Potential Distribution over Suspension Insulator String

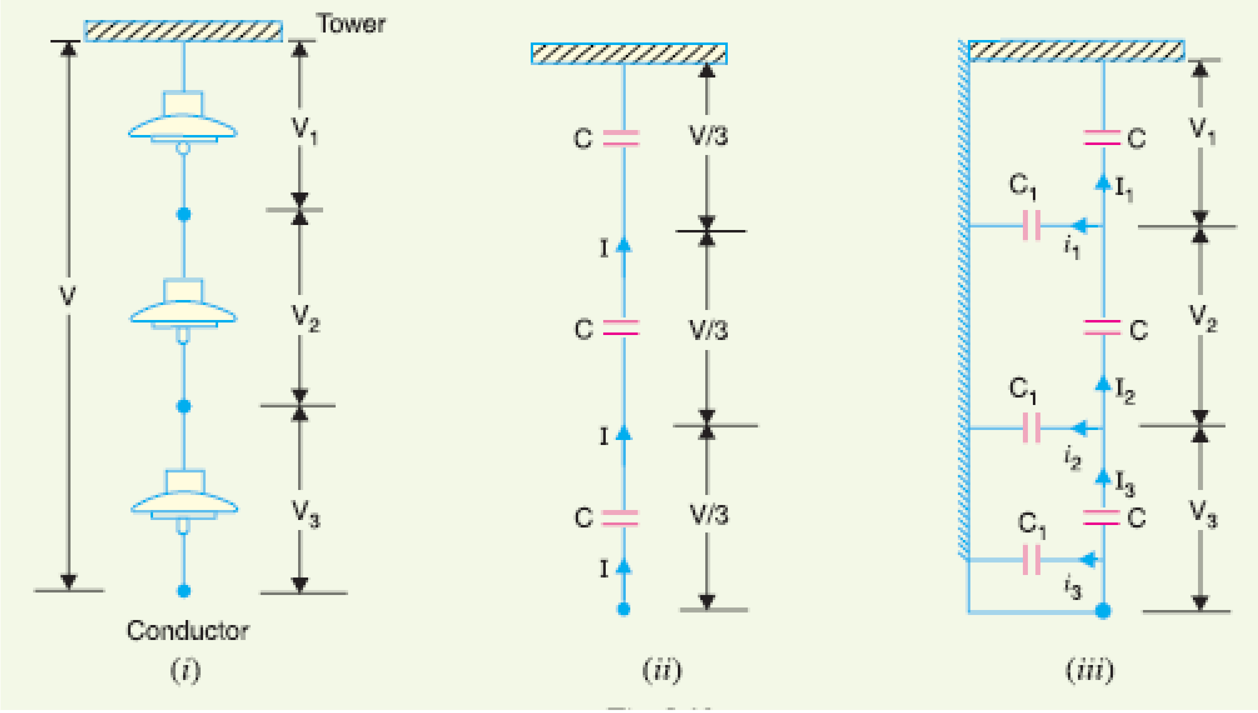
Dr.-Ing. Getachew Biru

Potential Distribution over Suspension Insulator String

- A string of suspension insulators consists of a number of porcelain discs connected in series through metallic links.
- The Fig. shows 3-disc string of suspension insulators. The porcelain portion of each disc is in between two metal links. Therefore, each disc forms a capacitor C as shown in the Fig.
- This is known as mutual capacitance or self-capacitance. If there were mutual capacitance alone, then charging current would have been the same through all the discs and consequently voltage across each unit would have been the same i.e., V/3.

Potential Distribution over Suspension Insulator String

- However, in actual practice, capacitance also exists between metal fitting of each disc and tower or earth. This is known as *shunt capacitance* C_1.
- Due to shunt capacitance, charging current is not the same through all the discs of the string. Therefore, voltage across each disc will be different. Obviously, the disc nearest to the line conductor will have the maximum voltage



Potential Distribution over Suspension Insulator String

String Efficiency

- As stated above, the voltage applied across the string of suspension insulators is not uniformly distributed across various units or discs.
- The disc nearest to the conductor has much higher potential than the other discs. This unequal potential distribution is undesirable and is usually expressed in terms of string efficiency.

Potential Distribution over Suspension Insulator String

String Efficiency

- The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as string efficiency i.e.,

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across disc nearest to conductor}}$$

$$n = \text{number of discs in the string.}$$

- String efficiency is an important consideration since it decides the potential distribution along the string. The greater the string efficiency, the more uniform is the voltage distribution.

Potential Distribution over Suspension Insulator String

String Efficiency

- Fig. shows the equivalent circuit for a 3-disc string. Let us suppose that self capacitance of each disc is C.
- Let us further assume that shunt capacitance C_1 is some fraction K of self-capacitance i.e., $C_1 = K*C$.
- Starting from the cross-arm or tower, the voltage
- across each unit is V_1,V_2 and V_3 respectively as shown.

Potential Distribution over Suspension Insulator String

String Efficiency

- Applying Kirchhoff's current law to node A, we get,

Applying Kirchhoff's current law to node *A*, we get,

$$I_2 = I_1 + i_1$$

or $$V_2 \omega C^* = V_1 \omega C + V_1 \omega C_1$$

or $$V_2 \omega C = V_1 \omega C + V_1 \omega K C$$

$\therefore$ $$V_2 = V_1 (1 + K)$$

Applying Kirchhoff's current law to node *B*, we get,

$$I_3 = I_2 + i_2$$

or $$V_3 \omega C = V_2 \omega C + (V_1 + V_2) \omega C_1 \dagger$$

or $$V_3 \omega C = V_2 \omega C + (V_1 + V_2) \omega K C$$

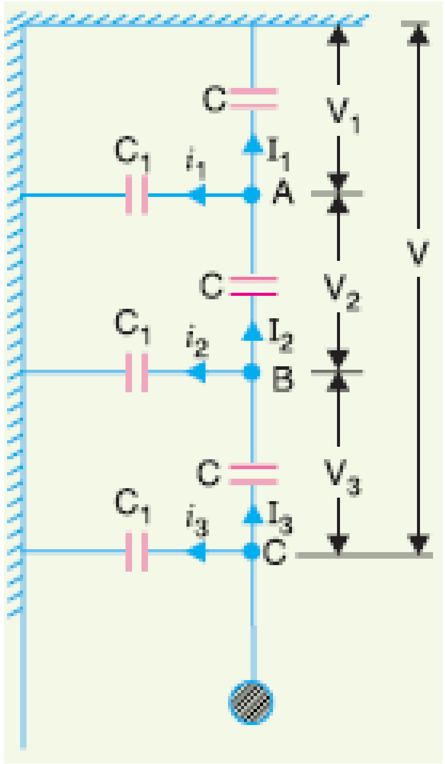
or $$V_3 = V_2 + (V_1 + V_2) K$$

$$= K V_1 + V_2 (1 + K)$$

$$= K V_1 + V_1 (1 + K)^2$$

$$= V_1 [K + (1 + K)^2]$$

$\therefore$ $$V_3 = V_1 [1 + 3K + K^2]$$



Potential Distribution over Suspension Insulator String

String Efficiency

Voltage between conductor and earth (*i.e.*, tower) is

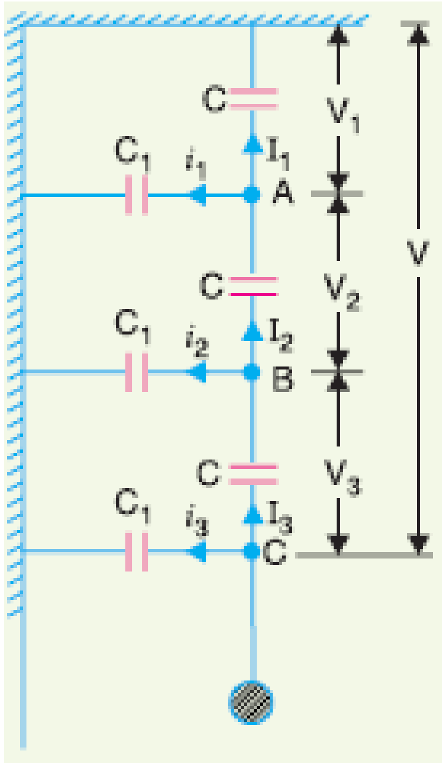
$$V = V_1 + V_2 + V_3$$
$$= V_1 + V_1(1+K) + V_1(1+3K+K^2)$$
$$= V_1(3+4K+K^2)$$

$$\therefore \quad V = V_1(1+K)(3+K)$$

From expressions (*i*), (*ii*) and (*iii*), we get,

$$\frac{V_1}{1} = \frac{V_2}{1+K} = \frac{V_3}{1+3K+K^2} = \frac{V}{(1+K)(3+K)}$$

$\therefore$ Voltage across top unit, $V_1 = \dfrac{V}{(1+K)(3+K)}$

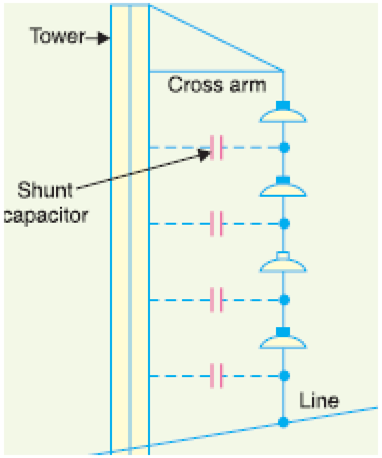


- The greater the value of K (= C_1/C), the more non-uniform is the potential across the discs and lesser is the string efficiency.
- The inequality in voltage distribution increases with the increase of number of discs in the string. Therefore, shorter string has more efficiency than the larger one.

Potential Distribution over Suspension Insulator String

Methods of Improving String Efficiency

- By using longer cross-arms. The value of string efficiency depends upon the value of K i.e., ratio of shunt capacitance to mutual capacitance. The lesser the value of K, the greater is the string efficiency and more uniform is the voltage distribution. The value of K can be decreased by reducing the shunt capacitance.



- In order to reduce shunt capacitance, the distance of conductor from tower must be increased i.e., longer cross-arms should be used. However, limitations of cost and strength of tower do not allow the use of very long cross-arms. In practice, K = 0·1 is the limit that can be achieved by this method.

Potential Distribution over Suspension Insulator String

Methods of Improving String Efficiency

- By grading the insulators. In this method, insulators of different dimensions are so chosen that each has a different capacitance. The insulators are capacitance graded i.e. they are assembled in the string in such a way that the top unit has the minimum capacitance, increasing progressively as the bottom unit (i.e., nearest to conductor) is reached. Since voltage is inversely proportional to capacitance, this method tends to equalize the potential distribution across the units in the string. This method has the disadvantage that a large number of different-sized insulators are required.

Potential Distribution over Suspension Insulator String

Methods of Improving String Efficiency

By using a guard ring. The potential across each unit in a string can be equalized by using a guard ring which is a metal ring electrically connected to the conductor and surrounding the bottom insulator as shown in the Fig.. The guard ring introduces additional capacitance. The result is that same charging current I flows through each unit of string. Consequently, there will be uniform potential distribution across the units.