Transmission and Distribution of Electrical Power

By

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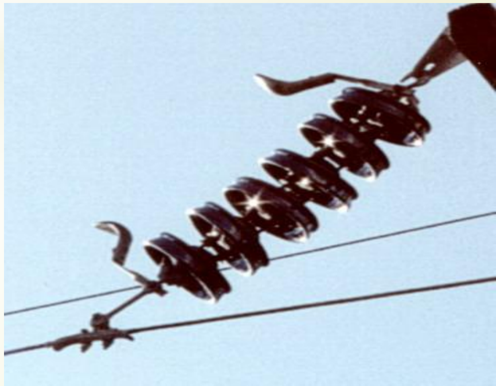
Lecture (2)

Overhead Line Insulators

What is Overhead Line Insulator?

Overhead line insulator is insulating fixture that is used to secure the conductors of an overhead transmission (or distribution) from current leakage to the earth through the supports.



Characteristics of Overhead Line Insulators

- **Mechanically very strong in order to withstand the load due to weight of the conductors.**
- **High relative permittivity in order to give high dielectric strength.**
- **High ratio of rupture to flash-over voltage.**

Characteristics of Overhead Line Insulators

- **High insulation resistance in order to avoid leakage of current to earth.**
- **The material employed should not be porous and there should be no effect of change in temperature.**
- **Free from internal impurities and crack and should be impervious to the fluids and gases in the atmosphere.**

Characteristics of Overhead Line Insulators

- High insulation resistance
- High Relative Permittivity
- Mechanically Very Strong
- Free from internal impurities and crack
- High Ratio of Rupture to Flash-Over Voltage
- Impervious to the fluids and gases in the atmosphere

Insulation Material

Porcelain

* Advantages
  * Mechanically strong
  * Its surface is not affected by dirt deposits
  * Less susceptible to temperature changes
* Disadvantage
  * It is not so homogeneous as glass.
  * It is not transparent

Insulation Material

Glass

* Advantages
  * cheaper than porcelain
  * It has a lower coefficient of thermal expansion
* Disadvantages
  * moisture more readily condense on its surface

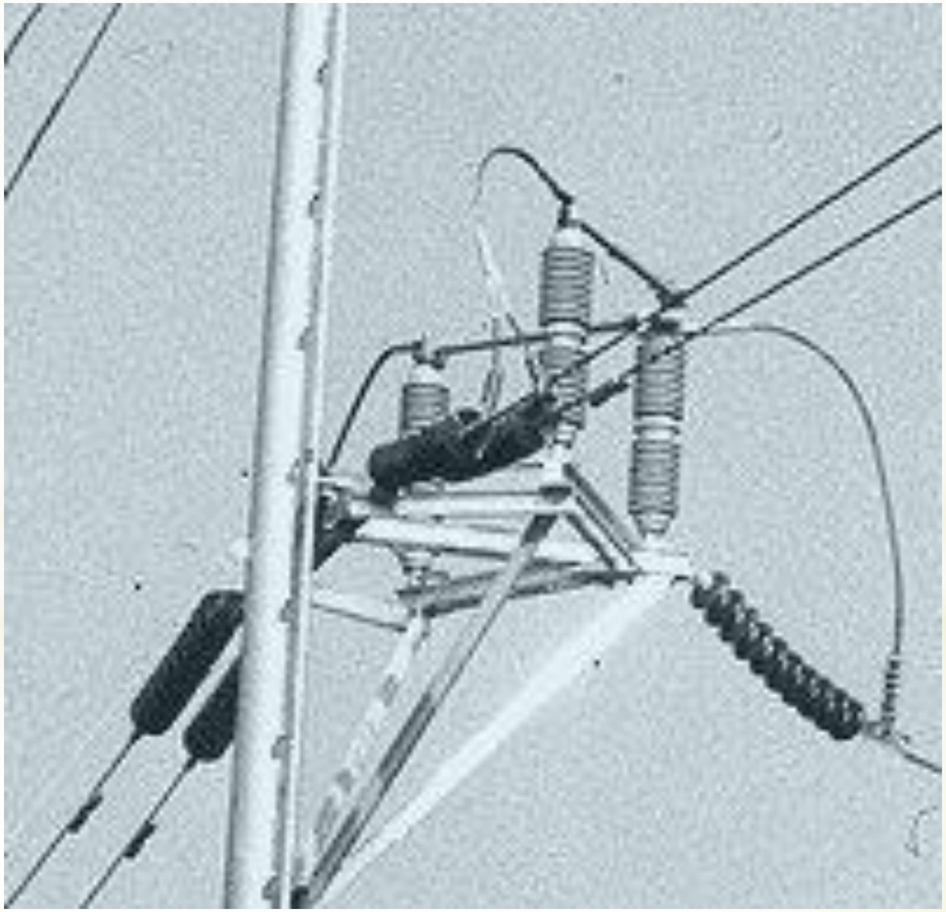
Insulation Material

Steatite

* Advantages
  * It can be used at tension towers
* Disadvantages
  * It has a much higher tensile and bending stress

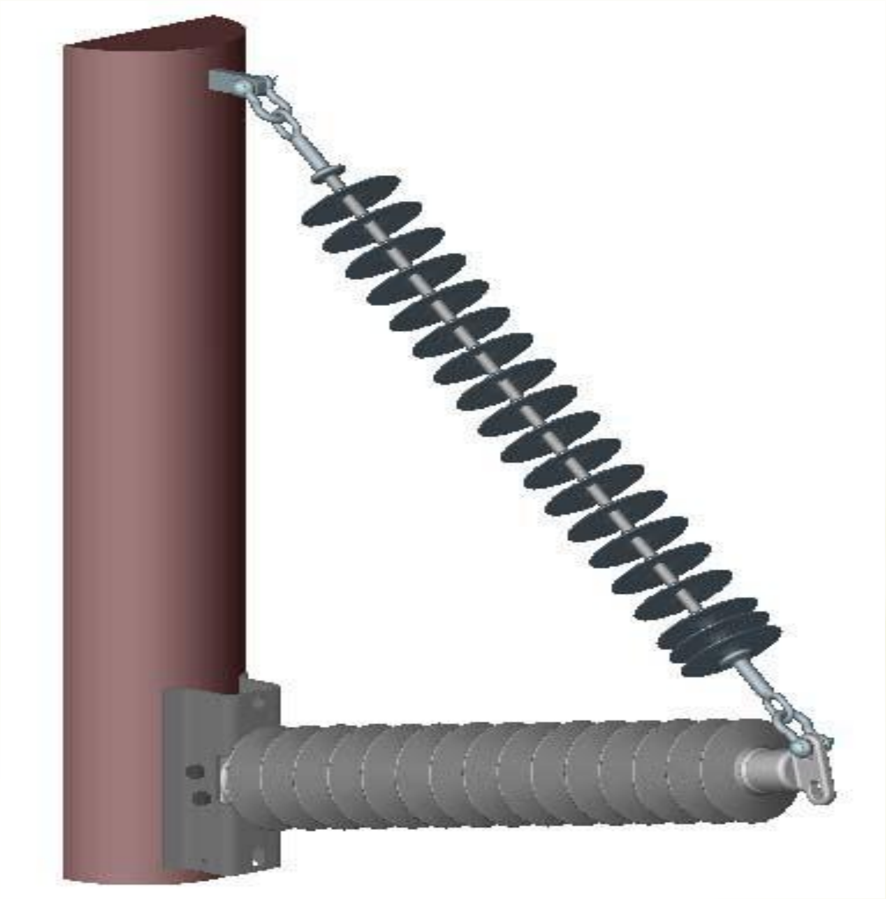
Types of insulators

Pin type insulator



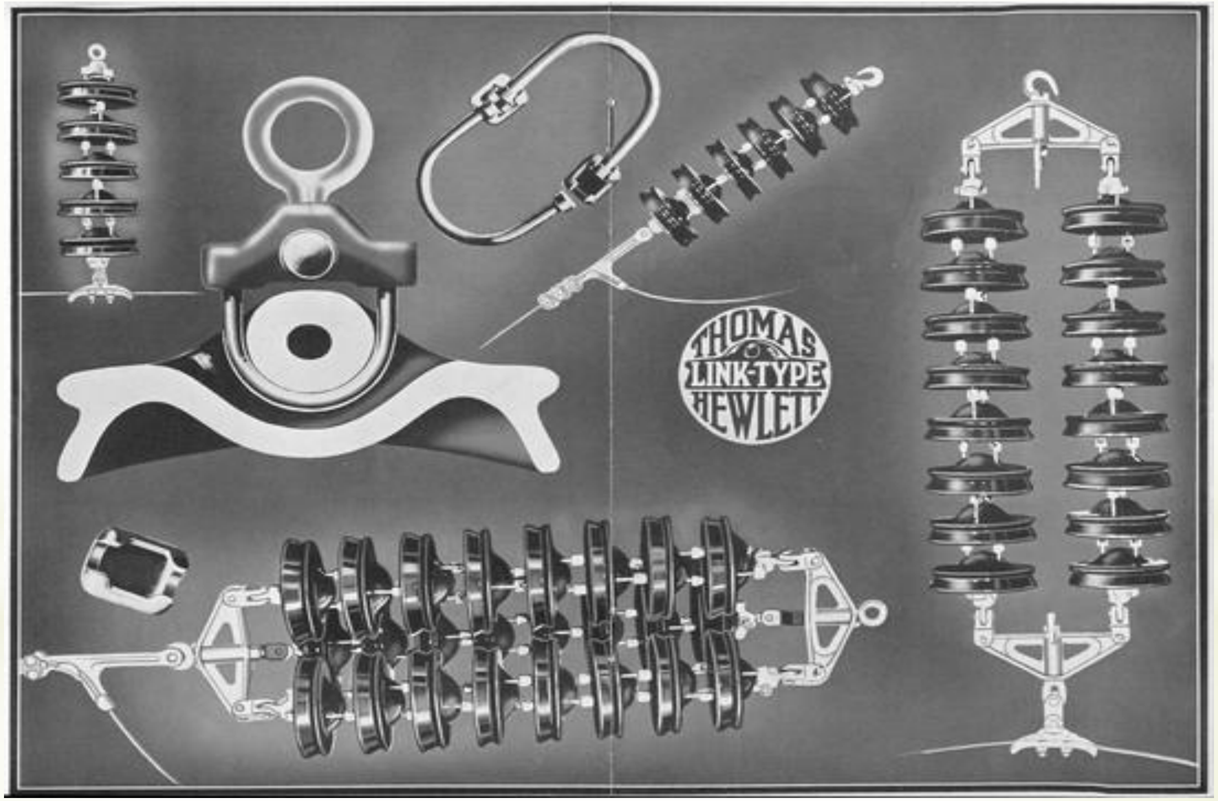
Types of insulators

Suspension type insulator



Types of insulators

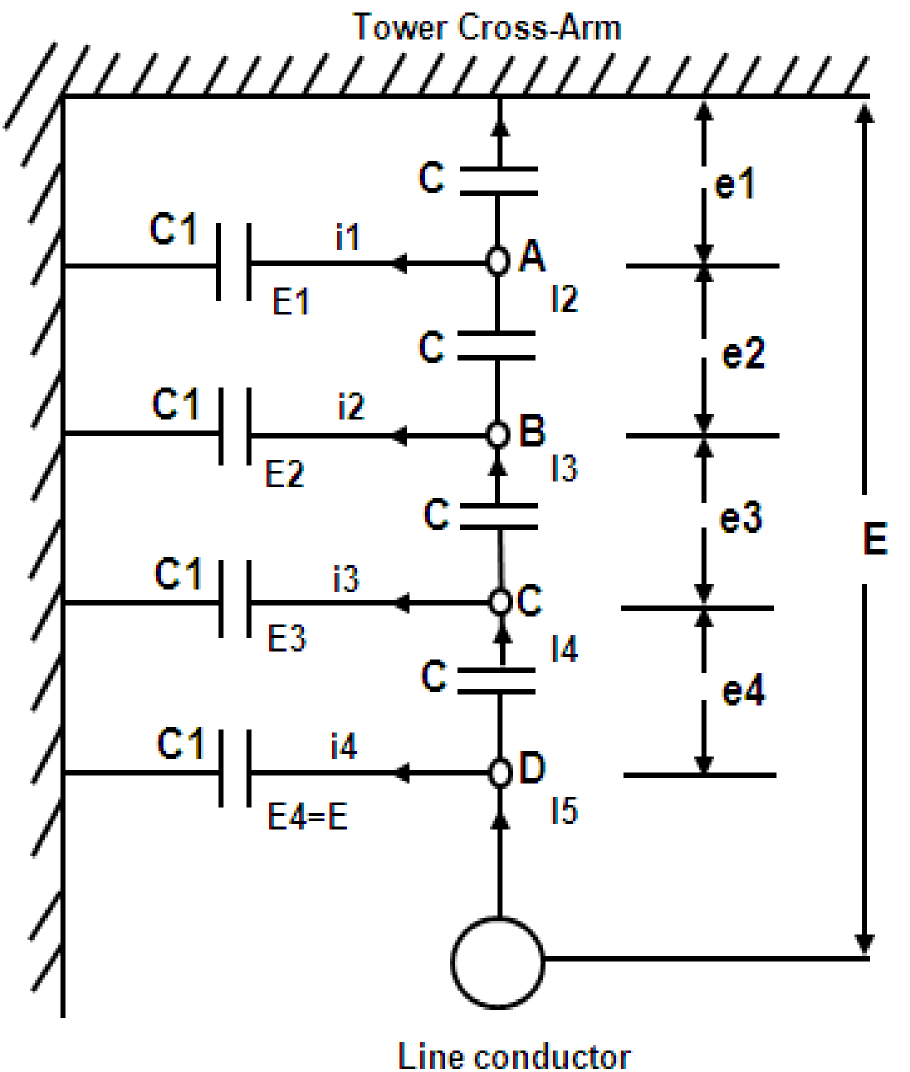
Strain insulator

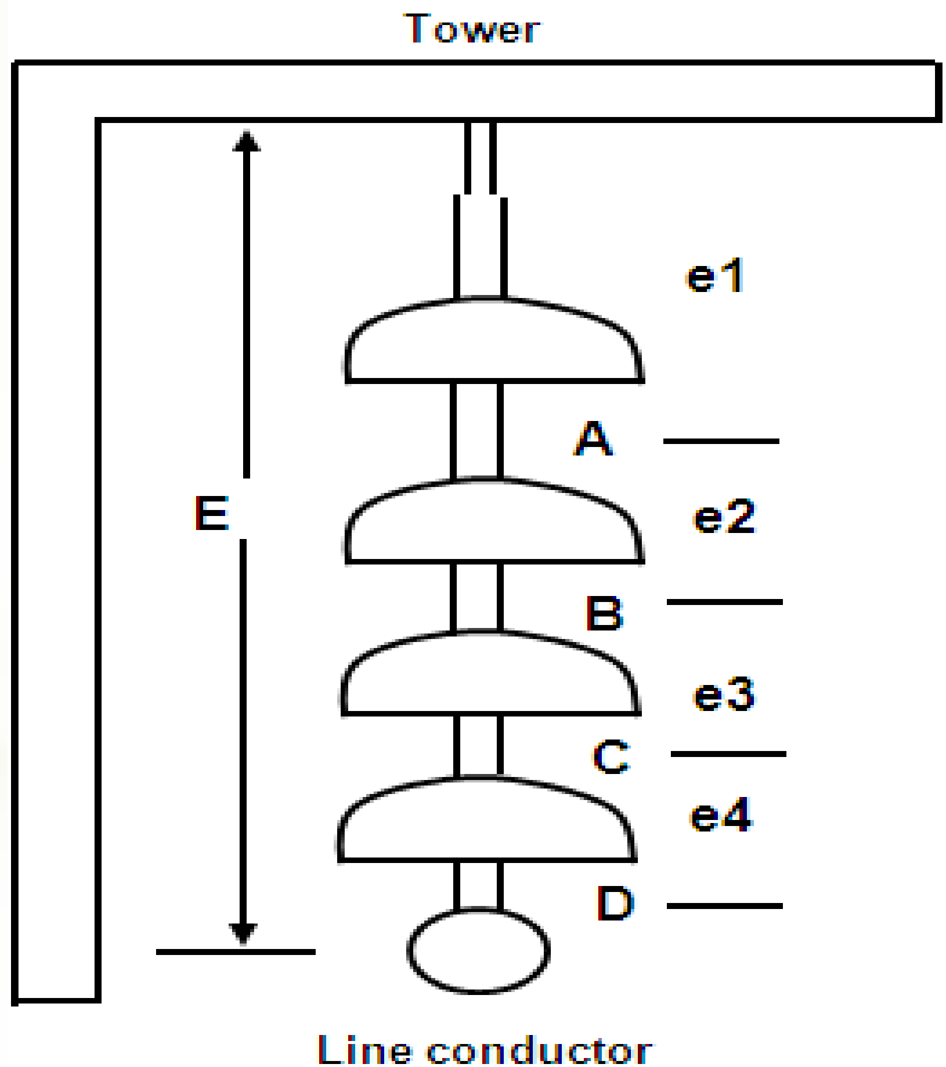


insulators Failure

* The causes of the failure of insulators are given below:
  * Cracking of insulator
  * Porosity of the material
  * Improper verification
  * Flashover
  * Mechanical stresses
  * Short circuit
  * Deposition of dust

Potential distribution over a string of suspension insulators





- Let the mutual capacitance between the links be C
- Shunt capacitance between links and earth be C_1.
- The voltage across the first unit (nearest the cross arm) be e_1
- The voltage across the second unit e_2.
- The voltage across the third unit e_3.
- The voltage across the last unit (nearest the line conductor) be e_4
- The voltage between conductor and earth be E.

Let

$$\frac{C_1}{c} = K \quad \text{or} \quad C_1 = Kc$$

Appling Kirchhoff's first law to node a, we gets:

$$I_2 = I_1 + i_1$$

$$\omega C e_2 = \omega C e_1 + \omega C_1 e_1$$

$$\omega C e_2 = \omega C e_1 + \omega K c_1$$

Or

$$e_2 = e_1(1 + K)$$

Voltage across the first capacitance C_1 from top =E1=e1
Appling Kirchhoff's first law to node B, we get:

$$I_3 = I_2 + i_2$$

$$\omega C e_3 = \omega C e_2 + \omega C_1(e_1 + e_2)$$

Voltage across the second shunt capacitance C1 from top =E2=e1+e2

Or

$$\omega C e_3 = \omega C e_2 + \omega C_1 (e_1 + e_2)$$

Or

$$e_3 = e_2 + K(e_1 + e_2)$$

Or

$$e_3 = Ke_1 + e_2(1 + K)$$

Or

$$e_3 = Ke_1 + e_1(1 + K)(1 + K)$$

Since

$$e_3 = Ke_1 + e_1(1 + K)^2$$

Or

$$e_3 = e_1(1 + 3K + K^2)$$

Appling Kirchhoff's third shunt capacitance C1 from top $E_3=e_1+e_2+e_3$

$$\omega ce_4 = \omega ce_1\left(1+3K+K^2\right)+\omega Kc\left[e_1+e_1\left(1+K\right)+e_1\left(1+3K+K^2\right)\right]$$

Or

$$e_4 = e_1\left(1+6K+5K^2+K^3\right)$$

Note that the voltage E1, E2 and E3 are finally voltage between conductor and earth

$$E = e_1 + e_2 + e_3 + e_4$$

$$= e_1 + e_1(1+K) + e_1(1+3K+K^2) + e_1(1+6K+5K^2+K^3)$$

$$= e_1(4+10K+6K^2+K^3)$$

Thus

$$\frac{e_1}{1} = \frac{e_2}{1+K} = \frac{e_3}{1+3k+K^2} = \frac{e_4}{1+6K+5K^2+K^3} = \frac{E}{4+10K+6K^2+K^3}$$

The greatest voltage will obviously be

e_4

which is given as

$$e_4 = \frac{1+6K+5K^2+K3}{4+10K+6K^2+K^3}E$$

$$\text{String efficiency} = \frac{E}{ne_4} \times 100 = \frac{E}{4 \times \frac{1 + 6K + 5K^2 + K^3}{4 + 10K + 6K^2 + K^3}}$$

Since n=4 flashover voltage of one unit = greatest voltage across any unit i.e e4

$$\text{String efficiency} = \frac{4 + 10K + 6K^2 + K^3}{4\left(1 + 6K + 5K^2 + K^3\right)} \times 100$$

Methods of Improving String Efficiency

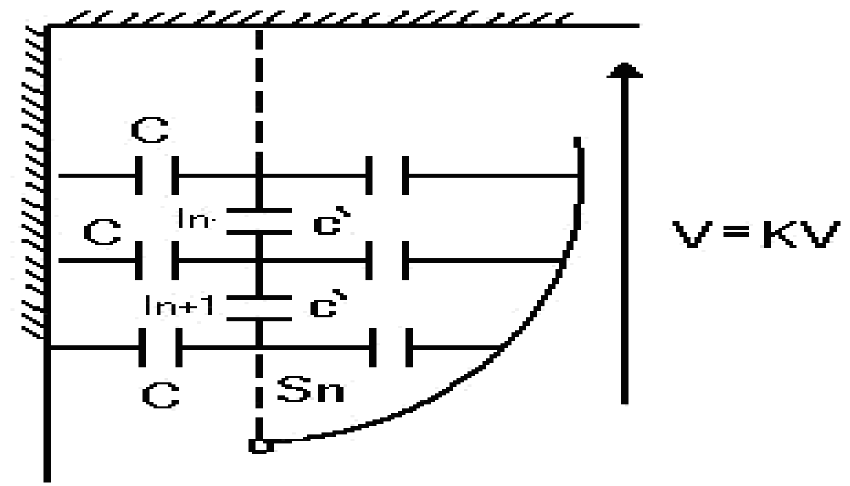
- Long Cross-arm Method (decreasing the value of K): The string efficiency increases with the decrease in the value of K. K can be decreased by using long cross-arms. But the limitation of cost and strength doesn't allow the cross-arms to be too long. In practice K shouldn't be less than 0.1.

Methods of Improving String Efficiency

- Capacitance Grading Method: Uniform voltage distribution across units of string of suspension insulators can be achieved by grading the mutual capacitance of the units by having the lower units of more capacitance - maximum at the line unit and minimum at the top unit, nearest to the cross-arms.

Methods of Improving String Efficiency

- Static Shielding: By using a guard or grading ring, which usually takes the form of a large metal ring surrounding the bottom unit and connected to the metal work at the bottom of this unit, and therefore to the line. The ring screens the units, reduces the earth capacitance and introduces a number of capacitances between the line and the insulator caps. But with this method it’s impossible to obtain an equal distribution of voltage.



At K=0.1

n (unit no.)	e_n (unit voltage)
1	0.1414
2	0.1556
3	0.1856
4	0.2342
5	0.3065
6	0.4097
7	0.5542
8	0.7546
9	1.031
10	1.4115

At K=0.1

11	1.9342
12	2.652
13	3.6373
14	4.9893
15	6.8444
16	9.3896
17	12.8817
18	17.6727
19	24.2457
20	33.2636
21	45.6357
22	62.6095

At K=0.1

$$\%Efficiency = \eta = 16.7663$$

At K=0.25

n (unit no.)	e_n (unit voltage)
1	0.004
2	0.005
3	0.0074
4	0.0116
5	0.0187
6	0.0306
7	0.0503
8	0.0829
9	0.1366
10	0.2253

At K=0.25

11	0.3714
12	0.6123
13	1.0095
14	1.6643
15	2.744
16	4.524
17	7.4589
18	12.2976
19	20.2753
20	33.4284
21	55.1141
22	90.8678

At K=0.25

$$\%Efficiency = \eta = 11.5522$$

Conclusion

* From the previous tables we note that the string efficiency decreases with the increase in the value of K.

* By using guard ring the efficiency becomes about 95-99%.

Thank You
For Your Attention

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