21EES101T-ELECTRICAL AND ELECTRONICSENGINEERING UNIT 5

Unit-5–Power Engineering

Electrical supply system- simple layout of Generation, transmission and Distribution of power, Typical AC and DC power supply schemes, overview on substation equipment with key diagram of 11kV/400 V indoor substation- Introduction to smart grid.

Safety Measures in Electrical systems- Basic Principle and importance of Earthing, precautions for Electric shock- safety devices

Introduction to renewable energy resources: Solar Photovoltaic- Introduction to energy storage systems-overview of battery, Fuel cell technologies-HEVs, PHEVs and EVs – EV, Charging station.

Practice session on different types of wiring circuits and safety measures

Electrical supply system

Electrical power is generated in power stations which are mostly located in remote places. This is because the generating stations are installed in the areas, where the resources for power generation are available. The bulk power generated is to be transmitted to different load centers. The transmission of electrical power is done at high voltages. The power received at the load centers is to be distributed to the consumers at normal voltage. There is a complex network of conductors between the power station and the consumers. This network is divided into major parts called transmission and distribution systems. Generation, transmission and distribution systems combinedly known as electric supply system or electric power system

1. POWER GENERATION

Electrical power is generated normally at 11 kV or at 6.6 kV by number of generators in parallel. Generation at still higher voltage will impose some technical problems. Power generated at 11 kV is stepped upto 110 kV or 230 kV or 400 kV or 765 kV or still higher voltage with the help of power transformers.

2. TRANSMISSION SYSTEM-AC

The powers generated at the generating stations is transmitted at higher voltage to the main load centers. This transmission system is known as primary transmission system. The voltage level here may be 765 kV, 400 kV or 220 kV. In India, highest transmission voltage is 765 kV.

There are advantages when power is transmitted at high voltages:

(i) The volume of conductor material required is low.

(ii) For a given amount of power transmitted, the current through the line is reduced, when the transmission system voltage is high. This reduces the line losses and hence efficiency of transmission is increased.

(iii) As the current is reduced the voltage in the line is reduced and hence the line regulation is improved.

The power from the main load centers is transmitted to different sub-load centers at voltages 33 kV, 66 kV or even at 110 kV. This part of transmission is known as secondary transmission system.

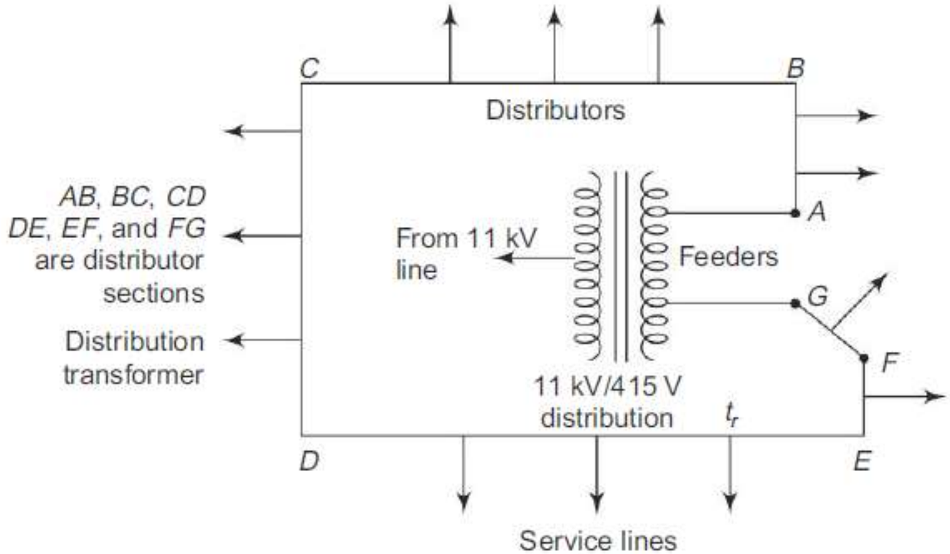
The primary transmission system employs overhead lines in general. The secondary transmission of power is either by means of OH lines or underground cable. In rural areas, OH lines are used and in city areas, underground cable system is used.

3. Distribution System

The power is received at the sub-load centre at voltages of 33 kV, 66 kV or 110 kV. The voltage level is stepped down to 11 kV at the sub-load centers. The power is distributed through the 11 kV lines, which runs along the main roads. This distribution system is referred to as primary distribution system.

Number of 11 kV/415 volts transformers are connected enroute 11 kV lines. Now the power is distributed through distribution lines, which run along all the streets of town/city/villages. This distribution line is called a distributor. The power is distributed with the help of 3-phase, 4-wire lines/cables. Voltage levels available are 1-phase or 230 V and 3-phase 415 volts. The lines feeding the power from the distribution transformer to the distributors are called feeders.

From the distributors, power is supplied to the consumers by means of lines called service lines. The feeder distribution and service lines combinedly, form the secondary distribution system which is shown in following fig. The distributors may be radial or ring. The secondary distribution of power is by means of ac only. This is because all the loads are designed to work on ac only, which are most efficient and less in cost.



Main Components of Transmission and Distribution Systems

(i) Conductors, which are used to carry the electrical power from one place to another place.

(ii) Supports, which may be RCC poles, MS, tubular poles or towers. These are used to keep the conductors at a proper height from the ground.

(iii) Cross arms, which are attached to the poles or towers and are used to support the conductors.

(iv) Insulators, which are used to isolate the conductors at higher potential from the ground.

(v) Miscellaneous items like lighting arresters, ground wires, stay wires, etc.

COMPARISON OF OVERHEAD (OH) AND UNDERGROUND (UG) SYSTEMS

In city area, secondary distribution of power is done by UG cable system. Sometimes the primary distribution is by means of UG cable system. The OH line and UG cable systems are compared based on the following factors.

(i) Public Safety: UG cable is preferred, as there is less chance of any hazard to the public.

(ii) Initial cost: the initial investment on UG cable system is about 10 times the rate on OH line system. So, OH line system is preferred.

(iii) Flexibility: OH line system is more flexible than the UG cable system. OH line system can be modified easily.

(iv) Faults: The chances of occurrence of fault in an UG cable system is less when compared to the OH line system, as it is exposed to the atmosphere.

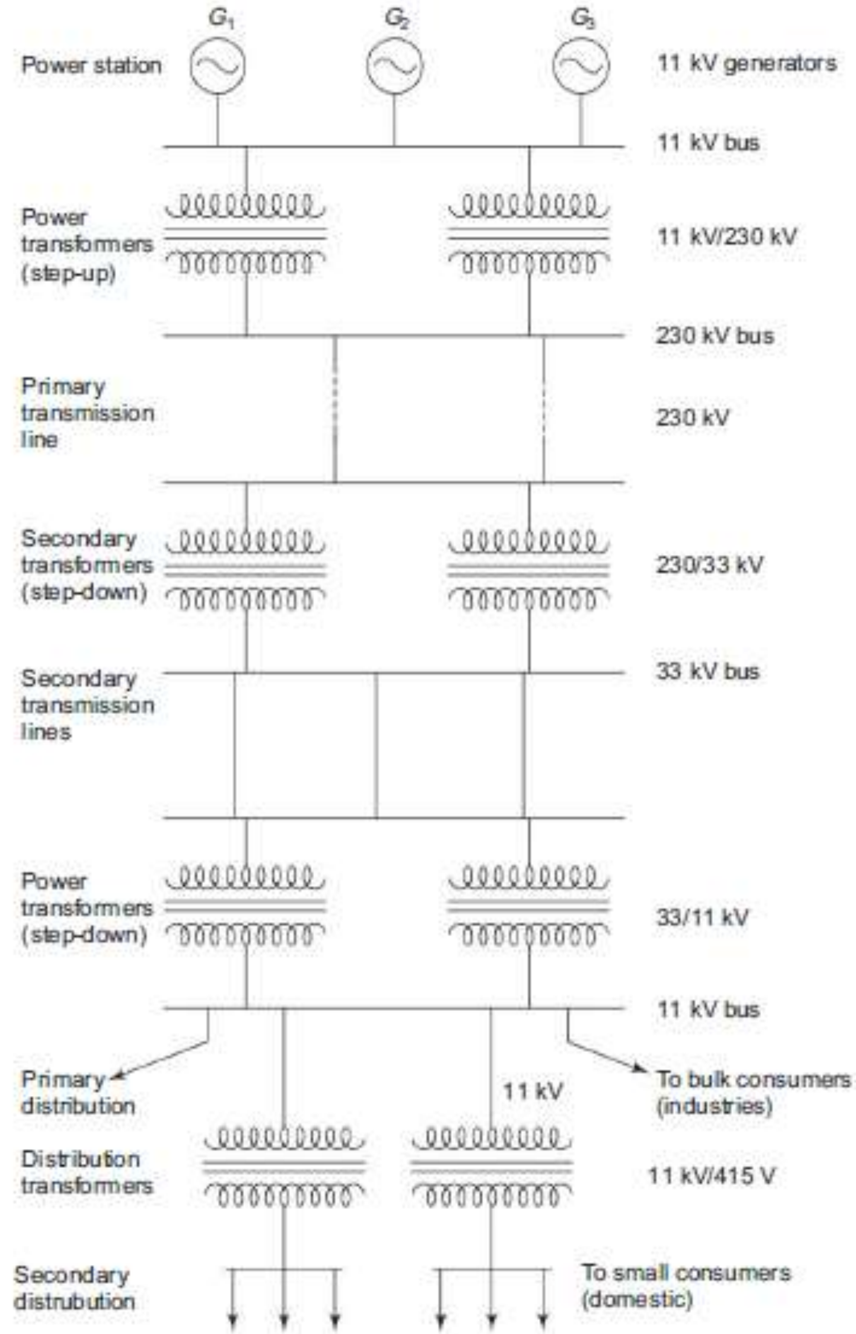
(v) Appearance: The general appearance of UG cable system is better.
(vi) Fault location and Repair: Fault location and rectification of fault is easier in OH line system.
(vii) Useful life: The useful life period of an OH line system is only 50% that of UG cable system.
(viii) Maintenance cost: The maintenance cost of UG cable system is low, as the chance of fault is less in an UG cable system.
(ix) Interference with communication circuits. It is less with an UG cable system and more with an OH line system.

From the above comparison, it is clear that systems have advantages and limitations. However in city areas we bother only about safety and not about the economics involved. So in this condition, UG cable system is preferred.

Simple layout of Generation, Transmission and Distribution of power

OR

Simple layout of Electrical Power System



Transmission System-DC

When power is transmitted by DC, there are a lot of advantages when compared to AC transmission systems.

(i) The amount of insulation required is less in dc transmission as compared to that for ac transmission.

The size of towers, cross arms required are small for dc transmission system.

(iii) It improves the stability of the system.

(iv) Power factor of dc transmission system is unity.

(v) There is no changing current.

(vi) There is skin effect. Skin effect increases the effective resistance of the line conductors.

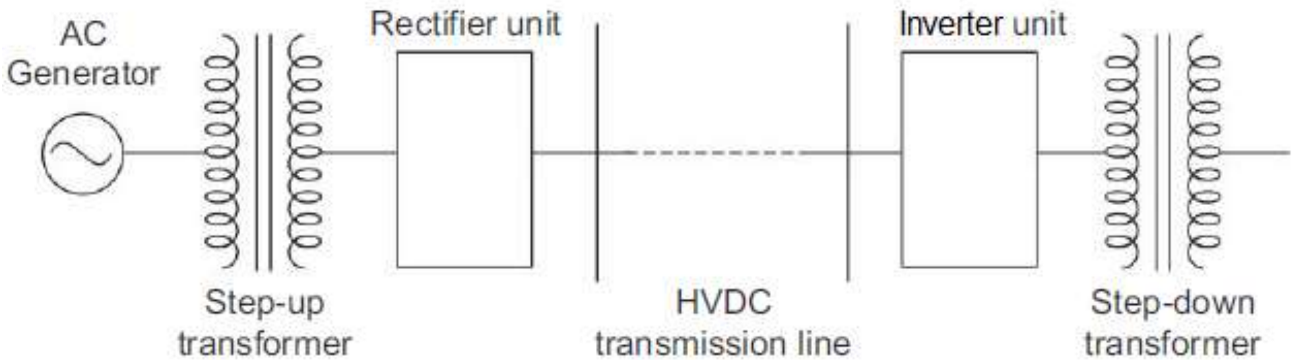
The main disadvantages of HVDC transmission are—

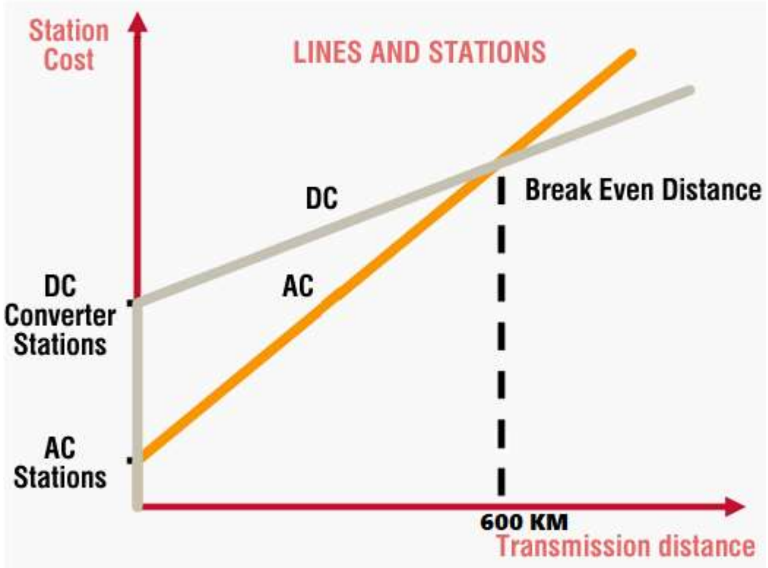
(i) There is no equipment like a transformer, available for step-up or step-down the voltage. So this has to be done on the ac side only.

(ii) Power cannot be generated at higher voltages because of commutation problem (iii) There are limitations with HVDC switching devices and circuit measures.

The HVDC transmission system is more economical when the distance of transmission is more than 600 km for OH line.

The components used in a substation for dc transmission purpose are more and are shown in following fig. The capital cost of dc transmission system is higher when compared to that of ac transmission system, when the length of the transmission line system is less than 600 km, and less when the length of the transmission line system is greater than 600 km.

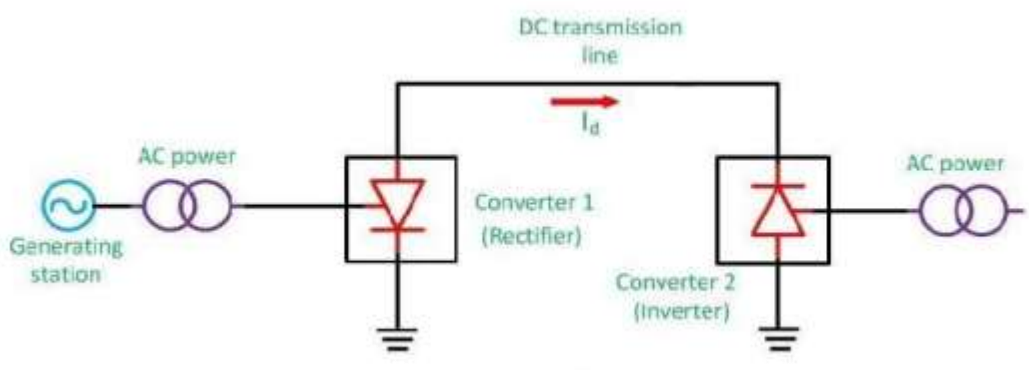




Types of DC link:

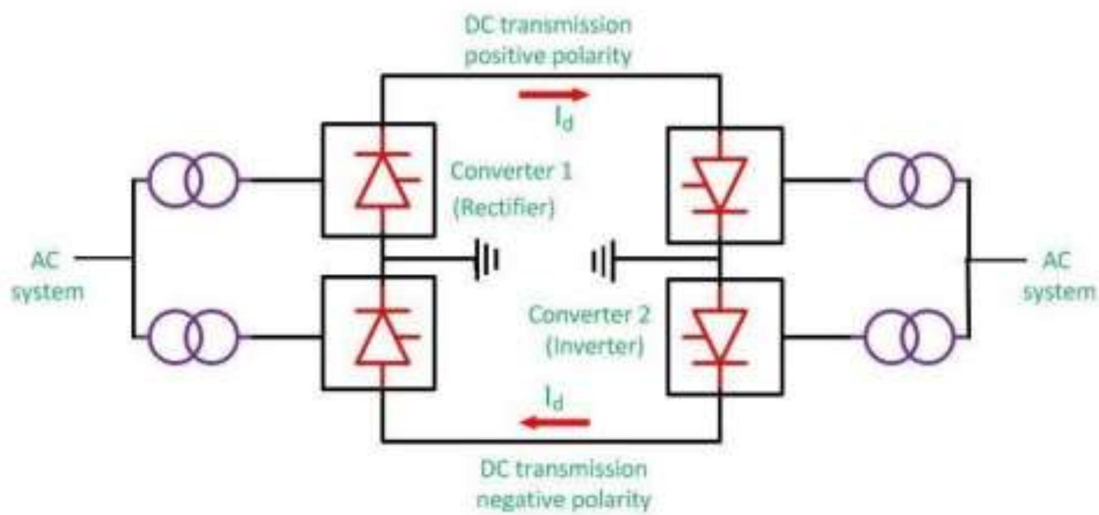
For connecting two networks or system, various types of HVDC links are used. HVDC links are classified into three types. These links are explained below:

1) Monopolar link: It has a single conductor of negative polarity and uses earth or sea for the return path of current. Sometimes the metallic return is also used. In the Monopolar link, two converters are placed at the end of each pole. Earthling of poles is done by earth electrodes placed about 15 to 55 km away from the respective terminal stations. But this link has several disadvantages because it uses earth as a return path. The monopolar link is not much in use nowadays.



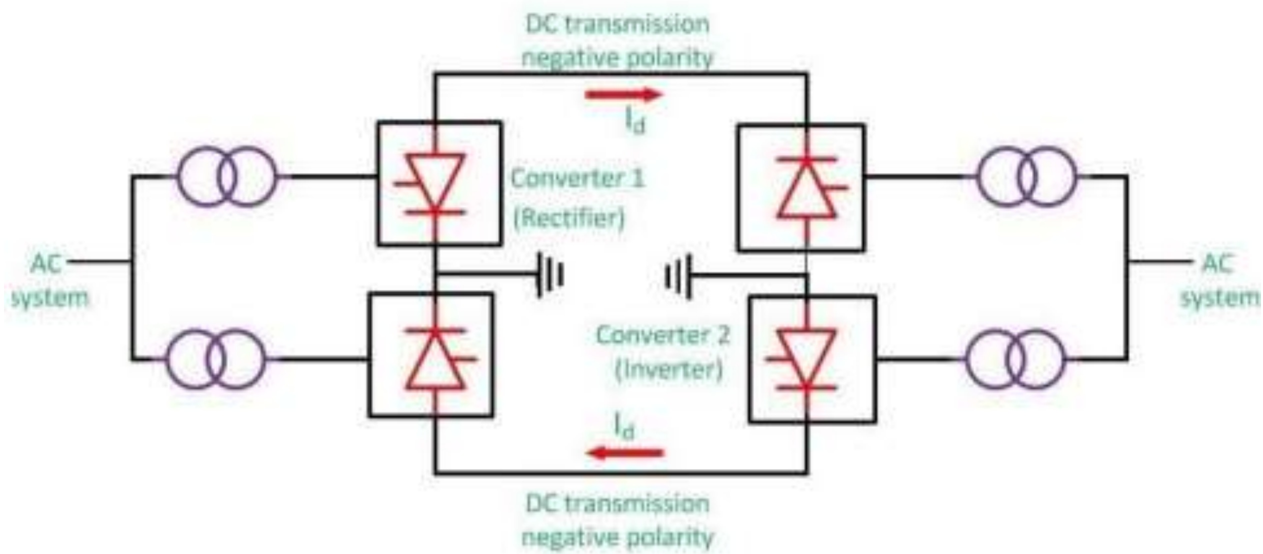
Monopolar DC link

2.Bipolar link: The Bipolar link has two conductors one is positive, and the other one is negative to the earth. The link has converter station at each end. The midpoints of the converter stations are earthed through electrodes. The voltage of the earthed electrodes is just half the voltage of the conductor used for transmission the HVDC. The most significant advantage of the bipolar link is that if any of their links stop operating, the link is converted into Monopolar mode because of the ground return system. The half of the system continues supplies the power. Such types of links are commonly used in the HVDC systems.



Bipolar DC link

3) Homopolar link : It has two conductors of the same polarity usually negative polarity, and always operates with earth or metallic return. In the homopolar link, poles are operated in parallel, which reduces the insulation cost. The homopolar system is not used presently.



Homopolar DC link

Equipment in a Transformer Sub-Station

The equipment required for a transformer sub-station depends upon the type of sub-station, service requirement and the degree of protection desired. However, in general, a transformer sub-station has the following main equipment :

1.Bus-bars

When a number of lines operating at the same voltage have to be directly connected electrically, bus-bars are used as the common electrical component. Bus-bars are copper or aluminium bars (generally of rectangular x-section) and operate at constant voltage. The incoming and outgoing lines in a sub-station are connected to the bus-bars. The most commonly used bus-bar arrangements in sub-stations are :

(i) Single bus-bar arrangement

(ii) Single bus-bar system with sectionalisation

(iii) Double bus-bar arrangement

2. Insulators

The insulators serve two purposes. They support the conductors (or bus-bars) and confine the current to the conductors. The most commonly used material for the manufacture of insulators is porcelain. There are several types of insulators (e.g. pin type, suspension type, post insulator etc.) and their use in the sub-station will depend upon the service requirement. For example, post insulator is used for bus-bars.

A post insulator consists of a porcelain body, cast iron cap and flanged cast iron base. The hole in the cap is threaded so that bus-bars can be directly bolted to the cap.

3. Isolating switches

In sub-stations, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or isolator. An isolator is essentially a knife switch and is designed to open a circuit under no load. In other words, isolator switches are operated only when the lines in which they are connected carry no current.

4. Circuit breaker

A circuit breaker is an equipment which can open or close a circuit under normal as well as fault conditions. It is so designed that it can be operated manually (or by remote control) under normal conditions and automatically under fault conditions. For the latter operation, a relay circuit is used with a circuit breaker. Generally, bulk oil circuit breakers are used for voltages upto 66kV while for high (>66 kV) voltages, low oil circuit breakers are used. For still higher voltages, air-blast, vacuum or SF6 circuit breakers are used.

5. Power Transformers

A power transformer is used in a sub-station to step-up or step-down the voltage. Except at the power station, all the subsequent sub-stations use step-down transformers to gradually reduce the voltage of electric supply and finally deliver it at utilisation voltage. The modern practice is to use 3-phase transformers in sub-stations ; although 3 single phase bank of transformers can also be used. The use of 3-phase transformer (instead of 3 single phase bank of transformers) permits two advantages. Firstly, only one 3-phase load-tap changing mechanism can be used. Secondly, its installation is much simpler than the three single phase transformers. The power transformer is generally installed upon lengths of rails fixed on concrete slabs having foundations 1 to 1·5 m deep. For ratings upto 10 MVA, naturally cooled, oil immersed transformers are used. For higher ratings, the transformers are generally air blast cooled.

6. Instrument transformers.

The lines in sub-stations operate at high voltages and carry current of thousands of amperes. The measuring instruments and protective devices are designed for low voltages (generally 110 V) and currents (about 5 A). Therefore, they will not work satisfactorily if mounted directly on the power lines. This difficulty is overcome by installing instrument transformers on the power lines. The function of these instrument transformers is to transfer voltages or currents in the power lines to values which are convenient for the operation of measuring instruments and relays. There are two types of instrument transformers viz.

(i) Current transformer (C.T.) (ii) Potential transformer (P.T.)

(i) Current transformer (C.T.): A current transformer in essentially a step-up transformer which steps down the current to a known ratio. The primary of this transformer consists of one or more turns of thick wire connected in series with the line. The secondary consists of a large number of turns of fine wire and provides for the measuring instruments and relays a current which is a constant fraction of the current in the line. Suppose a current transformer rated at 100/5 A is connected in the line to measure current. If the current in the line is 100 A, then current in the secondary will be 5A. Thus the C.T. under consideration will step down the line current by a factor of 20.

(ii) Potential transformer (P.T.): It is essentially a step down transformer and steps down the voltage to a known ratio. The primary of this transformer consists of a large number of turns of fine wire connected across the line. The secondary winding consists of a few turns and provides for measuring instruments and relays a voltage which is a known fraction of the line voltage. Suppose a potential transformer rated at 66kV/110V is connected to a power line. If line voltage is 66kV, then voltage across the secondary will be 110 V.

7. Metering and Indicating Instruments

There are several metering and indicating instruments (e.g. ammeters, voltmeters, energy meters etc.) installed in a sub-station to maintain watch over the circuit quantities. The instrument transformers are invariably used with them for satisfactory operation.

8. Miscellaneous equipment

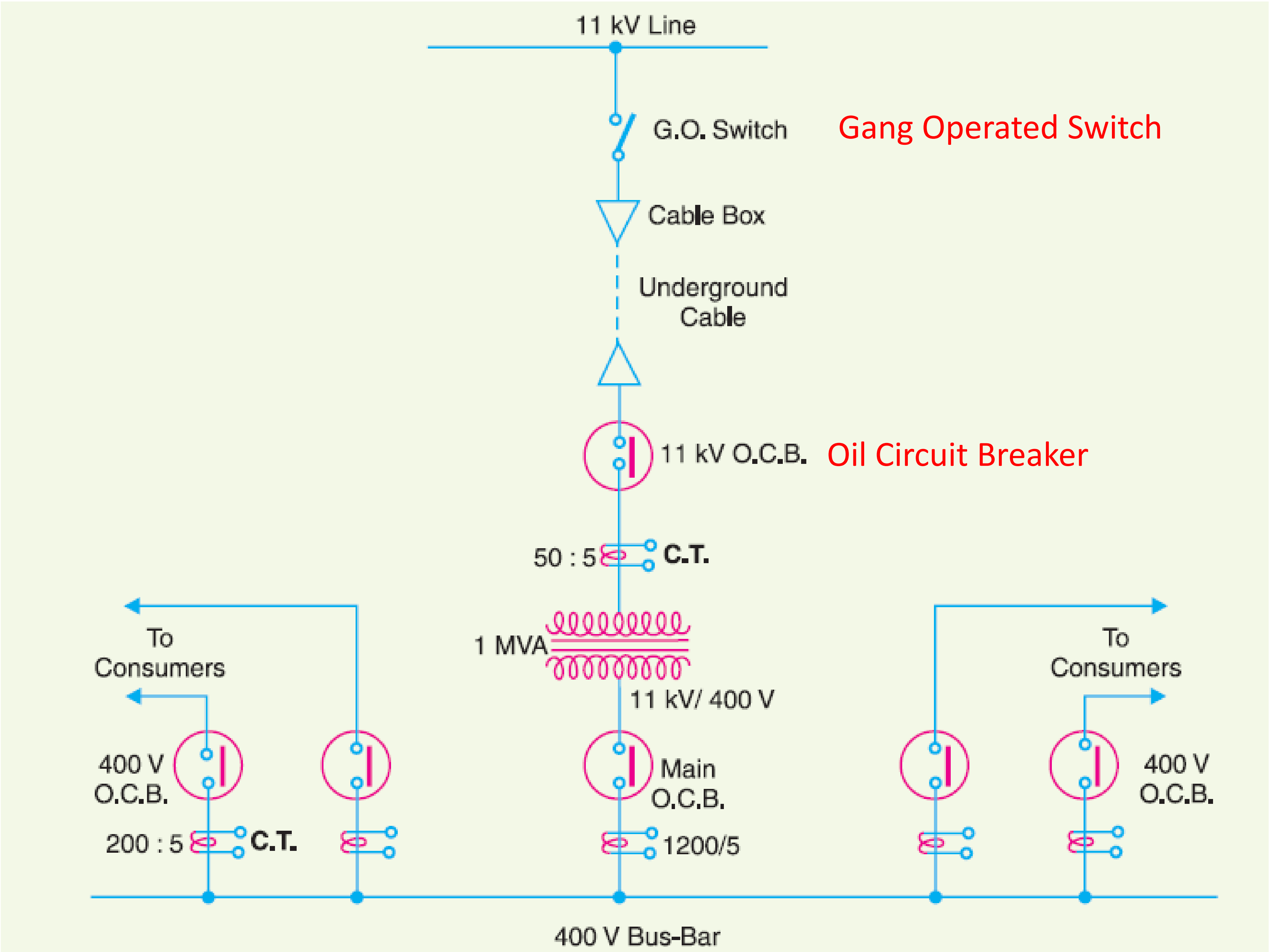
In addition to above, there may be following equipment in a sub-station :

(i) fuses

(ii) carrier-current equipment

(iii) sub-station auxiliary supplies

Key Diagram of 11 kV/400 V Indoor Sub-Station



The key diagram of this 11 kV/400 V sub-station can be explained as under :

(i) The 3-phase, 3-wire 11 kV line is tapped and brought to the gang operating switch installed near the sub-station. The G.O. switch consists of isolators connected in each phase of the 3-phase line.

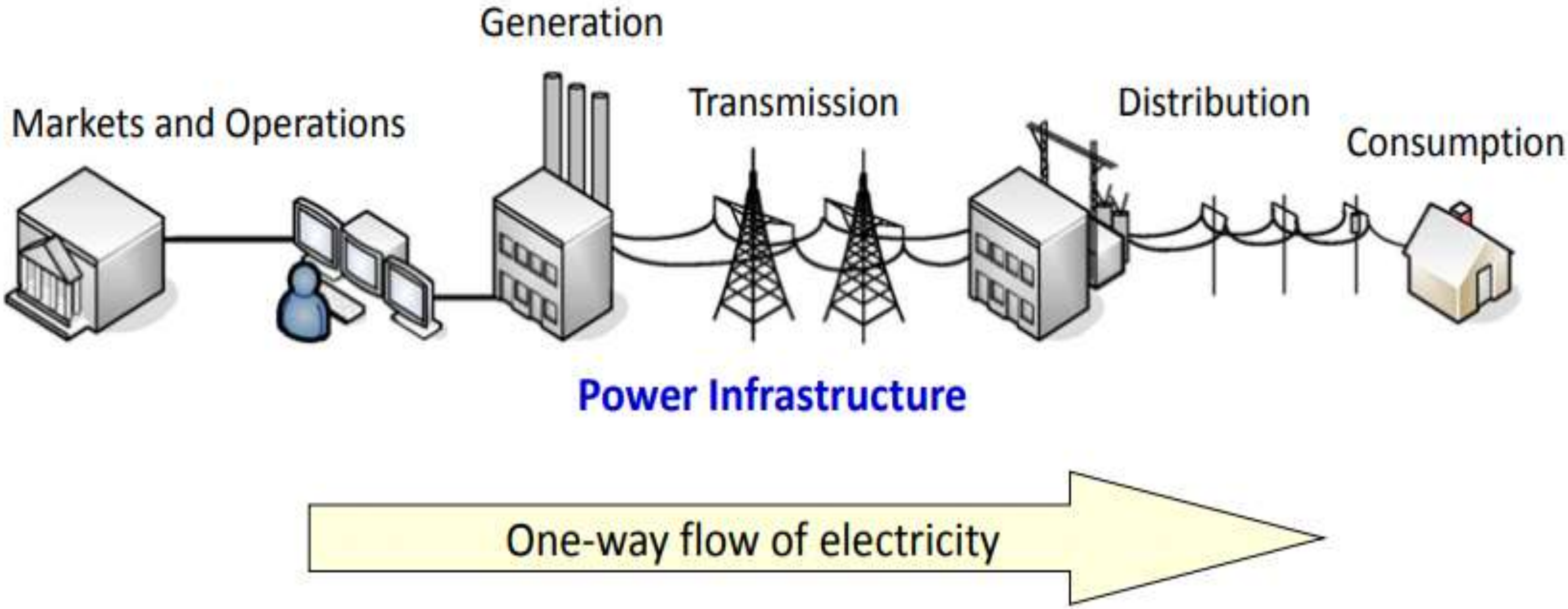
(ii) From the G.O. switch, the 11 kV line is brought to the indoor sub-station as underground cable. It is fed to the H.T. side of the transformer (11 kV/400 V) via the 11 kV O.C.B. The transformer steps down the voltage to 400 V, 3-phase, 4-wire.

(iii) The secondary of transformer supplies to the bus-bars via the main O.C.B. From the busbars, 400 V, 3-phase, 4-wire supply is given to the various consumers via 400 V O.C.B. The voltage between any two phases is 400 V and between any phase and neutral it is 230 V. The single phase residential load is connected between any one phase and neutral whereas 3-phase, 400 V motor load is connected across 3-phase lines directly.

(iv) The CTs are located at suitable places in the sub-station circuit and supply for the metering and indicating instruments and relay circuits.

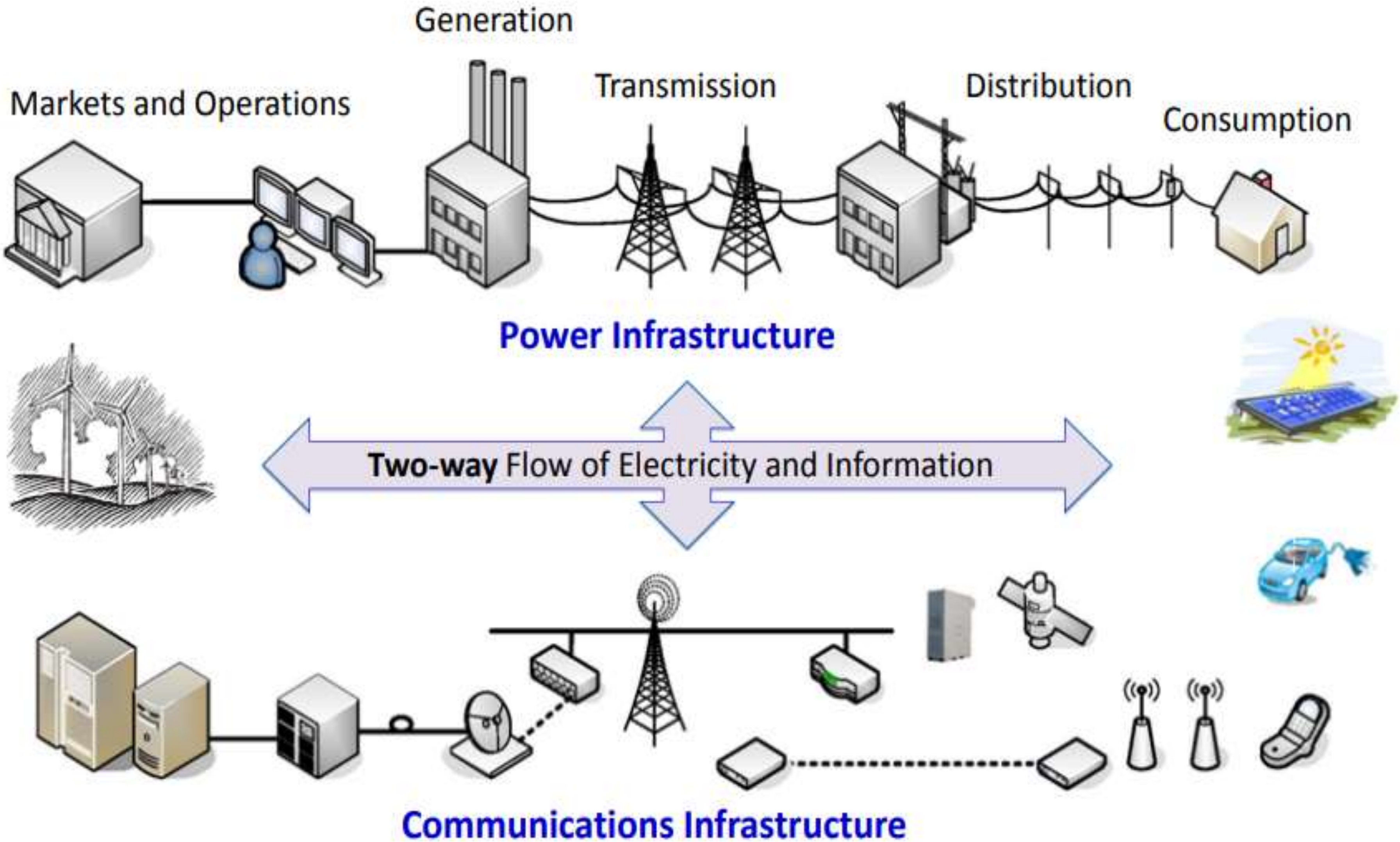
INTRODUCTION TO SMART GRID

1. TRADITIONAL POWER GRID



Centralized, bulk generation
Heavy reliance on coal and oil
Limited automation
Limited situational awareness
Consumers lack data to manage energy usage

2. SMART GRID



Generation
Markets and Operations
Transmission
Distribution
Consumption
Power Infrastructure
Two-way Flow of Electricity and Information
Communications Infrastructure

Safety Precautions when Working with Electricity

1. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of electric current.
2. Never use equipment with damaged insulation or broken plugs.
3. If you are working on any electrical socket at your home then always turn off the mains.
4. Always use insulated tools while working.(never use aluminium or steel ladder)
5. Electrical hazards include exposed energized parts and unguarded electrical equipment which may become energized unexpectedly -carries warning signs like “Shock Risk”. Always be observant such electrical signs.

6. when working electrical circuit always use appropriate insulated rubber gloves and goggles.

7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire.

8. Know the wire code of your country.

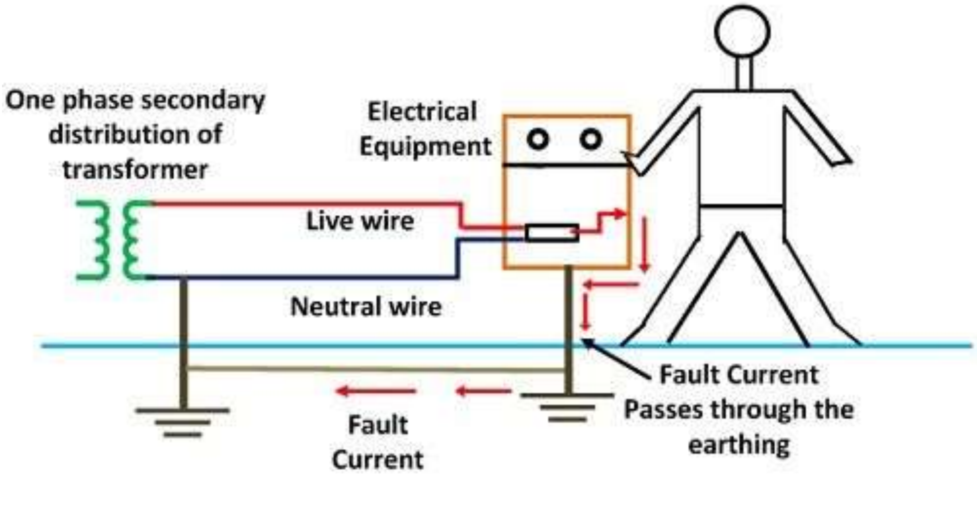
9. Always use a circuit breaker or fuse with the appropriate current rating. Circuit breakers and fuses are protection devices that automatically disconnect the live wire when a condition of short circuit or over current occurs. The selection of the appropriate fuse or circuit breaker is essential.

ELECTRICAL SAFETY DEVICES

- It is extremely important to have various safety devices to protect from fire and electrocution.
- **FUSE:** A fuse is an electrical safety device that has the capability to protect an electric circuit from excessive electric current. It is designed to allow current through the circuit, but in the event that the current exceeds some maximum value it will open, severing the circuit.
- **Circuit breaker:** Circuit breakers are devices that protect circuits from overload current conditions. They do the same job as fuses, but they are not destroyed when activated.

EARTHING

- The potential of the earth is considered to be at zero for all practical purposes.
- Earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential.
- This ensures safe discharge of electric energy, which may be due to reasons like failure of the insulation, line coming in contact with the casing etc.
- Earthing brings the potential of the body of the equipment to ZERO i.e. to the earth's potential, thus protecting the operating personnel against electrical shock.



Electrical System With Earthing

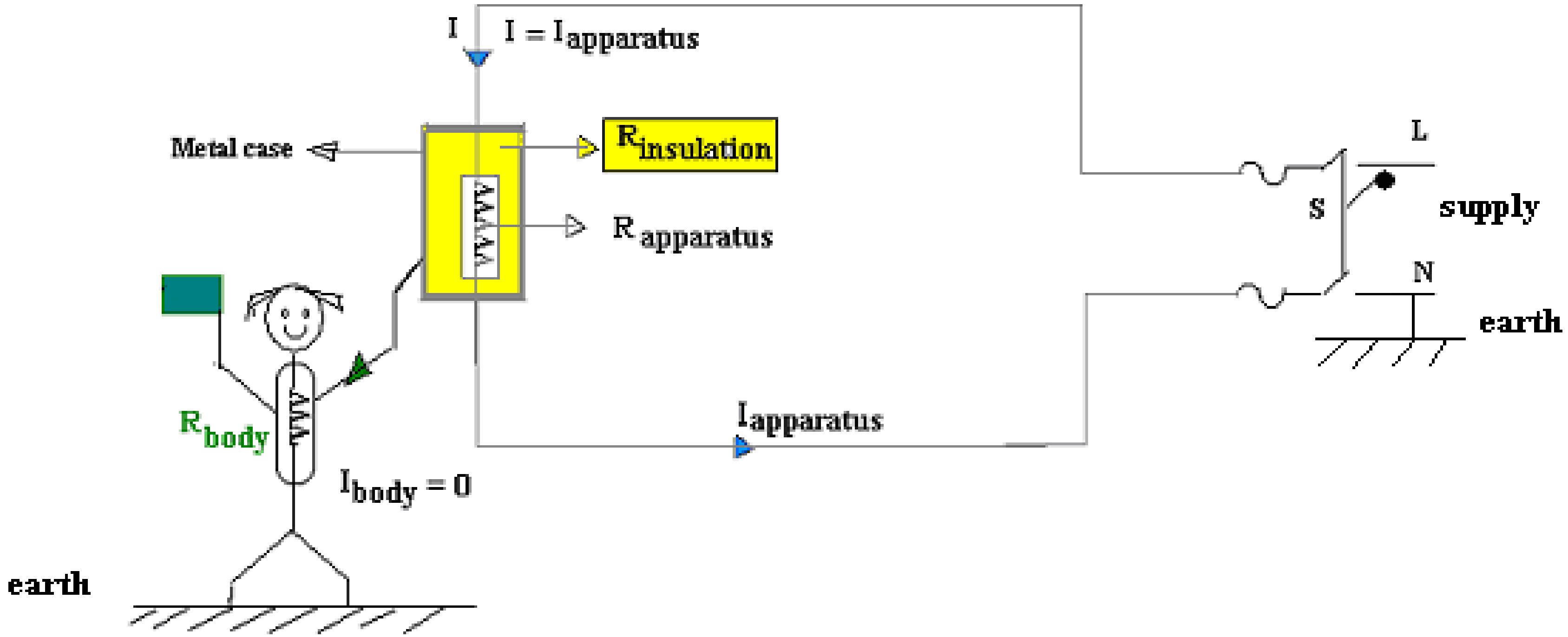
Plug with no earth PIN

Importance of Earthing

Case I

Healthy insulation

Apparatus not earthed

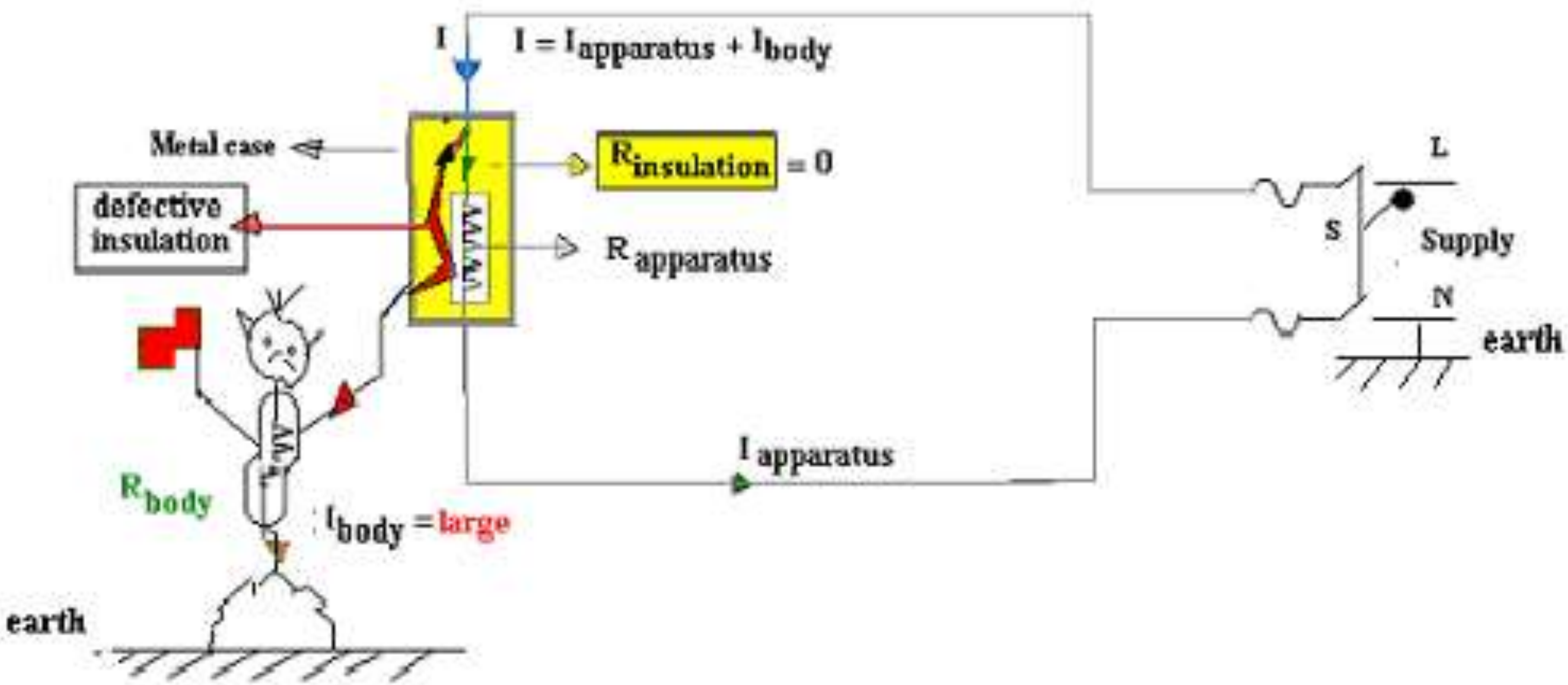


1. Insulation is healthy (R insulation $= \infty$)
2. Supply current flows through the resistence of the apparatus only ($R_{apparatus}$)
3. No current flows through the body resistance ($I_{body} = 0$)
4. The person is safe even if the apparatus is not earthed

Case II

Defective insulation

Apparatus not earthed

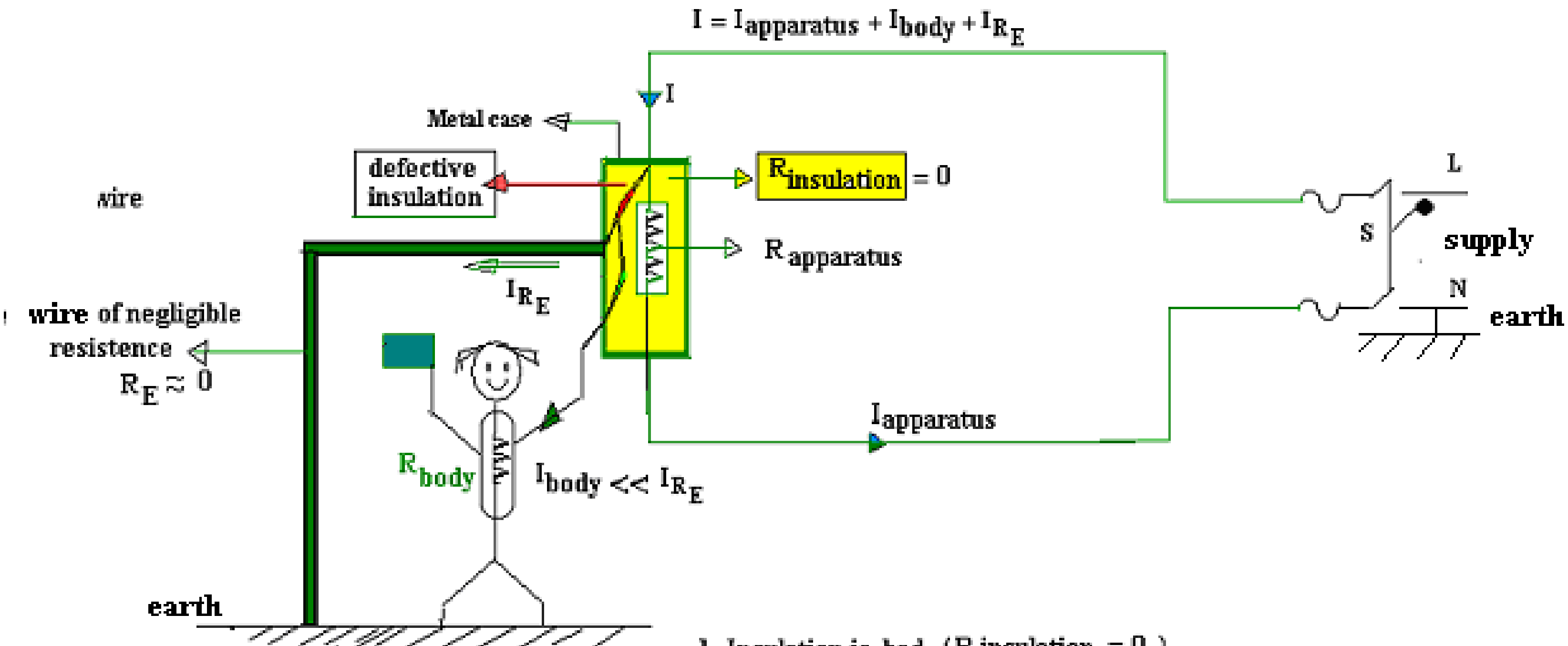


1. Insulation is bad (R insulation = 0)
2. Supply current now divides into $I_{apparatus}$ and I_{body}
3. A part of the supply current flows through the body to the ground I_{body}
4. The person experiences shock as the apparatus is not earthed

Case III

Defective insulation

Apparatus earthed



1. Insulation is bad (R insulation $= 0$)
2. Supply current now divides into $I_{apparatus}$ I_{body} and I_{R_E}
3. A part of the supply current I_{body} flows through the body to the ground
4. Now I_{body} is very less compared to the current flowing through wire of negligible resistance connecting the apparatus metal case to ground

   $I_{body} << I_{R_E}$

5. The person in contact with the apparatus does not experience any shock as the metal casing is earthed

EARTHING AND ITS NECESSITY

- Earthing means generally connected to the mass of the earth. It shall be in such a manner as to ensure at all times an immediate and safe discharge of electric current due to leakages, faults, etc.

- All metallic parts of every electrical installation such as conduit, metallic sheathing, armouring of cables, metallic panels, frames, iron clad switches, instrument frames, household appliances, motors, starting gears, transformers, regulators etc, shall be earthed using one continuous bus (barewire). If one earth bus for the entire installation is found impracticable, more than one earthing system shall be introduced. Then, the equipment and appliances shall be divided into sub-groups and connected to the different earth buses.

The earthing conductors, when taken out doors to the earthing point, shall be encased in pipe securely supported and continued up to a point not less than 0.3 more below ground level. No joints are permitted in an earth bus. Whenever there is a lightning conductor system installed in a building, its earthing shall not be bonded to the earthing of the electrical installation.

Before electric supply lines or apparatus are energized, all earthing system shall be tested for electrical resistance to ensure efficient earthing. It shall not be more than two ohms including the ohmic value of earth electrode.

Types of Earthing

1. **Plate Earthing**

2. **Pipe Earthing**

.1 Earthing through a G.I. Pipe

In this method a G.I. pipe used as an earth electrode. The size of the pipe depends upon the current to be carried and type of soil in which the earth electrode is buried.

For ordinary soils the length of the G.I. pipe used as an earth elctrode is 2 m long and 38 mm in diameter or 1.37 m long and 51 mm in diameter. For dry and

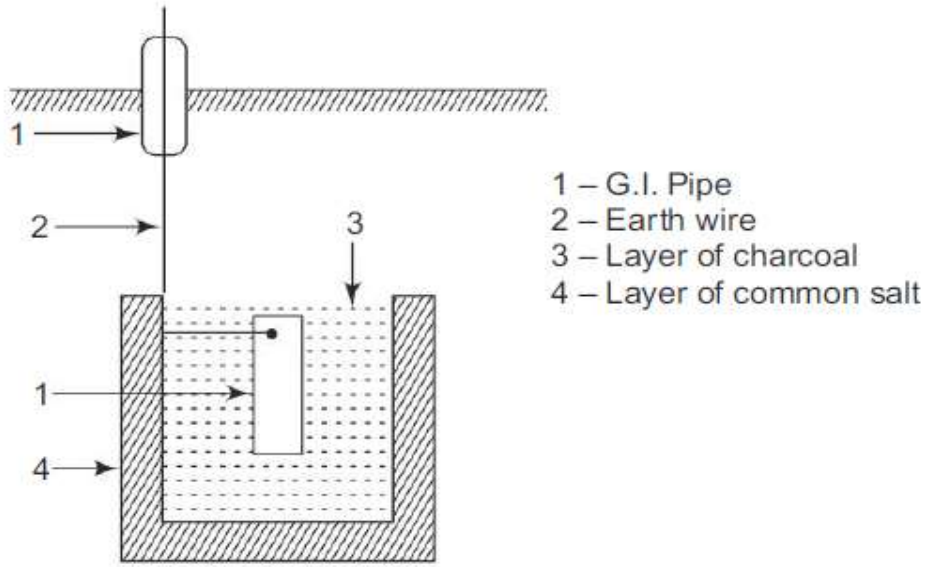
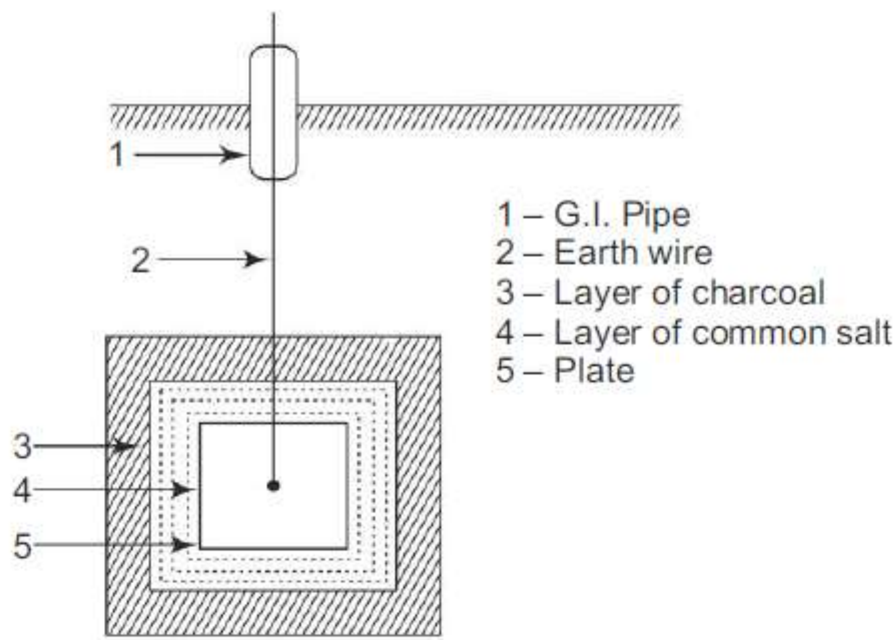


Fig. 8.3

rocky soils the length may be increased to about 2.75 metres and 1.85 metres respectively. The pipe is placed vertically, burying to a depth not less than 2 metres in as moist a place as possible, preferably in close proximity of water tap, water pipe or water drain and at least 0.6 metre away from all building foundations, etc as shown in Fig. 8.3. The pipe shall be completely covered by 80 mm of Charcoal with the layer of common salt 30 mm all around it. The charcoal and salt decreases the earth resistance.

.2 Earthing through a Plate

A G.I. or copper plate is used as an earth electrode. If a G.I. plate is used it shall be of dimensions 0.3 m × 0.3 m and 6.35 mm thick and if a copper plate is used it shall be of dimensions 0.3 m × 0.3 m and 3.2 mm thick. The plate is buried to a depth of not less than 2 m in as moist a place as possible preferably in close proximity of water tap, water pipe or water drain and at least 0.6 m away from all building foundations, etc. The plate shall be completely covered by 80 mm of charcoal with a layer of common salt of 30 mm all around it, keeping the faces of the vertical as shown in Fig. 8.4.



Precautions for Electric shock

It's vitally important to take safety precautions when working with electricity. Safety must not be compromised and some ground rules need to be followed first. The basic guidelines regarding electrical safety documented below will help you while working with electricity.

1. The first step of electrical safety, avoid water at all times when working with electricity. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of the electric current.
2. Never use equipment with frayed cords, damaged insulation, or broken plugs.

3. If you are working on any receptacle at your home then always turn off the mains. It is also a good idea to put up a sign on the service panel so that nobody turns the main switch ON by accident.

4. Always use insulated tools while working.

5. Electrical hazards include exposed energized parts and unguarded electrical equipment which may become energized unexpectedly. Such equipment always carries warning signs like “Shock Risk”. Always be observant of such signs and follow the safety rules established by the electrical code followed by the country you’re in.

6. Always use appropriate insulated rubber gloves and goggles while working on any branch circuit or any other electrical circuit.

7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire. Check all the wires, the outer metallic covering of the service panel, and any other hanging wires with an electrical tester before proceeding with your work.

8. Never use an aluminum or steel ladder if you are working on any receptacle at height in your home. An electrical surge will ground you and the whole electric current will pass through your body. Use a bamboo, wooden or a fiberglass ladder instead.

9. Know the wire code of your country.

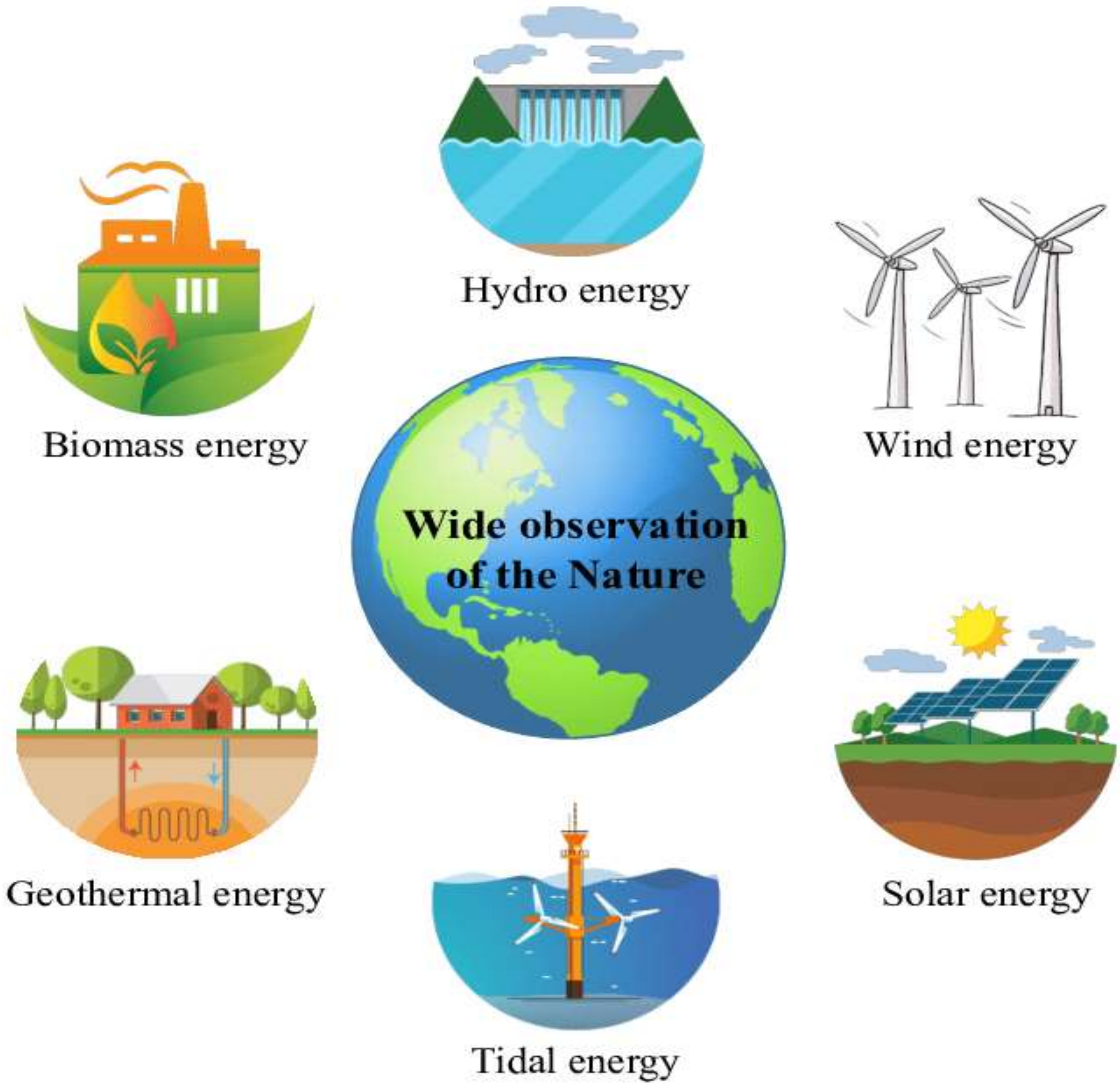
10. Always check all your GFCI’s once a month. A GFCI (Ground Fault Circuit Interrupter) is a RCD (Residual Current Device). They have become very common in modern homes, especially damp areas like the bathroom and kitchen, as they help avoid electrical shock hazards. It is designed to disconnect quickly enough to avoid any injury caused by over-current or short circuit faults.

RENEWABLE ENERGY

- Renewable energy is a term used to refer to forms of energy that are naturally obtained from the environment and from sources that can be replenished naturally.
- These include **solar energy, wind energy, geothermal energy, hydropower, tidal and biomass**.

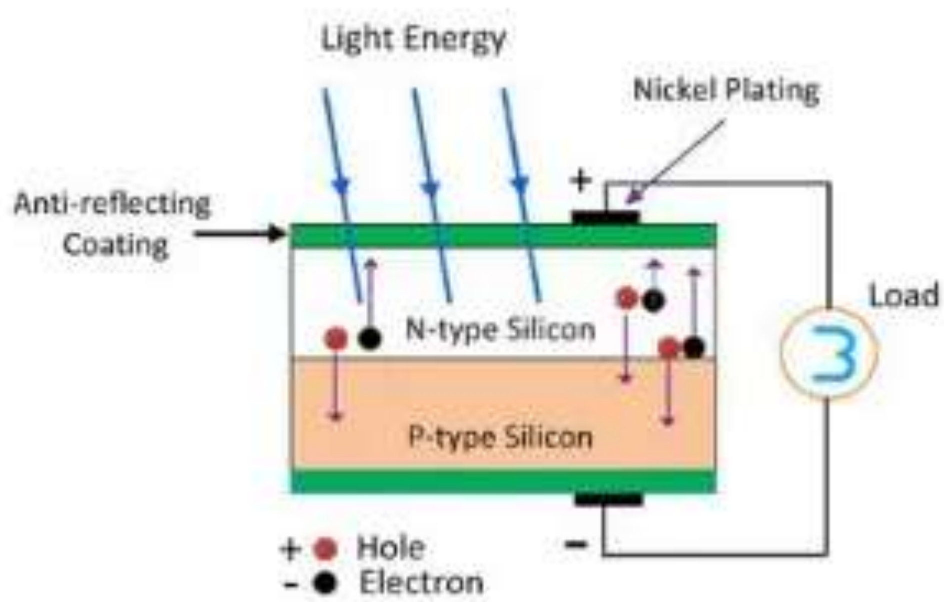
Advantages of Renewable Energy

- Less maintenance cost as most sources entail few or no moving parts, hence, less mechanical damages.
- Economical and can cut costs spent on fossil fuel.
- They emit little or no waste in the environment.
- Renewable energy sources do not deplete.


Hydro energy
Biomass energy
Wind energy
Wide observation of the Nature
Geothermal energy
Solar energy
Tidal energy

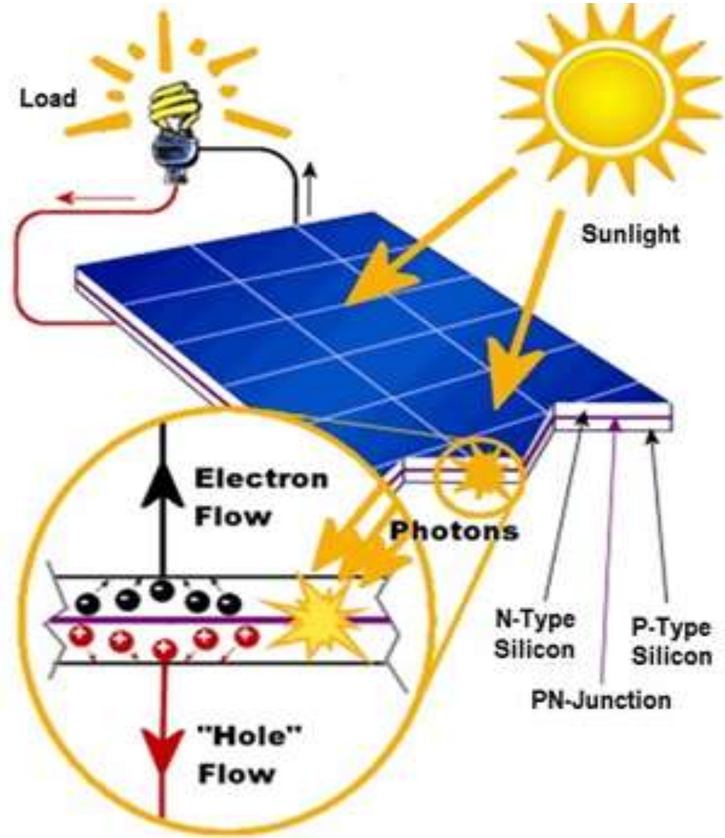
Solar Photovoltaic system

A **solar cell** (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light.



❑ Solar cells, a type of semiconductor device that efficiently absorbs solar radiation and converts it into electrical energy, are also known as photovoltaic cells because of their **photo-voltaic effect** using various potential barriers.

❑ A photovoltaic cell is also called a solar cell. It is a semiconductor device which converts sunlight into DC power using the photoelectric effect. Practically, all solar cells are photodiodes made of semiconductor material like silicon.



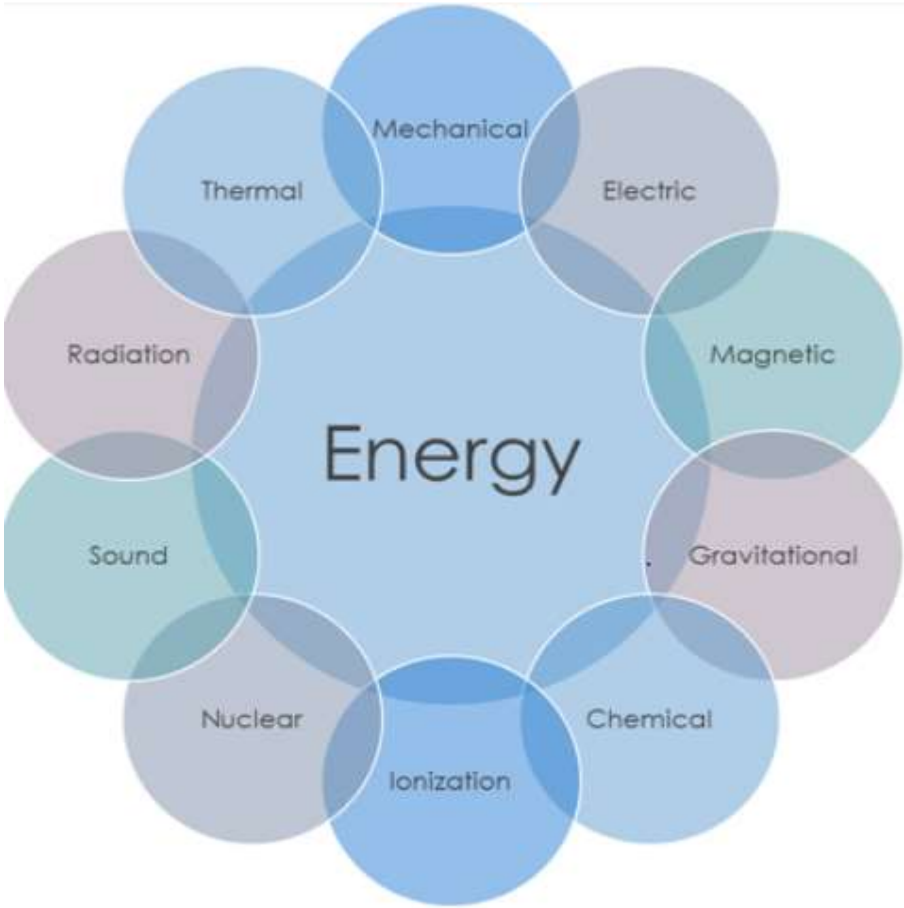
$$E = \hbar v = \hbar c / \lambda$$

Where E is the energy of the electromagnetic radiation, ħ is the Planck's constant with a value 1.055*10-34 J.s, ν is the frequency of the electromagnetic radiation, and c is the speed of light (3*108 m/s).

- A solar cell works in three steps: Photons in the sunlight hit the solar cell and are absorbed by the semiconductor material. Negatively-charged electrons are knocked off from their atoms and start flowing in the same direction to produce electric current.
- Output of a single solar cell is very small, **a large number of solar cells are interconnected to form a solar module, combination of solar modules is called panel and combination of panels is called solar array.** It is done to get the required power output from a PV system.
- When the solar cells are connected in series their voltage increases as much as the number of cells connected in series. But the current remains the same. When cells are connected in parallel, voltage remains constant, same as that of one cell but current gets multiplied

Solar Photovoltaic system

Introduction to Energy Storage

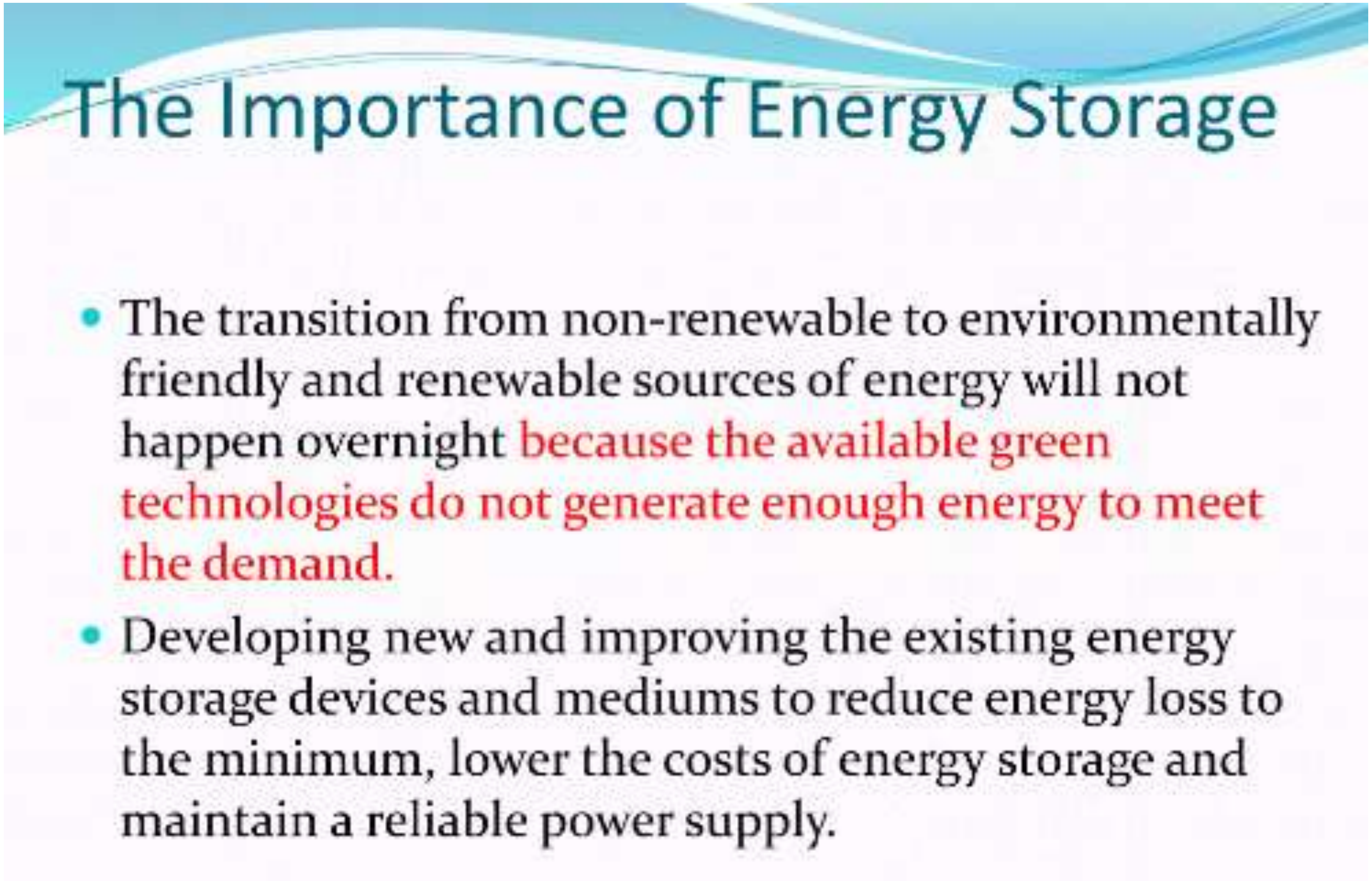


- ✓ Energy storage systems have been in use for a very long time, for diverse applications.
- ✓ Quantitative property held by an object or a system that can be consumed to perform work or convert the form of energy.
- ✓ retention of anything, whether physical or virtual, for (possible) usage in the future.

(i) Portable electronics (ii) Uninterruptible Power Supplies (UPS)

(iii) Energy offset for renewable energy

Energy storage systems



why is Energy Stored

- Energy storage uses various methods to store excess energy to be used at a later time which in turn allows the energy providers to balance between the demand and supply.
- A number of devices and media are used to store energy, while their selection depends primarily on the source of energy and the use.

Types of Energy Storage

- **Chemical energy storage.**
  - e.g : vanadium ; it is used in vanadium redox batteries
- **Electrochemical energy storage**
  - Battery.: chargeable and rechargeable batteries
  - Fuel cell
- **Electrical energy storage**
  - Capacitor and superCapacitor

- **Thermal energy storage**

Overview of Battery

- Batteries are a collection of one or more cells whose chemical reactions create a flow of electrons in a circuit. All batteries are made up of three basic components: an anode (the '+' side), a cathode (the '-' side), and some kind of electrolyte (a substance that chemically reacts with the anode and cathode).

Types:

1. **Lead acid**
2. **Nickel cadmium**
3. **Nickel metal hydride**
4. **Lithium ion**
5. **Sodium sulphur**
6. **Redox flow**

Fuel cell technologies

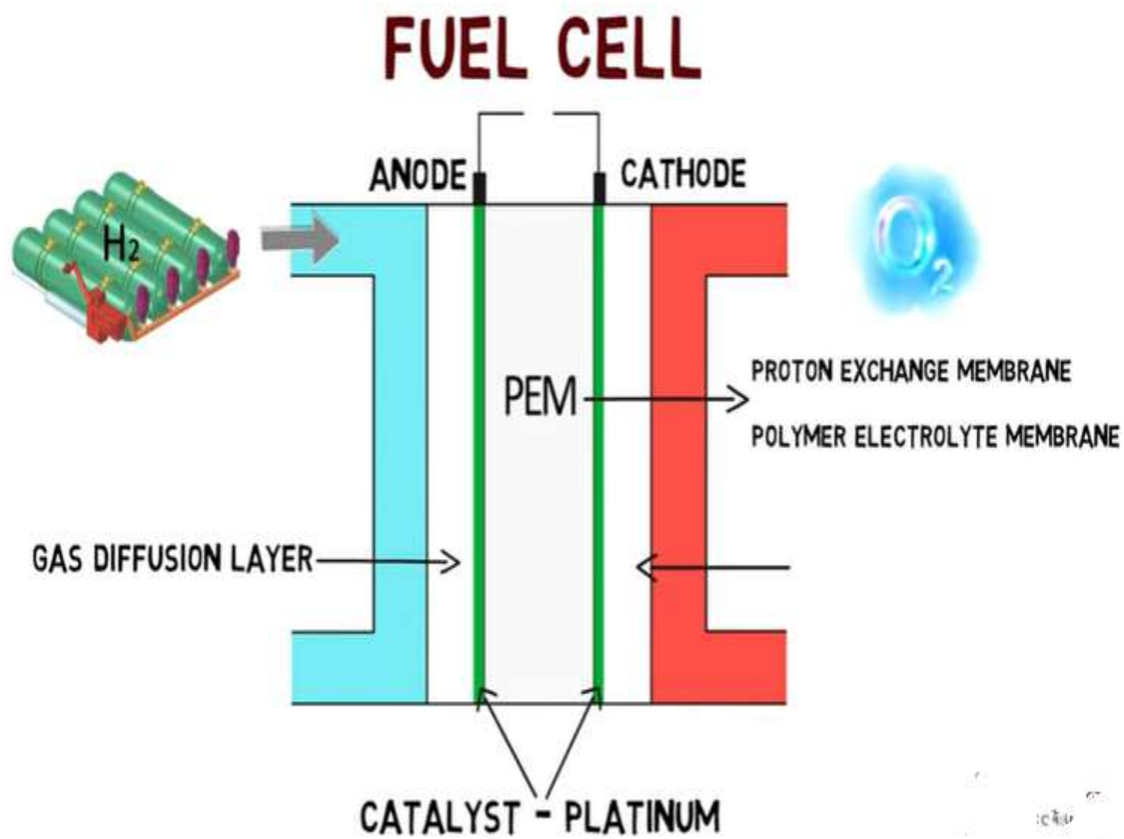
The fuel cell technology is a clean technology with low chemical pollution and is a chemical engineering way of producing energy based on electrochemical energy conversion of chemical energy of hydrogen and oxygen into electricity and heat which produces only water as the by product.

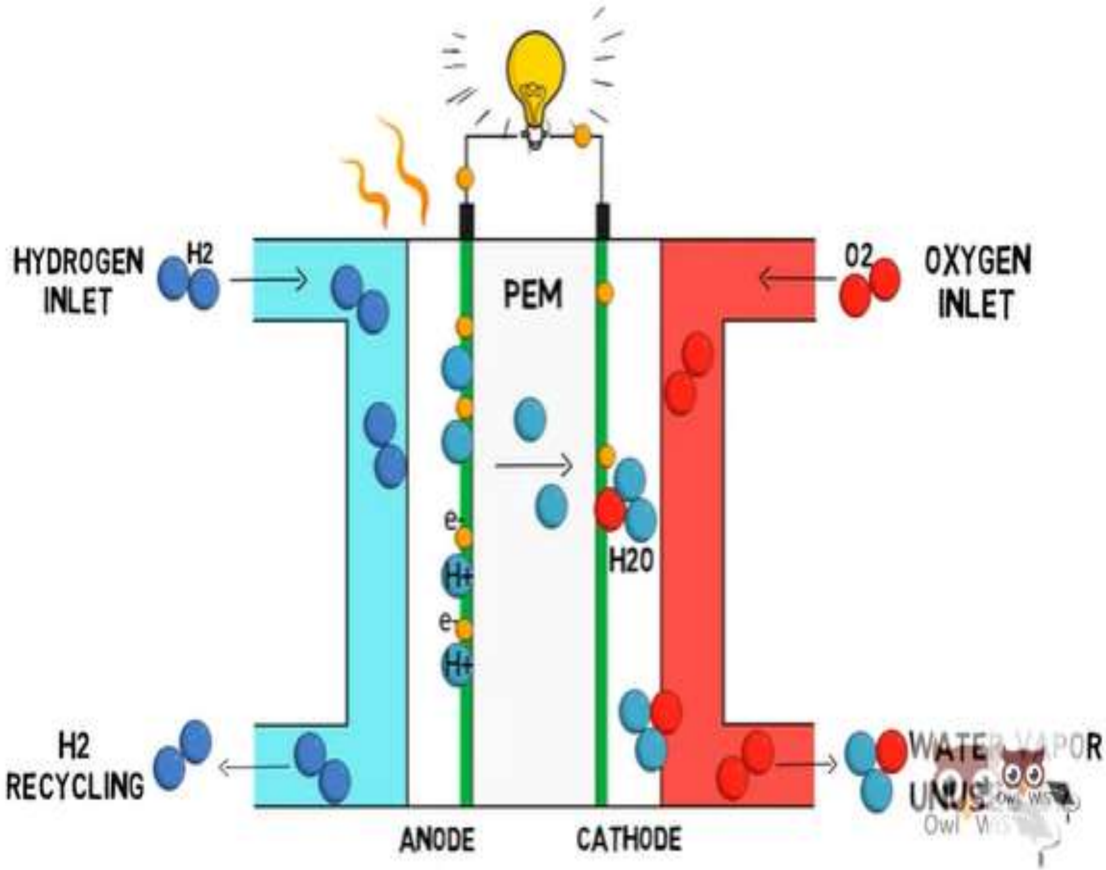
Working of a Fuel Cell

A fuel cell typically consists of two electrodes, namely, an anode and cathode separated by an electrolyte membrane. The organic fuel that can be used in a fuel cell to produce electricity includes hydrogen, methane, ethane, ethanol, etc. These fuels underdo combustion and release energy in the form of heat. Most of such reactions produce water and carbon-di-oxide as by-products and are prominently redox reactions. Redox reactions involve the transfer of electrons that leads to the conversion of chemical energy into electrical energy.

An electrolyte material is present between the electrodes. Fuel is supplied to both the electrodes individually. For instance, let us say that in a fuel cell the hydrogen is fed to the anode, while air is fed to the cathode. Here, the catalyst present at the anode side of the cell tends to break the hydrogen molecules into smaller particles, i.e., protons and electrons. Both the elements try to move towards the cathode following different paths.

The electrons reach the cathode following an external path, thereby producing the current, whereas the protons travel through the electrolyte membrane and reach the cathode to combine with oxygen molecules and electrons to produce water and heat as by-products.




HYDROGEN
INLET
H2
PEM
O2
OXYGEN
INLET
e-
H+
e-
H+
H20
H2
RECYCLING
ANODE
CATHODE

Advantages of a Fuel Cell

1. A fuel cell does not require any sort of recharging. A fuel cell is able to reproduce the energy till it is supplied with fuel.

2. If hydrogen is used as the input fuel, then the only byproducts observed are water, heat, and electricity, thereby producing electrical energy with utmost efficiency and with no release of toxic substances.

3. Fuel cells are highly efficient as they are able to directly convert chemical energy into electrical energy. In comparison to the other alternatives available in the market, fuel cells are 60% more efficient.

4. Fuel cells do not contribute to air pollution in any way.

5. Fuel cells are not hazardous and do not lead to health problems as the working of fuel cells does not lead to the formation of smoke or smog.

6. A fuel cell does not have any mechanical part; therefore, they are noiseless.

Disadvantages of a Fuel Cell

1. Fuel cells are expensive in nature.

2. Fuel cells are difficult to store as the fuel used in the cells require a particular temperature and pressure level to be maintained.

3. Fuel cells are comparatively less durable.

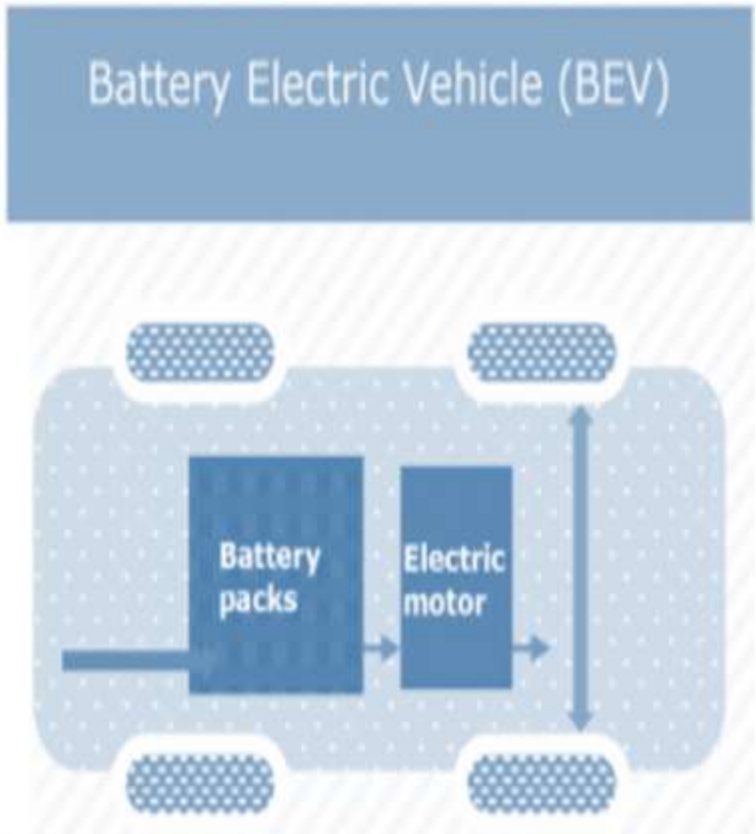
4. The average lifespan of fuel cells is not quite high.

Applications of a Fuel Cell

- Fuel cells are widely used in transportation vehicles such as buses, trucks, cars, etc. This is because fuel cells do not release toxic gases; therefore, these are cleaner alternatives to power vehicles. The use of fuel cells in vehicles tends to significantly increase reliability. It is also used to power FCEVs.
- Fuel cells are prominently employed in material handling equipment to ease the process of transporting heavy goods from one place to another.
- A number of backup power generation systems make use of fuel cells for their operation. Stationary fuel cells are a crucial element of the uninterrupted power supply devices installed in hospitals, residential buildings, industries, offices, etc.
- Hydrogen fuel cells provide a versatile option to power various electronic gadgets and communication devices such as mobile phones, laptops, etc.
- Fuel cells are often used to power rockets and space shuttles as they do not release much toxic waste into the environment.

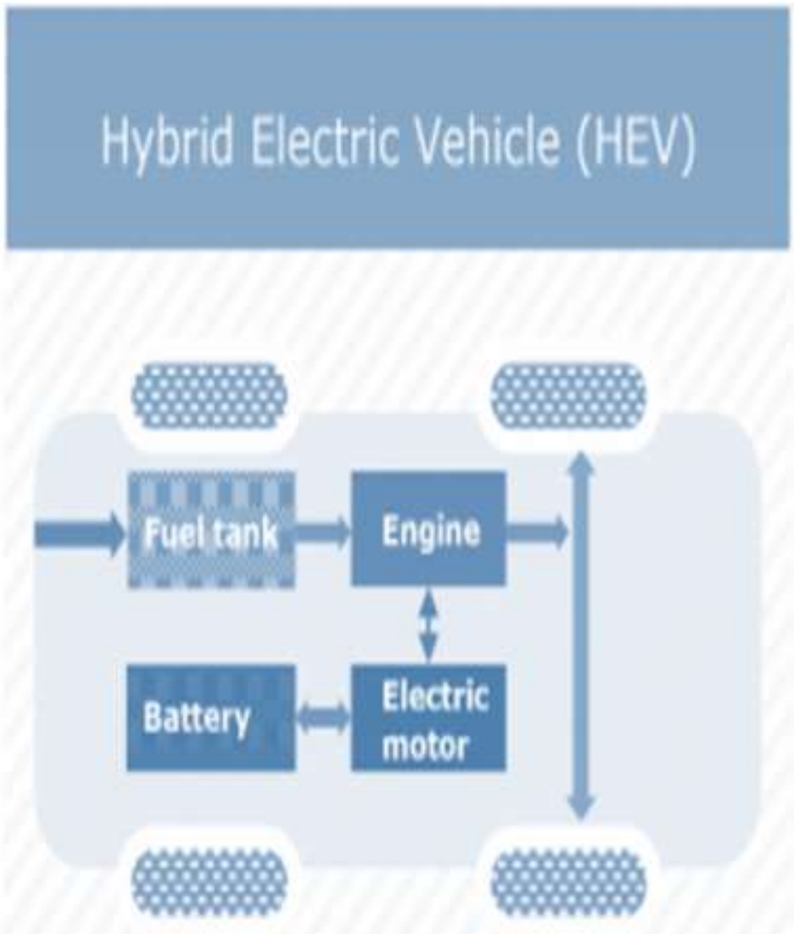
Types of EVS

(i) BEV (Battery Electric Vehicle)



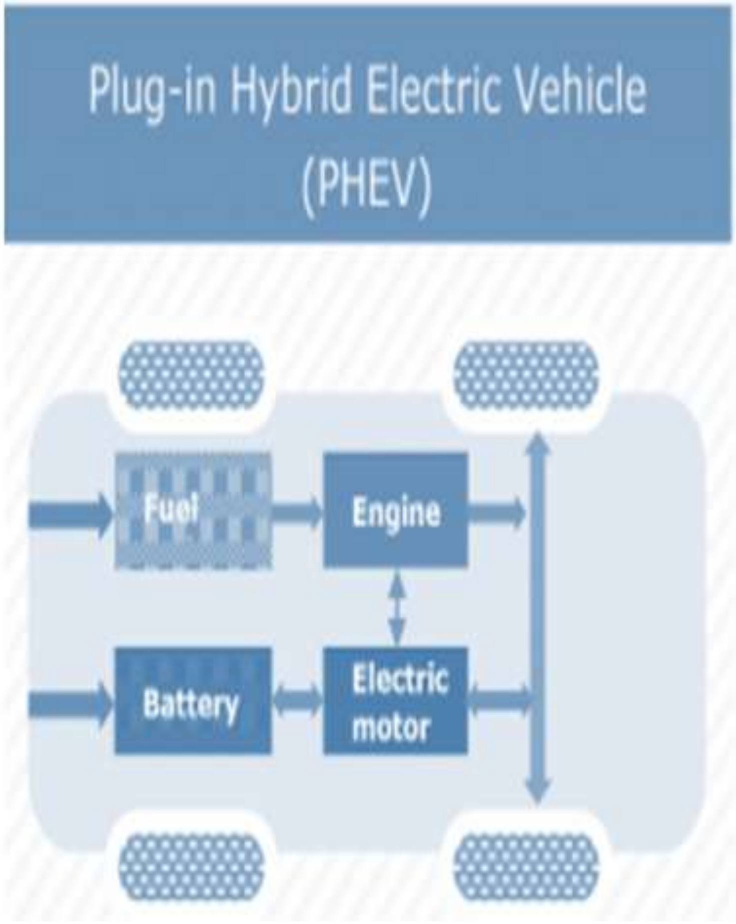
- EVs run on battery power without an internal combustion engine's assistance, they can run much faster on a single charge than hybrid vehicles.
- They're also known as battery electric vehicles, or BEVs. That's what distinguishes them from hybrids that run on battery power with assistance from internal combustion engines

(ii) HEV (Hybrid Electric Vehicle)



- ❑ HEVs run on both an internal combustion engine and an electric motor that uses energy stored in a battery. Unlike most electric vehicles, however, HEV drivers charge their batteries via regenerative braking.
- ❑ Regenerative braking stores the kinetic energy used to stop the car to charge its battery and help the internal combustion engine accelerate the vehicle.

(iii) PHEV (Plug in Hybrid Electric Vehicle)



- PHEVs expand on the concept of the standard hybrid vehicle. They have both an internal combustion engine and a battery-powered electric motor. This allows the battery to store enough power to feed the electric motor and in turn decrease your gas usage by as much as 60 percent.
- This can save you time and money at the gas pump. PHEVs can travel up to 40 miles on electric power alone, rather than a couple of miles with a standard hybrid vehicle.

EVs

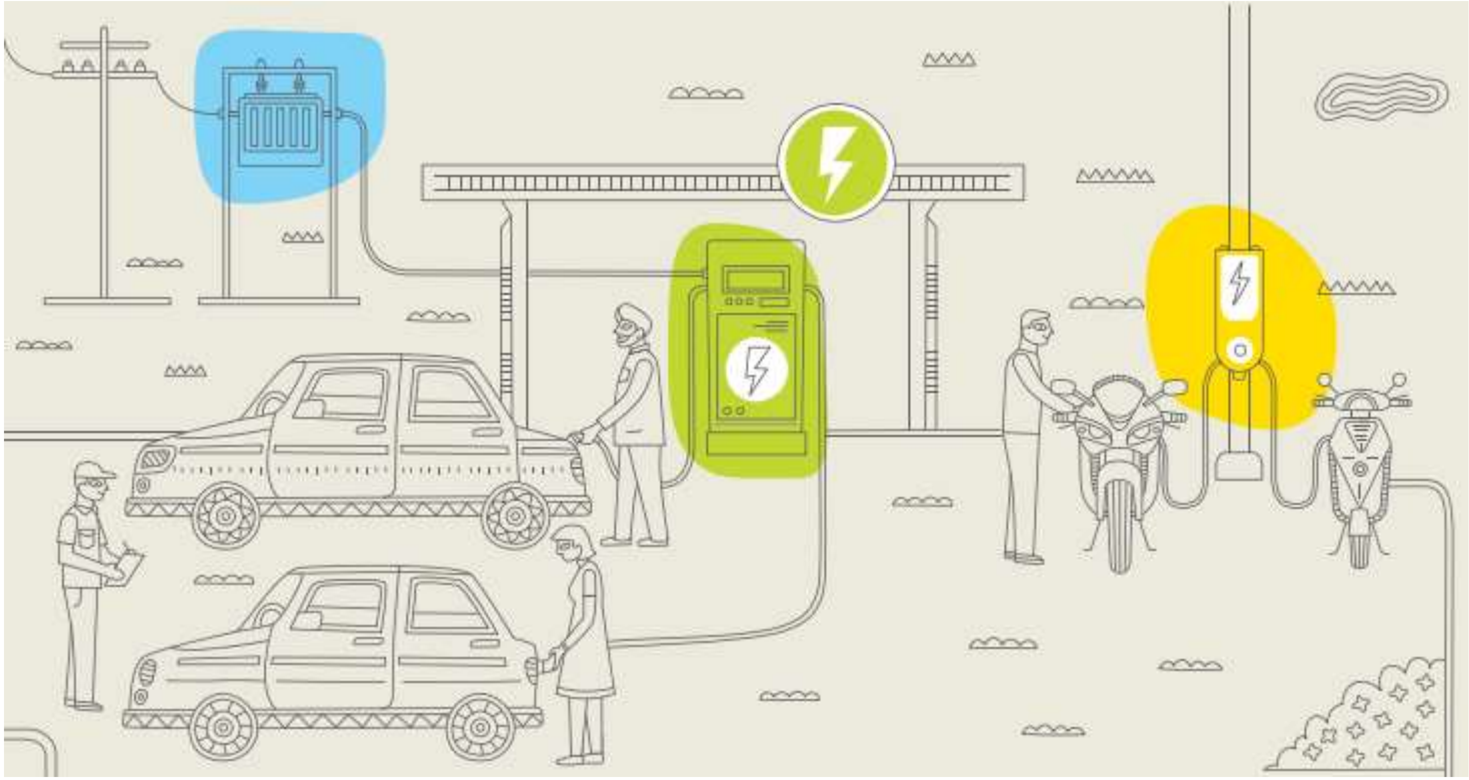
An electric vehicle (EV)is a vehicle that uses one or more electric motors for propulsion. It can be powered by a collector system, with electricity from extravehicular sources, or it can be powered autonomously by a battery (sometimes charged by solar panels, or by converting fuel to electricity using fuel cells or a generator).EVs include, but are not limited to, road and rail vehicles, surface and underwater vessels, electric aircraft , and electric spacecraft. For road vehicles, together with other emerging automotive technologies such as autonomous driving, connected vehicles, and shared mobility, EVs form a future mobility vision called Connected, Autonomous, Shared, and Electric (CASE) Mobility.

EVs first came into existence in the late 19th century, when electricity was among the preferred methods for motor vehicle propulsion, providing a level of comfort and ease of operation that could not be achieved by the gasoline cars of the time. Internal combustion engines were the dominant propulsion method for cars and trucks for about 100 years, but electric power remained commonplace in other vehicle types, such as trains and smaller vehicles of all types.

Government incentives to increase adoption were first introduced in the late 2000s, including in the United States and the European Union, leading to a growing market for vehicles in the 2010s.Increasing public interest and awareness and structural incentives, such as those being built into the green recovery from the COVID-19 pandemic, are expected to greatly increase the electric vehicle market. During the COVID-19 pandemic, lockdowns reduced the number of greenhouse gases in gasoline or diesel vehicles. The International Energy Agency said in 2021 that governments should do more to meet climate goals, including policies for heavy electric vehicles. Electric vehicle sales may increase from 2% of the global share in 2016 to 30% by 2030.As of July 2022 the global EV market size was $280 billion and was expected to grow to $1 trillion by 2026.Much of this growth is expected in markets like North America, Europe, and China; a 2020 literature review suggested that growth in the use of electric 4-wheeled vehicles appears economically unlikely in developing economies, but that electric 2-wheeler growth is likely. There are more 2 and 3 wheel EVs than any other type.

EV Charging station

- EV charging points are primarily defined by the power (in kW) they can produce and therefore what speed they are capable of charging an EV. While connector types are also a key issue, most EVs are equipped with two or more cables to allow the use of chargers with different connector outlets.



CHARGE POINT TYPES

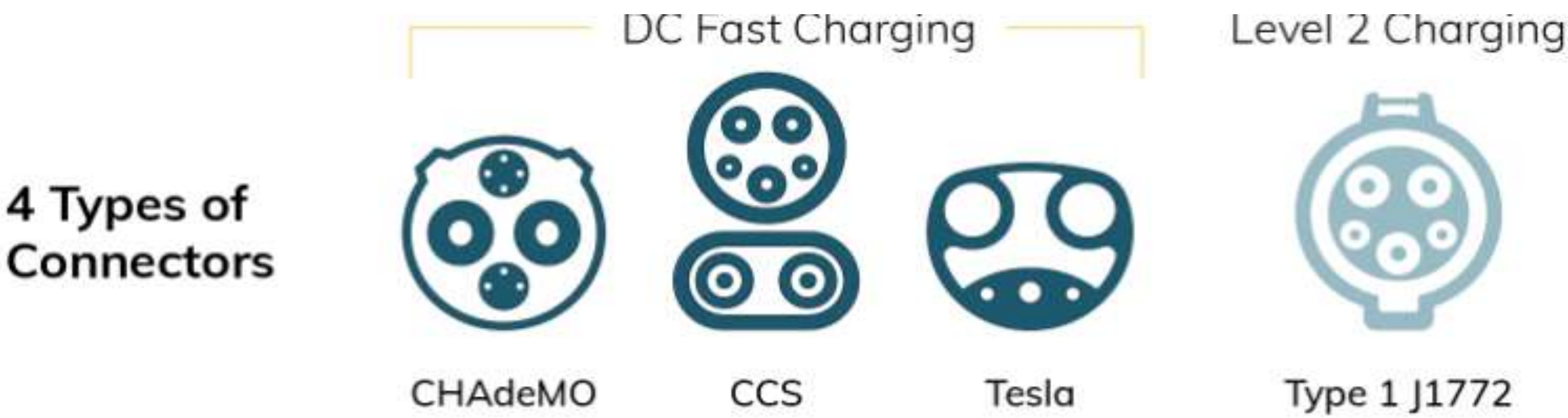
(i) Slow charging (up to 3kW)

(ii) Fast charging (7-22kW)

(iii) Rapid chargers (43-50kW)

4 categories:

- ❑ **The Process**
- ❑ **Time**
- ❑ **Price**
- ❑ **EVs are better for the environment**



'Charge de Move'
Nissan, Toyota, and Mitsubishi

Combined Charging System (all EVs except Tesla)

Only Tesla

DC Fast Charging

all EVs except Tesla