

Corona :-

The ionization of air around the conductor is called "corona".

OR

When the potential difference b/w conductor is applied whose spacing is very large as compared to their diameter at low voltage level there is no change in condition of air but when the voltage is gradually increased at stage arrived where as noise can be heard & glow of violet colour or Blueish colour will appear. This is called corona.

noise $\rightarrow$ Hissing noise.

Critical disruptive voltage :-

It is the voltage at which corona just initiate, & a noise can be heard but the glow will not appear is called Critical disruptive voltage.

$$V_d = g m r g \ln \frac{d}{r}$$

$\rightarrow$ It is a phase voltage.

Where,

g = dielectric strength of air = 21.1 kV/cm

m = Surface factor

$m = 0.9$ to 1 for hollow conductor / smooth

$m = 0.7$ to 0.9 ACSR / solid / rough surface

r = radius in cm,

δ = Air density factor = $\frac{3.92b}{273+T}$

b = Pressure

T = Temperature ($^{\circ}\text{C}$)

d = distance b/w conductor.

Imp't. points.

- * If applied voltage (V_{ph}) is less than the disruptive voltage then corona will not occur.

Corona loss ($P_c = 0$)

- * Higher value of V_d is better.

Critical visual voltage :-

It is the voltage at which glow of violet / Bluish colour will just initiate along with a noise is called critical visual voltage.

$$V_v = gmr\delta \left[1 + \frac{0.3}{\sqrt{r\delta}} \right] \ln \frac{d}{r}$$

$$V_v > V_d$$



Corona loss (P_L) :-

$$P_L = \frac{241 \times 10^5}{s} (f + 25) \sqrt{\frac{r}{d}} (V_{ph} - V_d) \text{ kW/km/pha}$$

where,

$$s = \text{Air density factor} = \frac{3.926}{273 + T}$$

r = radius of conductor

d = distance b/w conductor

V_{ph} = applied voltage

V_d = disruptive voltage

f = frequency.

NOTE:- When corona occurs ozone (O_3) gas will produced.

Advantage of corona:-

There is only one advantage when the high voltage surge occurs, the corona loss will also increase which reduce the magnitude of surge.

Disadvantages of Corona:-

A. Power loss :- Causes energy dissipation, reducing transmission efficiency.

2. Interference :- Produces electromagnetic interference (EMI), affecting nearby communication lines.
3. Noise and Light :- Produces undesirable hissing sounds and visible glow.
4. Insulation Damage :- Accelerates the aging and degradation of insulation materials.

Methods of Reducing corona :-

- ① Increase conductor size :-
Increasing the diameter of the conductor reduces the electric field intensity at the surface, which reduces corona.
- ② Increase conductor spacing :-
Increasing the distance between conductors raises the voltage at which corona occurs.
- ③ Use bundled conductors :-
Bundled conductors increase the effective diameter of the conductor, reducing the corona effect.

④ Use corona rings :-

Corona rings reduce the electric field intensity at the sharp edges of the conductors or insulators.

Explain Transmission and Distribution losses :-

Transmission losses :-

① Radiation losses :-

② Copper losses :-

Generally known as Resistance loss is in the form of heat.

$$\text{Copper loss} \propto I^2$$

$$\text{Copper loss} \propto \frac{1}{2}$$

③ Dielectric loss :-

→ happens due to air present between conductor and earth.

→ Dielectric medium is present in co-axial cables.

→ Dielectric loss $\propto$ voltages across dielectric



→ Dielectric loss $\propto \frac{1}{2}$

(iv) Reflection loss:-

→ Also known as Mismatched loss.

→ Reflection loss in nepers =

$$\ln \left| \frac{I_2'}{I_2} \right| = \ln \left| \frac{1}{k} \right| = \ln \left| \frac{Z_1 + Z_2}{2 \sqrt{Z_1 Z_2}} \right|$$

→ Reflection loss in decibels =

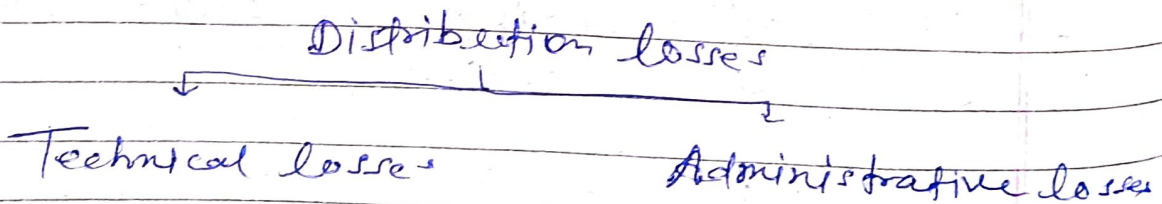
$$20 \log_{10} \left| \frac{Z_1 + Z_2}{2 \sqrt{Z_1 Z_2}} \right|$$

(v) Insertion loss:-

Inserting any elements or device in the communication line

Distribution losses:-

It refers to losses during process of delivering electrical energy from 11 kV feeder to residential street or consumers.



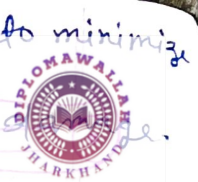
① Technical losses :- Produces due to energy dissipated in conductor & equipment used for distribution of power.

→ These are within the distribution network due to cables, overhead lines, transformer etc.

② Administrative losses :- Due to lack of administration, financial constraint, power theft, defective meter, etc.

① camper - These are devices attached to the conductors to minimize vibration caused by wind.
• Excessive vibration can lead to conductor fatigue and

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Main Components of overhead T_o line:

① Conductors :-

The conductors carry electric power from the sending end station to the receiving end station.

→ The most commonly used conductor materials in overhead lines in Aluminium and its alloys.

② Cross - Arms & Clamps :-

Cross - arms and clamps are used mainly for supporting and holding the conductors and insulators.

③ Guy's & stays :-

The Guy's and Stays are used for the termination of the lateral forces by making the pole support in angle.

④ Fuses & isolating switches :-

• The fuses are used to protect the appliances from high voltages and faults.

• The isolating switches are used for isolating the different appliances in transmission.

The type of support used depends on the voltage of the line, the distance between conductors and the terrain.

Support: These are the structures that hold the conductors above the ground. They can be made of wood, concrete or steel or towers (typical steel lattice structures).



Earth wire :- Earth wire is used for collecting high voltage from lightning arrestors and supplying it to the earth. The earth wire will be running on the top of the tower.

Lightning Arrestors :-

- Lightning arrestors are used for the protection of the overhead lines from high voltage surges.
- The lightning arrestors are placed at the top of the overhead line as it collects the high voltage surges and give them to the ground.
- Lightning arrestors play a vital role in bad weather conditions mainly during rainy.

Insulators :-

The material which holds the property of insulation is called an insulator.

- The major application of using the insulators is to provide support for the conductor and maintain distance from one conductor to the other.

Types of Conductors:-

ACSR (Aluminium Conductor Steel Reinforced):-

- Characteristics:-
 - Consists of a stranded steel core surrounded by layer of aluminium strands.
 - Offers high tensile strength due to the steel core allowing for longer spans between towers.
 - Good electrical conductivity due to the aluminium outer layer.
 - Relatively lightweight compared to all steel conductors.

• Applications:-

- Overhead T_L line, especially for long spans and high voltages.
- River crossings and other areas where long spans are required.
- Overhead ground wires for lightning protection.

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AAC (All - Aluminium Conductor):-

⇒ Characteristics :-

- Made entirely of stranded aluminium.
- Offers good electrical conductivity and corrosion resistance.
- Lower tensile strength compared to ACSR.
- Lighter weight than ACSR.

Applications:-

- Overhead distribution lines.
- Urban areas where shorter spans are common.
- Coastal areas where corrosion resistance is critical.

AAAC (Al - Aluminium Alloy Conductor) :-

Characteristics:-

- Made of stranded aluminium alloy, typically containing silicon and magnesium.
- Offers higher tensile strength than AAC while maintaining good electrical conductivity.
- Excellent corrosion resistance.
- Relatively lightweight.

• Applications :-

- Long span transmission lines where high strength is required.
- Areas with high wind or ice loads.
- Coastal and marine environments.

Comparison b/w ACSR, AAC, AAAC

Feature	ACSR	AAC	AAAC
Tensile strength	High	Moderate	High
Material	Aluminium strand over steel core	Stranded Aluminium	Stranded aluminium alloy
Electrical Conductivity	Good	Good	Good
Corrosion Resistance	Moderate	High	Excellent
Weight	Moderate	Light	Light
Cost	Moderate	Low	Moderate

Types of ACSR Conductor :-

1. Standard ACSR :-

Construction :- Consist of a solid or stranded steel core surrounded by layer of aluminium strands.

Application :- Widely used in overhead transmission and distribution lines for various voltage levels.

2. Compact ACSR :-

Construction :- Similar to standard ACSR, but with a more compact arrangement of Aluminium strands, resulting in a smaller diameter.

Application :- Used where space is limited, such as in urban areas or congested corridors.

3. AA - Aluminium Conductor (AAC) :-

Construction :- Consist entirely of aluminium strands, without a steel core.

Application :- Used in areas with low wind and ice loads, or lower

tensile strength is acceptable.

4. Aluminum Conductor Composite Core (ACCC) :-

Construction :- Similar to ACSR, but with a composite core made of carbon fiber and aluminum instead of steel.

Application :- Offers higher current-carrying capacity and lower sag compared to traditional ACSR, making it suitable for high-capacity transmission lines.

5. Aluminum Conductor Steel Supported (ACSS) :-

Construction :- Similar to ACSR, but with the steel strands placed on the outside of the aluminum strands.

Application :- Used where less reinforcement is needed, such as in areas with low wind and ice loads.

Types of Insulators :-

① Pin Type Insulator :-

- The pin insulator is used in power distribution for the voltage upto 33 kV. It is placed on the cross arm of the supporting tower.
- The pin insulator has grooves on the upper end for keeping the conductor. Pin insulator uses non conducting material like porcelain, ceramic, silicon rubber, polymer etc.
- For low voltage, the single piece pin insulator is used, and for high voltage two or more pieces are cemented together for maintaining the proper thickness of the insulator.



② Shackle Type Insulator :-

- It is used in low tension line or distribution line, It is only used for 11 kV or less Tr. line.

- It is only used for move or turn Tr. line.
- It can be used for horizontal line or vertical line.

③ Disc Type Insulator:-

- It is most basic insulator, made by porcelain, polymer and glass.
- 1 disc = 11 kV.
- If high voltage is required so connect disc insulator in series.
- It is also used in suspension or strain type insulator.

④ Suspension Type insulator:-

- It is made by connected disc insulator in series.
- 1 disc = 11 kV.
- So for 33 kV we use 3 disc, for 66 kV we use 6 disc and are also known as disc insulator.

It is connected vertically in Tr. line.

It can use for 765 kV line depends on number of connected.

Strain Type Insulator :-

It is used when we need to move or turn Tr. line at high voltage.

→ It can use horizontally depends on the applications.

→ It can also use up to 765 kV line, which is depends on no. of disc connected.

Stay type Insulator :-

→ It is used in pole supporting wire.

→ Stay insulators are primarily used to prevent stay wires from accidentally broken line wires. They, therefore function to provide insulation between stay clamps and Tr. poles.

→ Stay insulators are mounted at a height of at least 3 meters from ground level.



⑦ Post Type Insulator :-

→ It is connected in generating station or substation.



Guy Assembly :-

A Guy assembly is a system of cables, hardware, and anchors used to provide additional support to structured like utility poles, towers and masts. It helps to counteract the force exerted by wind, ice and the weight of the structured itself.



GI Wires :-

GI wires stands for Galvanised Iron wire. It is a type of steel wire that has been coated with zinc to protect it from corrosion. GI wire is commonly used in guy assemblies due to its strength and durability.

11 kV Cross-arms :-

Cross-arms are horizontal beams attached to utility poles that support electrical insulators and conductors. 11 kV cross-arms are designed to carry high-voltage power lines.

L.T. Line Spacers :-

L.T. line spacers are devices used to maintain the proper spacing between low voltage power spacing conductor. They help prevent electrical arcing and ensure safe operation of the power line.

GO switches (Gang Operated Switches) :-

⇒ Function :- A type of isolator switch used to isolate high voltage lines for maintenance or fault clearance.

⇒ Operation :- Operated mechanically or electrically to open or close multiple phases simultaneously.

⇒ Voltage Range :- Typically used in 11 kV or higher systems.

Spacing between conductors:-

⇒ To prevent flashovers and arcing between conductors.

Sag:- It is defined as the vertical distance between line support to of Tower and conductor lowest point is known as Sag.

→ Sag indicated by S .

Factor affecting the sag:-

① Weight of conductor:-

Weight of conductor is directly proportional to the sag.

$$W \propto \text{Sag} \uparrow$$

② Span length of Conductor:-

We can say if span length increase then its sag also increase.

③ Tension on Conductor:-

It is inversely proportional to Sag.

$$T \propto \frac{1}{\text{Sag}}$$

④ Temperature :- So, Temperature is also directly proportional to the sag.

⑤ Wind :- If wind speed increase then sag also increase.

Concept of length of span :-

The length of span refers to the distance between two consecutive support structures (e.g., poles or towers) in a power line.

Guarding :-

A protective arrangement of wires or structures placed under overhead conductors to prevent accidents in case of conductor breakage.

Types of Guarding :-

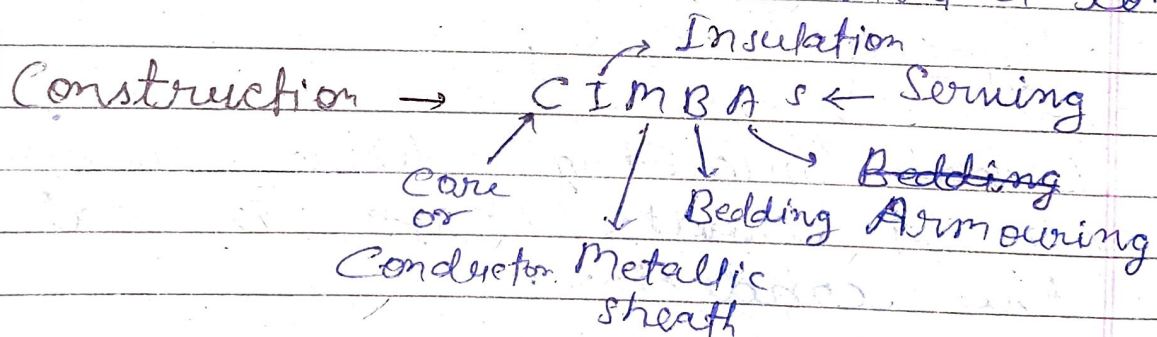
- Cradle Guarding :- Wires arranged in a cradle shape to catch the conductor.
- Rod Guarding :- Metal rods are placed below conductors for protection.

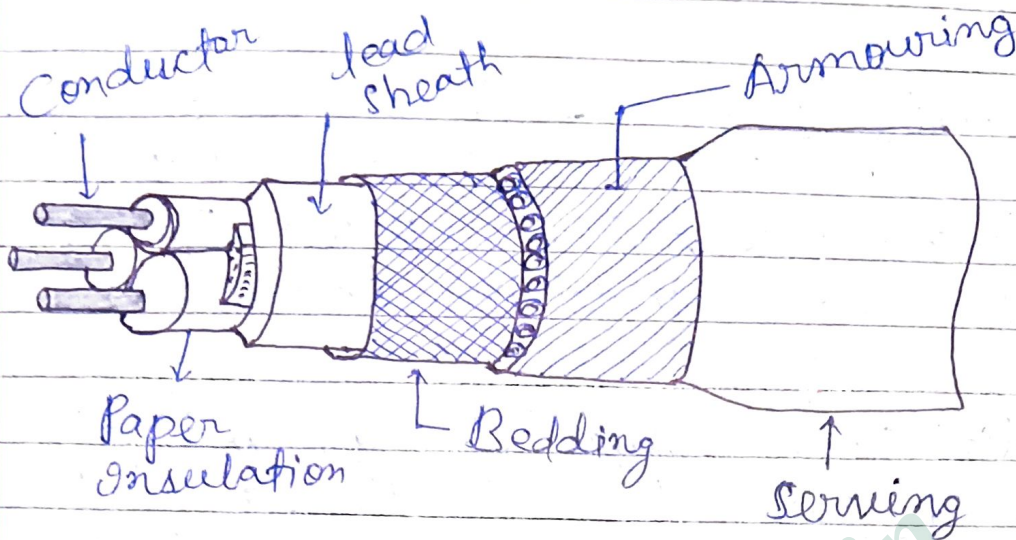
- Pipe Guarding :- Steel pipes are used for added safety in critical areas.

Underground Transmission line :-

An underground transmission line is a type of power transmission system in which electrical cables are installed below the surface of the ground to transfer electricity from one location to another. These cables are typically insulated and buried to protect them from external elements such as weather, physical damage, or interference.

Underground tr. line are commonly used in areas where overhead lines are impractical or undesirable due to urban congestion, aesthetic considerations, or environmental concerns.





Cable and its rating :-

A cable is made up of one or more conductors that are covered with protective layer, wrapped with an appropriate insulation. The various parts of a cable are:

1. Conductor or cores
2. Insulation
3. Metallic lead sheath
4. Bedding
5. Armouring
6. Serving

1. Conductor :- Usually made of copper or aluminium, carrying the electrical current.

2. Insulation :- A layer of insulating material surrounding the

conductor, such as paper, XLPE, or EPR.

3. **Metallic sheath** : A layer of metal, often lead or aluminum, providing mechanical protection and acting as a moisture barrier.
4. **Bedding** :- A layer of insulating material applied over the sheath to protect it from mechanical damage.
5. **Armouring** :- A layer of steel wires or tapes wound around the bending for mechanical protection.
6. **Serving** :- Serving is a layer of fibrous material (like jute) like bedding is placed on top of the armouring to protect it from atmospheric conditions.

The rating of different types of cables are given below :-

- ① Low Tension (L.T) cables $\rightarrow$ upto 1000V
- ② High Tension (H.T) cables $\rightarrow$ upto 11 KV
- ③ Super Tension (S.T) cables $\rightarrow$ from 22KV to 33KV
- ④ Extra high tension (E.H.T) cables $\rightarrow$ from 33KV to 66KV
- ⑤ Extra super Voltage cables - beyond 132KV

Insulating material for cable:-

Properties:-

1. High insulation Resistance ✓
2. High dielectric strength ✓
3. Good mechanical properties ✓
4. Non inflammable ✓
5. Low coefficient of thermal expansion.

Types of insulating material:-

1. Rubber:- dielectric strength 30 kV/mm
2. Impregnated paper:- It is prepared from wood pulp plant fibre and its dielectric strength is 30 kV/mm .
3. VIR (Vulcanized India Rubber):-
It is prepared by mixing India rubber with sulphur, zinc oxide, and Red lead. Dielectric strength $10-20 \text{ kV/mm}$.
4. PVC : dielectric strength 17 kV/mm
5. Polythene:-
6. Varnished cambric
7. Gutta parcha:- mostly used for submarine cable for telephone and telegraph purpose.

Need of HT cables :-

HT cables are essential for transmitting power over long distances at high voltage to reduce transmission losses. They are mainly used in industrial, urban and power distribution systems.

Advantages of HT cables :-

Reduced Losses :- High voltage reduces current, minimizing I^2R losses.

Space saving :- Require less physical space compared to overhead lines.

Environmental Impact :- Safer and less visually intrusive.

Safety :- Protection from weather, animals and external damages.

Disadvantages :-

High cost :- Installation and maintenance are expensive.

Heat Dissipation issues :- Poor heat dissipation compared to overhead lines.

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Fault Detection :- Faults are harder to locate and repair.

Limited flexibility :- Limited ability to adapt to future power demands.

Selection of HT and LT underground cables:

The selection of HT and LT underground cables depends on various factors, including:

Voltage level :- The voltage level determines the type of insulation and conductor material required.

Current rating: The current rating determines the type of size of the conductor.

Environmental conditions :- The environmental conditions, such as soil type and moisture content, influence the choice of cable materials and installation methods.

Cost :- The cost of the cable and installation must be considered.

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- Reliability Requirements :- The required level of reliability influences the choice of cable type and installation methods.

* Construction of PVC :-

- Insulation :- A layer of material that surrounds the conductor and prevents current leakage. PVC is a common choice for low voltage applications due to its affordability, ease of use, and good electrical insulation properties.

* Construction of 3 core XLPE cables :-

- Insulation :- Cross-Linked Polyethylene (XLPE) is a superior insulator compared to PVC, offering higher electrical strength, better resistance to moisture and chemicals and improved performance at high temperatures.
- Semi - conducting layers :- These thin layers are applied between the conductor and XLPE insulation and between the insulation and metallic sheath.

* Advantages of Underground power cable system :-

- **Safety** :- Underground cables are insulated and shielded, making them safer than overhead lines.
- **Weather protection** :- Underground cables are protected from wind, wildfires, and tree branches.
- **Reduced voltage drop** :- Underground cables have smaller voltage drops than overhead lines.
- **Reduced faults** :- Underground cables have a lower chance of developing faults than overhead lines.
- **Low maintenance costs** :- Underground cables have lower maintenance costs than overhead lines.

* Disadvantages of Underground Power cable systems :-

1. **High Installation cost** :- Excavation, insulation, and installation costs are higher compared to overhead lines.

2. Difficult fault detection :- locating and repairing faults is time-consuming and expensive.
3. Limited Flexibility :- Harder to modify or upgrade.
4. Heat Dissipation Issues :- Heat buildup can affect efficiency.
5. Impact on Environment :- Digging trenches may disturb ecosystems and increase initial carbon footprint.

Scope of IS 7098-1 and IEC standards for various cables (IEC 60502-1, IEC 60502-2).

Solvet ① IS 7098-1

- Scope :- This standard covers the requirements for cross-linked polyethylene (XLPE) - insulated cables for working voltages from 1.1 kV up to and including 3.3 kV.
- Applications :- Used for electrical power transmission and distribution in various industrial and domestic applications.

IEC 60502 - 1

Title :- Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV) - Part 1: cables for rated voltages of 1 kV and 3 kV.

scope :- Covers cables with extruded solid dielectric insulation for fixed installations in various environments, including underground, air, or conduit.

Applications :- Widely used in low-voltage power distribution systems, both in industrial and residential settings.

2. IEC 60502 - 2

- Title :-** Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV) - Part 2: cables for rated voltages from 6 kV ($U_m = 7.2$ kV) up to 30 kV ($U_m = 36$ kV).

- Scope :-** Specifies medium-voltage power cables with extruded insulation for applications in power distribution and Tr. networks.

Application :-

Medium - voltage cable installations, typically used in industrial plants, utilities, and power stations.

Comparison between IS 7098-1 and IEC standards :-

Standard	Voltage Range	Applications	Key features
IS 7098-1	upto 3.3 kV	low voltage	XLPE - insulated cables
IEC 60502-1	1kV - 3 kV	low voltage power distribution	Cables with extruded insulation
IEC 60502-2	6 kV - 30 kV	Medium voltage power distribution	Focus on medium voltage systems

Compare BtW pvc & XLPE :-

pvc

XLPE

→ Residence	Industrial
→ 70°C	90°C
→ 20 years	40 years
→ Overload 90°C	Overload 130°C
→ Short circuit 135°C	Short circuit 250°C

Comparison between Overhead system & Underground system:-

Overhead system	Underground systems
① The overhead system transmission is by using tr. line.	① The underground system tr. is by using the cables of conductor.
② The overhead system is not insulated wire used.	② The underground system is insulated wire used.
③ The voltage level is used can be as high and upto 765 KV.	③ The voltage level is used is below 66 KV due to insulation difficult.
④ The overhead system is not costly.	④ The underground system is costly.
⑤ No insulation cost as air act is insulation.	⑤ The underground system is insulation cost is high.
⑥ The maintenance cost is less.	⑥ The maintenance cost is high.

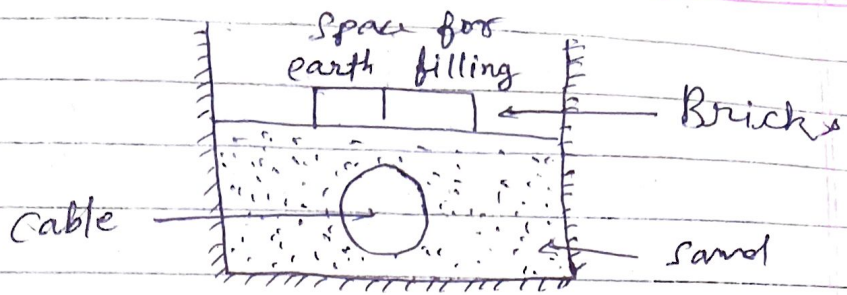
Methods of laying :-

- ① Direct laying method
- ② Draconin system
- ③ Solid system

① Direct laying method :-

This is the simplest and easiest method for laying cables.

1. A trench is dug with a depth of 1-1.2 meters and a width of 0.6 meter.
- The bottom of the trench is filled with a 10 cm layer of sand.
- The cable is laid on top of this sand layer.
- Another 10 cm layer of sand is spread on top of the cable to protect it from moisture.
- Bricks are placed above the sand layer to protect the cable.
- Finally, the trench is filled back with soil and compacted to restore the ground.



Drawn in system:-

Advantages:-

It is simple and economical.

The excess heat from the cable is easily dissipated into the ground.

Disadvantages:-

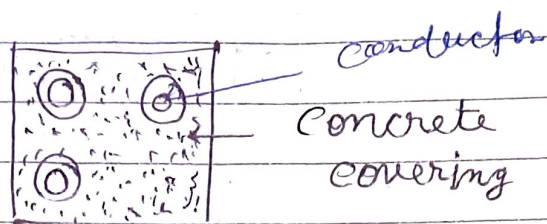
Modifications in the cable network are not easy.

The installation cost is high.

Fault detection is difficult.

Drawn in system:-

This is also called an attractive method. In this system, a trench is dug first. After that, conduits or pipes are laid inside it. These pipes are made of cement, concrete, or clay. After laying the pipes they are filled with sand or soil. Later, the cable is pulled through the pipes with the help of a manhole.



Advantages:-

- More durable and reliable
- Maintenance work is simple.
- Maintenance cost is less.

Disadvantages:-

- Initial cost is very high.
- The heat dissipation is low.

Troughing (3) Solid system:-

In this method, a trench is also dug, but it is not filled with soil on all sides. The trench is made of concrete. After this, bituminous material is poured. On solidification of this material is, the cable gets a solid shape. By pouring bituminous material, the effect of moisture will not reach the cable. After that, it is covered with concrete.

Advantages:-

1. Durable and reliable:- The cable is protected from chemical reaction in the ground.

High electrical capacity.

Disadvantages:-

High installation:

Takes more time to install.

Requires skilled labour.

Faults in UG cable:-

1. Open circuit fault:- When the conductor is broken, resulting in no continuity.
2. Short circuit fault:- When two or more conductors come in contact due to insulation failure.
3. Earth fault:- When a conductor comes in contact with the earth.

Cable gland:-

A cable gland is fitting used to seal the entry point of a cable into an enclosure or equipment. It provides a watertight and airtight seal while also protecting the cable from mechanical damage.

Types:-

- Compression glands:- Use a compression ring to seal the cable.
- Metric glands:- Designed for metric-sized cables.
- Armor glands:- Used for armored cables.
- Extruded glands:- Made from a single piece of material, offering a smooth and seamless seal.

Lug:- A lug is a terminal used to connect a cable to a conductor or equipment. It is typically has a hole for bolting or crimping.

Types:-

- Ring lugs:- Have a circular hole for bolting.
- Spade lugs:- Have a flat, spade-shaped end for crimping.
- Fork lugs:- Have two prongs for connecting to a busbar.
- Butt lugs:- Have a flat end for crimping onto a flat conductor.

Bonding and grounding :-

Bonding :- The process of connecting metallic parts of the system to each other to ensure they are at the same electrical potential. This helps to prevent potential differences that could lead to electrical shock or equipment damage.

Grounding :- The process of connecting the system to the earth.

This provides a low-resistance path for fault currents to flow, protecting people and equipment from electrical hazards.

Underground cable Testing :-

1. Acceptance tests at works :-

(a) Conductor resistance test :- This test measures the electrical resistance of the cables conductor. A low resistance indicates good conductivity.

(b) Voltage Test :- This test applies a high voltage to the cable to check of insulation break down.

③ Dielectric Power factor / Voltage Test:-

This tests measure the insulation's ability to store and release electrical energy.

Sample Tests at works:-

These are additional tests performed on a sample of the cables to ensure quality and consistency.

Performance Tests:-

These tests are done on the installed cable to ensure it meets the required performance standards.

Tests on Oil-filled and Gas-filled cables:-

a) Load cycle tests:- These tests simulate the cables operation under different load condition to check for temperature rise and insulation degradation.

b) Thermal Stability Test (for 132 kV cables only):- This tests evaluate the cables ability to withstand high temperature during operation.

Impulse test :- This test applies a high-voltage, short-duration impulse to the cable to simulate lightning strikes and ensure the cable can withstand such events.

④ Dielectric Thermal Resistance Test :-
This test measures the insulation's resistance to heat stress.

⑤ Cold Power factor/voltage test :-

This test measures the insulation's properties at low temperatures.

⑥ Mechanical test :- This test checks the cable's strength and resistance to bending, twisting and other mechanical stresses.

⑦ Binding test :- This test ensures the cable's armor (if any) is properly attached and provides adequate protection.