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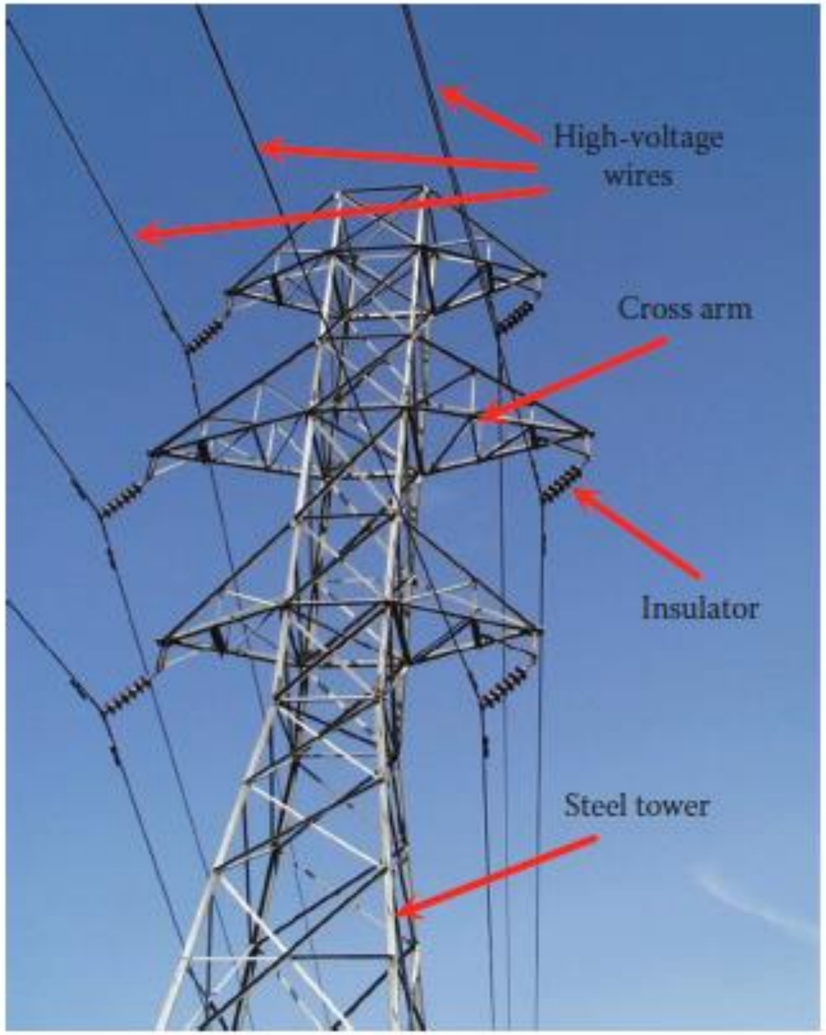
Components of Overhead Line



- Main Components of overhead line
  - *Conductors*
  - *Insulators*
  - *Cross-arms*
  - *Supports*

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Components of Overhead Line ‘Insulators’

- They provide insulation of h.v wire with the metal structure and also provide support to the conductor
- In general, the insulators should have the following desirable properties :
  - High mechanical strength in order to withstand conductor load, wind load etc.
  - High electrical resistance of insulator material in order to avoid leakage currents to earth.
  - High relative permittivity of insulator material in order that dielectric strength is high.
  - The insulator material should be non-porous, free from impurities and cracks otherwise the permittivity will be lowered.
  - Low loss tangent and power losses

Components of Overhead Line 'Insulators'

- Relative permittivity
  - It indicates how easily a material can become polarized by imposition of an electric field on an insulator.
- The dielectric strength
  - It is a measure of the electrical strength of an insulator.
  - It is defined as the maximum voltage required to produce a dielectric breakdown through the material and is expressed in terms of Volts per unit thickness.
  - The higher the dielectric strength of a material the better an electrical insulator it makes.

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Components of Overhead Line ‘Insulators’

- Loss tangent of insulator ($\tan\delta$):
  - ➢It is defined as the ratio of the equivalent series resistor of the insulator to its capacitive reactance .
  - ➢Or the ratio of capacitive reactance to the equivalent parallel resistor of the insulator

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Components of Overhead Line 'Insulators'

Resistivity Calculation

- Consider an insulator of length L with cross section area of A and contains charge carriers:
- If a voltage V is applied across the ends of the sample, the corresponding electric field, E, is given by:

$$E = \frac{V}{L}$$

- and the current density, J, is given by: $J = \frac{I}{A}$

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Components of Overhead Line 'Insulators'

- The current density can be further represented by:

$$J = \frac{I}{A} = qnv_d$$

where n is volume density and v_d is the charge drift velocity

- In this case, the current I is given by

$$I = Aqnv_d$$

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Components of Overhead Line 'Insulators'

- The drift velocity can be expressed as:

$$v_d = ME$$

where M is the mobility

- In this case, the current I can be expressed as:

$$I = AqnME = \frac{AqnMV}{L}$$

- Finally, the resistance of the material, R, is given by:

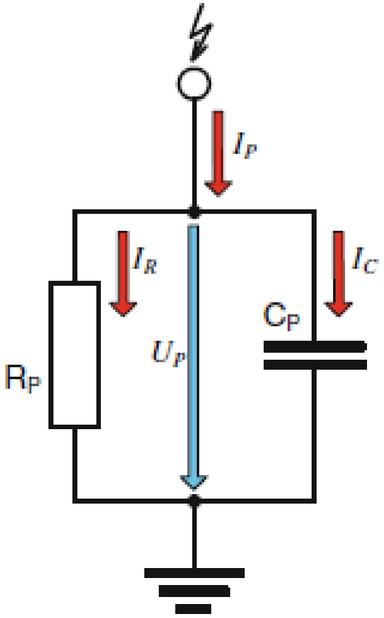
$$R = \frac{V}{I} = \frac{L}{AqnM} = \rho\frac{L}{A}; \qquad \rho = \frac{1}{qnM}$$

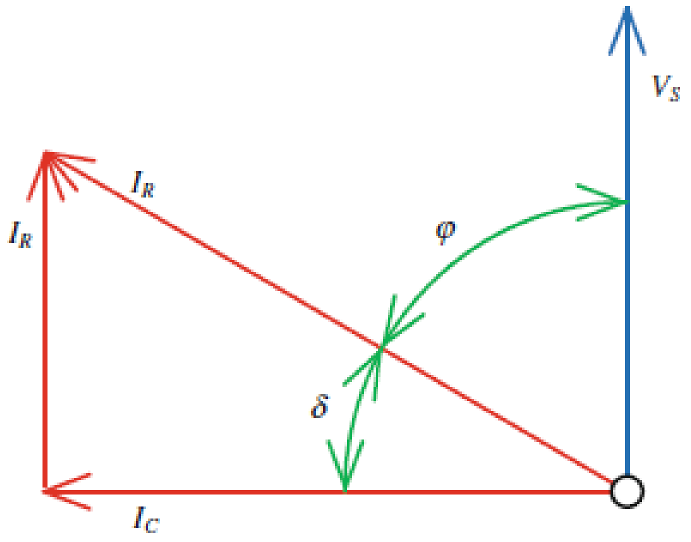
Components of Overhead Line 'Insulators'

Loss Tangent Calculation

- This figure shows the equivalent parallel circuit and associated vector diagrams of h.v insulator.
- It is used for the definition of the loss factor:

$$\tan\delta = \frac{I_R}{I_C} = \frac{\frac{V_S}{R_p}}{\omega C_p V_S} = \frac{1}{\omega R_p C_p}$$





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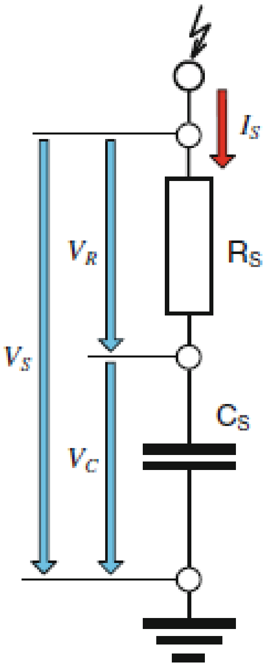
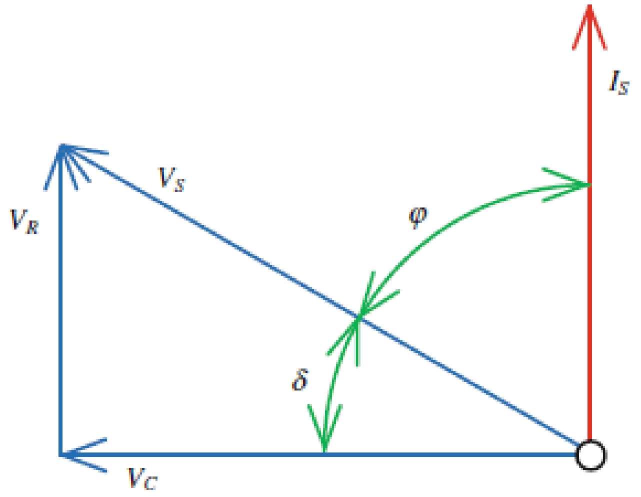
Components of Overhead Line ‘Insulators’

- This figure shows the equivalent series circuit and associated vector diagrams of h.v insulator.
- It is used for the definition of the loss factor:

$$\tan\delta = \frac{V_R}{V_C} = \frac{R_s I_S}{\left(\frac{1}{\omega C_s}\right) I_S} = \omega R_s C_s$$





Components of Overhead Line ‘Insulators’

Example

A solid insulator has a dielectric constant of 4.2, and loss tangent of 0.001 at a frequency of 50 Hz. If it is subjected to an alternating field of 50 kV/cm, calculate the heat generated in a $1cm^3$ due to the dielectric loss.

Components of Overhead Line 'Insulators'

$$P_R = V^2 \omega C \tan\delta = (Ed)^2 \omega \left(\frac{\varepsilon_0 \varepsilon_r A}{d} \right) \tan\delta$$

$$= E^2 \omega \varepsilon_0 \varepsilon_r A d \tan\delta = E^2 \omega \varepsilon_0 \varepsilon_r v \tan\delta$$

$$= \left(50 \times 10^5\right)^2 (2\pi \times 50)\left(8.85 \times 10^{-12}\right)(4.2)\left(10^{-6}\right)\left(10^{-3}\right)$$

$$= 0.291 \text{ mW/cm}^3$$

Components of Overhead Line ‘Insulators’

	Porcelain	*Glass*	*Polymer*
Dielectric strength [kV/cm]	200	250	160-200
Volume resistivity [Ω.m]	10^{11}	10^{11}	10^{12}
Relative permittivity	6-7	7	4
Maximum safe operating temperature [°C]	160	110	350
tan δ	0.01-0.03	0.006	0.02-0.03

Components of Overhead Line ‘Insulators’

- Types of overhead line insulators
  - Pin type insulator
  - Suspension type insulator
  - Strain type insulator
  - Shackle insulator

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Components of Overhead Line
‘Insulators, pin type’

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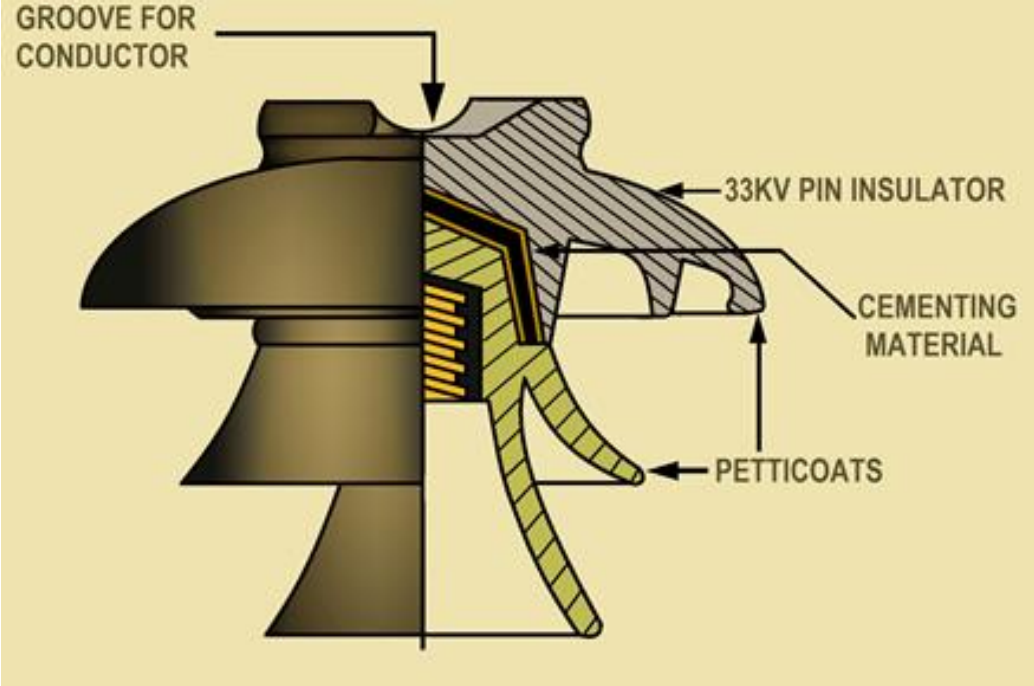
Components of Overhead Line ‘Insulators, pin type’

- It is designed to be mounted on a pin which in turn is installed on the cross-arm of the pole
- The insulator is screwed on the pin and the electrical conductor is placed in the groove at the top of insulator
- It is tied down with soft copper or aluminum binding wire according to the material of conductor
- Pin type insulators are made from glass or porcelain
- It is earliest developed, but still popularly used in power network up to 33 kV
- They are designed for voltages up to 90 kV, but they are seldom used on lines above 33 kV as for higher voltages, the pin type insulator become bulky and uneconomical.

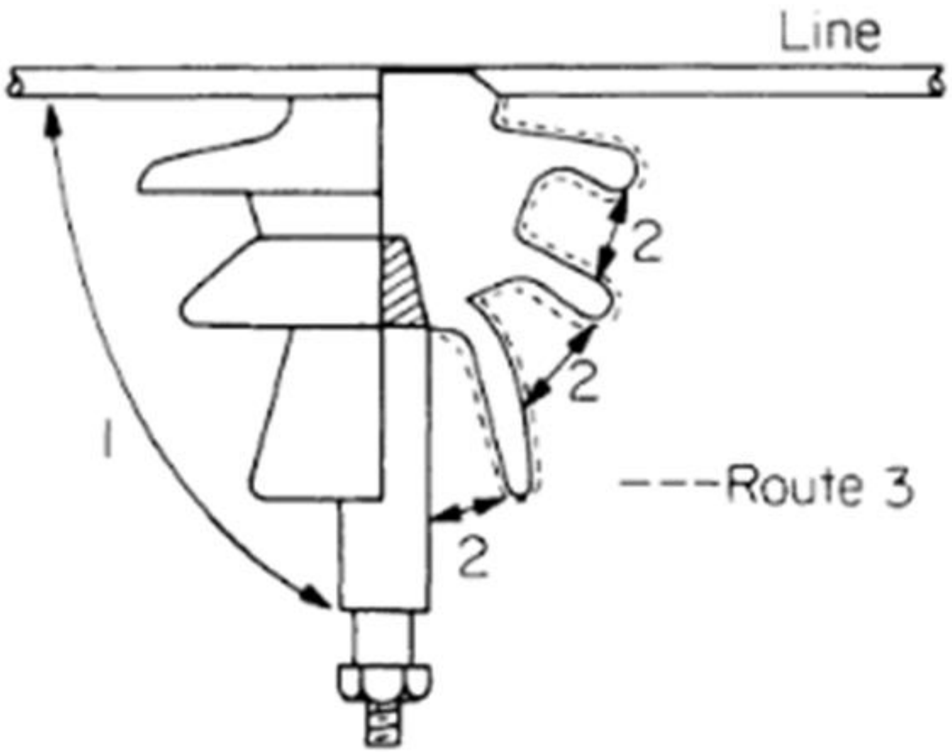
Components of Overhead Line
'Insulators, pin type'

- When the insulators are wet, their outer surface is almost conducting
- To keep the inner side of the insulator dry, rain sheds or petticoats are provided.
- The upper most petticoat has umbrella type designed
  - to protect the rest lower parts of the insulator from rain
  - to minimize the decrease of flash-over distance when the insulator is wet



Components of Overhead Line ‘Insulators, pin type’

- An electrical breakdown or flashover can occur in three ways:
  - ➢ A dry flashover can occur. This means that an arc will form round the insulator from line to pin along the track 1
  - ➢ A wet flashover can occur. When the top surfaces of insulator are wetted by rain they become conducting so that the sheds are so disposed to keep undersides dry. The flashover can occur along the track 2.
  - ➢ Puncture where the current can leak from the line over the surface of the insulator along the track 3



Components of Overhead Line 'Insulators, pin type'

- In case of flash-over, the insulator will continue to act in its proper capacity unless extreme heat produced by the arc destroys the insulator.
- In case of puncture, the discharge occurs from conductor to pin through the body of the insulator. When such breakdown is involved, the insulator is permanently destroyed due to excessive heat.

Components of Overhead Line 'Insulators, pin type'

- Puncture arc: It is a breakdown and conduction of the material of the insulator, causing an electric arc through the interior of the insulator. The heat resulting from the arc usually damages the insulator irreparably.
- Puncture voltage: It is the voltage across the insulator (when installed in its normal manner) which will cause a puncture arc.

Components of Overhead Line ‘Insulators, pin type’

- Flashover arc: It is a breakdown and conduction of the air around or along the surface of the insulator, causing an arc along the outside of the insulator. They are usually designed to withstand this without damage.
- Flashover voltage: It is the voltage which will cause a flashover arc.
- Design specifications: Most high voltage insulators are designed with a lower flashover voltage than puncture voltage, so they will flash over before they puncture, to avoid damage.

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Components of Overhead Line 'Insulators, pin type'

- In practice, sufficient thickness of porcelain is provided in the insulator to avoid puncture by the line voltage.
- The ratio of puncture strength to flashover voltage is known as safety factor *i.e*

$$\text{Safety factor of insulator} = \frac{\text{puncture strength}}{\text{flashover voltage}}$$

- It is desirable that the value of safety factor is high so that flash-over takes place before the insulator gets punctured. For pin type insulators, the value of safety factor is about 3-5.