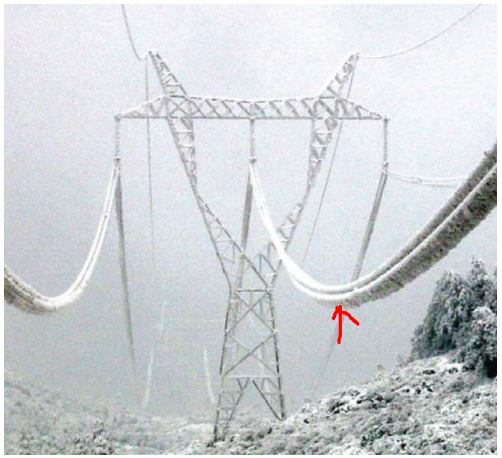
EEN-206: Power Transmission and Distribution

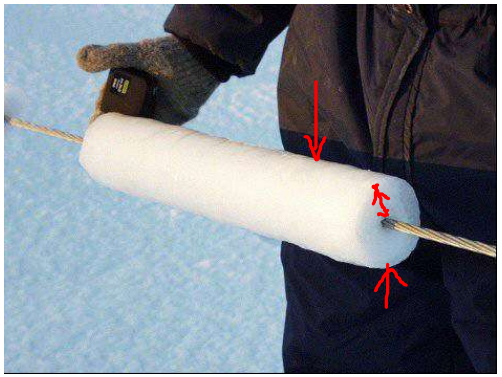
Lecture -08

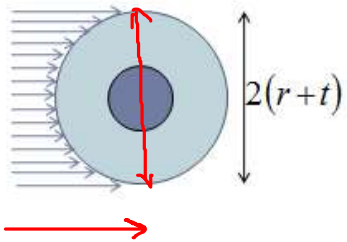
Chapter 2: Overhead Transmission Lines

- Insulators
- Electrical Design

Effect of Ice Covering and Wind

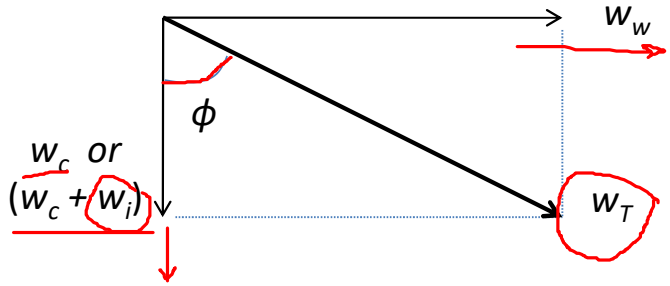






Total weight (W_T)

$$W_T = W_c + W_i$$



Conductor alone

$$w_T = \sqrt{w_c^2 + w_w^2} \text{ kg/m}$$

Conductor + Ice

$$w_T = \sqrt{(w_c + w_i)^2 + w_w^2} \text{ kg/m}$$

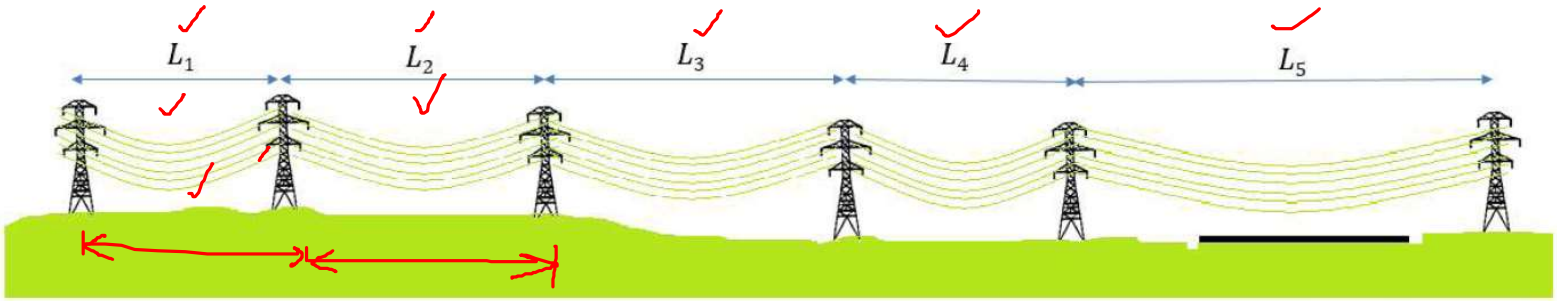
Conductor alone

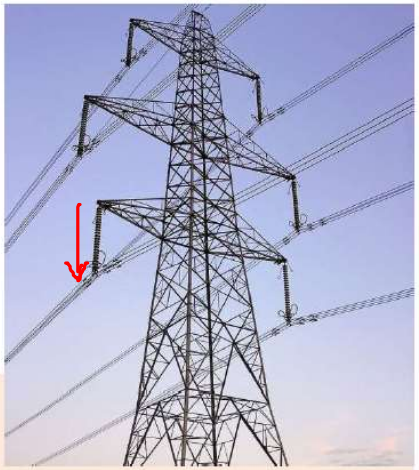
$$\phi = \tan^{-1}(w_w / w_c)$$

Conductor + Ice

$$\phi = \tan^{-1}(w_w / (w_c + w_i))$$

Ruling or Equivalent Span





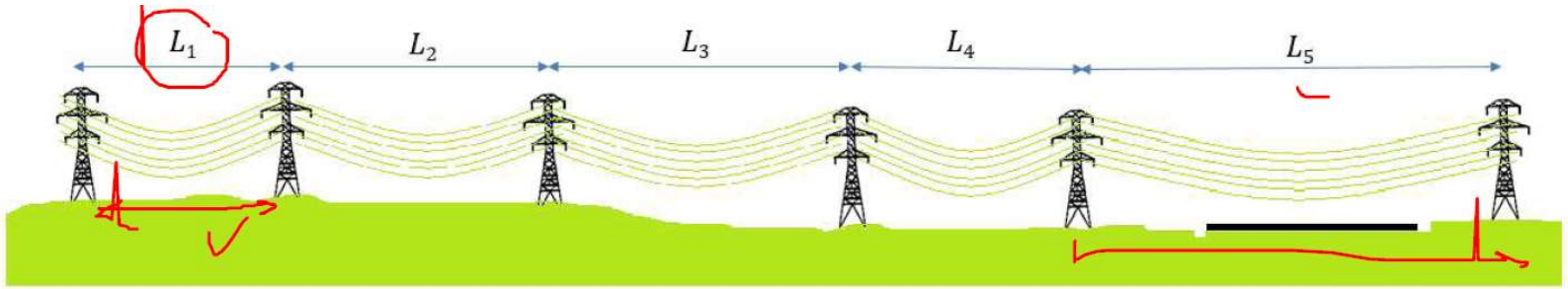
- There are several situations span length is not same. Therefore, tension in each span will be different.

$$T_i = H_i\left(1+\frac{wL_i^2}{2H_i}\right)$$

- This is not possible in case of suspension type insulator, because it will swing to equalize the tension.
- Therefore, the uniform tension in each span is calculated by defining the equivalent span (or ruling span).
  - L_e is the equivalent or ruling span
  - L_i is the each individual span in line

$$L_e = \sqrt{\frac{L_1^3+L_2^3+L_2^3+\cdots+L_n^3}{L_1+L_2+L_3+\cdots+L_n}} \Rightarrow T = H_e\left(1+\frac{wL_e^2}{2H_e}\right)$$

Ruling or Equivalent Span



- Also approximate ruling span is:
  - L_{avg} is the average span in line
  - L_{max} is the maximum span in line

$$L_e = L_{avg} + \frac{2}{3}\left(L_{max} + L_{avg}\right)$$

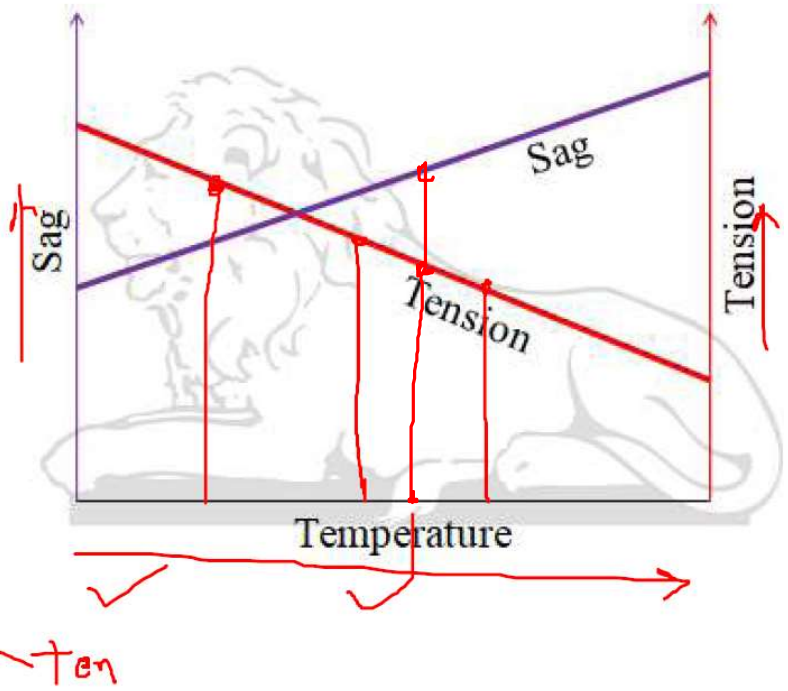
- The *ruling span* is then used to calculate the horizontal component of tension, which is to be applied to all the spans between the anchor points. Then the sag at each span is computed using

$$T = H_e\left(1 + \frac{w L_e^2}{2H_e}\right) \quad \Rightarrow \quad d_i = \frac{w l_i^2}{2H_e}$$

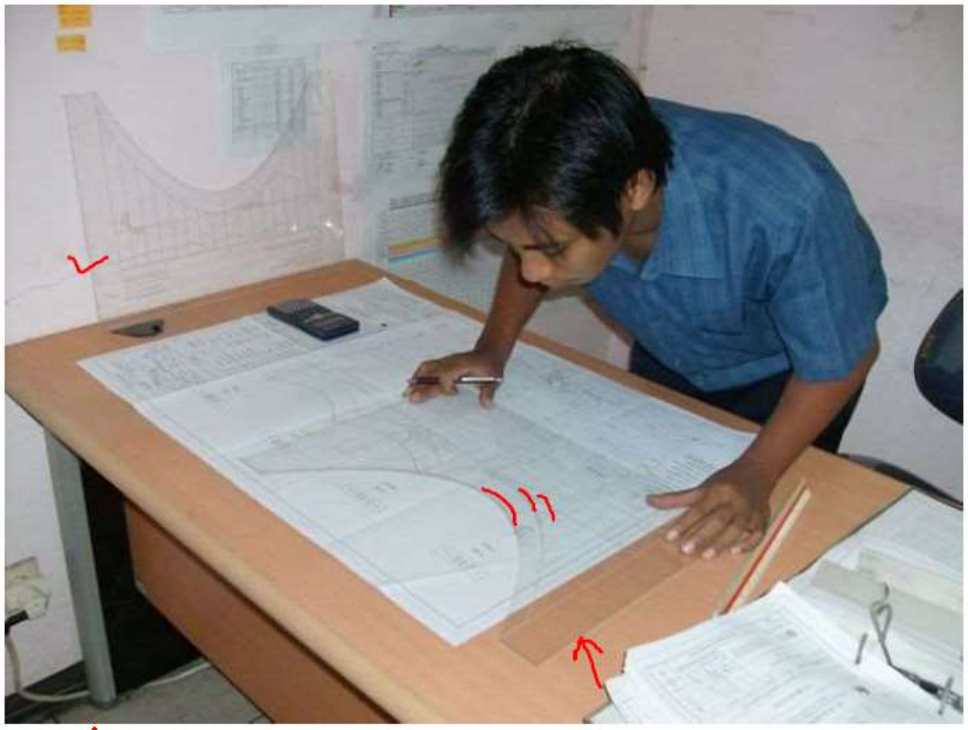
- Span should not be more than twice the *ruling span* or less than half the *ruling span*.

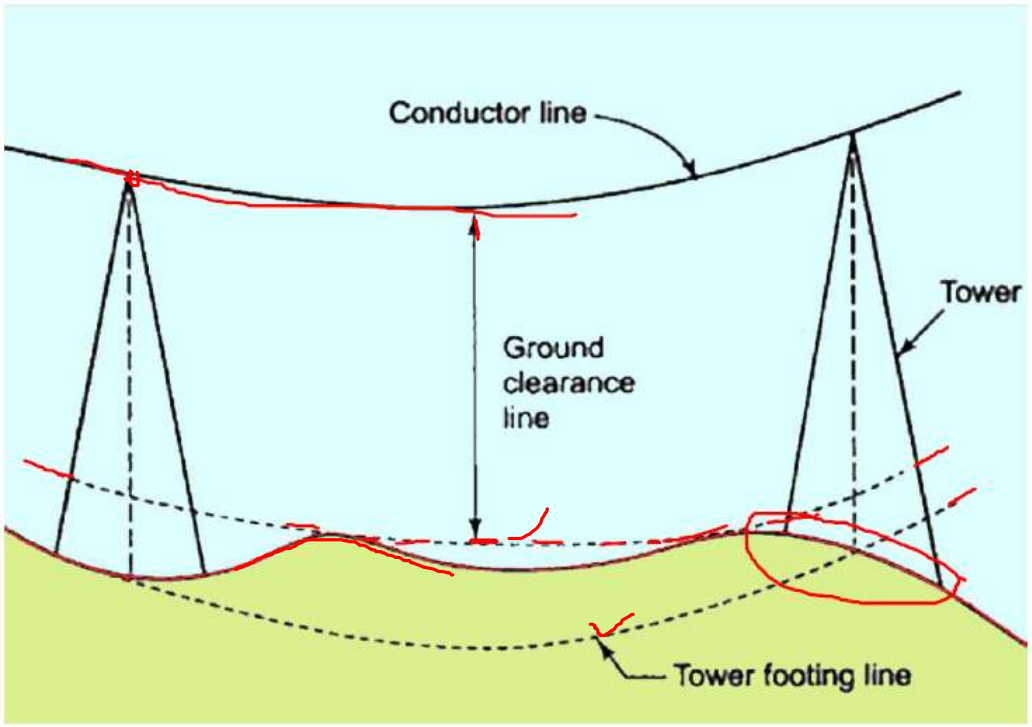
Stringing Chart

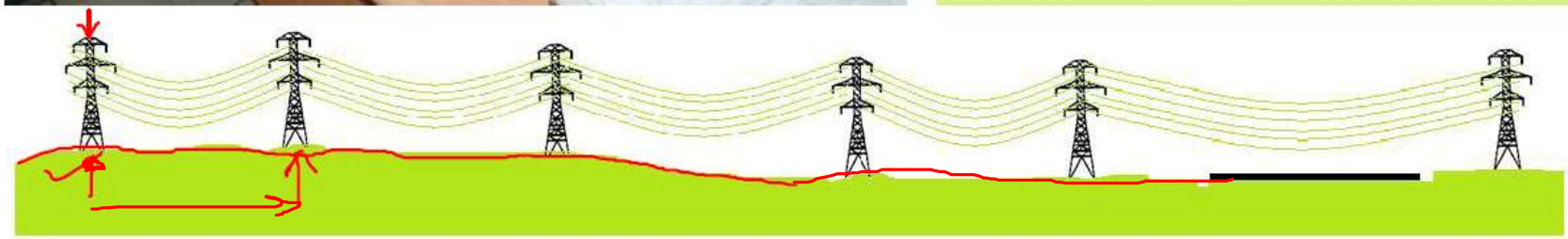
- The curves of sag and tension with temperature variation are called the *Stringing Charts*.
- Stringing chart is helpful in providing sag and tension at any temperature, if the sag and tension is know at any particular temperature.
- They are useful in erecting line conductors at specified temperature and loading conditions.
- At high temperature, sag is more and tension is less whereas at low temperature sag is less but tension is more.



Sag Template

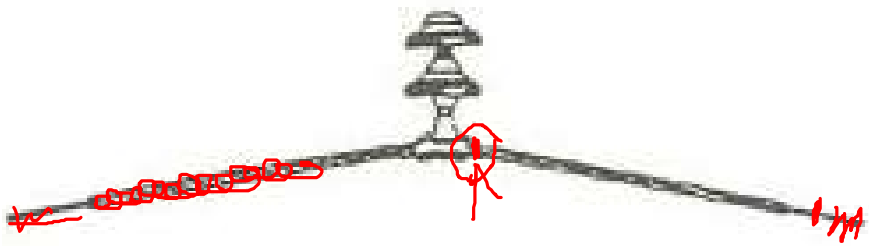




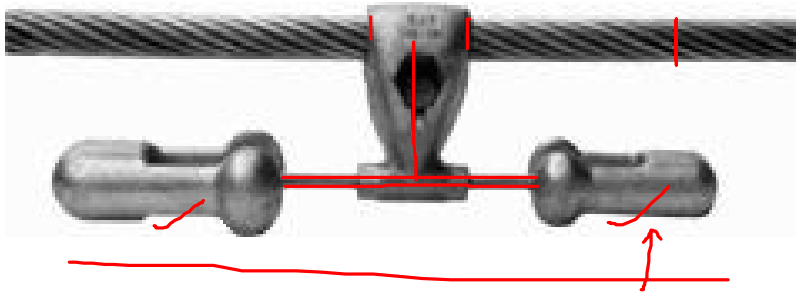


Conductor Vibrations

- **Aeolian or resonant vibrations:**
  - It is caused by vortex phenomena in light winds.
  - Low magnitude (up to 5 cm), loop length 1-10 m, and high frequency (5-40 Hz)
  - Less harmful because of small magnitude
  - These vibrations are common in conductor and more or less always present.
  - The *Armour rods* or *dampers* are used to damp these vibrations.

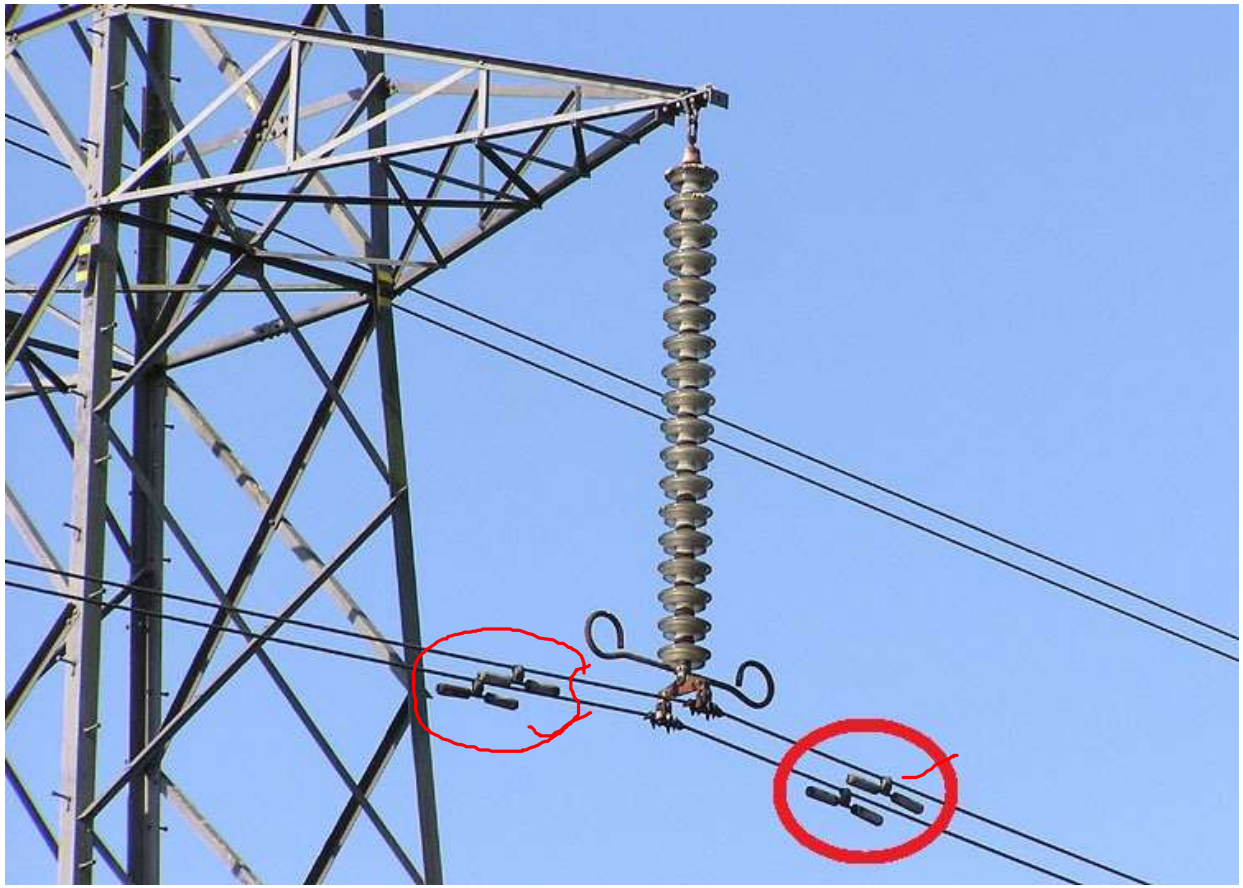


Armour rods



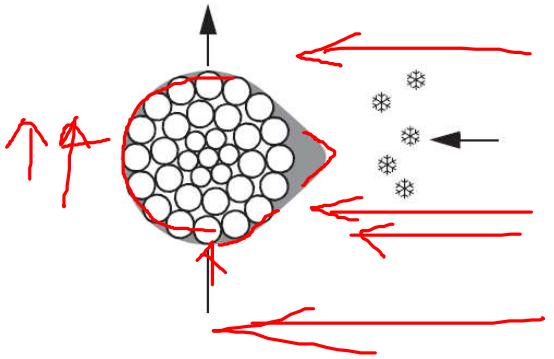
Stock-bridge dampers

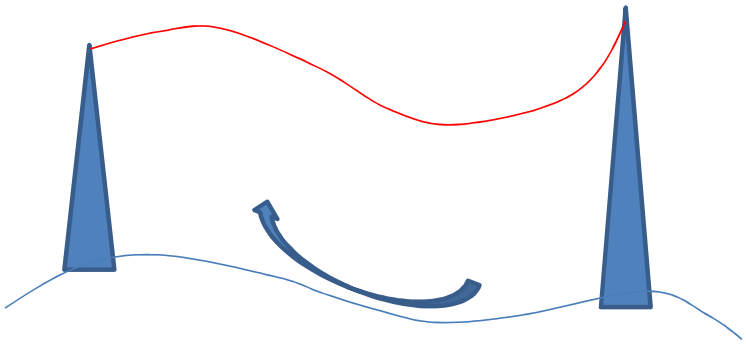
Stock-Bridge Dampers



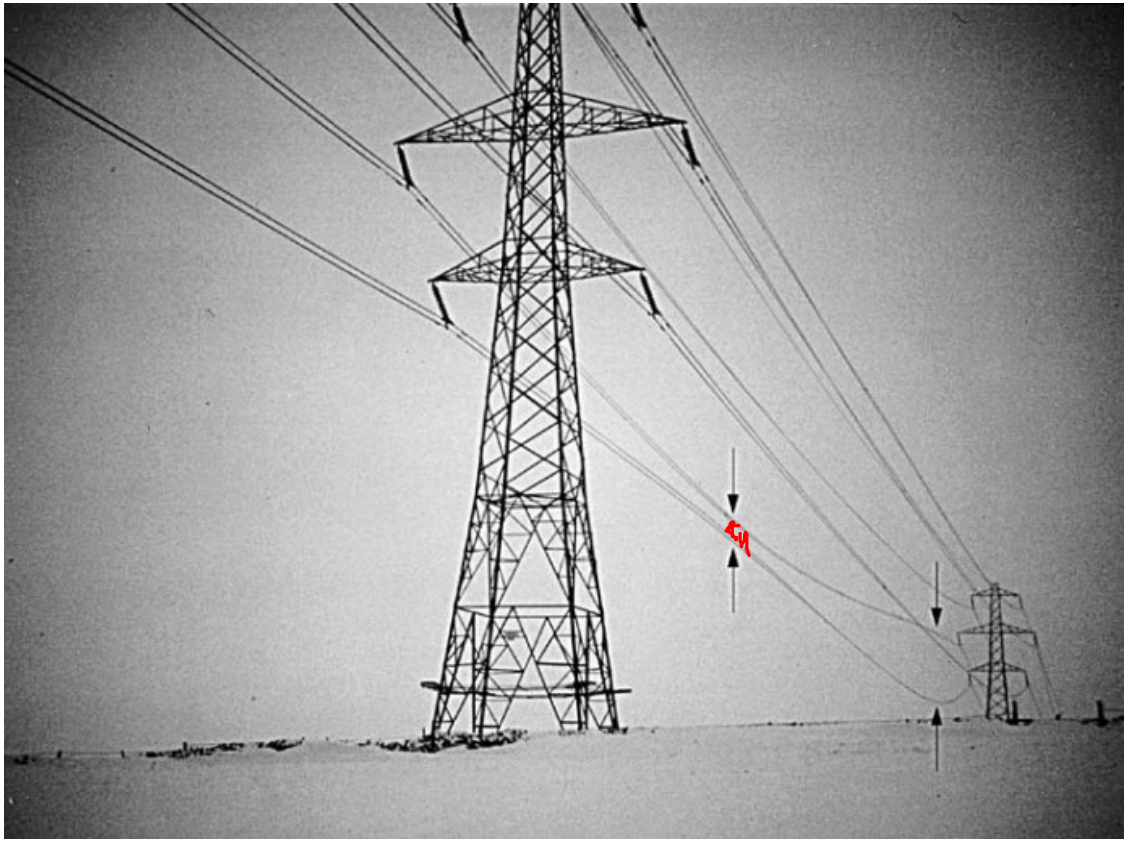
Conductor Vibrations

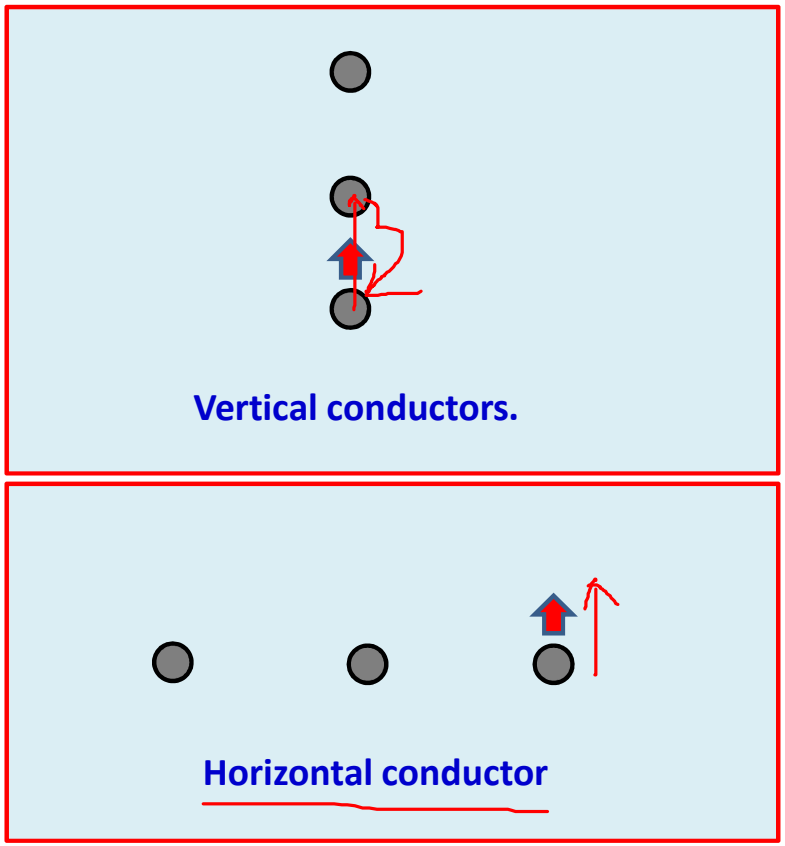
- **Galloping (or dancing conductors):**
  - Generally happened due to asymmetrical layer of ice formation.
  - When this asymmetrical ice coated conductor exposed to light winds (particularly when the slope of ground is higher).
  - High magnitude (up to 6 m) and low frequency (0.25-2 Hz).
  - These vibration may cause flashover between the conductors.
  - To avoid this flashover horizontal configuration is preferred.
  - Also if conductor is perfectly circular the effect can be minimized.
  - The stranded conductors can be wrapped up with PVC to make conductor perfectly circular.





Galloping (or Dancing Conductors)

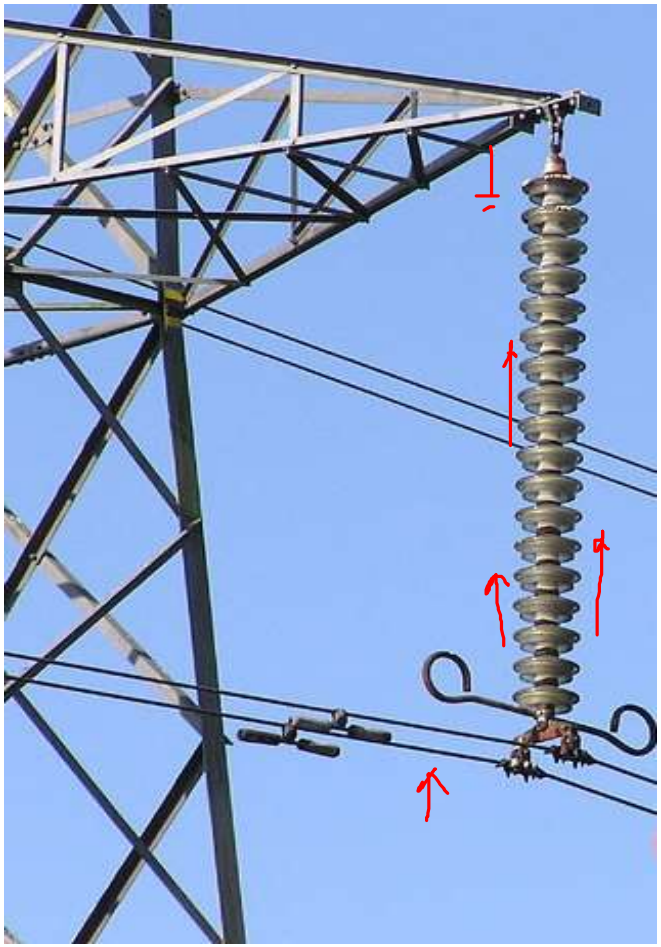


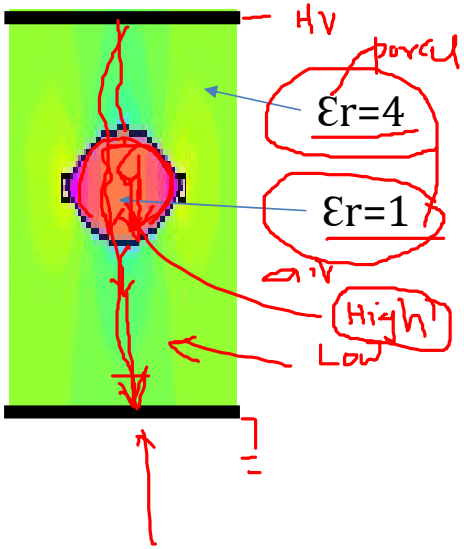


Insulators and Electrical Design

Insulators for Overhead Line

- *Insulators* are used to insulate towers from the live conductors
- The insulators are attached to the tower and support the line conductors.
- **Important characteristics:**
  - Homogeneous materials without voids and impurities.
  - Minimum leakage current.
  - High dielectric or breakdown strength.
  - Mechanically strong to bear the conductor load
  - Longer life.



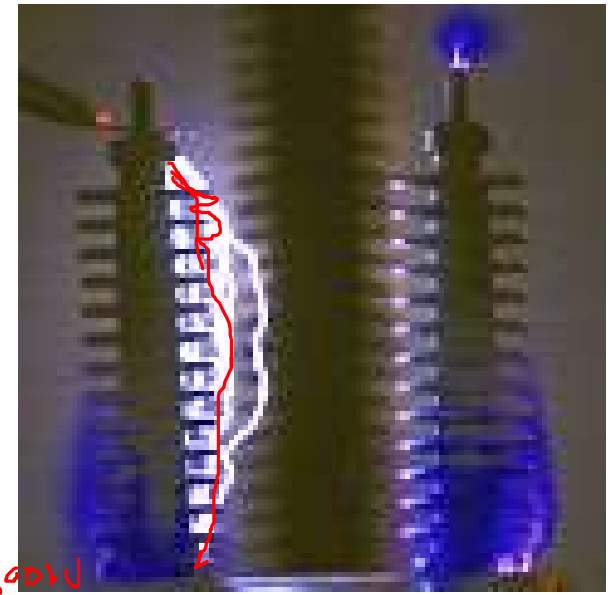


Insulator Ratings

- Three voltages ratings
  - Working voltage
  - Puncture voltage
  - Flashover voltage

$$\text{Safety Factor} = \frac{\text{Flashover Voltage}}{\text{Working Voltage}}$$

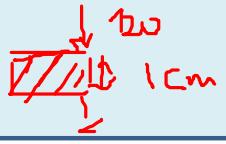
- Flashover voltage is less than puncture voltage.



Insulators for Overhead Line

❑ Porcelain:

- Porcelain (silica, felspar, and clay) is widely used as it is cheap.
- It is thoroughly vitrified to remove voids and glazed before use to keep surface free of dust and moisture.
- Breakdown strength is around 120-280 kV/cm

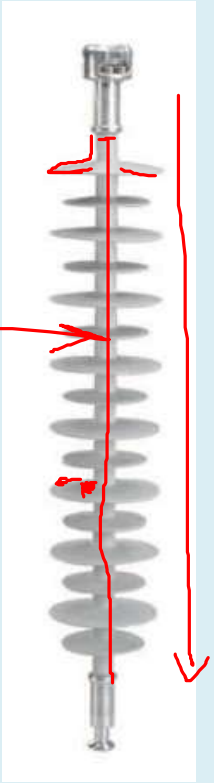


❑ Toughened Glass:

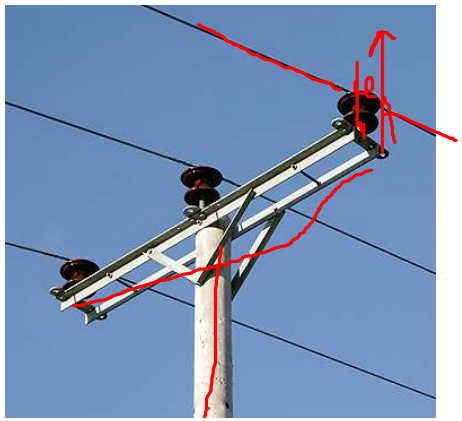
- Toughened glass is another choice having higher dielectric strength (1200 kV/cm), mechanical strength and life, higher thermal shock resistant, lower coefficient of expansion
- Flaws can be detected easily by visual inspection.
- Main disadvantage is moisture rapidly condenses on the surface giving high surface leakage current.
- Expensive

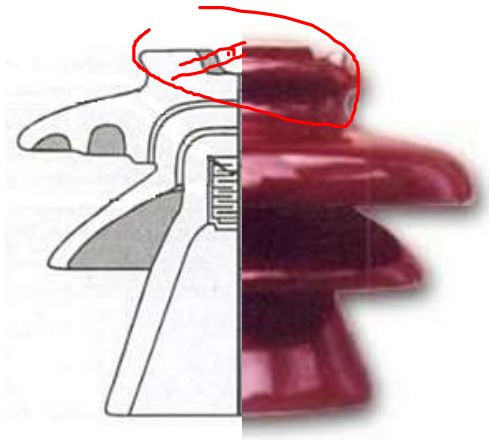
Insulators for Overhead Line

- **Polymeric Insulation:**
  - Silicone rubber and EPDM (Ethylene propylene diene monomer) are used for insulation purpose.
  - Low cost, light weight, smaller in size, higher life, improved dielectric performance under moderate pollution.
  - They are used in combination with fiber glass rod.
  - These are under field trials and may take time to be used extensively.
  - Tracking and erosion of the shed material, which can lead to bad pollution performance and can cause flashover.
  - Chalking and crazing of the insulator's surface, which resulted in increased contaminant collection, arcing, and flashover.



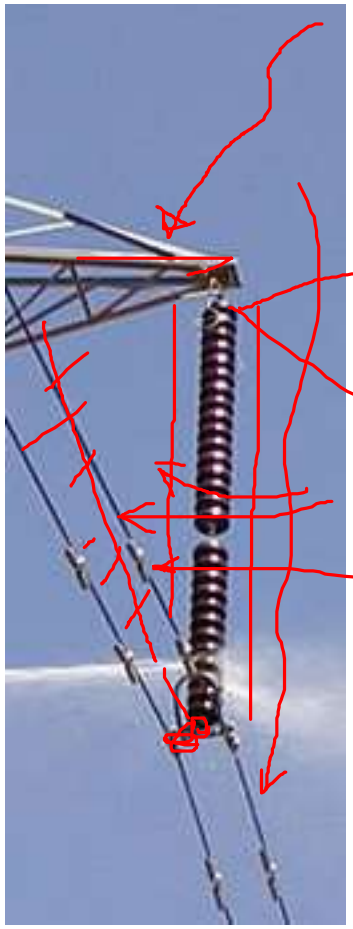
Pin Type Insulator

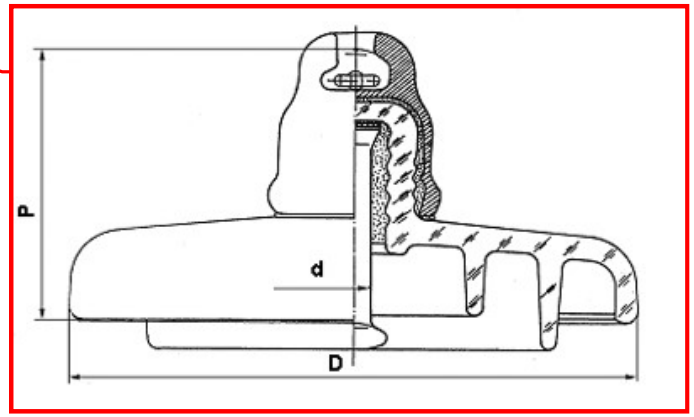




- Supported on steel bolt or pin which is firmly supported on cross-arm.
- Conductor is tied to insulator on groove by annealed binding wire.
- Usually used for 11 kV and 33 kV lines.
- They can be made in one piece up to 33 kV and two pieces for higher voltages.
- Pin type insulators are uneconomical for higher voltages.

Suspension Type Insulators



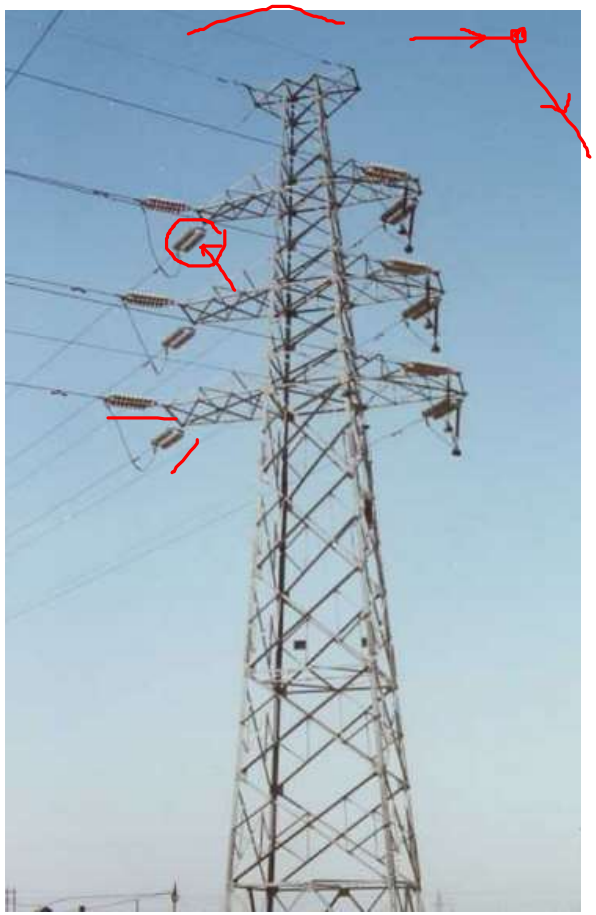


- Consists of one or more insulating units hung from cross arm and conductor is connected at lowest unit.
- String is free to swing (lower mechanical stresses); thus long cross arms are required.
- Economical voltages above 33 kV. Each typical unit is designed for 11 kV.

- Failed unit can be changed without changing whole string.
- Less lightning strike to conductors
- V shaped insulator strings can also be used to avoid the swings.
- 400 -> 21-23 units -> 3.84 m

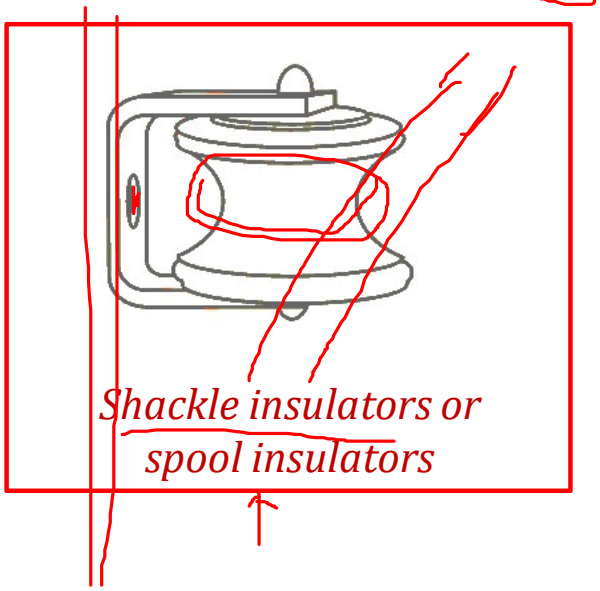
Strain Type Insulator

- The insulators are similar to suspension type insulator but used in horizontal position.
- Generally used at the towers with dead end, angle towers, and road and river crossings.
- They can take tension off the conductors. When tension is very high two or more strings are used in parallel.

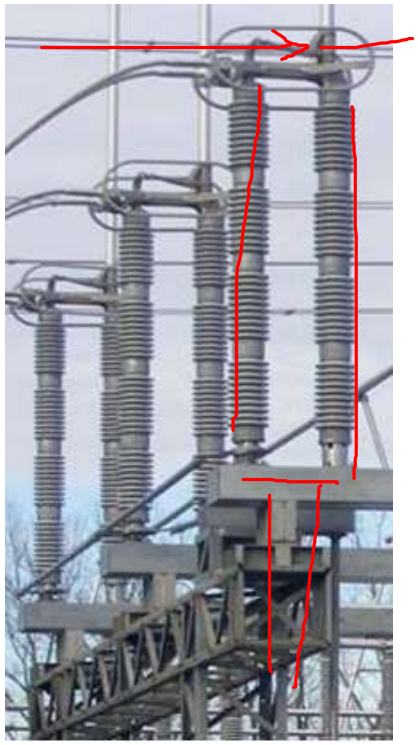


https://wikimedia.org

Shackle, Post, and Polymeric Insulators



Shackle insulators or spool insulators



Post type insulators

Polymeric insulators

Thank You