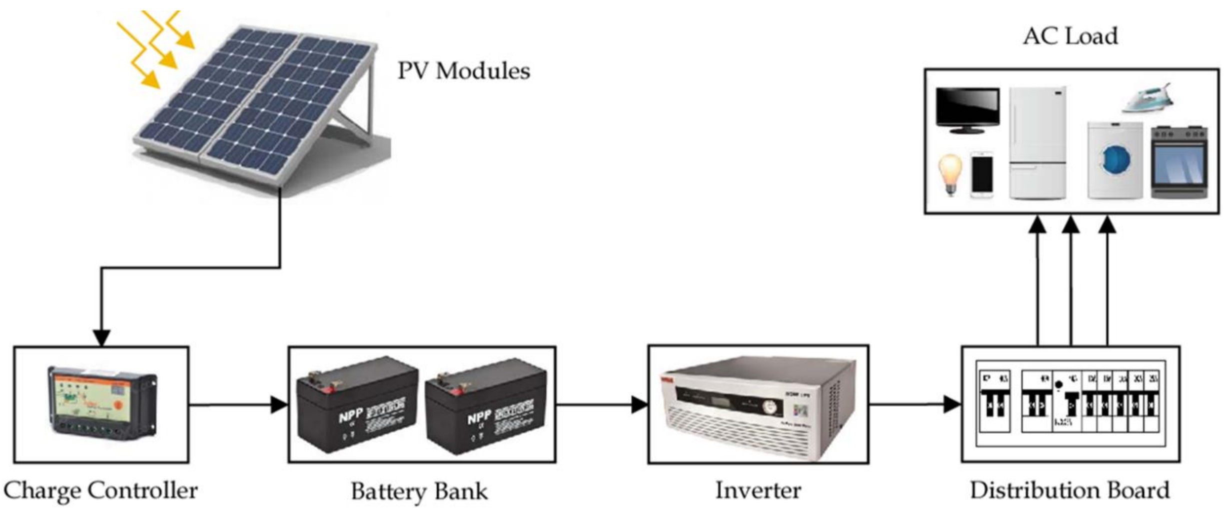
Figure 5 – Three-phase, 3-wire system

DC Power Supply System:

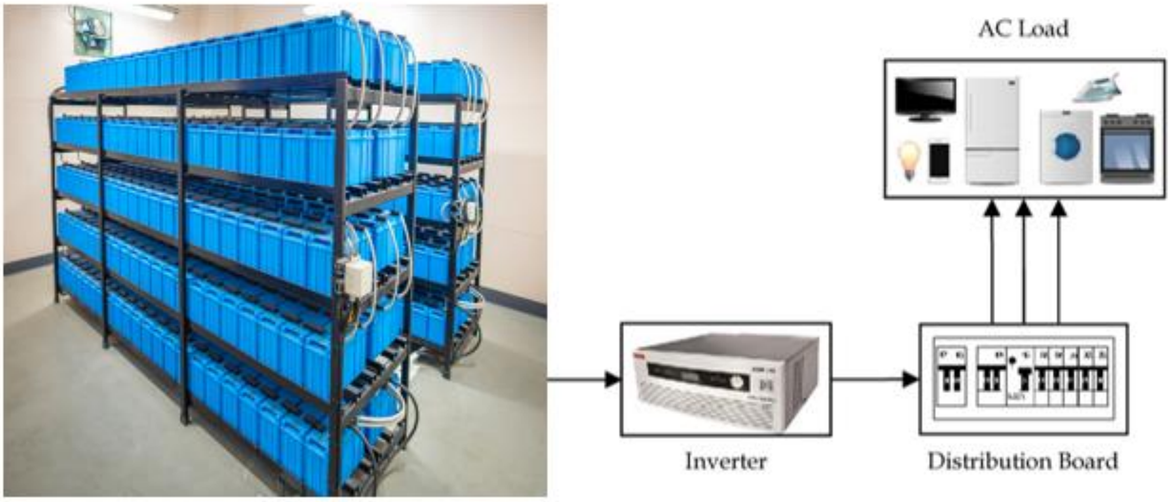
The DC power supply system based on solar energy and battery storage

Solar Energy Based DC System

The DC power supply directly generated form solar panel and battery. The generated DC power charges are control by charge charger. Then, the electrical power is temporarily stored in battery bank. The stored energy is converted into DC to AC with use of inverter. Finally, the distribution board is used to electrical power transferred to all connected load.



Battery based DC supply System



Indoor substation

A substation is an installation that interconnects elements of an electric utility's system. These elements can include generators, transmission lines, distribution lines and neighboring utility systems.

Functions of a Substation

A substation performs a major role in our power system. The functions of a substation may include one or more of the following:

- To isolate a faulted element from the rest of the utility system.
- To allow an element to be disconnected from the rest of the utility system for maintenance or repair.
- To change or transform voltage levels from one part of the utility system to another.
- To control power flow in the utility system by switching elements into or out of the utility system.
- To provide sources of reactive power for power factor correction or voltage control.

- To provide data concerning system parameters for use in operating the utility system

Single Line Diagram for Substation

A single line diagram also called the one-line diagram is a symbolic or graphical representation of a three-phase power system. It has a diagrammatic representation of all the equipment and connections. The electrical elements such as circuit breakers, transformers, bus bars, and conductors, are represented using standardized schematic symbols so that they can be read and understood easily.

In a single line diagram, instead of representing each of three phases with separate lines, only a single conductor is represented using a single line. A single line diagram makes it easy to understand an electrical system, particularly in the case of complicated systems in substations. It helps in a detailed study and evaluation of the system and its efficiency.

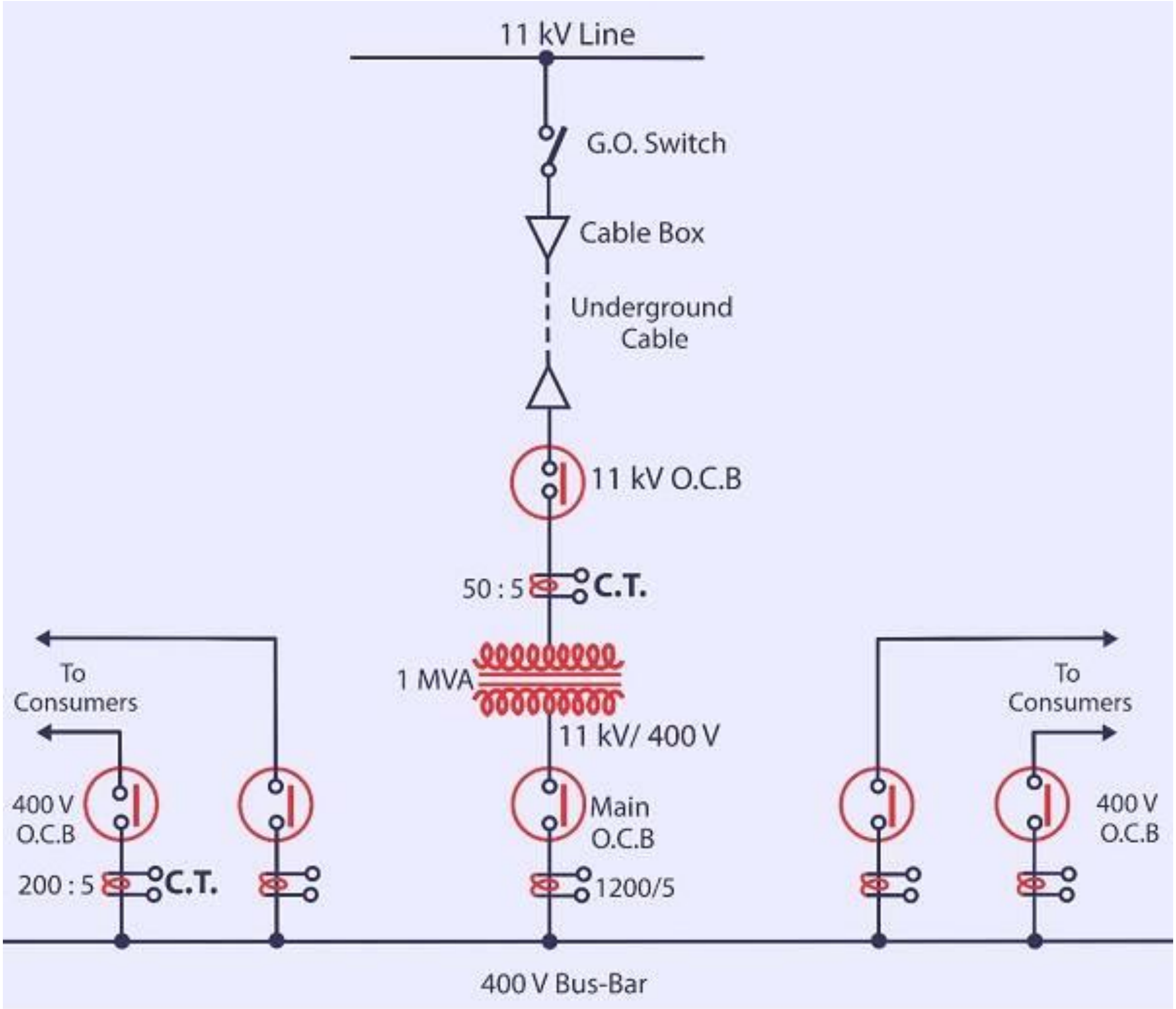
Important Equipments of single-line diagram:

Isolating switch: In power substations, it is required to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or an isolator. An isolator is essentially a switch designed to open a circuit under no load. For example, if the entire substation is divided into five sections. Each section can be disconnected with the help of an isolator for maintenance.

Busbar: A busbar is an assembly of bus conductors with associated connection joints and insulating supports. It is a grounded metal enclosure containing factory-mounted, bare or insulated conductors, usually copper or aluminium bars, rods or tubes.

Circuit breaker: A circuit breaker is a circuit component that can open or close a circuit under normal and fault conditions. It is designed such that it can be operated manually under normal conditions and automatically under fault conditions. It is a special type of switching device which can be operated safely under huge current carrying conditions. It is used for timely disconnecting and reconnecting different parts of the power system for protection and control.

Transformers: Transformers are essential components in power transmission and distribution. They are used to step up or step down the voltage. Mostly at a power station, a step-up transformer is used to increase the generated voltage to a higher value. At subsequent substations, a step-down transformer is used to reduce the supply voltage and then finally deliver it at the utilization end. A current transformer is a step-up or step-down transformer that multiplies the current to a known ratio. For example, if a current transformer has a rating of 100/5A, the current on the primary side is 100A and the secondary is 5A. It is a type of instrument transformer. Another type of instrument transformer is the voltage transformer or potential transformer.



The 3-phase, 3-wire 11 kV line is tapped and brought to the gang operating switch installed near the substation. The gang operated switch (G.O. switch) consists of isolators connected to each phase of the 3-phase line. From the G.O. switch, the 11 kV line is brought to the indoor substation as an underground cable. It is then connected to the high voltage or primary side of the transformer (11 kV/400 V) via the 11 kV Oil Circuit Breaker. The transformer steps down the voltage to 400 V, 3-phase, 4-wire.

A single-phase residential load can be connected between any one phase and neutral. A 3-phase, 400 V motor load is to be connected across 3-phase lines directly. Current Transformers are located at suitable places in the substation circuit and supply for the metering and indicating.

The secondary of the main transformer supplies to the busbars through the main circuit breaker. From the busbars 400V, 3-phase, 4 wire supply is given to customers via 400V Circuit breaker. The voltage between any two phases is 400V, and that between one phase and one neutral is 230V.

Earthing

Earthing is defined as **"the process in which the instantaneous discharge of the electrical energy takes place by transferring charges directly to the earth through low resistance wire."**

Low resistance earthing wire is chosen to provide the least resistance path for leakage of fault current.

There are mainly 4 types of Earthing systems in India, Plate Earthing, Pipe Earthing, Mat Earthing, and Rod Earthing.

Pipe earthing is one of the popular earthing systems in India that suits every soil type. Earthing in large-scale residential, as well as commercial areas, prevents mishappenings on account of electrical shock. It protects your building and the electric boxes that are home to different types of electrical wires or cables.

Pipe earthing is joining a steel pipe with the earth's electrical conductors. An Iron and steel pipe can transfer fault currents in an electrical system efficiently. Earthing involves discharging electricity to the earth via low resistance electrical cables to prevent voltage surges resulting from an improper earthing system. Short circuits are a result of loose insulation and may occur anytime. However, a grounding wire may prevent these damages that can also be easily removed by technicians later.

Types of Earthing:

Electrical grounding, also known as earthing, is done in several ways like housing, wiring, electrical device, and more. The different types of electric earthing systems in India are:

1: Pipe Earthing

Pipe earthing is a common form of earthing in India that uses a steel pipe to connect with the earth's electrical conductors. The size of the iron pipe depends on the soil moisture and the magnitude of the current. The soil's moisture will decide the depth for the placement of the steel pipe.

2: Plate Earthing

Plate earthing is where a copper plate is distanced at 3 meters from the earth and vertically placed in the ground pit.

3: Coil Earthing

Coil earthing connects vertical and horizontal electrodes – a horizontal electrode represses the current generated due to a massive fault while the vertical electrode dissipates the current into the earth.

4: Rod Earthing

Rod earthing is the safest earthing technology that uses low-resistant copper earth electrodes that are specially manufactured to deliver a premium quality earthing system for solar power plants. It is a dark grey material that is mixed with cement and water to produce safe and secure earthing system.

The techniques of earthing are conventional earthing and maintenance-free earthing. Every electrical installation requires a grounding system that is essential for life safety, offering a quality power supply and preventing any damage caused due to lightning or fault. Earthing transfers the extra voltage to the earth with the help of a wire that reduces overloading chances and saves a lot of money on the electricity bills.

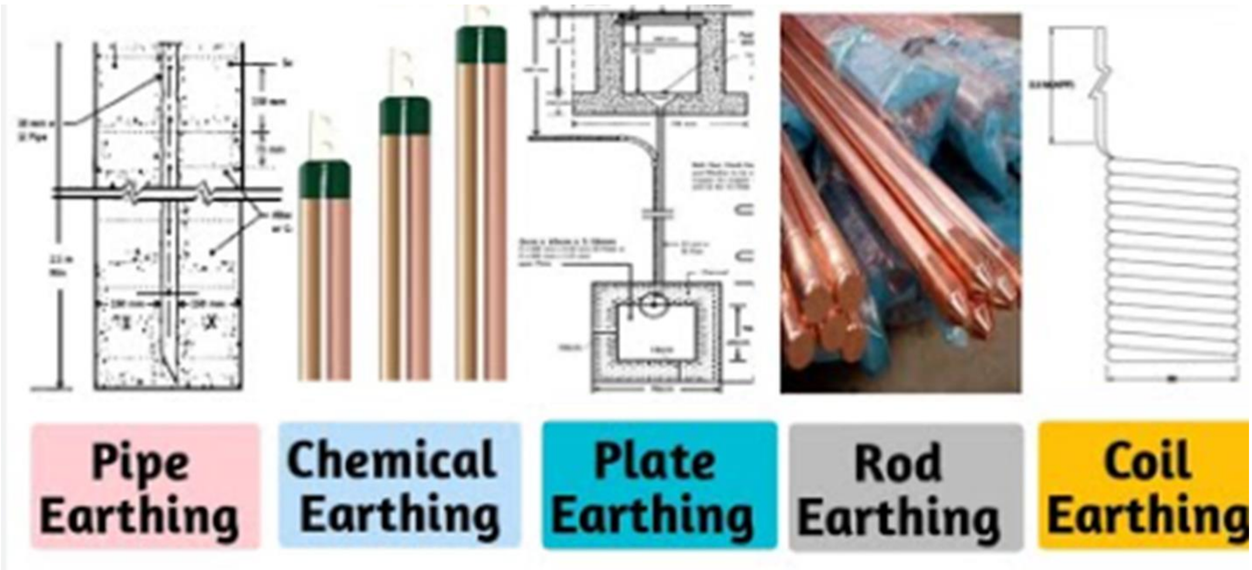
Some factors affect earthing installations like soil condition, dissolved salts, soil resistivity, soil moisture, climatic conditions, earth pit's location, physical composition, and more. Earthing requires using a non-current device to discharge electricity directly to the ground. Proper installation can save you from shocks and, a low-resistant cable, earth rods, and conductors can work effectively in the electricity transmission process.

Importance of Earthing

The main motive of earthing is to avoid any electric shock that may occur due to the extra current produced from the ground. Planned insulation can restrict any voltage from the ground. Whenever a metallic element comes in contact with a wire, it starts collecting extra current resulting in severe electric shock. Electrical appliances are grounded to discharge the electricity directly to the ground.

Benefits of grounding are – voltage stabilization, safety from overvoltage, and prevention from any severe damage. The essential components used in the earthing system are earth cable, earthing joint, and earth plate.

Many electronic, electrical, and civil engineers handle electrical earthing that prevents damages or some breakdown in any of the electrical instruments, but the safety of these workers also matters. Earthing is the work of skilled technicians and therefore requires proper planning and use of quality devices to execute an electrical earthing project.



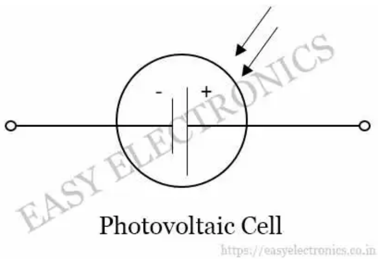
Photovoltaic Cell or Solar Cell:

A photovoltaic cell is a specialized semiconductor device that operates on the principle of the photovoltaic effect.

The photovoltaic effect is a process in which a light-sensitive semiconductor converts the visible light into a voltage or into a direct current.

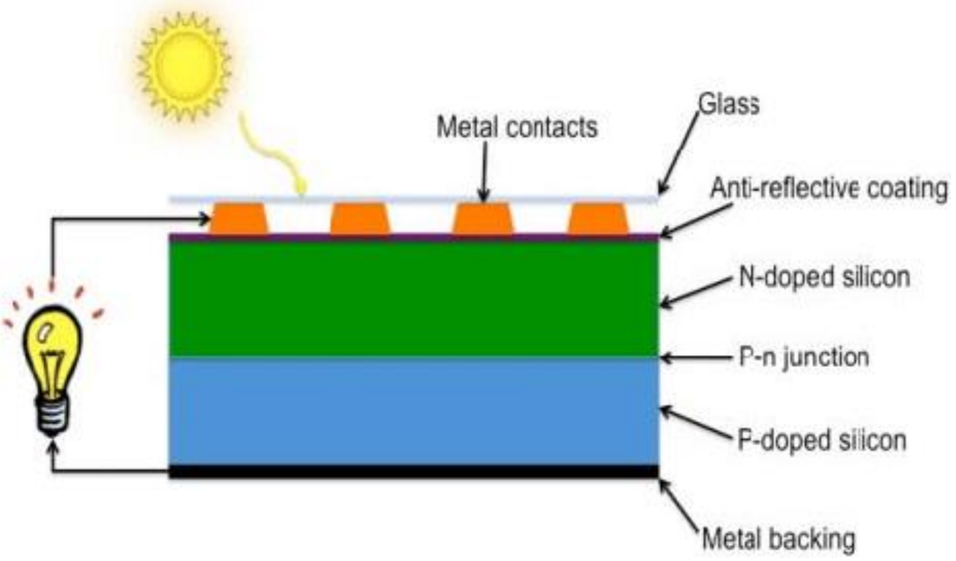
- Some photovoltaic cells convert even infrared or ultraviolet radiation into direct current.
- The photovoltaic cells (PV) are usually made of silicon doped with other elements. New materials such as copper indium diselenide (CIS), gallium arsenide(GaAs), and cadmium telluride (CdTe) have also been developed for use in photovoltaic cells.

Circuit symbol of Photovoltaic Cell:



Construction and working of Photovoltaic Cell

- In the construction of a photovoltaic cell (PV), two separate semiconductors are sandwiched together forming a p-n junction at the interface. In the device, although both materials are electrically neutral, n-type has excess electrons and p-type silicon has excess holes.
- The device is constructed in such a way that when the junction is exposed to visible light, a voltage difference is produced between the p-type and n-type materials. This is due to the flow of excess electrons from the n-type material to the p-type material, and the holes thereby vacated from p-type material flow towards n-type material.
- Due to these electrons and hole fowl, the two semiconductors act as a battery creating an electric field at the junction.
- Electrodes connected to the semiconductor layer, allow current to be drawn from the device which is proportional to the intensity of incident light.



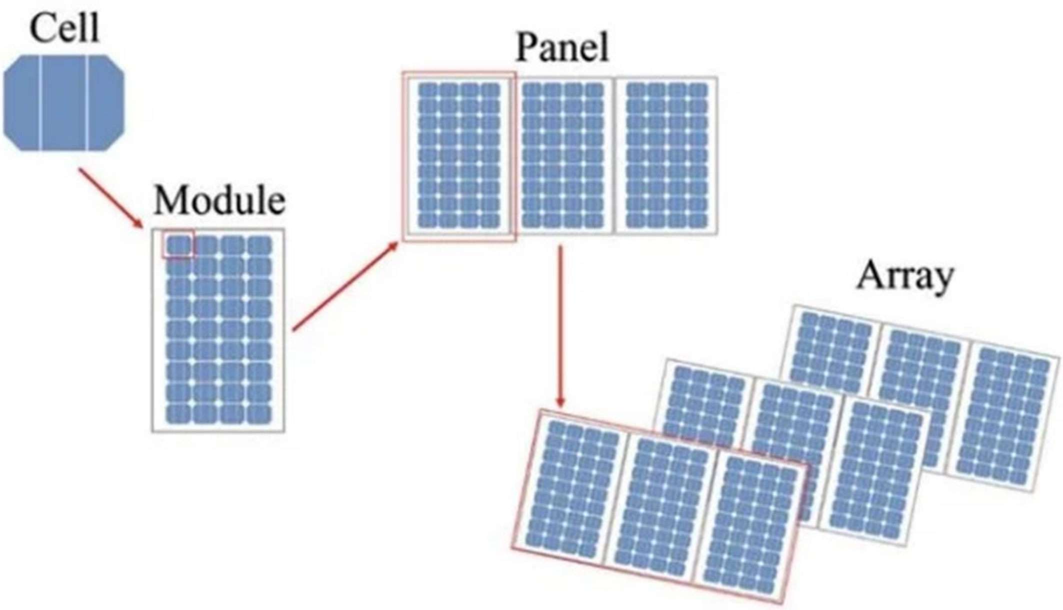
Advantages

1. The photovoltaic cell does not require any external battery for its own operation, i.e. it is self-generating.
2. Since solar energy is unlimited, once the photovoltaic system is installed, it can produce energy years together.

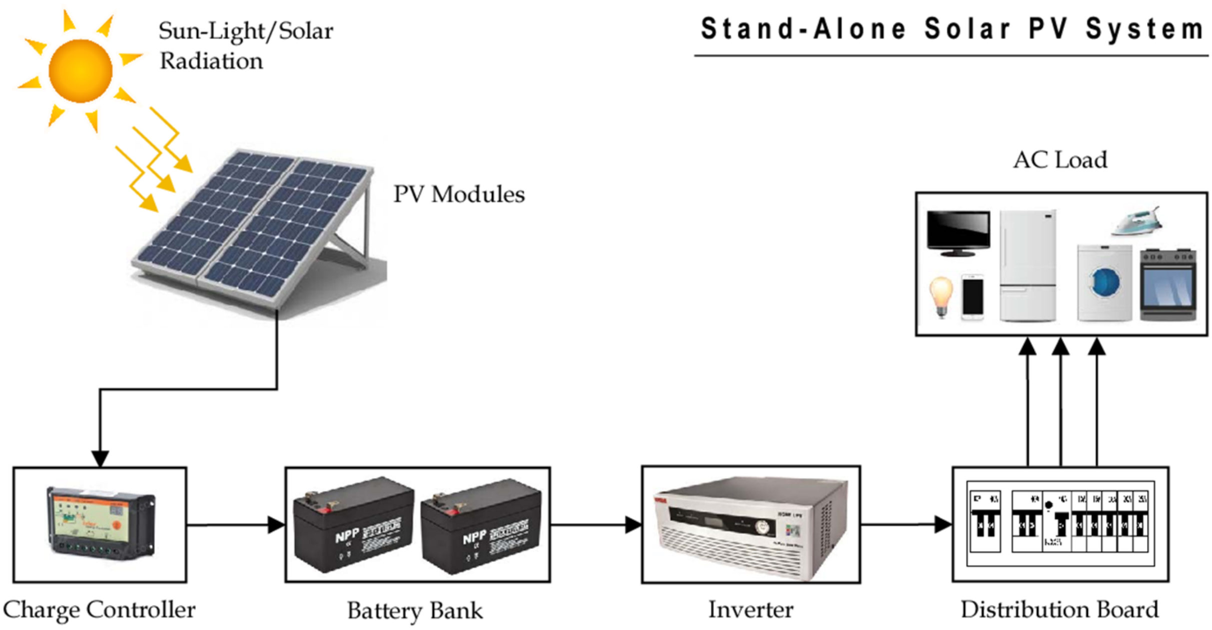
3. The maintenance cost is minimum.
4. It is non-polluting.

Application

1. The photovoltaic cells are used in low-power devices such as light meters.
2. They are used in solar-powered scientific calculators.
3. A large set of photovoltaic cells can be connected together to form solar modules, panels, or arrays.



Solar Cell-Based Electric System



Electric vehicle

Electric vehicle have an electric motor instead of an internal combustion engine. The electric vehicle uses a large battery pack to power the electric motor. Charging station or wall outlet provides charging of the large traction battery. The proliferation of electric cars is a little difficult, because charging station were not beeing built everywhere.

ELECTRIC CAR CONSIST OF:

1. Battery;
2. Charge port;
3. DC/DC Convertor;
4. Electric traction motor;
5. Onboard charger;
6. Power electronics controller;
7. Thermal system;
8. Traction battery pack;
9. Transmission.

Battery (all-electric auxiliary) main purpose of the auxiliary battery is providing electricity to power vehicle accessories in an electric vehicle.

Every electric car has got own **Charge Port**, that allows the vehicle to connect to an external power supply in order to charge the traction battery pack

Vehicle accessories work need a low-voltage DC power, so electric car has mounted **DC/DC converter**. It`s nessasary Because device provides normal vehicle accessories work and recharge the auxiliary battery.

Electric traction motor drives the electric vehicle's wheels with using power from the traction battery pack.

Onboard charger converts AC electricity to DC power for the traction battery charging. Also It has control function of main battery characteristics such as voltage, temperature, current, and state of charge while charging the pack.

Power electronics controller manages the flow of electrical energy delivered by the traction battery. Also it controlling the speed of the electric traction motor and the torque it produces.

Cooling system (thermal system) maintains a proper operating temperature range of the electric motor, power electronics, and other components.

Traction battery pack provides stores electricity for use by the electric traction motor.

Electric transmission transfers mechanical power from the electric traction motor to the drive wheels.

Types of Electrical Vehicles