UNIT-5

ELECTRICAL INSTALLATION:-

Switchgear:- In electrical power system, switchgear refers to the device used for switching, controlling and protecting the electrical circuits and components.

Essential Features of Switch Gear:-

The essential features of protective devices are:

i) **Complete reliability:-** It is the most important feature, which all the protective devices should have, in the power system. If a fault occurs in any part of the power system, then the protective device should operate in such a way that the faulty section gets isolated from the other part of the power system.

ii) **Absolutely discrimination:-** clear and accurate descrimination between the faulty section and healthy section is required to isolate the faulty section.

iii) **Quick operation:-** The time taken by the protective device to isolate the faulty section must be minimum so that other parts of the system do not get damaged.

iv) **provision for manual control:-** Even if the protective device can be made automatic, there should be a provision for manual control to carry out the necessary operations when the automatic control fails.

Components of Switch Gear:-

The switch gear comprises of wide range of components whose primary functions are switching and interrupting currents during both normal and faulty conditions. The basic components of switch gear; switches, fuses, circuit breakers, relays and other equipment.

i, **Switch:-** The device which is used to open (or) close an electrical circuit in a most conventional way is called switch. It can be operated at any condition of the circuit. The main disadvan-tage of the switch is that it cannot interrupt the current occuring due to faulty condition. The switches are classified as air and oil switches based on the medium where the contacts are opened.

(ii) **Fuse:-** A simple protective device used to protect the cables and electrical equipment under overload and short circuit conditions is called fuse. It consists of a small piece or thin strip of wire which melts when fault current flows through it for a sufficient time. Hence, the circuit gets protected from the fault current.

iii, **protective relay:-** In the power system, a device which continuously monitors the electrical quantities like current and voltage to sense the faulty condition is called protective relay. The main function of protective relay is to send the information about the faulty condition to the circuit breaker.

iv, **circuit breaker:-** A switching device, which can be used to make or break a circuit manually, automatically or with the help of remote control, under different conditions i.e., normal and faulty conditions, is known as a circuit breaker. In this ~~chap~~ chapter, some of the types of circuit breaker are discussed in detail.

→* **Fuse:-** A fuse is a short piece of wire or metal or thin strip which is inserted in series to the circuit. when the fault current flows through the fuse for a sufficient time, it melts and thus isolates the circuit.

—* Desirable characteristics of fuse element materials:.

The desirable characteristics of the material used in the fuse to have satisfied performance are:

1) low melting point e.g.., tin, lead
2) high conductivity e.g.., silver, copper.
3) least effect to oxidation eg.., silver
4) affordable eg...., lead, tin, copper.

—* Important Terms.

The following are the terms which are required in fuse analysis:

i) Current rating of fuse element:- It is the amount of current which the fuse element can carry under normal operation without over heating or melting. It depends on temperature rise in fuse holder, fuse material and surroundings of the fuse

~~ii) Fusing factor:~~

ii) Fusing current:- It is the minimum current at which the fuse element melts or blows away and isolates the healthy portion of the power system. It is higher than the current rating of fuse element.

iii) Fusing factor:- It is the ratio of the fusing current to the current rating of fuse element and its value is always greater than 1.

iv) Prospective current:- It is the RMS value of the fault current which is obtained by replacing the fuse with the conductor of negligible resistance.

v) cut-off current:- It is the maximum value of fault current obtained before the fuse element melts.

vi) Pre-arcing time:- The time taken to cut off the fault current from its commencement is known as pre arcing time.

vii) Arcing time:- The time taken to extinguish the arc after the pre-arcing time is known as arcing time

viii) Total operating time:- It is the summation of pre-arcing and arcing time

ix) Breaking capacity:- The RMS value of the maximum prospe-ctive current which a fuse can deal at rated voltage is known as breaking capacity.

—* Advantages and Disadvantages of fuse:-

The advantages and disadvantages of fuse are given below:

* Advantages:-

1) Cheapest form of protection device
2) Requires no maintenance
3) Operation of fuse is completely automatic
4) Easily breaks the large amount of fault current
5) pollution free protection device i.e,...., does not create any smoke or noise
6) suitable for over-current conditions due to its inverse current-time characteristics.
7) Requires less time in isolating the faulty part of the circuit.

* Disadvantages:

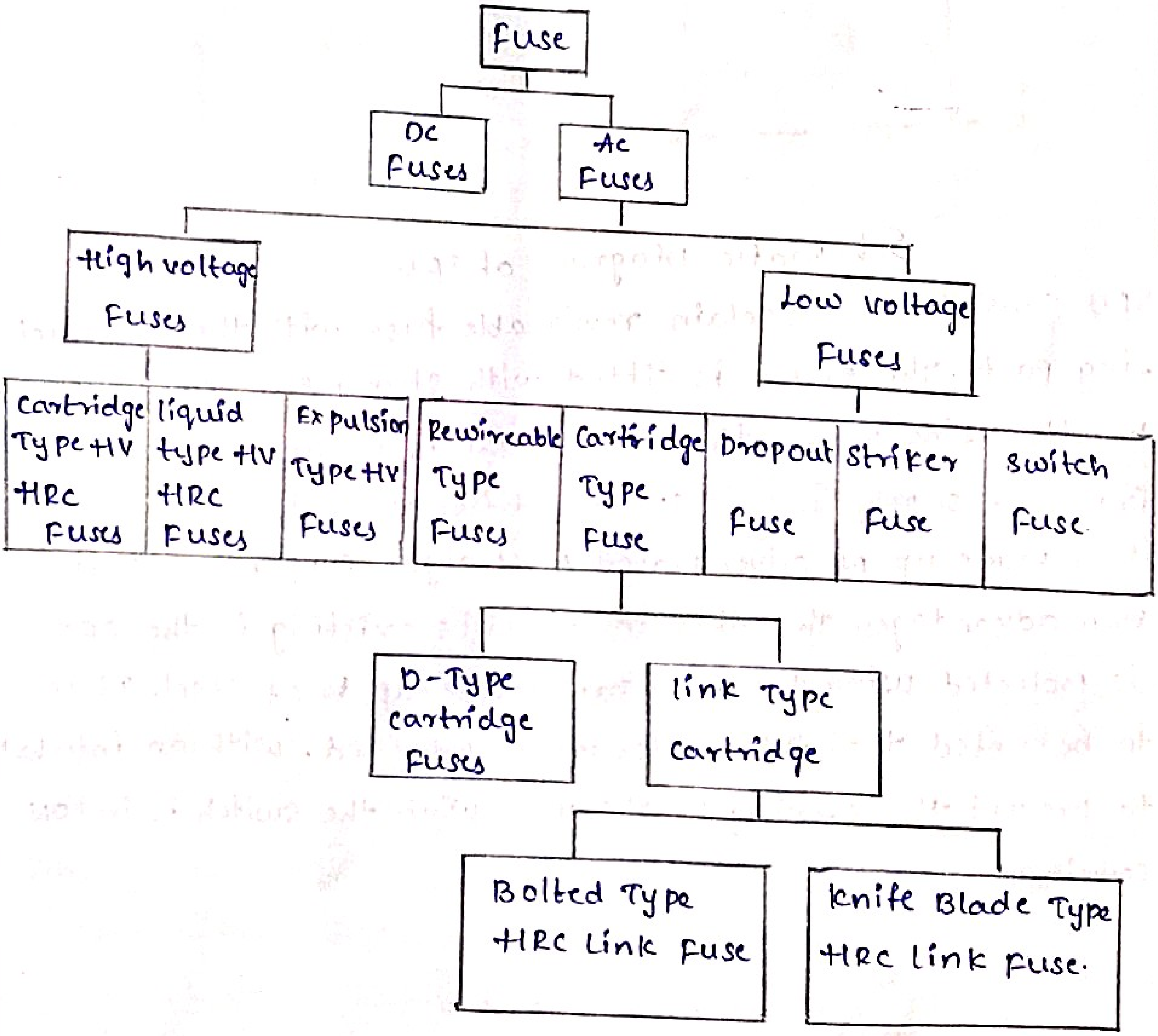
1) Rewiring or replacing a fuse takes a considerable time
2) Discrimination between fuses connected in series is not possible
3) Co-relation of the characteristics of fuse with the protected device is not always possible

Classification of Fuses:-

The general classification of fuses is shown in fig. 5.2.

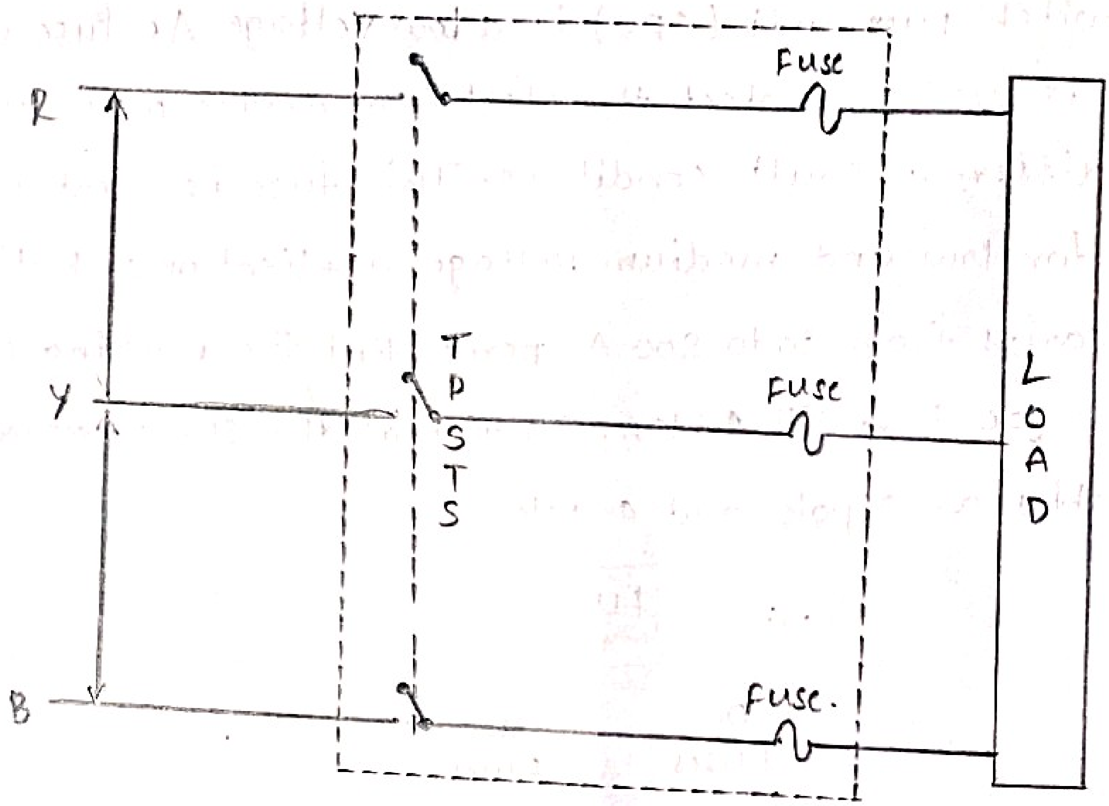
→ * Switch Fuse unit (SFU):-

The switch fuse unit (SFU) is a low voltage AC fuse unit which is used to protect the electrical device or equipment from different fault conditions. This fuse is most commonly used for low and medium voltage applications. Rating of SFU varies from 30 to 800 Amperes. But the making capacity of SFU goes high till 46 kA. In general the SFU is ~~ava~~ availables as 3 pole and 4 pole



classification of Fuse

unit. SFU has the capability of withstanding till the fault Current reaches 3 times full load Current.



Schematic Diagram of SFU

SFU Consists of porcelain rewireable fuse with their conducting parts. The switch is fitted with strong side operating handle using which the circuit ~~the~~ is made or isolated from the supply. In this SFU, the different contacts existing in it is made up of silver plated electrolytic copper due to its own advantages. The other components existing in the SFU is protected using the enclosure made up ~~to~~ of steel. It is to be noted that the enclosure is provided, with an interlock to prevent the opening of the unit when the switch is in ON condition.

* Switch Fuse Unit (SFU):- A fuse is a protective device which acts quickly. In abnormal condition, it blows and disconnects the circuit from the supply. Thus it provides circuits protection by destroying itself.

* A switch is used to isolate the circuit from the supply purposely for repair and maintenance. Generally it is manually operated.

* A unit which consists of the combinations of fuse and switch together is called switch fuse unit. It is shown in Fig. Q.2.1.

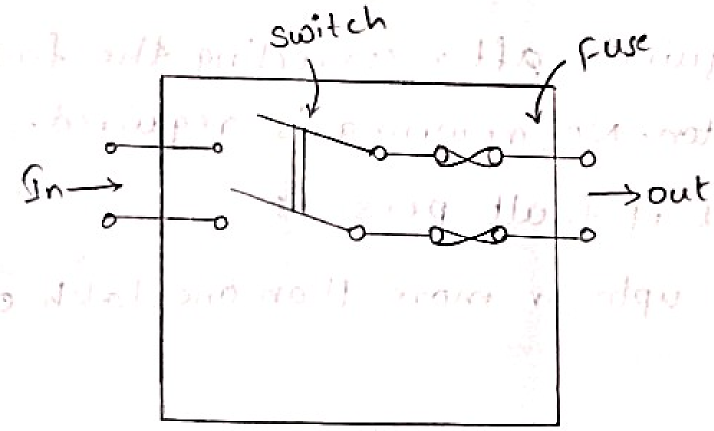


Fig. Q.2.1 switch fuse unit.

* The advantage of such switch fuse unit are,

i) The number of joints in the circuit get reduced.

ii) Due to compact construction, less space is required.

iii) Easy from handling point of view.

* Miniature Circuit Breaker (MCB):-

* A miniature circuit breaker is an electromechanical device which makes and breaks the circuit in normal operation and disconnects the circuit under the abnormal condition when current exceeds a preset value.

* MCB is a high fault capacity current limiting, trip free, automatic switching device with thermal and magnetic operation to provide protection against overload and short circuit.

* It is necessary to use MCB because of its following features

1) Its operation is very fast and opens in less than one milli-second.

2) No tripping circuit is necessary and the operation is automatic.

3) Provides protection against overload and short circuit without noise, smoke or flame.

4) It can be reset very quickly after correcting the fault, just by switching a button. No rewiring is required.

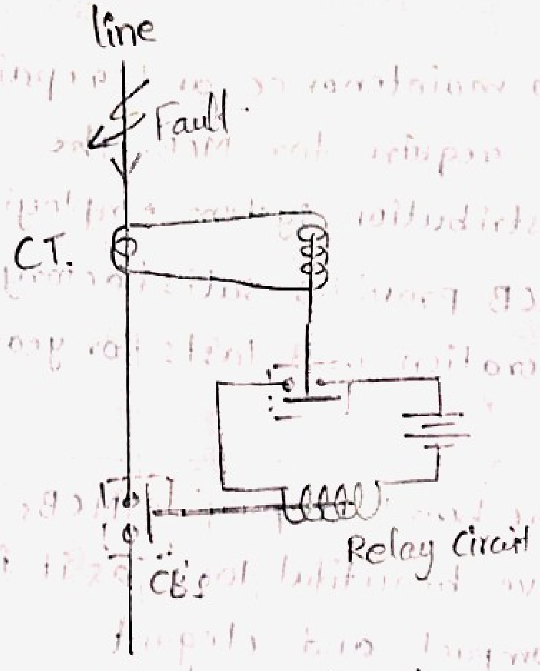
5) It can not be reclosed if fault persists.

6) The mechanical life is upto or more than one lakh operating cycle.

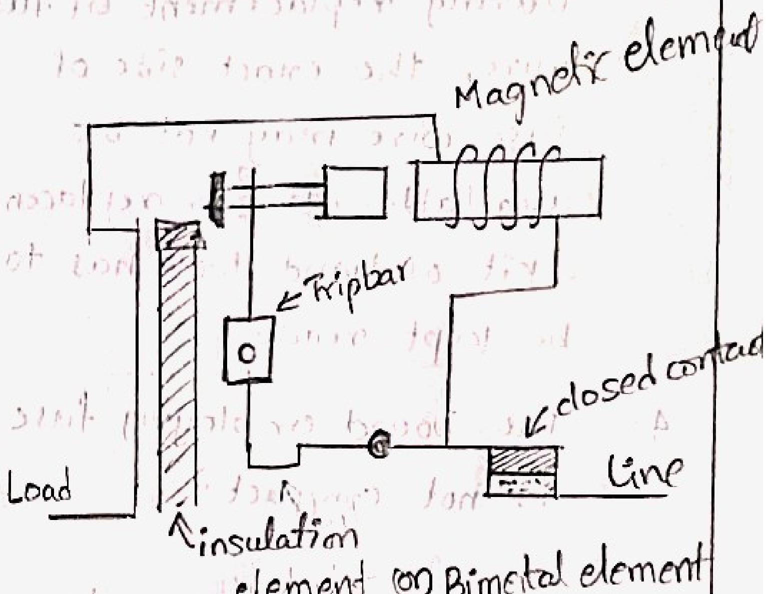
* Hence now a days MCBs are used rather than rewirable fuse.

* Generally MCBs are rated for a.c voltage of 240 V for single phase, 415 V for three phase or 220 V d.c. The current rating available is from 0.5 A to 63 A. It is available as single pole (SP), Double pole (DP), Tripple pole (TP) with short circuit breaking capacity from 1 kA to 10 kA with a rated frequency.

* A typical view of MCB and its practical appearance is shown in Fig. below.



Equalent Circuit of CB'S



Basic diagram of MCB's

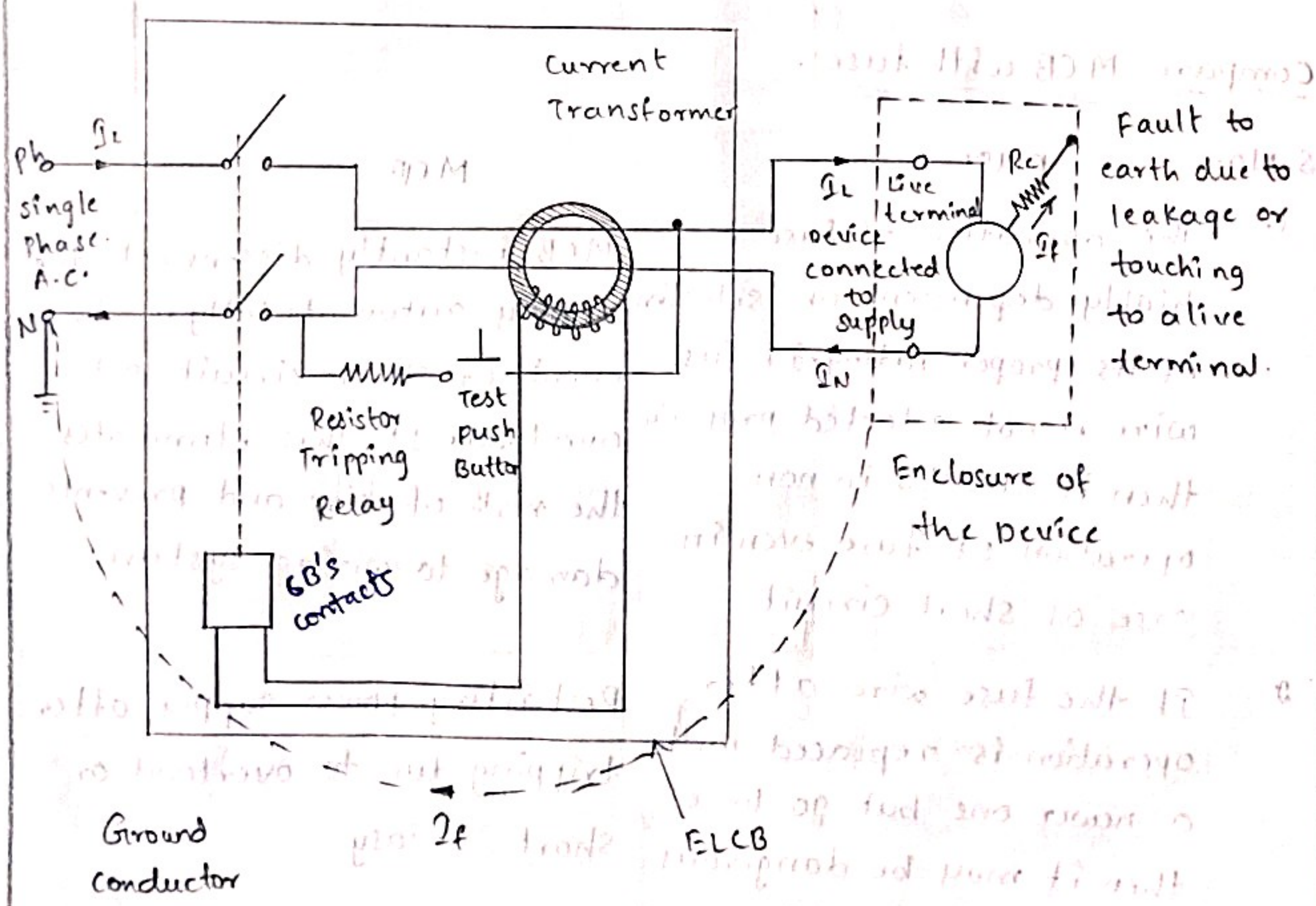
Compare MCB with fuse:-

S.No.	Fuse	MCB
1.	The operation of fuse is highly dependent on selection of its proper rating. If fuse wire is not selected properly then it results in non operation of fuse even in case of short circuit.	MCB instantly disconnects the supply automatically in the event of short circuit (or) overload. It thus eliminates the risk of fire and prevents damage to wiring system.
2.	If the fuse wire after operation is replaced with a newer one but go loose then it may be dangerous. Also to replace a blown fuse in ~~button~~ between	Restarting power supply after tripping due to overload or short is easy.

	Current carrying points is dangerous specially in dark.	
3.	During replacement of fuse wire, the exact size of fuse wire may not be available. Also for replacement a kit of hand tools has to be kept ready	No maintenance and repairs is require for MCB. The distribution system employing MCB provides satisfactory operation and lasts for years.
4.	The board employing fuse is not compact.	The board employing MCBs give beautiful look as it is compact and elegant.

—* **Earth Leakage Circuit Breaker (ELCB):-**

* The schematic of ELCB is as shown in the fig Q.5.1



As shown in the Fig. Q.51 ELCB consists of a small current transformer surrounding live and neutral wire. The seconda-ry winding of current transformer is connected to relay circuit which can trip the circuit breaker which is connected in the circuit.

under normal conditions, the current in line and neutral conductor is same so the net current ($I_L - I_N$) flowing through the core is zero. Eventually there will not be any production of flux in the core and no induced e.m.f. so the breaker does not trip.

* If there is a fault due to leakage from live wire to earth or a person by mistake touching to the live terminal then the net current through to the core will no longer remain as zero but equal to $I_L - I_N$ or I_f which will set up flux and emf in C.T. As per the present value, the unbalance in current is detected by C.T. and relay coil is energized which will give tripping signal for the circuit breaker. As C.T. operates with low value of current, the core must be very permeable at low flux densities.

* Thus ELCB provides protection against electric shock when a person comes in contact with live parts. resulting in flow of current from body to earth.

* A properly connected ELCB detects such small currents in milliamperes flowing to earth through human body or earth wire and breaks the circuit to reduce the risk of electrocution to humans.

* There are certain situations where leakge current can flow through the metal bodies of appliances, when person touches to such appliances. Thus person can get a shock.

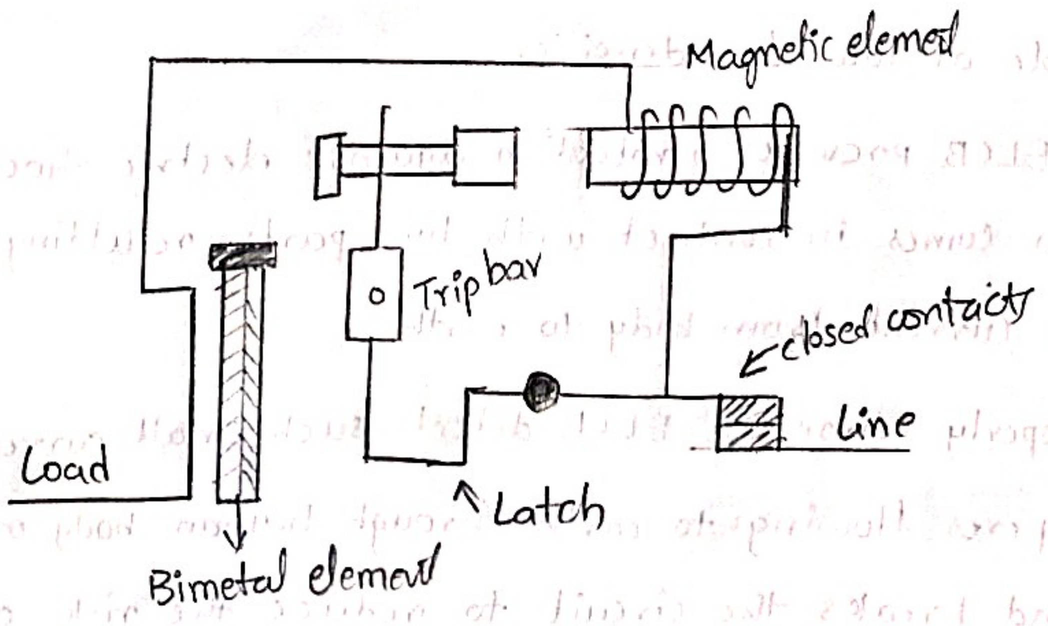
* Similarly there is risk of fire due to such earth leakage currents.

* Thus a protective device is necessary which can sense small leakage current and disconnect the circuit from supply. Such a device is called earth leakage circuit breakers (ELCB).

1) provides protection to a human against the electric shock.
2) Detects very small leakage currents.
3) Reduces the Risk of fire due to hot spots.
4) Saves electrical energy due to leakage.
5) Energy conservation can be achieved.

—* Moulded Case Circuit Breaker (MCCB):-

* MCCB is similar to MCB but used when the load currents exceed the capabilities of MCB. It is used for circuits having current ranges from 63A to 3000A.



* Its working is based on thermal mechanism. It has a bimetallic contact which expands and contracts when there are changes in temperature. under normal condition, the Contacts are closed allowing current to pass. under over load or short circuit condition, current exceeds its safe value. Due to this, heat is generated and the contacts are opened to interrupt the circuit.

* Due to the interruption of high current, there is arc formation. Hence in MCCB there are arc extinguishers which suppress the arc.

* There is a disconnection switch, with the help of which, the MCCB can be operated manually.

* ~~pratic~~ practically it has adjustable trip settings and hence it can be used for high current applications.

* It can be easily reset after the fault rectification. Thus it Provides operational safety and convenience.

* All the Operating parts of MCCB are covered within a plastic moulded housing made in two halves. The two halves are joined together to form the whole structure.

* The basic difference between MCB and MCCB is the current rating. Hence MCCBs are used for industrial and commercial applications such as main feeder protection, generator and motor protection, capacitor bank protection, welding application and applications which require adjustable trip setting.

* MCCBs are used for high current protection such as,

1) Generator protection

2) Main feeder protection

3) motor protection

4) Capacitor bank protection

5) Welding applications

6) Applications which need adjustable current trip setting.

—* Types of wires:-

1) vulcanised India Rubber wires (V.I.R)

2) Cab Tyre sheathed wires (C.T.S)

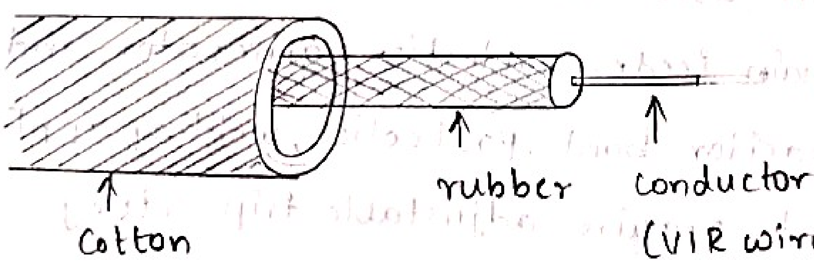
3) poly vinyl chloride wires (P.V.C)

4) Flexible wires.

* The various type of wires which are used for various wirining schemes are:

1) Vulcanised India Rubber wires (V.I.R.):-

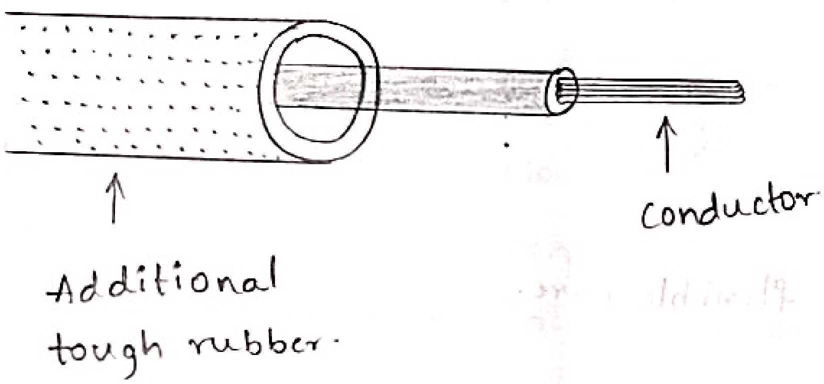
* This type of wire consists tinned conductor coated with rubber insulation. This is further covered with protective cotton and bitumen compound and finally finished with wax. This makes it moisture and heat resistant. These are always single core wire. Though are covered with a cotton layer it has tendency to absorb moisture and hence rarely used, now a days.



(VIR wire)

2) Cab Tyre sheathed wires (C.T.S.)

In this type, ordinary rubber insulated conductors are Provided with an additional tough rubber sheath. The wire is also known as Tough Rubber sheathed (T.R.S) wire. It Provides additional insulation and along with that a protection against moisture, chemical fumes and wear and tear. These are also available in single core, double core and three core varieties.



3) Poly Vinyl Chloride wires (P.V.C) :-

These are most commonly used wires. These have conductors with P.V.C insulation. P.V.C has following characteristics:

1) It is nonhygroscopic and moisture proof.
2) It is tough and hence durable.
3) Resistant to corrosion.
4) It is chemically inert.
5) As it is tough so additional converging is not required.

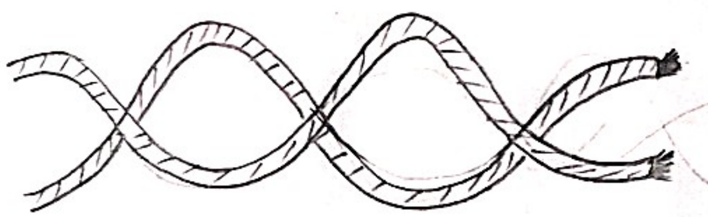
The only disadvantages is, it softens at highs temperature and hence it avoided where entreme of temperature may occur. eg. in heating appliances.

4) **Flexible wires:-**

* These are used very commonly in domestic wiring or ~~fire~~ for wiring or for wiring of temporary nature.

* It consist of two seperately insulated stranded conductors. The insulation is mostly rubber. more commonly available in parallel (or) twisted twins.

* Due to its flexible nature, the handling of these wire become very easy.



Twisted twin flexible wire.

—* **Types of cables:-**

* An underground cable is defined as the groups of individually insulated one or more conductors which is put together and finally provided with number of layers of insulation to give proper mechanical support.

* The Fig. Q.12.1 shows the general construction of a cable. The cable shows is single conductor underground cable. Its various parts are,

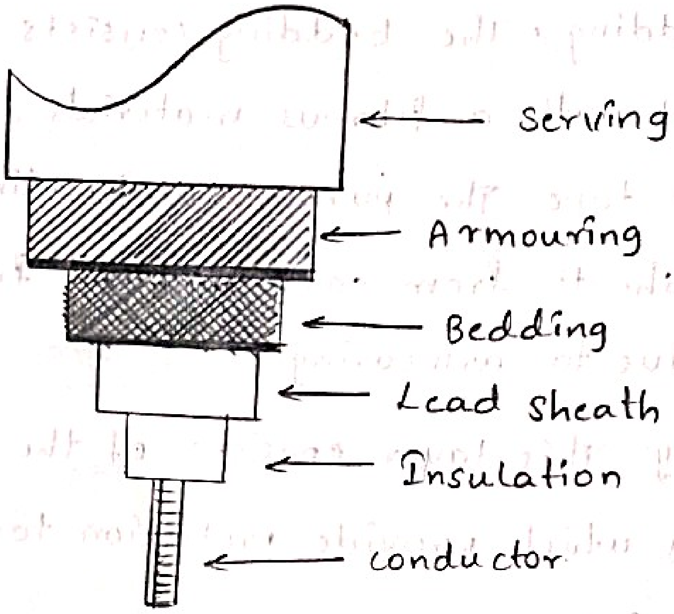


Fig. Q.12.1 General construction of a cable.

1) Conductor (or) Core:- This section consists of single conductor or more than one conductor. The conductors are also called cores. A cable with three conductors is called three core cable. The conductors used are aluminium or annealed copper. The conductors are stranded conductors in order to provide flexibility to the cable.

2) Insulation:- Each conductor or core is covered by insulation of proper thickless. The commonly used insulating materials are varnished cambric, vulcanized bitumen and impregna-ted paper.

3) Metallic sheath:- The insulated conductors are covered by lead sheath or aluminium sheath. This provides the mecha-nical protection but mainly restricts moisture and other gases to each to the insulation.

4) Bedding:- The metallic sheath is covered by another layer called bedding. The bedding consists of paper tape compounded with a fibrous materials like jute strands or hessian tape. The purpose of bedding is to protect the metallic sheath from corrosion and from mechanical injury resulting due to armouring.

5) Armouring:- This layer consists of the layers of galavized steel wires which provide protection to the cable from the mechanical injury.

6) Serving:- The last layer above the armouring is serving. It is a layer of fibrous material like jute cloth which protects the armouring from the atmospheric conditions.

* The type of cable is basically decided on the voltage level for which it is manufractured and the material used for the insulation such as cotton, paper, rubber etc.

* Based on voltage level, the various types of cables are,

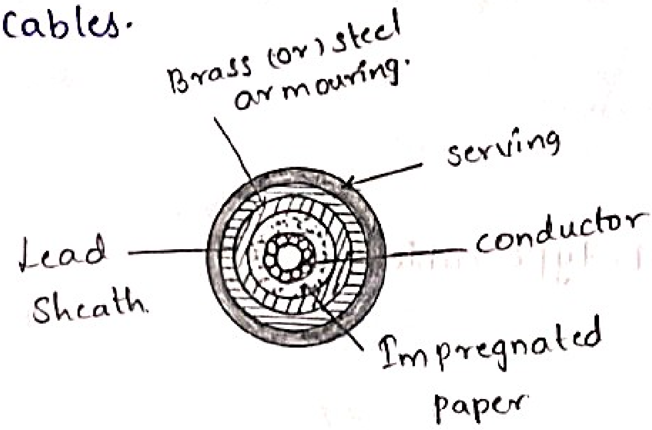
1. Low Tension (L.T) cables:- used for the voltage levels upto 6.6 KV.

2. Medium tenstion cables:- Used for 11 kv level and are called belted cables.

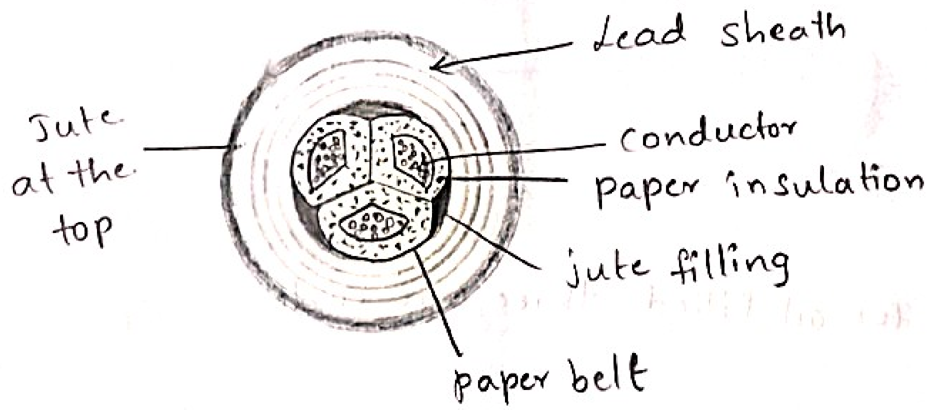
3. High tension cables:- used for 22 kV and 33 kV levels. These are screened type cables and further classified as: i) H type cables and ii) S.L. cables i.e, separate lead screened cables.

4. Extra high tension cables:- used for voltage levels more than 33kV. These are pressure cables which are further classifed as: i) oil filled cables and ii) Gas pressure cables.

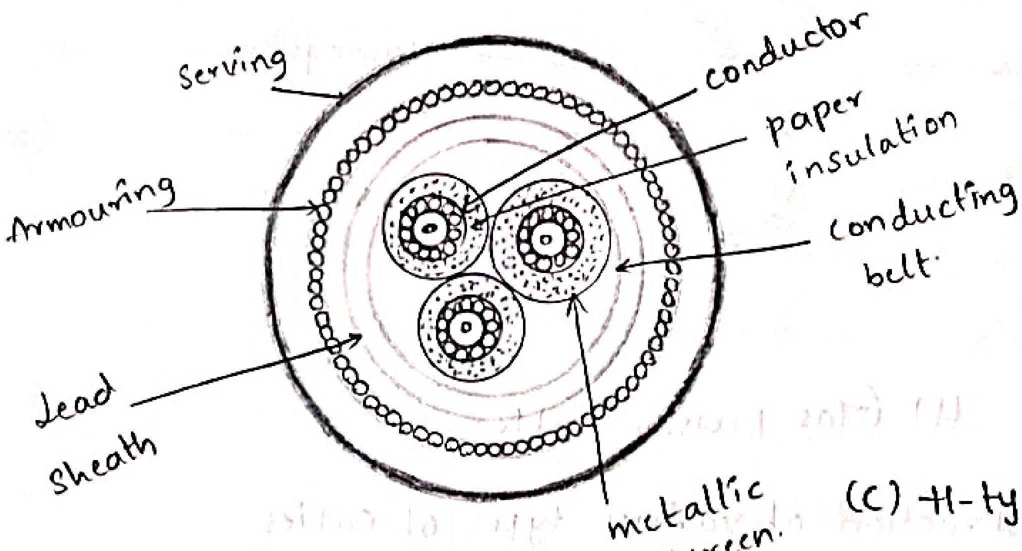
* The fig Q13.1 shows the constructional details of various types of cables.



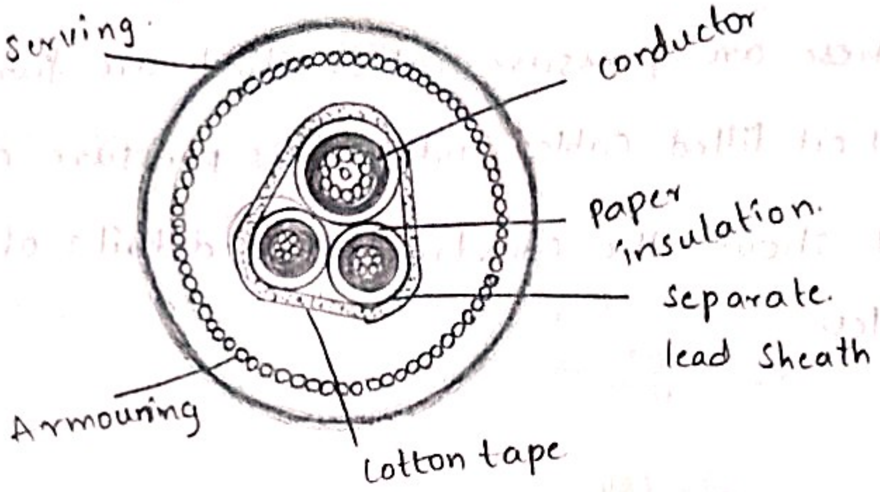
(a) Single Core L.T. Cable.



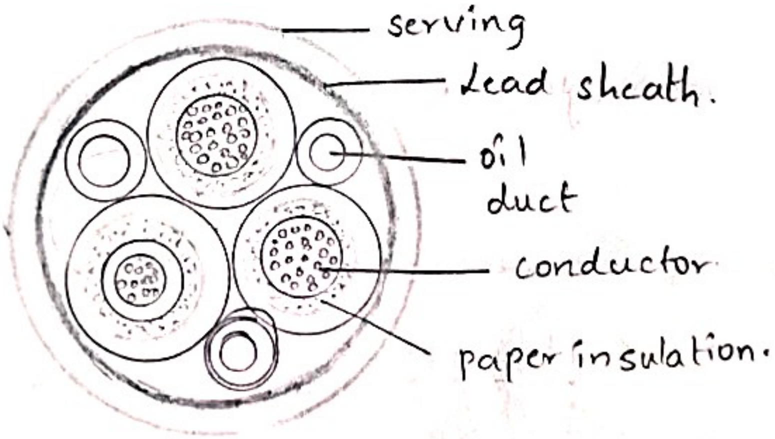
(b) Belted 3 Core Cable.



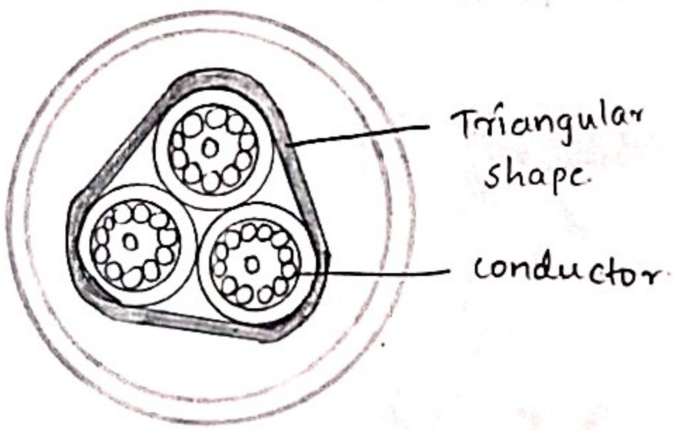
(C) H-type Cable.



(d) S.L. type cable.



(e) oil filled three core cable.



(f) Gas pressure cable.

Fig. Q.13.1 construction of various types of cables.

* Based on the cores, the various types of cables are,
(i) single core (ii) Two core and (iii) Three core cables.

* The advantages are,

1. Require less maintenance.
2. The voltage drop is less than overhead lines.
3. Not affected by lightning, storms and other weather conditions.
4. Beauty of towns and cities gets maintained.
5. Possibility of accidents is less.
6. possibility of faults is less.

* The limitations are,

1. Initial cost is very high.
2. The size is more hence installation is difficult and costly
3. Insulation cost is high.
4. Long distance transmission is not possible.

* For distribution of power in town and cities which are thickly populated areas.

* For providing power to areas where overhead lines are not permitted.

* For electrification of areas where beauty is required to be maintained such as gardens, hotels, educational builidings etc.

* For supplying mining machines in mining industries.

* used in power networks.
* Specials cables are used in switch control, relay and instrumentation panels of power switch gear.

—* Importance of Earthing:-

* The connection of electrical machinery to the general mass of earth, with a conducting material of very low resistance is called "earthing" or "grounding".
* consider a machine which is not earthed. It is operated at supply voltage v.
* If a person touches to the outer part of the machine then as long as insulating of the machine is perfect, person will, not get a shock. The insulation resistance of perfect insula -tion is infinite.
* But if there is some fault and insulation becomes weak or if one of the windings is touching to the cover of the machine then insulation resistance becomes zero. If person touches to such a machine, current flows through the body resistance is small, current through the body is high so that the person receives a shock.
* To avoid such a situation, the body of the machine is Connected to the earth with a very low resistance. This is called earthing.
* If machine is earthed an person touches to a faulty machine then body resistance and earthing resistance

appears to be in parallel.

* As earthing resistance is very small than the resistance of the body hence almost entire current flows through earthing connection.

* Thus current through the body of the person is almost zero and person doesnot receive any shock.

* Similarly due to earthing, the tall buildings, structures and other machines are protected from high voltage in over-head lines and the atmospheric lightening as high voltage and lightening as high voltage and lightening gets discharging to earth through earthing connection.

* Due to earthing the line voltage is maintained at constant value.

* Hence earthing is necessary for all domestic appliances, machines, buildings and structures, equipments power stations etc.

1) Plate earthing.
2) Pipe earthing.
3) Rod earthing.
4) Earthing through water main
5) Horizontal strip earthing.

Plate Earthing

1. * The earth connection is provided with the help of copper plate or Galvanized Iron (G.I) plate. The copper plate size is 60cm × 60cm × 3.18 mm while G.I. plate size is not less than 60cm × 60cm × 6.3mm. The G.I plates

are commonly used now-a-days. The plate is embedded 3 meters (10 feet) into the ground. The plate is kept with its face vertical.

* The plate is surrounded by the alternate layer of coke and salt for minimum thickness of about 15cm. The earth wire is draw through G.I. pipe and is perfectly bolted to the earth plate. The nuts and bolts must be of copper plate and must be of galvanized iron for G.I. plate.

* The earth lead used must be G.I wire or G.I strip of sufficient cross-sectional area to carry the fault current safely. The earth wire is drawn through G.I. pipe of 19mm diameter, at about 60cm below the ground.

* The G.I. pipe is fitted with a funnel on the top. In order to have an effective earthing, salt water is poured periodi-cally through the funnel.

* The earthing efficiency, increases with the increases of the plate area and depth of embedding. If the resistivity of the soil is high, then it is necessary to embed the plate vertically at a greather depth into the ground.

* The only disadvantage of this method is that the discon-tinuity of the earth wire from the earthing plate below the earth can not be observed physically. This may cause misleading and may result into heavy losses under fault conditions.

* The schematic arrangement of plate earthing is shown in the fig. Q.18.1

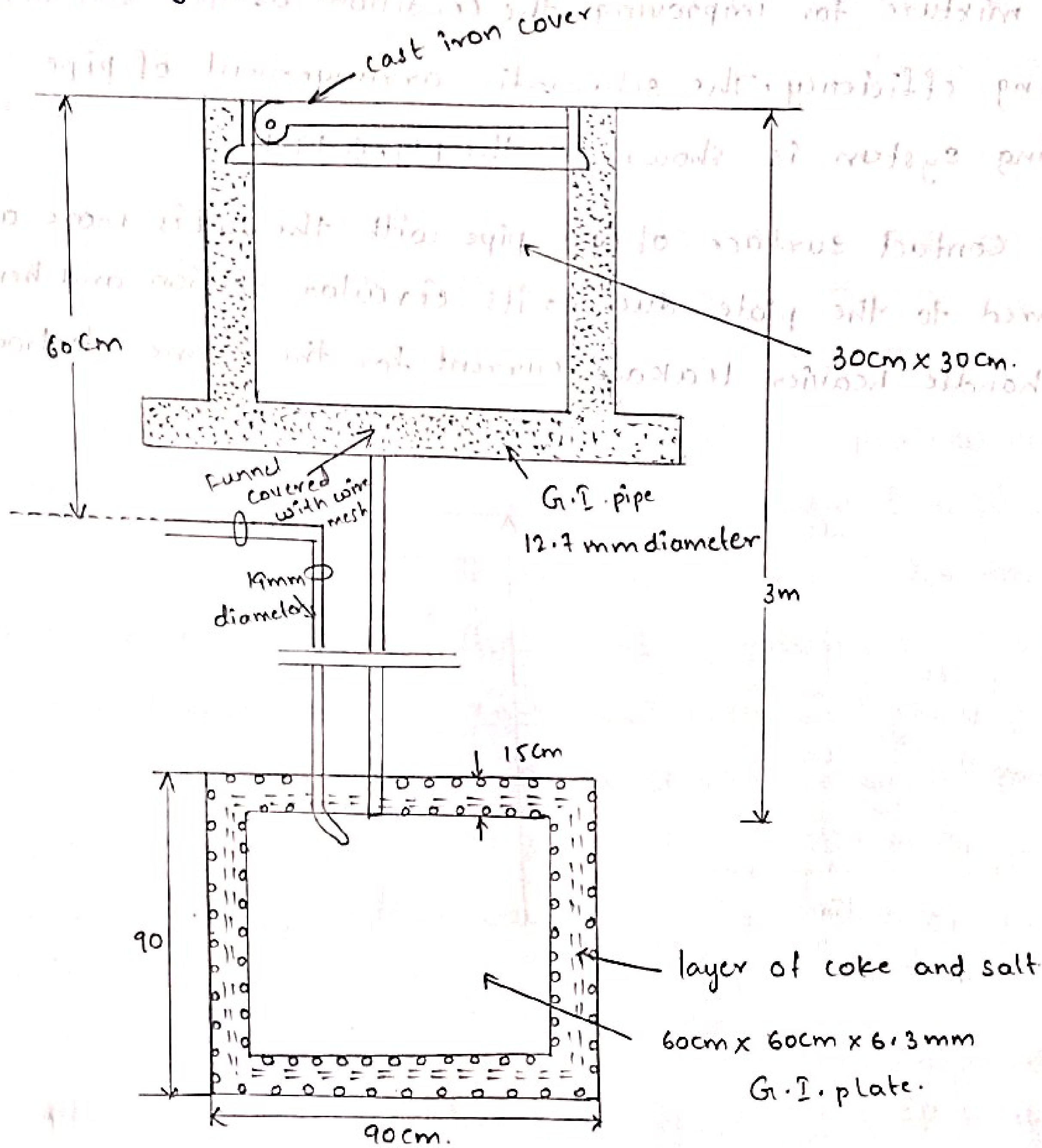


Fig. Q.18.1 plate earthing.

(2) Pipe earthing

* In this method of earthing a G.I. pipe of 38mm diameter and 2 meter (7 feet) length is embedded vertically into the ground. This pipe acts as an earth electrode. The depth depends on the condition of the soil.

* The earth wires are fastented to the top section of the pipe above the ground level with nut and bolts.

* The pit area around the pipe is filled with salt and coal mixture for improving the condition of the soil and earthing efficiency. The schematic arrangement of pipe earthing system is shown in the fig. Q.19.1

* The contact surface of G.I pipe with the soil is more as compared to the plate due to its circular section and hence can handle heavier leakage current for the same electrode size.

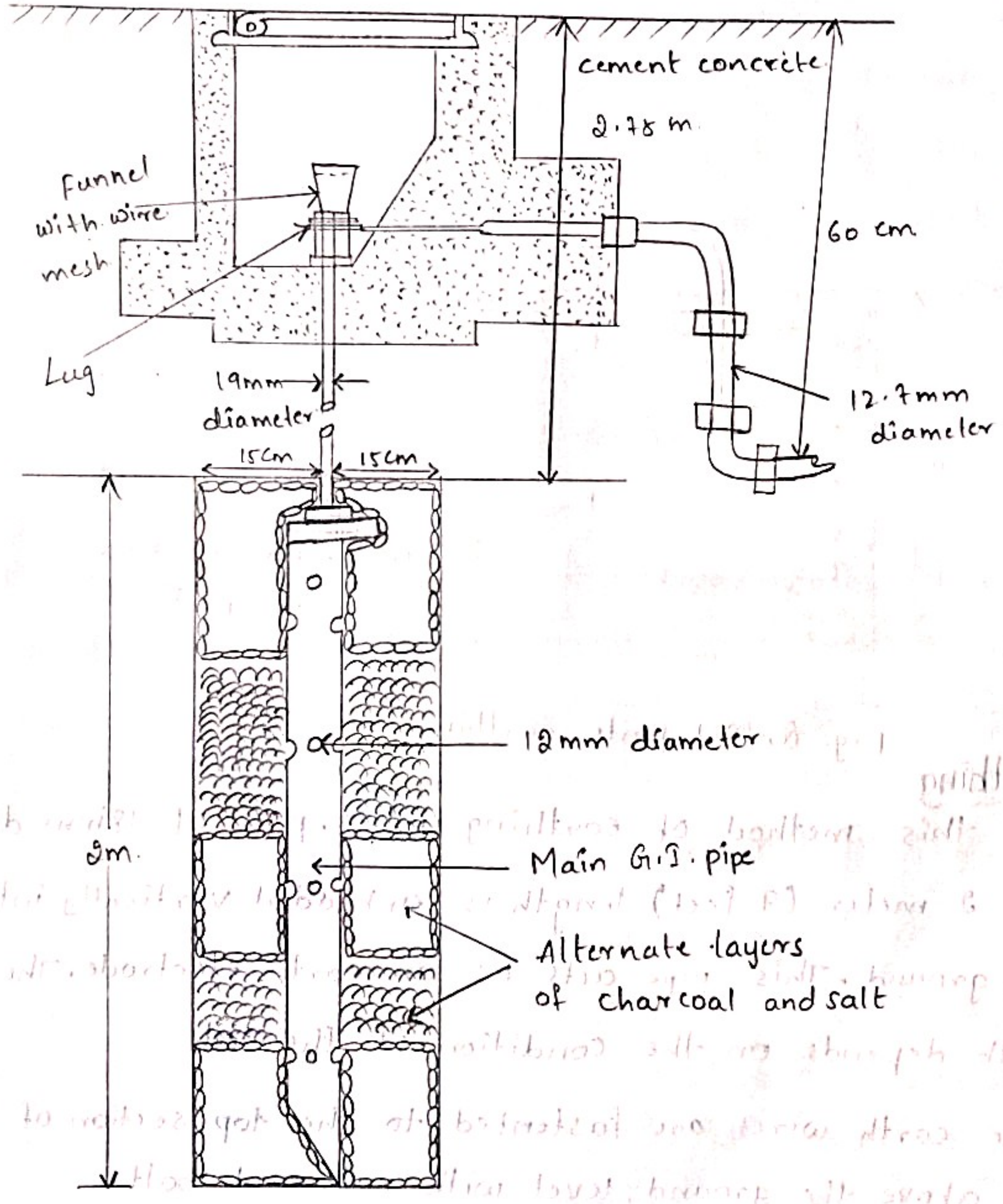


Fig. Q.19.1 pipe earthing.

* According to Indian standard, the pipe should be placed at a depth of 4.75m. Impregnating the coke with salt decreases the earth resistance. Generally alternate layers of salt and coke are used for best results.

* In summer season, soil becomes dry. In such case salt water is poured through the funnel connected to the main G.I. pipe through 19mm diameter pipe. This keeps the soil wet.

* The earth wires are connect. to the G.I. pipe above the ground level and can be physically inspected from time to time. These connections can be checked for performing continuity tests. This is the important advantage of pipe earthing over the plate earthing. The earth lead used must be G.I. wire of sufficient cross-sectional area to carry fault current safely. It should not be less than electrical. equivalent of copper conductor of 12.97 mm^2 cross-sectional area.

* The only disadvantage of pipe earthing is that the embedded pipe length has to be increased sufficiently in case the soil specific resistivity is of high order. This increases the excavation work and hence increased cost. In ordinary soil condition the range of the earth resistance should be 2 to 5 ohms.

* In the places where rocky soil earth bed exists; horizontal strip earthing is used. This is suitable as soil excavation required for plate or pipe earthing is difficult in such places. For such soils earth resistance is between 5 to 8 ohms

→ * Types of Batteries:-

S.No.	Type of battery	Applications.
1.	Lead acid battery	In automobiles for starting and lighting, battery electric vehicles, backup operations like rail road signals, air traffic controls and critical systems in submarines, for lights and fans in trains etc...
2.	Nickel - cadmium battery	In railways for lighting and air conditioning systems, for starting engines and provide emergency power supply in millitary aeroplanes and helicopters, in movie cameras and photoflash, in electric shower, variety of cordless electronic devices etc..
3.	NiMH battery (Nickel metal hydride)	cellular phones, portable computers. and laptops, digital cameras, electronic toys, providing emergency supply to various electronic instruments etc.
4.	Lithium battery (Lithium ion)	consumer products such as camcorders, calculators, electric razors, medical equipments, portable radios, in traction.
5.	SMF battery [sealed maintenance Free]	ups systems, telecommunications. equipments, fire alarms and security systems, office automation equipments, etc...

* **Important characteristics for Batteries:-** The various important characteristics for batteries are.

1. **Nominal voltage:-** It is indicated on a battery depending on the amount of cells connected in series. It is the open circuit voltage of a battery.

2. **Battery capacity (or) battery life:-** It is specified in ampere-hours (Ah).

* It indicates the amount of electricity which a battery can supply at the specified discharge rate till its voltage falls to a specified value.

* Mathematically product of discharge current (I_D) in amperes and the time for discharge (T_D) in hours till voltage falls to a specified value is the capacity of a battery

$$\therefore \boxed{\text{Battery capacity} = I_D \times T_D \ (Ah)}$$

3. **Specific gravity of electrolyte:-** More the specific gravity of electrolyte, more is the battery capacity. It decides internal resistance of a battery.

4. **Specific energy:-** The battery capacity expressed in watt-hour per kg weight is called specific energy. It is also called gravimetric energy density of a battery.

5. **Electrical characteristics:** These characteristics include, the charging and discharging curves for a battery. It is the graph of terminal voltage against charging or discharging time in hours at normal rate. The fig. Q.21.1 shows such curves for

a ~~sp~~ typical battery. From the given charging and discharging curves, the time of discharge for a specified voltage level can be obtained.

6. Battery efficiency:- It is defined as the ratio of the output during discharging to the input required during charging, to regain the original state of the battery.

* It is commonly called ampere-hour efficiency or quantity efficiency and denoted as η_{Ah}.

$$\eta_{Ah} = \frac{\text{Amp-hours on discharge}}{\text{Amp-hours on charge}}$$

$$\therefore \quad \boxed{\%\ \eta_{Ah} = \left[\frac{\text{current} \times \text{Time on discharge}}{\text{current} \times \text{Time on charge}}\right] \times 100}$$

* For lead acid battery, it is about 80% to 90%.

—* Calculations for Energy Consumption:-

* The total electrical energy consumption is the addition of electrical energy consumption of various domestic appliances or industrial machinery.

* To calculate the consumption of an electrical appliance, following factors are required,

1. capacity of electrical appliance in watts.
2. Numbers of hours for which appliances is in use in one day.
3. Numbers of days per month or years as per the required energy calculation.

* Mathematically energy consumption of an appliance is given by,

$$\frac{\begin{bmatrix}\text{Capacity of}\\ \text{appliance in W}\end{bmatrix} \times \begin{bmatrix}\text{Number of}\\ \text{hours/ day}\end{bmatrix} \times \begin{bmatrix}\text{Number of}\\ \text{days / month}\end{bmatrix}}{1000} = \text{kWh per month}$$

* The division of 1000 is to express energy consumption in kWh i.e, units [1 unit = 1 kWh].

* Addition of such energy consumptions of all the appliances, total energy consumptions per month can be obtained.

* But practically an energy meter is installed which directly measures the total energy consumption of a house or industry.

* Thus for pratical energy consumption calculation we need,

1. Energy meter reading at the start of counting period.
2. Energy meter reading at the end of counting period.
3. Number of days in a counting period which is generally a month.

∴ Total energy consumption per month = final reading in kWh after a month − Initial reading in kWh.

* To find the consumption for one year, the energy consumption per day is multiplied by 365 days.

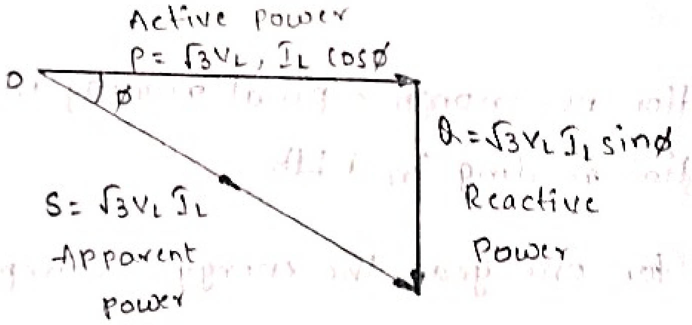
* For calculating energy savings use

$$\begin{matrix}\text{Energy saving}\\ \text{(kWh / year)}\end{matrix} = \begin{bmatrix}365 \times \text{Energy consumption}\\ \text{per day in previous } \cancel{\text{day}} \text{ year}\end{bmatrix} - \begin{bmatrix}\text{energy consumption}\\ \text{per current year}\end{bmatrix}$$

* By knowing energy consumption of each appliance and replacing bulbs by lower wattage bulbs if possible, saving in energy can be be achieved.

—* Power factor improvement and battery backup:-

* In a.c circuits the cosine of angle between voltage and current is called power factor. It is denoted as $\cos\phi$.
* The active power consumption in a.c. circuits is the product of voltage and the component of the current which is in phase with the voltage which is decided by the $\cos\phi$.
* Thus the power factor affects the active power consumption of the circuit.
* The power triangle for three phase circuit which is as shown in the Fig. Q.23.1. It is also called as KVA triangle.
* The power factor can be obtained as the ratio of active power to apparent power.
* If the lagging reactive power component is shown downwards. then the leading reactive power component is shown upwards.



$$\boxed{\cos\phi = \frac{\text{Active power}}{\text{Apparent power}}}$$

* So if lagging reactive power is more, ϕ will be more and $\cos\phi$ will be less. Due to this to supply same amount of active power the current drawn by the circuit will be more which is not desirable.
* If an additional load drawing leading reactive power is connected in parallel with the original load then leading reactive power is in opposite direction to lagging reactive power. So it partly neutralises the effect of lagging reactive

Power. Due to this, ϕ reduces and $\cos\phi$ increases. This reduces the current required to supply same amount of active Power will reduce.

* So lagging reactive power tries to lower the power factor while the leading reactive power increases the power factor.

* The main cause of low power factor is inductive loads. Such loads include,

(i) Transformers (ii) Induction motors (3 phase and single phase) (iii) Induction generators (iv) Domestic appliances and lighting load (v) High intensity discharge lighting (vi) Industrial induction furnaces etc...

* All these loads constitute a major portion of the power consumption while leading power factor loads are very less in number.

* Hence the overall power factor is very low.

* The various problems of low power factor are,

1. Lower is the power factor, higher is the load current for the same amount of active power.
2. The conductor size depends on the current. For higher current greater conductor size is required.
3. Higher conductor size increases the cost of the system.
4. Large current causes more copper losses (I^2R). This results into poor efficiency.
5. Large current causes large voltage drop (IZ) in transmission lines, alternators and transformers. This reduces the voltage available at the supply end. This results

into poor regulation of the various devices.

* Power factor improvement: The basic requirement to improve power factor is the leading reactive power loads. one of such loads is capacitors.

* Thus by connecting capacitor is parallel with the lagging power factor load, the overall power factor can be improved.

* Consider a lagging power ~~load~~ factor load as shown in the Fig. Q.24.1 (a). The corresponding phasor diagram is shown in the Fig. Q.24.1 (b).

* Let I_1 be the current drawn at a lagging power factor angle of ϕ_1.

* To improve the power factor, a capacitor is connected across the load as shown in the Fig. Q.24.2.

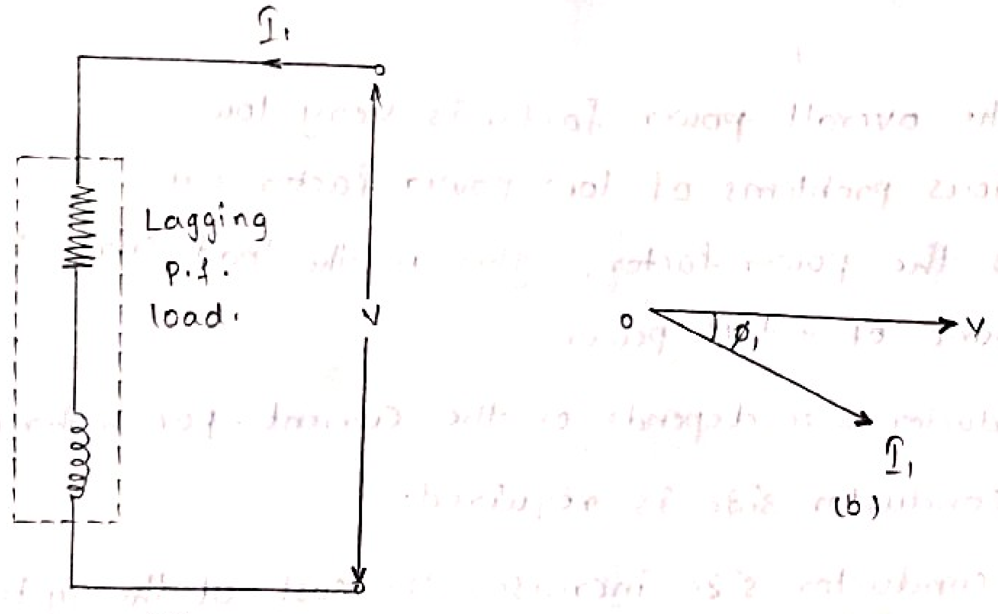


Fig Q.24.1

* The capacitor takes a leading current I_2, which leads voltage v by an angle of 90° as shown in the Fig. Q.24.2 (a).

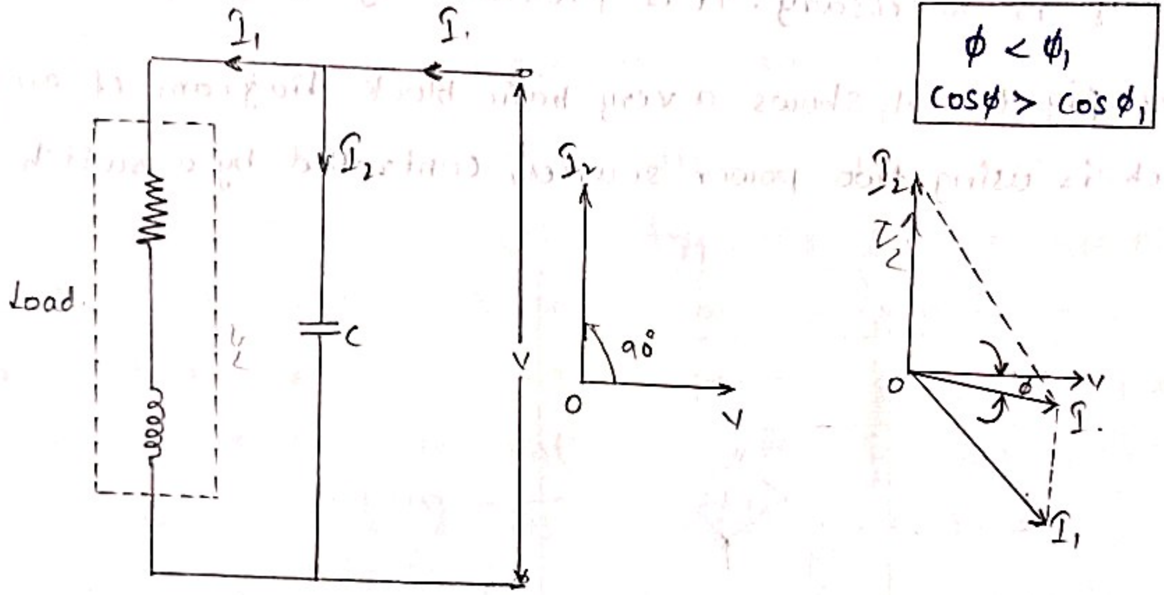
* This leading component of current I_2 tries to neutralize the lagging effect of I_1. Hence the resultant current becomes

as shown in the Fig Q.24.2(b).

* It can be seen that the effective power factor angle becomes ϕ. which is less than ϕ_1. Hence $\cos\phi$ is more than $\cos\phi_1$, thus there is improvement in the power factor of the system.

* The devices generally used to improve the power factor are,

1) Bank of static capacitors,
2) Synchronous condensers,
3) phase advancers.



—* **Battery Backup:-** A battery backup device is an electronic device that supplies secondary power in the absence of the main power. It can also protect electronic hardware from power spikes and fluctuations.

The main battery backup device which is commonly used is called uninterruptible power supply [**UPS**].

Need of ups:-

1. Most of the systems operate on a.c. supply, Thus a.c. supply failure causes periodical stoppage of the various systems.

2. Most of the modern systems use computers and micropr-ocessors. Any interruption in the power supply may result into the loss of the work and may make system ineffecti-ve.

3. Many important places likes hospitals, temples, playing grounds, banks etc. require continuous supply for their efficient operation.

* To avoid all these adverse and serious situations, battery backup is necessary. It is provided by using ups.

* The Fig. Q.26.1 shows a very basic block diagram of an ups which is using two power sources, controlled by a switch.

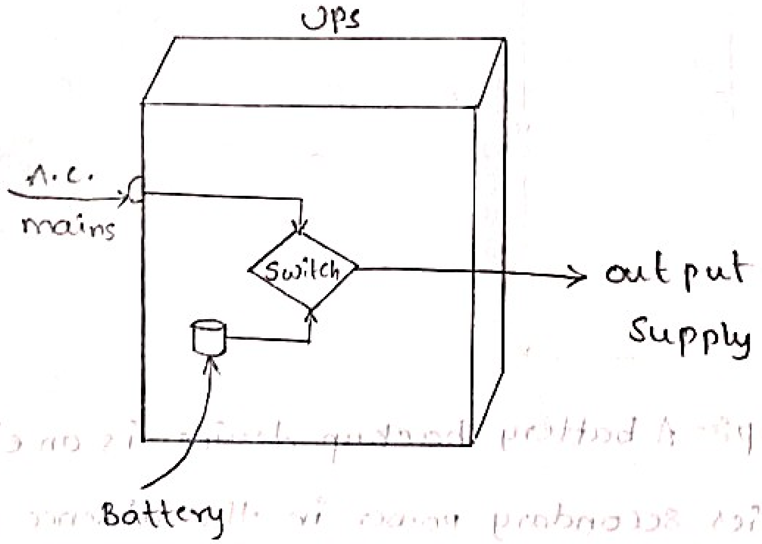


Fig. Q.26.1 Basic concept of ups.

* The ups is designed so that there is one source of power, usede under normal conditions, known as.
Primary power source (usually a.c. mains) and other source that comes into action if the primary source is disrupted. This another sources is called. the secondary power source. (usually battery). A switch is used as a controlling device. It changes from primary sources to secondary when it

detects that the primary source has failed. It automatica-lly switches back from the secondary power sources to the primary when it is detected that the primary source has returned to normal.

* The power available from mains is a.c. All batteries provide d.c. Hence in UPS there UPS there is circuity to convert a.c to d.c for battery charging called a converter. Similarly there is a device converting d.c. from battery to a.c. as required by the load. This is called an inverter. These are important components of any UPS.

* The two types of UPS are: 1) on line UPS 2) off line UPS.

* The ON line UPS is also called true UPS. In this type of UPS, there are two power sources and a transfer switch that selects between them. The important feature of this UPS is that it uses the battery as its primary power source and a.c. mains power as its secondary power source.

* The Fig. Q.27.1 shows the block schematic of ON line UPS.

* under normal operations, the UPS is running off the battery while the line power runs the battery charger. The rectifier converts a.c. mains to d.c. and inverter converts d.c to a.c and is given to the load. Thus there are two conversions in this type of UPS hence it is called double conversion ON line UPS. As inverter is always working in normal conditions, it is also called inverter preferred. The normal operation path is shown by dark line in the Fig. Q.27.2.

* If the power goes out, the inverter and load continues to work on the battery. Only the battery charger fails in such

a case. This path is shown in the Fig. Q.27.2 The time required by ups to transfor on battery is called transfer time which is important characteristics of ups. But in ON line

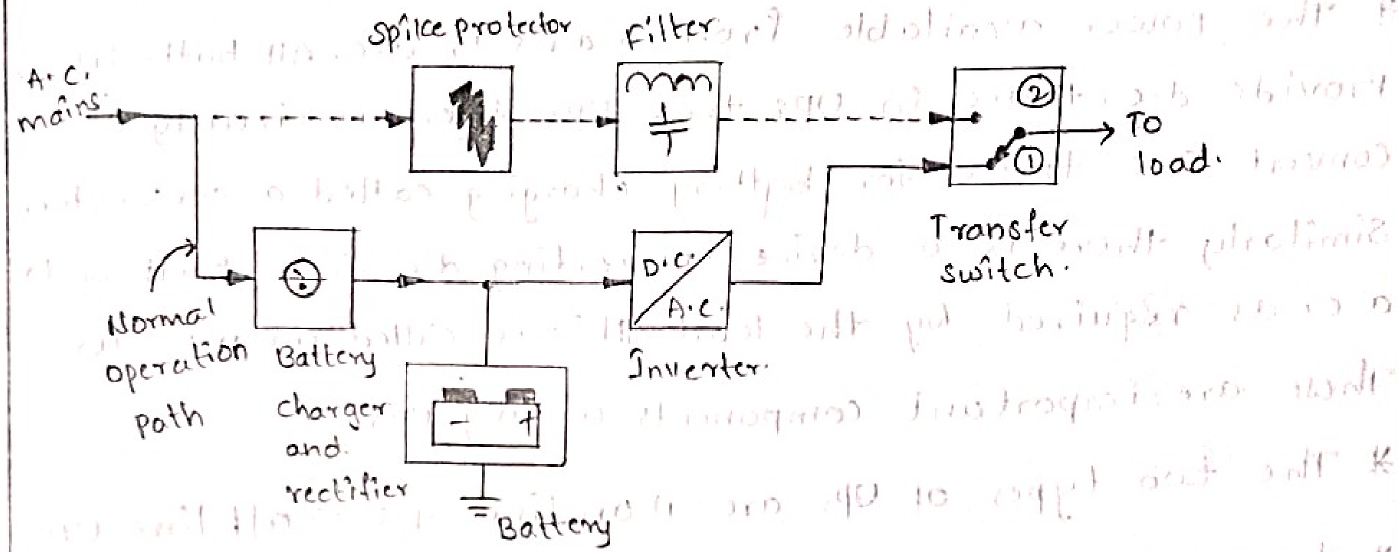


Fig. Q.27.1 Block schematic of ON line ups.

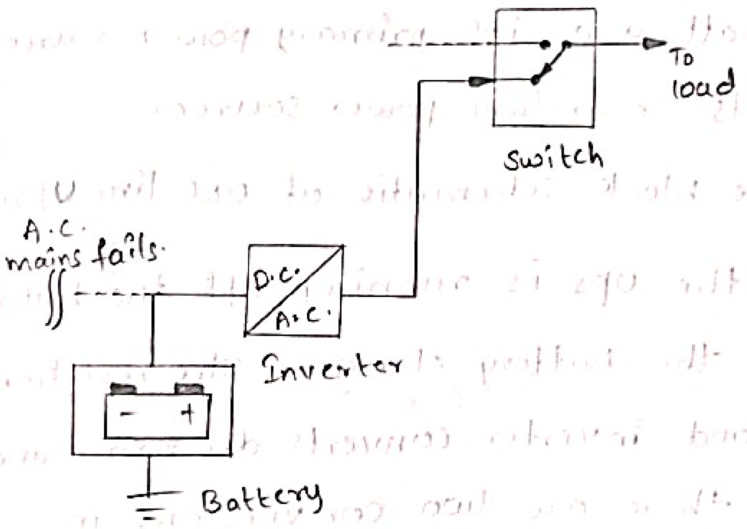


Fig. Q.27.2 Path when a.c. mains fails.

ups, there is no transfer time and UPS instantly switches over to the battery when mains fails. The load keeps running without any kind of interruption. only bettery starts run down as there is no line power to charge it.

* Now let us understand the importance of the secondary power path. It is shown dashed in the Fig. Q.27.2. It comes into the action if the inverter fails. The transfer switch automatically changes from position 1 to position 2, to switch the load on a.c. mains. The spike protector protects the load from position1 to position 2, to switch the load on a.c. mains. The spike protector protects the load from surges in line power and filters them out. In this switch over, transfer time is important which should be as small as possible. But in Practice, main power failures are much more common than the inverter failure.

* The important advantage of this ups is, in normal condition the double conversion process totally isolates the output power from the input power. Any severe changes in main power affect the battery charger and not the output loads.

* The important consideration while designing ON line ups is that converter (rectifier) and inverter are running 24 hours a day and so on. Hence quality of the components must be superior to avoid the inverter failure conditions. The size and cost of ON line ups is more than other types of ups.

* A part from cost, another disadvantage of ON line ups is inefficiency. All the power reaching to the load is convered from a.c to d.c and back to a.c. Thus much of the power is dissipated as heat. This is happening all the time and not just when mains fails.

* The applications of ON line UPS are,
1) Network components such as gateways and bridges.
2) Tele communications systems.
3) voice mail and E-mails systems.
4) Test and diagnostic equipments.
5) Network servers.
6) other critical electronic equipments.

* The ON line UPS are availables from 5000 VA upto hundreds of thousands of VA capacity.

* The OFF line UPS is also called Stand by UPS. In this type of UPS, the primary power source is the mains power and the secondary power sources is the battery.

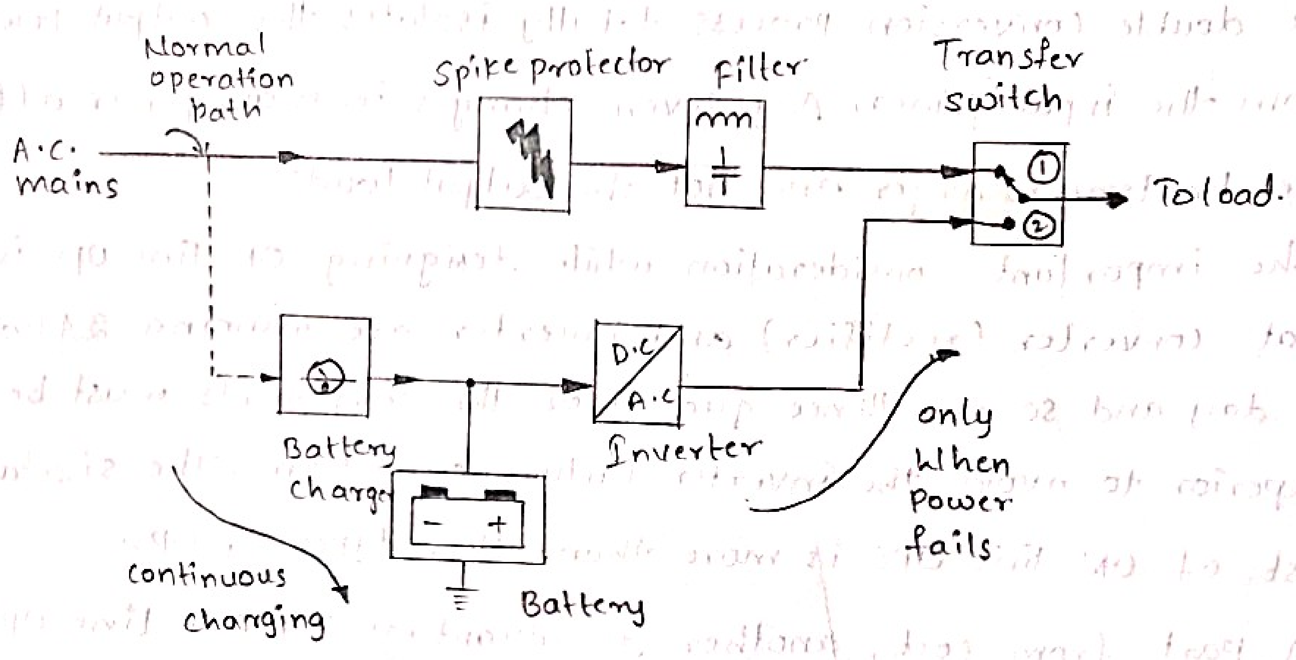


Fig. Q.29.1 Block schematic of OFF line UPS.

* The Fig. Q.29.1 shows the blocks schematics of OFF line UPS.

* In this UPS, the battery and inverter are normally not supplying power to the load. The battery charger is using the line power to charge the battery but battery and inverter are waiting in stand by mode till they are needed. Hence

the UPS is called standby UPS. As main line is primary Power source, it is also called line preferred UPS.

* The spike protector and filter are used to filter the line noise and surges and to protect the loads from severs mains conditions.

* When the a.c. mains powers goes out, the transfer switch detects it and automatically switches from position 1 to 2. Thus battery starts supplying the load through inverter. This is shown in the Fig. Q.29.2 This path is similar to that of ON line.

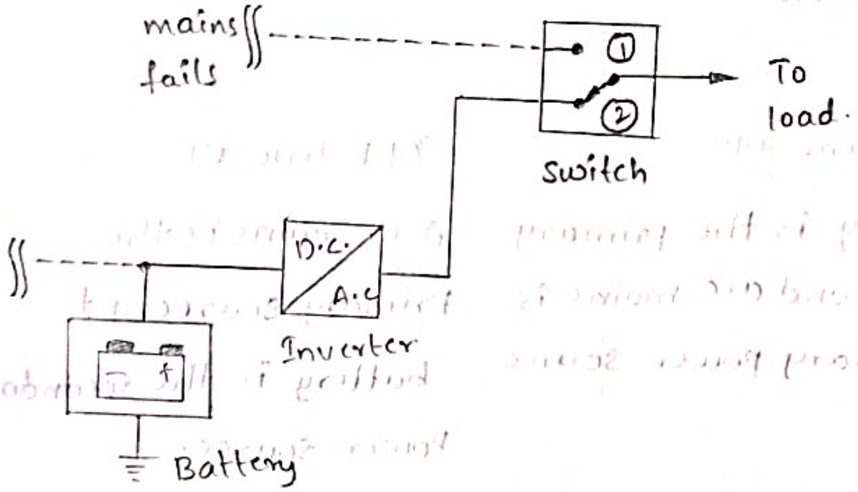


Fig. Q.29.2 path When a.c mains fails.

UPS. The battery now starts run drown as there is no line power to charge it.

* As seen, every OFF line UPS requires a finite time to transfer the switch from position 1 to 2 and such a transfer can not happen instantly. This time is called transfer time or switch time. The units supplied from UPS have some holdup time, means they can hold the power for fractions of seconds when mains fails.

Key point:- The transfer time of UPS must be much less than the holdup time.

* Thus transfer time is an important consideration in case of critical loads. The transfer time is in the range of ms to μs.

* The various applications of OFF line UPS are,

1) Work stations and peripherals.
2) Modems.
3) Office and home PCs.
4) Small desktop hubs.
5) Small business centers.
6) Switches

S.No	Parameter	ON line UPS	OFF line UPS.
1.	Operations	Battery is the primary source and a.c mains is secondary power source	A.c. mains is the primary source and battery is the secondary power source.
2.	Isolation	complete isolation between load and a.c. mains.	No isolation between load and a.c. mains.
3.	Reliability	Highest and transfer time is zero	Lower and transfer time is few m sec.
4.	Economy	High const	Low cost
5.	Size	Large size	Small size
6.	Efficiency	Less due to power dissipation	High efficiency.