CBCS SCHEME

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BEE402

Fourth Semester B.E./B.Tech. Degree Examination, Dec.2024/Jan.2025
Transmission and Distribution

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	With the help of single line diagram, explain the structure of electrical power system indicating standard voltages.	06	L2	CO1
	b.	Explain the effects of high voltage transmission based on the conductor volume, transmission efficiency and percentage line drop.	06	L2	CO1
	c.	The towers of height 95 m and 70 m respectively support a transmission line conductor at water crossing. The horizontal distance between the towers is 400 m. If the tension in the conductor is 1100 kg and its weight is 0.8 kg/m, calculate: (i) Sag at lower support (ii) Sag at upper support (iii) Clearance of lowest point on the trajectory from water level. Assume bases of towers are at water level.	08	L3	CO1
		OR			
Q.2	a.	Explain the different methods to equalize the potential across the string of suspension insulator.	06	L2	CO1
	b.	Write a short note on Bundled conductors.	06	L1	CO1
	c.	Each line of 3-phase system is suspended by a string of 3 similar insulators. If the voltage across the bottom most unit is 17.5 KV. Calculate the voltage across the insulator string. Also find the string efficiency. Assume that the earth capacitance is $1/8^{th}$ of mutual capacitance.	08	L3	CO1
		Module – 2			
Q.3	a.	Derive an expression for inductance of a single phase two wire line starting from fundamentals.	08	L3	CO2
	b.	Explain the terms (i) GMD and (ii) GMR with the help of suitable examples.	06	L1	CO2
	c.	The three conductors of a 3-phase line are arranged at the three corners of a triangle of sides 2 m, 2.5 m and 4.5 m. Calculate the inductance per km of the line when conductors are regularly transposed. The diameter of each conductor is 1.24 cm.	06	L3	CO2
		OR			
Q.4	a.	Derive an expression for capacitance of a 3-phase line with equilateral spacing.	08	L3	CO2
	b.	Compare single circuit and double circuit lines.	05	L2	CO2
	c.	A single-phase over head line 30 km long consists of two parallel wires each 5 mm in diameter and 1.5 m apart. If the line voltage is 50 KV, 50 Hz. Calculate the charging current with line open circuited.	07	L3	CO2
		Module – 3			
Q.5	a.	Briefly explain the purpose of overhead transmission line and how transmission lines are classified.	06	L2	CO3
	b.	Discuss the terms voltage regulation and transmission efficiency as applied to transmission line.	04	L2	CO3

	c.	A three phase 50 Hz overhead transmission line 100 km long has following constants: Resistance/ph/km = 0.1 Ω ; Reactance/ph/km = 0.2 Ω; susceptance/ph/km = 0.04×10^{-4} siemens. Determine: (i) Sending end current (ii) Sending end voltage (iii) Sending end p.f. (iv) Transmission efficiency When supplying a balanced load of 10,000 KW at 66 KV, 0.8 p.f. lagging. Use nominal T-method.	**10**	**L3**	**CO3**
		OR			
Q.6	**a.**	With the help of vector diagram, explain the nominal-π method for obtaining the performance of medium transmission line.	**08**	**L3**	**CO3**
	b.	What are A, B, C, D parameters? Briefly explain.	**04**	**L2**	**CO3**
	c.	A 3-phase transmission line is 400 km long and feeds a load of 450 MVA, 0.8 p.f. lagging at 345 KV. The ABCD constants are $A = D = 0.8181\angle 1.3^\circ$; $B = 172.2\angle 84.2^\circ$, $C = 1.93\times10^{-3}\angle 90.4$ ℧. Calculate sending end current and percentage voltage drop at full load.	**08**	**L3**	**CO1**
		Module – 4			
Q.7	**a.**	Briefly explain the factors influencing the corona.	**06**	**L2**	**CO4**
	b.	Explain the terms with reference to corona: (i) Critical disruptive voltage (ii) Visual critical voltage (iii) Corona power loss	**06**	**L2**	**CO4**
	c.	Determine the critical disruptive voltage and the visual critical voltage for a 3-phase, 132 KV, 50 Hz line situated in a temperature of 30°C and at a barometric pressure of 74 cm. The conductor diameter is 1.5 cm while the spacing between the conductors is 2.75 m. The surface irregularity factor is 0.9 while $m_u = 0.75$ and $m_0 = 0.9$.	**08**	**L3**	**CO4**
		OR			
Q.8	**a.**	With the help of cross sectional diagram, explain the construction of single core cable.	**06**	**L2**	**CO4**
	b.	Explain the inter sheath grading of cables.	**06**	**L2**	**CO4**
	c.	Single core, lead covered cable has a conductor diameter of 3 cm with insulation diameter of 8.5 cm. The cable is insulated with two dielectrics with permittivities 5 and 3 respectively. The maximum stress in the two dielectrics are 38 KV/cm and 26 KV/cm respectively. Calculate radial thickness of insulating layers and the working voltage of the cable.	**08**	**L3**	**CO4**
		Module – 5			
Q.9	**a.**	Explain the following terms with reference to distribution system: (i) Radial feeder (ii) Parallel feeder (iii) Loop feeder (iv) Interconnected network	**08**	**L2**	**CO5**
	b.	A single phase distributor 2 km long supplies a load of 120 A at 0.8 p.f lagging at its far end and a load of 80 A at 0.9 p.f. lagging at its mid point. Both power factors are referred to the voltage at the far end. The resistance and reactance per km (go and return) are 0.05 and 0.1 Ω respectively. If the voltage at the far end is maintained at 230 V, calculate: (i) Voltage at the sending end (ii) Phase angle between voltages at the two ends.	**12**	**L3**	**CO5**
		OR			
Q.10	**a.**	Define the terms: (i) Reliability (ii) Availability (iii) Adequacy (iv) Security	**08**	**L2**	**CO5**
	b.	Explain with neat sketch different failure modes of bath tub curve.	**06**	**L2**	**CO5**
	c.	Write a short note on power quality.	**06**	**L2**	**CO5**

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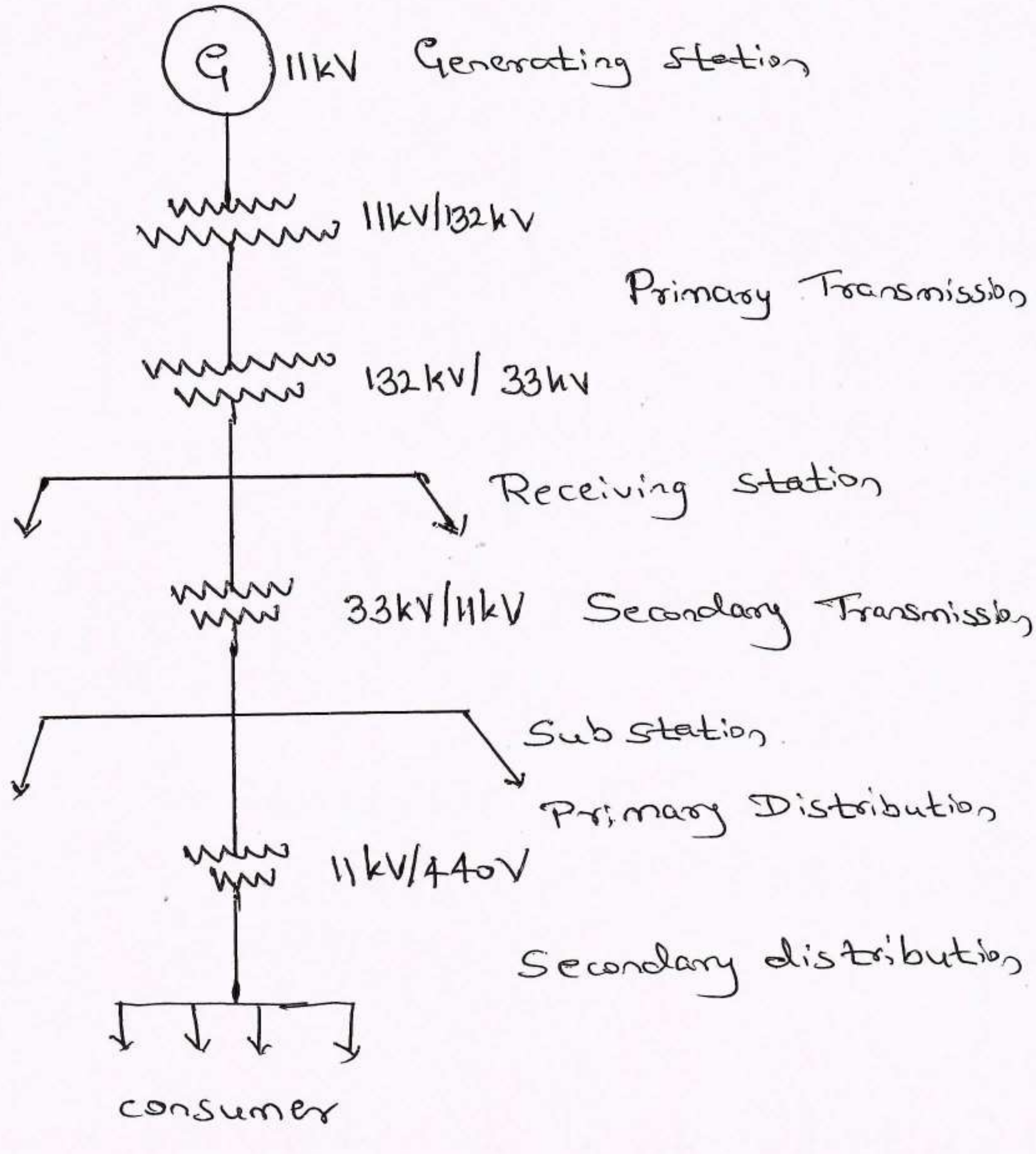
Module 1

Q1a) With the help of single line diagram, explain the structure of electrical power system indicating standard voltages. 6M

Ans:-



Generating Station

Power is generated in generating station with different voltage ranges like 3.3 kV, 6.6 kV, 11 kV etc. Main components used in generating station is generator, Turbine, protective equipment

Primary Transmission

The generated voltage is steped ~~uped~~ up from 11 kV to 132 kV & transmitted long distance. As per the thumb rule of transmission 1kV is safel transmitted up to 1 km. Major equipment used in this stage power transformer (Δ-Δ), supporting structure, conductors, insulators & protective equipment when receiving station come voltage reduced to 132 kV to 33 kV.

Secondary Transmission

Between receiving station to substation the stage is called as secondary Transmission. Voltage is step down from 33 kV to 11 kV then supply to substation.

Primary Distribution

Substation to till primary side of distribution transformer is called as primary distribution. Feeder & distributor are the main components.

Secondary Distribution

Secondary side of distribution transformer to consumer is called secondary distribution. 11 kV step down to 440V, 3ϕ, 4 wire connected to 3ϕ consumer, 1ϕ, 2 wire connected to 1ϕ consumer.

b) Explain the effect of high voltage transmission based on the conductor volume, transmission efficiency & percentage line drop. 6M

Ans:- Reduce the volume of conductor material

Load current $I = \frac{P}{\sqrt{3}\, V \cos\phi}$

Resistance/conductor, $R = \rho l / a$

Total power loss, $W = 3 I^2 R = 3 \left(\frac{P}{\sqrt{3}\, V \cos\phi} \right)^2 \times \frac{\rho l}{a}$

$$W = \frac{P^2 \rho l}{V^2 \cos^2\phi \, a}$$

Area of X-section, $a = \frac{P^2 \rho l}{V^2 \cos^2\phi \, a}$

Total volume of conductor material required

$$= 3al = 3\left(\frac{P^2 \rho l}{V^2 \cos^2\phi \, a}\right) l$$

$$= \frac{3 P^2 \rho l^2}{W V^2 \cos^2\phi}$$

Square of transmission voltage is inversely proportional to volume of conductor material.

ii] Increases Transmission efficiency

Input power = P + Total losses

$$= P + \frac{P^2 \rho l}{V^2 \cos^2\phi \, a}$$

$$a = I/J$$

$$\text{Input power} = P + \frac{P^2 \rho l J}{V^2 \cos^2\phi \, I}$$

$$= P + \frac{\sqrt{3} \, P J \rho l}{V \cos\phi}$$

$$= P\left[1 + \frac{\sqrt{3} J \rho l}{V \cos\phi}\right]$$

$$\text{Transmission efficiency} = \frac{\text{Output power}}{\text{Input power}}$$

$$\eta_T = \frac{P}{P\left[1 + \frac{\sqrt{3} J \rho l}{V\cos\phi}\right]}$$

iii] Decreases percentage line drop

$$\text{Line drop} = IR = I\frac{\rho l}{a}$$

$$= \rho l J$$

$$\text{Percentage line drop} = \frac{J\rho l}{V} \times 100$$

c) The towers of height 95m & 70m respectively support a transmission line conductor at water crossing. The horizontal distance between the towers is 400m. If the tension in the conductor is 1100kg & its weight is 0.8 kg/m, calculate:

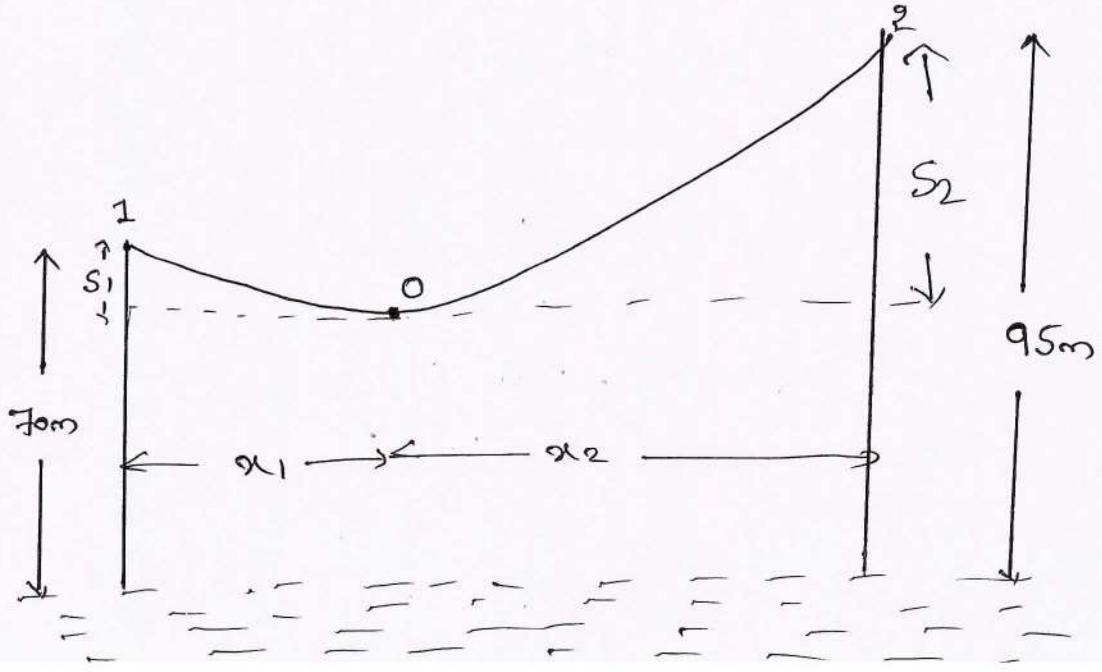
i] Sag at lower support

ii] Sag at upper support

iii] Clearance of lowest point on the trajectory from water level.

Assume bases of towers are at water level. 8M

Ans: -



$l = 400m \quad T = 1100kg \quad \omega = 0.8 kg/m$

$h = 95 - 70 = 25m$

$$x_1 = \frac{l}{2} - \frac{Th}{\omega l} = \frac{400}{2} - \left[\frac{1100 \times 25}{0.8 \times 400}\right] = 114.m$$

$$x_2 = \frac{l}{2} + \frac{Th}{\omega l} = \frac{400}{2} + \left[\frac{1100 + 25}{0.8 + 400}\right] = 285.9m$$

i] Sag at lower support (S_1)

$$S_1 = \frac{\omega x_1^2}{2T} = \frac{0.8 \times 114.1^2}{2 \times 1100} = 4.73m$$

ii] Sag at upper support (S_2)

$$S_2 = \frac{\omega x_2^2}{2T} = \frac{0.8 \times 285.9^2}{2 \times 1100} = 29.72m$$

iii] Clearance of lowest point on the trajector from water level.

= Height of the lower support $- S_1$

$= 70 - 4.73$

$= 65.27m$

Q2a) Explain the different methods to equalize the potential across the string of suspension insulator. 6M

Ans:- Methods to equalize the potential across the string of suspension insulator explained below;

i] By using longer cross-arms

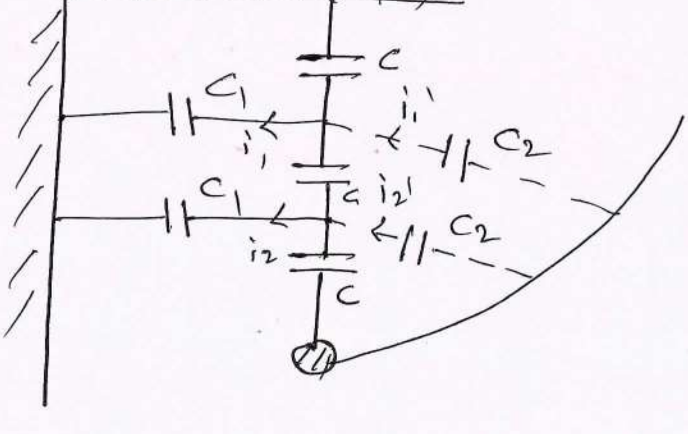
The value of string efficiency depends upon the value of K i.e. ratio of shunt capacitance to mutual capacitance. The lesser the value of K, the greater is the string efficiency & more uniform is the voltage distribution. When distance between conductor to tower increases shunt capacitances decreases. This leads low K. By using longer cross arm we can achieve this.

ii] By grading the insulators.

Insulators of different diemensions are so choosen that each has a different capacitance. The insulators are capacitance graded, they assembled like size of insulator from line is bigger, subsequient insulator line to cross arm size reduces. Manifacturing of different size insulator increases the cost.

iii] By using a guard ring

By connecting metal ring electrically connected to the conductor & surrounding the bottom insulator. The guard ring introduces the capacitance between metal fitting and the line conductor. Guard ring introduce the counter current for shunt capacitance like i_1', i_2' .... etc.



2b) Write a short note on bundled conductor 6M

Ans:- A bundled conductor is a set of two or more conductors grouped together & used as a 1ϕ conductor in high voltage power transmission system. The bundled conductors lower the electric field intensity around them, minimizing corona discharge & energy loss. They help to decreases the inductance & increase the capacitance of transmission line. It Improves the current carrying capacity without overheating.

~~2c) Each line of 3ϕ line are arranged at the 3 corners of a~~

2c) Each line of 3ϕ system is suspended by a string of 3 similar insulators. If the voltage across the bottom most unit is 17.5kV. Calculate the voltage across the insulator string. Also find the string efficiency. Assume that the earth capacitance is 1/8th of mutual capacitance. 8M

Ans:- $K = \frac{1}{8} = 0.125$, $V_3 = 17.5kV$

$$V_2 = V_1(1+K) = V_1 \; 1.125$$

$$V_3 = V_1[1+3K+K^2] = V_1[1+3\times0.125+(0.125)^2]$$

$$V_3 = 1.39V_1$$

Voltage across top unit $V_1 = \frac{V_3}{1.39} = \frac{17.5k}{1.39} = 12.59kV$

Voltage across middle unit $V_2 = V_1 \times 1.125 = 12.59\times1.125 = 14.16kV$

Voltage across string $V = V_1 + V_2 + V_3$

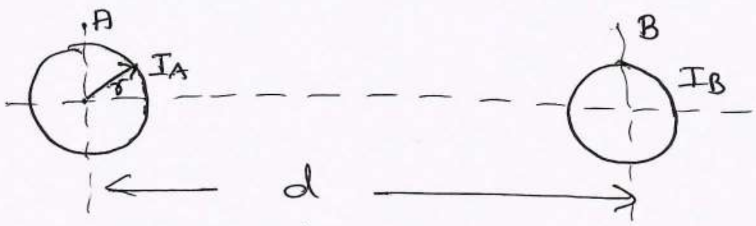
$$= 12.59 + 14.16 + 17.5$$
$$= 44.25kV$$

String efficiency $= \frac{V}{n \times V_3} = \frac{44.25}{3\times17.5} \times 100 = 84.28\%$.

Module 2

3a) Derive an expression for inductance of a 1ϕ two wire line starting from fundamentals. 8M

Ans: -



Conductor A & B placed at 'd' meter apart. 'r' is the radius of conductors.

$$I_A + I_B = 0$$

Flux linkages due to I_A w.r.t conductor A

$$= \frac{\mu_0 I_A}{2\pi}\left[\frac{1}{4} + \int_r^{\infty} \frac{dx}{x}\right]$$

Flux linkages with conductors A due to I_B

$$= \frac{\mu_0 I_B}{2\pi}\int_d^{\infty} \frac{dx}{x}$$

Total flux linkage with conductor A (ψ_A)

$$\psi_A = \frac{\mu_0 I_A}{2\pi}\left[\frac{1}{4} + \int_r^{\infty}\frac{dx}{x}\right] + \frac{\mu_0 I_B}{2\pi}\int_d^{\infty}\frac{dx}{x}$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} + \int_r^{\infty}\frac{dx}{x}\right) I_A + I_B\int_d^{\infty}\frac{dx}{x}\right]$$

$$= \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4} + \log_e \infty - \log_e r\right) I_A + \left(\log_e \infty - \log_e d\right) I_B\right]$$

$$= \frac{\mu_0}{2\pi}\left[\frac{I_A}{4} - I_A \log_e r - I_B \log_e d\right]$$

$$\left(\because I_A + I_B = 0\right), \quad -I_B = I_A$$

$$\psi_A = \frac{\mu_0}{2\pi}\left[\frac{I_A}{4} + I_A \log_e d - I_A \log_e r\right] \text{ wb-turns/m}$$

$$= \frac{\mu_0 I_A}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{ wb-turns/m}$$

Inductance of conductor A

$$L_A = \frac{\psi_A}{I_A}$$

$$= \frac{\mu_0}{2\pi}\left[\frac{1}{4} + \log_e \frac{d}{r}\right] \text{ H/m}$$

$$= 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{d}{r}\right] \text{H/m}$$

Loop inductance $= 10^{-7}\left[1 + 4\log_e \frac{d}{r}\right]$ H/m

Q3b) Explain the terms i] GMD & ii] GMR with the help of suitable examples. 6M

Ans:- i] Geometrical Mean Distance (GMD)

The mutual GMD is the geometrical mean of the distances form one conductor to another.

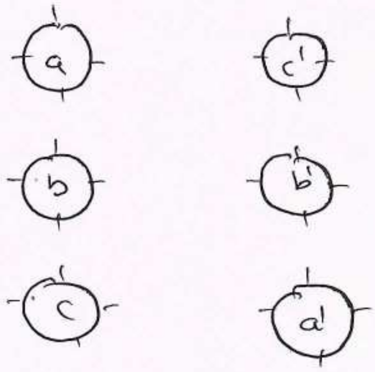
* The mutual GMD between two conductor

$D = d =$ spacing between two conductor

* 3ϕ single circuit

$$D_m = (d_1 \times d_2 \times d_3)^{1/3}$$

* 3ϕ double circuit



Self GMD of conductor $= 0.7788\,r$

Self GMD of combination aa'

$$D_{S1} = (D_{aa} \times D_{aa'} \times D_{a'a} \times D_{a'a'})^{1/4}$$

$$D_{S2} = (D_{bb} \times D_{bb'} \times D_{b'b} \times D_{b'b'})^{1/4}$$

$$D_{S3} = (D_{cc} \times D_{cc'} \times D_{c'c} \times D_{c'c'})^{1/4}$$

$$D_s = (D_{S1} \times D_{S2} \times D_{S3})^{1/3}$$

Mutual GMD between Phase A&B

$$D_{AB} = (D_{ab} \times D_{a'b} \times D_{ab'} \times D_{a'b'})^{1/4}$$

$$D_{BC} = (D_{bc} \times D_{b'c} \times D_{bc'} \times D_{b'c'})^{1/4}$$

$$D_{CA} = (D_{ca} \times D_{c'a} \times D_{ca'} \times D_{c'a'})^{1/4}$$

$$D_m = (D_{AB} \times D_{BC} \times D_{CA})^{1/3}$$

ii] Geometrical Mean Radius (GMR)

GMR is also called as self GMD, due to the skin effect electrons concentrate on surface of conductor. So that inductance equation is modified as $2 \times 10^{-7} \log_e \frac{d}{r}$.

Self GMD of a conductor depends upon the size & shape of the conductor & independent of the spacing between the conductor.

3c) The three conductors of a 3ϕ line are arranged at the 3 corners of a triangle of sides 2m, 2.5m & 4.5m. Calculate the inductance per km of the line when conductors are regularly transposed. The diameter of each conductor is 1.24cm. 6M

Ans:-

Equivalent Equilateral Spacing Deq

$$D_{eq} = (D_{12} \times D_{23} \times D_{31})^{1/3} = (2 \times 2.5 \times 4.5)^{1/3} = 282\,cm = 2.82\,m$$

$$\text{Inductance/ph/m} = 10^{-7}\left(\frac{1}{2} + 2\log_e \frac{D_{eq}}{r}\right)$$

$$= 10^{-7}\left(1/2 + 2\log_e \frac{282}{0.62}\right)$$

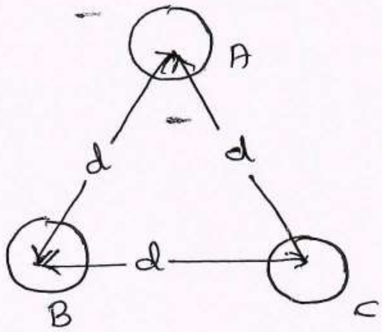
$$= 12.74 \times 10^{-7}\,H$$

$$\text{Inductance/ph/km} = 12.74 \times 10^{-7} \times 10^{3}$$

$$= 12.74 \times 10^{-4}\,H$$

4a) Derive an expression for Capacitance of 3ϕ line with equilateral spacing. 8M

Ans:-



Conductor A, B & C are 'd' meter apart and Q_A, Q_B & Q_C are charges with respective conductors.

Overall potential difference between conductor A & infinite neutral plane is given by

$$V_A = \int_r^{\infty} \frac{Q_A}{2\pi x \varepsilon_0} dx + \int_d^{\infty} \frac{Q_B}{2\pi x \varepsilon_0} dx + \int_d^{\infty} \frac{Q_C}{2\pi x \varepsilon_0} dx$$

$$= \frac{1}{2\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d} + Q_C \log_e \frac{1}{d}\right]$$

$$= \frac{1}{2\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r} + (Q_B + Q_C) \log_e \frac{1}{d}\right]$$

$$= \frac{1}{2\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r} - Q_A \log_e \frac{1}{d}\right]$$

$$V_A = \frac{Q_A}{2\pi\varepsilon_0}\left[\log_e \frac{d}{r}\right]$$

$$C_A = \frac{Q_A}{V_A}$$

$$= \frac{Q_A}{\frac{Q_A}{2\pi\varepsilon_0} \log_e \frac{d}{r}}$$

$$C_A = \frac{2\pi\varepsilon_0}{\log_e \frac{d}{r}} \text{ F/m}$$

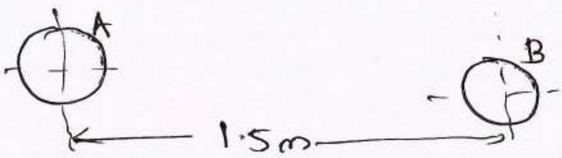
4b) Compare single circuit & Double circuit lines.

Ans! -

Single Circuit	Double Circuit
* This type of arrangement is less dangerous during repair work.	* This type of arrangement is comparatively dangerous
* The circuit is less reliable	* Circuit is much reliable.
* It requires lesser foundation & less weight of steel tower member	* It requires more foundation as the structure is of heavier member. The height of tower is more.
* The spacing of conductor required is greater	* The spacing of conductor required is lesser
* Reactance is high	* Reactance is low

c) A 1ϕ over head line 30km long consists of two parallel wires each 5mm in diameter & 1.5m apart. If the line voltage is 50kV, 50Hz. Calculate the charging current with line open circuited. 7M

Ans:- $r = \frac{d}{2} = 2.5 \times 10^{-3}$ m $\quad \varepsilon_0 = 8.854 \times 10^{-12}$



$$C_{AB} = \frac{\pi \varepsilon}{\ln\left(\frac{D}{r}\right)} \text{ F/m}$$

$$= \frac{\pi \times 8.854 \times 10^{-12}}{\ln\left(\frac{1.5}{2.5m}\right)} = 4.3481 \text{ nF/km}$$

Total capacitance for 30km = $4.3481 \times 30 = 130.4$ nF

charging current $I_c = \frac{V}{X_c} = 2\pi f C V$

$= 2\pi \times 50 \times 130.4n \times 50k = 2.049A$

Module -3

5a) Briefly explain the purpose of overhead transmission line & how transmission lines are classified. 6M

Ans:- Overhead transmission lines are required to transmit the power from generating station to distribution side. Bulk amount of power transmission not possible without conductors. So transmission line plays vital role.

Classification of transmission line

1] Short Transmission Line

When the distance ~~between generating station to~~ of transmission line is 50km, its called as short transmission line. Working voltage is about 20kV. Capacitance effect is neglected, R&L effect is considered to analyse the line.

2] Medium Transmission Line

The span length is about 50 to 150km, its called as medium transmission line. Working voltage is about 100kV. Lumped capacitance is considered for analysis

3] Long Transmission Line

The span length is morethan 150km & 100kV is called as long transmission line. Regirous method used.

b) Discuss the terms voltage regulation & transmission ~~line~~ efficiency as applied to taransmission line. 4M

Ans:- Voltage Regulation

"The difference in voltage at the receiving end of a transmission line between conditions of no load & full load is called as voltage regulation".

Percentage voltage regulation = $\frac{V_S - V_R}{V_R} \times 100$

Transmission efficiency

"The ratio of receiving end power to the sending end power of a transmission line is called as transmission efficiency".

$$\eta_T = \frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

$$= \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$$

c) A 3ϕ 50Hz overhead transmission line 100km long has following constants:

Resistance/ph/km = 0.1Ω ; Reactance/ph/km = $0.2\,\Omega$; susceptance/ph/km = 0.04×10^{-4} siemens. Determine :

i] Sending end current ii] sending end voltage

iii] Sending end p.f iv] Transmission efficiency

when supplying a balanced load of 10,000kW at 66kV, 0.8 p.f lagging. Use nominal T- method.

Ans:- Total resistance/ph $R = 0.1 \times 100 = 10\Omega$

" reactance/ph $X_L = 0.2 \times 100 = 20\,\Omega$

Capacitive susceptance/ph $Y = 0.04 \times 10^{-4} \times 100 = 4 \times 10^{-4}\,S$

Load current $I_R = \frac{10000k}{\sqrt{3} \times 66k \times 0.8} = 109A$

$\vec{Z} = R + jX_L = (10 + j20)\,\Omega$

$\vec{V_R} = V_R + j0 = (38105 + j0)\,V$

$\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R) = 109(0.8 - j0.6) = (87.2 - j65.4)\,A$

$\vec{V_1} = \vec{V_R} + \vec{I_R}\frac{\vec{Z}}{2} = 38{,}105 + (87.2 - j65.4)(5 + j10)$

$\vec{V_1} = 39{,}195 + j545$

Charging current $\vec{I_c} = j\vec{Y}\vec{V_1} = j4\times10^{-4}(39{,}195 + j545)$

$= (-0.218 + j15.6)\,A$

i] Sending end current $\vec{I_s}$

$\vec{I_s} = \vec{I_R} + \vec{I_c} = (87.2 - j65.4) + (-0.218 + j15.6)$

$= 87 - j49.8 = 100\angle{-29.47^\circ}\,A$

ii] Sending end voltage $\vec{V_s}$

$\vec{V_s} = \vec{V_1} + \vec{I_s}\frac{\vec{Z}}{2}$

$= (39{,}195 + j545) + (87 - j49.8)(5 + j10)$

$= 40128 + j1170$

$= 40145\angle{1.4^\circ}\ V$

Line value of $V_s = \sqrt{3}\times 40145 = 69.53\,kV$

iii] $\phi = 1.4 + 29.47 = 31.27^\circ$

Power factor $\cos\phi = \cos 31.27^\circ = 0.853$ lag

iv] Sending end power $= 3V_sI_s\cos\phi_s$

$= 3\times 40145\times 100\times 0.853$

$P_s = 10273.105\,kW$

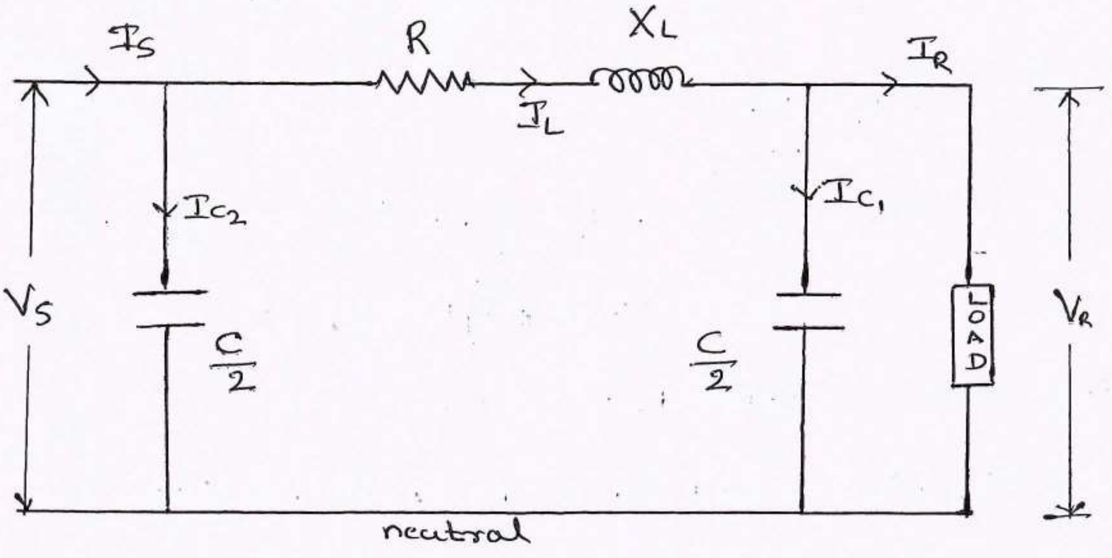
Transmission efficiency $\eta_T = \frac{P_R}{P_s}\times 100$

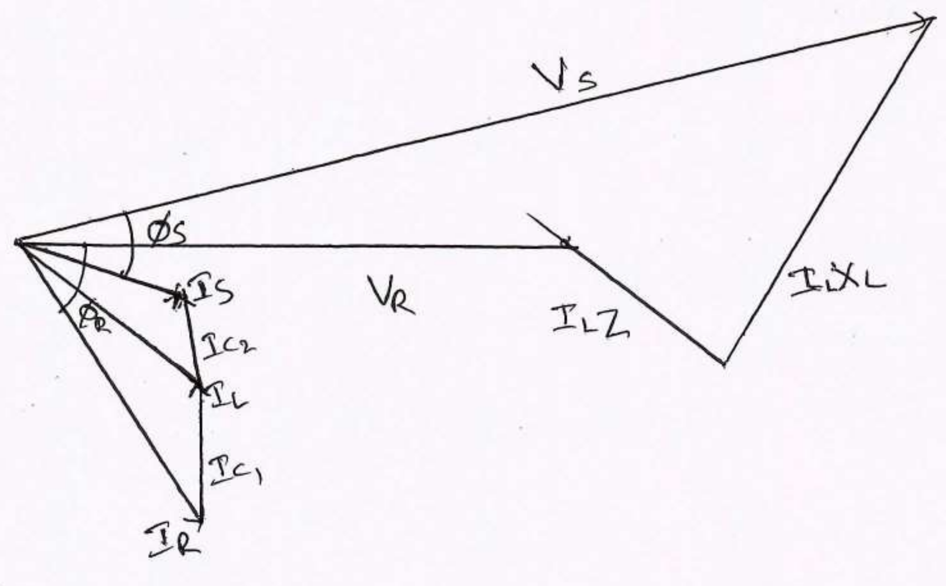
$= \frac{10000}{10273}\times 100$

$= 97.43\,\%$

6a) With the help of vector diagram, explain the nominal-π method for obtaining the performance of medium transmission line. 8M

Ans:-





$\vec{V_R} = (V_R + j0)$ volts

$\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$

Line current $\vec{I_L} = \vec{I_R} + \vec{I_{C_1}}$

$\vec{I_{C_1}} = j\omega(C/2)\vec{V_R} = j\pi f C \vec{V_R}$

Sending end voltage $\vec{V_S} = \vec{V_R} + \vec{I_L}\vec{Z}$

charging current at sending end

$\vec{I_{C_2}} = j\omega(C/2)\vec{V_S}$

$\vec{I_S} = \vec{I_L} + \vec{I_{C_2}}$

b) What are A,B,C,D parameters ? Briefly explain 4M

Ans :- $\vec{A}, \vec{B}, \vec{C}$ & $\vec{D}$ are the generalised circuit constant. These are generally complex numbers. The values of these constants depend upon the particular method adopted for solving a transmission line.

* The constants $\vec{A}$ & $\vec{D}$ are diemensionless whereas the diemensions of $\vec{B}$ & $\vec{C}$ are ohms & siemen respectively.
* For given transmission line $\vec{A} = \vec{D}$
* $\vec{A}\vec{D} - \vec{B}\vec{C} = 1$

c) A 3ϕ transmission line is 400km long feeds a load of 450 MVA, 0.8 p.f. lagging at 345kV. The ABCD constant are $A = D = 0.8181 \angle 1.3^\circ$; $B = 172.2 \angle 84.2^\circ \ \Omega$, $C = 1.93 \times 10^{-3} \angle 90.4 \ \mho$. calculate sending end current & percentage voltage drop at full load. 8M

Ans :- $\vec{A} = \vec{D} = 0.8181 \angle 1.3^\circ$

$\vec{B} = 172.2 \angle 84.2 \ \Omega$

$\vec{C} = 1.93 \times 10^{-3} \angle 90.4 \ \mho$

Receiving end current $I_R = \dfrac{450M}{\sqrt{3} \times 345k} = 753.A$

$\vec{I_R} = 753 \angle -36.86^\circ \ A$

$$\vec{V_S} = \vec{A}\vec{V_R} + \vec{B}\vec{I_R}$$

$$\vec{I_S} = \vec{C}\vec{V_R} + \vec{D}\vec{I_R}$$

$$\vec{V_S} = 0.8181 \angle 1.3^\circ \times \left(\frac{345k}{\sqrt{3}}\right) + 172.2 \angle 84.2^\circ \times 753 \angle -36.86^\circ$$

$$= 315.13 + j\,168.84$$

$$= 358.73 \text{ kV}$$

$$\vec{I_S} = 1.93 \times 10^{-3} \angle 90.4 \times \left(\frac{345k}{\sqrt{3}}\right) + 0.8181 \angle 1.3^\circ \times 753 \angle 36.86$$

$$= 865.19 - j\,236.22 \text{ A}$$

$$= 898.04 \text{ A}$$

Percentage voltage drop

$$= \frac{|V_S| - |V_R|}{|V_R|} \times 100$$

$$= \frac{358 - 345}{345} \times 100$$

$$= 79.5\ \%$$

Module 4

7a) Briefly explain the factors influencing the corona. 6M

Ans:- Factors influencing the corona

* Line Voltage → The line voltage directly affects the corona & corona loss. For lower line voltage corona may be absent. But for voltages higher than disruptive voltage, corona starts.

* Atmospheric conditions → The most important atmospheric factors are pressure & temperature. The value of δ is dependent on atmospheric condition.

* Size of the conductor → The corona loss is directly proportional to square root of radius of conductor. So it appears that loss is more if size of conductor is more.

* Surface condition → The corona depends on the surface condition. For rough & uneven surfaces, the value of disruptive voltage is less & corona effect is dominant.

* Spacing between conductors → If the spacing is made very large, corona can be absent.

b) Explain the term with reference to corona:

i] Critical disruptive voltage

ii] Visual critical voltage

iii] Corona power loss

6M

Ans:- i] Critical disruptive voltage

" It is the minimum phase neutral voltage at which corona occurs."

$$V_c = m_o g_o \delta r \log_e \frac{d}{r} \text{ kV/phase}$$

V_c = Critical disruptive voltage

m_o = Irregularity factor

δ = air density correction factor

$$\delta = \frac{3.92b}{273+t}$$

r = Radius of conductor

d = Distance between conductors.

g_o = Potential gradient

ii] Visual Critical voltage

" It is the minimum phase-neutral voltage at which corona glow appears all along the line conductors".

$$V_v = m_v g_o \delta r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \log_e \frac{d}{r} \text{ kV/phase.}$$

iii] Corona Power loss

Formation of corona is always accompanied by energy loss which is dissipated in the form of light, heat, sound & chemical action.

$$P = 242.2 \left(\frac{f+25}{\delta}\right) \sqrt{\frac{r}{d}} \, (V-V_c)^2 \times 10^{-5} \text{ kW/km/phase}$$

c) Determine the critical disruptive voltage & the visual critical voltage for a 3ϕ, 132 kV, 50 Hz line situated in a temperature of 30°c & at a barometric pressure of 74 cm. The conductor diameter is 1.5 cm while the spacing between the conductors is 2.75 m. The surface irregularity factor is 0.9, while $m_v = 0.75$ & $m_o = 0.9$.

Ans:- $\delta = \frac{3.92 b}{273+t} = \frac{3.92 \times 74}{273+30} = 0.9573$

$r = \frac{1.5}{2} = 0.75 \text{ cm}$

$d = 2.75 \text{ m}$

$g_{o(max)} = 30 \text{ kV/cm}$

$g_{o\,rms} = \frac{30}{\sqrt{2}} = 21.21 \text{ kV/cm}$

Critical disruptive voltage (V_c)

$$V_c = g_o m_o r \delta \log_e \frac{d}{r}$$

$$= 21.21k \times 0.9 \times 0.75 \times 0.9573 \log_e \left(\frac{275}{0.75}\right)$$

$$= 80.923 \text{ kV/ph (rms)}$$

$$= 140.16 \text{ kv (line value)}$$

Visual Critical voltage (V_v)

$$V_v = m_v \delta g_o r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \log_e \frac{d}{r} \text{ kV/ph}$$

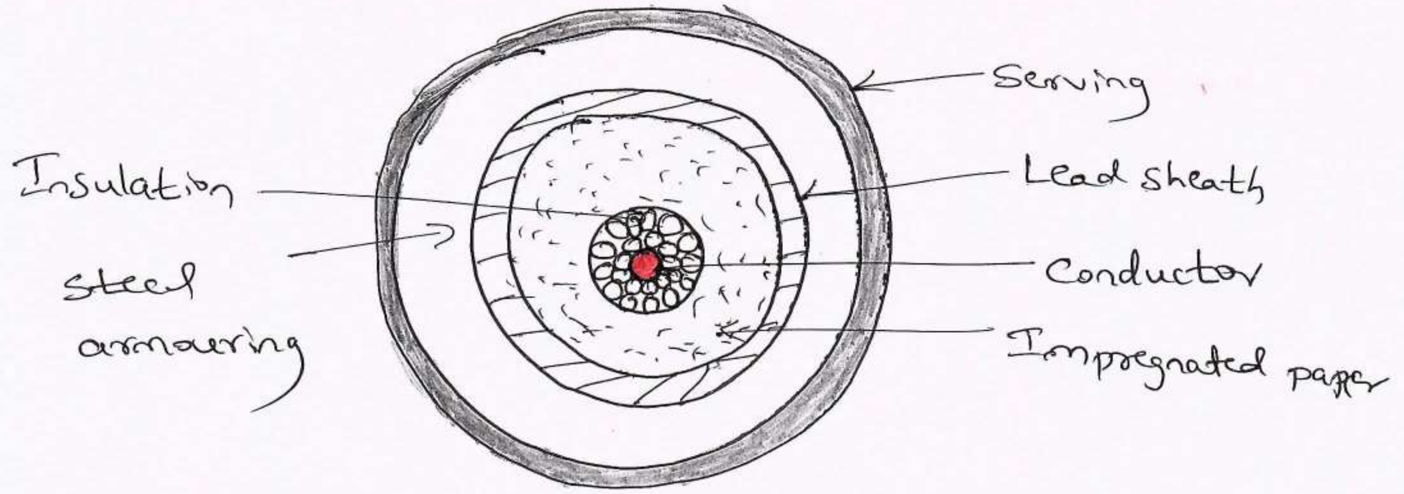
$$= 0.75 \times 0.9573 \times 21.21 \times 0.75 \left(1 + \frac{0.3}{\sqrt{0.75 \times 0.9573}}\right) \log_e \left(\frac{275}{0.75}\right)$$

$$= 91.31 \text{ kV/ph (rms)}$$

$$= 158.15 \text{ kV (line value)}$$

Q8a) With the help of cross sectional diagram, explain the construction of single core cable. 6M

Ans:- Single Core Cable



Conductor -> Normally aluminium or aluminium alloy conductors are used. It consist only one core.

Insulation -> Bare conductor is covered with dielectric material. normanlly rubber, VIR material is used. It should have high resistance.

Impregnated paper -> It also acts as insulation material

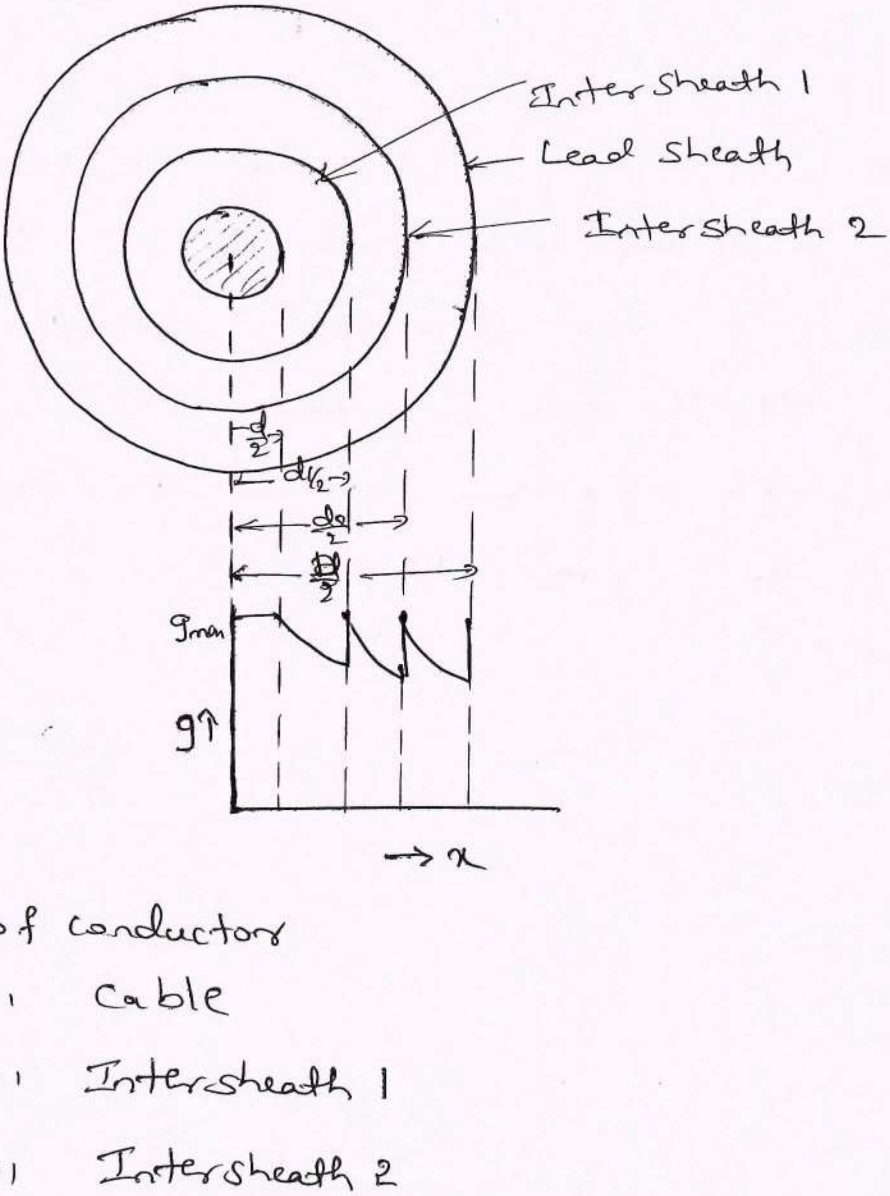
Lead sheath -> A lead sheath layer is provided over paper belt. It gives more flexibility to cable.

Steel Armouring -> It protects the all inner layer of cable from mechanical injury.

Serving -> It is ~~outer~~ outer most layer of cable it prevents moisture or water enters inside.

b) Explain the inter sheath grading of cables. 6M

Ans: - Metallic intersheaths inserted between the core & lead sheath. The intersheaths are held at suitable potential & earth potential. This arrangement proves voltage distribution in the dielectric of the cable & consequently more uniform potential gradient is obtained.



d = diameter of conductor

D = " " Cable

d_1 = " " Intersheath 1

d_2 = " " Intersheath 2

Maximum stress between core & intersheath 1

$$g_{1max} = \frac{V_1}{\frac{d}{2}\log_e \frac{d_1}{d}}$$

$$g_{2max} = \frac{V_2}{\frac{d_1}{2}\log_e \frac{d_2}{d_1}}$$

$$g_{3max} = \frac{V_3}{\frac{d_2}{2}\log_e \frac{D}{d_2}}$$

$$g_{1max} = g_{2max} = g_{3max}$$

$$V = V_1 + V_2 + V_3$$

c) Single core, lead covered cable has a conductor diameter of 3 cm with insulation diameter of 8.5 cm. The cable is insulated with two dielectrics with permittivities 5 & 3 respectively. The maximum stress in the two dielectrics are 38 kV/cm & 26 kV/cm respectively. Calculate radial thickness of insulating layers & the working voltage of the cables.

8M

Ans:- $g_{1max} = 38\ kV/cm$ $\quad g_{2max} = 26\ kV/cm$

$$\frac{g_{1max}}{g_{2max}} = \frac{\varepsilon_2 d_1}{\varepsilon_1 d}$$

$$d_1 = \frac{g_{1max}}{g_{2max}} \times \frac{\varepsilon_1 d}{\varepsilon_2} = \frac{38}{26} \times \frac{5 \times 3}{3} = 7.30\ cm$$

Radial thickness of inner dielectric

$$= \frac{d_1 - d}{2} = \frac{7.30 - 3}{2} = 2.15\ cm$$

Radial thickness of outer dielectric

$$= \frac{D - d_1}{2} = \frac{8.5 - 7.3}{2} = 0.6\ cm$$

Permissible peak voultage for the cable

$$= \frac{g_{1max}}{2} d \log_e \frac{d_1}{d} + \frac{g_{2max}}{2} d_1 \log_e \frac{D}{d_1}$$

$$= \frac{38}{2} \times 3 \log_e \frac{7.30}{3} + \frac{26}{2} \times 7.30 \log_e \frac{8.5}{7.3}$$

$$= 50.68 + 14.44$$

$$= 65.12 \text{ kV}$$

Safe working value (rms) of voultage

$$= 65.12 \times \sqrt{2} = 92.09 \text{kV}$$

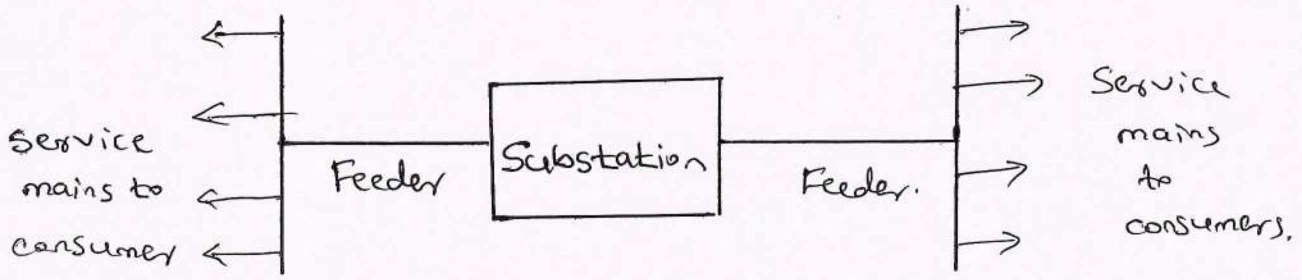
Module 5

9a) Explain the following terms with reference to distribution system:

i] Radial feeder ii] Parallel feeder iii] Loop feeder

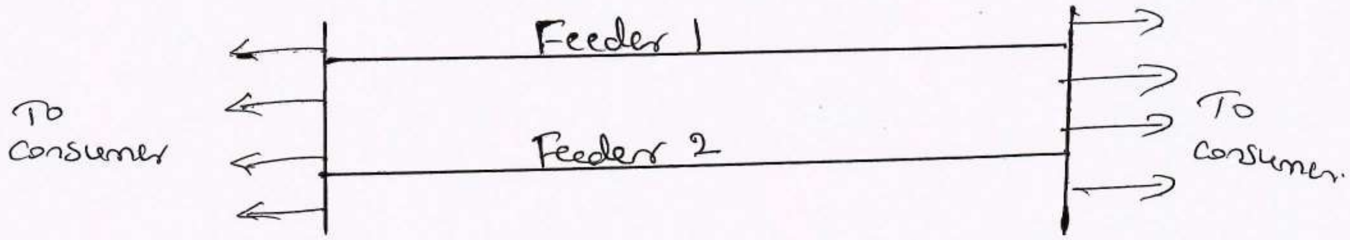
iv] Interconnected network 8M

Ans:- i] Radial feeder



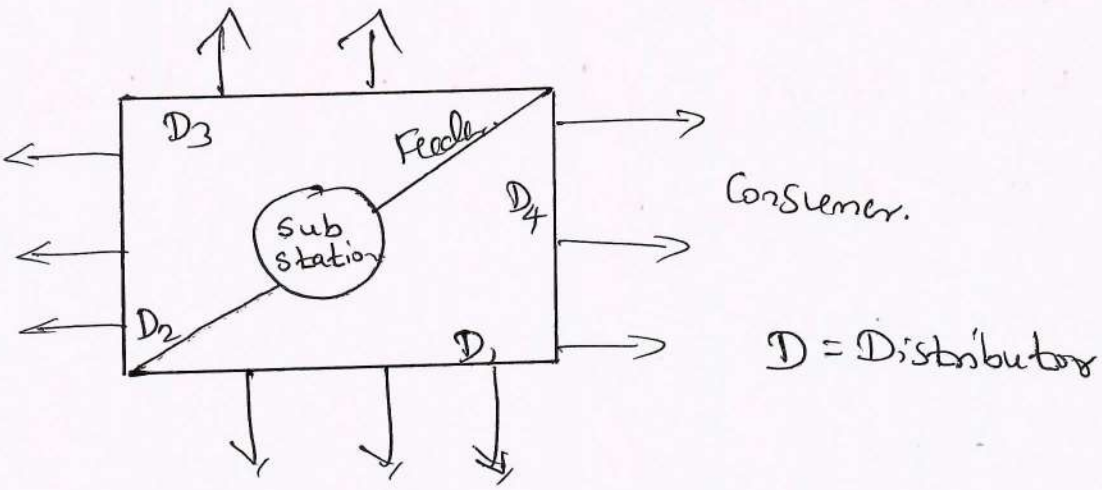
When the distributor is connected to substation on one end only with the help of feed is called as radial feeder. Its simple & less costly. End of the distributor side is heavily loaded. Interruption of feeder interrupts system supply.

ii] Parallel Feeder



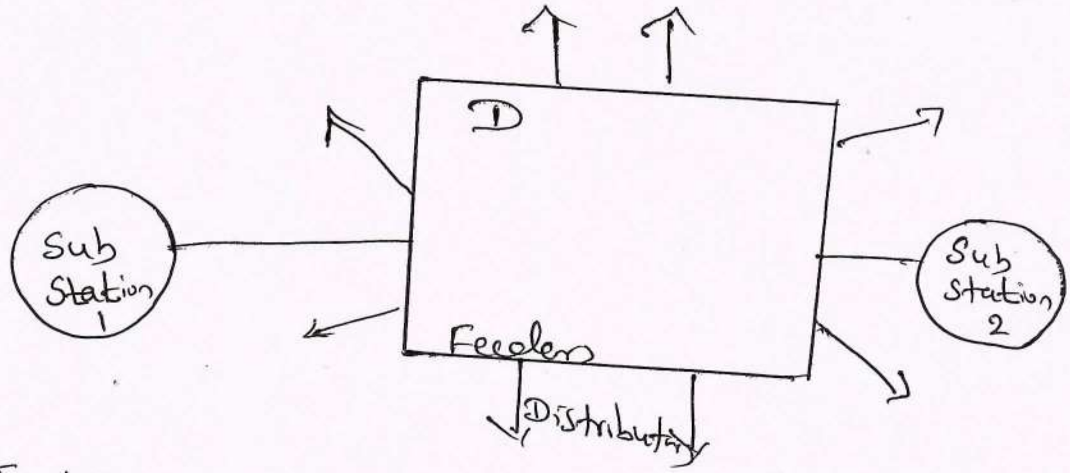
Parallel feeders reduce the demerits in the radial feeder. The intial cost of this system is much more as the number of feeders is doubled. Such system maybe used where reliability of the supply is important.

iii] Loop Feeder



All the distributors are interconneted in loop feeder. If any one of the feeder out of service, supply will be resumed from another distributor. Reliability is much more higher than parallel feeder.

iv] Inter connected network

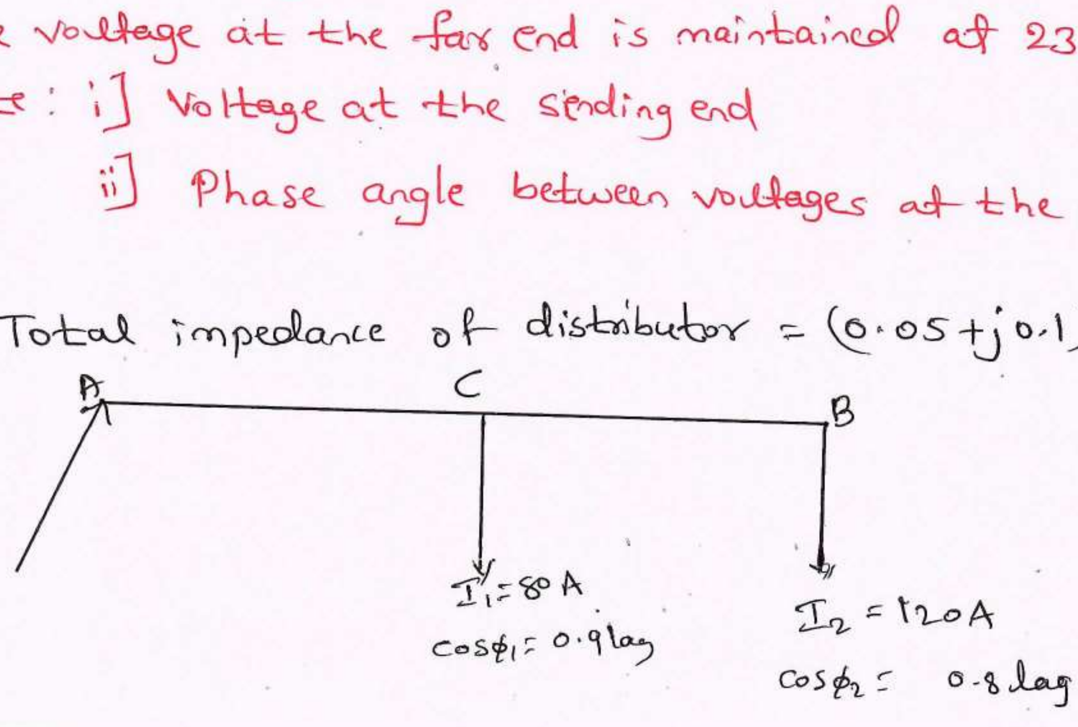


In this system substations also interconnected, like feeders. So that system can supply electricity to each consumer as per their need. Its highly reliable, but complex.

b) A single phase distributor 2 km long supplies a load of 120A at 0.8 p.f. lagging at its far end & a load of 80 A at 0.9 p.f lagging at its mid point. Both power factors are referred to the voltage at the far end. The resistance & reactance per km (go & return) are 0.05 & 0.1 Ω respectively. If the voltage at the far end is maintained at 230V. Calculate: i] Voltage at the sending end

ii] Phase angle between voltages at the two ends.

Ans:- Total impedance of distributor = $(0.05 + j0.1)\ \Omega$



$$\vec{Z}_{AC} = \vec{Z}_{CB}$$

$$= (0.05 + j0.1) \times \frac{1000}{1000}$$

$$= (0.05 + j0.1)\ \Omega$$

Load current at point B (I_2)

$$\vec{I}_2 = I_2(\cos\phi_2 - j\sin\phi_2) = 120\,(0.8 - j0.6) = (96 - j72)\text{ A}$$

Load current in section CB

$$\vec{I}_{CB} = \vec{I}_2 = (96 - j72)\text{ A}$$

Load current at point C

$$\vec{I}_1 = I_1(\cos\phi_1 - j\sin\phi_1) = 80\,(0.9 - j0.43) = (72 - j34.4)\text{ A}$$

Current in section AC

$$\vec{I}_{AC} = \vec{I}_1 + \vec{I}_2 = (168 - j106.4)\text{ A}$$

Voltage drop in section CB

$$\vec{V}_{CB} = \vec{I}_{CB}\,\vec{Z}_{CB} = (96 - j72)(0.05 + j0.1) = 13.416\angle 26.57 = (12 + j6)\text{ V}$$

Voltage drop in section AC

$$\vec{V}_{AC} = \vec{I}_{AC}\,\vec{Z}_{AC} = (168 - j106.4)\,(0.05 + j0.1)$$

$$= 22.231\angle 31.09 = (19.037 + j11.48)\text{ V}$$

Sending end voltage

$$\vec{V}_A = \vec{V}_{AC} + \vec{V}_{BC} + V_B$$

$$= (19.037 + j11.48) + (12 + j6) + (230 + j0)$$

$$= 261.037 + j17.48 = 261.62\angle 3.83^\circ \text{ volts}$$

The phase difference between V_A & V_B is $3.83°$.

10 a) Define the terms :

i] Reliability ii] Availability iii] Adequacy iv] Security

Ans :- i] Reliability

The probability that an item will perform a required function without failure under stated conditions for a stated period of time.

ii] Availability

The amount of power availability in the power system to serve the customer.

iii] Adequacy

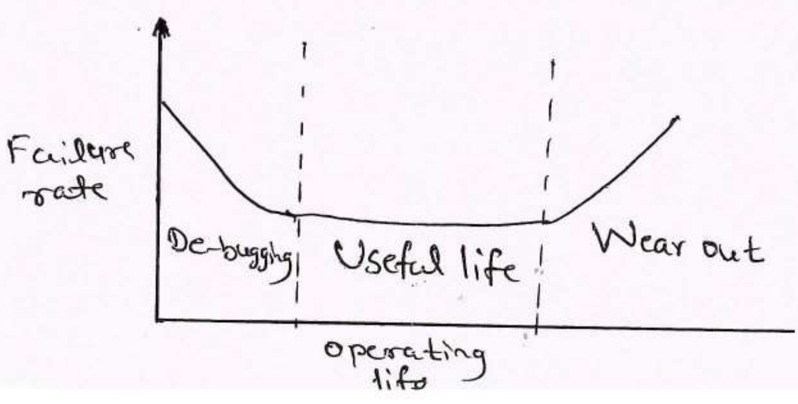
Its related to the sufficient facilities within the system to satisfy customer demand.

iv] Security

Its related to the ability of the system to respond to disturbances arising within that system.

b) Explain with neat sketch different failure modes of bath tub curve

6M



* The initial period is known as debugging period or the period of infant mortality. In this failures may be high due to errors in design or manufacturing. These errors are detected or removed in an initial period. This region shows a decreasing failure rate.

* The middle portion is normal operating life or useful life. In this period failure rate is only due to chance & failure is comparitively low & failure rate is nearly constant.

* In wear out period failure rate increases & usually repairs in this period are very costly.

c) Write a short note on power quality. 6M.

Ans:- Power quality refers to maintenance of voltage waveform undistorted, balanced at rated frequency & at rated voltage.

Most common types of power quality problems are

* Voltage dip → A decrease of voltage level between 10% to 90%.
* Voltage swell → Its momentry increase of voltage.
* Harmonic distortion → Due to presence of harmonics, voltage & current waveforms are having nonsinusoidal shape.
* Voltage fluctuation → Oscillations of voltage value, its amplitude be termed as voltage fluctuations.
* Noise → Superimposing of high frequency signals on the waveform of power frequency is noise.

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