3.7 METHODS OF IMPROVING STRING EFFICIENCY

It has been seen above that potential distribution in a string of suspension insulators is not uniform. The maximum voltage appears across the insulator nearest to the line conductor and decreases progressively as the cross arm is approached. If the insulation of the highest stressed insulator breaks down or flash over takes place, the breakdown of other units will take place in succession. This necessitates equalizing the potential across the various units of the string *i.e.* to improve the string efficiency. The various methods for this purpose are:

(i)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.

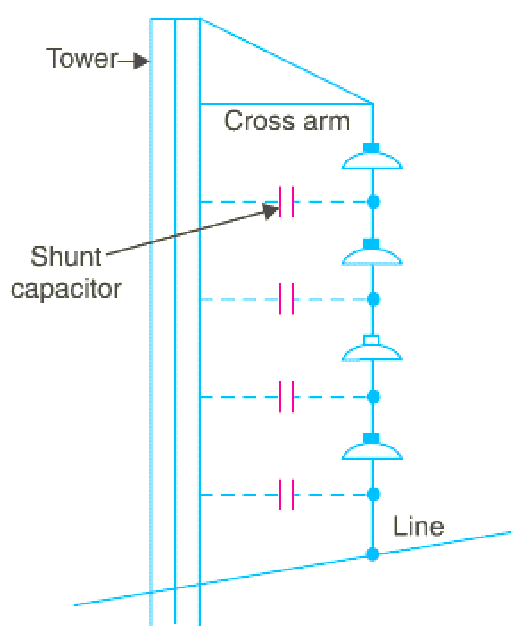

Figure 3.7.1 Longer Cross- Arms

[Source: "Principles of Power System" by V.K.Mehta Page: 170]

(ii) 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. However, good results can be obtained by using standard insulators for most of the string and larger units for that near to the line conductor.

(iii)By Using A Guard Ring

The potential across each unit in a string can be equalised 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 capacitance between metal fittings and the line conductor. The guard ring is contoured in such a way that shunt capacitance currents i1, i2 etc. are equal to metal fitting line capacitance currents i′1, i′2 etc. The result is that same charging current I flows through each unit of string. Consequently, there will be uniform potential distribution across the units.

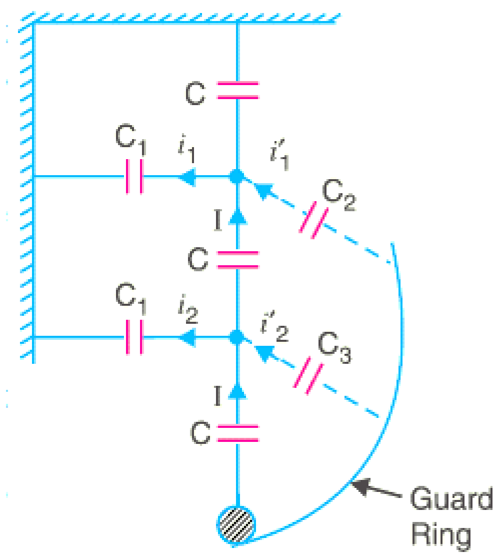

Figure 3.7.2 A Guard Ring

[Source: "Principles of Power System" by V.K.Mehta Page: 171]

Problem 1

In a 33 kV overhead line, there are three units in the string of insulators. If the capacitance between each insulator pin and earth is 11% of self-capacitance of each insulator, find (i) the distribution of voltage over 3 insulators and (ii) string efficiency.

Solution

The equivalent circuit of string insulators is,

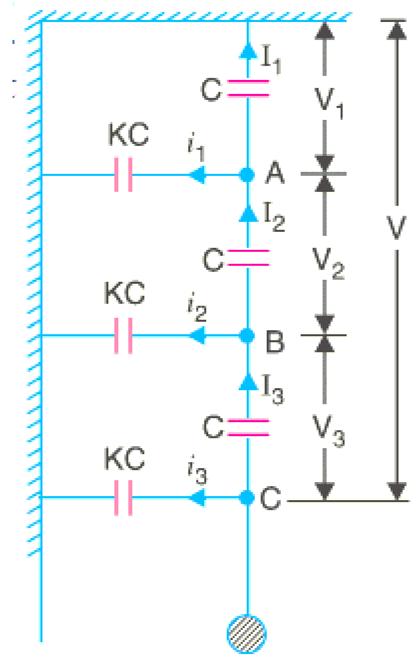

Figure 3.7.3 Equivalent circuit of string insulators

[Source: "Principles of Power System" by V.K.Mehta Page: 171]

$$K = \frac{\text{Shunt Capacitance}}{\text{Self-capacitance}} = 0.11$$

$$\text{Voltage across string, } V = 33/\sqrt{3} = 19{\cdot}05 \text{ kV}$$

At Junction A

$$I_2 = I_1 + i_1$$

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

$$V_2 = V_1 (1 + K) = V_1 (1 + 0{\cdot}11)$$

$$V_2 = 1{\cdot}11 V_1$$

At Junction B

$$\begin{aligned} I_3 &= I_2 + i_2 \\ V_3\,\omega\,C &= V_2\,\omega\,C + (V_1 + V_2)\,K\,\omega\,C \\ V_3 &= V_2 + (V_1 + V_2)\,K \\ &= 1{\cdot}11 V_1 + (V_1 + 1{\cdot}11\,V_1)\,0{\cdot}11 \\ V_3 &= 1{\cdot}342\,V_1 \end{aligned}$$

(i) Voltage across the whole string is

$$\begin{aligned} V &= V_1 + V_2 + V_3 = V_1 + 1{\cdot}11\,V_1 + 1{\cdot}342\,V_1 = 3{\cdot}452\,V_1 \\ 19{\cdot}05 &= 3{\cdot}452\,V_1 \end{aligned}$$

$\therefore$ Voltage across top unit, $V_1 = 19{\cdot}05/3{\cdot}452$

= 5·52 kV

Voltage across middle unit, $V_2 = 1{\cdot}11\,V_1 = 1{\cdot}11 \times 5{\cdot}52$

= 6.13 kV

Voltage across bottom unit, $V_3 = 1{\cdot}342\,V_1 = 1{\cdot}342 \times 5{\cdot}52$

= 7.4 Kv

(ii) String efficiency

$$= \frac{\text{Voltage across string}}{\text{No. of insulators} \times V_3} \times 100 = \frac{19 \cdot 05}{3 \times 7 \cdot 4} \times 100$$

= 85.8 %