

**SYSTEM DISTRIBUTION
LINES MAINTENANCE
COURSE MODULE 2
SLD - M2**

CHAPTER 1

1.0 CLASSIFICATION OF TRANSFORMERS

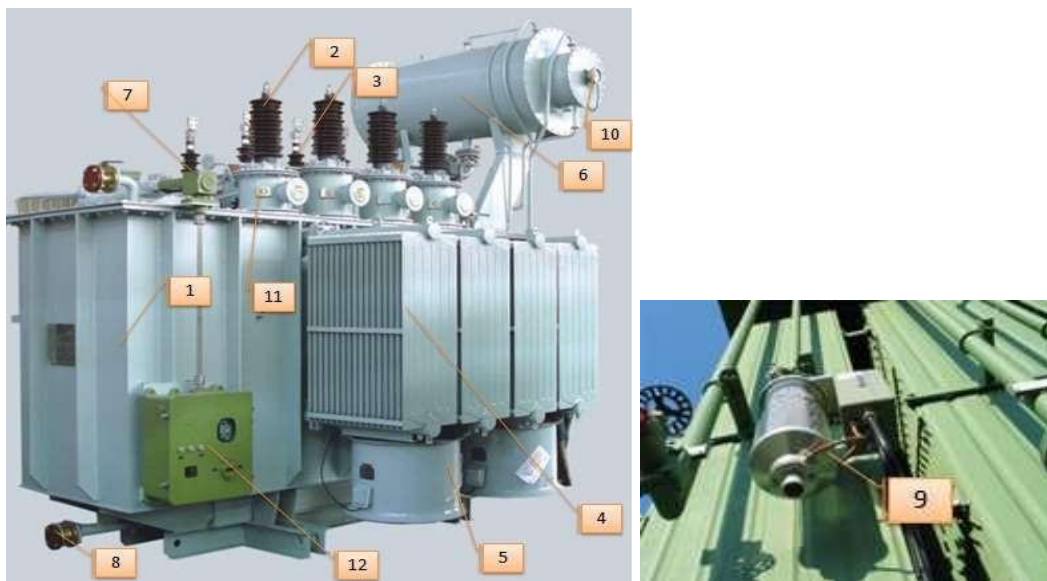
OBJECTIVES: - At the end of the class, participants would be able to:

1. Define a transformer.
2. Describe transformers according to their classes.
3. Clearly explain the main components of a transformer.
4. State the rating of a transformer.

INTRODUCTION: Transformer is a vital link in a power system which has made possible the power generated at low voltages (6600 to 22000 volts) to be stepped up to extra high voltages for transmission over long distances and then transformed to low voltages for utilization at proper load centers. With this tool in hands it has become possible to harness the energy resources at far off places from the load centers and connect the same through long extra high voltage transmission lines working on high efficiencies. At that, it may be said to be the simplest equipment with no motive parts. Nevertheless it has its own problems associated with insulation, dimensions and weights because of demands for ever rising voltages and capacities.

1.1 DEFINITION OF TRANSFORMER: A static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power.

1.2 PARTS OF THE TRANSFORMER:



1. Transformer Tank
2. High Voltage Bushing
3. Low Voltage Bushing
4. Cooling Fins/Radiator
5. Cooling Fans
6. Conservator Tank
7. System Ground Terminal
8. Drain Valve
- 9 .Dehydrating breather
10. Oil Temperature/Pressure gauges
11. Bushing Current Transformers
12. Control Panel
13. Surge Arresters

1.3 Main components of a transformer are:

- Magnetic core
- Primary and secondary windings
- Insulation of windings
- Expansion tank or conservator
- Tank, oil, cooling arrangement, temperature gauge, oil gauge
- Buchholz relay
- Silica gel breather

(i) MAGNETIC CORE:

- Magnetic core consists of an iron core. The core is laminated and made of silicon steel.
- Thickness varies from 0.35mm to 0.5mm.
- Laminations are insulated from each other by coating then with a thin coat of varnish.
- Various types of stampings and laminations employed in the construction of transformers.

There are two types of transformer cores, they are:

(a) Shell type (b) Core type

Shell type – Two windings are carried by central limb. Core is made up of E and I stampings and has three limbs. Have two parallel paths for magnetic flux.

Core type- Has two limbs for two windings and is made up of two L-type stampings. Has only one magnetic path.

(ii) Winding:

- There are two windings in a transformer.
- They are primary and secondary windings.
- Made up of copper.

(iii) Insulation:

- Paper is still used as basic conductor insulation.
- For power transformers enameled copper with paper insulation is also used.

(iv) Insulating oil:

- The oil used in transformer protects the paper from dirt and moisture and removes the heat produced in the core and coils,
- It also acts as insulating medium.

Oil must possess following properties:

- High dielectric strength
- Free from inorganic acid, alkali and corrosive sulphur.
- Low viscosity to provide good heat transfer.
- Good resistance to emulsion so that the oil may throw down any moisture entering the tank instead of holding it.

(v) EXPANSION TANK OR CONSERVATOR:

- A small auxiliary oil tank mounted above the transformer and connected to main tank by a pipe.
- Its function is to keep transformer tank full of oil.



(vi) TEMPERATURE GAUGE:

- Is to indicate hot oil or hottest spot temperature.
- It is self-contained weather proof unit made of alarm contacts.

TEMPERATURE GAUGE



(vii) OIL GAUGE:

- Every transformer is fitted with an oil gauge to indicate the oil level present inside the tank.
- It is provided with an alarm contact which gives an alarm when the oil level drops beyond permissible height due to oil leak or due to any other reason.



(viii) BUCHHOLZ RELAY:

- First warning that fault is present is given by presence of bubbles in oil.

- It gives an alarm in case of minor fault and to disconnect transformer from the supply mains in case of severe faults.



(ix) Breather:

- * It is a chamber which prevents entry of moisture inside the transformer tank.
- * It is filled with drying agent such as calcium chloride or silica gel.
- * This absorbs moisture and allows dry air to enter transformer tank. It is replaced regularly.

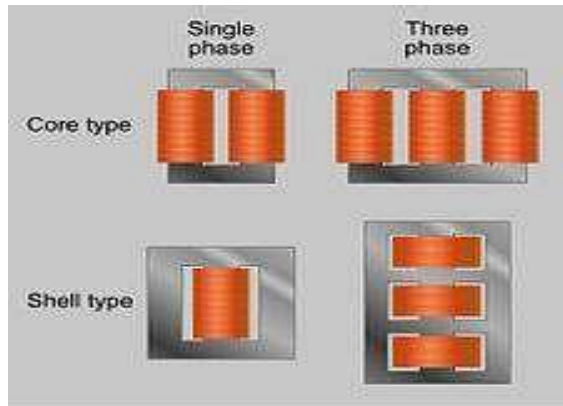


1.4 CLASSIFICATION OF TRANSFORMERS: Transformers are classified on basis of:

- Duty they perform**
 - Power transformer – from transmission and distribution
 - Current transformer- instrument transformers
 - Potential transformer- instrument transformers

ii. Construction:

- a. Core type transformer
- b. Shell type transformer
- c. Berry type transformer



iii Voltage output:

- a. Step down transformer (Higher to Lower)
- b. Step up transformer (Lower to Higher)
- c. Auto transformer (Variable from '0' to rated value)

iv. Application:

- a. Welding transformer
- b. Furnace transformer

v. Cooling:

- a. Duct type transformer
- b. Oil immersed transformer
 - * self-cooled
 - * Forced air cooled
 - * Water cooled
 - * Forced oil cooled

vi. Input supply:

a. Single phase transformer

b. Three phase transformer

Star- star

Delta-Star

Star-delta

Open- Delta

Delta-delta

Scott connection

1.5 RATING OF TRANSFORMER:

- The rating of transformer is expressed by Volt- Ampere (VA)
- Cu loss depends on Current (A)
- Iron loss depends on Voltage (V)
- Total loss depends upon Volt- Ampere (VA)
- It is independent of Load power factor $\cos \Phi$.

SAMPLE QUESTIONS

- a. Define a Transformer
 - b. What is Transformer Rating?
- a. Enumerate Five (5) components of a transformer.
 - b. Explain any Three (3) Of them.
- a. List the **basis** on which transformers are classified.
 - b. Explain any Two (2) of them.

CHAPTER 2

2.0 DISTRIBUTION NETWORK FUSES

OBJECTIVES: At the end of the lesson participants would be able to:

1. Define the functions of Distribution Network Fuses.
2. Explain the different types fuses used in the network.
3. Distinguish between primary and secondary distribution network fuses.
4. Select and use the right fuse for a given voltage level.

INTRODUCTION: Fuses are among the best known of electrical devices because most of us have quite large numbers of them in our homes and, unless we are extremely fortunate, we are made aware of their presence from time to time when one must be replaced because it has blown or, to use the official term, operated. They are basically simple and relatively cheap devices, although their behavior is somewhat more complex than may be generally realized.

2.1 FUSES AND APPLICATIONS FUSE: is the simplest current interrupting device for protection against excessive currents, usually in form of a “*weak-link*” which melts, cuts-off, ruptures, breaks, blows-off, or burns-off after “*operation*”.

2.2 Types of Fuses:

Rewirable Fuses: Semi-enclosed: Domestic applications;

Cartridge Fuses: Totally-enclosed: Industrial applications;

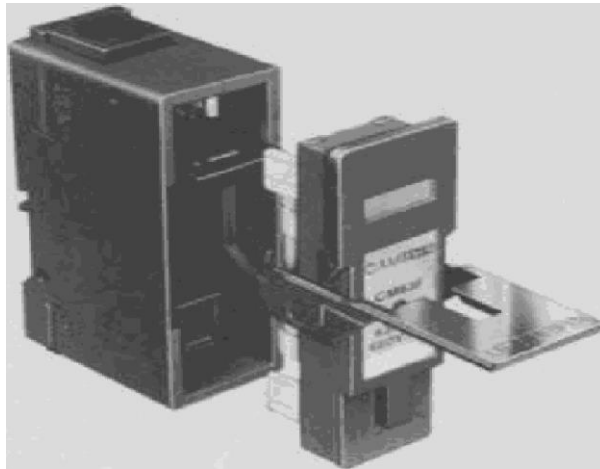
Drop-out Fuses: Power Utility applications (Over-headlines);

Expulsion Fuses: Restricted applications: Chemical Environment;

High Rupturing Capacity (HRC) Fuses: widest safest applications;

Striker Fuses: Industrial/Utility applications :(RMUs).

Enclosed fuses: As the name implies enclosed fuses are designed to keep the arc products within the enclosure during specified operation. Enclosed fuse links are often of cylindrical form and are referred to as cartridge fuses. Cartridge fuses, which form a very important and certainly the most numerous group, may be designed for HV, LV or miniature applications. For LV applications, the Fuse link, which is replaceable, is often fitted into a fuse holder that consists of a fuse carrier and a fuse base, a particular example being illustrated in the figure below.



plug fuse



cartridge fuse



knife-blade cartridge fuse



Plug fuse: Having a maximum capacity of 30 amperes, it screws in like a light bulb and protects a circuit of 120 volts.

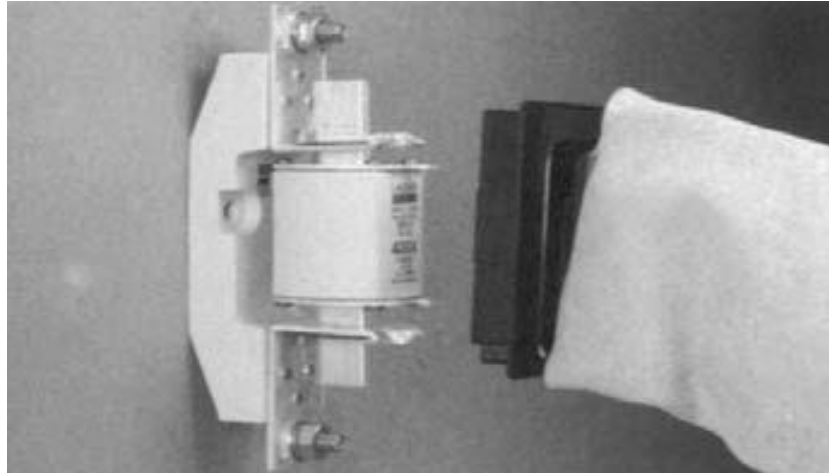
Cartridge fuse: Having a maximum capacity of 60 amperes, it protects a circuit of 240 volts.

Knife-blade cartridge fuse: Having a capacity of 60 to 600 amperes, it protects the main electric circuit.

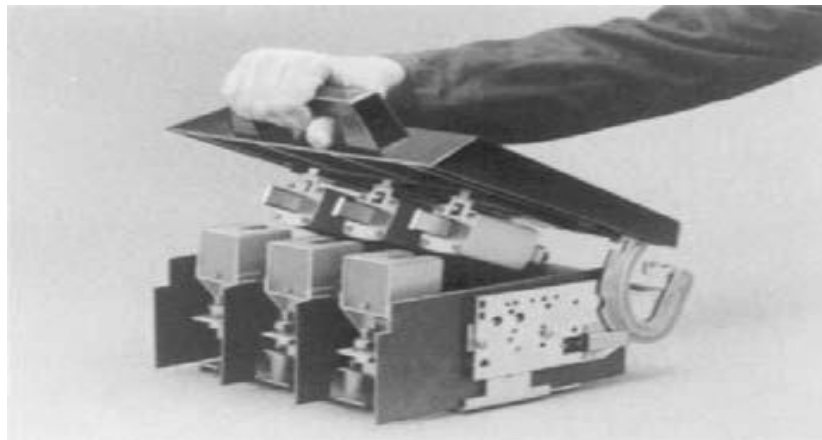
Blade-contact-type fuses: These are generally referred to as NH fuses, NH being an abbreviation of Niederspannungs Hochleistungs which is German for low-voltage high-breaking-capacity. They are for use by authorized persons, mainly for industrial applications, and are used in factory distribution systems and also in the distribution cabinets of the ESI in power-distribution networks.

NH fuse links are generally available for applications up to and including 1250A, for AC circuits operating at levels up to 500V and DC circuits of voltages up to 440V. Designs with restricted current ratings are available for 690V AC systems.





NH feeder pillar showing use of handle



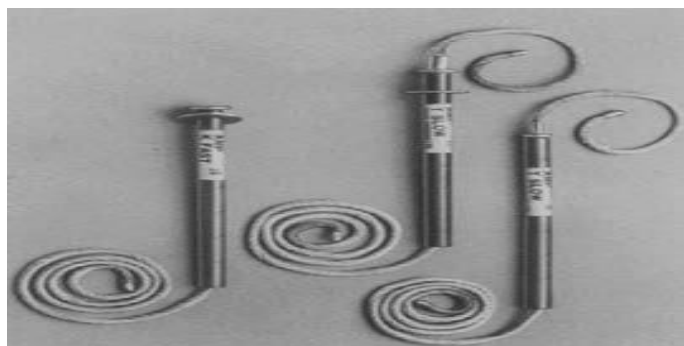
NH fuse switch

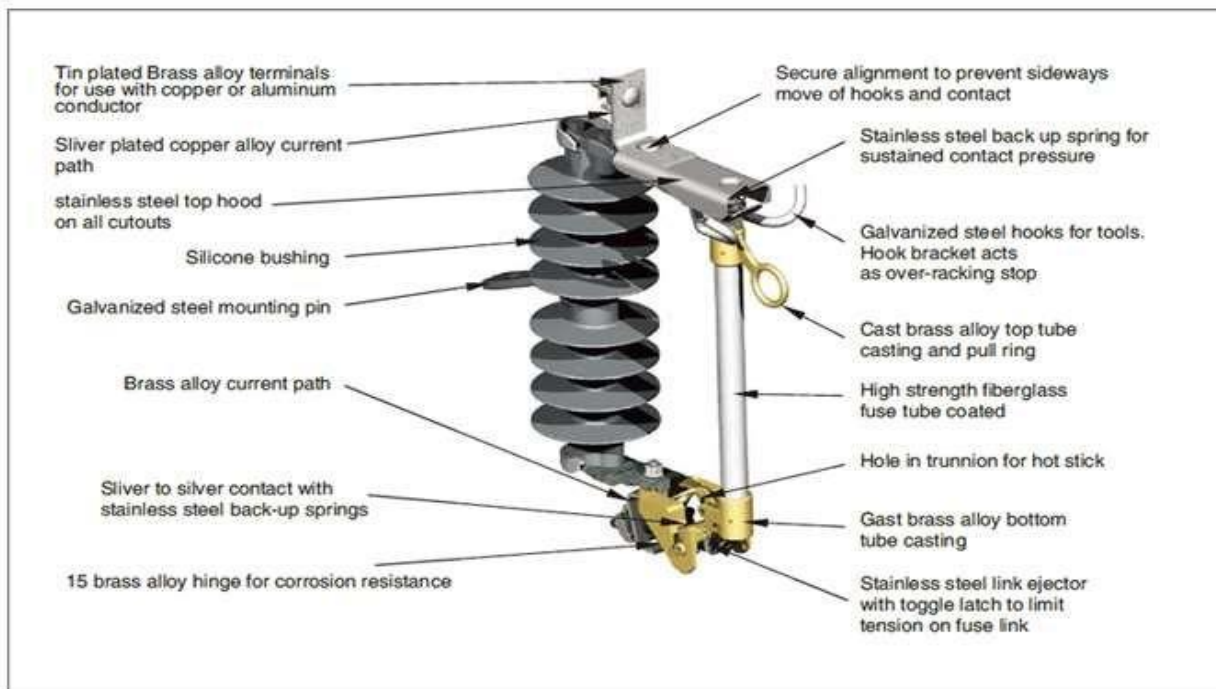
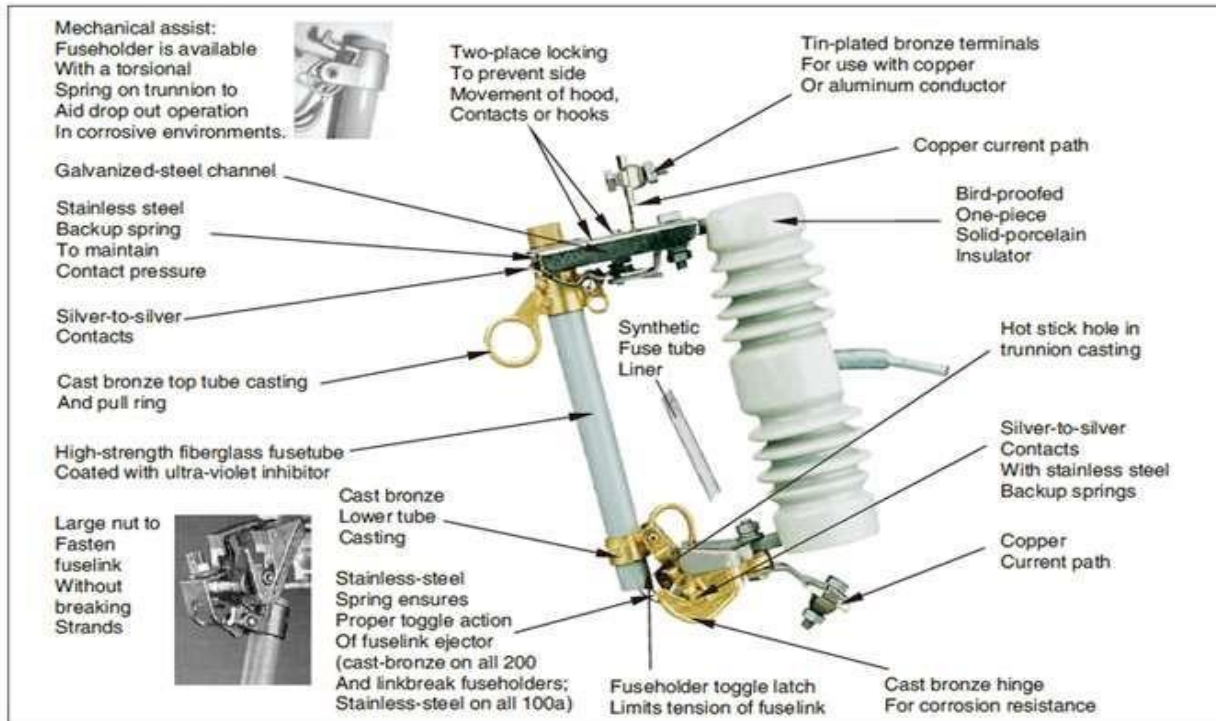
For electricity supply industry applications, NH fuse links are used in fuse distribution cabinets, including packaged substations and cable distribution cabinets. This has led to the introduction of integral three-phase shrouded units which are mounted directly onto the distribution bus bars. This system has become standardized in *IEC 60269-2-1* and is referred to as 'fuse rails'. A shrouded three-phase unit is shown in the figure below.



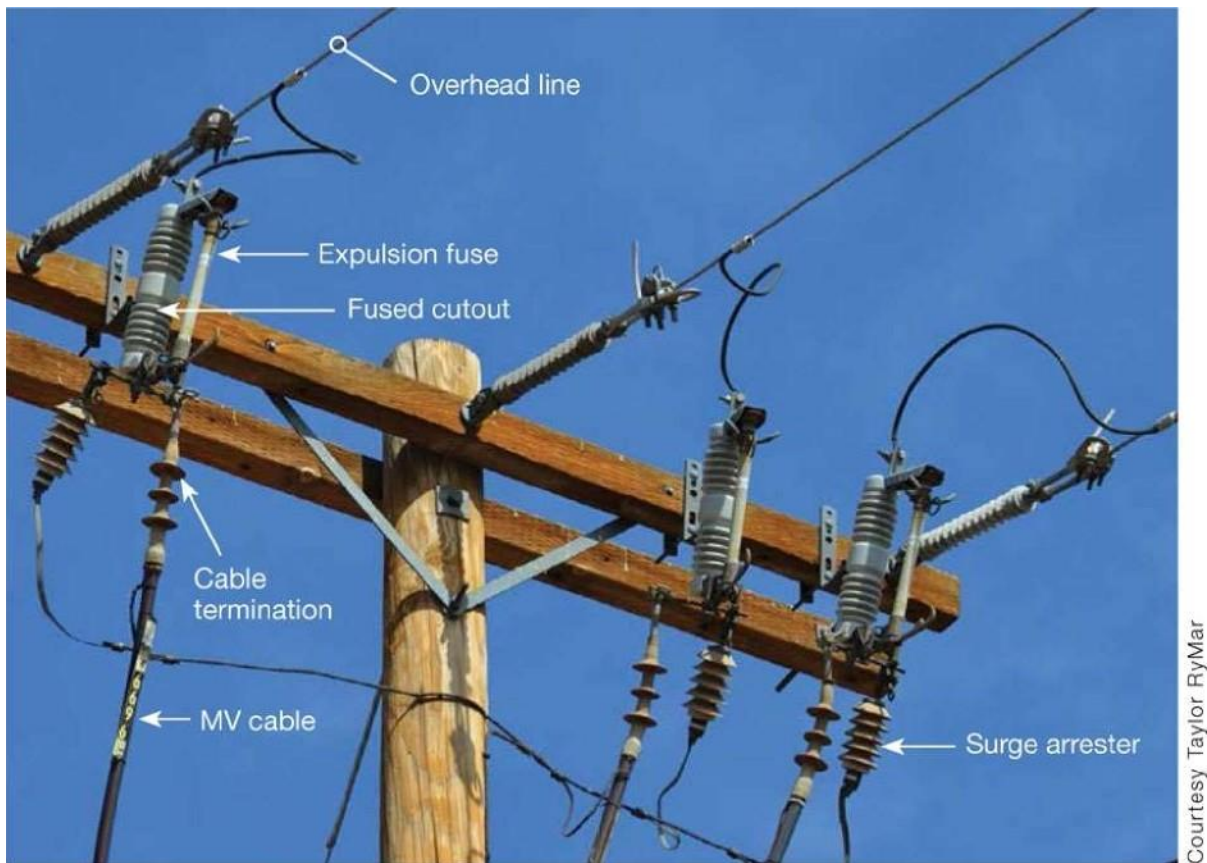
Shrouded three-phase NH 'fuse rail' unit.

2.3 Expulsion fuses: These fuse links contain a short element of tin or tinned-copper wire in series with a flexible braid. These items are mounted in a fuse carrier incorporating a tube of organic material, usually closed at the top with a frangible diaphragm, and containing a liner of gas-evolving material such as fibre. The fuse element carries a closely fitting sleeve of gas-generating fabric. The flexible braid is brought out of the open lower end of the tube and held in tension, by a spring attached to the lower end of the fuse base.





Expulsions fuse assembly.



Courtesy Taylor RyMar

Figure 2 The major components used at the transition between underground and overhead MV wiring methods are identified here.





The Lawson JPU200 Fuse Link

2.4 The Lawson JPU200: is a 415 Volt a.c. 200 Amp Electricity Supply Distribution Fuse-link. 'J' type fuse-links are for use in electricity supply networks such as distribution boards, feeder pillars, link boxes, pole mounted cut-outs and heavy duty service intakes.

SAMPLE QUESTIONS

Q1. a. What is an electrical fuse?

b. What are the advantages of using an electrical fuse?

Q2. a. Why electrical fuse units are used in electrical system?

b. List the types of fuses used in distribution network.

Q3. a. What is the function of High Rupturing Capacity (HRC) fuses?

b. State the range of their applications in the network.

Q4. a. What is cartridge type fuse?

b. Enumerate Five (5) disadvantages of using fuse in the network.

CHAPTER 3

3.0 Nature of Electricity

Objectives: At the end of the class participants would be able to:

1. Explain the nature of electricity.
2. Describe the materials that interact with electric charges.
3. Explain Ohm's Law.
4. Describe the conditions necessary for current to flow.

Introduction: Electricity is the most common form of energy. Electricity is used for various applications; such as lighting, transportation, cooking, communication, production of various goods in factories and much more. None of us exactly know that what electricity is. The **concept of electricity** and theories behind it can be developed by observing its different behaviors. For observing **nature of electricity**, it is necessary to study the structure of matters.

3.1 ATOM: Every substance in this universe is made up of extremely small particles known as molecules. The molecule is the smallest particle of a substance into which all the identities of that substance are present. The molecules are made up of further smaller particles known as atoms. An atom is the smallest particle of an element that can exist. There are two types of substances. The substance, that's molecules are made of similar atoms is known as an element. The matter, whose molecules consist dissimilar atoms, is called a compound. The concept of electricity can be achieved from the atomic structures of substances.

3.2 Structure of Atom: An atom consists of one central nucleus. The nucleus is made up of positive protons and charge less neutrons. This nucleus is surrounded by numbers of orbital electrons. Each electron has a negative charge of -1.602×10^{-19} Coulomb and each proton in the nucleus has a positive charge of $+1.602 \times 10^{-19}$ Coulomb. Because of the opposite charge there is some attraction force between the nucleus and orbiting electrons. Electrons have relatively negligible mass compared to the mass of the nucleus. The mass of each proton and neutrons is 1840 times the mass of an electron. As the modulus value of each electron and each proton are same, the number of electrons is equal to the number protons in an electrically neutral atom. An atom becomes positively charged ion when it loses electrons and similarly an atom becomes negative ion when it gains electrons.

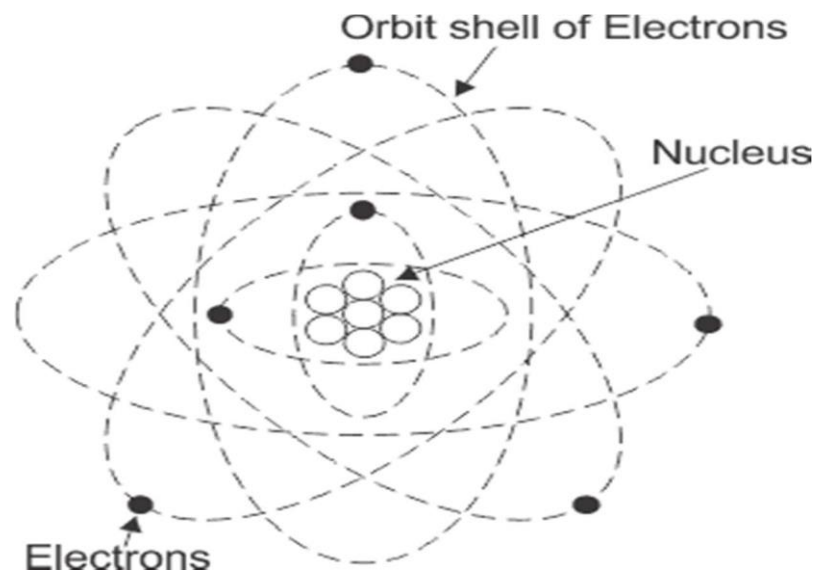
3.3 Where do charges come from?

Matter is made up of atoms.

Proton (positive charge) +

Neutron (neutral)

Electron (negative charge) –

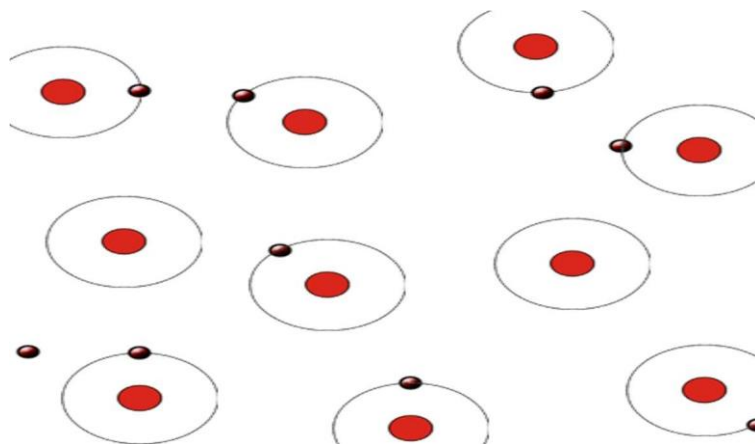


Electrons:

- Are located on the outer edges of atoms...they can be moved.
- A concentration of electrons in an atom creates a net negative charge.
- If electrons are stripped away, the atom becomes positively charged.

Atoms may have loosely bonded electrons in their outermost orbits. These electrons require a very small amount of energy to detach themselves from their parent atoms. These electrons are referred to as free electrons which move randomly inside the substance and are transferred from one atom to another. Any piece of substance which as a whole contains an unequal number of electrons and protons is referred to as electrically charged. When there is more number of electrons compared to its protons, the substance is said to be negatively charged and when there is more number of protons compared to electrons, the substance is said to be positively charged.

The basic **nature of electricity** is, whenever a negatively charged body is connected to a positively charged body by means of a conductor, the excess electrons of the negative body start flowing towards the positive body to compensate the lack of electrons in that positive body.

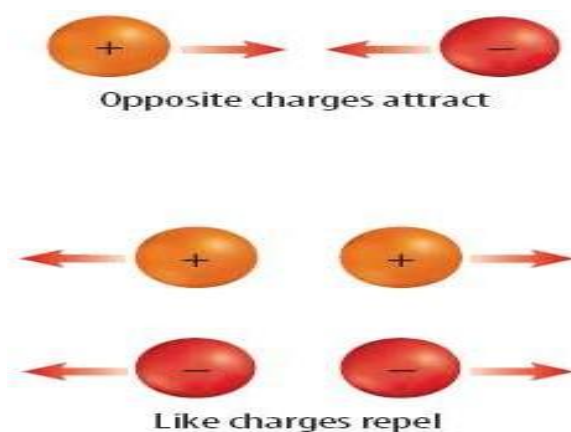


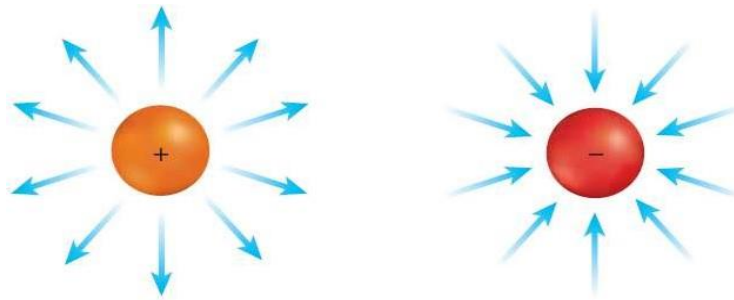
There are some materials which have plenty of free electrons at normal room temperature. Very well-known examples of this type of materials are, silver, copper, aluminium, zinc etc. The movement of these free electrons can easily be directed to a particular direction if the electrical potential difference is applied across the piece of these materials.

Because of plenty of free electrons these materials have good electrical conductivity. These materials are referred as good conductor. The drift of electrons in a conductor in one direction is known as the current. Actually electrons flow from lower potential (-Ve) to higher potential (+Ve) but the general conventional direction of current has been considered as the highest potential point to lower potential point, so the conventional direction of current has been just opposite of the direction of flow of electrons.

In non-metallic materials, such as glass, mica, slate, porcelain, the outermost orbit is completed and there is almost no chance of losing electrons from its outermost shell. Hence there is hardly any free electron present in this type of material. Hence, these materials cannot conduct electricity in other words electrical conductivity of these materials is very poor. Such material are known as non – conductor or electrical insulator.

Charges interact with each other:





Surrounding every charge is an electric field. Through the electric field, a charge is able to push or pull on another charge.

3.4 What Is Static Electricity?

- A stationary electrical charge that is built up on the surface of a material
- The charge builds up but does not flow.
- Static electricity is potential energy. It does not move. It is stored.

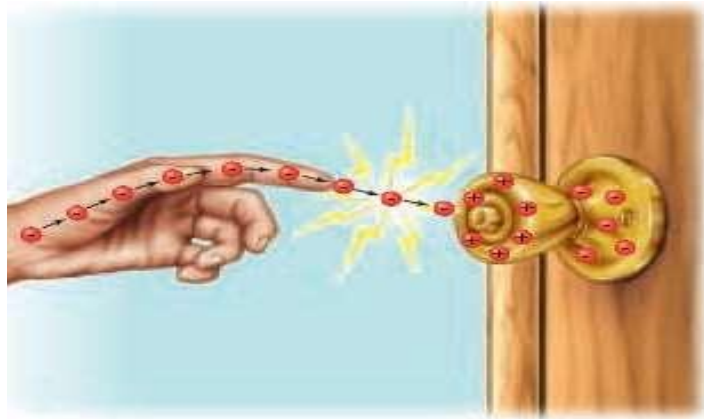


Static Discharge: Occurs when there is a loss of static electricity due to three possible things:

- I Friction - rubbing
- li Conduction – direct contact
- lii Induction – through an electrical field (not direct contact)

What causes you to be shocked when you rub your feet across carpet?

As you walk across a carpeted floor, your body builds up a static charge. When you reach for a metal doorknob, the charges flow between your hand and the doorknob and you feel a shock.



An electrical discharge is the passing of an electric current through the air from a negatively charged object to a positively charged object. This is what causes lightning.



The **nature of electricity** is to flow through a conductor while an electrical potential difference applied across it, but not to flow through insulator even high electrical potential difference applied across them.

3.5 What is Resistance?

- The opposition to the flow of an electric current, producing heat.
- The greater the resistance, the less current gets through.
- Good conductors have low resistance.

Conditions that influence Resistance:

i Material of wire – aluminum and copper have low resistance

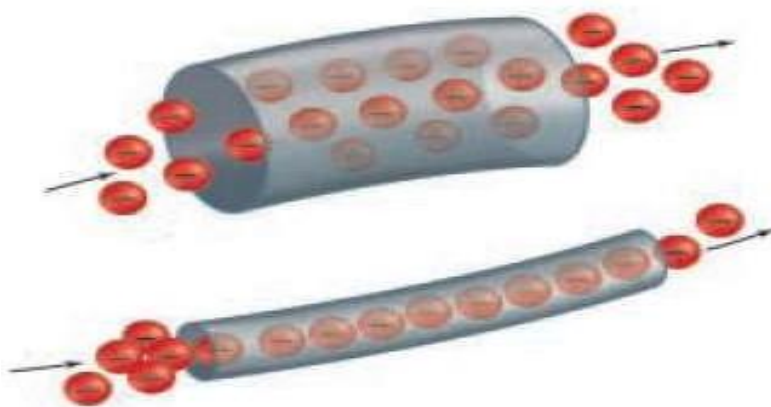
ii Thickness – the thicker the wire the lower the resistance

iii Length – shorter wire has lower resistance

iv Temperature – lower temperature has lower resistance

The unit for measuring resistance is the **Ohm (Ω)**.

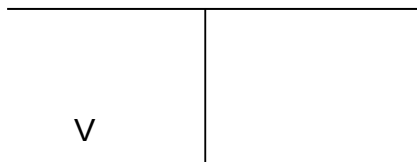
The resistance of a short, thick piece of wire is less than the resistance of a long, thin piece of wire.



3.6 Voltage:

- i. The measure of energy given to the charge flowing in a circuit.
- ii. The greater the voltage, the greater the force or “pressure” that drives the charge through the circuit.

Ohm’s Law: Current is directly proportional to voltage and inversely proportional to resistance.



Ohm’s Law Example 1:

$$\text{current} = \frac{\text{voltage difference}}{\text{resistance}}$$

$$I(\text{A}) = \frac{V(\text{V})}{R(\Omega)}$$

$$V = IR$$

A toy car with a resistance of $2\ \Omega$ is connected to a $3\ \text{V}$ battery. How much current flows through the car?

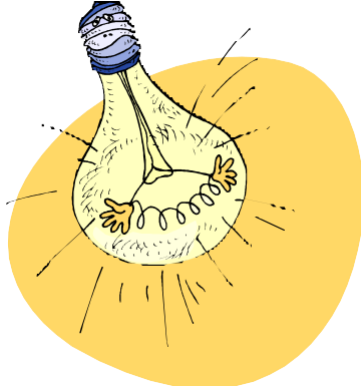
$$I(\text{A}) = \frac{V(\text{V})}{R(\Omega)}$$

$$I = \frac{3\ \text{V}}{2\ \Omega}$$

$$I = 1.5\ \text{Amps}$$

Example 2:

A light bulb operates on a 110 volt circuit. The bulb draws a current of .91 amps. What is the resistance of the light bulb?



$$V=IR$$

$$R=V/I$$

$$R=110V/.91A$$

$$120.8 \text{ Ohms, } \Omega$$

SAMPLE QUESTIONS

1.
 - a. What is Electricity?
 - b. What is Static Electricity?
2.
 - a. What is Static Discharge?
 - b. List the Three (3) possible conditions necessary for static discharge to occur.
3.
 - a. Explain the relationship between Voltage, Current and Resistance with respect to Ohm's Law.
4.
 - a. Enumerate and explain the conditions which influence the Resistance of a conducting material.
 - b. Explain what the electrical terms voltage, current and resistance mean, using your own words.

CHAPTER 4

4.0 MINIATURE CIRCUIT BREAKER (M C B)

OBJECTIVES: At the end of the class participants would be able to:

1. Describe Miniature Circuit Breaker (MCB).
2. State the functions of M C B.
3. Explain types of M C B and their minimum and maximum trip currents.
4. Select proper M C B for different loads.
5. Describe the working and operation of M C B.

Introduction: All fuses need to be replaced when they have operated. Unlike a fuse, an MCB operates as automatic switch that opens in the event of excessive current flowing through the circuit and once the circuit returns to normal, it can be reclosed without any manual replacement. MCBs are used primarily as an alternative to the fuse switch in most of the circuits. A wide variety of MCBs have been in use nowadays with breaking capacity of 10KA to 16 KA, in all areas of domestic, commercial and industrial applications as a reliable means of protection.

4.1 What is Miniature Circuit Breaker (MCB)?

An MCB is a mechanical switching device which is capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and automatically breaking currents under specified abnormal circuit conditions such as those of short circuit. It can be manually switched ON and OFF as similar to normal switch if necessary.

MCBs are of time delay tripping devices, to which the magnitude of overcurrent controls the operating time. This means, they get operated whenever overload exist long enough to create a danger to the circuit being protected. Therefore, MCBs doesn't respond to transient loads such as switches surges and motor starting currents. Generally, they are designed to operate at less than 2.5 milliseconds during short circuit faults and 2 seconds to 2 minutes in case of overloads (depending on the level of current).

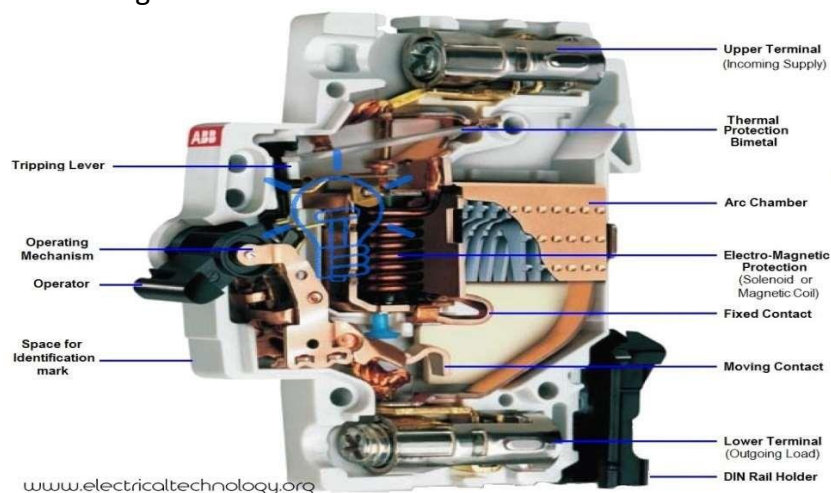
A typical external appearance of an MCB is shown in figure below. MCBs are manufactured in different pole versions such as single, double, triple and four pole structures with different fault current levels. Mostly, MCBs are linked to give two and three-pole versions such that a fault in one line will break the complete circuit and hence complete circuit isolation are provided. This feature will be helpful in case of single phasing in three phase motor protection.

They are rated at 220V for DC supply and 240/415 for AC supply (single and three-phase) with different short circuit current capacity. Typically, single phase devices have load current range of up to 100 A. Some MCBs have facility to adjust its tripping current capacity while some devices are fixed for some load current and short circuit rating.

MCBs are used to perform many functions such as local control switches, isolating switches against faults and overload protection devices for installations or specific equipment or appliances.

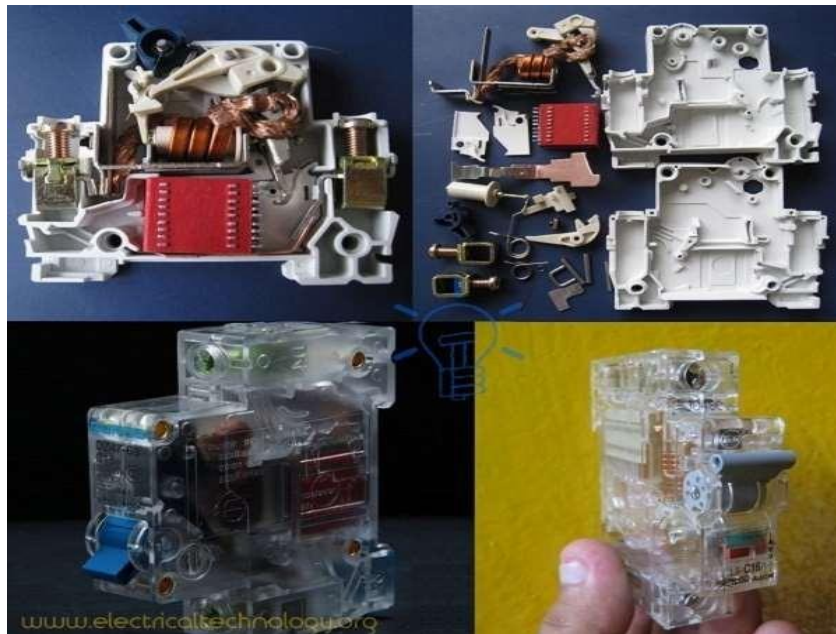


4.2 Construction of MCB: An MCB embodies complete enclosure in a moulded insulating material. This provides mechanically strong and insulated housing. The switching system consists of a fixed and a moving contact to which incoming and outgoing wires are connected. The metal or current carrying parts are made up of electrolytic copper or silver alloy depending on the rating of the circuit breaker.



As the contacts are separated in the event of an overload or short circuit situation, an electric arc is formed. All modern MCBs are designed to handle arc interruption process where arc energy extraction and its cooling are provided by metallic arc splitter plates. These plates are held in a proper position by an insulating material. Also, arc runner is provided to force the arc that is produced between the main contacts. The operating mechanism consists of both magnetic tripping and thermal tripping arrangements.

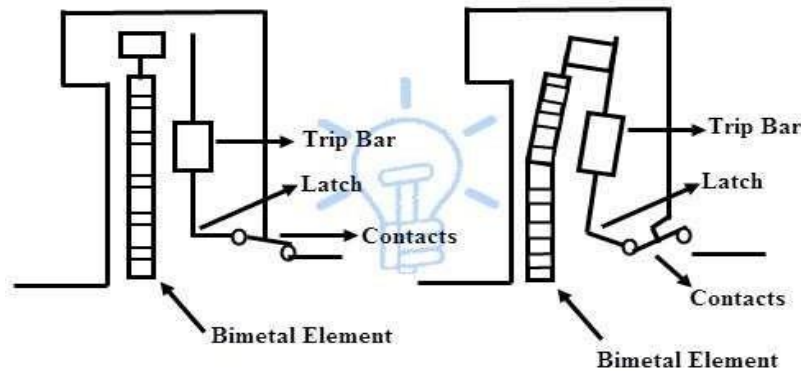
The magnetic tripping arrangement essentially consists of a composite magnetic system that has a spring loaded dashpot with a magnetic slug in a silicon fluid, and a normal magnetic trip. A current carrying coil in the trip arrangement moves the slug against spring towards fixed pole piece. So the magnetic pull is developed on the trip lever when there is a sufficient magnetic field produced by the coil. In case of short circuits or heavy overloads, strong magnetic field produced by the coils (Solenoid) is sufficient to attract the armature of trip lever irrespective of the position of slug in the dashpot.



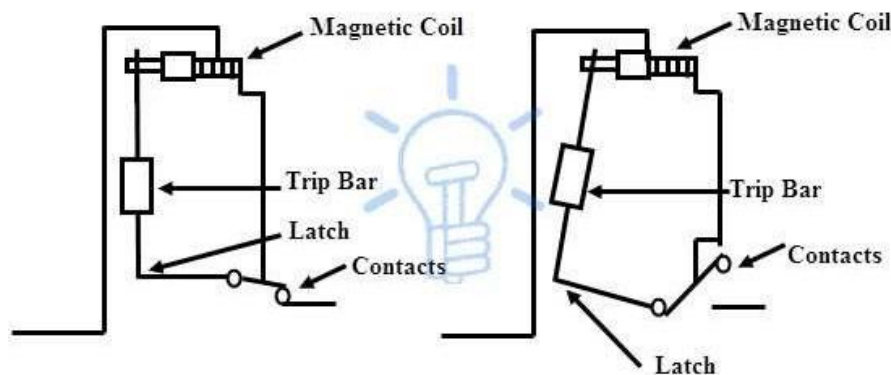
The thermal tripping arrangement consists of a bimetallic strip around which a heater coil is wound to create heat depending on the flow of current. The heater design can be either direct where current is passed through bimetal strip which effect part of electric circuit or indirect where a coil of current carrying conductor is wound around the bimetallic strip. The deflection of bimetallic strip activates the tripping mechanism in case of certain overload conditions.

The bimetal strips are made up of two different metals, usually brass and steel. These metals are riveted and welded along their length. These are so designed such that they will not heat the strip to the tripping point for normal currents, but if the current is increased beyond rated value, strip is warmed, bent and trips the latch. Bimetallic strips are chosen to provide particular time delays under certain overloads.

4.3 Working & Operation of MCB: Under normal working conditions, MCB operates as a switch (manual one) to make the circuit **ON** or **OFF**. Under overload or short circuit condition, it automatically operates or trips so that current interruption takes place in the load circuit. The visual indication of this trip can be observed by automatic movement of the operating knob to OFF position. This automatic operation MCB can be obtained in two ways as we have seen in MCB construction; those are magnetic tripping and thermal tripping.



Under overload condition, the current through the bimetal causes to raise the temperature of it. The heat generated within the bimetal itself enough to cause deflection due to thermal expansion of metals. This deflection further releases the trip latch and hence contacts get separated. In some MCBs, magnetic field generated by the coil causes develop pull on bimetal such that it deflection activates the tripping mechanism.



Under short circuit or heavy overload conditions, magnetic tripping arrangement comes into the picture. Under normal working condition, the slug is held in a position by light spring because magnetic field generated by the coil is not sufficient to attract the latch. When a fault current flows, the magnetic field generated by the coil is sufficient to overcome the spring force holding slug in position. And hence slug moves and then actuate the tripping mechanism.

A combination of both magnetic and thermal tripping mechanisms is implemented in most of MCBs. In both magnetic and thermal tripping operations, an arc is formed when the contacts start separating. This arc is then forced into arc splitter plates via arc runner. These arc splitter

plates are also called arc chutes where arc is formed into a series of arcs and at the same time energy extracted and cools it. Hence this arrangement achieves the arc extinction.

4.4 Types of Miniature Circuit Breakers (MCB's)

MCBs are classified into three major types according to their instantaneous tripping currents. They are

1. Type B MCB
2. Type C MCB
3. Type D MCB

Type B MCB: This type of MCB will trip instantly at a rate of three to five times its rated current. These are normally used for resistive or small inductive loads where switching surges are very small. Therefore, these are suitable for residential or light commercial installations.



Type C MCB: This type of MCB will trip instantly at a rate of five to ten times its rated current. These are normally used for high inductive loads where switching surges are high such as small motors and florescent lighting. In such cases, type C MCBs are preferred to handle higher value of short circuit currents. Therefore, these are suitable for highly inductive commercial and industrial installations.



Type D MCB: This type of MCB will trip instantly at a rate of ten to twenty five times its rated current. These are normally used for very high inductive loads where high inrush current are very frequent. These are suitable for specific industrial and commercial applications. The common examples of such applications include x-ray machines, UPS systems, industrial welding equipment, large winding motors, etc.



The above three types of MCBs provide protection within one tenth of a sec. The minimum and maximum trip currents of these MCBs are given in a tabular form below, where I_r is the rated current of the MCB. MCBs can also be classified based on number of poles such as single pole, double pole, triple pole and four pole MCBs

MCB Type	Minimum Trip Current	Maximum Trip Current
Type B	3 I_r	5 I_r
Type C	5 I_r	10 I_r
Type D	10 I_r	20 I_r

4.5 How to Select Proper MCB for different loads: Choosing a particular MCB for a specific application is a careful task to ensure reliable protection against overloads and short circuits. If it is not selected according to the circuit requirements, there will be chances to lead frequent unwanted tripping. If it is undersized (MCB rating less than the nominal load current), MCB causes frequent tripping and causes to interrupt the current to the load it is being connected, because the MCB nominal current less than nominal current value of the load. Similarly, if it is oversized (MCB rating more than the nominal load current), the load to it is connected will not be protected efficiently. In such case, the MCB will not trip even though load is drawing overcurrent.

The following are the three factors to be considered for selecting an MCB for specific application.

i Nominal rating of the circuit breaker: This is the rated ampere current rating of MCB. This value must be lower than the current carrying capacity of wiring system and higher than or equal to the maximum full load current in the wiring system. Generally, this rating should be such that it can handle 125 percent of continuous load plus rating of noncontinuous load. Typically this can be expressed as

Maximum full load current in the system $\leq$ Current rating of MCB $\leq$ Cable rating.

ii KA rating or breaking capacity: This rating refers to the capability of MCB that can trip or interrupt the circuit under short circuit conditions. It is expressed in Kilo Amps (KA). This rating must not be less than the prospective short-circuit current. The prospective short-circuit current is the maximum current that exist in the circuit during short-circuit conditions. In residential installations 6KA MCB is sufficient while 10 KA or above rating MCB is needed for commercial and light industrial applications.

iii Type of MCB: The type of MCB needed for a specific application decided by operating characteristics such that various current ratings are required to operate the loads instantaneously. We have already mentioned various types of MCBs for different applications above.

SAMPLE QUESTIONS:

Q1. a. What is Miniature Circuit Breaker?

b. Distinguish between Fuse and M C B.

Q2. Explain the Working and Operation of M C B.

Q3. List and explain the Three (3) types of MCBs according to their instantaneous tripping currents.

Q4. Enumerate and explain the Three (3) factors to be considered when selecting MCB for specific application.

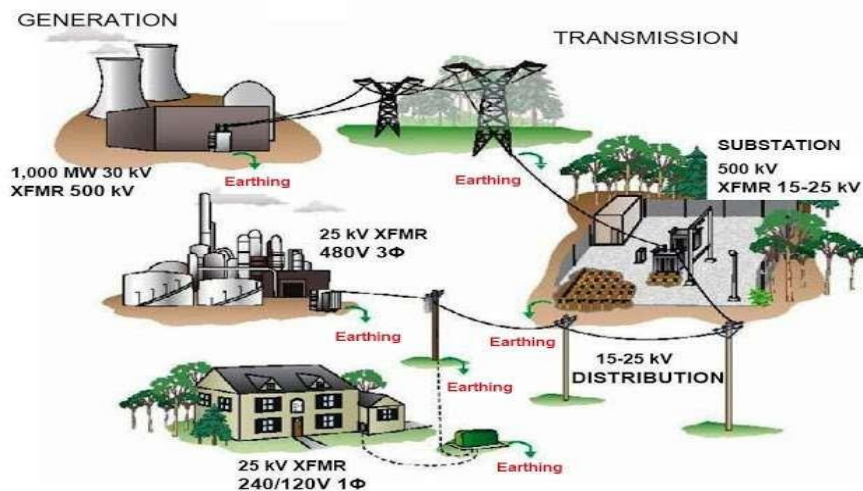
CHAPTER 5

5.0 EARTHING SYSTEM

OBJECTIVES: At the end of the lesson participants would be able to:

1. Define earthing system with respect electrical equipment.
2. State the purpose of earthing system in the Utility Network.
3. Explain the types of earthing system used in electrical network.
4. Describe the various methods of earthing applied in electrical equipment.

INTRODUCTION: Every building, equipment, power plants, substations and /or facilities included in Electrical Utility System that use electricity require Grounding, either directly or through a grounding system.



5.1 DEFINITION: Earthing means connecting any non-current carrying conductor part of an electrical system with general mass of earth in such a manner that there is an immediate discharge of electrical energy to the earth in the event of electrical potential developed at that part of the system. For example, metallic frame work of electrical appliances, metallic covering of electrical cables, the earth terminal of three pin socket outlets, stay wires and also neutral point of single phase and three phase supply systems must be properly earthed.

A protective earth (PE): connection ensures that all exposed conductive surfaces are at the same electrical potential as the surface of the Earth, to avoid the risk of electrical shock if a person touches a device in which an insulation fault has occurred. It ensures that in the case of an insulation fault (a "short circuit"), a very high current flows, which will trigger an overcurrent protection device (f use, circuit breaker) that disconnects the power supply.

A functional earth: connection serves a purpose other than providing protection against electrical shock. In contrast to a protective earth connection, a functional earth connection may carry a current during the normal operation of a device. Functional earth connections may be required by devices such as surge suppression and electromagnetic interference filters, some types of antennas and various measurement instruments. Generally the protective earth is also used as a functional earth, though this requires care in some situations.

Earthing Main Divisions: The earthing is broadly divided as:

- i. **System earthing:** Connection between part of plant in an operating system like LV neutral of a Power Transformer winding and earth.
- ii. **Equipment earthing (Safety grounding):** Connecting frames of equipment (like motor body, Transformer tank, Switch gear box, operating rods of Air break switches, etc.) to earth.

5.2 FUNCTIONS OF EARTHING:

- To ensure safety of life and property from hazards of electric shock and electric fires.
- To ensure that system voltages on healthy lines remain within reasonable limits under fault Conditions thereby preventing insulation breakdowns.
- To provide a low impedance path (safe path) to dissipate lightning and short circuit currents.
- To minimize arcing burn downs as in an earthed system arcing fault would produce a current in ground path thereby providing an easy means of detecting and tripping against phase to earth arcing fault breakdowns.
- To provide stable platform for operation of sensitive electronic equipment i.e. To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.
- To provide an alternative path for induced current and minimize the electrical noise in cables.
- To provide protection against static electricity from friction.

5.3 IEC TERMINOLOGY: International standard IEC 60364 distinguishes three families of earthing arrangements, using the two-letter codes **TN**, **TT**, and **IT**. The first letter indicates the connection between earth and the power-supply equipment (generator or transformer):

T Direct connection of a point with earth (Latin: terra);

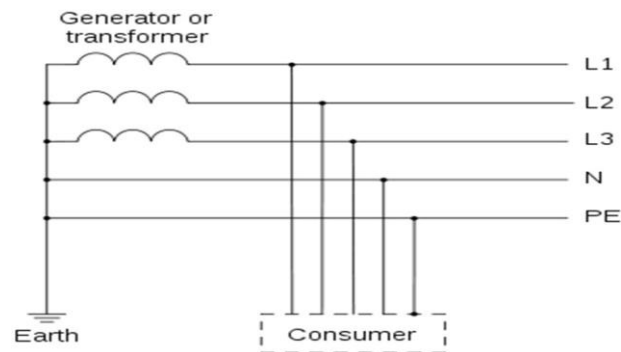
I No point is connected with earth (isolation), except perhaps via high impedance.

The second letter indicates the connection between earth and the electrical device being supplied:

T Direct connection of a point with earth

N Direct connection to neutral at the origin of installation, which is connected to the earth.

5.4 TN NETWORKS: In a **TN** earthing system, one of the points in the generator or transformer is connected with earth, usually the star point in a three-phase system. The body of the electrical device is connected with earth via this earth connection at the transformer.



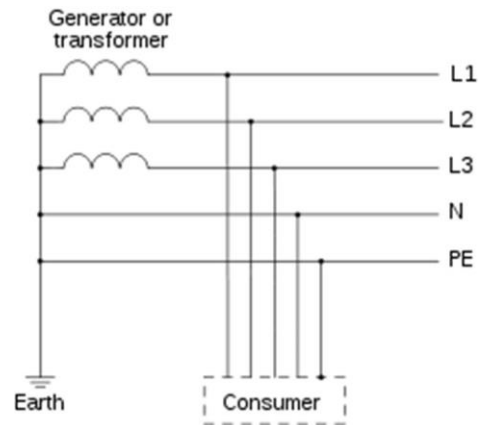
The conductor that connects the exposed metallic parts of the consumer is called *protective earth (PE)*. The conductor that connects to the star point in a three-phase system, or that carries the return current in a single-phase system, is called *neutral (N)*. Three variants of **TN** systems are distinguished:

TN-S: PE and N are separate conductors that are connected together only near the power source.

TN-C: A combined PEN conductor fulfills the functions of both a PE and an N conductor. Rarely used.

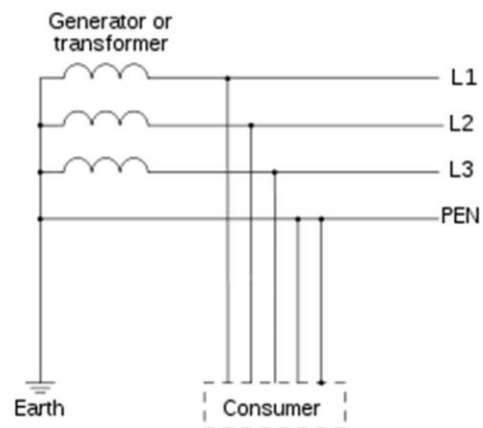
TN-C-S: Part of the system uses a combined PEN conductor, which is at some point split up into separate PE and N lines. The combined PEN conductor typically occurs between the substation and the entry point into the building, and separated in the service head. In the UK, this system is also known as *protective multiple earthing (PME)*, because of the practice of connecting the combined neutral-and-earth conductor to real earth at many locations, to reduce the risk of broken neutrals - with a similar system in Australia being designated as *multiple earthed neutral (MEN)*.

TN-S: separate protective earth (PE) and neutral (N) conductors from transformer to consuming device, which are not connected together at any point after the building distribution point.



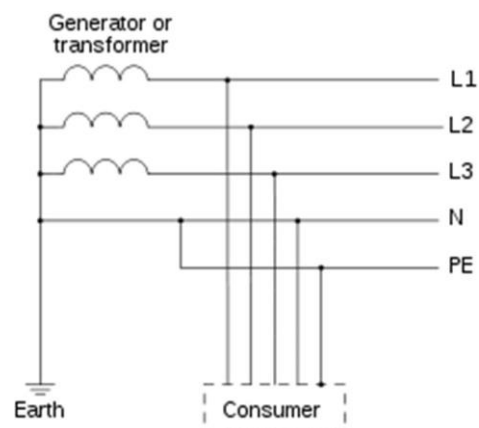
TN-S

TN-C: combined PE and N conductor all the way from the transformer to the consuming device.



TN-C

TN-C-S earthing system: combined PEN conductor from transformer to building distribution point, but separate PE and N conductors in fixed indoor wiring and flexible power cords.

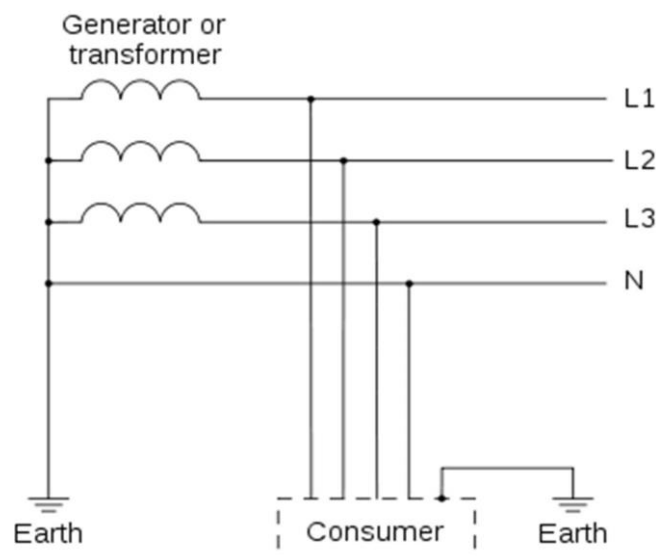


TN-C-S

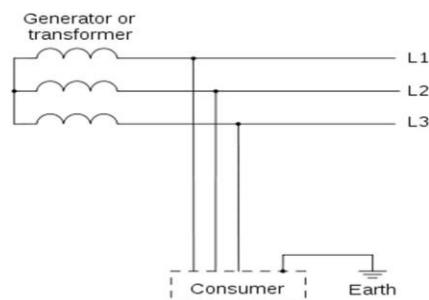
5.5 TT network: In a TT earthing system, the protective earth connection of the consumer is provided by a local connection to earth, independent of any earth connection at the generator.

The big advantage of the TT earthing system is the fact that it is clear of high and low frequency noises that come through the neutral wire from various electrical equipment connected to it. This is why TT has always been preferable for special applications like telecommunication sites that benefit from the interference-free earthing. Also, TT does not have the risk of a broken neutral.

In locations where power is distributed overhead and TT is used, installation earth conductors are not at risk should any overhead distribution conductor be fractured by, say, a fallen tree or branch.

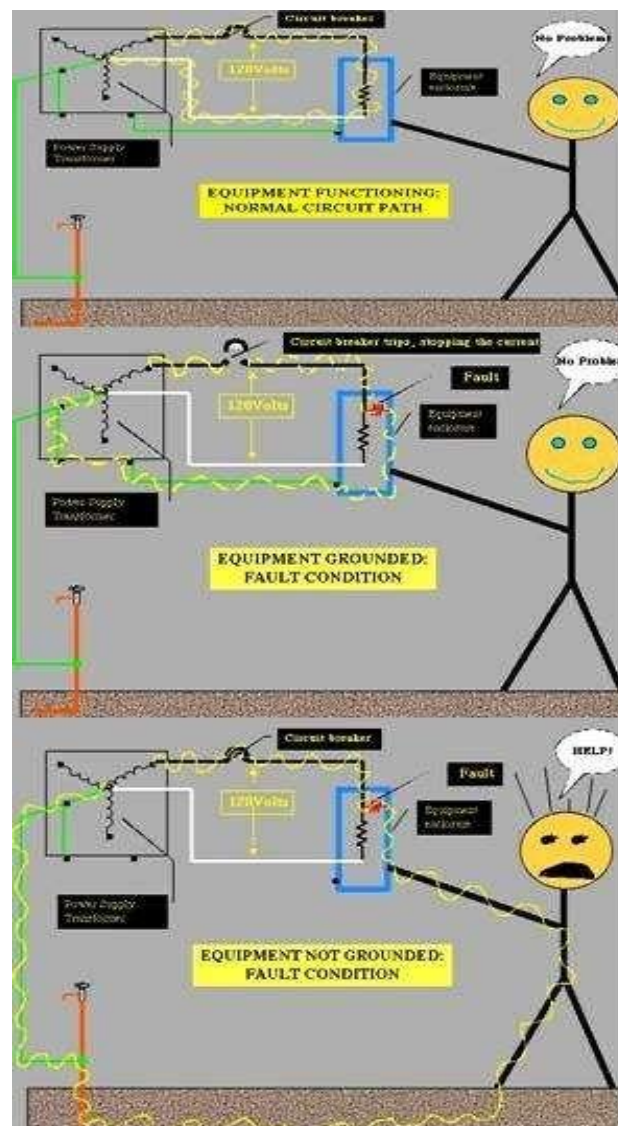


5.6 IT network: In an IT network, the distribution system has no connection to earth at all, or it has only a high impedance connection. In such systems, an insulation monitoring device is used to monitor the impedance. For safety reasons this network is not accepted under European and other countries' norms.

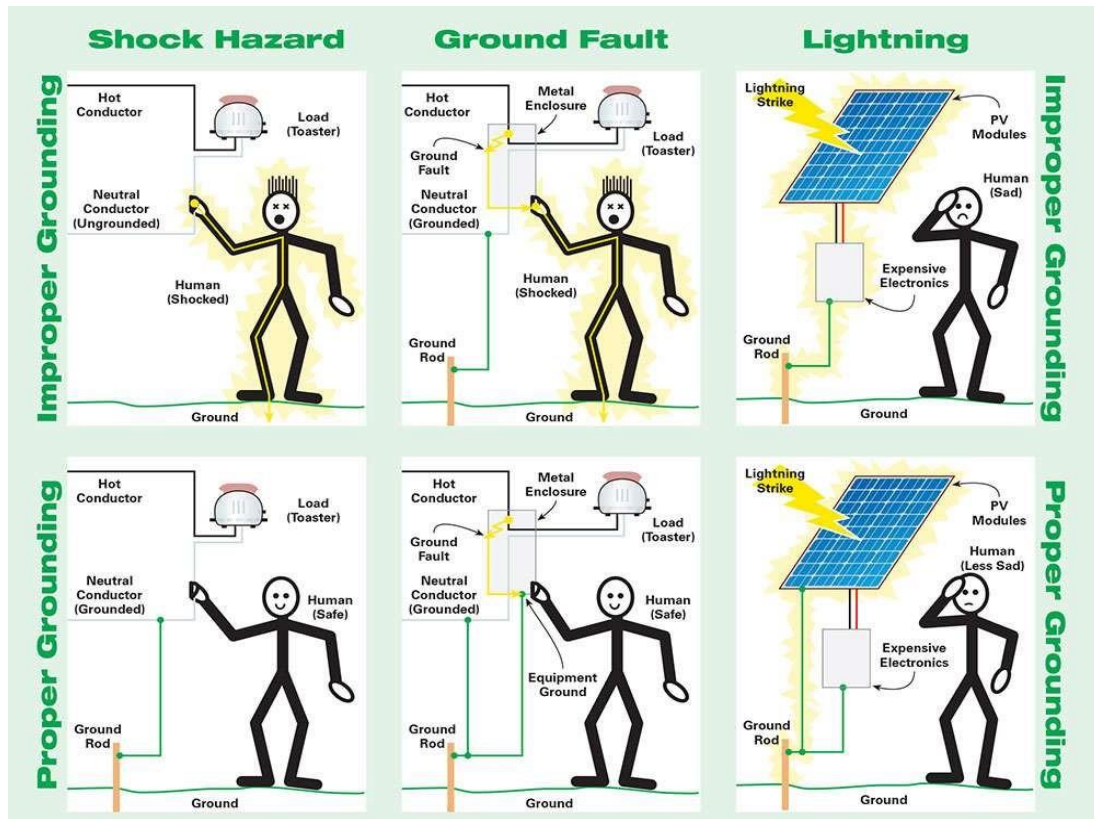


5.7 How Earthing system works: The grounding system is essential to complete an electrical path to ground if there is non-designed or unanticipated above-normal potential current or voltage surges during operating conditions. Personal injury, death or equipment damage can result if the grounding system is not designed and installed properly to guide these potentially dangerous charges safely to ground.

The grounding systems under normal conditions carry NO current. The only time they carry current is under abnormal conditions when an electrical appliance or piece of electrical equipment is faulty and has become a potential shock or fire hazard. Under a fault condition the grounding conductor that is connected to the outer shell or sheet metal of the equipment or appliance must be able to provide a very low resistance path back to the source of the power (utility company's transformer) so that enough current will flow causing a breaker or fuse to open the circuit and automatically disconnect the hazard from the system.



It is NOT the purpose of grounding system to send current through the ground. Sending equipment fault currents through the earth can be a fatal misunderstanding of how a grounding system works. For the most part, the only time you intentionally send current into the earth is during a lightning strike or line surge due to a nearby lightning strike.



5.8 Earthing System Components: Earthing system in an installation is normally comprised of the following components:

- i. Earth wells and accessories,
- ii. Earthing grid conductors,
- iii. Marshalling earth buses (earthing distribution buses),
- iv. Earthing wires and cables.

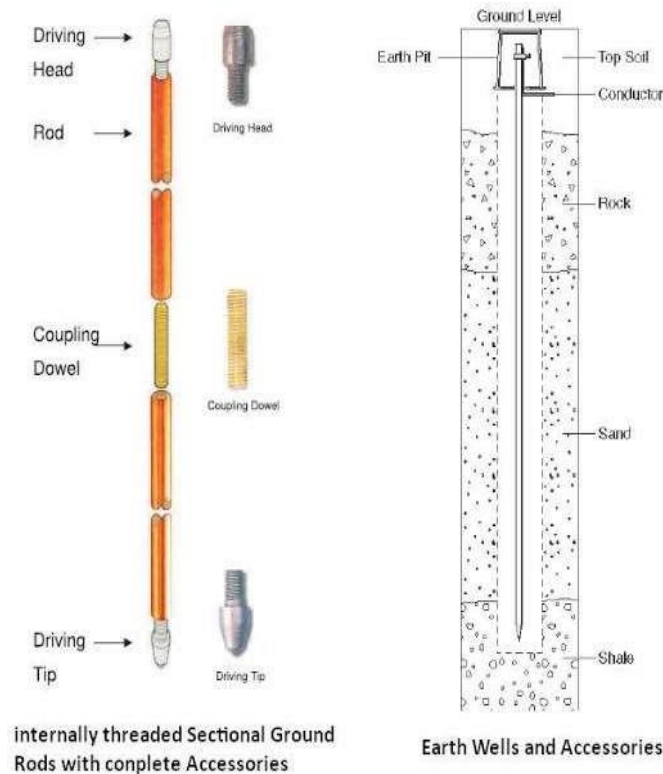
Earth Wells and Accessories:

- Earth wells for a specific building or installation are actually the location, where the pure zero potential is provided and practically act as drain pits for any rush current which accidentally appears in the earthing system grid in the event of an earth fault (connection of electrical live parts to the earthing system).

- There are different types of components that can be used to set up an earth well
Depending on the following factors:
 - i. Soil conductivity of the location in which the earth wells are installed,
 - ii. The required technical specifications of the earthing system.

However, the prime components and accessories of an earth well include:

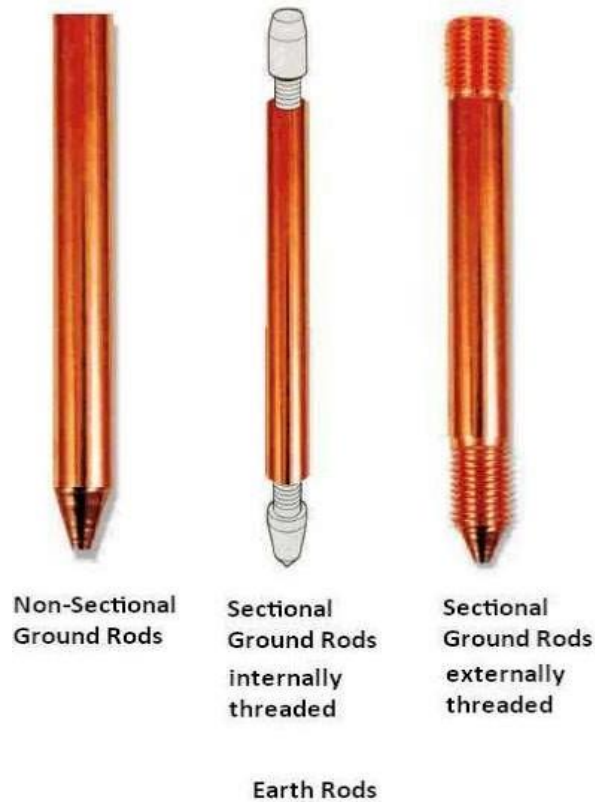
- i. Earth Rod,
- ii. Earth Plate,
- iii. Earthing Clamp,
- iv. Earthing Rod Coupling,
- v. Earthing Rod Tip,
- vi. Earthing Rod Driving Head with driving sleeve,
- vii. Earth Access Pit,
- viii. Earth Pit Cover,
- ix. Earth Enhancement Materials.



- **Earth Rods:** Depending on the design for a specific earth well, a number of rods are driven into the ground by means of hammering or driving to form the main earthing electrode in the earth well.

The earth rod has three types:

- i. Non-Sectional Ground Rods: have unthreaded top.
- ii. Sectional Ground Rods: have externally threaded top.
- iii. Sectional Ground Rods: have internally threaded top.



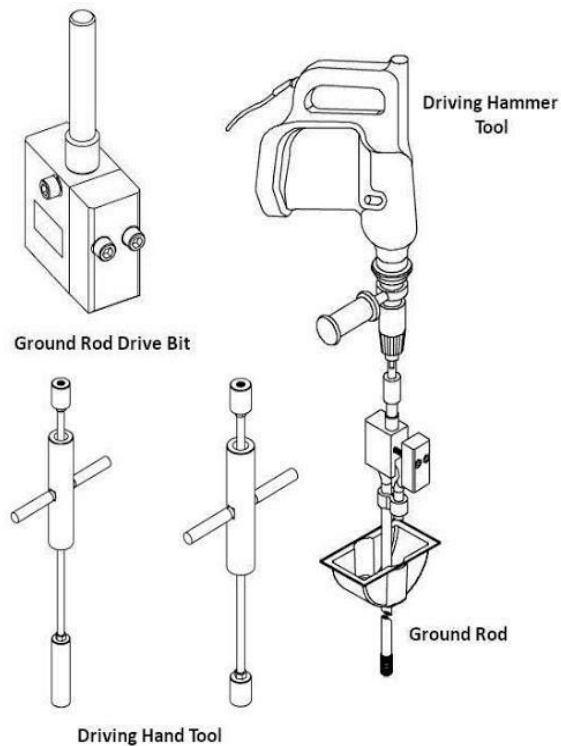
Notes:

- In Cases where two or more earth rods are to be driven, the individual rods are coupled to each other by means of “earth rod coupling”.
- Ground rods coupling process are used to help reduce ground resistance in poor soils such as sand and gravel.
- Doubling rod length theoretically reduces ground resistance about 40%.

Methods for Driving Earth Rod into Ground:

- i. **Hammering:** by using a hammer, a drive stud and rod tip.

- ii. **Driving:** by using a Driving Hammer Tool and Ground Rod Drive Bit or using a Driving Hand Tool.



Notes:

- During the hammering or driving of rod into the ground, and to protect the earth rod against impact of hammering, a “driving head” is screwed onto the top of the rod.
- For easy and convenient driving of the earth rod into the ground an earth rod tip with sharp point is screwed to the first rod.
- Earth rods are used in installation of plain earthing well where, based on design specification of the earthing system, the carbon bedding is not necessary and applicable.

Earth Rod Material: The solid rod electrode of copper or other suitable non-ferrous metal, or a solid rod electrode of iron or steel with a copper or other suitable non-ferrous metal or stainless steel jacket, shall have a diameter not less than ½ inch thick.

Earth Rod Dimensions:

a- Diameter:

- Depending on the design specification of the earthing system and the corresponding earthing wells, various earth rods of different dimensions would be incorporated.
- the solid rod electrode shall have a diameter not less than $\frac{1}{2}$ inch thick.
- In Europe and middle east, The range of diameter for the earth rods vary from 13 mm to 25mm (13mm,16mm, 20mm, 25mm).

b- Length: Different lengths of earthing rods are used in design and installation of earth wells, the standard lengths are:

- 2, 3, 5, 8 and 10 feet.
 - In Europe and middle east: 1200mm, 2400 mm (2×1200 mm), 3600 mm (3×1200 mm) and 4800 mm (4×1200 mm).
- **Earth Plate:** In earth wells with carbon beddings, earthing plates are normally used instead of earthing rods. The earth plate is made of copper and shaped in the following forms:
- i. Flat rectangular copper plate,
 - ii. Perforated rectangular copper plate (Earth Mat).



Flat rectangular copper plate



Perforated rectangular copper plate (Earth Mat)

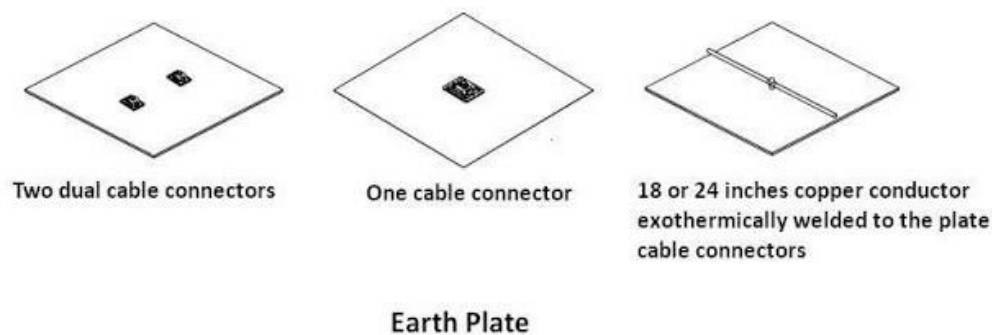
Earth Plate

Copper ground plates are used instead or with the ground rods in the following situations:

- In areas having little or no top soil,
- If it is required to enhance ground grid systems,
- In conjunction with earth enhancements materials.

For securing good electrical connections with the ground plate, ground plate use:

- a. One cable connector,
- b. Two dual cable connectors,
- c. 18 or 24 inches (depending on the plate size) copper conductor exothermically welded to the plate cable connectors.



Earth Plate Size:

- In North America: 18 x 18 inches or 24 x 24 inches.
- In Europe and other African countries, including Nigeria :
 - a. The flat rectangular earth plate is normally 100 × 100 × 3 mm.
 - b. The standard cross section area for the copper rod or copper strips used in construction of the perforated rectangular earth plate is normally 75 sq-mm.

Differences between Earth rods and Earth Plates

Earth rods and plates or any combination thereof can be used to achieve an effective earth depending on the site conditions. The main difference between Earth rods and Earth Plates is as follows:

- Earth rods take advantage of lower resistivity soils at greater depths than normal excavation will allow.
- While, Earth plates are used to attain an effective earth in shallow soils with underlying rocks or in locations with large amounts of buried services. They can also provide protection at potentially dangerous places e.g. HV switching positions.

•Earthing Clamp:

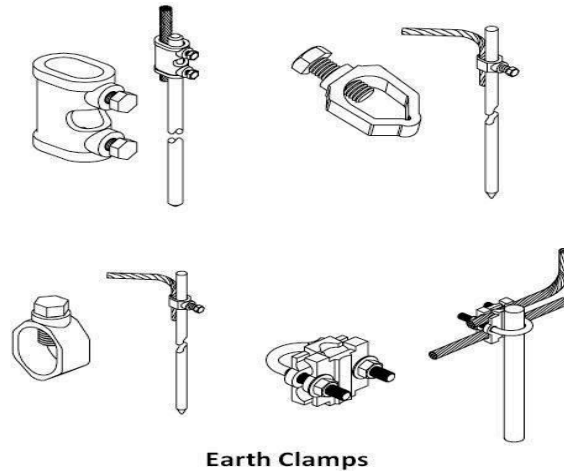
- Earthing grid conductors are connected to the earth rods, already driven into the ground, by means of earthing clamps.

- This Connection between earth rod and Earthing grid conductors is essentially made by tightly clamping of the grid conductor to the rod by one of the two following methods:

Mechanical Clamps,

Exothermic Welding Clamping.

Mechanical Clamps:

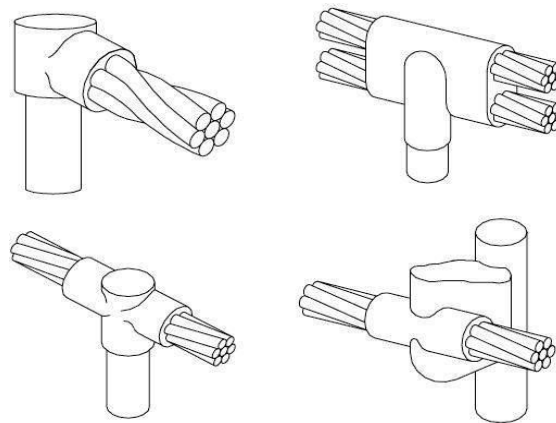


- They are Used Where permanent connections are not appropriate, mechanical clamps offer the ideal solution. These are typically used on smaller scale installations where periodic disconnection for testing is required.
- The mechanical earthing clamp may come with one bolt or two bolts, the two bolts give more good electrical connection with the earth rod.
- Mechanical Earthing clamps and associated bolts nuts, washers, etc. are made of brass, bronze or copper.
- The mechanical earth clamps sizes shall be selected to accommodate the diameters of earth rod and grounding conductors.

Types of Mechanical Earthing Clamps:

- i. **Light duty type:** this type is acceptable for electrical grounding but not for lightning protection.
- ii. **Heavy duty type:** this type is acceptable for lightning protection and requires 1-1/2 inches of surface contact between conductor and earth rod.

Exothermic Welding Clamping:



Exothermic Welding Clamping

- A simple, self-contained method of forming high quality electrical connections which requires no external power or heat source. Connections are made using the high temperature reaction of powdered copper oxide and aluminium.
- Exothermic Welding connections allow conductors to carry higher currents than other types of connections. They will never loosen, are highly conductive and have excellent corrosion resistance.

● Earthing Rod Coupling:

- In some cases, Depending on the design for a specific earth well, there is need to drive two or more earth rods into the ground, the individual rods are coupled to each other by means of “earth rod coupling”.
- There are three types of rod couplers according to the used type of ground rods as follows:
 - i. Unthreaded Coupler for Non- sectional ground rods,
 - ii. Threaded Coupler for sectional ground rods externally threaded,
 - iii. Coupling Dowel for sectional ground rods internally threaded.



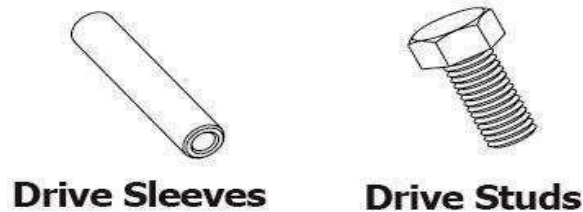
- The coupling material is essentially the same as the material for the earth rod with respect to the rigidity and the required conductivity.
- Earth rod coupling shall have the same diameter of the earth rod.

● **Earth Rod Tip:**



- The earth rod tip is used for easy and convenient driving of the earth rod into the ground because it secures a sharp head for the first rod driven into ground.
- The earth rod tip material is not necessarily the same as the earth rod itself, as only a rigid quality is essentially required for the tip other than conductivity. Therefore the earth rod tip is primarily made of steel with slight coating of the copper for conductivity purpose as well as protection against corrosion reasons.
- Earth rod tip shall have the same diameter of the earth rod.

● **Earth Rod Driving Head with Driving Sleeve:** During the hammering or driving of rod into the ground, and to protect the earth rod against impact of hammering, a “driving head” is screwed onto the top of the rod with a driving sleeve.



- So, the main function of driving sleeve is to prevent Mushrooming top of ground rod while driving into ground.
- And, the main function of a driving head stud is to prevent damage to the coupler or ground rod threads when driving the ground rods.

The driving head material is not necessarily the same as the earth rod itself, as only a rigid and robust quality is essentially required for the driving head to withstand the impact of hammerings. Driving head is practically discarded when the earth rods are all driven and installed in the ground.

5.9 Soil Resistivity: is a measure of how much the soil resists the flow of electricity. It is a critical factor in design of systems that rely on passing current through the Earth's surface. An understanding of the soil resistivity and how it varies with depth in the soil is necessary to design the grounding system in an electrical substation, or for lightning conductors. It is needed for design of grounding (earthing) electrodes for substations and High-voltage direct current transmission systems.

In most substations the earth is used to conduct fault current when there are ground faults on the system. In single wire earth return power transmission systems, the earth itself is used as the path of conduction from the end customers (the power consumers) back to the transmission facility. In general there is some value above which the impedance of the earth connection must not rise, and some maximum step voltage which must not be exceeded to avoid endangering people and livestock.

Permissible Values of Earth Resistance:

- Power stations - 0.5 ohms
- EHT stations - 1.0 ohms
- 33KV SS - 2 ohms

- DTR structures - 5 ohms
- Tower foot resistance - 10 ohms

5.10 Earth/ Ground Enhancement Materials (GEM):

- Only rarely do grounding system designers and contractors get to work on a site with good grounding conditions.
- Even under ideal circumstances, soil structure can vary and make it difficult to achieve uniform, low levels of resistivity across a wide area. Under almost all soil conditions, the use of a ground enhancement material will improve grounding effectiveness. Some are permanent and require no maintenance.

i. Where and when Earth Enhancement Materials should be used?

- Earth Enhancement Materials improves grounding effectiveness regardless of soil conditions and provides excellent permanent conductivity:
 - For areas with high resistance, such as rocky ground, mountain tops, and sandy soil,
 - As a backfill when you have to drill because the ground is too hard to drive, or where ground rods cannot be driven, when used as a backfill for earth electrodes, soil conditioning agents effectively act to increase the electrodes surface area thus lowering its resistance to earth.
 - Where limited space makes adequate grounding difficult by conventional methods.

iii. **Types of Earth Enhancement Materials:** Many types of Earth Enhancement Materials are used to improve grounding effectiveness regardless of soil conditions and provide excellent permanent conductivity, like:

A- Carbon and Salt Bedding: Depending on the technical design specification of the earthing system and primarily for soil conductivity reasons of the area where the earth wells are to be installed, the earth rods are embedded in carbon bedding. To install the carbon bedded earth wells, pre-excavation of the ground, to sufficient size and dimension, would be carried out to provide room for the carbon bedding and the earthing components (rods, plates, etc.). To achieve the maximum conductivity for the earth well, an appropriate amount of salt is added to the carbon and mixed before charging into the earth well.

B- Marconite Compound: Marconite forms a permanent solution when mixed with cement and is used when certain ground conditions make it difficult to obtain a reliable earth resistance or installation might require a low resistance.

C- Bentonite Compound: Bentonite can be supplied in powder or granular form and is moisture retaining clay which is used to reduce soil resistivity. It has two types:

- i. **Granular:** It's easier to handle in granular form, the powder can cause dust in windy conditions and below away, granular is the preferred option for filling trenches where the conductor is covered with bentonite and the water poured over and mixed in the trench.
- ii **Powder:** Powder is the preferred method for pouring into bore holes to ensure the mixture is a thin enough to reach the bottom of the bore hole, if diamond drilling is required for deep holes possibly 40 meters and deeper and the bentonite is to be pumped through the core into the hole, powder will be the preferred option.

SAMPLE QUESTIONS:

Q1 a. What is Earthing System?

b Briefly explain the following terms:

- i Protective earth.
- ii Functional earth.

Q2 a. Distinguish between **System Earthing** and **Equipment Earthing**.

b List any Five (5) functions of earthing system.

Q3. With the aid of a simple sketch, describe the **TN-S** and **TN-C** earthing systems.

Q4 a. Differentiate between **Earth Rod** and **Earth Plate**.

b List the Four (4) earthing system components.

Q5. Where and when Earth Enhancement Materials should be used in earthing system?

CHAPTER 6

6.0 Distribution Transformer

OBJECTIVES: At the end of the class participants would be able to:

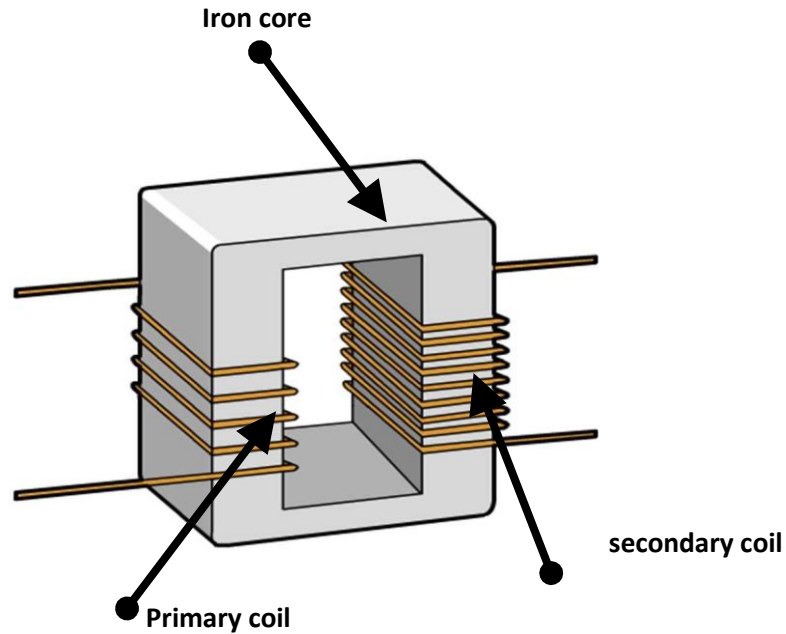
1. Define Distribution Transformer
2. State the purpose of distribution transformer.
3. Distinguish between Power Transformer and Distribution Transformer.
4. State the cooling system of a distribution transformer.

INTRODUCTION: One of the main reasons that we use alternating AC voltages and currents in our homes and workplace's is that AC supplies can be easily generated at a convenient voltage, transformed (hence the name transformer) into much higher voltages and then distributed around the country using a national grid of pylons and cables over very long distances.

The reason for transforming the voltage to a much higher level is that higher distribution voltages implies lower currents for the same power and therefore lower I^2R losses along the networked grid of cables. These higher AC transmission voltages and currents can then be reduced to a much lower, safer and usable voltage level where it can be used to supply electrical equipment in our homes and workplaces, and all this is possible thanks to the basic Voltage Transformer.

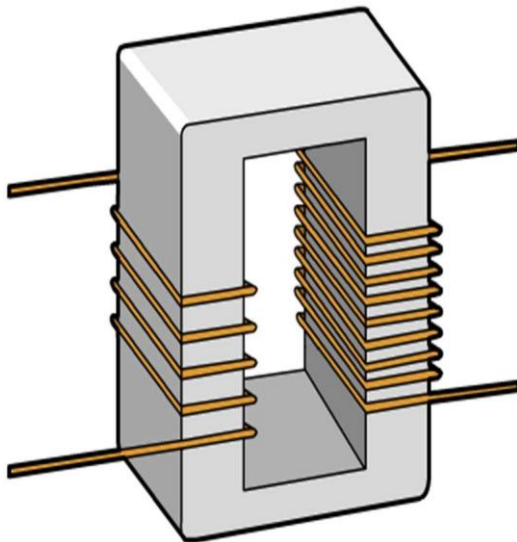
6.1 Definition of Transformer: A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors—the transformer's coils.

A transformer contains two coils that are wound around a soft iron core. The alternating current in the primary (input) coil produces an alternating magnetic field. This alternating magnetic field induces an alternating current in the secondary (output) coil.

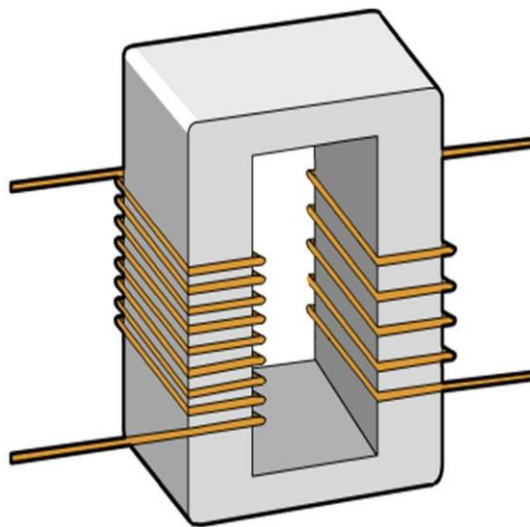


6.2 How does a transformer change voltage?

The **voltage induced** in the secondary (output) coil depends on the **number of turns** on the primary and secondary coils.



Step-up Transformer



Step-down transformer

A **step-up transformer** has more turns on the secondary coil and so **increases voltage**.

A **step-down transformer** has fewer turns on the secondary coil and so **decreases voltage**.

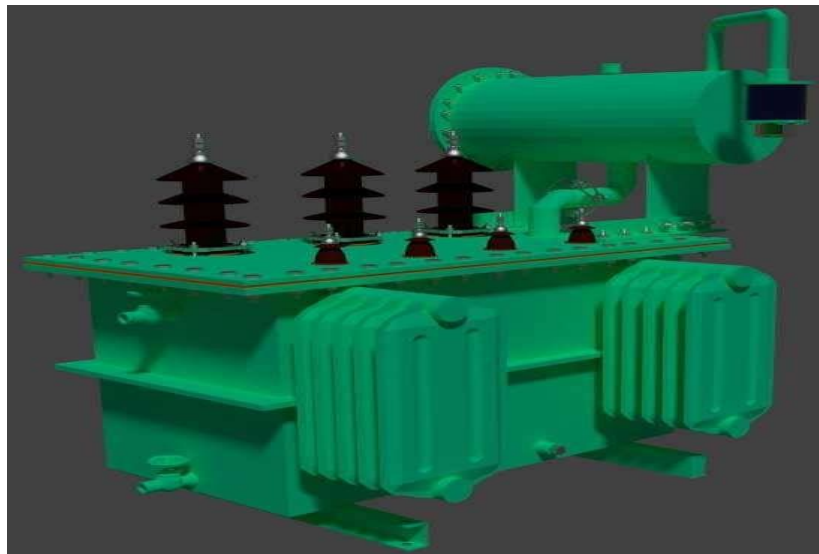
6.3 Where are transformers used?

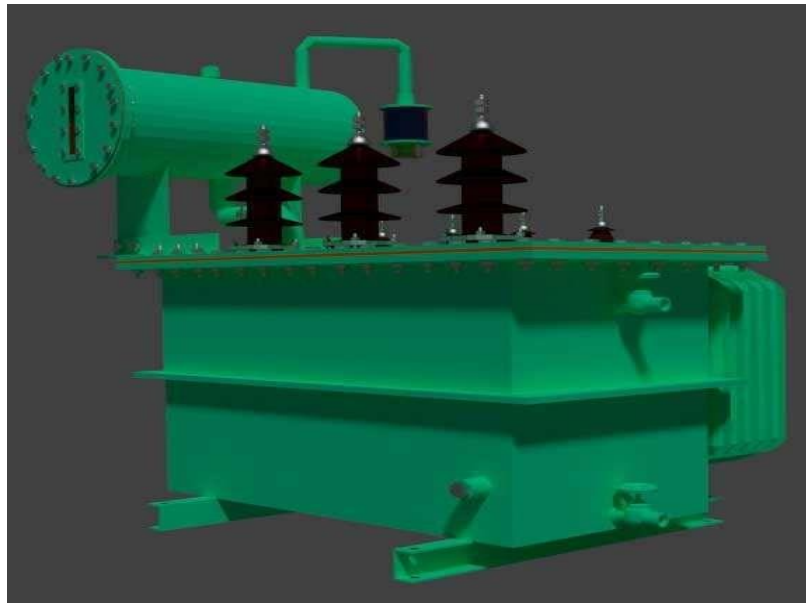


This outdoor transformer decreases the voltage of the electricity carried by the national grid. It is an example of a step-down transformer.

The step down transformers used for **electric power** distribution purpose are referred as **distribution transformers**. There are several types of transformer used in the distribution system. Such as single phase transformer, three phase transformer, pole mounted transformer, pad mounted transformer, and underground transformer.

Distribution transformers are generally small in size and filled with insulating oil. These transformers are available in the market in various sizes and efficiencies. Selection of distribution transformer depends upon the purpose and budget of the end users.





Distribution Transformer

6.4 PARTS OF A POWER TRANSFORMER:

1 Core and windings

Both are held together by a pressed structure and bolted together with the tank lid. The complete unit can be lifted out of the tank.

2 Core

High-quality electric sheet steel, most modern core design and optimized lamination provide for low-loss and noise-optimized operation.

3 Windings

Construction and materials guarantee a long service life.

4 Tap changer

Used to adjust the ratio to the local voltage conditions. It can be adjusted from outside in de-energized condition.

5 Low-voltage bushings

6 High-voltage bushings

7 Thermometer bag

Important accessory for temperature monitoring.

8 Tank

The TUMETIC design shown here is hermetically sealed. Elastic corrugated walls take up the volume changes of the transformer fluid.

9 Truck

Plain transport wheels can be aligned for longitudinal or transversal movement.

10 Conservator

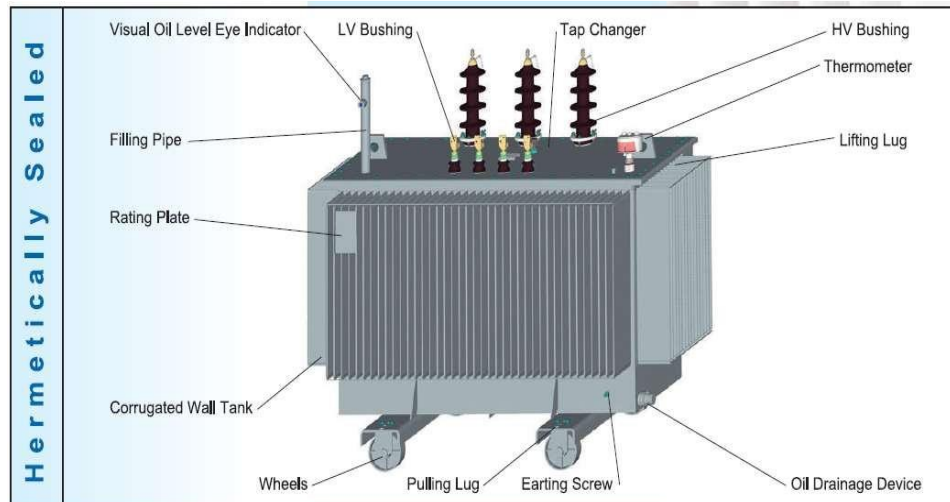
In the TUNORMA type, it is equipped with an oil level indicator and a filling socket.

11 Corrosion protection

The surface gets a multicoating in the standard color cement gray (RAL 7033). Special colors or galvanization are possible.



**Distribution Transformer
(Conservator Type)**



Distribution Transformer
(Hermetically Sealed)

6.5 Transformer Rating:

- It is written in terms of Apparent Power.
- Apparent power is the product of its rated current and rated voltage.

$$VA = V_1 I_1 = V_2 I_2$$

□ Where,

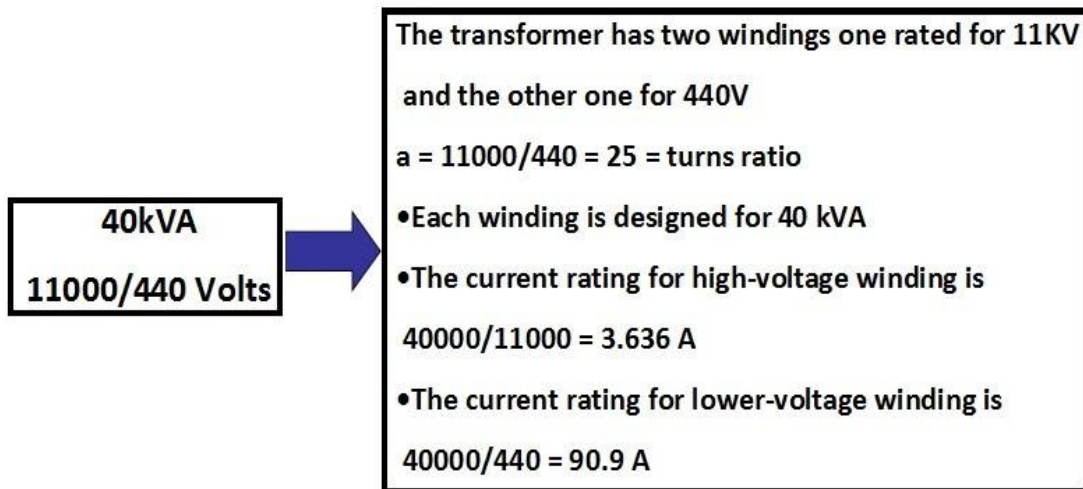
- I_1 and I_2 = rated current on primary and secondary winding.
- V_1 and V_2 = rated voltage on primary and secondary winding.
- Rated currents are the full load currents in transformer.

6.6 Transformer Rating and Name Plate:

Assume that the transformer has the following name plate ratings:

40 kVA, 11 kV/ 440 V, 50 Hz

What do these numbers imply?



6.7 Distribution loads:

- Types of Load:

- Residential
- Commercial
- Industrial
- Public Transportation
- Public Lighting, etc.

Residential Load:

- Consist of lighting, radio, TV, refrigerator,
Kitchen appliances, washing machine, etc.

- Usually, increases in the evening around 6 p.m. and return to a nominal value around 12 p.m.

Commercial Load:

- Consists of lighting, air-condition and small appliances.
- Shops, business premises, schools, universities etc.
- The load is fairly constant from 9am until 9pm with the exception of any mid-day break.

Industrial Load:

- Mainly consists of motor load, air conditioner, lighting, welding and furnaces etc.

It can be divided into small, medium and large category.

SAMPLE QUESTIONS:

Q1. a. Define a Distribution Transformer.

b Explain its working principles.

Q2. a. Define step-up and step-down transformers.

b Briefly explain the following:

i Transformer tank

ii Bushing

iii Conservator

iv Breather

Q3. What is the difference between power transformer and distribution transformer?

CHAPTER 7

7.0 FEEDER PILLAR

OBJECTIVES: At the end of the lesson participants would be able to:

1. Define feeder pillar.
2. Classify feeder pillars according to their units (ways).
3. List and explain feeder pillar components.
4. Explain the steps involved in changing blown feeder pillar fuses.

INTRODUCTION: A feeder pillar is essential in a power system distribution network to distribute electric power (three-phase, 415V ac) from a step-down transformer to the low-tension (LT) lines for the consumers. A default feeder pillar consists of a panel which embodies all other sub-units of the feeder pillar, bus-bars in which are connected the incoming and outgoing lines, an ammeter which records the voltage across the bus-bars, the fuse holders holds the fuses, high-rupturing-capacity fuses for making contact and for protection purposes.

7.1 FEEDER PILLAR: Feeder Pillar is a cupboard like metallic cabinet used by the Utility Company to feed residential and some small-scale commercial consumers in our big towns and cities. In some areas York-Shire connectors are used instead of feeder pillars. Both the feeder pillar and York shire connectors get their power supply from the secondary side or low tension of the transformer feeding them.

Feeder pillars are named according to the number of out goings in each namely four, six, eight, or even ten way feeder pillars and their sizes varies accordingly.

The incomer into the feeder pillar is either linked or fused with fuse of higher current ratings, while the outgoing units to overhead lines are protected with between 400 – 300amperes fuses.

Modern feeder pillars are incorporated with a digitalized voltmeter and a phase sequence relay, earth-leakage circuit breaker, three phase overload relay and a contactor used for over-current, overload and earth-fault protection. This will solve the problem of constantly changing the fuses when it blows due to excessive current. The circuit breakers will operate on all conditions (on-load and no-load conditions). This set up protects the transformer from direct faults from the feeder pillar and from the feeder pillar to the 415V LT lines, protecting the bus-bars (incoming and outgoing circuit).

It is designed as compact and robust for vandalism protection. The metal enclosure is made of sheet steel of minimum 2mm thickness mounted on a steel base frame of minimum 3mm thickness. Enclosure is suitable for outdoor application.

The low voltage feeder pillar comprises of the following components:

-Feeder Pillar Enclosure

-Bus bars

-Current transformer

-Instrumental panel

-Incoming Units

-Outgoing Units

7.2 Mini Feeder Pillar Features:

*Standard Rated Current: 400A – 2 Nos. (Incoming)

- 160A – 6 Nos. (Outgoing)

- Rated Operational Voltage: 440 Volts

- Rated Insulation Voltage: 1000 Volts

- Rated Short Circuit withstand strength with fuse link: 6kA/1 sec

- Cable Termination: 300 sq.mm (Incoming):70 sq.mm (Outgoing)

- Fuse Base: 160A (suitable for DIN Fuses)

- Enclosure: Suitable for Outdoor

- Degree of Protection: IP54

- Overall Size (L x H x W):650mm x 1245mm x340mm.



4- Way feeder pillar





- Suitable for all Power distribution
 - Application up to 1600 Amps/660 Volts/50 Hz
- Design for outdoor installation





7.3 Changing of blown fuses in the feeder pillar:

Care should be taken when changing fuses in the feeder pillar as there could be leakage in the underground cable or in the overhead lines.

A fault man should check for the leakage before any blown fuses could be changed in the feeder pillar. Either a potential tester which could test line to line or phase voltage or two globes of the same wattage wired in series could be used to test for the leakage.

Proper tools should be used when changing fuses in the feeder pillar, that is to say you should use the fuse carrier to replace blown fuses instead of using pliers, which is the normal practice of our fault men. Also using strands of copper conductor to bridge the normal blown fuses should be discouraged as this always results in accidents to the Fault men.

It is advisable to patrol overhead lines when more than a fuse is blown on an overhead unit in the feeder pillar before changing the fuses.

When clearing faults in the feeder pillar proper check should be conducted on all the contacts therein and loose ones to be properly tightened.

Fault men should ensure that neutral links are properly tightened as this may cause high voltage and this will burn consumers' apparatus. Fault men should not indulge in changing phase for consumers, as this may be dangerous because their usual practice is to change only the phase line and leave the neutral. Fault men should note that on some shackle pole supply from different power sources meet there, this is where it could be dangerous when changing phases for consumers and leaving the neutral which gets its power supply from another source, which may feedback to isolated lines.

SAMPLE QUESTIONS

Q1. Define a feeder pillar.

Q2. List and explain the components of a feeder pillar.

Q3. Explain the steps to be taken before changing feeder pillar fuses.

Q4. How do you differentiate between feeder pillars?

CHAPTER 8

8.0 RING MAIN UNIT (RMU)

OBJECTIVE: At the end of the class participants would be able to

- 1 Define Ring Main Unit (RMU)
- 2 Explain the function/purpose of R M U in the network.
- 3 Differentiate the types of R M Us used in the network.

INTRODUCTION: RING MAIN UNIT is compact Switchgear with unique flexibility for distribution network .It is a completely sealed system with a stainless steel tank containing all the live parts and the switching equipment. Constant atmospheric conditions in the sealed tank ensure a high level of reliability, safety and a virtually maintenance-free system.

8.1 DEFINITION: Ring Main Units (RMUs) are load break switches used in Distribution System Voltages up to 33kv to service feeder load areas in complement of feeder circuit Breaker. They provide flexibility for switching during normal and abnormal operating conditions for the purpose of operation and maintenance. RMUs are either fused or unfused with extension facilities or as an interconnection between two feeders. HRC fuses are used in most extensible RMUs.

RMUs serve the following requirements.

- (a) Breaking rated current
- (b) Making rated current
- (c) Carrying specified short circuit (fused version)

RMUs are robust construction with electrical parts usually immersed in insulating (Txf) oil. The closing and the opening of RMUs are by manual efforts using the operating handle.

The fused RMUs have HRC fuses with striker pins operating a trigger action to unlatch a mechanism to trip-off the RMU.

The RMU can only be reclosed after the clearance of the fault and any blown fuse replaced with a new one. Care must be taken to replace the HRC fuse properly to align the fuse-pin position correctly to ensure the trip-off action of the striker pin if fuse blows off.

8.2 Basic Construction Aspects of RMU:

The equipment is metal enclosed, free standing or transformer mounted type (in DEWA, they call it Substation and Pocket types respectively). Free standing RMU shall be stable and rigid on its own support. The unit is provided with lifting facilities of proven design for easy handling. The equipment is complete with necessary cable termination boxes, earth fault indicating device with current transformers, fuse switch and switching equipment with necessary interlocks for safety and designed for minimum maintenance.

The mechanical design and strength of the unit and components are able to bear the mechanical stresses on the switch terminals when installed and in operation. The equipment can withstand the electro-dynamic forces without reduction of the switches reliability or current carrying capacity.



Ring Main Unit (RMU)



THE SF₆ TYPE R M U



8.3 Cable Terminations:

The ring cable terminations are provided on the sides of the RMU. The T-off termination is provided on its rear in the case of free standing type. In the case of transformer mounted type, T-off connection is brought out in such a manner to connect direct to the transformer HT side. The cable terminations are suitable to receive three core underground cables of sizes up to 240mm. sq. of XLPE Copper cables.

8.4 Operational Switches:

RMU Switch is composed of a bank of three positions (ON, OFF, EARTH) single break type suitable for the three phase current carrying capacity. Tee-off switch is composed of a bank of three positions (ON, OFF, EARTH) double-break type suitable for the phase current carrying capacity. Current limiting device is composed of the striker pin type and also fuse links capable to actuate a common tripping bar to protect the distribution transformer and to avoid chances of single phasing.

8.5 Classification of RMUs:

The popular brands used in the network are by: -

- (a) Lucy: DEOS, EFS
- (b) Long and Crow ford: - R3, R4, J3, J4, GF3, GF3F
- (c) Siemens

8.6 Interlocks:

Positive mechanical interlocks are incorporated which ensures that following operations are prevented: -

- (i) Switching circuit through "ON" to "EARTH" and "EARTH" to "ON"
- (ii) Opening of test access cover insertion or withdrawal of test device with the switch in other than the "EARTH" position.
- (iii) Switching to the "ON" position, with the test cover open.
- (iv) Access for fuse renewal, with the switch in the "ON" position.

(v) Switching to the “ON” position when a blown fuse is in circuit, with its striker pin protruding.

8.7 Padlocking:

Padlocking facilities are provided and as standard equipment, allowing the switches to be locked in the “ON” “OFF” or “EARTH” positions, with facilities for independently padlocking off the “EARTH” or “ON” positions.

8.8 Maintenance/Working on R.M.U:

Many workmen have lost their lives as a result of accidents while working on R.M.U. To prevent such accidents, care should be taken to see “NO” metallic object should be in one’s shirt pocket, rings and wrist watches should be removed before work could be out on RMU tank. The above precaution should be taken to prevent dropping of any of these objects in the tank, which may result in an explosion if it makes contact with any live part of the equipment. RMU should be made completely dead and earthed performing any maintenance work on it. Limited maintenance is necessary and production units have been endurance tested for 1000 mechanical operations, without requiring any adjustment. Under reasonable load diversity, a similar contact life should be reached. Inspection and oil sampling the condensate from the bottom of the tanks is recommended every seven years.

Should contact become severely damaged or corroded, a replacement set, with new pull rods, needs to be lifted. It will be useful to examine contacts after fault operations.

If more than one fuse were blown off in an RMU, there should be a reason for that and a fault man should probe or carry out trouble shooting to find out the cause and clear it if the fuses were blown due to the circuit before they were changed. Some fuses may blow or rupture and the shot pins may not operate, megger or Avometer should be used to test the continuity of the fuse.

All fuses in the RMU must be of the same current ratings and proper fuses must be used to protect the transformer according to their sizes.

The table below shows the fuses and transformer sizes.

200KVA transformer	=	20A
300KVA transformer	=	30A
500KVA transformer	=	50A

SAMPLE QUESTIONS

Q1. Define R M U

Q2. Briefly explain Three (3) functions of an R M U

Q3. Differentiate between the oil type RMU and SF₆ RMU

Q4. Briefly explain the following terms

I Interlocking

II Padlocking

CHAPTER 9

9.0 OHM'S LAW FORMULA

OBJECTIVES: At the end of the class, participants would be able to

1. Define OHM'S LAW
2. Distinguish between series circuit and parallel circuit
3. Solve simple calculations using Ohm's Formula
4. Explain the relationship between Voltage, Current and Resistance.

INTRODUCTION: OHM'S LAW FORMULA- When voltage is applied to an electrical circuit, current flows in the circuit. The following special relationship exists among the voltage, current and resistance within the circuit: the size of the current that flows in a circuit varies in proportion to the voltage which is applied to the circuit, and in inverse proportion to the resistance through which it must pass. This relationship is called Ohm's law, and can be expressed as follows:

$$E = I R$$

Voltage = Current x Resistance

E Voltage applied to the circuit, in volts (**V**)

I Current flowing in the circuit, in amperes (**A**)

R Resistance in the circuit, in ohms

In practical terms " $V = I \times R$ " which means
"Voltage = Current x Resistance".

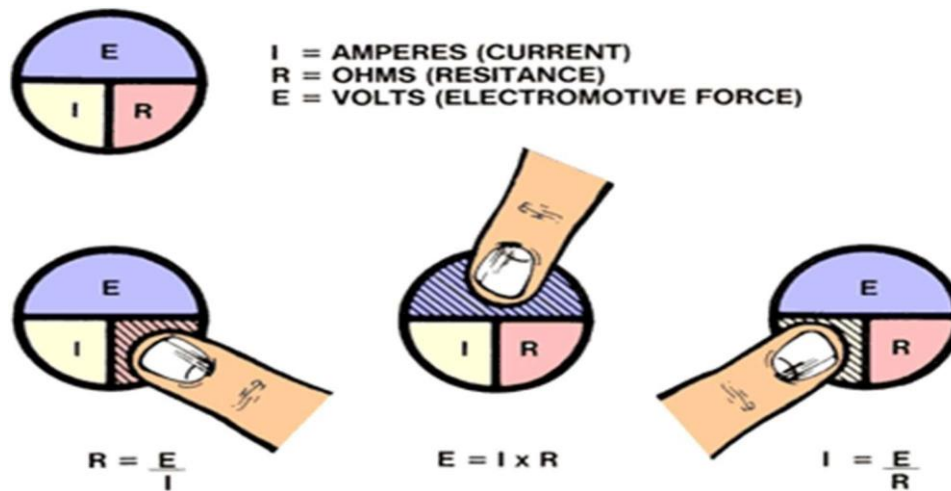
1 volt will push one amp through 1 ohm of resistance.

NOTE:

$E = IR$, $V=AR$, or $V=IR$ are all variations of the same formula. How you learned Ohm's law will determine which one you will use. Personal preference is the only difference; anyone will get you the correct answer.

9.1 OHM'S LAW SYMBOL SHORTCUT: Mathematical formulas can be difficult for many who don't use them regularly. Most people can remember a picture easier than a mathematical formula. By using the Ohms law symbol below, anyone can remember the correct formula to use.

By knowing any two values you can figure out the third. Simply put your finger over the portion of the symbol you are trying to figure out and you have your formula.

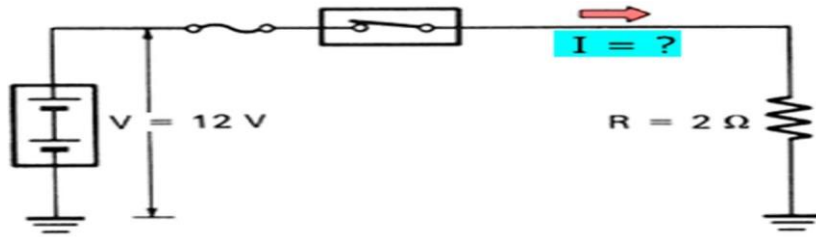


9.2 APPLICATIONS OF OHM'S LAW: As an application of Ohm's law, any voltage **V**, current **I** or resistance **R** in an electrical circuit can be determined without actually measuring it if the two others values are known. This law can be used to determine the amount of current **I** flowing in the circuit when voltage **V** is applied to resistance **R**. As stated previously, Ohm's law is:

$$I = \frac{V}{R}$$

Current = Voltage / Resistance.

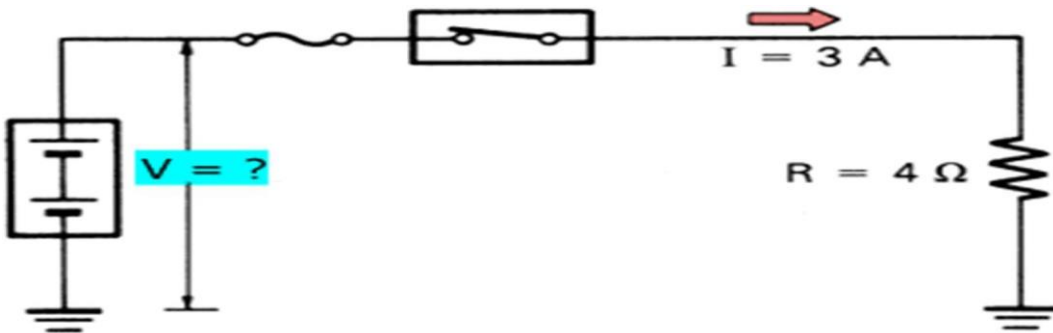
In the following circuit, assume that resistance **R** is 2 and voltage **V** that is applied to it is 12 V. Then, current **I** flowing in the circuit can be determined as follows:



$$I = \frac{V}{R} = \frac{12\text{ V}}{2\ \Omega} = 6\text{ A}$$

This law can also be used to determine the voltage V that is needed to permit current I to pass through resistance R : $V = I \times R$ (Voltage= Current x Resistance).

In the following circuit, assume that resistance R is 4 ohms. The voltage V that is necessary to permit a current I of 3 A to pass through the resistance can be determined as follows:

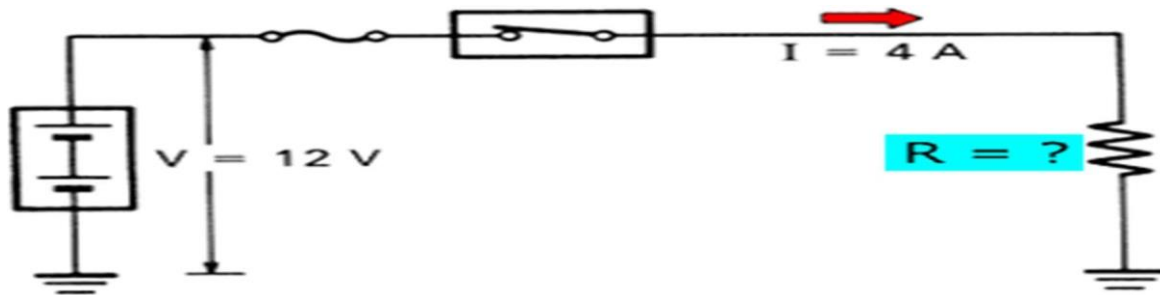


$$\begin{aligned} V &= I \cdot R \\ &= 3\text{ A} \times 4\ \Omega = 12\text{ V} \end{aligned}$$

Still another application of the law can be used to determine the resistance R when the voltage V which is applied to the circuit and current I flowing in the circuit is already known:

$$R = \frac{V}{I}$$

In the following circuit, assume that a voltage V of 12 V is applied to the circuit and current I of 4 A flows in it. Then, the resistance value R of the resistance or load can be determined as follows:



$$R = \frac{V}{I}$$

$$= \frac{12 \text{ V}}{4 \text{ A}} = 3 \Omega$$

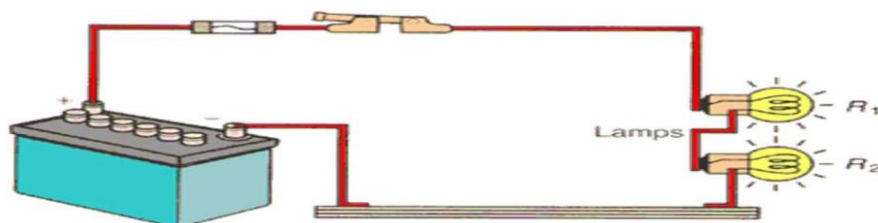
9.3 TYPES OF CIRCUITS: Individual electrical circuits normally combine one or more resistance or load devices. The design of the automotive electrical circuit will determine which type of circuit is used. There are three basic types of circuits:

Series Circuit

Parallel Circuit

Series-Parallel Circuit

SERIES CIRCUITS: A series circuit is the simplest circuit. The conductors, control and protection devices, loads, and power source are connected with only one path to ground for current flow. The resistance of each device can be different. The same amount of current will flow through each. The voltage across each will be different. If the path is broken, no current flows and no part of the circuit work. Christmas tree lights are a good example; when one light goes out the entire string stops working.

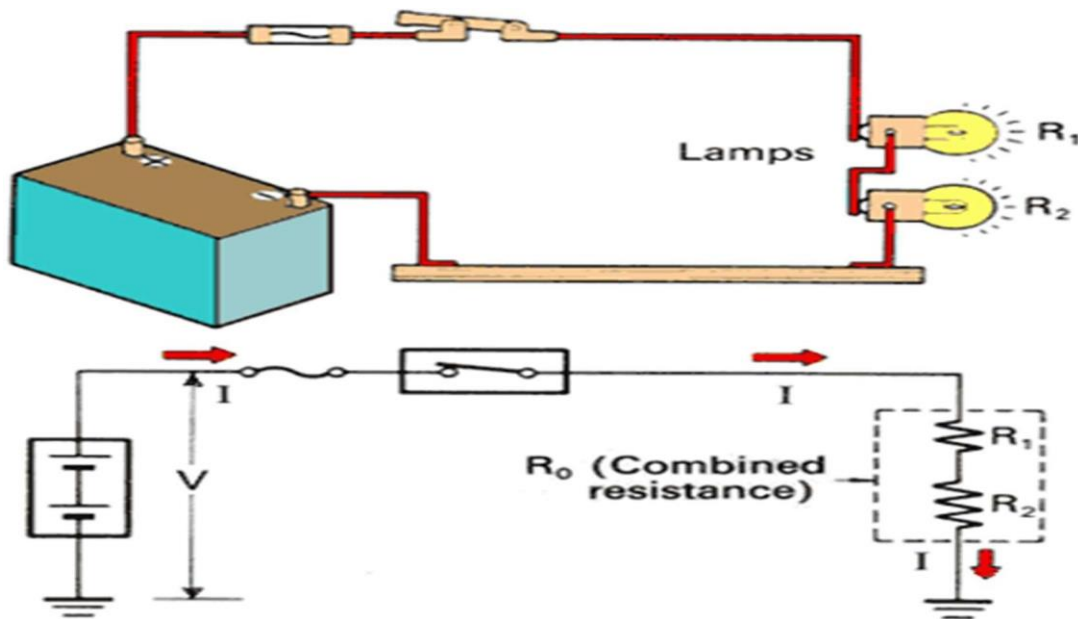


A Series Circuit has only one path to ground, so electrons must go through each component to get back to ground. All loads are placed in series.

Therefore:

- i. An open in the circuit will disable the entire circuit.
- ii. The voltage divides (shared) between the loads.
- iii. The current flow is the same throughout the circuit.
- iv. The resistance of each load can be different.

SERIES CIRCUIT CALCULATIONS: If, for example, two or more lamps (resistances R_1 and R_2 , etc.) are connected in a circuit as follows, there is only one route that the current can take. This type of connection is called a series connection. The value of current I is always the same at any point in a series circuit.



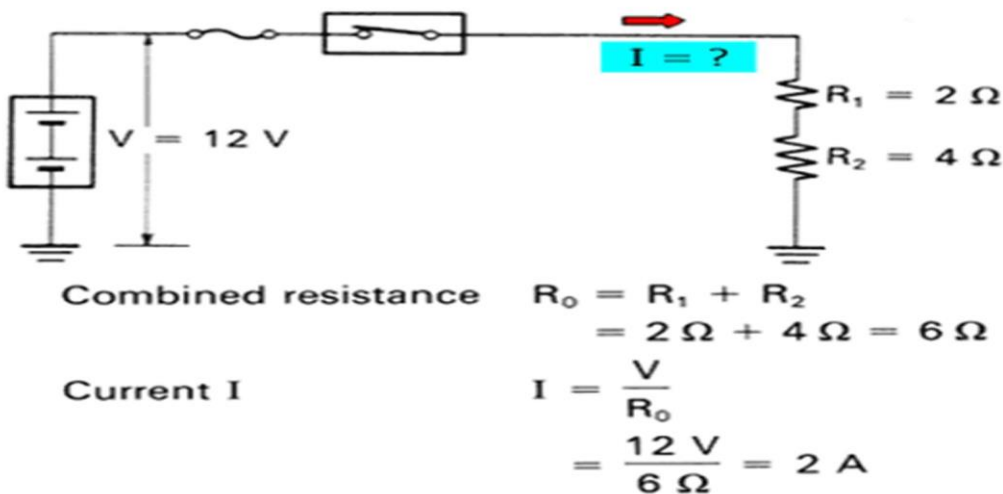
The combined resistance R_0 in this circuit is equal to the sum of individual resistance R_1 and R_2 . In other words: The total resistance (R_0) is equal to the sum of all resistances ($R_1 + R_2 + R_3 + \dots$)

$$R_0 = R_1 + R_2$$

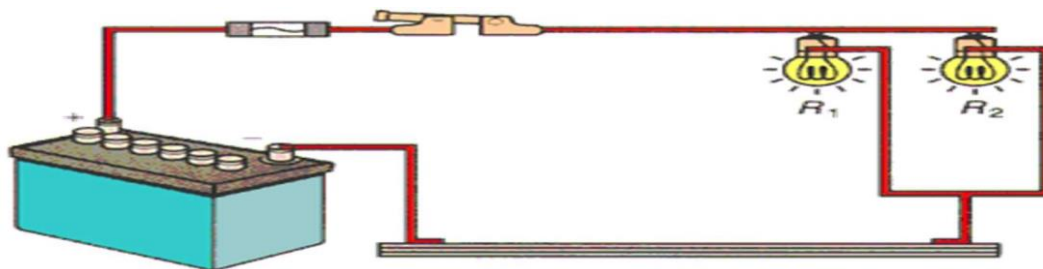
Therefore, the strength of current (I) flowing in the circuit can be found as follows:

$$I = \frac{V}{R_0} = \frac{V}{R_1 + R_2}$$

Resistance R_0 (a combination of resistances R_1 and R_2 , which are connected in series in the circuit as illustrated) and current I flowing in this circuit can be determined as follows



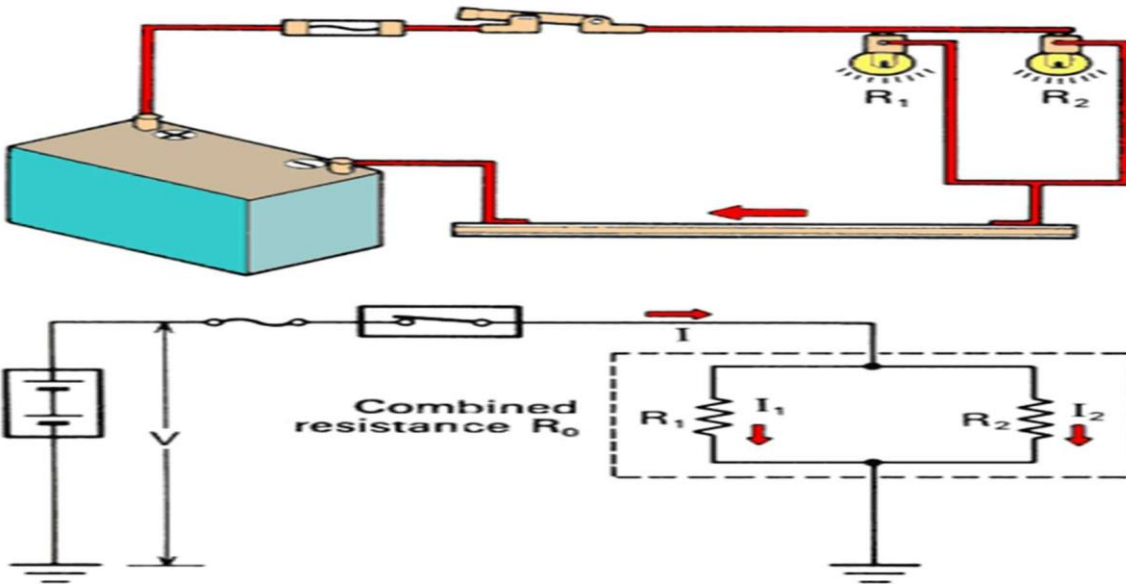
PARALLEL CIRCUIT: A parallel circuit has more than one path for current flow. The same voltage is applied across each branch. If the load resistance in each branch is the same, the current in each branch will be the same. If the load resistance in each branch is different, the current in each branch will be different. If one branch is broken, current will continue flowing to the other branches.



A Parallel Circuit has multiple paths or branches to ground. Therefore:

- i. In the event of an open in the circuit in one of the branches, current will continue to flow through the remaining.
- ii. Each branch receives source voltage.
- iii. Current flow through each branch can be different.
- iv The resistance of each branch can be different.

In parallel connection, two or more resistances (R_1 , R_2 , etc.) are connected in a circuit as follows, with one end of each resistance connected to the high (positive) side of the circuit, and one end connected to the low (negative) side. Full battery voltage is applied to all resistances within a circuit having a parallel connection.



Resistance R_0 (a combination of resistances R_1 and R_2) in a parallel connection can be determined as follows:

$$R_0 = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{R_1 \times R_2}{R_1 + R_2}$$

From the above, the total current **I** flowing in this circuit can be determined from Ohm's law as follows:

$$I = \frac{V}{R_0} = \frac{V}{\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}} = V \frac{R_1 + R_2}{R_1 R_2}$$

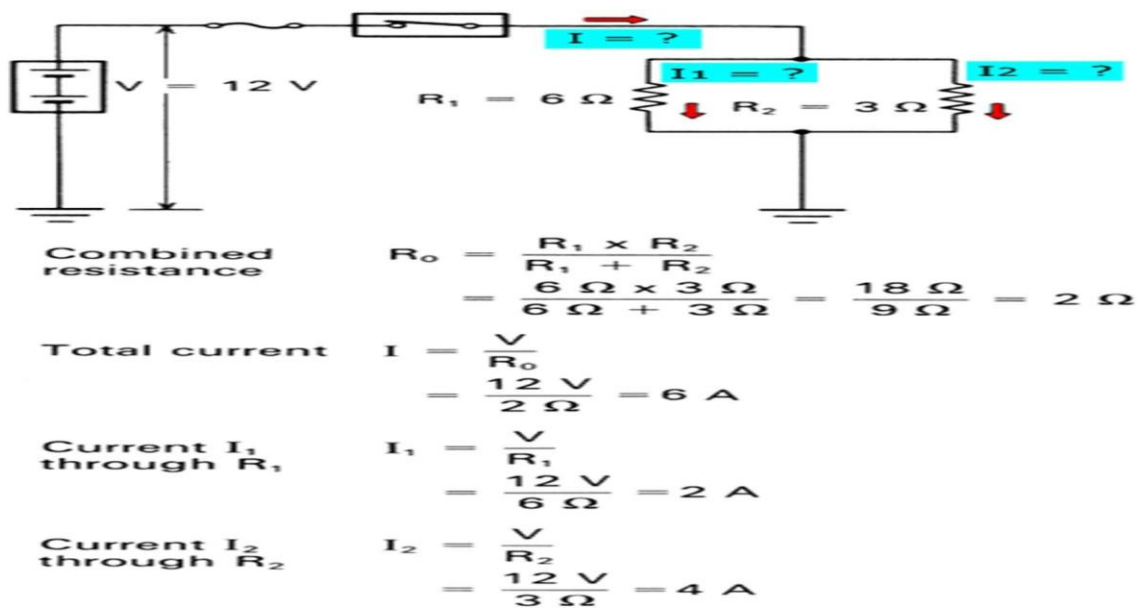
The total current **I** is also equal to the sum of currents **I1** and **I2** flowing through individual resistances **R1** and **R2**

$$I = I_1 + I_2$$

Since battery voltage **V** is applied equally to all resistances, the strength of currents **I1** and **I2** can be determined from Ohm's law as follows:

$$I_1 = \frac{V}{R_1} \qquad I_2 = \frac{V}{R_2}$$

Resistance **RO** (a combination of resistances **R1** and **R2**, which are connected in parallel in the circuit as shown below), the total current **I** flowing in the circuit, and currents **I1** and **I2** flowing through resistances **R1** and **R2**, can be determined respectively as follows:



SAMPLE QUESTIONS

Q1. Define Ohm's Law.

Q2. With the aid of a simple diagram distinguish between series circuit and parallel circuit.

Q3. Calculate the Current I in a series circuit with resistance $R_1 = 4\ \Omega$ and $R_2 = 6\ \Omega$. The Voltage V across the circuit is 24V.

Q4. A circuit connected in parallel with resistance $R_1 = 4\ \Omega$ and $R_2 = 2\ \Omega$ and the voltage across it is 12V. Calculate currents I_1 , I_2 and the total current I_T across the circuit.

CHAPTER 10

10.0 MAINTENANCE OF OVERHEAD LINES

OBJECTIVES: At the end of the class participants would be able to

- a. Carry out routine inspection of overhead lines
- b. Identify some inspection techniques
- c. Carry out preventive and repair maintenance of overhead lines.
- d. Understand Maintenance Management
- e. Identify faulty components of the overhead lines.

INTRODUCTION: For maintaining continuity of supply through overhead lines, regular maintenance is essential. Maintenance work pertaining to the overhead lines consists of the following:

- i. A pre-planned routine inspection followed by necessary preventive maintenance.
- ii. A special inspection, usually before the difficult operating periods of the system (such as before monsoons), followed by the preventive maintenance.
- iii. An emergency inspection, after each interruption of supply (power supply), to locate the fault, followed by necessary repairs.

Process in maintenance:

- ✓ Identify old and failing equipment and targeting it for replacement. Equipment deteriorates over time. Several rural enterprises have increasingly older infrastructures. Equipment fails at varying rates over its lifetime.
- ✓ Do restoration (e.g. when storms knock lines and equipment down, and crews put them back.
- ✓ Do tracking equipment quality and failures (to help improve the reliability of MV network). For overhead MV line, most failure causes are external but still tracking equipment failure and targeting bad equipment help the operator to maintain the service. It should be noted that failure occurs in clusters: particular manufacturer, particular models, and particular manufacturing years.
- ✓ Identify non proper application of equipment to prevent overloading equipment excessively and to apply good surge protection.
- ✓ Elaborate inspection program.

Inspection techniques used for distribution line:

- ✓ Visual inspections (drive-by): find severely degraded poles, broken conductor strands, and broken insulators.
- ✓ Infrared thermography
- ✓ Wood pole test: e.g hammer test
- ✓ Operations count (recloser, arrestor, regulator tap changer etc)
- ✓ Oil test.

10.1 ROUTINE INSPECTION AND MAINTENANCE OF OVERHEAD LINES:

All overhead lines should be patrolled regularly at ground level while the line is alive. There are varied opinions as to the number of line patrols which should be carried out each year. Many engineers are of the opinion that HV lines should be patrolled every month while others 3 or 4 times a year. On HV lines of major importance, frequent patrolling may be desirable, but on LV lines, less frequent patrolling is necessary.

The patrols recommended are ground inspections using field glasses for the examination of any parts above normal height. The principal items to be noted on patrols are the condition of supports, cross arms, insulators and fittings, conductors and earth wires, guys and their accessories, foundations, anti-climbing devices, infringement of clearances by trees, buildings, haystacks etc., gang-operated (GO) switches fuse unit on 11kv lines and lightning arresters.



Figure 1 Engineers patrolling and inspecting a HT line

The purpose of the inspection is

- to check the circumstance of the on-site distribution facilities and the environment surrounding them and
- to check the existence of any abnormalities on them at present time and in the future.
- To determine what tools, materials and manpower needed to ensure continuous smooth operations

It is very important to keep the record, in order to make it the fundamental data of planning and execution. There are 2 (two) kinds of maintenance management;

- **Management over the whole thing;** in order to grasp the progress for the overall plan and to check the record.
- **Management of individual activity;** in order to record the result of every individual activity.

The inspection work has to be precise and accurate, to strongly decide the necessity of replacement or repair work for each facility and also, to grasp the priority and expected effect of the work. These are useful to organize the reasonable and effective maintenance work plan.

The maintenance work in the broad sense is executed in the following way.

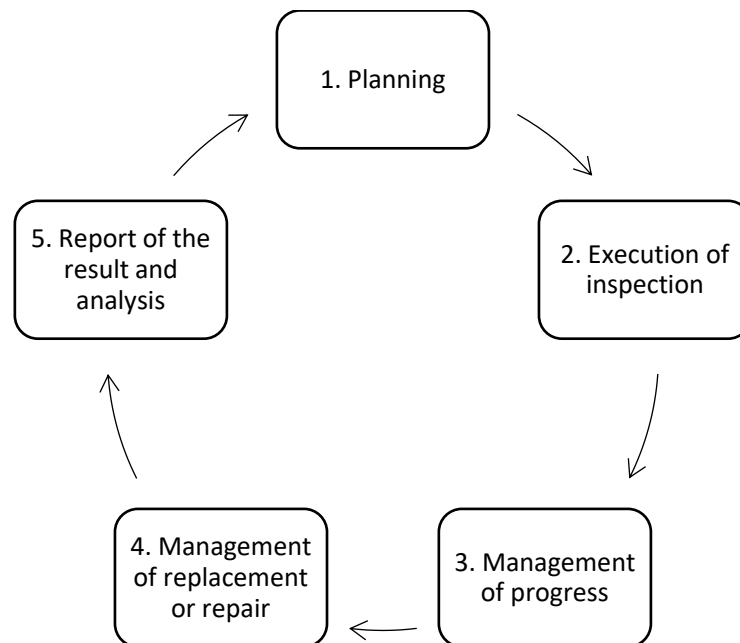


Figure 2 Maintenance Work Cycle

1. Planning

The maintenance work in the broad sense should be done reasonably and smoothly, based on the related information from a long-term and wide perspective, including the regional characteristic and deterioration tendency of facilities.

2. Execution of inspection

Inspection work should be done in order to find the defective parts of the facilities, and grasp the deterioration circumstance of distribution facilities. If the extent of deterioration is slight enough, it is desirable to be replaced or repaired at once. The rest of the deterioration found has to be incorporated in the plan of replacement or repair, and the replacement or repair work has to be carried out as early as possible. The deteriorated facilities which cannot be replaced or repaired early have to be controlled properly so that no one forget that the facilities have to be replaced or repaired.

3. Management of progress

On a monthly basis, it is necessary to check if there is any progress delay in the plan of inspection work and the result of the check is to be reported to the verifier. If there exists any delay, the measure(s) to make up for it must be developed/chosen and executed quickly.

4. Management of replacement or repair

On a monthly basis, it is necessary to check if there is any progress delay for the deadline of replacement or repair and the result of the check is to be reported to the verifier. If there exists any delay, the measure(s) to make up for it must be developed/chosen/selected and executed quickly.

5. Report of the result and analysis

The whole maintenance work result of the year should be reported to the verifier, and the route or the effect of the inspection have to be analyzed. The analysis result becomes the basis of the next year's maintenance work plan so that the inspection work can be done more efficiently.

10.2 SUPPORTS:

The supports may be wooden metallic or plain cement concrete (PCC) or reinforced cement concrete (RCC). The wooden poles should be checked for correct alignment and also the underground portion of the pole should be checked to verify that it is healthy and not eaten by termites, the pole and the adjacent soil must be carefully examined for evidence of termite infestation. In case of metallic supports the condition of the concrete foundation should be examined for possible damage. If any soil erosion is noticed at the foundation, it should be set right by earth filling and ramming to prevent the pole from tilting/falling. The PCC/RCC poles should be checked for cracks. Cracks due to ageing, thermal stress or other factors on support (i.e pole) constitute a potential hazard. If some kind of cracks is overlooked, the pole might collapse and lead to the disaster to the workers or even to the public, in the worst case



Figure 3 Cracked Electrical Poles

The below pictures depict the worst-case scenario if quick interventions are not taken



Figure 4 Falling Poles due to unattended cracks

10.3 CROSS-ARMS:

Wooden cross arms should be checked for tilting and/or decaying owing to rot while the metallic cross-arms (Channel iron) should be checked for tilting and rusting. Cross arms are also frequently used by birds (like the White Storks, ravens, magpies etc) for perching, roosting and nesting. The cross-arms should be checked for birds' nests and cleared



Figure 5 Bed Nesting on Pylons

10.4 INSULATORS AND FITTING:

Insulators and fitting should be checked for the defects such as

- (i) Accumulation of dust, coal etc. on insulators
- (ii) Burnt and fused spots on the insulator glaze
- (iii) Broken and chipped porcelain
- (iv) Tilted insulators and
- (v.) Rusting of fitting



Figure 7 Tilted Insulator

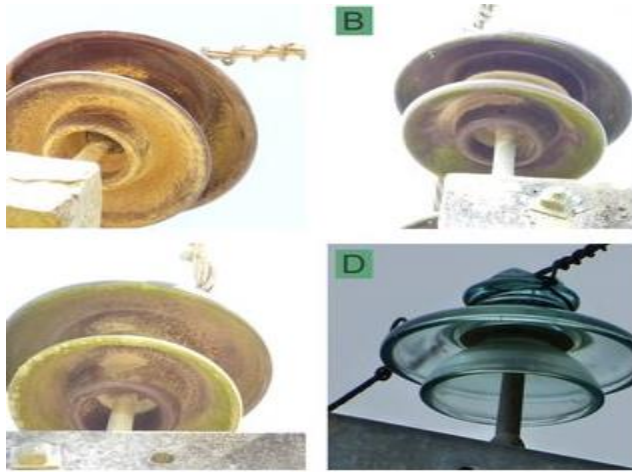


Figure 6 Cracked Insulator



Figure 8 Dust Contaminated Insulator

Figure 9 Chipped and Rusted Porcelain

Damaged insulators should be replaced, tilted insulators set right and dirty insulators cleaned but after disconnecting the line from supply.

10.5 CONDUCTORS AND EARTH WIRES:

Using stabilized binoculars, the conductors must be inspected throughout their length for broken, burnt or unraveled strands, or foreign objects such as kites, sneakers or fence wire. Particular attention is to be given to the evidence of rust on steel and steel cored conductors, the associated tie wires, armour rods and dead-ends



Category	Description	Defect priority
1	No corrosion, 100% galvanized	No action required
2	Light surface corrosion with negligible pitting	No action required
3	Medium surface corrosion with mild pitting	Reassess next inspection
4	- Heavy surface corrosion with mild to medium pitting - Annealing or thinning of conductor	Replace within 1 year
5	- Heavy surface corrosion with medium to heavy pitting - Heavy surface corrosion with history of conductor failure	Replace within 3 months or prior to the commencement of the dry season whichever is earliest

Note - This applies to overhead steel conductors with any number of strands

Figure 10 Steel conductor condition/corrosion categories

Clearance of phase wires and earth wires to ground, clearance between phase wires and that between the various phase wires and the earth wire should be checked, also clearance between phase wires and building or vegetation should be checked to verify they are within prescribed limits under IE rules. In case if any discrepancy is noticed, the sag should be adjusted and any foreign object found on the conductors or earth wire should be removed but after disconnecting the line from the supply and it is important that buildings are not too close to power lines' path to prevent the conductor from touching the building and causing earth fault or preventing people from touching live conductors



Figure 11 Structures too close to Distribution Tower

Conductor too close to the balcony that the resident can reach the live conductor quite easily which is very dangerous.

10.6 CONDUCTOR FITTINGS AND JOINTS:

Defects to be noted are

- (i) Broken strands
- (ii) Burnt jumpers and loose fittings PG clamps
- (iii) Looseness of binding on insulators and at joints and
- (iv) The slipping of conductor from the insulator seat

Broken strands should be repaired by providing aluminium conductors repairs sleeves, burnt jumpers should be replaced and loose fitting of clamps should be tightened, slipped conductors should be placed on the insulators and bound again but after disconnecting the line from supply

10.7 GUYS/STAYS AND THEIR ACCESSORIES

These should be checked for the following defects.

- (i) Loose guys
- (ii) Broken or chipped guy insulators
- (iii) Corrosion of guy rods
- (iv) The condition of the guy anchoring
- (v) Earthing arrangement of guys, broken or missing.
- (vi) Low Height of Guy-wire (Not too low)



Figure 13 Stay Wire

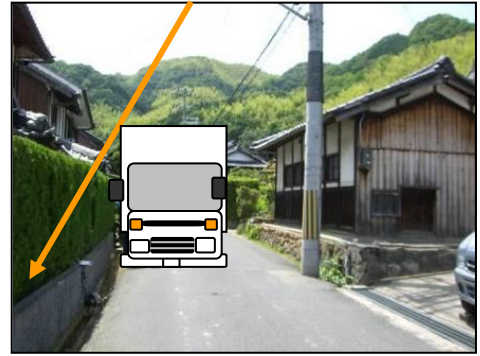


Figure 12 Short Stay wire affecting vehicular movement

Loose guys should be tightened, guy anchoring should be filled with earth, broken guy insulators should be replaced and earthing arrangement should be restored.

10.8 G.O SWITCHES AND FUSES UNIT:

Checking should be made for the defects such as

- (i) Missing or broken earth wire
- (ii) Defective switch
- (iii) Cracked or overheating of contacts.
- (iv) Damaged arching contacts and
- (v) Burning or overheating of contacts.
- (vi) Rusting

Adjustment should be made for contact alignment and adequate contact pressure. Damaged contacts should be replaced/repared, earth connection, if broken, should be restored; bearings should be lubricated for correct and smooth operation of the moving parts. Attention should be paid to rust; Rust makes holes on the body of switchgear or around the bushing and let water in which may cause earth fault or short circuit.



Figure 14 Cracked and rusted body which is a potential point of water ingress into the switchgear

10.9 LIGHTNING ARRESTERS:

It should be ensured that the line lead of the lightning arrester is firmly connected with the phase wires, the earth connection is tight and the earth resistance of earth wire is below 10 ohms. Cracks on lightning arrester maybe an indication of the frequency of activities on it which will often an indication of when a replacement should be made. Arresters are irreparable and should be changed if cracks are observed

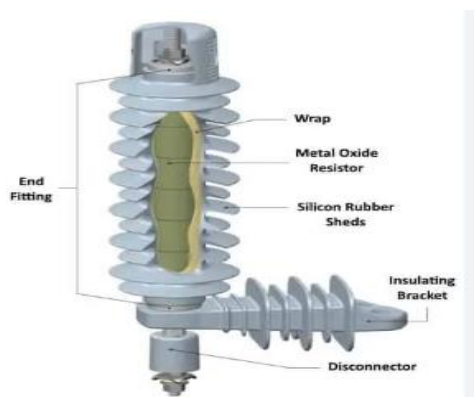


Figure 15 Cracked Lightning Arrester

10.10 TREE CLEARANCE:

Trees or branches coming close to the lines should be trimmed/removed-a minimum clearance of 1.8m should be maintained on each side of the line but after disconnecting the line from supply.

Indicators of vegetation clearance breach:

1. Bare conductors that are in contact with vegetation;
2. Covered conductors that are touching heavy branches that are likely to cause insulation damage to the conductor;
3. Branches laying across bare mains;
4. Branches applying downward pressure to services creating over-tension.



Figure 16

Vegetation clearance breach

10.11 TRANSFORMERS (POLE OR GROUND MOUNTED)

Transformers should be checked for at least the following defects,

- i. Too much rust on the body
- ii. Crooked cover
- iii. Cracked bushings
- iv. Airtight deterioration
- v. Trail of thunder

Rust on transformers' bodies has to be inspected carefully, because some kind of rust might lead to a hole on the body, causing the transformer tank to leak the insulating oil out onto the ground. This has adverse environmental implications.

[Rank A] Black rust is generated on body of transformer. Where on the body does not matter. Transformers having this black rust must be replaced as soon as possible.



[Rank B] Reddish brown rust is generated on bottom plate or heat radiating plate of transformer (Black rust might be generated locally so inspection should be done very carefully). This kind does not have to be replaced immediately but have to be observed continuously.



[Rank C] No rust is generated on bottom plate, and some reddish brown rust is generated other than on bottom plate.



No rust on bottom plate

For example, the priority of replacement can be classified into 3 ranks, A, B, and C. Generally black rust easily breaks and becomes a hole, so transformers which have black rust must be replaced as soon as possible.

10.12 EMERGENCY INSPECTION:

Whenever any overhead line trips and the fault sustains, such inspection is required to be carried out to locate the fault and determine the nature of fault. Such faults may be loose sag, snapping of conductors, conductors falling on cross arms, tree branches coming over the lines, birdage etc. The necessary repairs should be carried out and remedial measures be taken so that the reoccurrence of such faults may be avoided.

10.13 SPECIAL INSPECTION:

Such inspections of lines are required to be carried out before and after the monsoon/heavy rains because interruptions and breakdowns on overhead lines are usually more frequent during the rainy season owing to rains and thunderstorms. Any defect(s) noticed during inspection should be removed/set right.

10.14 WHERE TO PAY ATTENTION ON PATROL AFTER OUTAGE

Power Outage: Is the loss of electrical power to the consumer. Outages can be classified as follows

- A partial outage describes a component state where the capacity of the component to perform its function is reduced but not completely eliminated.
- A total outage is an outage where the component is completely incapable of performing its functions.
- A forced outage is an outage that result from emergency conditions directly associated with a component, requiring that component be taken out of service immediately, either automatically or as soon as switching operations can be performed or an outage caused by improper operation of equipment or human error.
- Planned outages are outages due to planned or scheduled maintenance when a component is deliberately taken out of service at a selected time, usually for purposes of construction, preventive maintenance or repairs
- Emergency outages: arises from loss of power supply from the generating station either due to inadequate generation or drop in the load coordination frequencies. The normal frequency is 50Hz.

When patrolling after the outage incident(s), it is very important to understand the situation well, to prevent disasters to the public or to yourselves, and to make every effort for quick restoration. Information can be provided not only from the distribution division, but also from transmission company or customer care division.

What should be had before the patrol includes but not limited to the following;

- Tripping date and time
- Substation and feeder
- Relay indication
- Phase of the fault
- Information from customers
- other

Where to pay attention on patrol after outage includes the following;

■ On conductor

- a. Breaking of conductor, touching the other phase, abnormal sag
- b. Damaged insulator, crack or discoloration on insulator
- c. Damaged instruments on poles, such as
 - Damage or discoloration on bushing
 - Oil leaking
 - other
- d. Trace of arc on accessories

■ Near conductor

- a. Objects on the ground such as dead animals, fragments of damaged insulator, etc.
- b. Flying objects having conductivity such as tin, iron string, animal, etc.
- c. Vegetation or building close to conductor
- d. Construction work beneath conductor

Here are some examples of major and frequent cause of forced outage incidents. They will help you find where to pay attention on patrol in order to find the fault point quickly.

1. Thunder and lightning

By thunder and lightning, insulators or other facilities get damaged and conductors get broken.





2 Natural disasters

(1) Collapse of trees

Trees that collapsed are fallen on conductor. They break the conductor and the current leaks out via the trees or metal band on the pole and causes earth faults. They also cause short circuit via their bodies.



Trace of the leaking current

(2) Rain and Flooding

Heavy rainfall can cause flooding in certain locations in the country. Floods may cause damage to electrical equipment which in turns lead to earth faults and short circuits. To prevent major damage, The utility may often need to shut the equipment down, affecting service to some customers.

(3) Wind

High winds may cause objects, such as fallen trees, to come in contact with power lines. If that happens, circuit breakers or other protective equipment will shut off the flow of power. Wind may also blow tree limbs or entire trees onto the power lines, causing the lines to fall to the ground, or breaking the lines and poles.

2. Traffic accidents

(1) Cars crash into poles and break them.

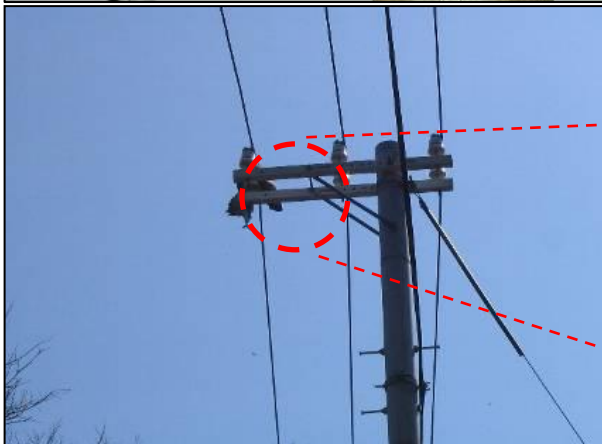


(2) Heavy machineries operated incorrectly break poles or other facilities.

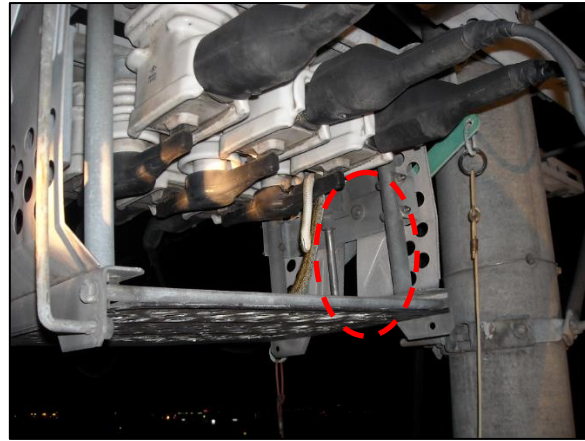


3. Small animals

(1) Birds pecking the conductor get electric shock and cause earth faults via their bodies.



(2) Snake trying getting into the insulator covers on the pole or moving inside the switchgear touches the conductor.

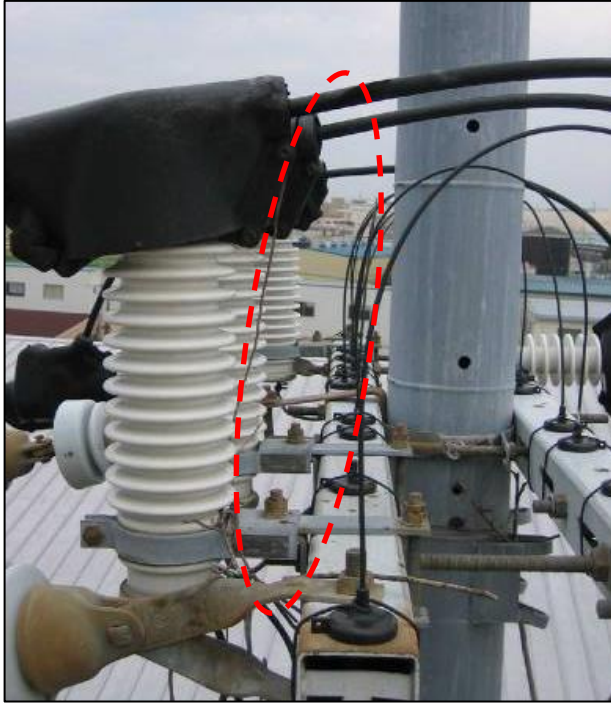


4. Other object

(1) Bird's nest on switchgear or other accessories touching the energized bushing causes earth fault.



(2) Small iron string or tree branch, dropped by a bird or blown by wind, bridge between the conductor and the metal accessories.



(Small iron string)

6. Vandalism

This has been a major concern as one of the causes of poor power supply, vandalism of gas pipe line, electrical towers and electrical network element has been the biggest challenge the power sector is facing. This has caused massive blackouts across major cities and town in the country



SAMPLE QUESTIONS

- Q1. Explain how routine inspection of overhead line is carried out.
- Q2. Briefly explain the terms Emergency Inspection and Special Inspection.
- Q3. Itemize any Ten (10) principal components to be noted when patrolling overhead lines.
- Q4. List the defects to be noted on conductor fittings and joints during patrol of overhead lines.

CHAPTER 11

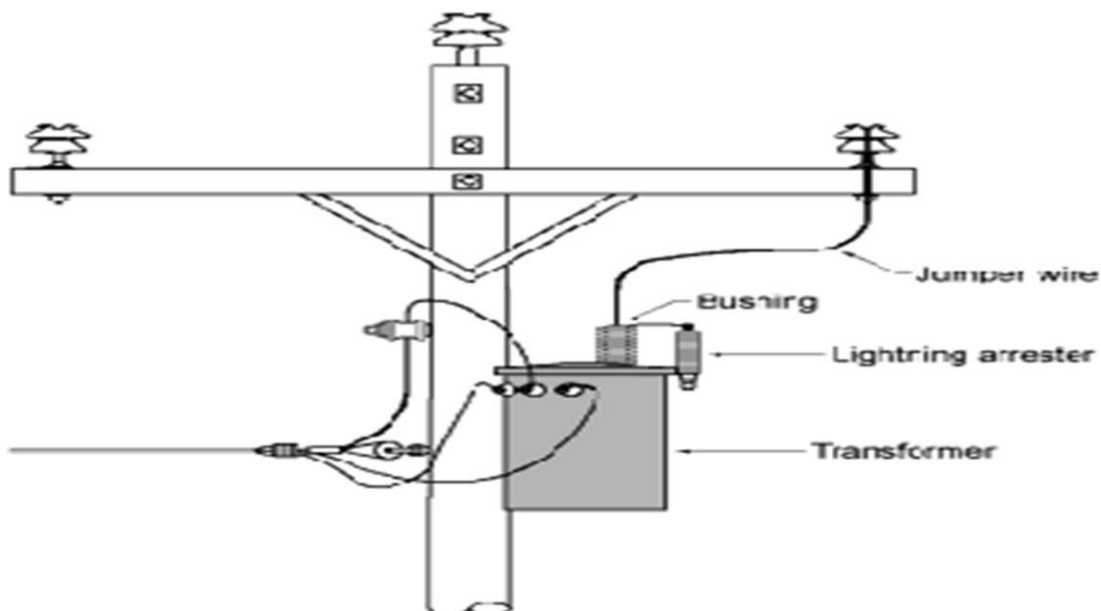
11.0 LIGHTNING ARRESTER

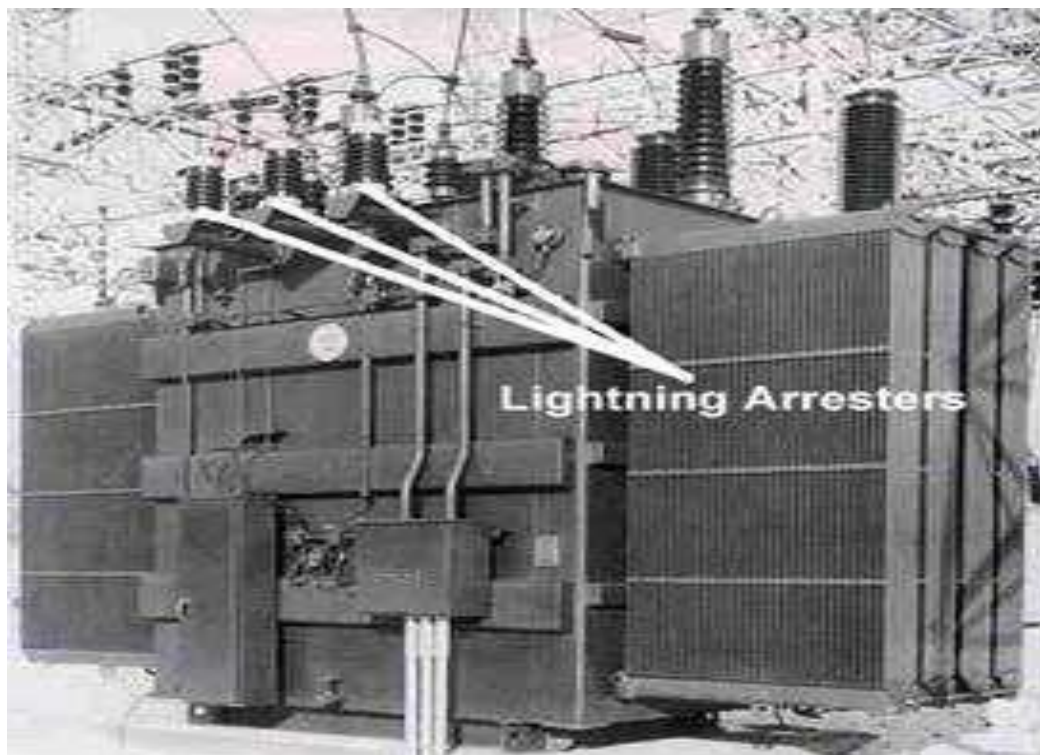
OBJECTIVES: At the end of the lesson participants would be able to

1. Explain what lightning arrester is
2. State its application in the network
3. Explain its function in the network
4. Describe the types of lightning arresters used in the network.
5. Explain its working principles.

INTRODUCTION: [Lightning arresters](#) are protective devices for limiting surge voltages due to lightning strikes or equipment faults or other events, to prevent damage to equipment and disruption of service. Also called surge arresters.

11.1 Installation: Lightning arresters are installed on many different pieces of equipment such as power poles and towers, power transformers, circuit breakers, bus structures, and steel superstructures in substations. The arrester should be connected to ground to a low resistance for effective discharge of the surge current. The arrester should be mounted close to the equipment to be protected & connected with shortest possible lead on both the line & ground side to reduce the inductive effects of the leads while discharging large surge current.

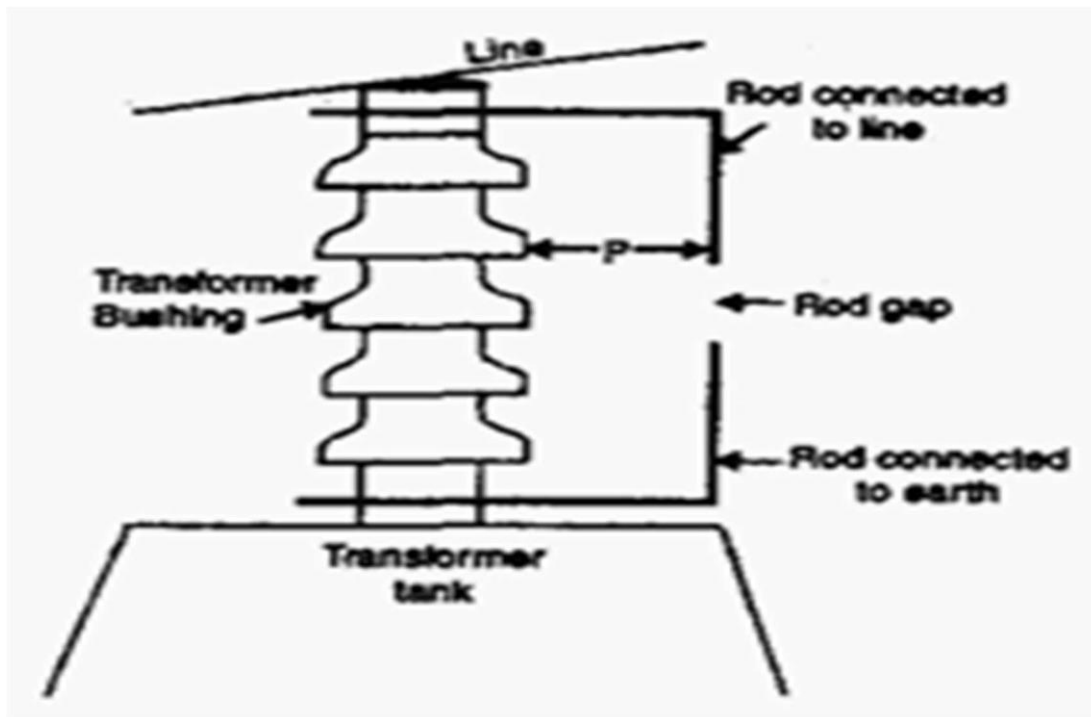




Lightning Arresters



Classification of
lightning arresters



11.2 Types of Lightning Arresters:

i. Horn Gap Arresters - Horn gap arresters are named for their two horn-shaped metal rods. These rods are arranged around a small air gap, and the distance between the two rods increases as they rise from the gap. The rods are placed on porcelain insulators.

The horn is connected to two different wires: One attaches to the electrical line. Between it and the horn is a resistance and a choke coil. The resistance regulates the level of current allowed into the arrester at once, and the choke coil increases the reactivity of the arrester when transient frequency occurs. The other wire is connected to a ground, which siphons the excess electricity to the ground.

ii Multi-Gap Arresters - Multi-gap arresters are made from a series of metal cylinders. These cylinders are all insulated from one another as well as separated by air gaps. The first cylinder gets connected to the electrical line, while all of the other cylinders are attached to the ground through a series resistance, which gradually wears down the power of the current. Some of the gaps between the later cylinders have a shunt resistance that catches a surge when there is an excess of voltage.

iii Valve-Type Arresters - Valve-type arresters are commonly used in more high-powered electrical systems. They consist of two main parts: a series of spark gaps and a series of non-linear resistor discs. Valve-type arresters work when excessive voltage causes the spark gaps to

touch, and the non-linear resisters carry the voltage into the ground. Once the surge of excess power ends, the resisters push the spark gaps apart.

iv. Pellet-Type Arresters - Pellet-type arresters are made up of glass tubes filled with lead pellets. The pellets are made from an interior of lead peroxide coated by lead oxide. Lead oxide is not strongly conductive; lead peroxide is. When the lead oxide is heated, it becomes lead peroxide, giving the current a place to flow. After the current is transferred, the lead peroxide changes back to lead oxide. This type of arrester is no longer widely used.

11.3 How It Works: When a surge of electricity such as a lightning strike hits an electrical system, it naturally seeks a way to equalize and dissipate itself as quickly as possible, taking the path of least resistance. A resistor provides the most efficient route for the surge by diverting the electricity away from the equipment's insulation and channeling it into the ground via grounding rods.

In order to do this, the resistor uses a metal oxide varistor (MOV), which is a component with a diode-like nonlinear current-voltage characteristic that is triggered when voltages reach sensitive levels. Specifically, the varistor's symmetrical, sharp breakdown characteristics allow it to achieve a high level of transient electrical suppression performance. The word "varistor" is a portmanteau that combines "variable" and "resistor."

11.4 Grounding Techniques: In order for the lightning arrestor to be effective, it needs to have a proper channel to the ground outside. Soft, moist clay soils tend to be the best for grounding, although other types of soils may also work, albeit less effectively. The key is to ensure that the soil's resistance level is as low as possible in order to allow the surge to dissipate quickly before damage is caused.

In addition, it is important to make sure that the grounding rods are connected by a heavy solid copper wire, are placed at least 10 feet apart from each other, and are approved by Underwriters Laboratories (UL), a nationally recognized, nonprofit safety-testing agency.

11.5 Places They Are Used: Lightning arrestors can be attached to residential electric equipment such as power boxes in order to protect home wiring, household appliances, watt-hour meters and personal computers. Industrial applications include power substations, oil rig drilling equipment and water well motors, while popular commercial uses range from television antennae arrays to radio tower lights and transmitters.

Arrestors can vary greatly in their capacity to withstand surges. On average, industrial and commercial lightning arrestors can withstand a greater number of surges, stronger maximum current and higher energy level than residential arrestors.

Sample Questions

Q1. What is lightning arrester?

Q2. Explain where lightning arresters are installed in distribution network.

Q3. List Four (4) types of lightning arresters and explain any One (1) of them.

Q4. Briefly explain the Grounding Techniques of a lightning arrester.

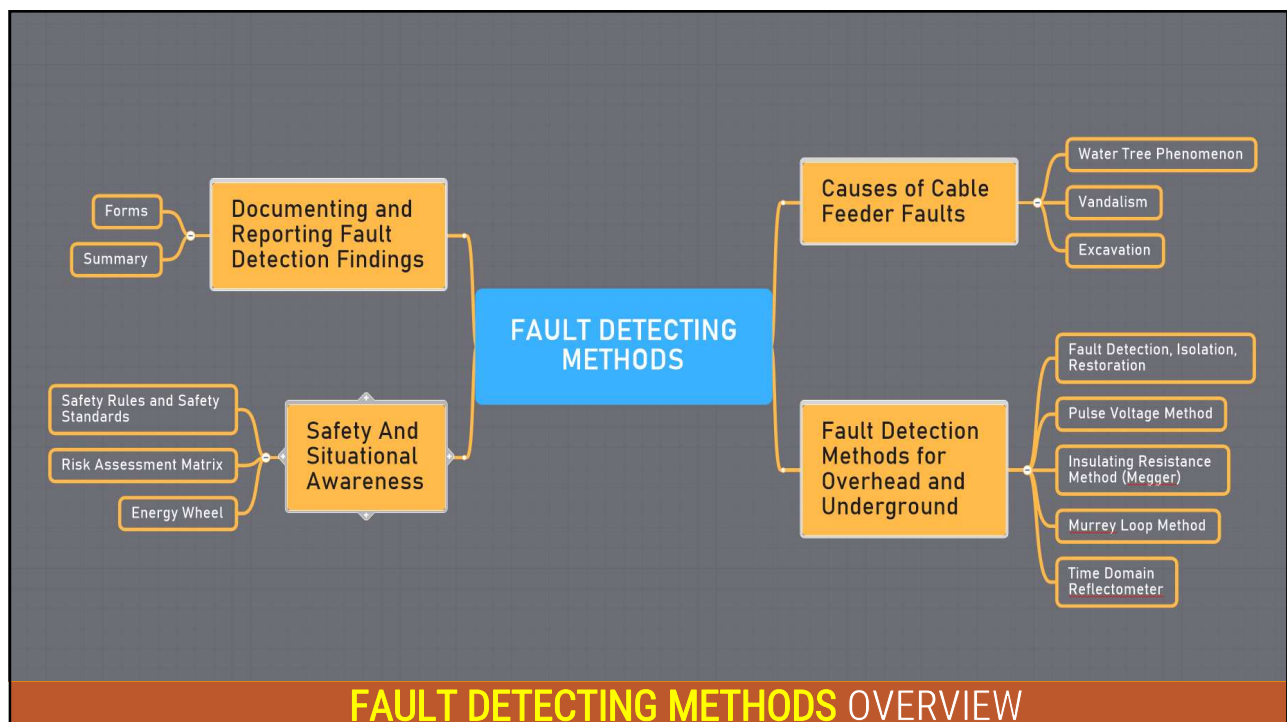
NATIONAL POWER TRAINING INSTITUTE OF NIGERIA



RELIABILITY IMPROVEMENT

Fault Detecting Methods

Engr. Chukwudum Okeke



Fault Detection Methods

LEARNING OBJECTIVES

- Discuss the Causes of faults in Power Distribution Feeders
- Discuss the theory behind the Fault Detection Methods
- Prioritize safety and situational awareness when utilizing fault detecting equipment
- Effectively Communicate fault detection findings in a concise manner



CAUSES OF UNDERGROUND CABLE FAULTS

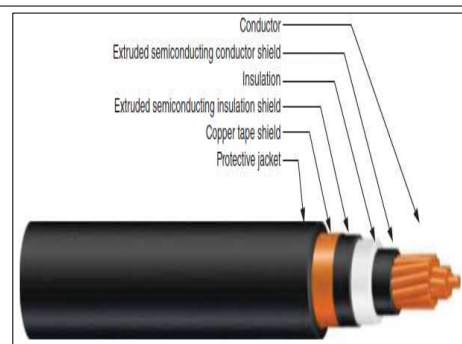
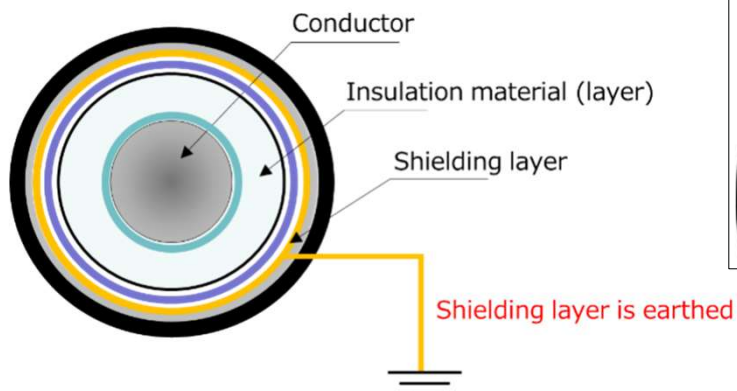
CAUSES OF UNDERGROUND CABLE FAULTS LEARNING OUTCOMES

- Discuss the different parts of a U/G cable
- Discuss the causes of faults in Underground Cables
- Describe the Water Tree Phenomenon



PARTS AND FEATURES OF POWER CABLES

STRUCTURE OF CV(T) Cable



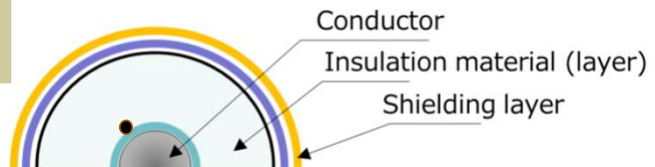
The CV cable (Cross-linked polyethylene insulated with Vinyl sheathed cable) The main insulation is composed of the solid organic material XLPE.

CAUSES OF UNDERGROUND CABLE FAULTS

WATER TREE PHENOMENON

[How does it happen?]

(1) Due to the manufacturing process or malfunction during cable installation, foreign substance (such as water) or gap appear in the insulation layer.

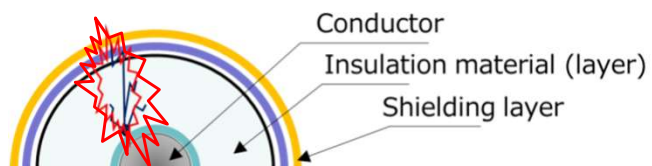


CAUSES OF UNDERGROUND CABLE FAULTS

WATER TREE PHENOMENON

[How does it happen?]

(6) Finally insulation between the conductor and the shielding layer gets broken down, and the earth fault on the cable occurs.



CAUSES OF UNDERGROUND CABLE FAULTS

VANDALISM

Vandalizers destroy the conduit to steal the cable in order to get money by selling the metal (copper).



CAUSES OF UNDERGROUND CABLE FAULTS

EXCAVATION, VEHICLES

In excavation sites, underground cables sometimes unintentionally get damaged by workers or heavy machineries. This activity can cause a gradual deterioration of cables or immediately lead to a fault.



CAUSES OF UNDERGROUND CABLE FAULTS

Summary

1. Power Grids are not fault proof
2. faults in overhead lines and underground cables occur principally due to failure of insulation. This failure is experienced as either a ground fault or a short-circuit
3. Underground Cables are prone to faults caused by Water Tree Phenomenon
4. Vandalism, Excavation and vehicular activity contribute to Faults in O/H and U/G Cables
5. water blocking measures are already in place when a cable is deployed, providing protection from moisture from the moment of installation. However, care must be taken during installation to ensure that cable ends and joints are properly sealed to prevent longitudinal water ingress.

Summary CAUSES OF UNDERGROUND CABLE FAULTS



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LEARNING CHECK -> CAUSES OF UNDERGROUND CABLE FAULTS

REFERENCES & FURTHER READING

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Fault detecting methods

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Pre-Diagnostic Questionnaire -> FAULT DETECTING METHODS

Fault detecting method (overhead/underground) at distribution voltage level (33kV and 11kV)
LEARNING OUTCOMES

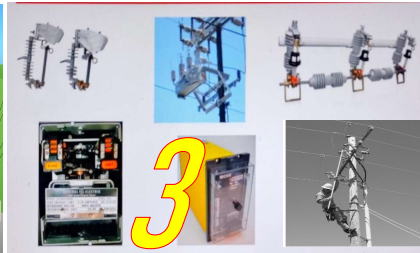
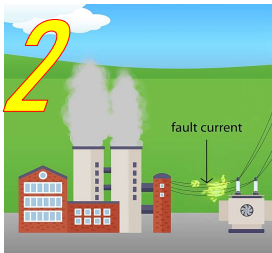
- State some fault detecting Methods for overhead and underground distribution systems
- Discuss the theory behind some fault detection methods
- Describe the role of Fault Detection In Reliability Improvement



THE PROCESS OF DETECTION AND ISOLATION BEFORE RESTORATION



When a fault occurs on the grid, protective relays act to detect the fault and then cause protective switchgear to isolate the portion of the grid where the fault occurred.

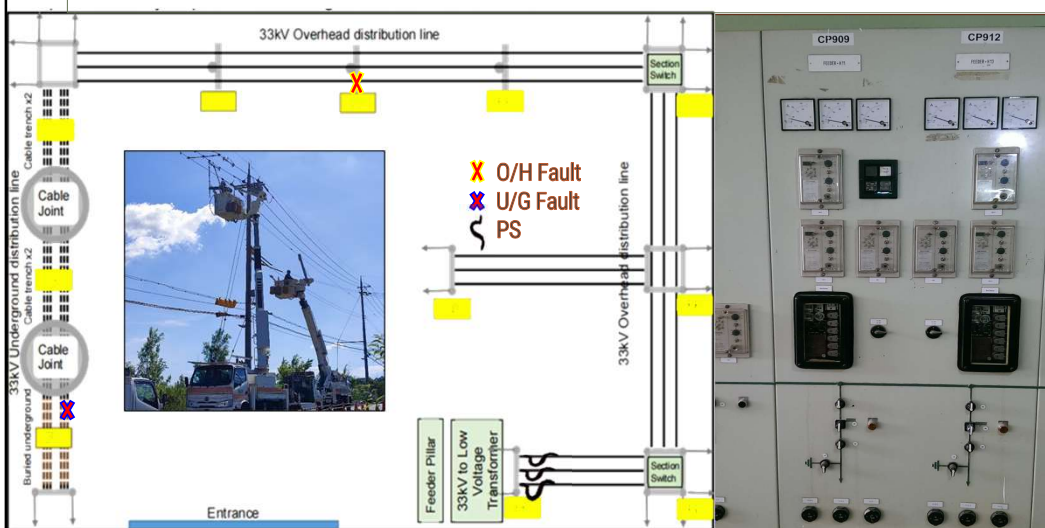


Protective Switchgear (PS) are Automatic switchgear, reclosers, fuses, Circuit Breakers.



Fault detecting method (overhead/underground)

THE PROCESS OF DETECTION AND ISOLATION BEFORE RESTORATION



Fault detecting method (overhead/underground)

FAULT DETECTING BY PULSE VOLTAGE APPLYING ("HIPOTRONICS")



Portable-type pulse voltage applying devices

On-vehicle-type pulse voltage applying devices

One tool used to obtain a near-fix on the exact location of the fault is the hi-pot tester. A hi-pot tester checks for good isolation between all phases and between phases and ground.

This usually works by using a pulse voltage applying device to apply a high potential (hi-pot) voltage to the Section of the grid under test and determining the **leakage current** that may flow due to fault(s) on the grid.

Methods for Fault detection

FAULT DETECTING BY PULSE VOLTAGE APPLYING ("HIPOTRONICS")

1. ALWAYS FOLLOW ESTABLISHED COMPANY WORK RULES and procedures including JHAs!

2. Protective Device has tripped and distribution office (DSO) has communicated the faulted section to the field.

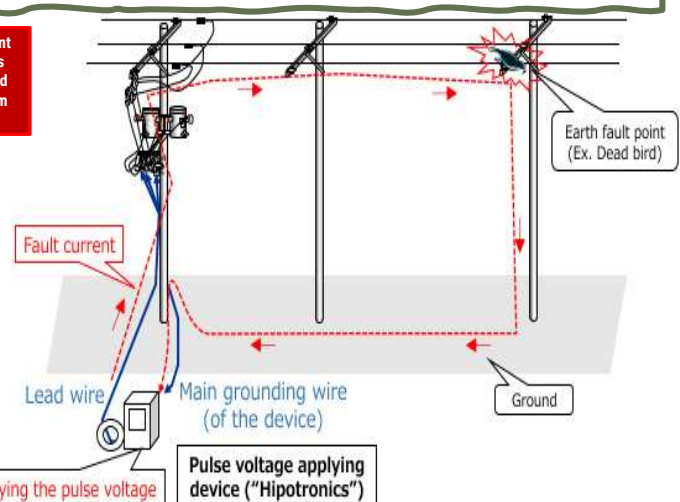
3. all equipment or Cable that is not to be tested is isolated from the circuit

4. Connect the ground lead of the HIPOT Tester to a suitable building ground or grounding electrode conductor. Attach the high voltage lead to one of the isolated circuit phase conductors.

5. Switch on the HIPOT Tester. Set the meter to voltage required by applicable standard. Push the "Test" button on the meter and after one minute observe the milliampere reading. Record the reading for reference.

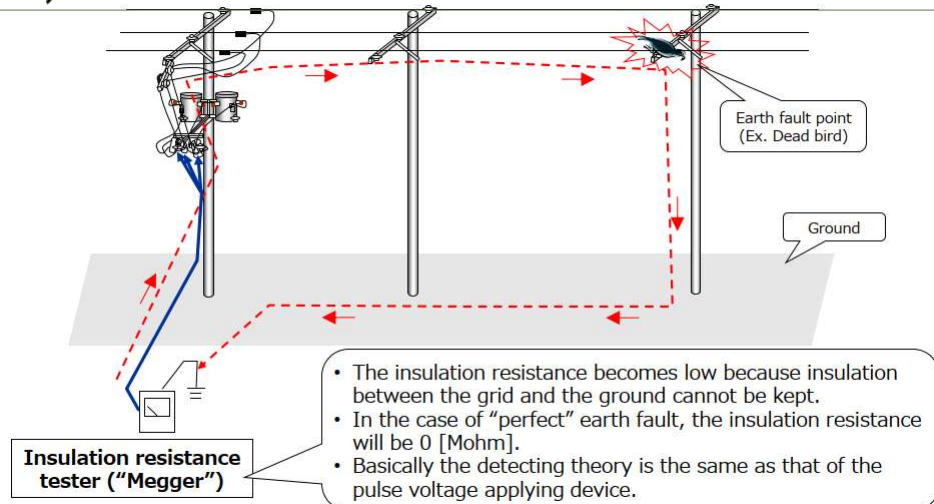
6. At the end of the one minute test, switch the HIPOT Tester from the high potential test mode to the voltage measuring mode to confirm that the circuit phase conductor and voltage of HIPOT Tester are now reading zero volts. Repeat this test procedure for all circuit phase conductors testing each phase to ground and each phase to each phase.

The presence of leakage current coupled with less than satisfactory IR values indicates the presence of a fault in the phase conductor



Methods for Fault detection

FAULT DETECTING BY INSULATING RESISTANCE ("MEGGER")



Methods for Fault detection

3. FAULT DETECTING BY "MURREY LOOP METHOD"



Power source



Bridge circuit (Digital type)



Bridge circuit (analog type)

This method involves **measuring** some electrical characteristics of the faulted conductor from one of the cable terminals and **COMPARING** it with unfaulted conductor characteristics in terms of **the distance of the fault**.

This method does not pin-point the fault but it localizes the fault. Also, it is ineffective on open faults.

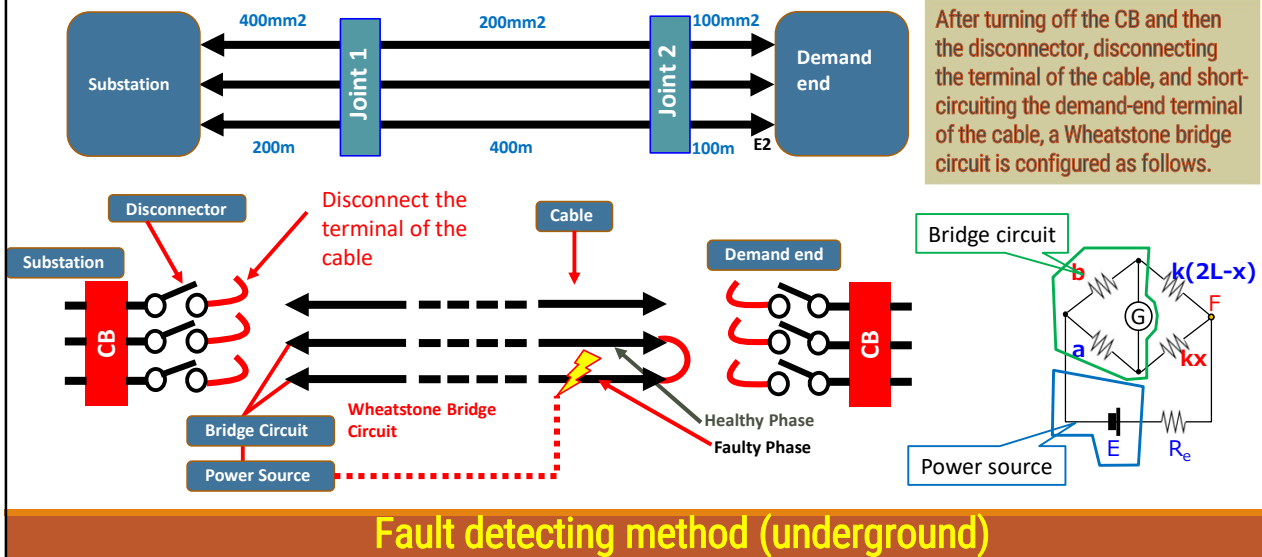
After measurements, the distance to the fault point can be **calculated** based on the balancing condition of "Wheatstone bridge circuit".

SAMPLE PICTURES OF MEASURING INSTRUMENTS

Fault detecting method (underground)

3. FAULT DETECTING BY "MURREY LOOP METHOD"

ILLUSTRATION ON MURREY LOOP METHOD OF CABLE FAULT LOCATION



IMPORTANT THINGS TO REMEMBER

When detecting the fault point, you have to pay attention to...

- The length that the devices can detect the fault point
- The threshold of fault current
- The readings from measuring devices depend on the specifications of the device, so follow the instruction from the manufacturer carefully before use otherwise you might make an incorrect detection, which will delay the restoration of the outage incident.
- After the restoration work, you should use the detecting device again and check that there is no fault current (which means there is no fault point any more).
- Because Murrey loop method needs a loop circuit at the fault point, this method cannot be applied if there is no healthy phase, or the healthy cable is breaking down
- Murrey Loop method is for underground cable faults

Fault detecting method (overhead/underground)

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LEARNING CHECK -> FAULT DETECTING METHODS



Safety and Situational Awareness



Safety and Situational Awareness

LEARNING OUTCOMES

- Recognize Safe Working Methods
- Demonstrate the use of energy wheel to recognize or anticipate hazards for last minute risk assessment
- Identify potential hazards by analyzing a Risk Assessment Matrix



Safety and Situational Awareness

Safe Working Methods

■ FIRST AID

Verify that the address and telephone number of the nearest ambulance, first aid center, or hospital are prominently displayed on the premises. Verify that the telephone to be used for emergency calls will be in service during the maintenance work. Have a First Aid Box.

■ LOCKOUT/TAGOUT (LOTO) PROCEDURE

Each employer shall document and implement lockout/tagout procedures to safeguard employees from injury while they are working on or near de-energized electric circuits and equipment.

The lockout/tagout procedures shall meet the requirements of the local authority.

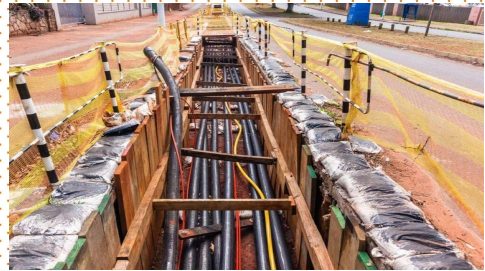
Lockout/Tagout Procedure

CALL OUT!!!!
INSPECT PPE AND TOOLS BEFORE WORK
TEST-BEFORE-TOUCH!+



Safety and Situational Awareness

- General Rules on Safety
- 3. Precautions should be taken to prevent accidental contact of live terminals by personnel, either by shielding the live terminals or by providing barriers around the area.



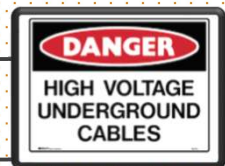
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Safety and Situational Awareness

- General Rules on Safety
- TEST AREA SAFETY PRACTICES

Appropriate warning signs, for example, DANGER – HIGH VOLTAGE, should be posted on or near the entrance gates.



Do not extinguish
with water



Danger: electricity



Safety helmet
must be worn



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Situational Awareness

WHAT IS SITUATIONAL AWARENESS?

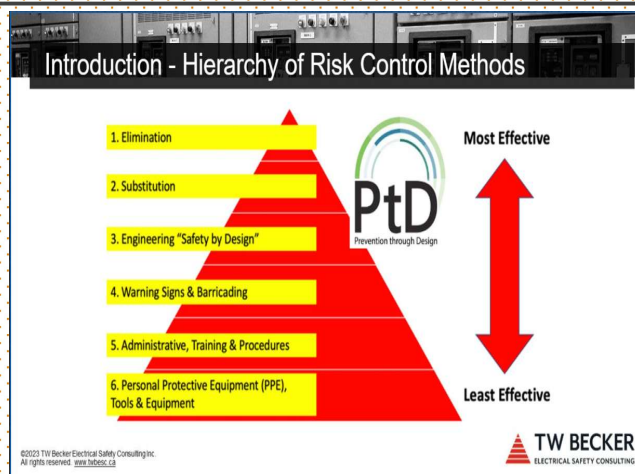
- Situational awareness involves being cognizant of the Critical Risk activities, the current environment, and potential changes that could affect safety and operations. It's about **understanding** what is happening around you to make **informed decisions** and **act effectively** in a safe manner.

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Situational Awareness

WHAT IS RISK ASSESSMENT?

- Risk assessment is a systematic process that involves identifying, analyzing and controlling hazards and risks. It is performed by a qualified person to determine which **measures** are, or should be, in place to eliminate or control the risk in the workplace in any potential situation.



?

Situational Awareness

5 STEPS TO PERFORM A RISK ASSESMENT

in order to make the most out of the tool and effectively identify risks and their possible controls consider the ff steps...

1. Identify hazards
2. Evaluate the risks
3. Decide on control measures to implement
4. Document and Communicate your findings
5. Review your assessment and update if necessary



EXAMPLE GENERAL & SPECIFIC RISK ASSESSMENT MATRIX



Situational Awareness

WHAT IS AN ENERGY WHEEL?



- In terms of injury prevention, an Energy Wheel is a visual tool used to identify the 10 sources of energy and to assess and control the hazards associated with each form of energy. It is a tool that helps utility workers heighten their awareness of energy sources on job sites that pose risk of injury.



Situational Awareness

WHAT IS AN ENERGY WHEEL?



Situational Awareness

How to apply the Energy Wheel on utility work sites



- **Pre-Work Safety Briefings:** Utilize the Energy Wheel during tailboard sessions to identify hazardous energy sources.
- **Individual Engagement:** Ask each crew member to point out an energy source from the Energy Wheel, enhancing hazard awareness.
- **High-Energy Hazards Focus:** Highlight the 10 high-energy hazards and assess their likelihood during the day's activities.
- **Job Hazard Analyses (JHAs):** Incorporate the Energy Wheel into JHAs to ensure a systematic approach to identifying risks.



Summary

1. Risk assessments should be carried out by qualified persons who are experienced in assessing hazard injury severity, likelihood, and control measures.
2. The communication of the risk assessment matrix is helpful for knowing how to act in hazardous situations, both as an individual and as part of a group.
3. Situational Awareness is essential for the initial identification of hazards which is the first step in risk assessment.
4. The Energy Wheel and the 10 high-energy hazards when applied consistently is an invaluable tool for improving situational awareness on utility sites and identifying more risks to workers.
5. The appropriate and effective use of LOTO procedures helps to control the risk posed by potentially damaging energy sources such as machine starting or sudden release



Summary SAFETY AND SITUATIONAL AWARENESS



Documenting/ Recording Fault Detection Findings



FORM # _____ ELECTRICAL EQUIPMENT SWITCHING & ISOLATION ORDER WORK CLEARANCE
Required when installing Temporary Protective Grounds on High Voltage Electrical Equipment

1. Pre-Job Planning / Preparation

Date of Work: _____ Location of Work: _____ Duration of Job: From: _____ To: _____
Description of Equipment: _____ Voltage: _____ TPG Set # _____
Scope of Work: _____
Name of Person(s) Completing this Form: _____ Affected Groups: _____
Lockout Authority & Phone Number: _____ Will Work Continue on Additional Shift: _____
2. Notification

Notify All Affected Personnel/Departments: ☐ YES ☐ NO If Yes, Who? _____

3. Equipment Needed (Mark the amount used for each)

List of Equipment: _____ Lockbox: _____ Personal Lock: _____ TPGs: _____ Applied TPGs Signs: _____

4. Electrical Isolation & LOTO

5. ISOLATION PROCEDURE ON BACK

Test For Absence of Voltage (e.g. Zero Energy) All Conductors & Circuit Parts

Test Instrument on Known Energized Source	Location	Time	Test on De-Energized Circuit	Location	Time	Re-Test Instrument on Known Energized Source	Location	Time

6. Applying Temporary Protective Grounds; Remember To Apply TPGs Signs

TPG Sets	Location of Temporary Protective Ground Sets & Signs	Time On	Time Off	Location of Applied TPG Signs	Initials

Documenting/Recording Fault Detection Findings

The test and inspection data obtained from fault detection methods has been traditionally recorded manually, but today with the computer based management programs much of data entry can be automated. Reports can be generated, stored and exported as software files for ease of use by relevant stakeholders.

Form A4 continued
Insulation tests:

	PCB Only		PCB and Leads or Leads Only	
	Megger	Hi-Pot Volt	Megger	Hi-Pot Volt
Closed breaker	_____	_____	_____	_____
A to ground	_____	_____	_____	_____
B to ground	_____	_____	_____	_____
C to ground	_____	_____	_____	_____
A to B	_____	_____	_____	_____
A to C	_____	_____	_____	_____
B to C	_____	_____	_____	_____

Print

Print All

Export

Share

FORMS



Summary

- Recording data from fault detection equipment is beneficial to reliability improvement
- Pooling data from various sources enhances analysis quality.
- Forms facilitate organized recording of data useful for analysis of fault detection findings.
- Manual recording of test and inspection data was traditional, but computer-based management programs automate data entry.
- Generated reports can be stored and exported for stakeholder convenience.

Summary Documenting/Recording Fault Detection Findings





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MAINTENANCE OF OVERHEAD LINES

Engr Mohammed Bashir O



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LEARNING OBJECTIVES

- Identify some inspection techniques
- Carry out routine inspection of overhead lines
- Carry out preventive and corrective maintenance of overhead lines
- Understand Maintenance Management
- Identify faulty components of the overhead lines



INTRODUCTION

- An Overhead Transmission Line is a very complex structure often spanning thousands of kilometers
- Subjected to huge electrical, mechanical and environmental stresses.
- It is hugely important for the continuity of supply through out the system
- Regular maintenance is essential
- Preventive maintenance is required to keep higher supply reliability



MAINTENANCE WORK OVERHEAD LINES ENTAILS

- A pre-planned routine inspection
- A special inspection usual before difficult operating periods
- An emergency inspection after supply interruption



MAINTENANCE PROCESSES

- Identify old and failing equipment and targeting it for replacement
- Do restoration
- Do tracking of equipment quality and failures
- Identify non proper application of equipment
- Carry out elaborate inspection program



INSPECTION GENERAL REQUIREMENT

- Authorization
- Duty of care
- Inspection
- Records and defects management



INSPECTION TECHNIQUES

- ✓ Visual inspections (drive-by):
- ✓ Digital mobile device
- ✓ Infrared thermography
- ✓ Wood pole test
- ✓ Operations count
- ✓ Oil test

Visual Inspection

- This is the simplest technique for identifying defects in equipment
- The inspection could be from the ground (drive by or walk through) or above using a binoculars/drones



Digital Mobile Device

- Web based applications that enable multiple users to go through assets inspections on multiple devices
- Streamline documentation work which is usually troublesome
- Makes inspection advanced and organize



Infrared Thermography

- Process by which thermal imaging infrared equipment is used to survey overhead transmission lines to examine the temperature rise of joints, terminations and defects of the associated equipment, including detection of a low/zero insulation insulator in the system.



Wood Pole Test

- It is important to determine the condition of the pole especially if its to be climbed.
- The weight of the employee, the weight of equipment being installed, and other working stresses (such as the removal or can lead to the failure of a defective pole



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PURPOSE OF INSPECTION

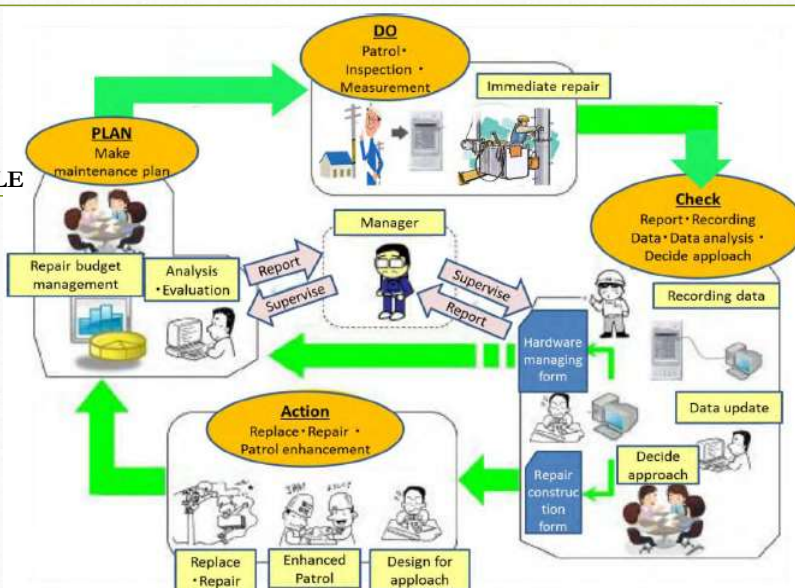
- To check the circumstance of the on-site distribution facilities and the environment surrounding them and
- To check the existence of any abnormalities on them at present time and in the future.
- To determine what tools, materials and manpower needed to ensure continuous smooth operations
- It is very important to keep the record, in order to make it the fundamental data of planning and execution
- The inspection work has to be precise and accurate , to strongly decide the necessity of replacement or repair work for each facility and also, to grasp the priority and expected effect of the work. Description? The complex terms need to be broken down.



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MAINTENANCE CYCLE

The maintenance work in the broad sense is executed in the following way.



✓ Improvement activities for preventive maintenance work would be carried out focusing on the key points shown below as OJT.

Plan		
Formulation of the equipment maintenance plan		
✓ In order to secure the accuracy of equipment data base, first, update the data based on the result of past patrol / inspection / repair record. ✓ Based on the result of the last patrol / inspection analysis of previous cycle, formulate the maintenance plan for the next cycle.		
Action		
Repair		
✓ Carry out the following repair (as precautionary measure) according to the situation or degree of deterioration.		
Replacement	Repair (including painting)	Increment of frequency of patrol/inspection
✓ Replace the equipment promptly if risk of outage or public disaster seems high. ✓ If the urgency is low, replace it in the plan.	✓ Equipment in minor defects should be repaired on the site	✓ In case the degree of deterioration is large but not so bad for planned replacement ✓ Such place as fast growing trees are approaching

Do		
Grasping the condition of the equipment		
✓ Grasp the condition of equipment such as abnormality or deterioration (eg, the situation of poles peeling off and the rust of the transformer) and confirm the consistency between the site situation and equipment data registered in the database.		
Patrol	Inspection/Measurement	Outage report
✓ By visual check of the current equipment condition, judge the soundness of the equipment up to the next patrol.	✓ Inspection: Examine each part of the target equipment precisely using five senses as visual inspection or using function testing tools etc. ✓ Measurement: In order to grasp the condition of deterioration by operation period etc., investigate the equipment using a measuring instrument.	✓ Report situation about outages of permanent / transient fault
Check		
✓ Consider the action based on the result of patrol / inspection / measurement. ✓ Result (evidence) of patrols / inspection / measurement shall be recorded for a certain period regardless of the presence or absence of defects. ✓ By accumulation and trend analysis of fault data etc., detect the progress situation or the area of equipment degradation. Through the process, grasp the priority point/area of maintenance.		

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WHERE AND WHAT TO LOOK AT DURING INSPECTION

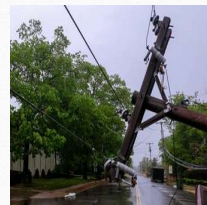
- The inspection work has to be precise and accurate, to strongly decide the necessity of replacement or repair work for each facility and also, to grasp the priority and expected effect of the work.
- Some of what to pay attentions to during repairs are: support, cross arms, insulators and fittings, conductors and earth wires, guys and its accessories etc



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SUPPORTS

- ✓ The supports may be wooden, metallic or PCC or RCC
 - ✓ Check for alignment
 - ✓ Check for termite infestation
 - ✓ Check for soil erosion
 - ✓ Check for cracks
- ✓ Damage as a result of vehicular impact
 - ✓ Fire Damage





CROSS-ARMS

- ✓ The supports may be wooden or metallic or fibre
 - ✓ Check for tilting and/or decaying
 - ✓ Check for rusting
 - ✓ Check for bird perching/nesting
 - ✓ Check for cracks
 - ✓ Fire Damage
 - ✓ Lightning damage



INSULATORS AND FITTINGS

- ✓ Accumulation of dusts
- ✓ Burnt or fused spots on the insulation glaze
- ✓ Broken and chipped porcelain
 - ✓ Tilted insulators
- ✓ Rusting of fittings



Damaged insulators should be replaced, tilted insulators set right and dirty insulators cleaned



CONDUCTORS AND EARTH WIRES

- ✓ The conductors must be inspected throughout their length for broken, burnt or unraveled strands or foreign objects
- ✓ Particular attention is to be given to the evidence of rust on steel and steel cored conductors
- ✓ Clearance between conductors, ground and buildings



CONDUCTORS AND JOINTS

- ✓ Broken strands
- ✓ Burnt jumpers and loose fittings
- ✓ Looseness of bindings on insulators and at joints
- ✓ Slipping conductor from insulator seat
- ✓ Low conductor clearance



- Category 1
- Category 2
- Category 3
- Category 4
- Category 5

Category	Description	Defect priority
1	• No corrosion, 100% galvanized	No action required
2	• Light surface corrosion with negligible pitting	No action required
3	• Medium surface corrosion with mild pitting	Reassess next inspection
4	• Heavy surface corrosion with mild to medium pitting • Annealing or thinning of conductor	Replace within 1 year
5	• Heavy surface corrosion with medium to heavy pitting • Heavy surface corrosion with history of conductor failure	Replace within 3 months or prior to the commencement of the dry season whichever is earliest

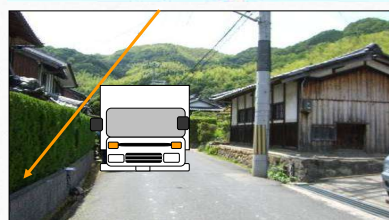
Note - This applies to overhead steel conductors with any number of strands



GUYS AND ACCESSORIES

- ✓ Loose guys
- ✓ Broken or chipped guy insulators
- ✓ Corrosion of guy rods
- ✓ Height of guy-wire
- ✓ Earthing arrangement of guys, broken or missing

Loose guys should be tightened, insulators should be replaced and earthing arrangement should be restored



G.O SWITCHES AND FUSES

- ✓ Missing or broken earth wire
- ✓ Defective switches
- ✓ Cracked or overheating contacts
- ✓ Damaged arching contacts
- ✓ Rusting

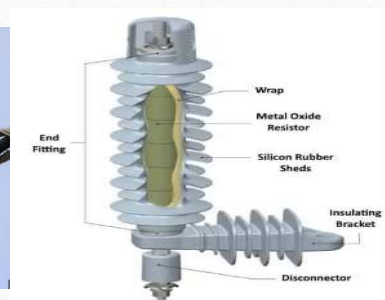
Adjustment should be made for contact alignment and adequate contact pressure. Damaged contacts should be replaced/repared, earth connection, if broken, should be restored; bearings should be lubricated for correct and smooth operation of the moving parts. Attention should be paid to rust.





LIGHTNING ARRESTER

- ✓ Line lead of the arrester is firmly connected
- ✓ The earth connection is tight
- ✓ The earth resistance of the earth wire is within acceptable limit
- ✓ Check for cracks
- ✓ Check the arrester counter



Arrester are irreparable and should be changed if cracks are observed



TREE CLEARANCE

- ✓ Bare conductors in contact with vegetation
- ✓ Covered conductors that are touching heavy branches that are likely to cause insulation damage to the conductor
- ✓ Branches laying across bare mains
- ✓ Branches applying downward pressure to services creating tension



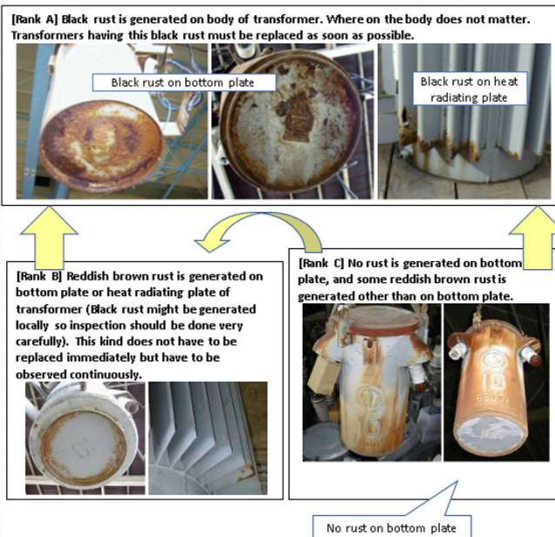
Trees/branches coming close to the lines should be trimmed/removed. A minimum clearance of 1.8m should be maintained on each side of the line



TRANSFORMERS

- ✓ Rust on the body
- ✓ Crooked cover
- ✓ Cracked bushings
- ✓ Airtight deterioration
- ✓ Trail of thunder

Rust on transformers' bodies has to be inspected carefully, because some kind of rust might lead to a hole on the body, causing the transformer tank to leak the insulating oil out.



WHERE TO PAY ATTENTION ON PATROL AFTER OUTAGE



Introduction:

- ✓ Power Outage: Is the loss of electrical power to the consumer
- ✓ Outages can be classified as follows:
 - ✓ Partial outage
 - ✓ Total outage
 - ✓ Forced outage
 - ✓ Planned outage
 - ✓ Emergency outage

When patrolling after the outage incident(s), it is very important to understand the situation well, to prevent disasters to the public or to yourselves and to make every effort for quick restoration



What should be had before patrolling a faulted line

- Tripping date and time
- Substation and feeder
- Relay indication
- Phase of the fault
- Information from customers
- others

Information can be provided not only from the distribution division, but also from transmission company or customer care division



Where to pay attention on patrol after outage

✓ On conductor

- a. Breaking of conductor, touching the other phase, abnormal sag
- b. Damaged insulator, crack or discoloration on insulator
- c. Damaged instruments on poles, such as
 - Damage or discoloration on bushing
 - Oil leaking
 - other
- d. Trace of arc on accessories



Where to pay attention on patrol after outage

✓ Near Conductor

- a. Objects on the ground such as dead animals, fragments of damaged insulator, etc.
- b. Flying objects having conductivity such as tin, iron string, animal, etc.
- c. Vegetation or building close to conductor
- d. Construction work beneath conductor



Major causes of forced outages

✓ Thunder and lightning



Major cause of forced outages

✓ Natural disasters

- Collapse of trees : Collapsed trees fallen on conductor. They break the conductor and the current leaks out via the trees or metal band on the pole and causes earth faults and sometimes short circuit





Major cause of forced outages

- **Rain and flooding:** Heavy rainfall can cause flooding in certain locations in the country. Floods may cause damage to electrical equipment which in turns lead to earth faults and short circuits.
- To prevent major damage, The utility may sometimes need to shut the equipment down, affecting service to some customers



Major cause of forced outages

- **Wind:** High winds may cause objects, such as fallen trees, to come in contact with power lines.
- If that happens, circuit breakers or other protective equipment will shut off the flow of power.
- Wind may also blow tree limbs or entire trees onto the power lines, causing the lines to fall to the ground, or breaking the lines and poles.



Major cause of forced outages

✓ Traffic Accidents

- Car crashing into poles and breaking them



Major cause of forced outages

✓ Traffic Accidents

Heavy machineries operated incorrectly break poles or other facilities.





Major cause of forced outages

✓ Small Animals

- Birds pecking on conductor get electric shock and cause earth faults via their bodies



Major cause of forced outages

✓ Small Animals

- Snake trying getting into insulator covers on the pole or moving inside switchgear touches the conductor

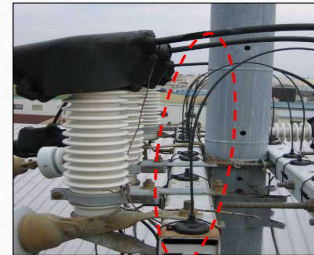




Major cause of forced outages

✓ Other object

- Bird's nest on switchgear or other accessories touching the energize bushing causes earth fault



Major cause of forced outages

✓ Vandalism

- This has been a major concern as one of the causes of poor power supply, vandalism of gas pipe line, electrical towers and electrical network element has been the biggest challenge the power sector is facing





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THANK YOU FOR LISTENING