String Efficiency

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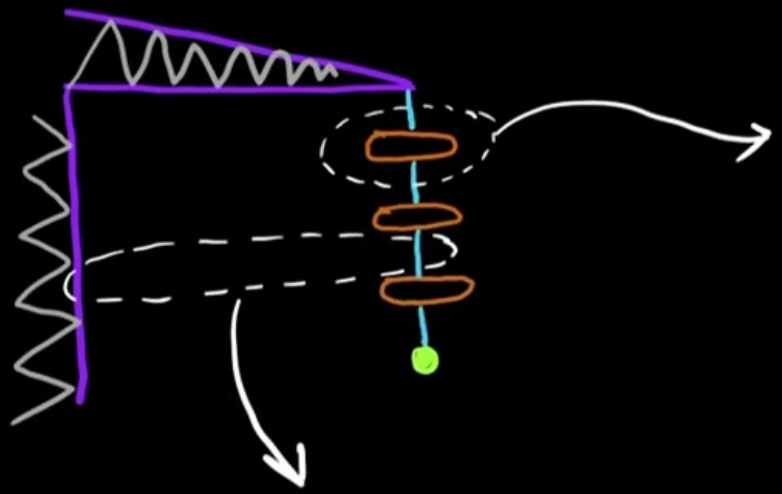
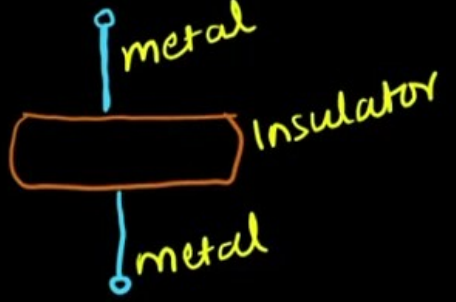
Capacitor model of Insulator string





≈

self capacitance

metal structure | AIR | metal string

as Insulator

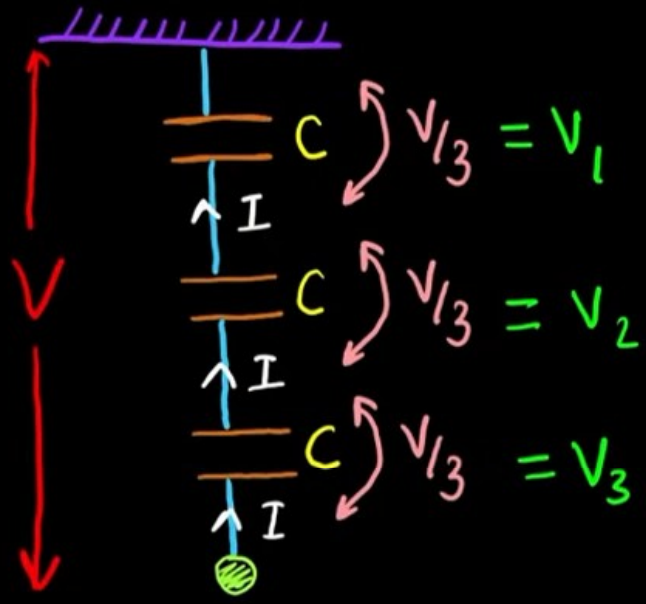
≈

Shunt Capacitance

Capacitance between Pin and Earth

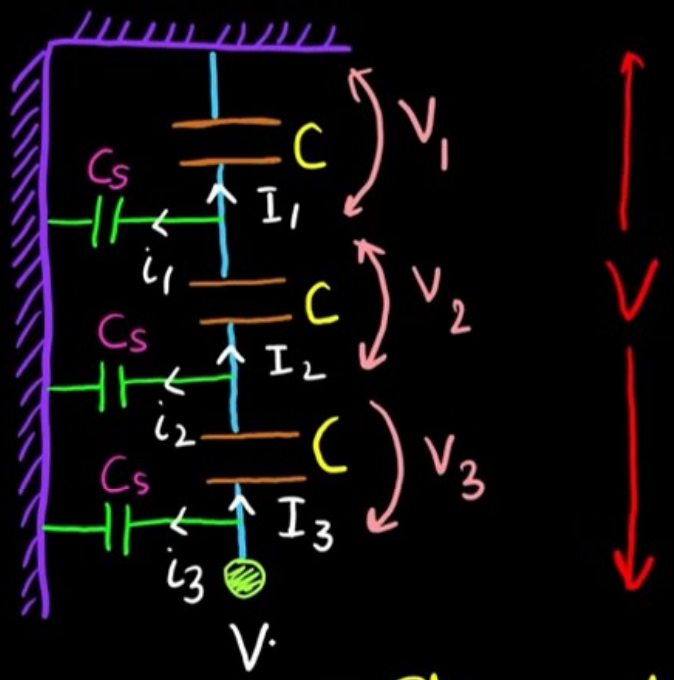
Voltage distribution

Ideally



$V_1 = V_2 = V_3$ → equal distribution of voltage

Practically



$V_1 \neq V_2 \neq V_3$ → unequal voltage distribution

String Efficiency

"This unequal distribution of voltage is expressed in terms of String η"

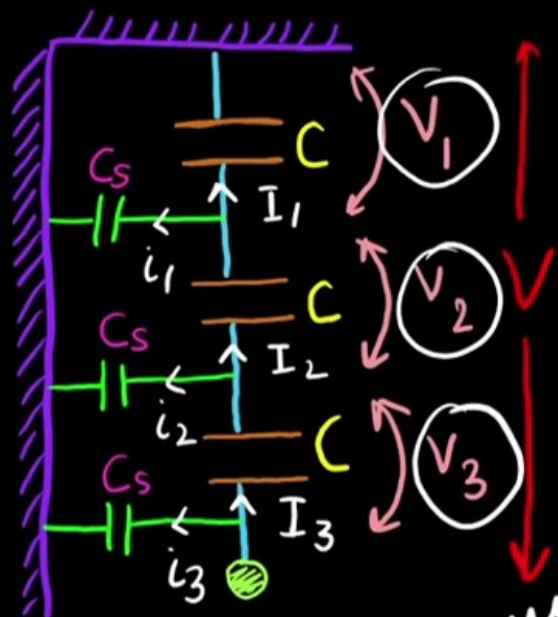
$$\text{String } \eta = \frac{\text{Voltage across the string}}{n \times \text{voltage across disc nearest to conductor}} \times 100$$

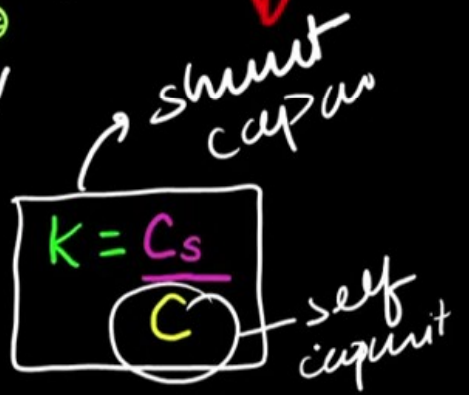
$$\text{String } \eta = \frac{V}{n \times V_3} \times 100$$

$V \rightarrow$ phase voltage

$n \rightarrow$ no. of disc in string

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



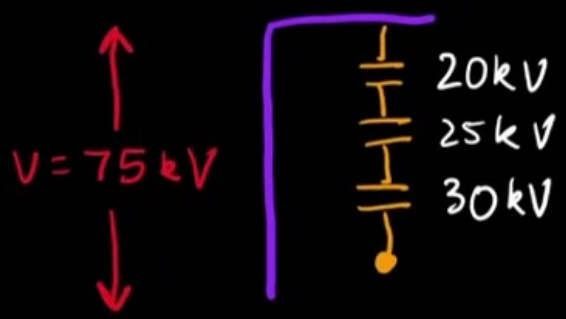


Important Observation

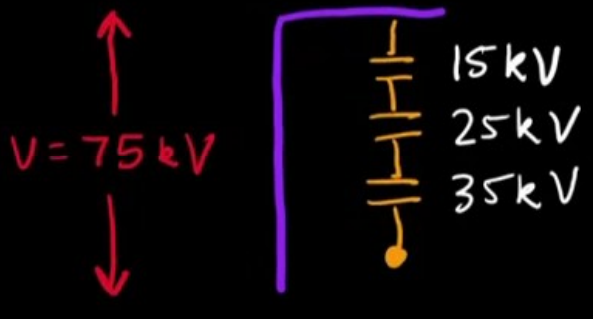
1. If $V_1 = V_2 = V_3$

"Uniform the voltage distribution, greater the string η"

$$\eta = \frac{V_1 + V_2 + V_3}{n V_3} = \frac{3V_1}{3V_1} = 100\ \%.$$



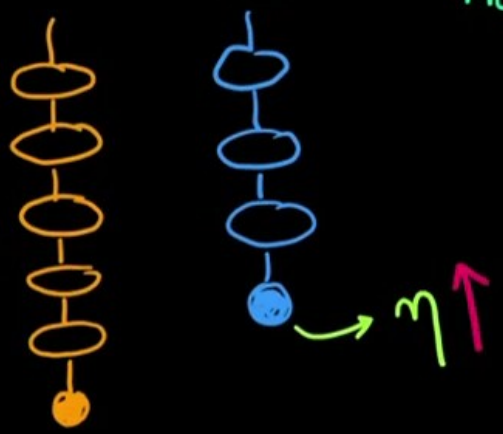
$$\eta = \frac{75\ kV}{3 \times 30kV} = 83.3\ \%$$



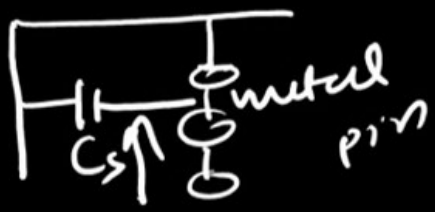
$$\eta = \frac{75\ kV}{3 \times 35kV} = 71.4\ \%.$$

2. String $\eta \propto \frac{1}{\text{no. of disc}}$

"Larger the no. of disc used in string, higher the non-uniformity in voltage distribution"



Tower



3. String $\eta \propto \frac{1}{V_3} \propto \frac{1}{(1+3K+\uparrow K^2)}$

uneven voltage distribution

$K\uparrow = \frac{C_s}{C}\uparrow$

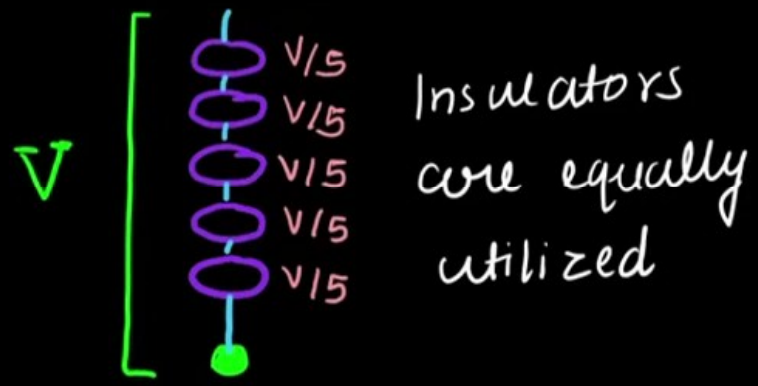
"Higher the shunt capacitance, Lower the string η"

4. Higher the string η ⟶ Better the utilization of Insulator

String η = 100 %.

↓

Equal voltage distribution

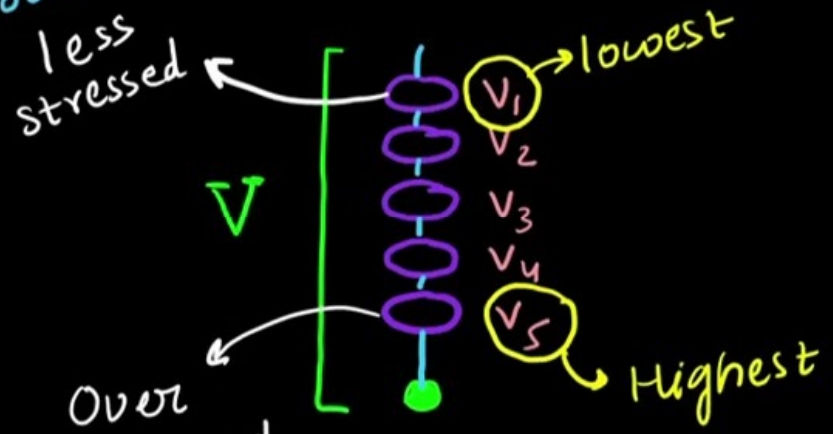


Insulators are equally utilized

String η = 70%.

↓

Unequal voltage distribution



Under utilized ← Under loaded or less stressed

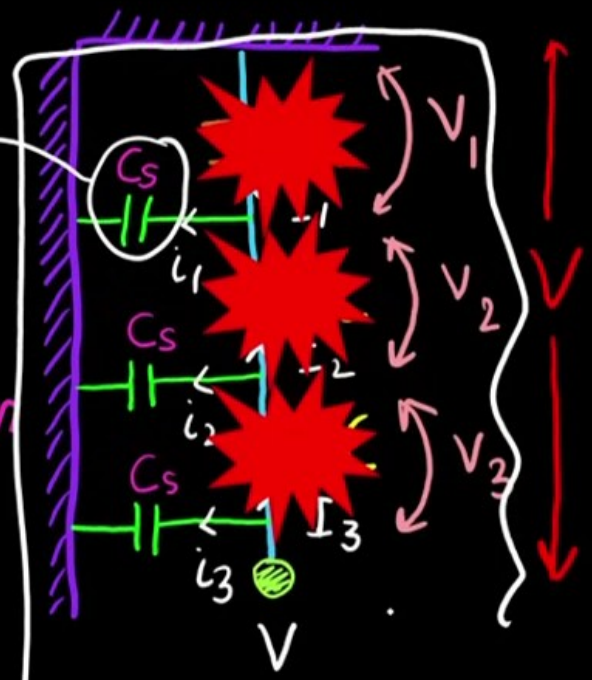
Over stressed or overloaded → Over utilized

5. It is important to improve string η

due to shunt Capacitance

Unequal distribution of charging current

$I_3 > I_2 > I_1$



$V_3 > V_2 > V_1$ → unequal voltage distribution

Maxm voltage across the disc nearest to conductor → more likely to be punctured

"It is important to equalize the voltage stress across each insulator"

→ 3 Methods

- → Large cross arm
- → Guard Ring
- → Grading of Insulator

IMPROVING STRING η

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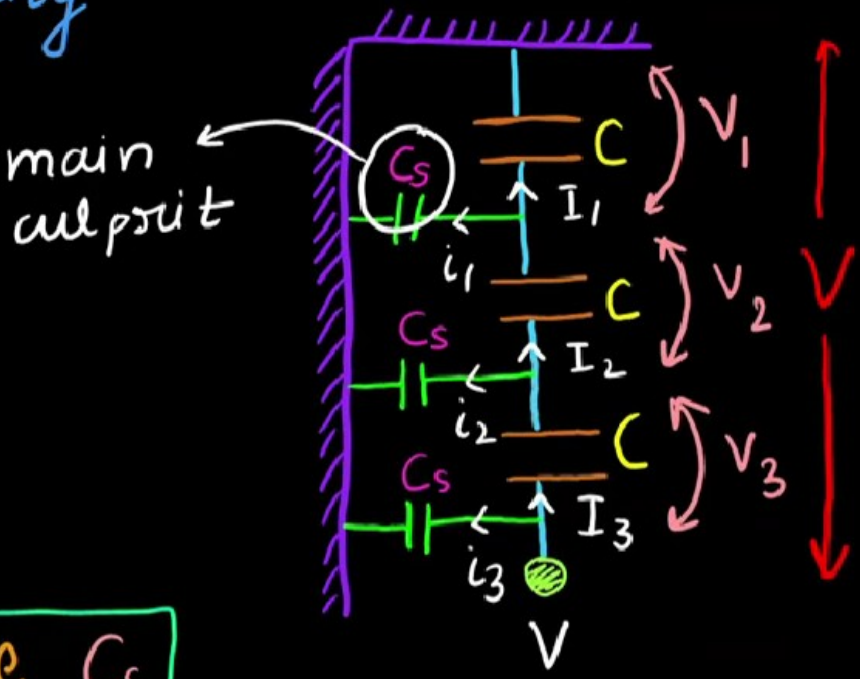
Main Culprit of voltage inequality

String $\eta \propto \frac{1}{V_3} \propto \frac{1}{(1+3K+K^2)}$

$K = \frac{C_s}{C}$

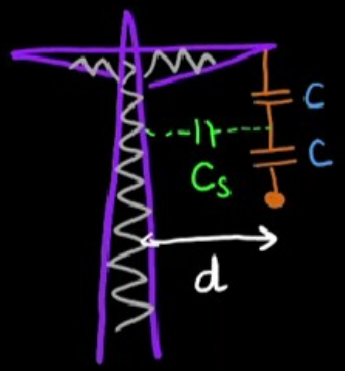


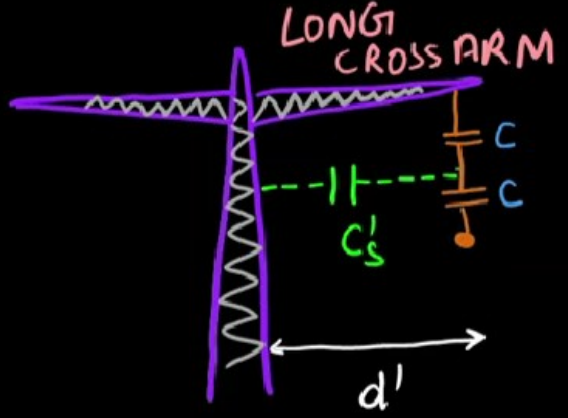
∴ It is important to **neutralize Cs**

- long cross Arm
- Guard Ring

Long Cross Arm

$$C_{sh} = \frac{\epsilon_0 A}{d}$$





$d < d'$

$C_s > C_s'$

K = 0·1 is limit

$K > K'$ → string η ↑

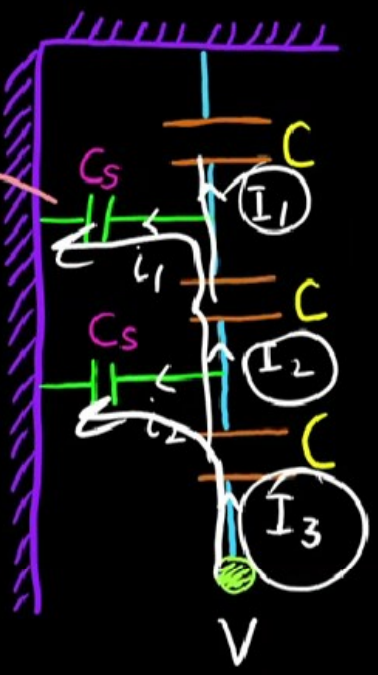
↳ costly

↳ weakens pole strength

Guard Ring

$i_2 = i_2'$

$i_1 = i_1'$ ← adjusted



Charging current of C_s

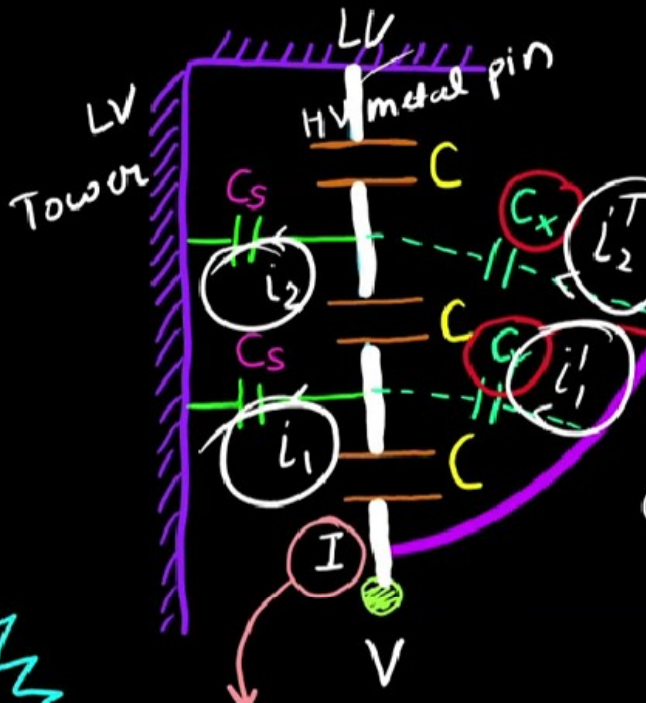
↓

Current division

↓

Unequal voltage distribution

String η Improves



Same charging current

↳ Equal voltage distribution

C

↓

Self Capacitance

↓

Capacitance of Insulator

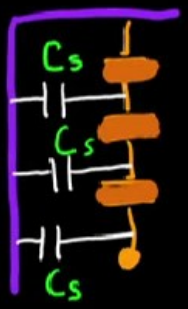
C_s

↓

Shunt Capacitance

↓

b/w Insulator pin and Tower or Insulator disc to Earth



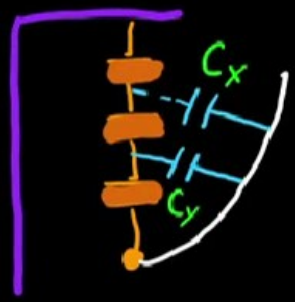
C_x

↓

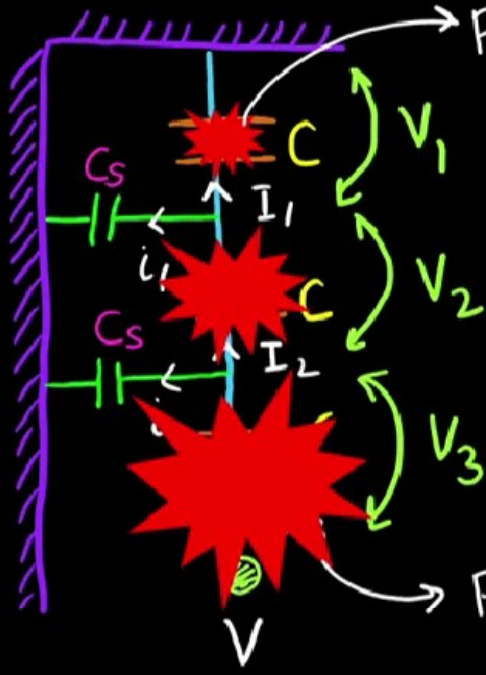
Line Capacitance

↓

b/w Insulator pin and line conductor (Guard Ring)



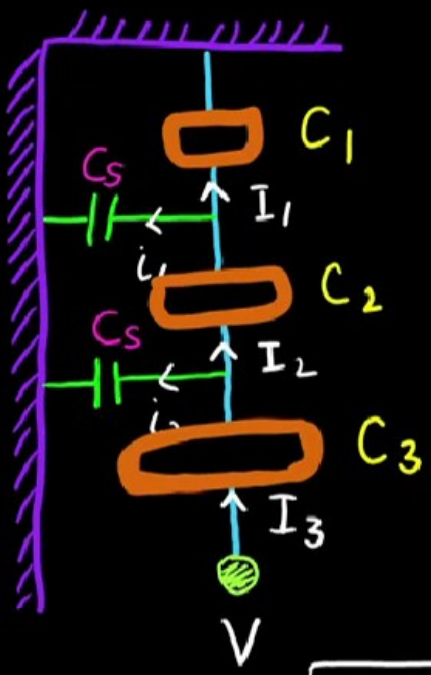
Grading of Insulator



Facing min^m voltage stress → Small size insulator

Facing max^m voltage stress → large size insulator

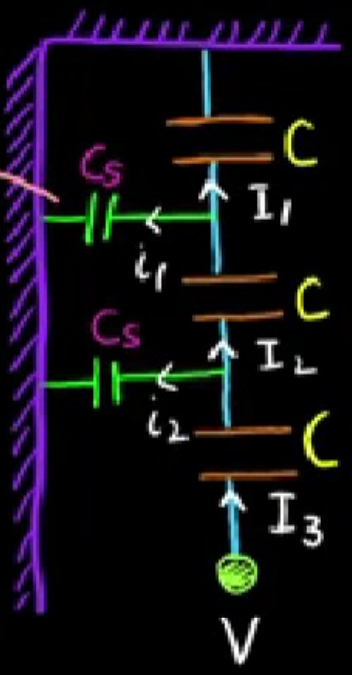
$V_1 < V_2 < V_3$



$C_3 > C_2 > C_1$

Disadvantage → Different size insulator required

Purpose



Charging current of C_s

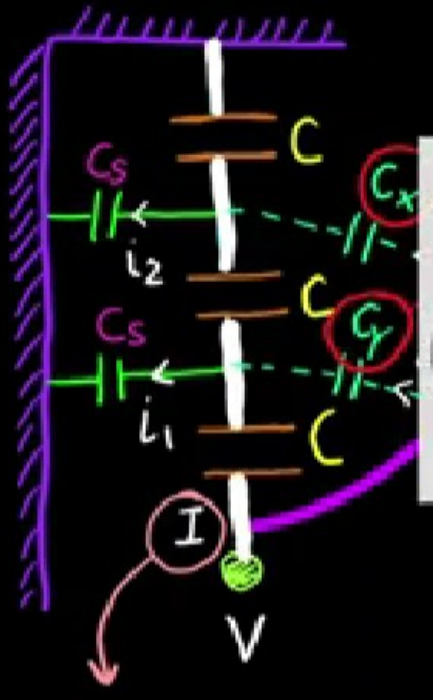
↓

Current division

↓

Unequal voltage distribution

String η Improves



GUARD RING

Reduce potential Gradient

Same charging current

↳ Equal voltage distribution

GRADING RING

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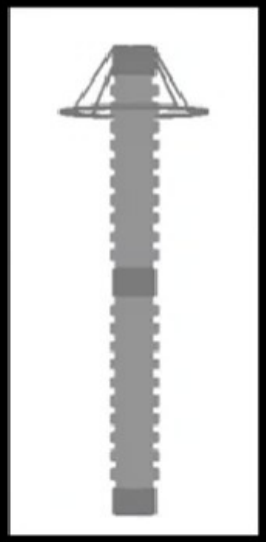
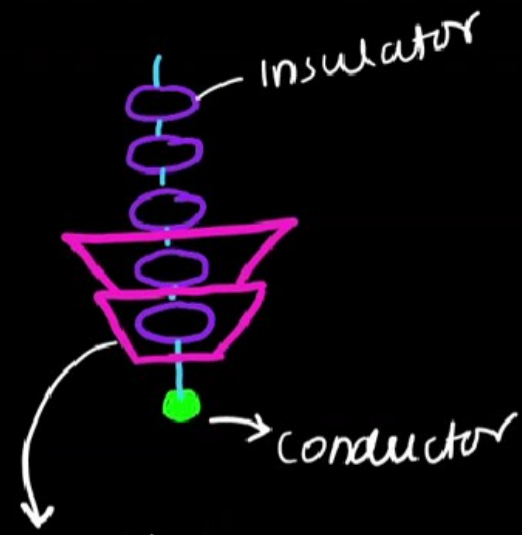
Grading Ring

" A metal ring that encircles the insulators which are close to conductor "

GRADING RING





Position → Place near insulator, next to conductor

Benefits of Goarding Ring

1. Reduces voltage gradient at the end insulator, allow the use of cheaper and small size insulator.
2. Improves String efficiency ⟶ leads to better utilization of insulators
3. Reduce aging and deterioration of Insulator.
4. Keeps the electric field away from Insulator body, thus prevents flashover.

Application

Current Transformers

Power Transmission

Lightning arrester

Surge Arrestors

High voltage test equipment


GRADING RING
Insulator life ↑
string η ↑
corona discharge ↓
CORONA RING