

Introduction to Electrical Power Systems

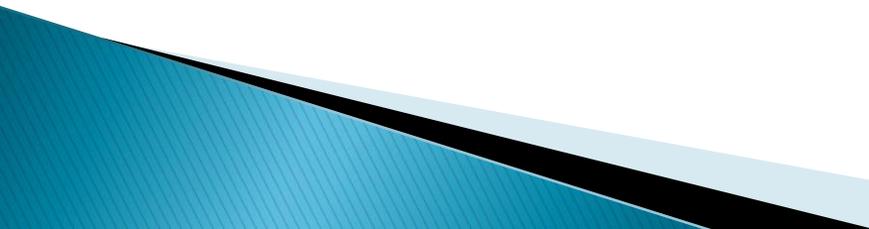
By Prof. N. M. Deshkar

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- ❖ **Power** and **Energy** are buzz words in today's world.
 - ❖ **Electricity** is emerged as basic necessity with Food, Shelter and Clothing for human being.
 - ❖ Life without **electricity** has become highly unimaginable.
 - ❖ Electric locomotives, Heating, Cooling, Fans, Blowers, Motors, Illumination are some applications that converts **electrical energy** into useful work.
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- ❖ Progress of any nation is measured in terms of per capita consumption of electrical energy.(KWH consumed per person per year)

 - ❖ India- 1075 KWH /person per year
UK- 15 times that of India
US- 30 times that of India

 - ❖ Reasons of Popularity of electricity:-
 - Clean environment for user
 - Higher efficiency
 - Better controllability
 - Quick transfer of power from source to load
 - Energy conservation is simple
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RES Scenario In India

- ❖ Wind Power --- 28700 MW
- ❖ Small Hydro --- 4333 MW
- ❖ Bio Power --- 7970 MW
- ❖ Solar PV --- 9012 MW

- ❖ Total Installed Capacity--- 50018 MW

Power Generation Scenario In India

❖ Thermal Power ---	2,14,654MW
❖ Hydro Power ---	44,190MW
❖ Nuclear Power ---	5780MW
❖ Other sources ---	50,018MW
❖ Total Installed Capacity---	3,14,642MW

Sources Of Electrical Power Generation

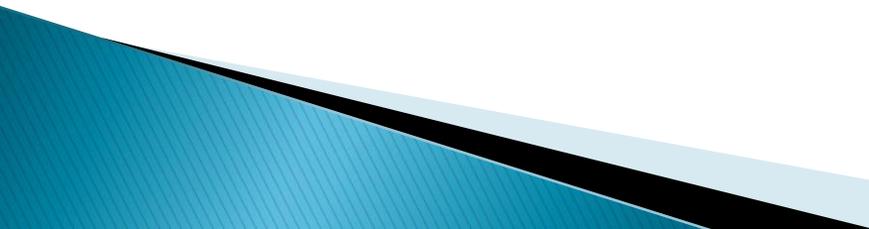
A. Conventional Sources

- ❖ Thermal (Coal)
- ❖ Nuclear
- ❖ Gas
- ❖ Water

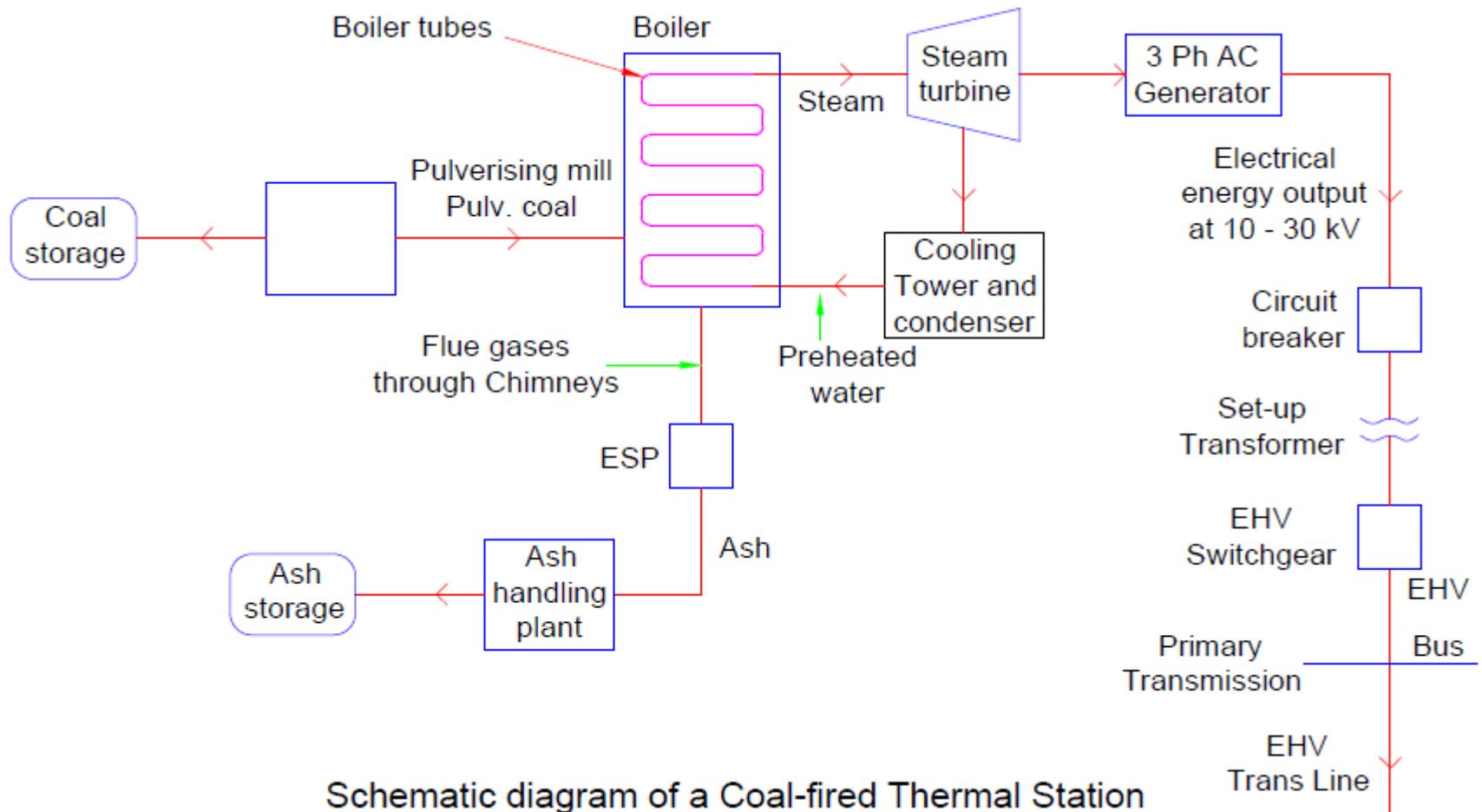
B. Non conventional Sources

- ❖ Wind
 - ❖ Solar- PV
 - ❖ Biomass
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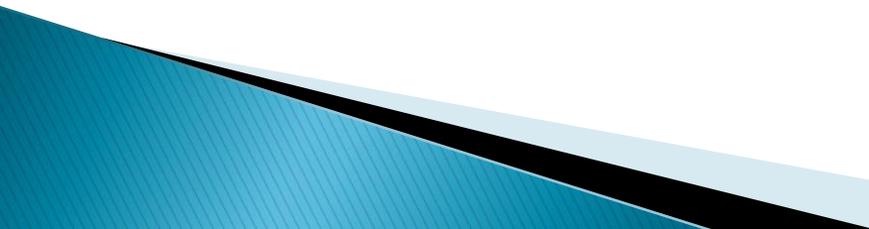
Disadvantages Of Conventional Sources

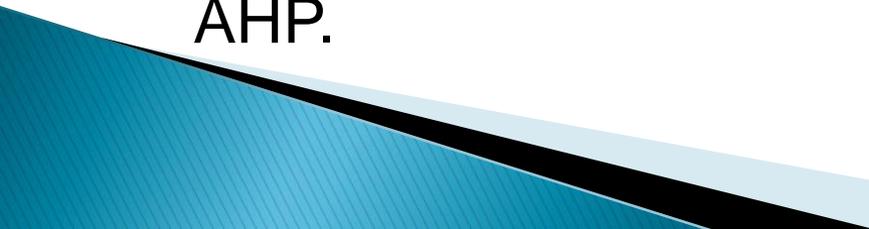
- ❖ Fossil fuels shall be depleted, forcing us to conserve them and find alternative resources.
 - ❖ Toxic, Hazardous gases, Residues pollute environment.
 - ❖ Overall conversion efficiency is very poor.
 - ❖ Sources are located at remote places with reference to load, increasing transmission cost.
 - ❖ Maintenance cost is high.
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Block Diagram Of Coal Fired Thermal Plant



Coal Based Thermal Power Plant

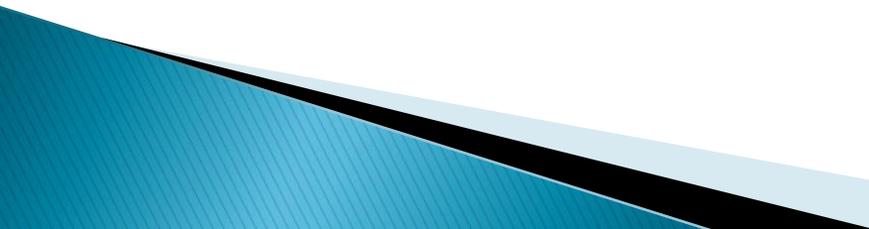
- ❖ India has rich stock of coal as natural resource.
 - ❖ Chemical energy stored in coal is transformed to electrical energy.
 - ❖ Coal powder is fired in boiler that converts water into steam at high temp. and pressure.
 - ❖ This steam is injected over the blades of steam turbine (prime mover) in controlled way and hence, rotor of 3 PH a.c. generator rotates.
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- ❖ Mechanical energy is converted into electrical energy at rated voltage(10-30KV).
 - ❖ Used steam is cooled down to water using cooling towers and condensers.
 - ❖ This preheated water is again injected in boiler tubes to convert back to steam.
 - ❖ Flue gases are passed into atmosphere and fine particles of ash are collected through ESP.
 - ❖ Ash(40% of coal weight) is collected and transported to AHP.
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Merits of Coal Thermal Plant

- ❖ Coal is cheap and available in abundance at present.
 - ❖ It is a time tested process, so no experimentation is required.
 - ❖ Less space required as compared to Hydro based station and less hazardous than Nuclear power plant.
 - ❖ Less initial cost as compared to other conventional process of power generation.
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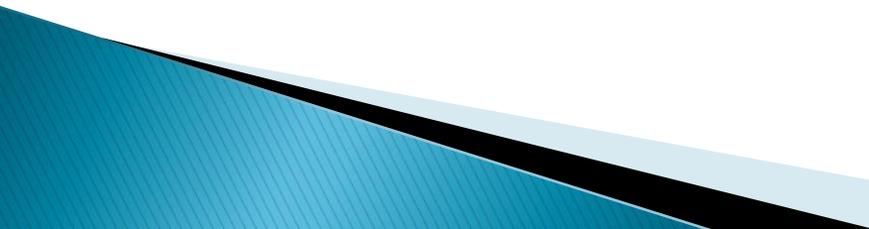
Demerits of Coal Thermal plant

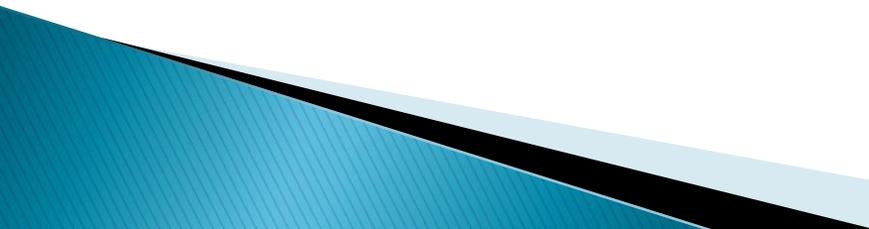
- ❖ Calorific value (Kcal/Kg) of Indian coal is very low and large ash content.
 - ❖ Huge volume of ash is produced daily and it's disposal is burning issue today.
 - ❖ Atmospheric pollution is very high.
 - ❖ Transportation of coal to plant and transmission of generated power to load centre involves large expenses.
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Nuclear Thermal Power Plant

- ❖ Huge amount of thermal energy is produced through Nuclear **Fusion** and **Fission** process of radioactive elements.
- ❖ This thermal energy is used to produce steam that can be utilized to rotate the turbine coupled to 3 PH a.c. generator.
- ❖ **Fusion** is the process in which two light weight nuclei combine to produce heavier nucleus, a neutron and lot of exothermic energy.

- ❖ In fusion Deuterium and Tritium nuclei are fused to produce heavy Helium, Neutron and 17.6 MeV of energy.
 - ❖ One gram of Deuterium contains 1,00,000 KWh of energy which is 10 million times that released by combustion of one gram of coal.
 - ❖ **Fission** is the reaction in which heavy nucleus is split in to two or more lighter nuclei with release of neutrons, fission fragment, gamma rays and lot of thermal energy.
 - ❖ Released neutrons has high KE and collides with other nuclei resulting into secondary fission which again produce same components as before.
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- ❖ This process results into sustained chain reaction producing huge amount of energy that can be utilized for producing steam that is subsequently used for rotating turbine.
 - ❖ The main requirement of fission is such that the reaction should be self sustained in nature.
 - ❖ For self sustained reaction the substance should be fissile, it should not decay quickly and should be available in nature in moderate quantity.
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- ❖ All radioactive elements are fissile and satisfy the conditions as specified for self sustained reaction. **Uranium-235** is commonly used for the process.
 - ❖ When it accepts neutron, it is fissioned into Barium, Krypton, neutrons, gamma rays and 200MeV energy.
 - ❖ All the time this huge heat energy is not required and if it is not controlled then may result in disaster.
 - ❖ Speed of neutrons is controlled by moderators like Graphite and heavy water to achieve critical speed of reaction.
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- ❖ Further more, control rods, like cadmium, are placed between fuel rods that absorb neutrons for regulation of reaction thereby to obtain power control of generators.
- ❖ The control rods are pushed in and pulled out to decrease and increase power output respectively.

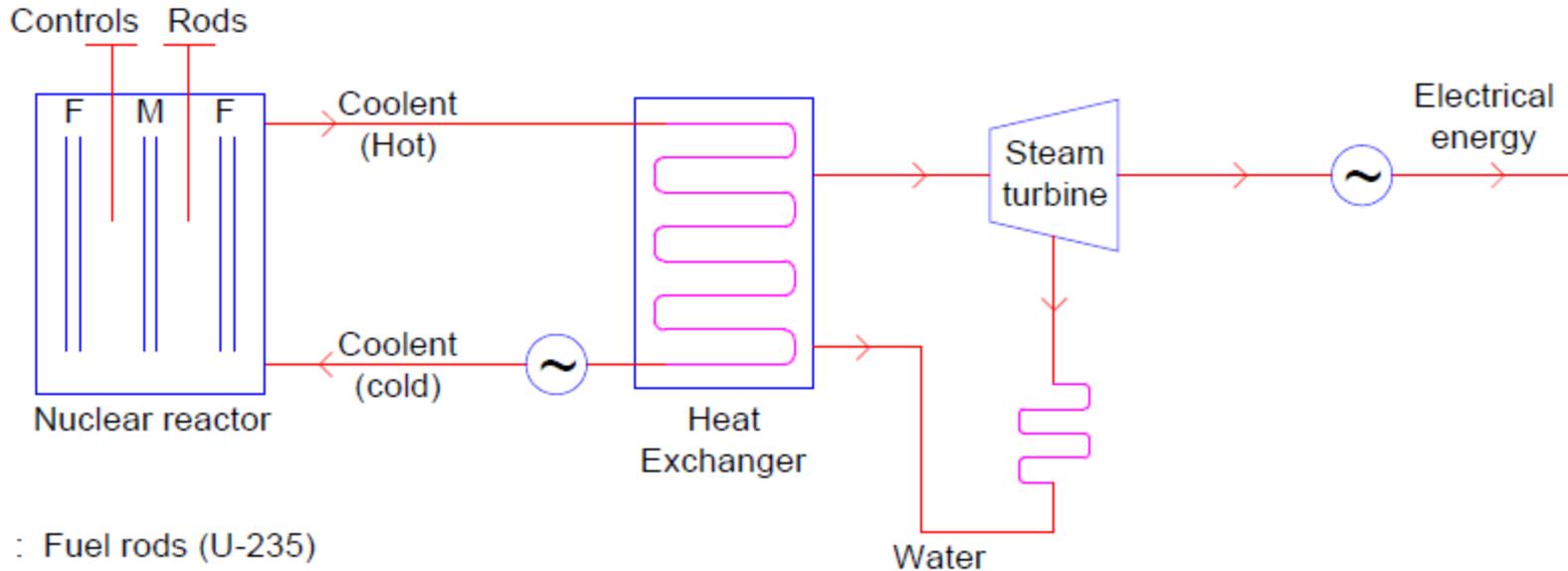
Advantages of Nuclear Power Generation

- ❖ Less quantity of fuel for generation of given amount of energy compared to other sources.
 - ❖ High reliability, Efficient and less running cost.
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Disadvantages of Nuclear Power Generation

- ❖ Fuel is expensive and not available in abundance everywhere.
 - ❖ High capital cost.
 - ❖ Maintenance cost is very high.
 - ❖ Nuclear waste disposal is a great problem.
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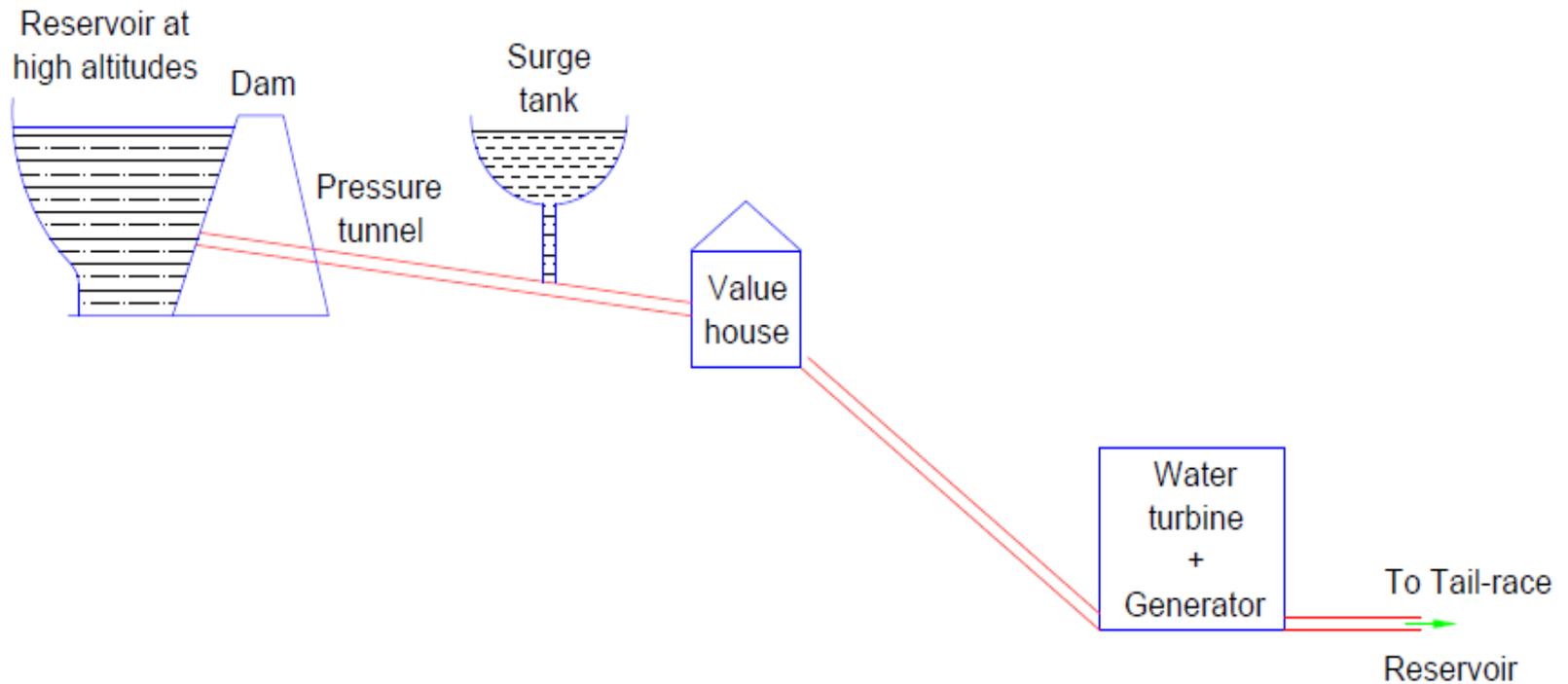
Block Schematic for Nuclear Power Plant



- F : Fuel rods (U-235)
- M : Moderator (Graphite)
- Control rods : Sodium metal
- P : Coolant circulating pump

Schematic diagram of a Nuclear Power Station indicating Main Components

Block Schematic for Hydroelectric Power Plant



Schematic diagram of a typical Hydroelectrical station

- ❖ Hydro-electric power is generated by the flow of water through turbine, turning the blades of the turbine.
 - ❖ A generator shaft connected to this turbine also rotates and hence generates electricity.
 - ❖ The main components of a hydel power plant are:
 - 1. Dam/Reservoir/Large buffer tank
 - 2. Penstock
 - 3. Power House
 - a. Turbines
 - b. Generators
 - c. Step-up Transformers
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Depending on the capacity, hydel power plants are divided into the following categories:

Category	Capacity	Application
Large Hydel Plant	50 MW to 1000 MW	Large Cities
Small Hydel Plant	1 MW to 50 MW	Small cities to Towns
Mini Hydel Plant	100 kW to 1000 kW	Towns
Micro Hydel Plant	< 100 kW	Rural community
Pico Hydel Plant	< 5 kW	Individual home

- ❖ Hydel plants are normally not in a continuous operation mode and used for peak periods during the day like the wee hours and in the evening.
 - ❖ Also, they are used when the continuously operating thermal plants go into overhauling.
 - ❖ This is possible due to the less start up time required by hydro power stations which is normally in few minutes as compared to thermal power plant which is more than 8 hours.
 - ❖ The command for starting or shutting is issued by from the related Load Dispatch Center (LDC) of that particular region
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- ❖ Hydel plants have an efficiency of 75%.
- ❖ The power delivered is given by the following expression:

$$\textit{Power delivered} = 7 \cdot H \cdot dQ/dt \text{ Kilo watts,}$$

Where,

H = Head in meters

dQ/dt = Rate of discharge in m³/s.

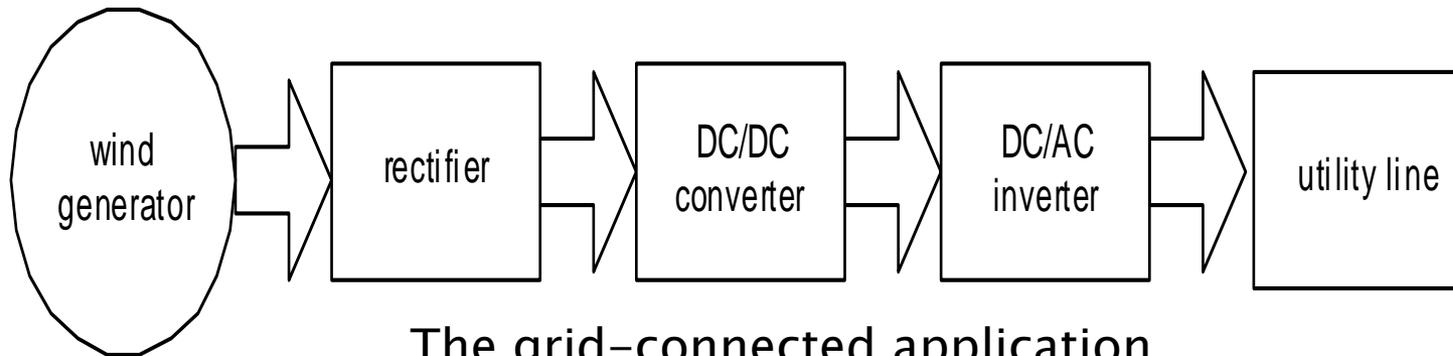
Advantages of Hydro Power Generation

- ❖ Once a dam is constructed, electricity can be produced at a constant rate
 - ❖ If electricity is not needed, the sluice gates can be shut, stopping electricity generation
 - ❖ The build up of water in the lake means that energy can be stored until needed, when the water is released to produce electricity.
 - ❖ The lake's water can be used for irrigation purposes.
 - ❖ Hydropower is fueled by water, so it's a clean fuel source. Hydropower doesn't pollute the air like power plants that burn fossil fuels, such as coal, oil or natural gas.
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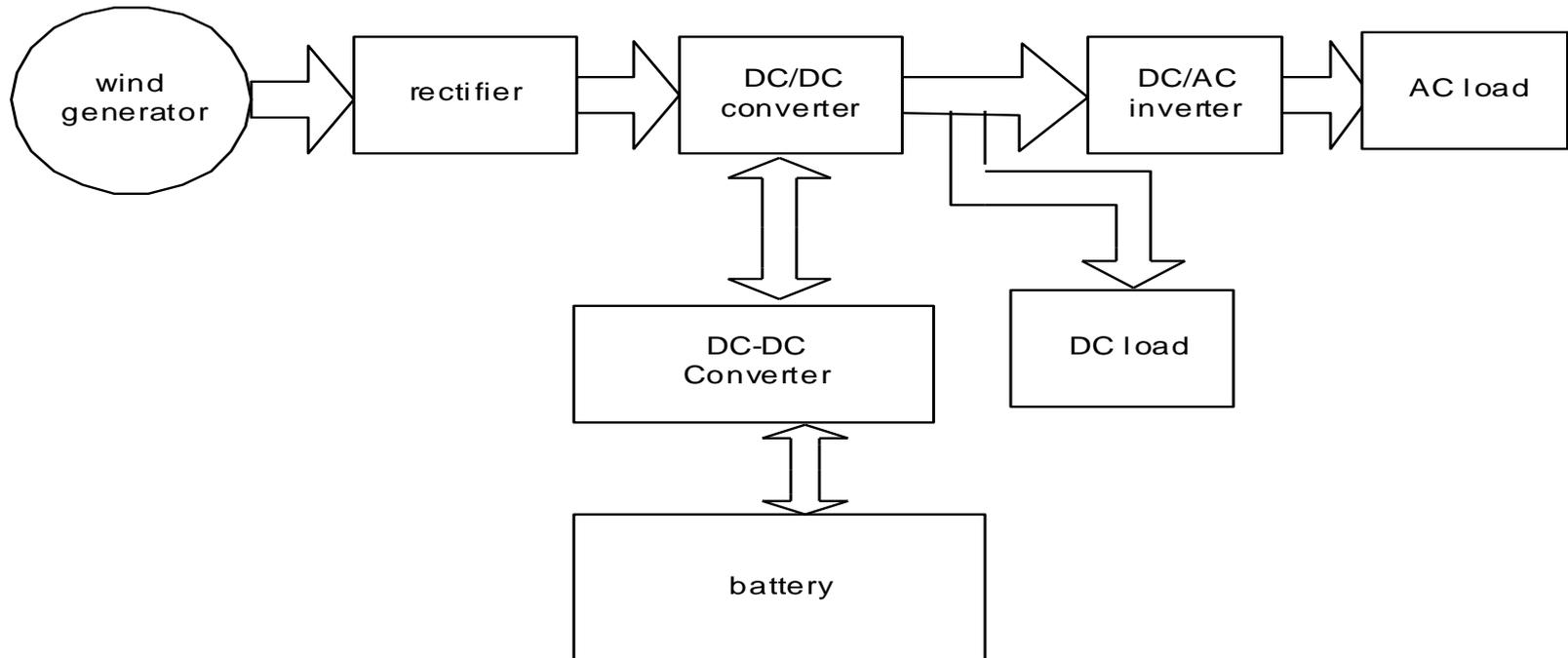
Disadvantages of Hydro Power Plant

- ❖ Dams are extremely expensive to build and must be built to a very high standard.
 - ❖ People living in villages and towns that are in the valley to be flooded, must move out.
 - ❖ Hydro power plants can be impacted by drought. When water is not available, the hydro power plants can't produce electricity.
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Block Schematic for Wind Power Plant

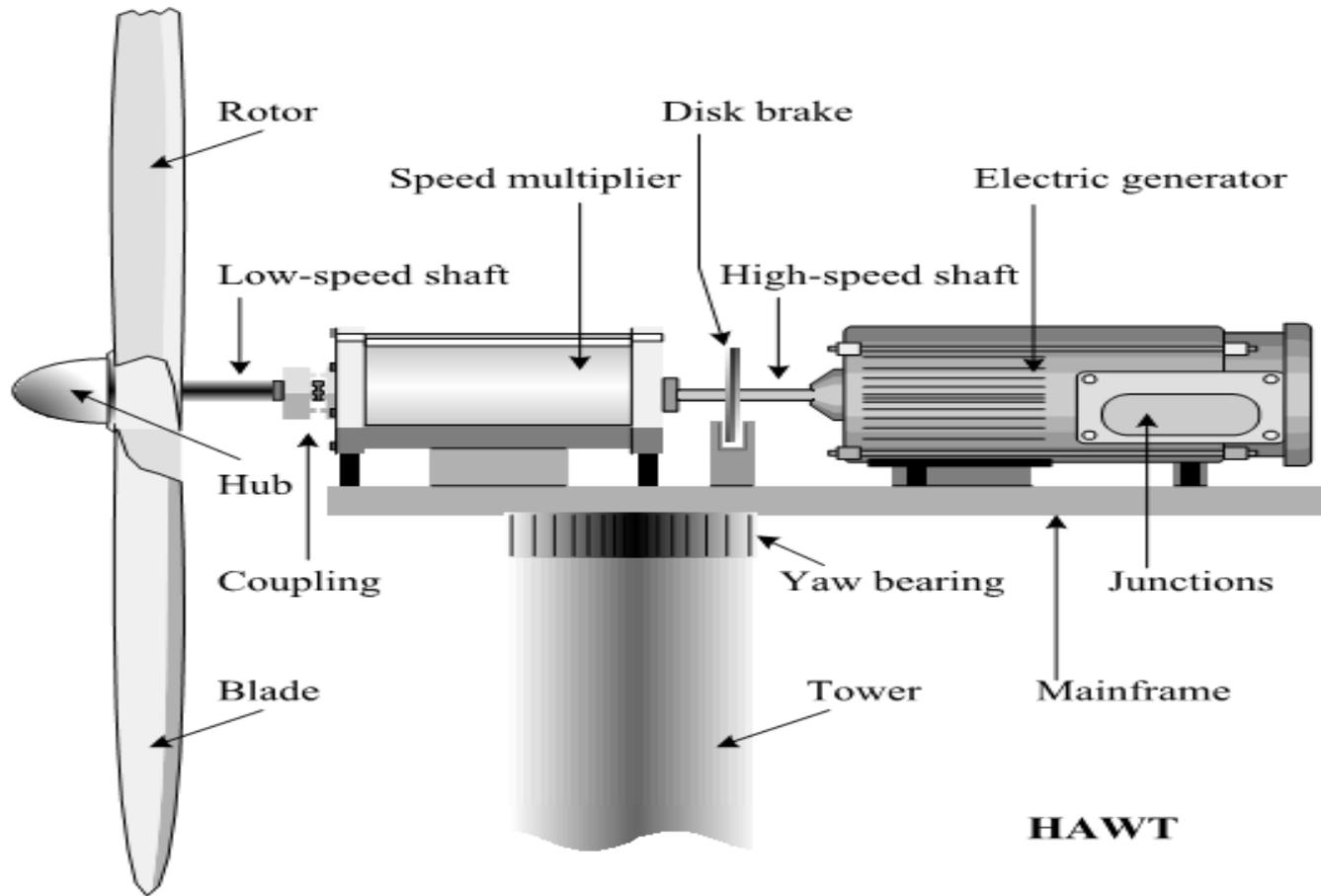


The grid-connected application

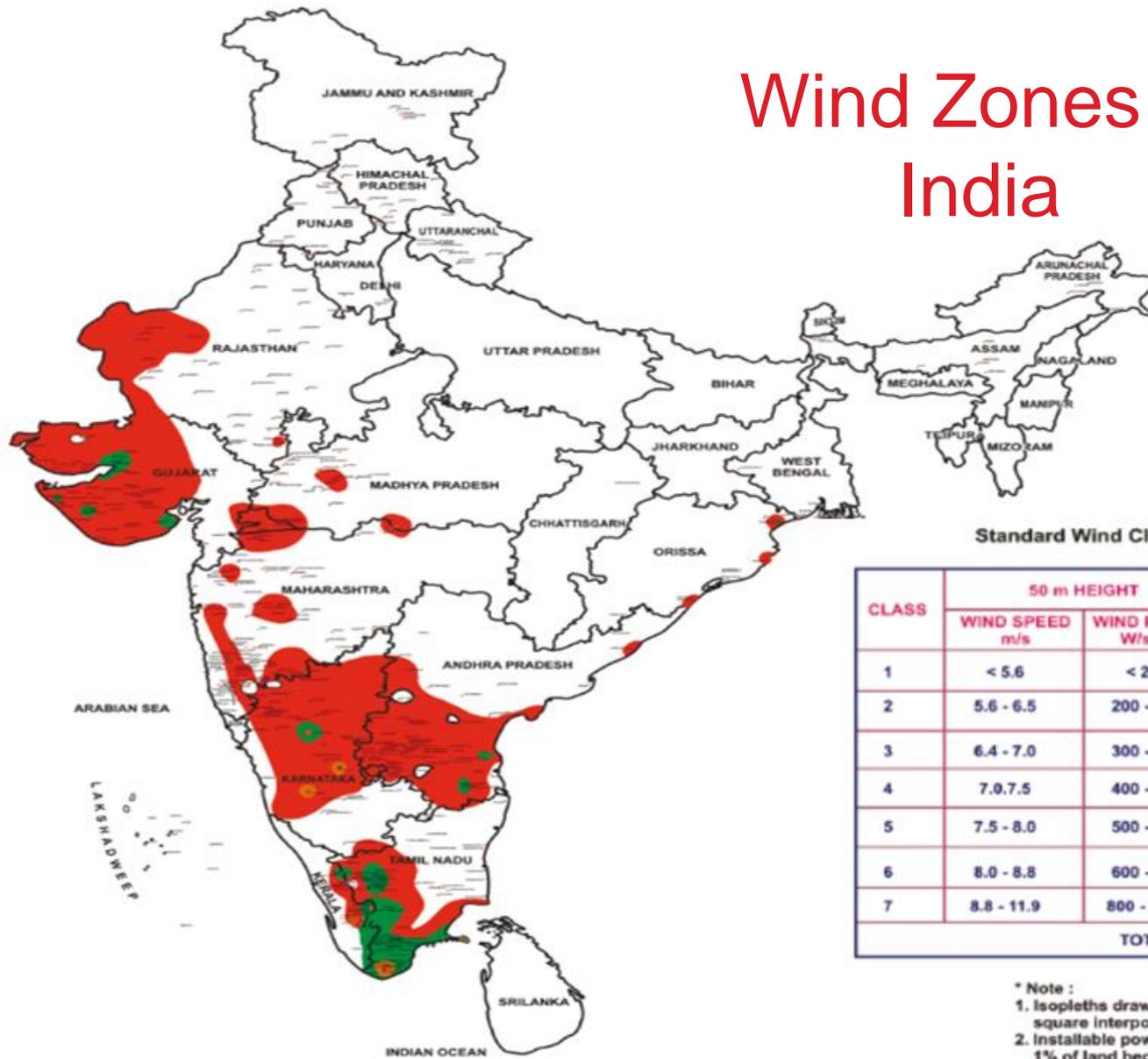


The stand-alone application

Wind Generator



Wind Zones in India



- * Note :
1. Isoleths drawn on the basis of Inverse square interpolation of WPDs among stations.
 2. Installable power on the assumption that 1% of land becomes available for wind farming.
 3. An area requirement of 12 hectares/MW assumed.

- ❖ The wind energy is one of the most effective renewable power and relevant technologies for its conversion in useful form.
 - ❖ India has the fifth largest installed wind power capacity in the world.
 - ❖ A Wind Energy Conversion System is a structure that transforms the **kinetic energy** of the incoming air stream into **electrical energy**.
 - ❖ There are two basic configurations namely vertical axis wind turbines (**VAWT**) and horizontal axis wind turbines (**HAWT**).
 - ❖ Today the vast majority of manufactured wind turbines are horizontal axis with either two or three blades.
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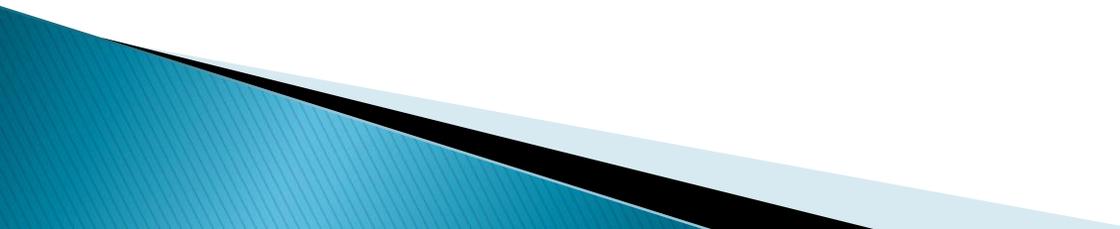
Types of Wind Energy Conversion System (WECS)

- ❖ There are two types of Wind Energy Conversion System (WECS).
 1. Variable-speed WECS
 2. Fixed-speed WECS.
- ❖ Variable-speed wind turbines are currently the most used WECS.
- ❖ Fixed-speed WECS operate at constant speed and Variable-speed WECS at variable speed.
- ❖ In Fixed-speed WECS generated voltage and frequency is constant but in Variable-speed WECS generated voltage and frequency is varying with respect to wind speed.

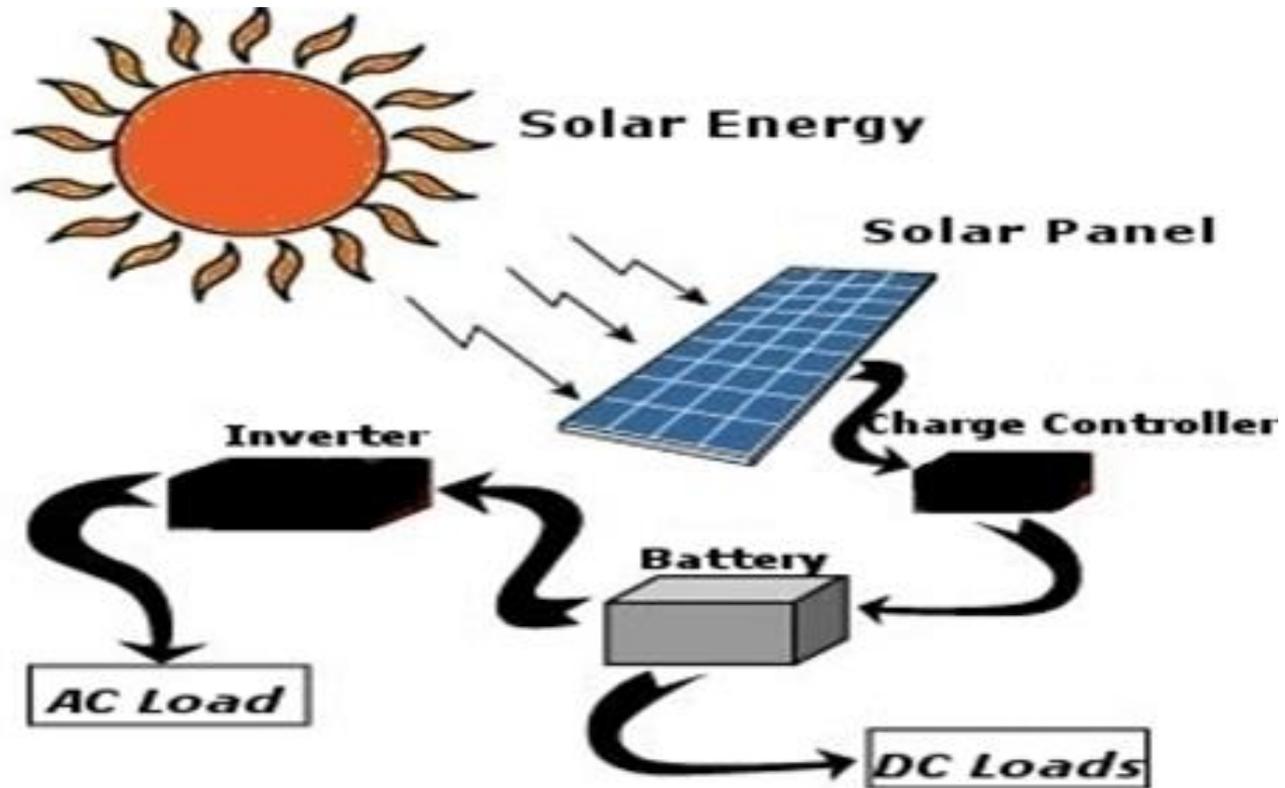
Advantages of Wind Energy System

- ❖ The wind is free and with modern technology it can be captured efficiently.
 - ❖ Once the wind turbine is built the energy it produces, does not cause green house gases or other pollutants.
 - ❖ Remote areas that are not connected to the electricity power grid can use wind turbines to produce their own supply.
 - ❖ Wind turbines are available in a range of sizes which means a vast range of people and businesses can use them.
 - ❖ Single households to small towns and villages can make good use of range of wind turbines available today.
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Disadvantages of Wind Power

- ❖ The strength of the wind is not constant and it varies from zero to storm force.
 - ❖ This means that wind turbines do not produce the same amount of electricity all the time.
 - ❖ There will be times when they produce no electricity at all.
 - ❖ Wind turbines are noisy.
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Solar Energy



- ❖ A photovoltaic cell is the basic device that converts solar radiation into electricity.
- ❖ PV cell can be either circular in construction or square.
- ❖ Cells are arranged in a frame to form a module. Modules put together form a panel. Many Panels together form an array.
- ❖ Each PV cell is rated in watt-peak (Wp).
- ❖ Only a small part of the radiant energy that the sun emits into space ever reaches the Earth, but that is more than enough to supply all our energy needs. The energy which reaches earth surface is taken as **1 KW/ sq.m** approximately

Applications

- ❖ **Solar Water Heating** : Solar energy can be used to heat water. A solar water heater works a lot like solar space heating. A solar collector is mounted on the roof where it can capture sunlight.



Photovoltaic Electricity:- Photovoltaic comes from the words photo meaning light and volt, a measurement of electricity. Sometimes photovoltaic cells are called PV cells or solar cells for short.

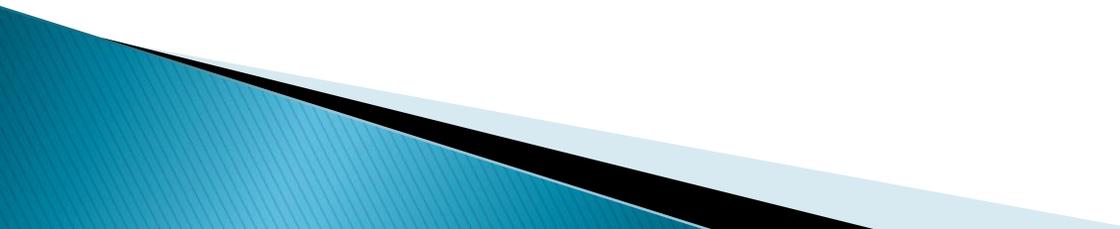
- ❖ Solar cells are made up of silicon, the same substance that makes up sand. Silicon is the second most common substance on Earth.
- ❖ Electricity is produced when sunlight strikes the solar cell, causing the electrons to move around.



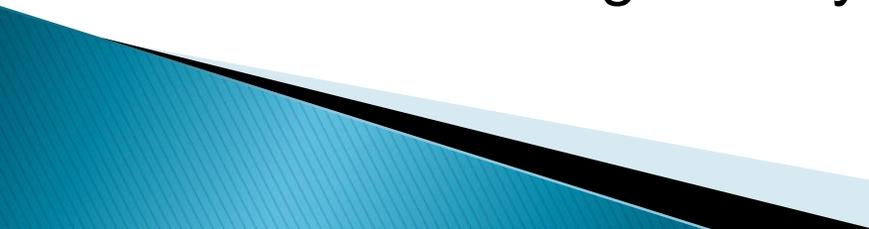
Advantages of Solar Energy Systems

- ❖ After initial investment, all the electricity produced is free.
 - ❖ Incentives and rebates from government and utility companies offset the initial investment.
 - ❖ Clean, renewable energy source.
 - ❖ No transmission costs for stand alone systems.
 - ❖ Virtually no maintenance and no recurring costs
 - ❖ Ideal for remote locations that cannot be tied to the grid
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Solar Energy Disadvantages

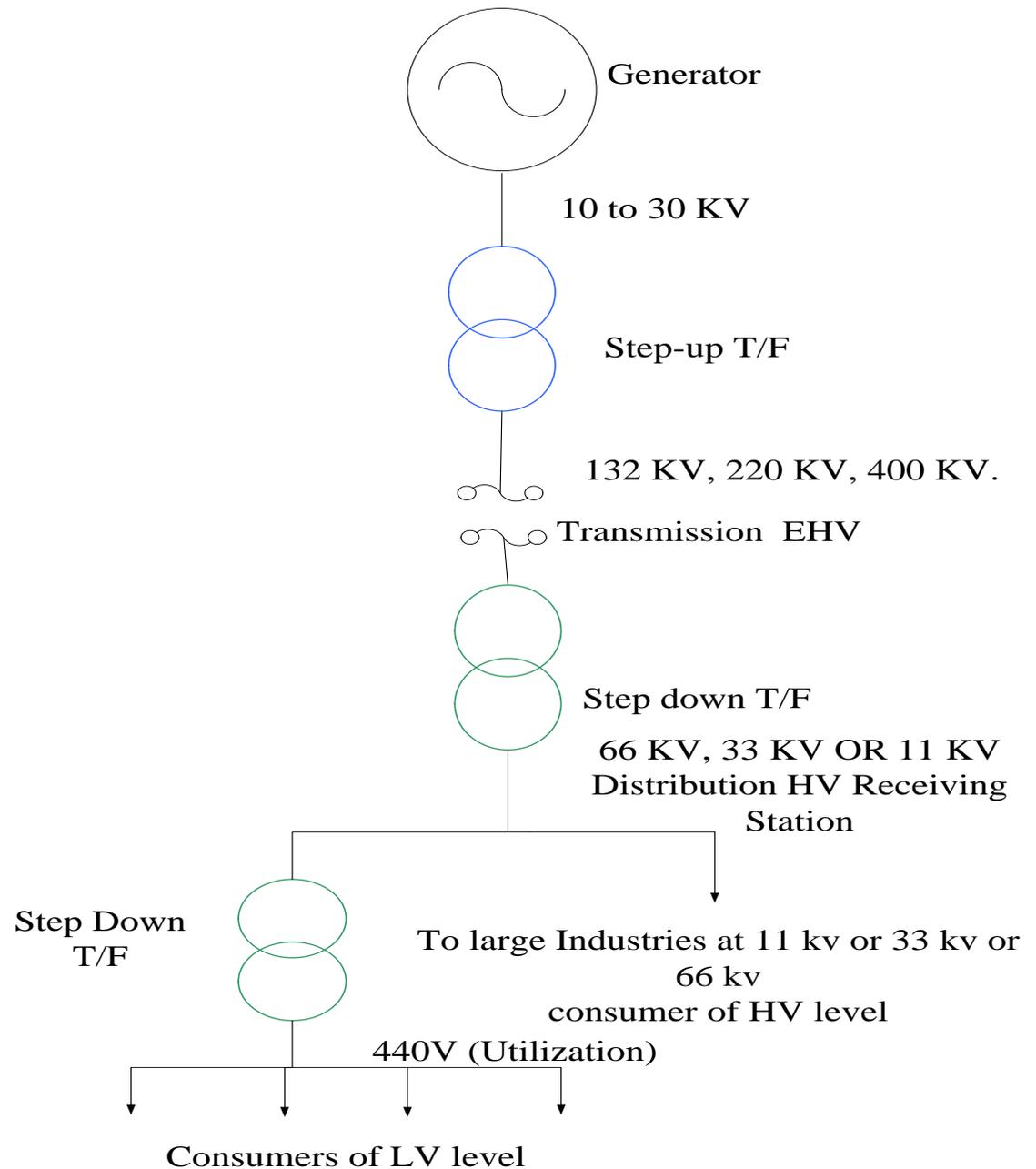
- ❖ High initial cost to purchase solar panel system
 - ❖ A relatively large area is required to install a solar system
 - ❖ The highest efficiency is dependent on full sun exposure
 - ❖ No electricity can be produced at night, and reduced production on cloudy/rainy days
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Interconnection of Generation, Transmission, Distribution and Utilization Systems

- ❖ Location for electrical power plant is normally decided near the fuel base (coal, gas, water)
 - ❖ The huge power generated cannot be consumed in the area in which it is generated.
 - ❖ The voltage level at which it is generated is between 10 to 30 KV.
 - ❖ The generated power is to be transmitted to the locations where it is demanded like Industries, cities, etc. which we generally refer as 'Load'.
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- ❖ Distances between generation plant and place where it is needed is very large.
 - ❖ Hence, to avoid Cu losses specifically, generated voltage needs to be stepped up to 132 KV , 220 KV, 400 KV, 765 KV and the latest 1200 KV for Transmission.
 - ❖ Once power is dispatched to Load Centres, the transmission voltage levels are stepped down to 66KV, 33KV or 11KV for distribution of power.
 - ❖ Once the power reaches to doorstep of consumer, the distribution voltage level is again stepped down to utilisation voltage level i.e. 440V or 650V
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Single Line Representation of Power System



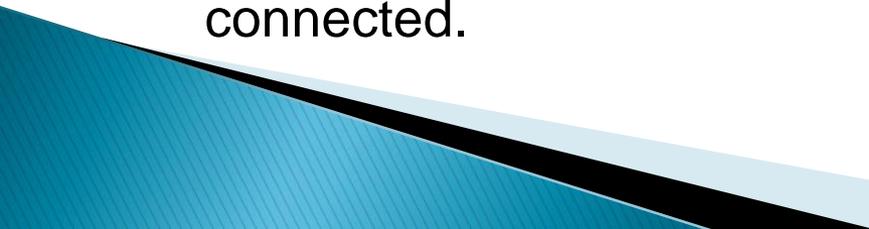
- ❖ Change in voltage level is possible due to Transformer.
- ❖ Generated power is transmitted and distributed through :
 1. Overhead transmission Lines
 2. Underground Cables.
- ❖ Transmission voltage level is very high and distance between generation point and receiving station is also very large.
- ❖ So, for transmission of power, **overhead system** is adopted than underground system considering the **voltage drops** and **cost** involved.
- ❖ Generation, transmission and distribution is exclusively **three phase** in nature and only three conductors are required.
- ❖ Utilization network can be **three phase** or **single** phase. So, it requires 3 or 4 conductors (additional conductor for neutral) respectively.

Types of Distribution System

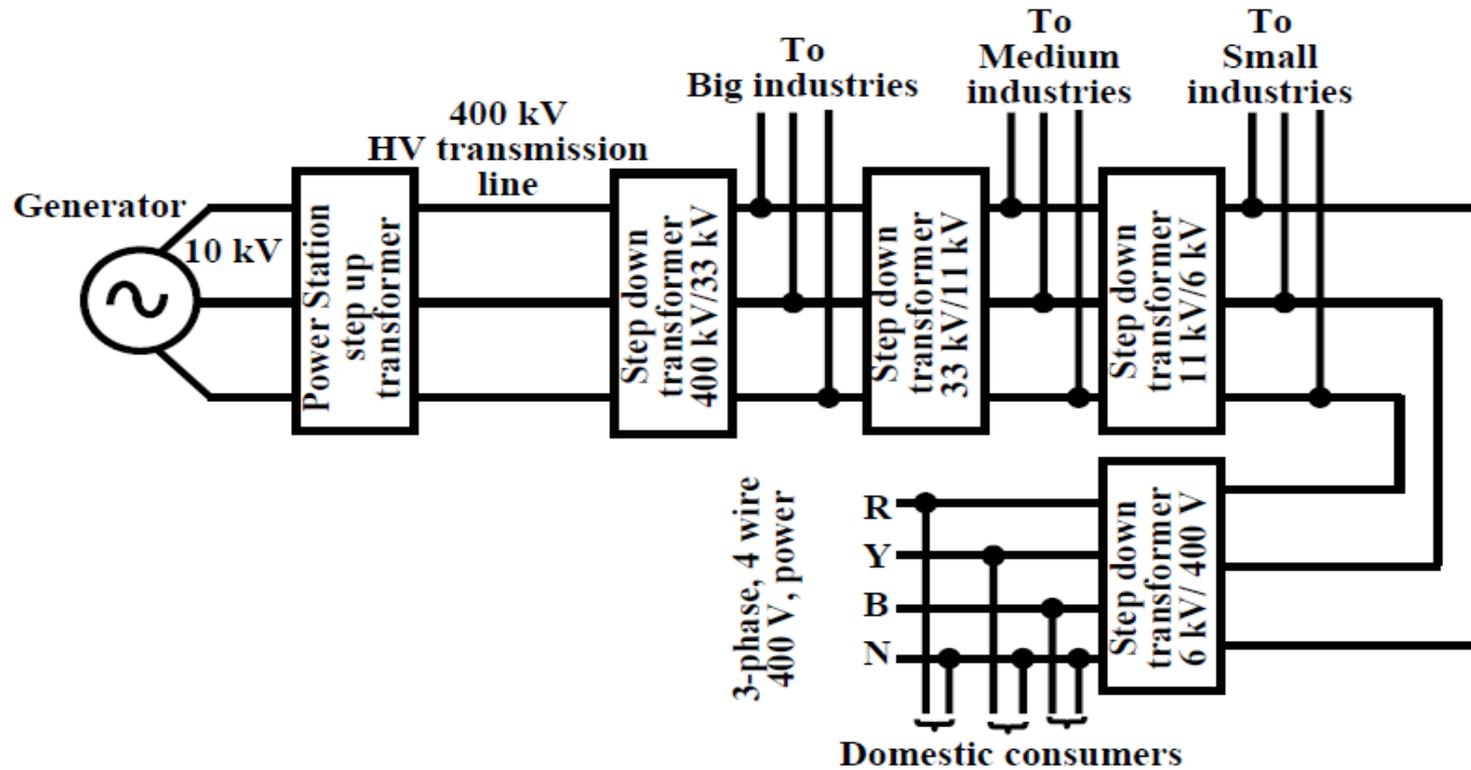
a) Three phase three wire system :

1. This system requires 3 wires or conductors for distribution
2. May be connected in Star or Delta. If Star connected, then star point is connected to earth. i.e. zero potential
3. Load must be of 3 phase nature and balanced i.e. magnitude of current should be same in each phase.
4. An electric load of single phase nature cannot be connected.

b) Three phase four wire system :

1. This system requires 4 wires or conductors for distribution.
 2. Can be connected in Star only. The star point is also called neutral.
 3. An electric load of 3 phase and also single phase can be connected.
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3 Phase 3 wire transmission / 3 phase 4 wire utilization



Typical voltage levels in a power system.

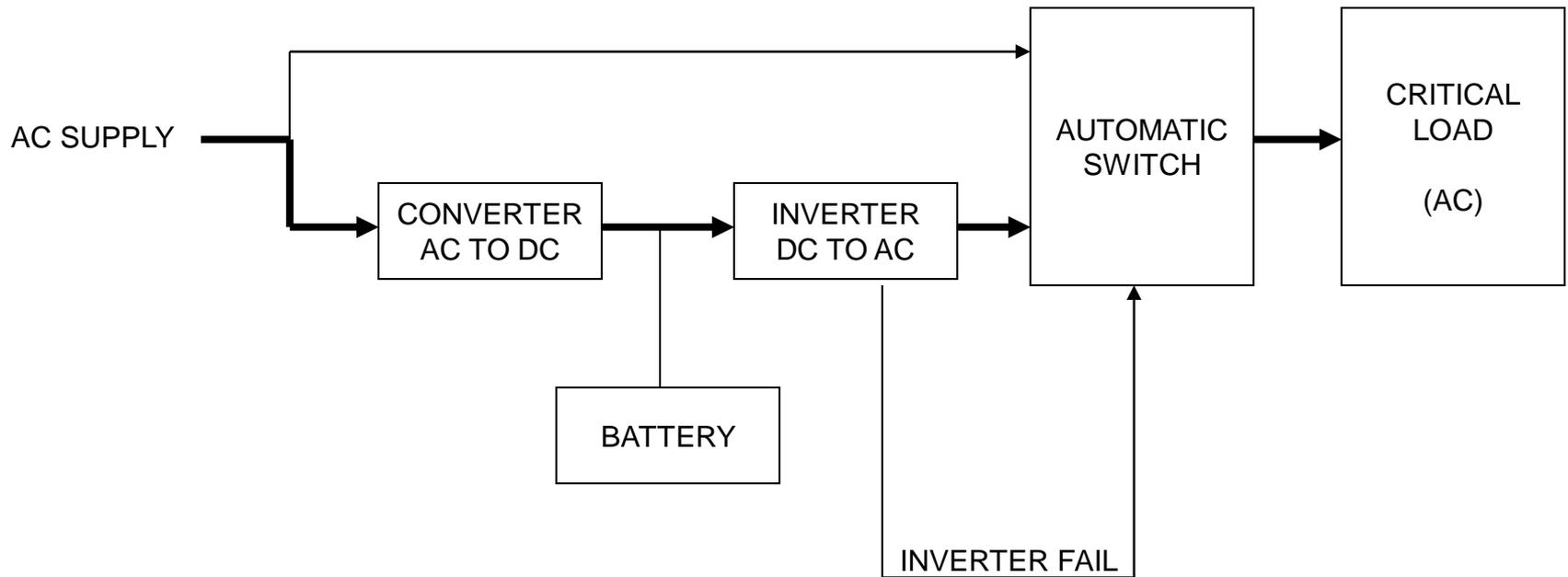
UPS

- ❖ An uninterruptible power supply (ups) is a device that has an alternate source of energy that can provide power when the primary power source is temporarily disabled.
- ❖ The switchover time must be small enough to not cause a disruption in the operation of the loads.
- ❖ It protects against multiple types of power disturbances.
and power outage

Offers protection against :

- Equipment not operating properly
- Computer and equipment damage
- Data loss
- Time and expense to recover back to where you were, if even possible

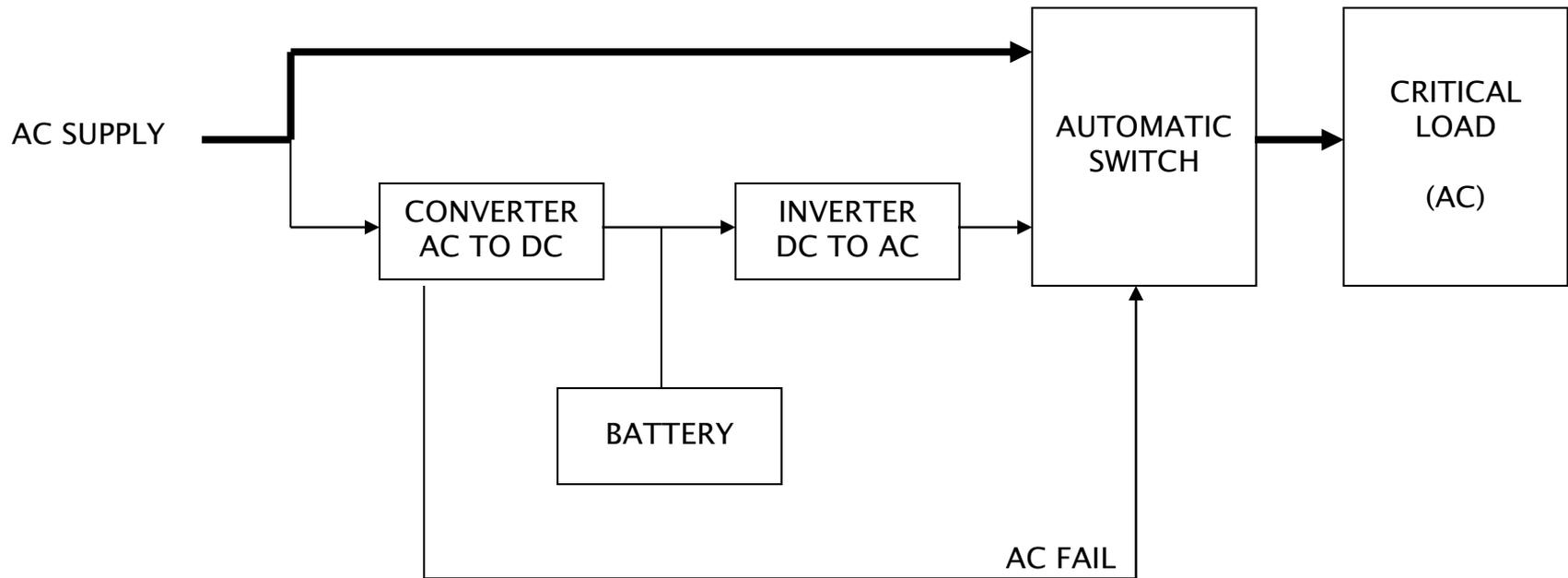
UPS Block Diagram



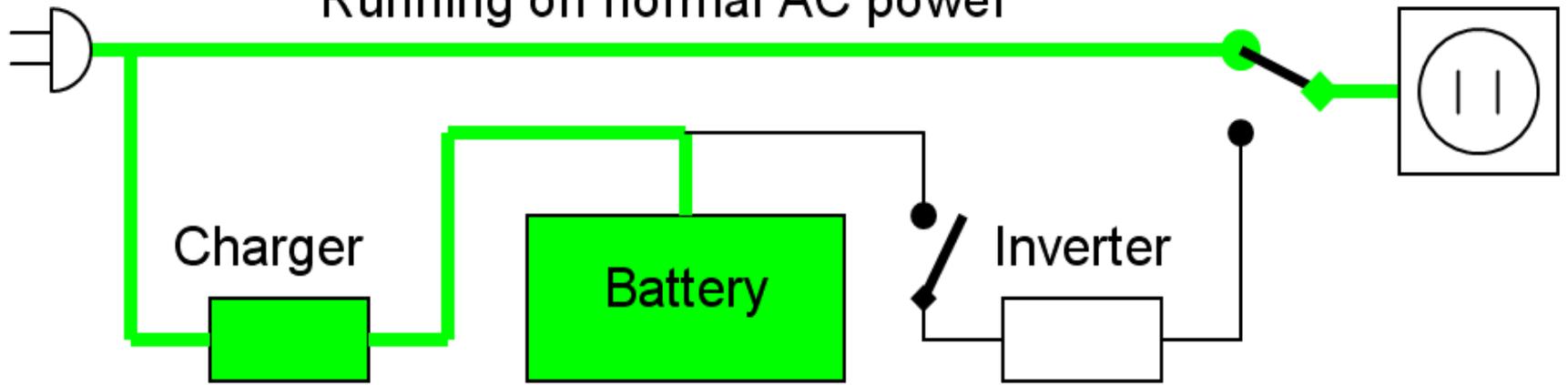
Inverter

- ▶ Inverters change Direct Current (DC) to Alternating Current (AC).
 - ▶ Stand-Alone inverters can be used to convert DC from a battery to AC to run electronic equipment, motors, appliances, etc.
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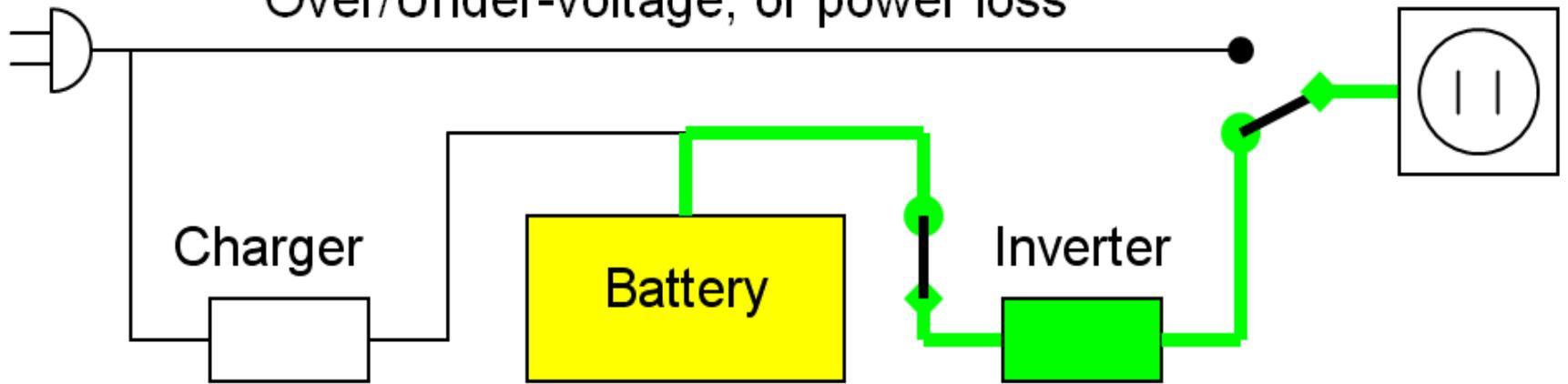
Inverter Block Diagram



Running on normal AC power



Over/Under-voltage, or power loss



UPS and Inverter Components

❖ CONVERTER - AC TO DC

- Surge Protection Devices (SPD) - Protects against SPIKES and TRANSIENTS

❖ BATTERY

- STORED ENERGY DEVICE - Protects against INTERRUPTIONS

❖ INVERTER – DC TO AC

- WAVEFORM SYNTHESIS – Protects against DC OFFSET and INTERHARMONICS
- FILTER – Protects against HARMONICS, NOTCHING and NOISE
- VOLTAGE REGULATOR – Protects against SAGS, SURGES and FLUCTUATIONS

Battery Safety

❖ MAINTENANCE

- INSPECT PERIODICALLY
- REPLACE AS NEEDED

❖ RISKS

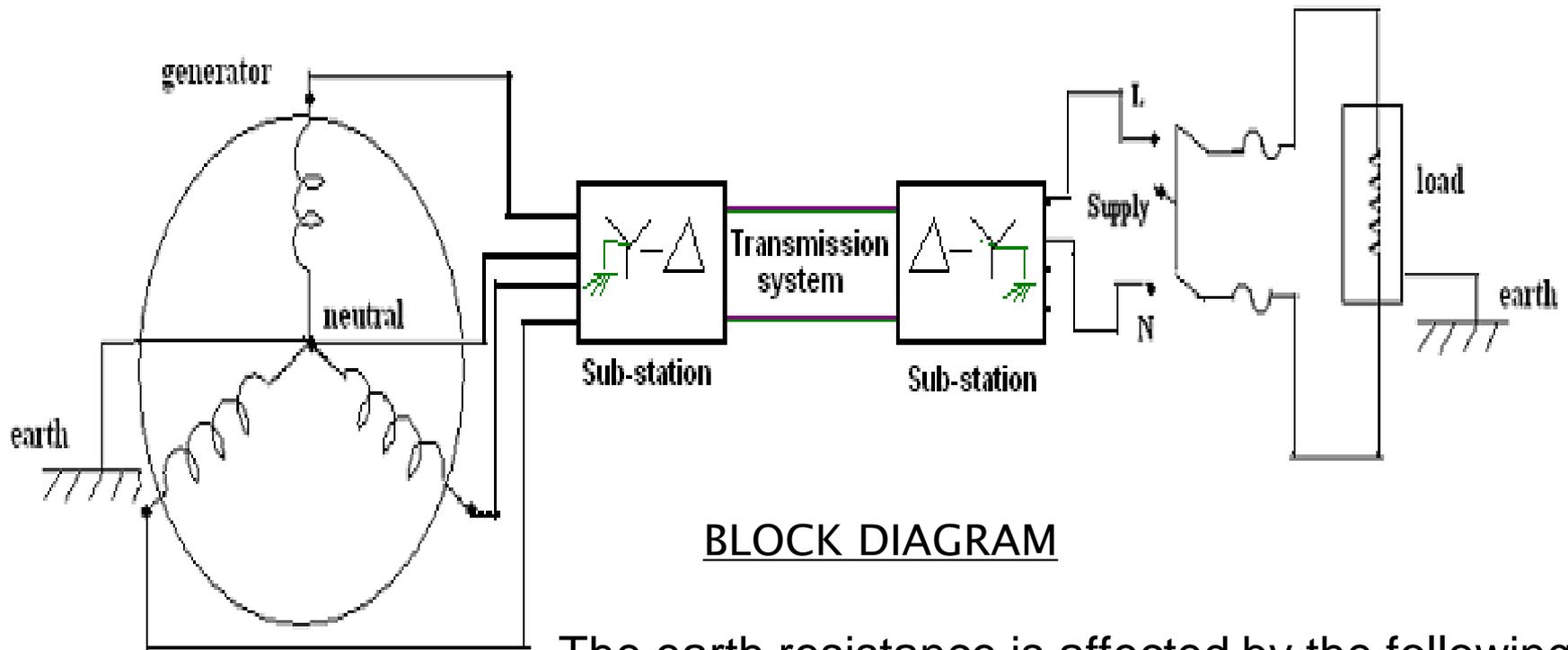
- ACID
- ELECTRIC SHOCK
- BURN
- FLYING, MOLTEN METAL (EYES)
- INJURIES RESULTING FROM CARRYING HEAVY BATTERY PACKS

❖ DISPOSAL

- DISPOSE OF PROPERLY
- RECYCLE WHENEVER POSSIBLE

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.
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The earth resistance is affected by the following factors:

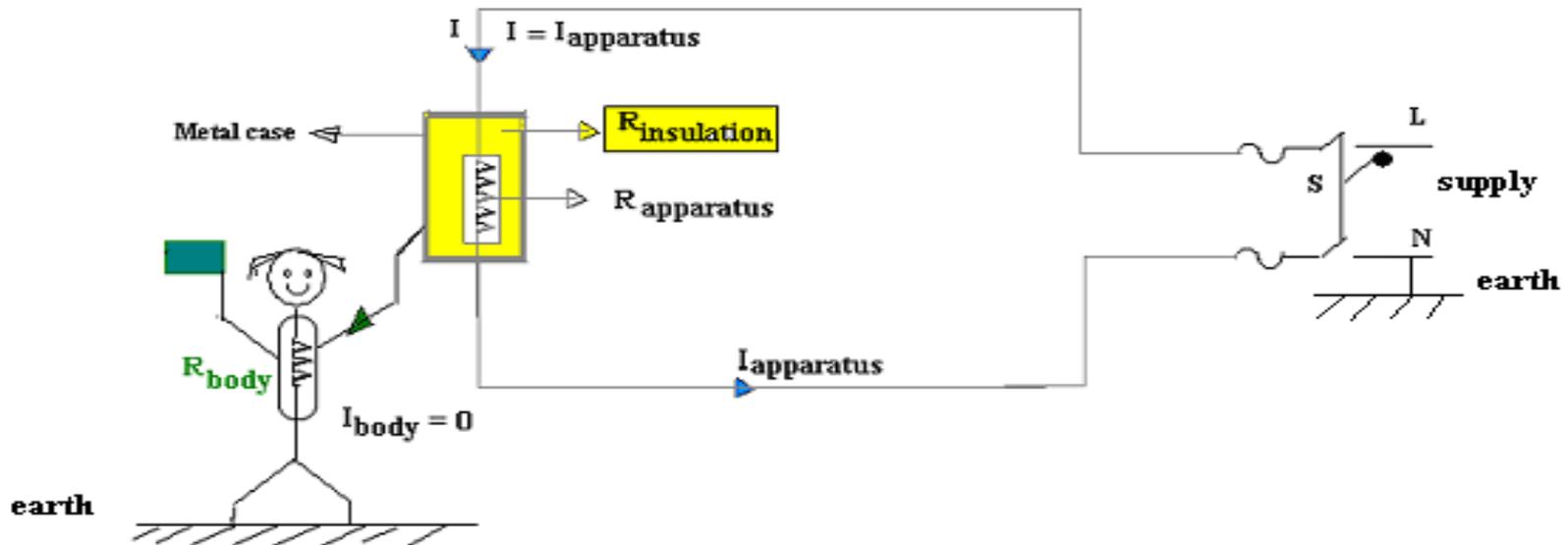
1. Material properties of the earth wire and the electrode
2. Temperature and moisture content of the soil
3. Depth of the pit
4. Quantity of the charcoal used

Importance of Earthing

Case I

Healthy insulation

Apparatus not earthed

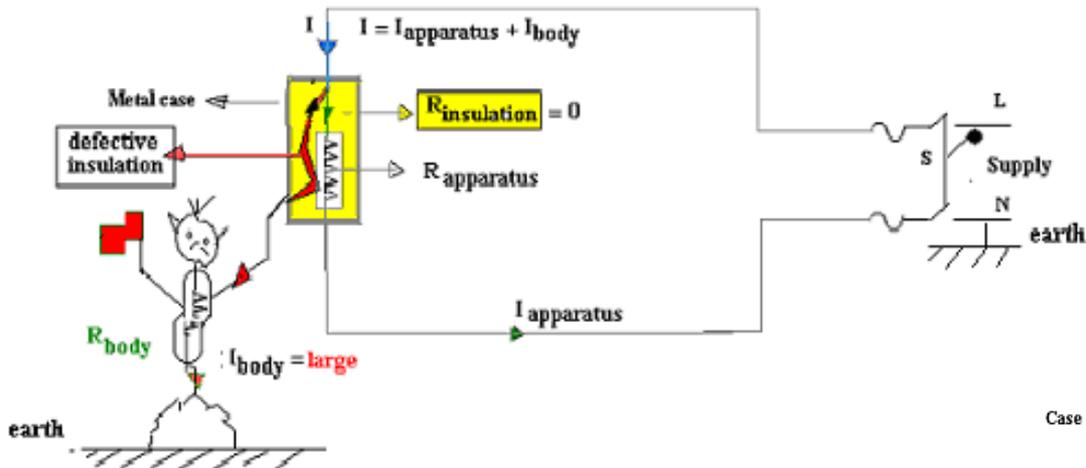


1. Insulation is healthy ($R_{\text{insulation}} = \infty$)
2. Supply current flows through the resistance of the apparatus only ($R_{\text{apparatus}}$)
3. No current flows through the body resistance ($I_{\text{body}} = 0$)
4. The person is safe even if the apparatus is not earthed

Case II

Defective insulation

Apparatus not earthed

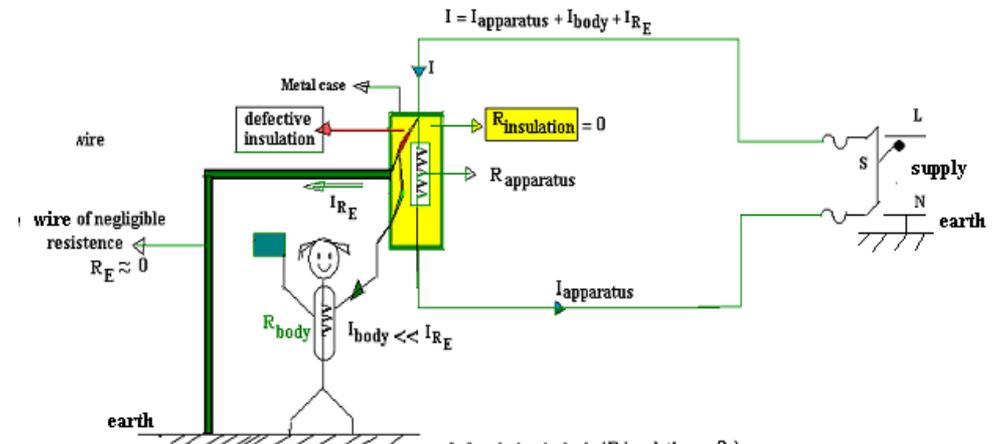


1. Insulation is bad ($R_{insulation} = 0$)
2. Supply current now divides into $I_{apparatus}$ and I_{body}
3. A part of the supply current flows through the body to the ground I_{body}
4. The person experiences shock as the apparatus is not earthed

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_{RE}
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 $I_{body} \ll I_{RE}$
5. The person in contact with the apparatus does not experience any shock as the metal casing is earthed

Necessity of Earthing:

- ▶ To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
- ▶ To maintain the line voltage constant under unbalanced load condition.
- ▶ Protection of the equipments
- ▶ Protection of large buildings and all machines fed from overhead lines against lightning.

Methods of Earthing:

- ▶ Plate earthing
 - ▶ Pipe earthing
 - ▶ Strip or wire earthing
 - ▶ Rod earthing
- 

Difference between Earth wire and Neutral wire

Neutral wire :

1. In a 3 phase 4 wire system, the fourth wire is neutral wire.
2. It acts as a return path for 3 phase currents when the load is not balanced.
3. In domestic single phase AC circuit, the neutral wire acts as a return path for line current.

Earth wire :

1. Earth wire is actually connected to the general mass of the earth and metallic body of the equipment.
 2. It is provided to transfer any leakage current from the metallic body to the earth.
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Protective Devices

- ❖ Protection for electrical installation must be provided in the event of faults such as
 - 1.Short circuit**
 - 2.Overload**
 - 3.Earth faults**

- ❖ Short circuit
 - a. In this phenomenon, the current is diverted from its desired path.
 - b. Its magnitude may be 10 to 20 times full load current and power losses are 100 to 400 times the normal value.
 - c. During short circuit, the rate of heat dissipation is very low or nil, but the rate of rise of conductor temperature is very high

2. Overload

a. Any increase in the conductor temperature above the recommended maximum temperature of associated insulation is called as an overload.

b. If insulation fails, it will result in short circuit.

c. Overload is a very slow process and is not a fault, but may lead to fault.

3. Earth faults.

a. Leakage currents are of small magnitude in milliamperes or a few amperes.

b. Due to small magnitudes, earth leakage currents are not detected by overload or SC protecting devices.

c. If not detected it may result into local heating and short circuits.

d. These leakage currents if flowing through human body, even for few seconds, may prove to be fatal for human being.

❖ The protective circuit or device must be fast acting and isolate the faulty part of the circuit immediately.

❖. It also helps in isolating only required part of the circuit without affecting the remaining circuit during maintenance.

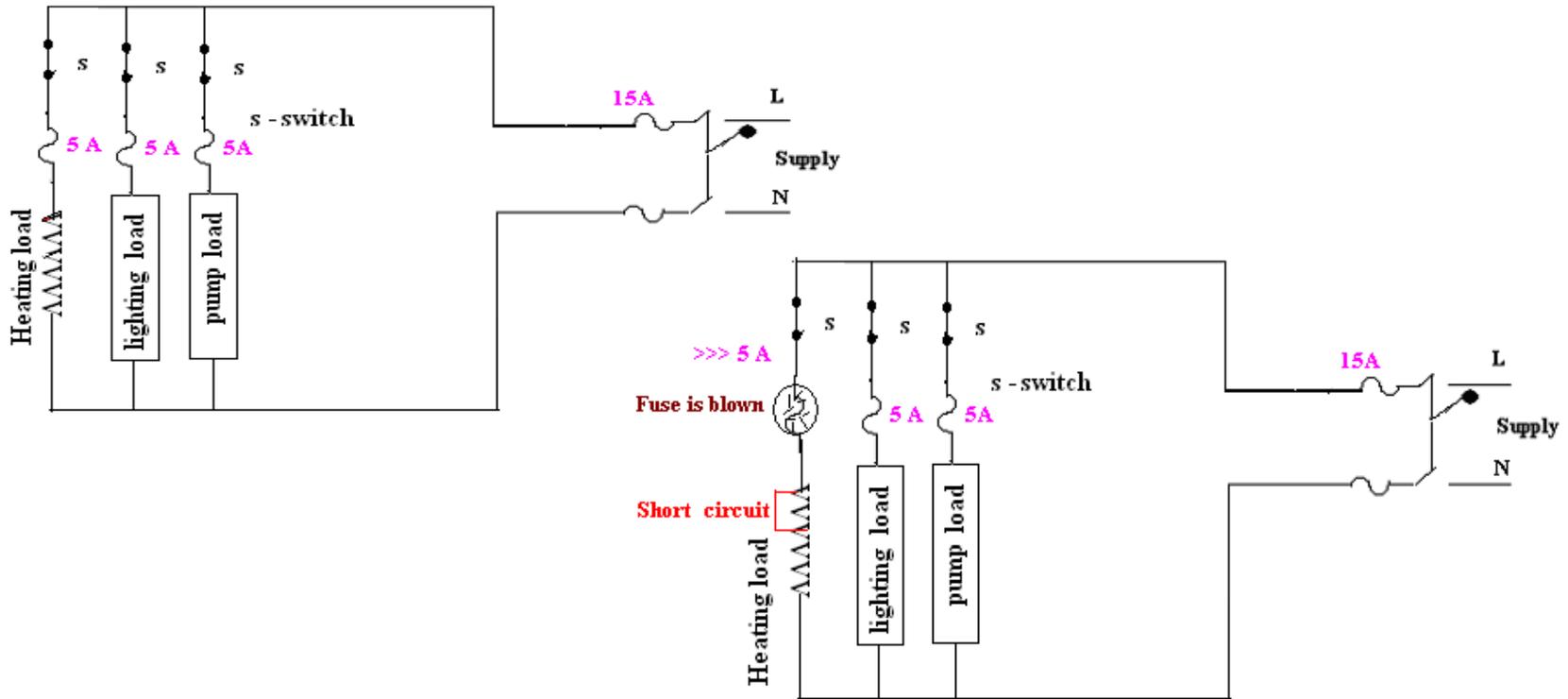
The following devices are usually used to provide the necessary protection:

- Fuses
- Miniature circuit breakers (**MCB**)
- Earth leakage circuit breakers (**ELCB**) or Residual Current Circuit Breaker (**RCCB**)
- Molten Clad Circuit Breaker (**MCCB**)
- Motor Protection Circuit Breaker (**MPCB**)
- Air Circuit Breaker (**ACB**)
- Vacuum Circuit Breaker (**VCB**)
- **SF6** Circuit Breaker

Fuse

- ❖ The electrical equipments are designed to carry a particular rated value of current under normal circumstances.
 - ❖ Under abnormal conditions such as short circuit, overload or any fault the current raises above this value, damaging the equipment and sometimes resulting in fire hazard.
 - ❖ Fuses are pressed into operation under such situations.
- 

- ❖ It is a short length of wire made of lead / tin /alloy of lead and tin/ zinc having a low melting point and low ohmic losses.
 - ❖ Under normal operating conditions it is designed to carry the full load current.
 - ❖ If the current increases beyond this designed value due any of the reasons mentioned above, the fuse melts (said to be blown) isolating the power supply from the load .
- 



The material used for fuse wires must have the following characteristics :

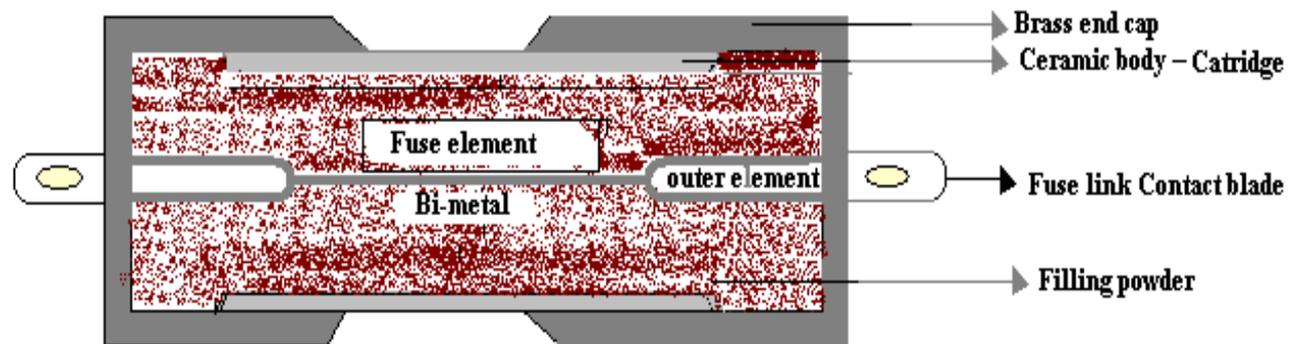
- Low melting point
- Low ohmic losses
- High conductivity
- Lower rate of deterioration

Re-wirable or kit -kat fuses

- ❖ These fuses are simple in construction, cheap and available up-to a current rating of 200A. They are erratic in operation and their performance deteriorates with time.

HRC cartridge fuse

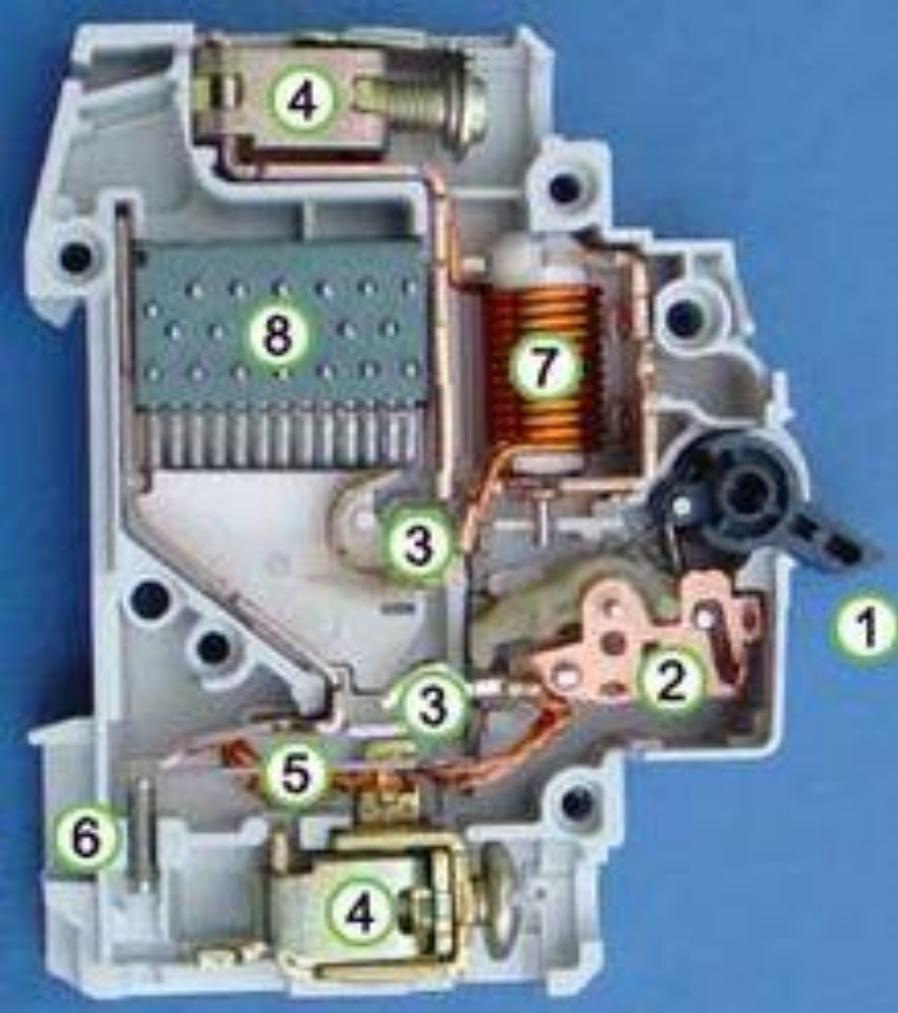
- ❖ The high rupturing capacity or (HRC) fuse consists of a heat resistant ceramic body.
- ❖ Then silver or bimetallic fuse element is welded to the end brass caps.



H R C Cartridge fuse

Miniature Circuit Breaker (MCB)

- ❑ MCBs are replacing the rewirable switch-fuse units for low power domestic and industrial applications in a very fast manner.
- ❑ The disadvantages of fuses like low SC interrupting capacity (say 3 KA), etc. are overcome with high SC breaking capacity of 10 KA.
- ❑ MCB is a combination of all three functions in a wiring system like switching, overload and short circuit protection.
- ❑ Overload protection by using bimetallic strips and short circuit protection by using solenoid.
- ❑ These are available in single pole, double pole, triple pole and four pole versions with neutral poles if required.
- ❑ The normal current ratings are available from 0.5 to 63 A with a symmetrical short circuit rupturing capacity of 3-10 KA, at a voltage level of 230/440V.



- The 10 ampere DIN rail -mounted thermal magnetic miniature circuit breaker is the most common style in modern domestic consumer units and commercial electrical distribution boards throughout Europe. The design includes the following components:
1. **Actuator lever** - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the "on" position. This is sometimes referred to as "free trip" or "positive trip" operation.
 2. **Actuator mechanism** - forces the contacts together or apart.
 3. **Contacts** - Allow current when touching and break the current when moved apart.
 4. **Terminals**
 5. **Bimetallic strip.**
 6. **Calibration screw** - allows the manufacturer to precisely adjust the trip current of the device after assembly.

7. Solenoid

8. Arc divider/extinguisher

Earth Leakage Circuit Breaker (ELCB)

- ❑ None of the protection devices like MCB, MCCB, etc. can protect the human life against electric shocks or avoid fire due to leakage current.
- ❑ The human resistance noticeably drops with an increase in voltage. It also depends upon the duration of impressed voltage and drops with increase in time.
- ❑ As per IS code, a contact potential of 65 volts is within tolerable limit of human body for 10 seconds, where as 250 Volts can be withstood by human body for 100 milliseconds.
- ❑ The actual effect of current through human body varies from person to person with ref. to magnitude and duration.
- ❑ The body resistance at 10 volts is assessed to be 19 k Ω for 1 second and 8k Ω for 15 min. At 240 V, it is 3 to 3.6 k Ω for dry skin and 1 to 1.2 k Ω for wet skin.
- ❑ ELCBs are available in sensitivity of 30, 100 and 300 mA. IEC specify 30 mA sensitivity ELCB for human life protection.
- ❑ They are also called Residual current circuit breakers (RCCB)