TRANSMISSION SYSTEM

DISCLAIMER

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PREFACE

This eBook is written to provide basic knowledge of subtopic in power systems, focusing mainly on concept of transmission system for electrical and electronics students in polytechnics.

Subtopic **1** focuses on Introduction to nature transmission system concepts by referring general circuit, T circuit and π Circuit . Subtopic **2** focuses on calculation and how to determine the performance of transmission system according on voltage regulation and efficiency. Subtopic **3** focuses on basic concept of losses in transmission system and Subtopic **4** is focuses an insulator that used in transmission system and the calculation of network string distributed voltage and efficiency.

We hope that this eBook will be very useful and will expose the readers, students and lecturers to basic knowledge of transmission system.

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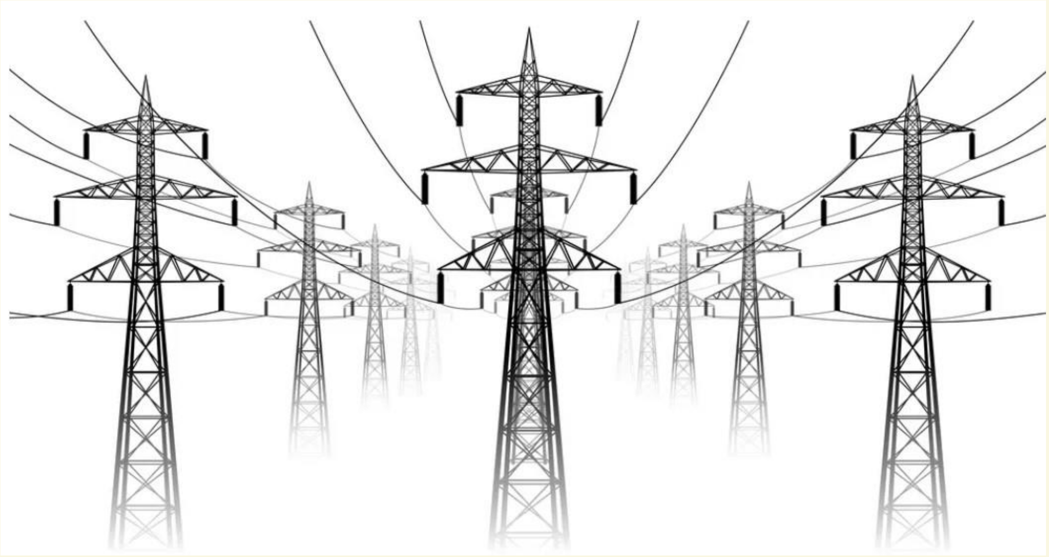
CHAPTER 1



1.0 Nature of transmission lines

1.1 Function of transmission lines
1.2 Types of transmission lines

Function of transmission lines :

To transmit the electrical energy from one area to another area.

It consists of THREE types of transmission lines:

- ✓ short line model,
- ✓ medium line model,
- ✓ long line model.

Each type is different based on :

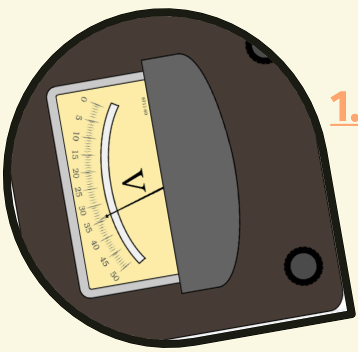
a. Range of voltage

b. Range of length

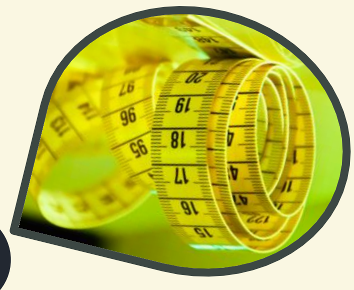
c. Equivalent circuit

1.3 Equivalents circuit either using T and π circuit

Short Line Model

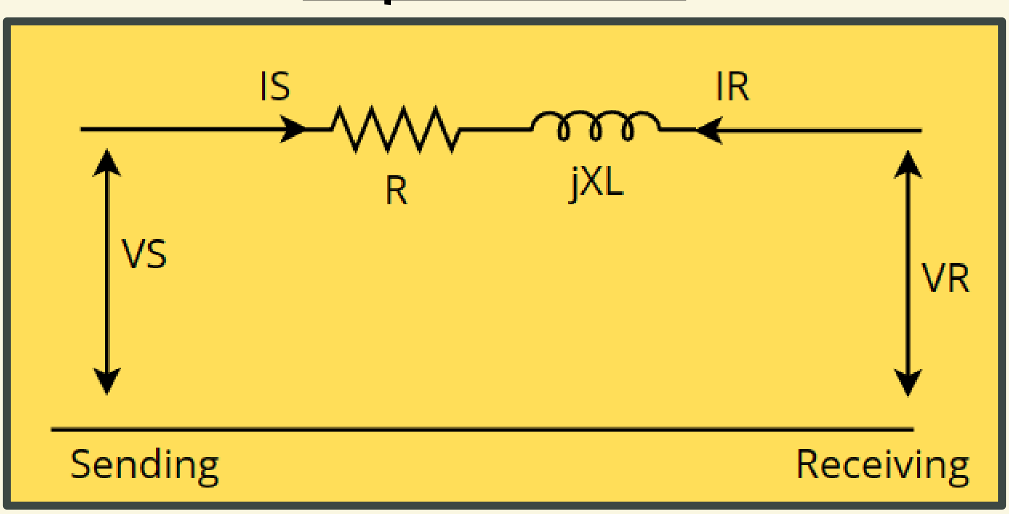


1. Range of voltage
Less than 20kV



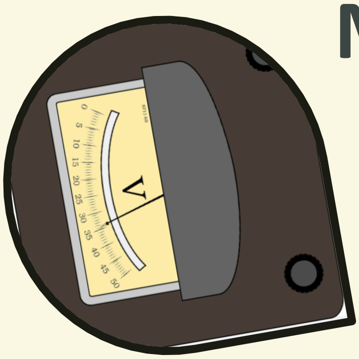
2. Length
Less than 60kM

3. Equivalent circuit



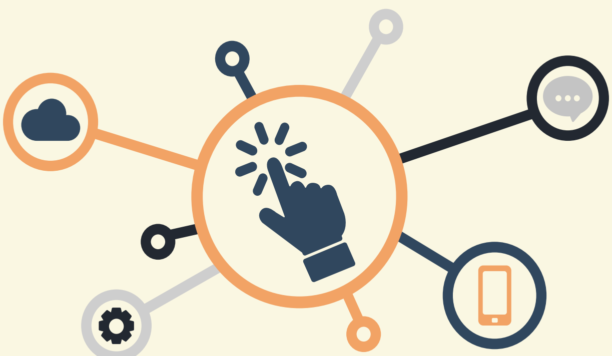
1.3 Equivalents circuit either using T and π circuit

Medium Line Model



1. Range of voltage

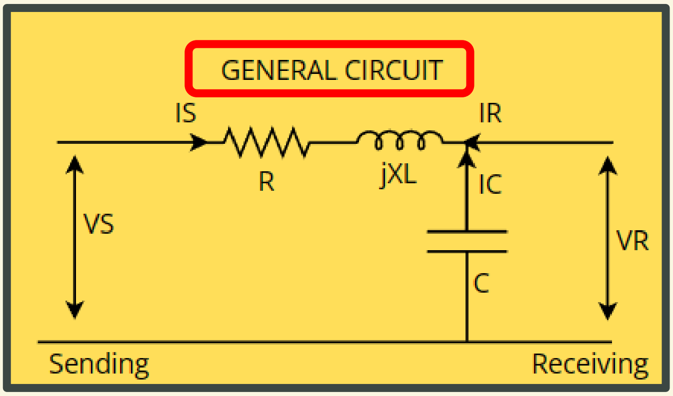
20kV – 100kV

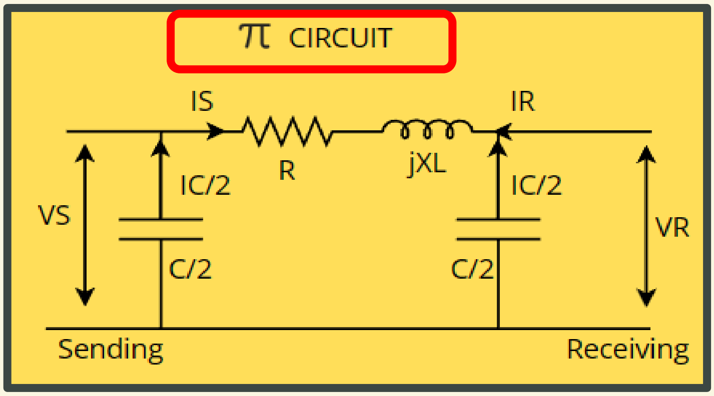


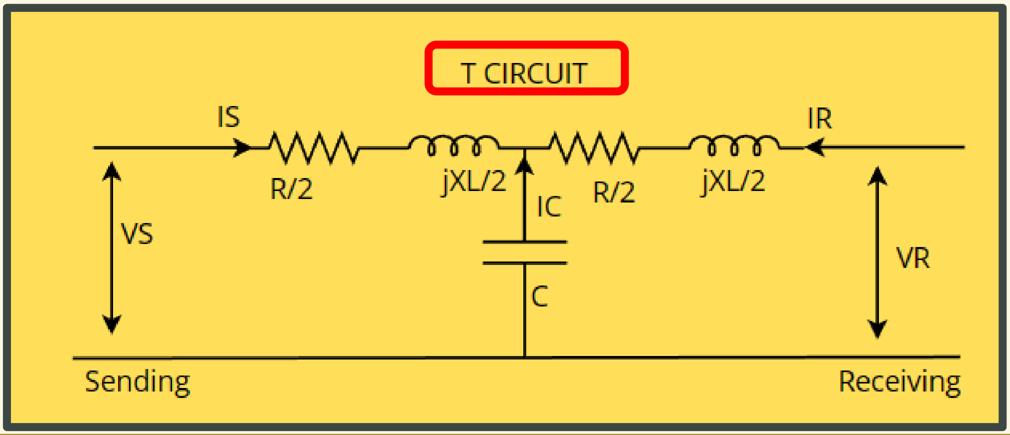
2. Length

60kM – 150kM

3. Equivalent circuit

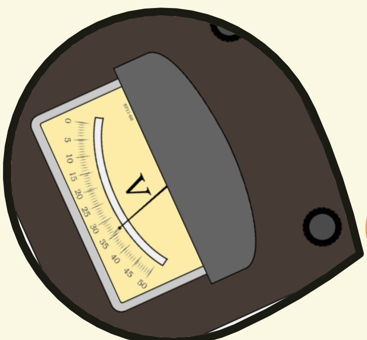


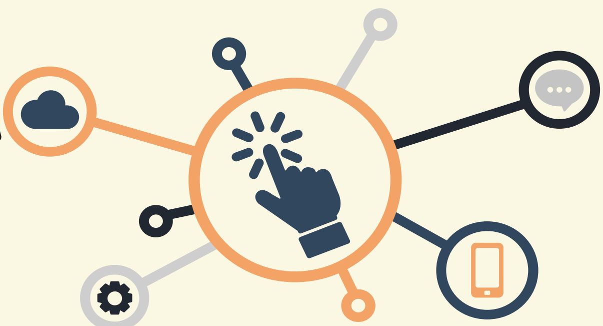


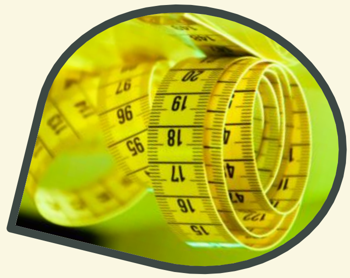


1.3 Equivalents circuit either using T and π circuit

Long Line Model







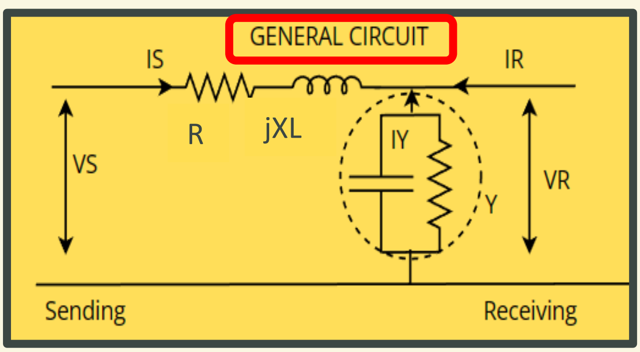
2. Length

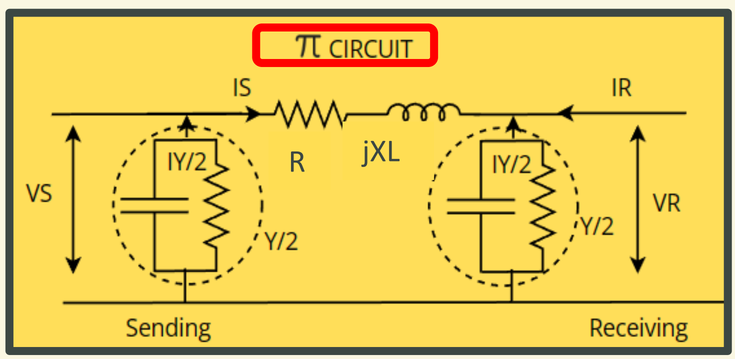
more than 150kM

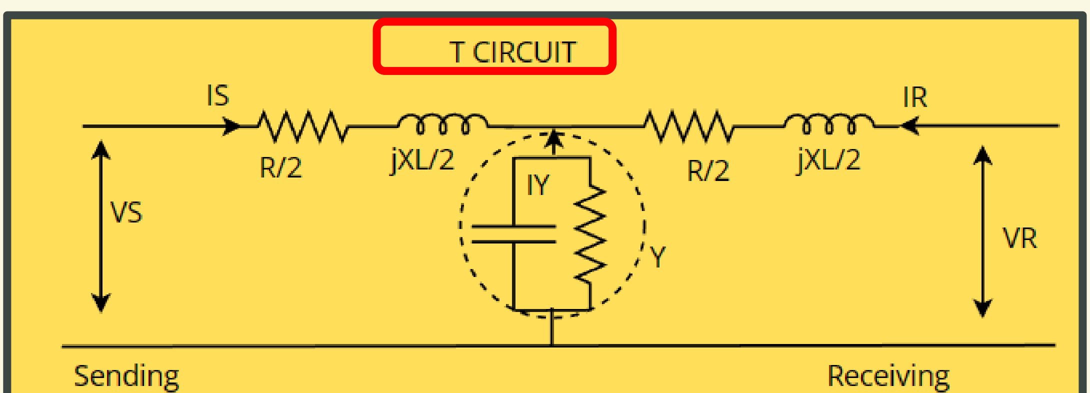
1. Range of voltage

more than 100kV

3. Equivalent circuit

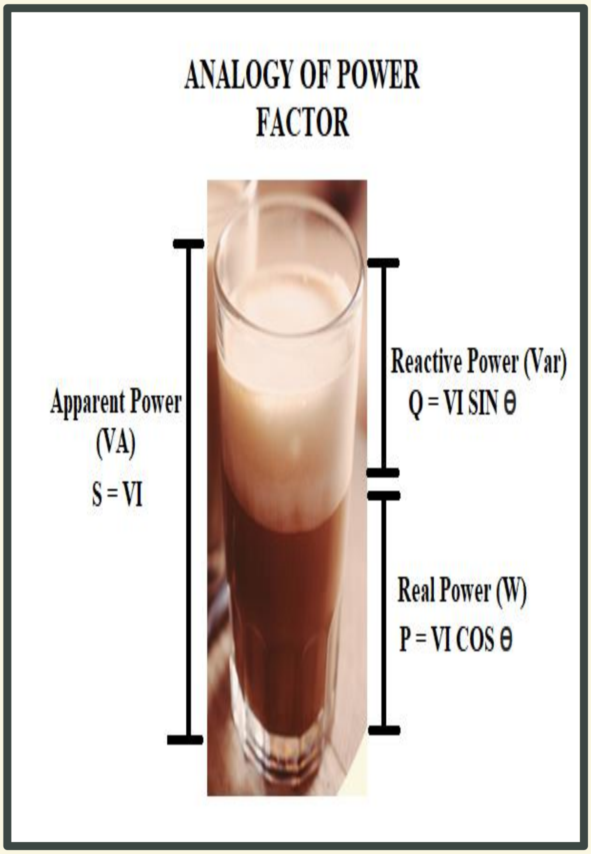






Power factor (PF)

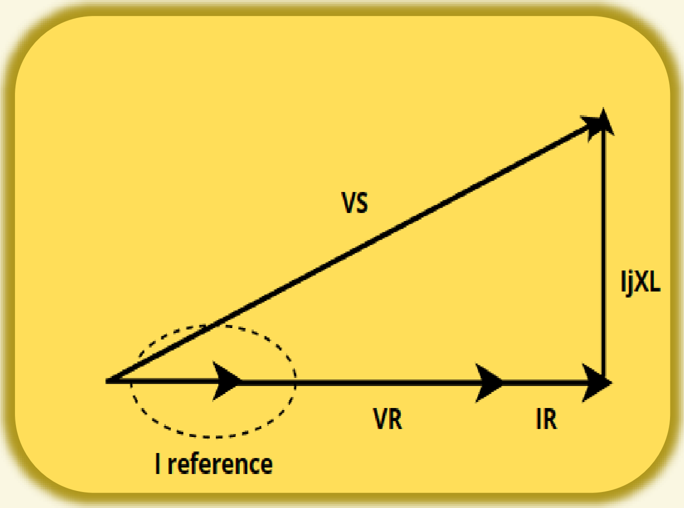
- The power factor (PF) is the ratio of the apparent power (measured in kilovolt amperes) (kVA) to the working power (measured in kilowatts) (kW).
- The amount of power used to run machinery and other equipment over a specific time period is measured as apparent power, also known as "demand."



- The Apparent power is referred to as demand power—power delivered to utilities.
- The Real power is referred to as useful power—energy that is used to do the work.
- The Reactive power is referred to as "waste power"—energy produced that can be harmful to the utility, such as heat or vibration.

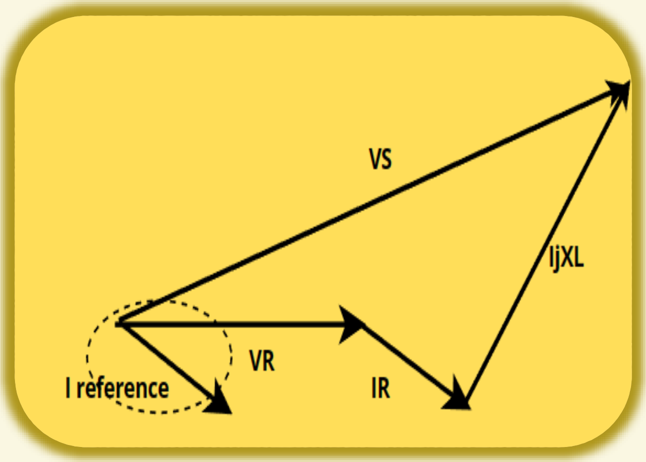
1.4 Phasor Diagram

1. Unity Power factor



- During unity power factor the reference current is in phase with the receiving voltage.
- The value of power factor is equal to 1.

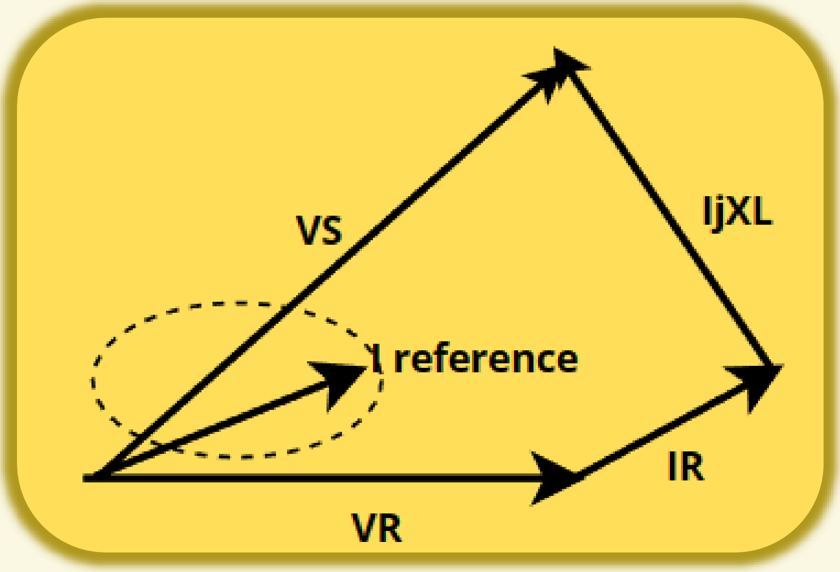
2. Lagging Power factor



- During lagging power factor the reference current is lagging with the receiving voltage.
- The phase angle is negative.

Phasor Diagram

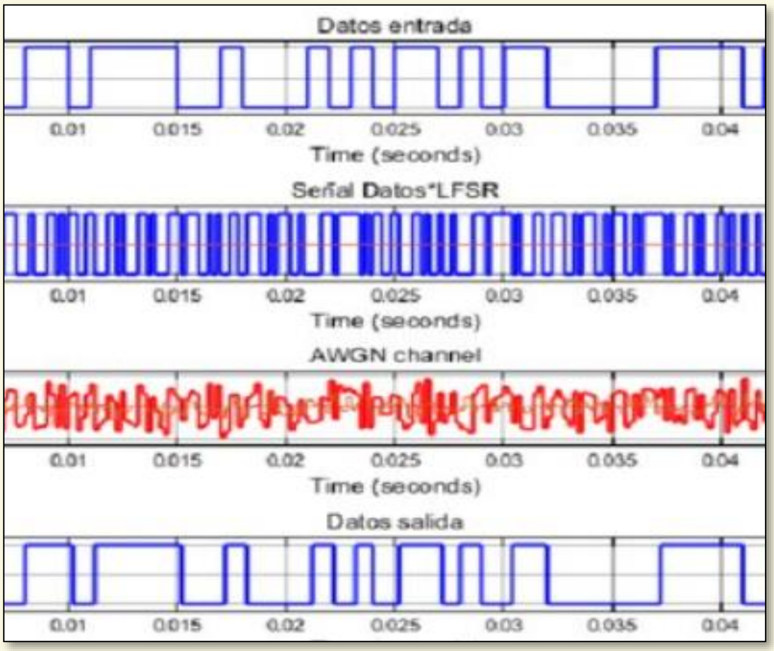
3. Leading Power factor



- ❑ During leading power factor the reference current is leading with the receiving voltage.
- ❑ The phase angle is positive.


TAKE
A BREAK
PLEASE SCAN ME

CHAPTER 2



Performance of transmission line based on Apparent Power (VA) and Real Power (W)

How to determine the performance of transmission line based on voltage regulation and efficiency?

- ✓ If the percent of voltage regulation **is less**, the performance of the transmission line is good.
- ✓ If the percent of efficiency **is high** (more than 90%), the performance of the transmission line is good.

2.1 Calculation of sending end voltage
2.2 Calculation of voltage regulation
2.3 Calculation of efficiency

- ✓ The calculation is focus for Short lines Model only.
- ✓ Its consists of TWO situation which based on:

1. Real Power, P (Watt)
2. Apparent Power, S (VA)

Calculation based on Real Power (W)

Step 1 : $$V_{R1\emptyset} = \frac{V_{R3\emptyset}}{\sqrt{3}}$$

$$P_{R3\emptyset} = 3V_{R1\emptyset} I_{R1\emptyset} \cos\theta$$

Step 2 : $$I_{R1\emptyset} = \frac{P_{R3\emptyset}}{3V_{R1\emptyset} \cos\theta}$$

$$\cos\theta = POWER\ FACTOR$$

$$\theta = \cos^{-1} POWER\ FACTOR$$

Step 3 : $$I_{S1\emptyset} = I_{R1\emptyset} < \pm\theta \quad [+LEAD, -LAG]$$

Step 4 : $$V_{S1\emptyset} = V_{R1\emptyset} + I_{S1\emptyset} Z$$

Step 5 : $$\%\ VOLTAGE\ REGULATION = \frac{V_S - V_R}{V_R}\ X\ 100$$

- ✓ Step 1 is required if the question is to provide a receiving voltage in three phase.

Continue....

Step 6 : → (Sending end power factor)

$$\cos\theta_S = \cos[\theta_{VS} - \theta_{IS}]$$

Step 7 : →

$$P_S = 3V_{S1\emptyset}I_{S1\emptyset}\cos\theta_S$$

Step 8 : →

$$(efficiency)\eta = \frac{P_R}{P_S} x\ 100$$

✓ If the question is about providing a receiving voltage in single phase, we can remove the 3 from the formula in Step 7.

Example 1

Trace the parameter or characteristic before solving this question.

A three-phase transmission line carrying a power of 2200 kW to consumer with a voltage of 33 kV in lagging power factor 0.8. This line have a resistance of 2Ω and inductance coil of 3Ω Find;

i). Sending end voltage.

ii). Percent of voltage regulation.

iii). Transmission Line Efficiency

Solution

Step 1: Convert the 3-phase receiving voltage to 1-phase

$$VR = \frac{33K}{\sqrt{3}} = 19.05KV$$

Step 2: Calculate IR based on Real Power

$$IR = \frac{PR}{3VR\ COS\ \theta} = \frac{2200K}{3X19.05KX0.8} = 48.119A$$

Step 3: Determine the value of IS and consider the phase angle

$$\cos\theta\ = 0.8\theta$$

$$= \cos^{-1} 0.8 = 36.87$$

$$IS = IR = 48.119 < -36.87A$$

Continue.....

Step 4: Calculate the value of sending end voltage (VS)

$$VS = VR + IS\ Z$$

$$= 19.05KV + [(48.119 < -36.87A)(2 + j3)]$$

$$= 19.214KV < 0.172$$

Step 5: Calculate percent voltage regulation

$$\%VR = \frac{VS - VR}{VR} X100$$

$$= \frac{19.214K - 19.05K}{19.05K} X100$$

$$= 0.86\%$$

Step 6: Calculate sending end power factor

$$\text{Cos}\ \theta S = \text{Cos}\ [\theta VS - \theta IS]$$

$$= \text{Cos}\ [0.172 - (-36.87)] = 0.798$$

Continue.....

Step 7: Calculate the sending end power (PS)

$$PS = 3VS\ IS\ COS\ ӨS$$

$$= 3\ (19.214KV)(48.119)(0.798)$$

$$= 2213.931KW$$

Step 8: Calculate percent efficiency

$$\%VR = \frac{PR}{PS} X100$$

$$= \frac{2200K}{2213.931K} X100$$

$$= 99.37\%$$

THE READING OF VOLTAGE REGULATION IS LOW AND EFFICIENCY IS HIGH, WHICH MEANS THE PERFORMANCE OF TRANSMISSION SYSTEM IS GOOD

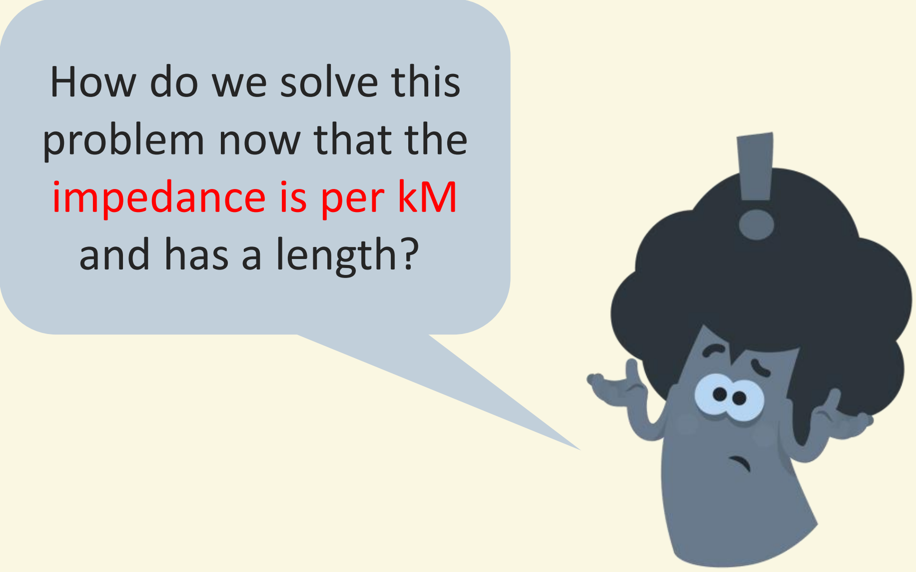
Example 2

A single-phase transmission line carrying a power of 2200 kW to consumer with a voltage of 11kV in lagging power factor 0.8. This line have a resistance of 0.2Ω per kM and inductance coil of 0.3Ω per kM. Given the lenght of transmission line is 20kM Find;

i). Sending end voltage.

ii). Percent of voltage regulation.

iii). Transmission Line Efficiency



Solution

Step 1: Calculate the real impedance

Z = (0.2 + j0.3)(20) = 4 + j6Ω

Step 2: Calculate IR based on Real Power

$$IR = \frac{PR}{VR\ COS\ \theta} = \frac{2200K}{11KX0.8} = 250A$$

Step 3: Determine the value of IS and consider the phase angle

$$cos\,0.8 = \theta$$

$$\theta = cos^{-1}\,0.8 = 36.87$$

$$IS = IR = 250\ < -36.87A$$

Continue.....

Step 4: Calculate the value of sending end voltage (VS)

$$\mathbf{VS = VR + IS\ Z}$$

$$\mathbf{= 11KV + [(250 < -36.87A)(4 + j6)]}$$

$$\mathbf{= 12.714KV < 2.705}$$

Step 5: Calculate percent voltage regulation

$$\%VR = \frac{VS - VR}{VR} X100$$

$$= \frac{12.714K - 11K}{11K} X100$$

$$= 15.58\%$$

Step 6: Calculate sending end power factor

$$\text{Cos}\ \theta S = \text{Cos}\ [\theta VS - \theta IS]$$

$$= \text{Cos}\ [2.705 - (-36.87)] \quad = 0.7708$$

Continue.....

Step 7: Calculate the sending end power (PS)

$$PS = VS\ IS\ \cos \theta S$$

$$= (12.714KV)(250)(0.7708)$$

$$= 2449.988KW$$

Step 8: Calculate percent efficiency

$$\%VR = \frac{PR}{PS} X100$$

$$= \frac{2200K}{2449.987K} X100$$

$$= 89.796\%$$

THE READING OF VOLTAGE REGULATION IS HIGH AND EFFICIENCY IS LOW THAN 90%, WHICH MEANS THE PERFORMANCE OF TRANSMISSION SYSTEM IS ACCEPTABLE

Calculation based on Apparent power (VA)

Step 1 : → $V_{R1\emptyset} = \frac{V_{R3\emptyset}}{\sqrt{3}}$

$$S_{R3\emptyset} = 3V_{R1\emptyset}I_{R1\emptyset}$$

Step 2 : → $I_{R1\emptyset} = \frac{S_{R3\emptyset}}{3V_{R1\emptyset}}$

$$\cos\theta = POWER\ FACTOR$$

$$\theta = \cos^{-1} POWER\ FACTOR$$

Step 3 : → $I_{S1\emptyset} = I_{R1\emptyset} < \pm\theta$ → $[+LEAD, -LAG]$

Step 4 : → $V_{S1\emptyset} = V_{R1\emptyset} + I_{S1\emptyset}Z$

Step 5 : → $\%\ VOLTAGE\ REGULATION = \frac{V_S - V_R}{V_R}\ X\ 100$

✓ Step 1 is required if the question is to provide a receiving voltage in three phase.

Continue....

Step 6 : → (Sending end power factor) $\cos\theta_S = \cos[\theta_{VS} - \theta_{IS}]$

Step 7 : → $P_S = 3V_{S1\emptyset}I_{S1\emptyset}\cos\theta_S$

Step 8 : → $P_R = 3V_{R1\emptyset}I_{R1\emptyset}\cos\theta$

Step 9 : → $(efficiency)\,\eta = \frac{P_R}{P_S}\,x\,100$

✓ If the question is about providing a receiving voltage in single phase, we can remove the 3 from the formula in Step 7.

Example 3

A three phase transmission line carrying a power of 250MVA to consumer in unity power factor at 67KV. This line have a resistance of 0.25 +j0.47Ω. Calculate;

i). Sending end voltage.

ii). Percent of voltage regulation.

iii). Efficiency of the system

Now, let's do the example using an **apparent power**!!

Solution

Step 1: Convert the 3-phase receiving voltage to 1-phase

$$VR = \frac{67K}{\sqrt{3}} = 38.682KV$$

Step 2: Calculate IR based on Apparent Power

$$IR = \frac{SR}{3VR} = \frac{250M}{3X38.682K} = 2154.318A$$

Step 3: Determine the value of IS and consider the phase angle

$$\cos 1 = \theta$$

$$\theta = \cos^{-1} 1 = 0$$

$$IS = IR = 2154.318 \ < 0A$$

Continue.....

Step 4: Calculate the value of sending end voltage (VS)

$$\mathbf{VS = VR + IS\,Z}$$

$$= \mathbf{38.682}\boldsymbol{KV} + [(\mathbf{2154.318} < 0\boldsymbol{A})(\mathbf{0.25 + j0.47})]$$

$$= \mathbf{39.234KV < 1.479}$$

Step 5: Calculate percent voltage regulation

$$\%\mathrm{V}R = \frac{VS - VR}{VR} X100$$

$$= \frac{39.234\mathrm{K} - 38.682K}{38.682K} X100$$

$$= \mathbf{1.427\%}$$

Step 6: Calculate sending end power factor

$$\mathrm{Cos}\ \theta S = \mathrm{Cos}\ [\theta \mathrm{VS} - \theta \mathrm{IS}]$$

$$= \mathrm{Cos}\ [\mathbf{1.479} - (\mathbf{0})] = \mathbf{0.9997}$$

Continue.....

Step 7: Calculate the sending end power (PS)

$$PS = 3VS\ IS\ COS\ ϴS$$

$$= 3(39.234KV)(2154.318)(0.9997)$$

$$= 253.483MW$$

Step 8: Calculate the receiving end power (PR)

$$PR = 3VR\ RS\ COS\ ϴ$$

$$= 3(38.682KV)(2154.318)(1)$$

$$= 249.999MW$$

Step 9: Calculate percent efficiency

$$\%VR = \frac{PR}{PS} X100$$

$$= \frac{249.999MW}{253.483MW} X100 \quad = 98.626\%$$

Example 4

A three phase, 50Hz transmission line carrying a power of 381MVA to consumer with a voltage of 220 kV in leading power factor 0.8. The line 40km. The resistance per phase is 0.15Ω per km and the inductance per phase is 1.3263mH per km. Calculate :-

i). Sending end voltage.

ii). Percent of voltage regulation.

iii). Efficiency of the system

Now the question is, given the value of the inductor, how do we solve this problem?

Solution

Step 1: Find the value of XL and Z

$$XL = 2\pi f L = 2\pi(50)(1.3263mH) = j0.417\Omega$$

$$Z = R + jXL(\ell) = 0.15 + j0.417\Omega\,(40)$$
$$= 6 + j16.68\Omega$$

Step 2: Convert the 3-phase receiving voltage to 1-phase

$$VR = \frac{220K}{\sqrt{3}} = 127.017KV$$

Step 3: Calculate IR based on Apparent Power

$$IR = \frac{SR}{3VR} = \frac{381M}{3X127.017K} = 997.241A$$

Solution

Step 4: Determine the value of IS and consider the phase angle

$$\cos 0.8 = \theta$$

$$\theta = \cos^{-1} 0.8 = 36.87$$

$$IS = IR = 997.241 < 36.87A$$

Step 5: Calculate the value of sending end voltage (VS)

$$\mathrm{VS = VR + IS\ Z}$$

$$= 127.017KV + [(997.241 < 36.87A)(6 + j16.68\Omega)]$$

$$= 122.99\mathrm{KV} < 7.897$$

Continue.....

Step 6: Calculate percent voltage regulation

$$\%VR = \frac{VS - VR}{VR} X100$$

$$= \frac{122.99KV - 127.017KV}{127.017KV} X100$$

$$= 3.17\%$$

Step 7: Calculate sending end power factor

$$\text{Cos } \theta S = \text{Cos } [\theta VS - \theta IS]$$

$$= \text{Cos } [7.897 - 36.87]$$

$$= 0.875$$

Continue.....

Step 8: Calculate the sending end power (PS)

$$PS = 3VS\ IS\ COS\ ϴS$$

$$= 3(122.99KV)(997.241)(0.875)$$

$$= 321.958MW$$

Step 9: Calculate the receiving end power (PR)

$$PR = 3VR\ RS\ COS\ ϴ$$

$$= 3(127.017KV)(997.241)(0.8)$$

$$= 303.999MW$$

Step 10: Calculate percent efficiency

$$\%VR = \frac{PR}{PS} X100$$

$$= \frac{303.999MW}{321.958MW} X100 = 94.42\%$$

Let's give these exercises a shot

CHAPTER 3

Losses in transmission lines

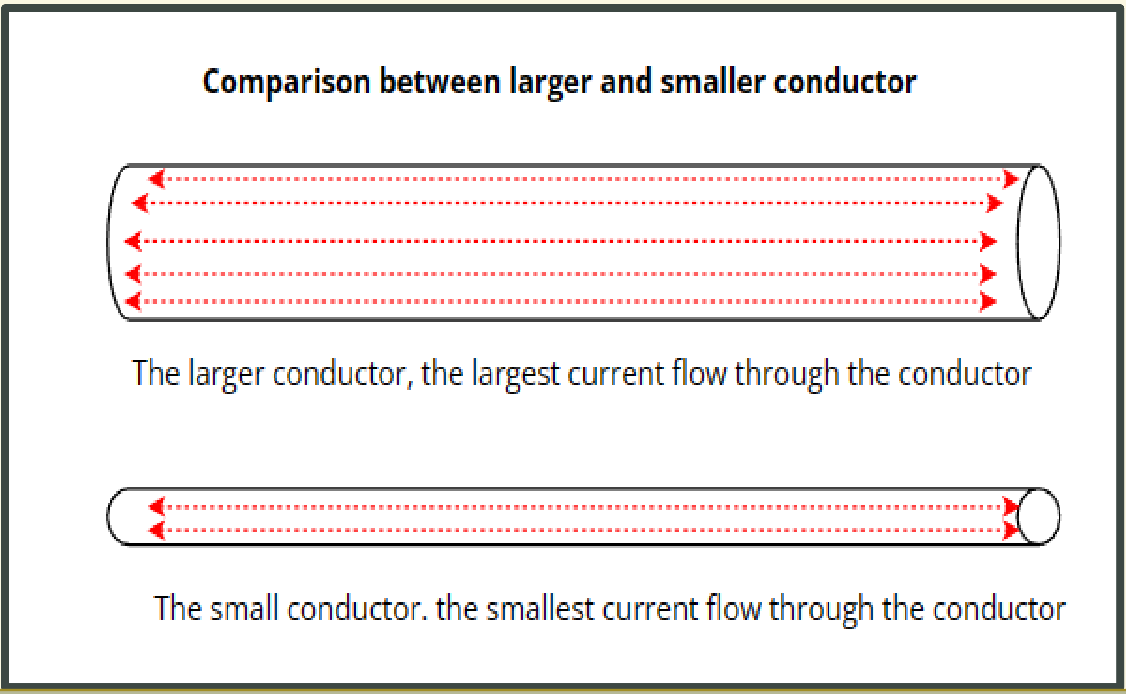
What is corona phenomenon and how it's happened?

- ✓ Corona is the term for the phenomenon of a violet glow, hissing sound, and ozone gas emission in an overhead transmission line.
- ✓ A hissing sound, ozone creation, power outages, and radio interference are all symptoms of the corona phenomenon.
- ✓ The luminous envelope grows larger and higher when the voltage is increased, and the sound, power loss, and radio noise also increase.
- ✓ If the voltage being used is increased to its breakdown value, the breakdown of air insulation will cause a flashover to happen between the conductors.

Factors affecting corona

i. Conductor size

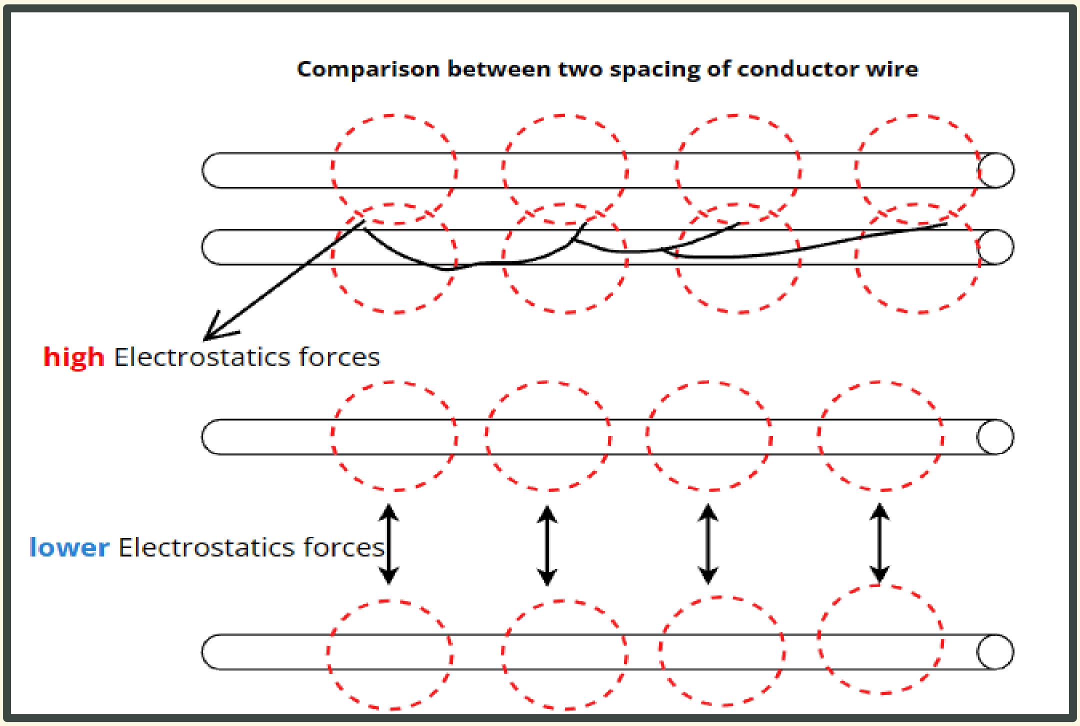
The conductors' configuration and shape have an impact on the corona effect. As a result of the surface's unbalance, which lowers the breakdown voltage, the rough and uneven surface will produce more corona. Because of its uneven surface, a stranded conductor produces more corona than a solid conductor.



Factors affecting corona

ii. Spacing between conductors

There might not be a corona effect if the conductors are spaced apart at relatively wide intervals compared to their diameters. This is because a greater separation between conductors lowers electrostatic forces at the conductor surface, preventing corona formation.



Factors affecting corona

iii. Line voltage

Corona is significantly impacted by line voltage. If it is low, the air surrounding the conductors does not contract, and no corona is produced. Corona is created if the line voltage is high enough to cause electrostatic tensions to occur at the conductor surface that cause the air surrounding the conductor to conduct.

iv. Atmosphere

Corona is impacted by the physical characteristics of the atmosphere since it is created by the ionization of the air surrounding the conductors. When it is stormy outside, there are more ions than usual, which causes a corona to form at a much lower voltage than when it is sunny outside.

Disadvantages of corona

- Loss of energy occurs along with the corona.
- This has an impact on the line's transmission effectiveness. Corona generates ozone, which, by chemical action, may result in conductor damage.
- Due to the non-sinusoidal nature of the current the line draws from the corona; the voltage drop in the line is also non-sinusoidal. Inductive interference with nearby communication cables could result from this.

Method to reduce corona

i. By increasing conductor size or bundle conductor

The voltage at which corona occurs is raised by increasing conductor size, and as a result, the consequences of corona are greatly diminished. This is one of the explanations for why transmission lines employ ACSR conductors with bigger cross-sectional areas.

ii. By increasing conductor spacing

Corona effects can be reduced by reducing the distance between conductors, which raises the voltage at which a corona develops. The cost of the supporting structure, such as larger cross arms and supports, may rise significantly if the spacing is raised too much.

LET'S DO THESE EXERCISES

CHAPTER 4

Transmission's insulators

Types of insulator: Pin type

Function : to isolate the current flow or short circuit current between the structure of transmission lines with conductor

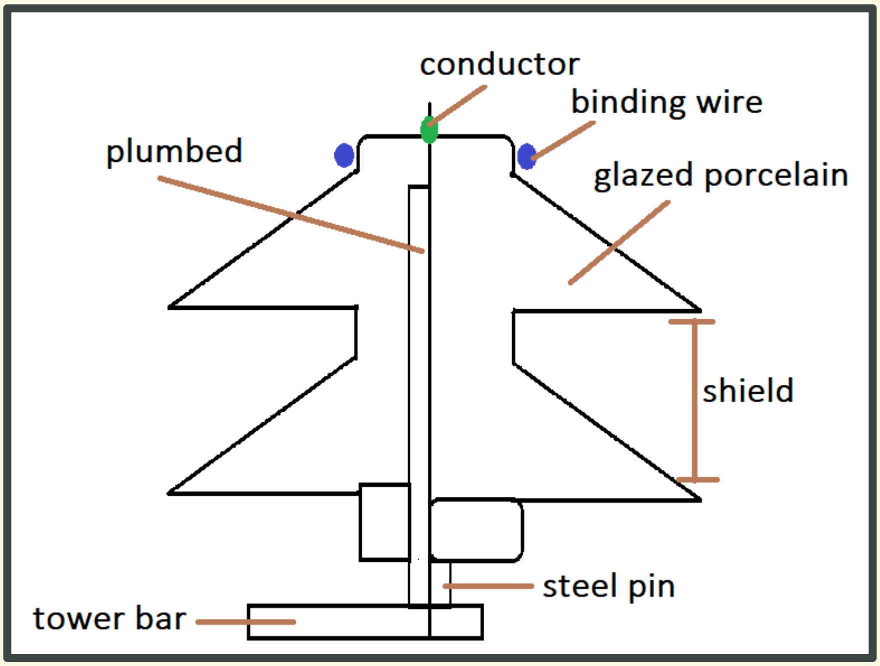


Diagram and schematic of pin type insulator

Types of insulator: Pin type

- Electric power transmission and distribution at voltages up to 33 kV using pin-type insulators The pin-type insulators become too bulky and therefore uneconomical at a voltage level higher than 33 kV.
- Depending on the application voltage, it may be a one-, two-,or three-part type. As the leakage path of the insulator is through its surface, it is desirable to increase the vertical length of the insulator's surface area to lengthening the leakage path.
- In the 11 KV system, we typically use one-part type insulators, where the entire pin insulator is one piece of properly shaped porcelain or glass.

Types of insulator: Pin type

Advantages of Pin Insulator

- Low initial cost
- Easy to install

Disadvantages of Pin Insulator

- If any fault occur at 1 disc need replace all the disc because all the disc is in one part.
- High cost for maintenance

Types of insulator: Suspension type

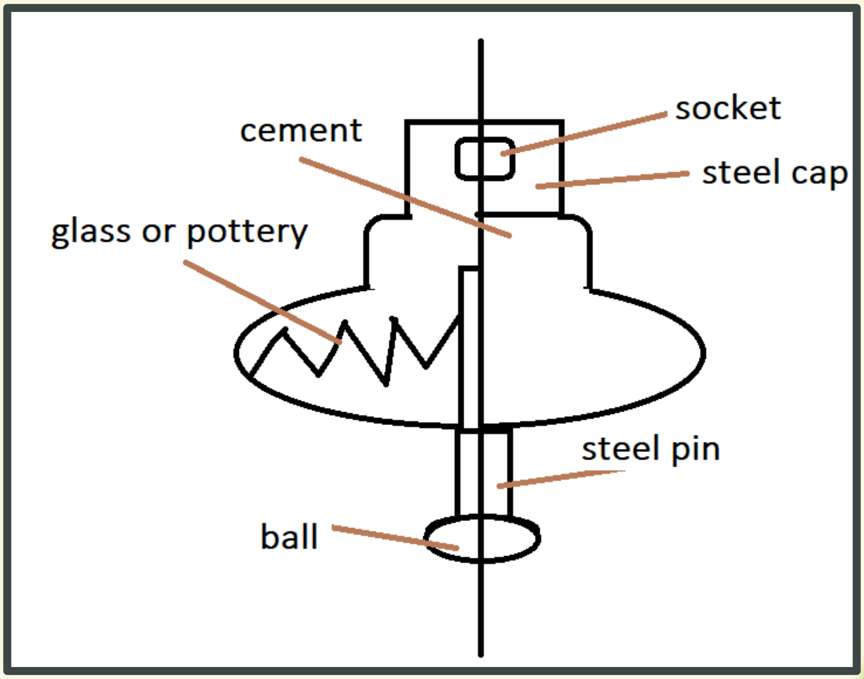


Diagram and schematic of suspension type insulator

Types of insulator: Suspension type

- As the working voltage is increased, the price of pin type insulators increases rapidly. As a result, this sort of insulator is not cost-effective over 33 kV.
- Each insulator of a suspension string is called disc insulator because of their disc like shape.
- consist of a string-like arrangement of porcelain discs joined to one another in sequence. This string has the conductor hanging at the bottom end, while the other end is attached to the tower's crossarm.

Types of insulator: Suspension type

Advantages of Suspension Insulator

- can be made suitable for any voltage level.
- If any one of the disc insulators in a suspension string is damaged, it can be replaced much easily.
- Mechanical stresses on the suspension insulator is less since the line hanged on a flexible suspension string.
- the conductors may be safe from lightening.

Types of insulator: Suspension type

Disadvantages of Suspension Insulator

- costlier than pin and post type insulator.
- requires more height of supporting structure than that for pin or post insulator to maintain same ground clearance of current conductor.
- more spacing between conductors should be provided.

Types of insulator: Strain/tension type

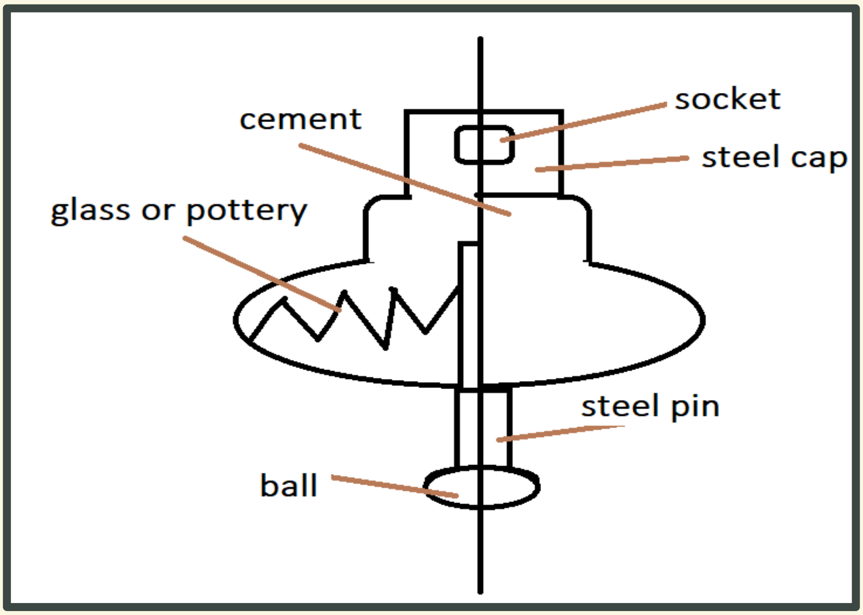
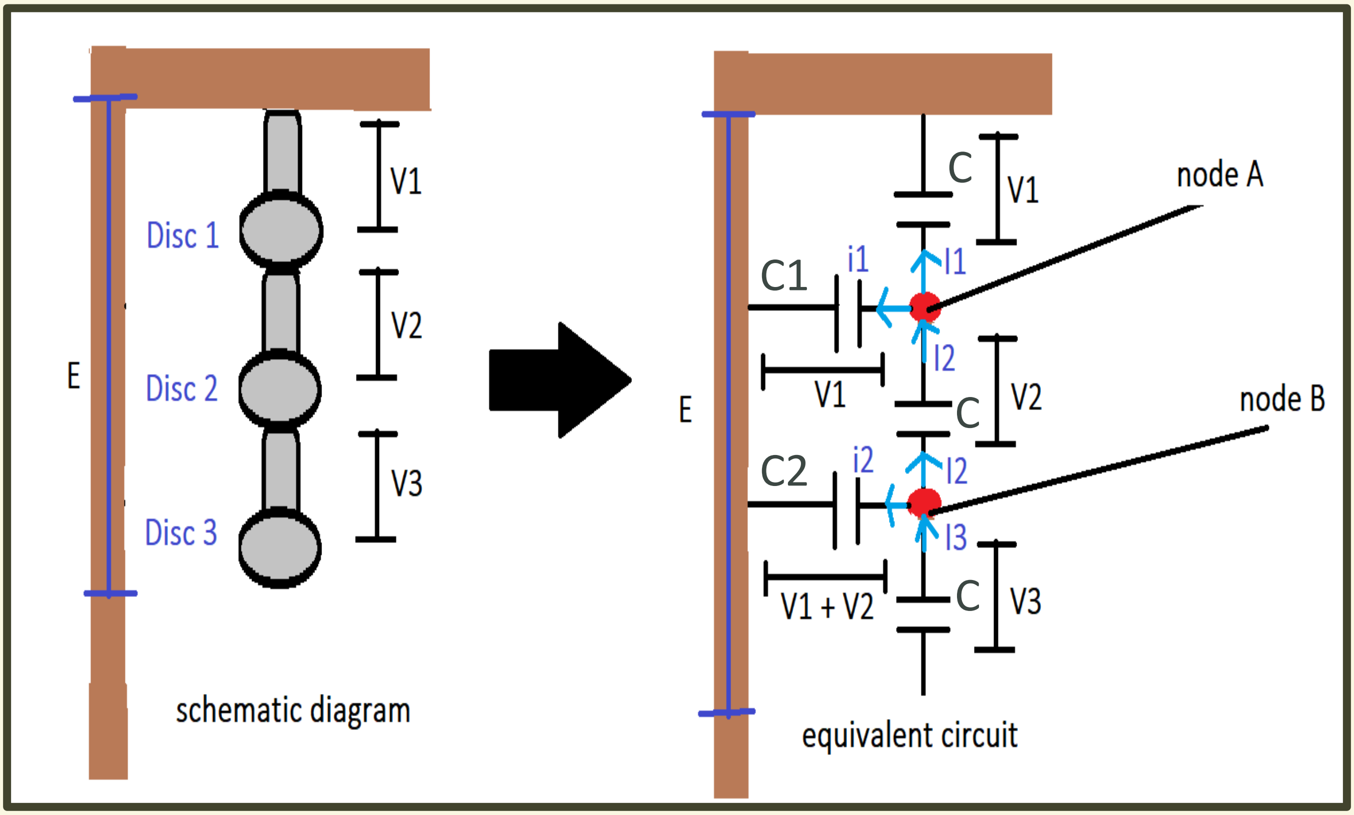


Diagram and schematic of Strain type insulator

Types of insulator: Strain/tension type

- The stress on the line is increased as it comes to a dead end, a corner, or a sharp curve. Strain insulators are used to release the line's excess stress.
- However, strain insulators for high-voltage transmission lines are made up of a collection of suspension insulators. In the vertical plane, strain insulator discs are utilized.
- In situations where there is extremely high line tension, such as at lengthy river bridges, two or more strings are used in parallel.

Calculation of distributed voltage at network string



Refering to above, known;

- C : Mutual capacitance
- C1 : Shunt fitness or air fitness
- V1 : Voltage negotiate first suspension insulator unit (near to tower post)
- V2 : Voltage negotiate second suspension insulator unit.
- V3 : Voltage negotiate third suspension insulator unit (near to conductor)
- E : Voltage between conductor and earth.
- Take K = C1 / C or C1 = KC

Calculation of distributed voltage at network string

Use law kirchhoff in node A we find out:-

$C_1 = KC$

$I_2 = I1 + i_1$
$CV_2 = CV1 + C_1V_1$
$CV_2 = CV1 + KCV_1$
$CV_2 = C(V_1 + KV_1)$
$V_2 = (V_1 + KV_1)$
$V_2 = V_1(1 + K)$ .... Get V_1

By using law kirchhoff in node B we find out:-

$I_3 = I_2 + i_2$
$CV_3 = CV_2 + C_1(V_1 + V_2)$ ....Voltage negotiate C1 air's fitness from tower post to insulator unit to two = (V1+ V2) ...... figure above and note
$CV_3 = CV_2 + KC (v_1 + V_2)$
$CV_3 = C [V_2 + K (V_1 + V_2)]$

know $V_2 = V_1 (1 + K)$

$V_3 = [V_2 + K(V_1 + V_2)]$
$V_3 = [KV_1 + V_2(1 + K)]$
$V_3 = [KV_1 + V_1 (1 + K) (1 + K)]$
$V_3 = V_1 [K + (1 + K) (1 + K)]$ ....Simplified.
$V_3 = V_1 (K + 1 + 2 K + K^2)$
$V_3 = V_1 (1 + 3 K + K^2)$ ....Get V_1

Voltage between tower conductor and post (to earth) :-

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

From this equation is found :-

$V_1 = E / (3 + 4K + K^2)$

After getting the next V1 V2 and V3 get the value. From the findings we will see the potential difference across each insulation voltage of this network.

Example 1

A network of three the insulation used to hang a conductor 33kV, three phase overhead line. Air or bypass capacitance between each lid and the tower is one tenth (1 / 10) of the capacitance per unit. Calculate the voltage across each insulator.

Step 1: Calculate the conductor voltage in single phase

$$E = \frac{33K}{\sqrt{3}} = 19.05KV$$

Step 2: Using the derivation formula to find V1

$$E = V_1 + V_2 + V_3$$

$$E = V_1 + V_1 + V_1K + V_1K^2 + V_13K + V_1$$

$$E = 3V_1 + V_1 + V_14K + V_1{}^2$$

Continue....

$$V_1 = \frac{E}{3+4K+K^2}$$

$$V_1 = \frac{E}{3+4K+K^2} = \frac{19.05K}{3+4(0.1)+(0.1)^2} = 5.587kV$$

Step 3 : Calculate distributed voltage at disc 2 and 3

$$V_2 = V_1 + kV_1$$

$$V_2 = 5.587kV + (0.1)\,5.587kV$$

$$V_2 = 6.146kV$$

$$V_3 = V_1K^2 + V_1 3K + V_1$$

$$V_3 = 5.587kV\,(0.1)^2 + 5.587kV\,(3)(0.1) + 5.587kV$$

$$V_3 = 7.319kV$$

How to determine network string efficiency

$$\text{Network Efficiency} = \frac{\text{The voltage across the Network}}{\text{n x Voltage across the insulation is a conductor}} \times 100\%$$

Or can be writen as,

$$\text{Network Efficiency} = \frac{E}{nVT} \; x \; 100\%$$

Where;

E = Voltan hinder network

n = number of insulator arranged by serial in network insulator

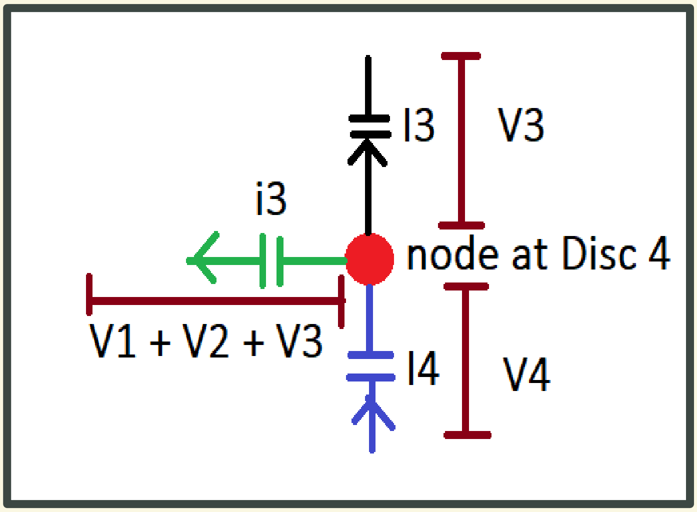
VT = Voltage Hinder Insulator near to conductor

How to determine network string efficiency

Example 2

A network of four the insulation used to hang a conductor 33kV, three phase overhead line. Air or bypass capacitance between each lid and the tower is one tenth (1 / 10) of the capacitance per unit. Calculate the insulation efficiency of the network

Solution



By using KCL:

$$I_4 = I_3 + i_3$$

$$CV_4 = CV_3 + C_1(V_1 + V_2 + V_3)$$

$$CV_4 = CV_3 + KC(V_1 + V_2 + V_3)$$

$$V_4 = V_3 + K(V_1 + V_2 + V_3)$$

How to determine network string efficiency

$V_4 = V_1K^2 + V_13K + V_1 + K(V_1 + V_1 + kV_1 + V_1K^2 + V_13K + V_1\ )$

$V_4 = V_1K^2 + V_13K + V_1 + K\ V_1 + KV_1 + k^2V_1 + V_1K^3 + V_13K^2 + KV_1$

$V_4 = V_1K^3 + V_15K^2 + V_16K + V_1$

Step 1 : calculate all distributed voltage

$E = V_1 + V_2 + V_3 + V_4$

$E = V_1 + V_1 + V_1K + V_1K^2 + V_13K + V_1 + V_1K^3 + V_15K^2 + V_16K + V_1$

$E = 4V_1 + V_110K + V_16K^2 + V_1K^3$

$$V_1 = \frac{E}{4 + 10K + 6K^2 + K^3} \qquad E = \frac{33K}{\sqrt{3}} = 19.05kV$$

$$V_1 = \frac{19.05K}{4 + 10(0.1) + 6(0.1)^2 + (0.1)^3} = 3.764kV$$

$V_2 = V_1 + kV_1$

$V_2 = 3.764kV + (0.1)\ 3.764kV$

$V_2 = 4.14kV$

How to determine network string efficiency

$V_3 = V_1K^2 + V_13K + V_1$

$V_3 = 3.764kV(0.1)^2 + 3.764kV(3)(0.1) + 3.764kV$

$V_3 = 4.931kV$

$V_4 = V_1K^3 + V_15K^2 + V_16K + V_1$

$V_4 = 3.764kV\,(0.1)^3 + 3.764kV(5)(0.1)^2 + 3.764kV\,(6)(0.1) + 3.764kV$

$V_4 = 6.214\ kV$

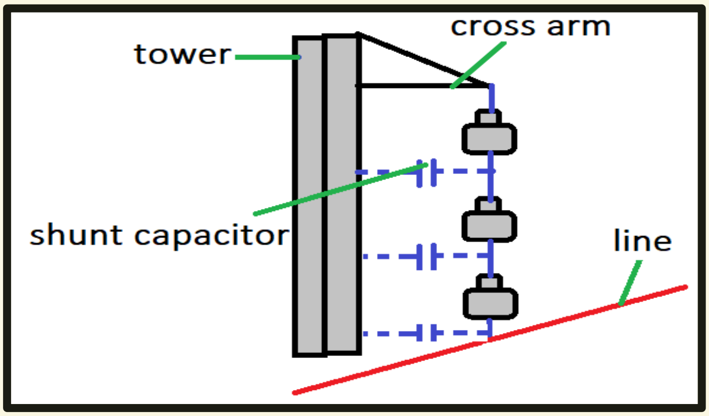
Step 2: calculate the network string efficiency

$$\%\eta = \frac{E}{nVT}x100 = \frac{19.05kV}{4(6.214kV)}x100 = 76.64\%$$

Methods to enhance network string efficiency

i. By using longer cross-arms.

- The value of K, or the ratio of shunt capacitance to mutual capacitance, determines the value of string efficiency. The string's efficiency increases and becomes more efficient as the value of K decreases.
- The voltage distribution is uniform. Shunt capacitance can be lowered to lower the value of K. Longer cross-arms should be used to increase the distance between the conductor and the tower, reducing shunt capacitance. However, using very long cross-arms is not an option due to tower strength and cost restrictions. The upper limit of this method is K = 01.



Methods to enhance network string efficiency

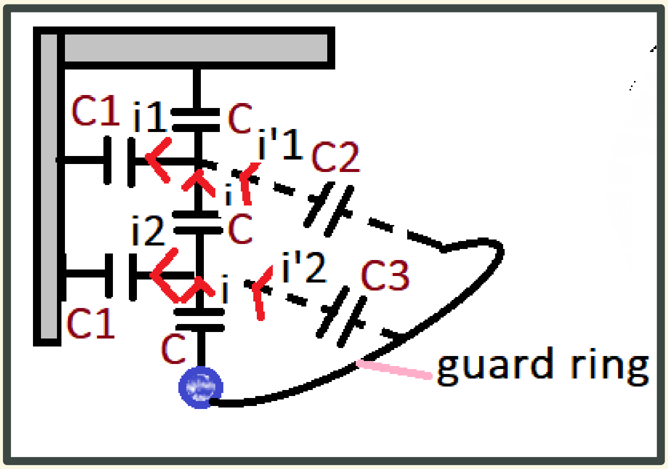
ii. By grading the insulators.

- This method involves selecting insulators with various sizes such that each has a unique capacitance.
- The insulators are capacitance graded, which means that they are put together in the string so that the top unit has the lowest capacitance, and the capacitance rises steadily until it reaches the bottom unit (i.e., the one closest to the conductor).
- Because voltage and capacitance have an inverse relationship, this technique tends to equalize the potential distribution among the units in the string.
- The drawback of this approach is the necessity of using numerous insulators of various sizes. However, if normal insulators are used for most of the string and larger units are used for the area close to the line conductor, good results can be obtained.

Methods to enhance network string efficiency

iii. By using a guard ring.

- A guard ring, which is a metal ring encircling the bottom insulator and electrically connected to the conductor, can be used to equalize the voltage across each unit in a string.
- The guard ring introduces capacitance between the metal fittings and the line conductor. Shunt capacitance currents i1, i2, etc. are equal to metal fitting line capacitance currents i'1, i'2, etc. As a result, each string unit receives the same charging current I and potential will be distributed equally among the units.



Never stop working towards your dreams.

PLEASE SCAN ME

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