CBCS SCHEME

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BEE402

Fourth Semester B.E./B.Tech. Degree Examination, June/July 2025

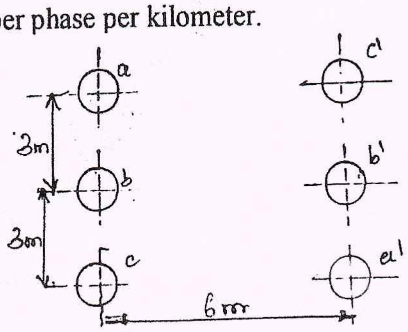
Transmission and Distribution

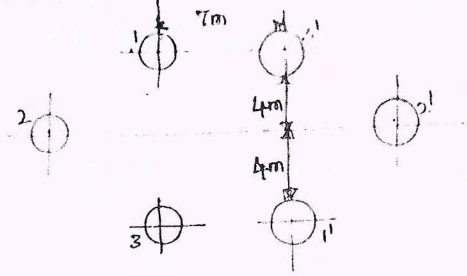
Time: 3 hrs. Max. Marks: 100

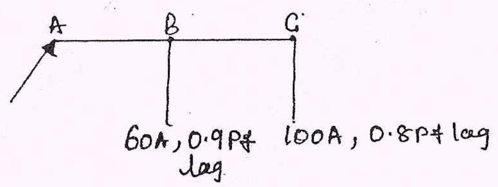
Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Draw a single line diagram of a typical transmission and distribution system. Indicate all the voltage levels and explain.	10	L1	CO1
	b.	Explain various types of line conductors used for overhead line.	6	L2	CO1
	c.	An overhead line has a span of 150 m between level supports. The conductor has a cross – sectional area of 2 cm^2. The ultimate strength is 5000 kg/cm^2 and safety factor is 5. The specific gravity of the material is 8.9 gm/cc. The wind pressure is 1.5 kg/m. Calculate the height of the conductor above the ground level at which it should be supported if a minimum clearance of 7 m is to be left between the ground and the conductor.	4	L3	CO1
		OR			
Q.2	a.	Draw a neat diagram of interconnection of component of distribution system and explain.	8	L1	CO1
	b.	Define Sag. With usual notations derive an expression for the sag of a transmission line when the supports are at equal level.	8	L1	CO1
	c.	Compare pin and suspension insulators.	4	L2	CO2
		Module – 2			
Q.3	a.	Derive an equation for inductance of 3 phase un-symmetrically spaced but transposed transmission line / km.	8	L2	CO2
	b.	Fig. Shows the spacings of a double circuit 3 phase – double circuit overhead line. The conductor radius is 1.3 cm and line is transposed. Calculate the inductance per phase per kilometer.	6	L3	CO2

Fig. Q3(b)



	c.	The six conductors of a double circuit three phase line are shown in Fig. Q3(c). The diameter of each conductor is 2.5 cm. Find the capacitance to neutral assuming that the line is transposed.  Fig. Q3(c)	6	L3	
		OR			
Q.4	a.	Derive an expression for capacitance of a 3 phase single circuit line with equilateral spacing.	8	L3	CO3
	b.	Calculate the loop inductance per km of a single phase line. Comprising of 2 parallel conductors 1 meter apart and 1 cm in diameter, when the material of conductor is i) Copper and ii) Steel of relative permittivity 50. Prove the formula used.	8	L3	CO3
	c.	Compare single circuit and double circuit arrangement of transmission lines.	4	L2	CO3
		Module – 3			
Q.5	a.	Deduce an expression for voltage regulation and transmission efficiency of single phase short transmission line by developing the vector diagrams.	10	L3	CO4
	b.	A 110 KV, 50 Hz, 3 phase transmission line delivers a load of 40 MW at 0.85 lag p.f at the receiving end. The generalized constants of the transmission line are $A = D = 0.95\angle 1.4^\circ$, $B = 96\angle 78^\circ\ \Omega$ $C = 0.0015\angle 90^\circ$ mho regulation of the line and charging current. Apply nominal T method.	10	L3	CO4
		OR			
Q.6	a.	Derive expression for the generalized A, B, C, D constants for equivalent T network.	10	L3	CO4
	b.	Determine the efficiency and regulation of a 3 phase, 100 km, 50 Hz, transmission line delivering 20 MW at a power factor of 0.8 lag and 66 KV to a balanced load. The conductors are of copper, each having resistance of 0.1Ω per km, 1.5 m outside diameter spaced equilaterally 2 meters between centers. Neglect leakage, use normal π method.	10	L2	CO4
		Module – 4			
Q.7	a.	Explain the phenomena of Corona. List the factors affecting Corona.	10	L2	CO4
	b.	A 33 KV, 3 phase underground cable, 4 km long uses three core cables. Each of the conductor has a diameter of 2.5 cm and the radial thickness of insulation 0.5 cm. the relative permittivity of the dielectric is 3. Calculate 1. Capacitance of the cable / ph 2. Charging current / phase 3. Total charging KVAR.	10	L3	CO4

			Marks	Level	CO
		OR			
Q.8	a.	Explain 1. Disruptive critical voltage 2. Visual critical voltages 3. Corona loss.	10	L2	CO5
	b.	Analyze grading of cables using capacitance grading method.	6	L4	CO5
	c.	The inner and outer diameters of a cable are 3 cm & 9 cm respectively. The cable is insulated with the two materials having permittivities of 5 and 4 respectively with corresponding maximum permissible stresses of 30 KV/cm and 20 KV/cm respectively. Calculate the radial thickness of each insulating layer and the safe working voltage of the cable.	4	L3	CO5
		Module – 5			
Q.9	a.	Explain 1. Radial distribution system 2. Ring main distribution system along with neat diagrams.	10	L2	CO6
	b.	Define Reliability. Explain different probability distributions.	10	L2	CO6
		OR			
Q.10	a.	A two wire distributor 1200 m long is loaded as shown in Fig. Q10(a) 'B' is the midpoint. The power factors at the two load points refer to the voltage at 'C'. The impedance of each line is (0.10 + j0.2) Ω. Calculate the sending end voltage, current and power factor. The voltage at point 'C' is 220 V.  Fig. Q10(a)	10	L3	CO6
	b.	Analyze the effect of disconnection of neutral in 3 phase 4 wire system.	6	L4	CO6
	c.	Explain any 4 limitations of distribution system.	4	L3	CO6

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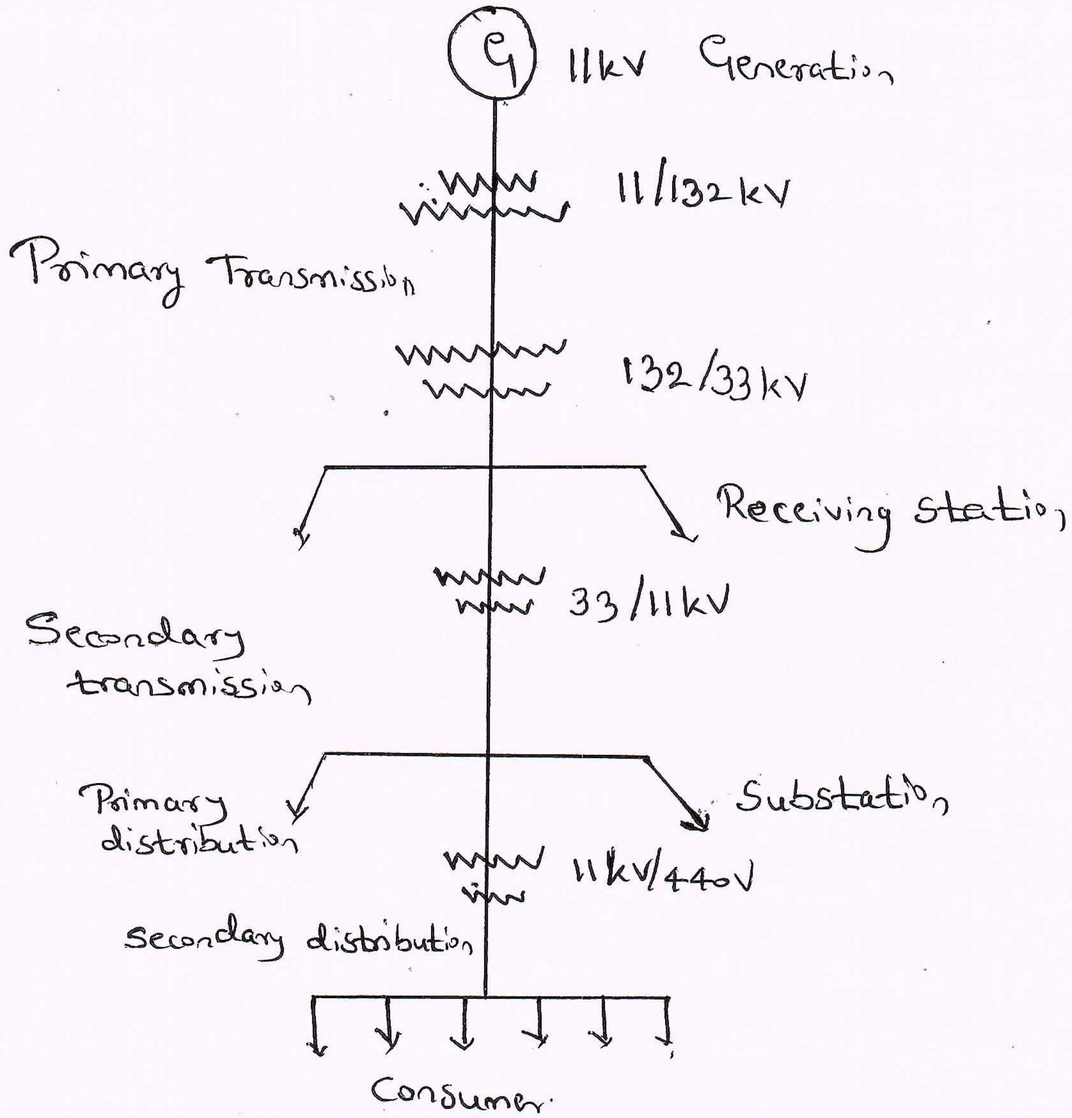
Q1a) Draw a single line diagram of a typical transmission & distribution system. Indicate all the voltage levels & explain. 10M

Ans:- Single line diagram of transmission & distribution system



1] Generation → Its the first stage of single line diagram. Generator is the main component, which generates the voltage of 11kV, 6.6 kV, 3.3 kV.

2] Primary Transmission → The generated voltage of 11kV is steped up to 132 kV using power transformers. Further its transmitted up to several distance & reduced voltage to 33 kV from 132 kV. High voltage transmission enhance the efficiency.

3] Secondary transmission → After the receiving station till substation stage called as secondary transmission. Here voltage is stepdown to 33 kV to 11 kV.

4] Primary distribution → After the substation distribution starts. 33 kV is reduced to 11kV in substation. ~~use~~ Further power is distributed through feeders.

5] Secondary distribution → Distribution transformer step downs the voltage from 11kV to 440V. 3ϕ, 4 wire system is used to distribute the power to consumers.

b) Explain various types of line conductors used for overhead line. 6M

Ans: - 1] Aluminium Conductor with Steel Reinforcement (ACSR)

Aluminium has low tensile strength, steel conductor is added at central part of cable. This increase the mechanical as well as tensile strength. Swining of conductor reduces under wind condition. This reduces skin effect & offers less corona loss.

2] All Aluminium Alloy Conductor (AAAC)

The conductor made from aluminium alloys are suitable in urban areas as they provide better tensile strength & conductivity. These alloys are known with different names in various countries. Some of these alloys are costly as they are heated. one of the alloys of aluminium is known as Silmalec which contains 0.5%

of silicon, 0.5% of magnesium & rest of aluminium. Due to this there is improvement in conductivity & mechanical strength.

iii] Galvanized Steel Conductors

This type of conductor is suitable for large length of line span in rural areas where load required is comparatively smaller. This type of conductor has large resistance, inductance & voltage drop.

iv] Thermal Resistant Aluminium Alloy Conductor (TACSR)

This conductor is similar in construction to ACSR conductor. The change is that EC grade aluminium wires are replaced by hard drawn aluminium wires of heat resistant aluminium alloy known as TAL. These wires are doped with zirconium which makes these conductors well suited for high temperatures.

c) An overhead line has a span of 150m between level supports. The conductor has a cross-sectional area of $2\ cm^2$. The ultimate strength is $5000\ kg/cm^2$ & safety factor is 5. The specific gravity of the material is 8.9 gm/cc. The wind pressure is 1.5 kg/m. Calculate the height of the conductor above the ground level at which it should be supported if a minimum clearance of 7m is to be left between the ground & the conductor.

4M

Ans:- $l = 200m$ $a = 1.9 cm^2$

Ultimate strength $= 5000 kg/cm^2 = 5000 \times 1.9 = 9500 kg$

Tension (T) $= \frac{9500}{5} = 1900 kg$

Weight of conductor w = Area of c/s × density

$= 1.9 \times 8.9$

$= 16.91 gm/cm$

$= 1.691 kg/m$

wind force $W_w = 1.5 kg/m$

Total weight $W_t = \sqrt{W^2 + W_w^2}$

$= \sqrt{(1.691)^2 + (1.5)^2}$

$= 2.2604 kg/m$

Sag $S = \frac{W_t l^2}{8T}$

$= \frac{2.2604 \times 200^2}{8 \times 1900}$

$= 5.9484 m$

The height at which conductor supported

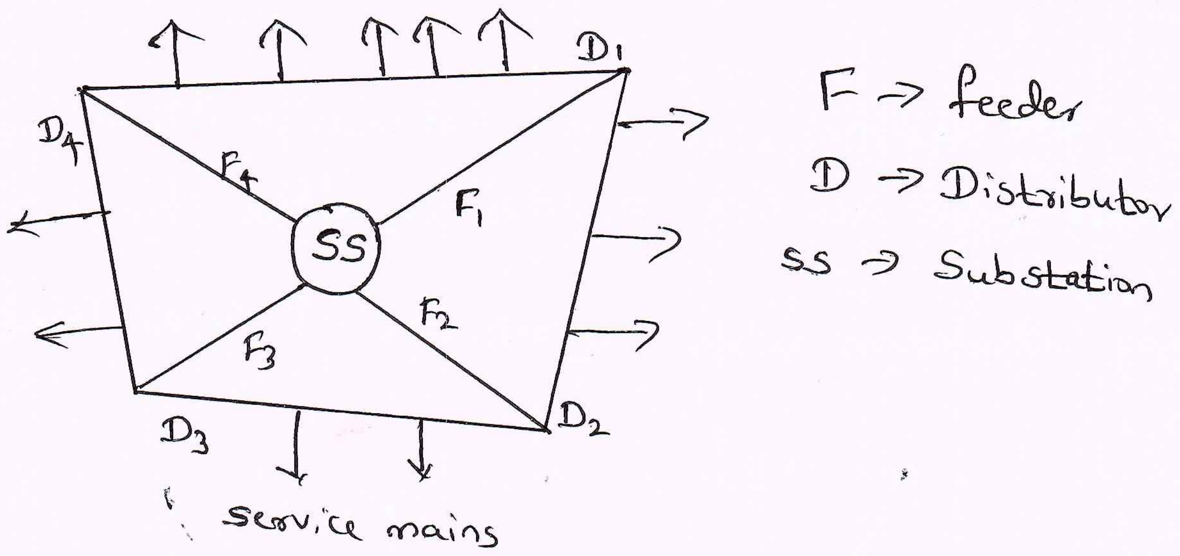
= Ground clearance + Sag

$= 7 + 5.9484$

$= 12.9484 m$

2 a) Draw a neat diagram of interconnection of component of distribution system and explain. 8M

Ans: -



Feeder → Feeder makes the connectivity between substation to distributors. Feeder rating decided based on ampere capacity. No tappings are taken from feeder. Normally feeder voltage is about 11kV.

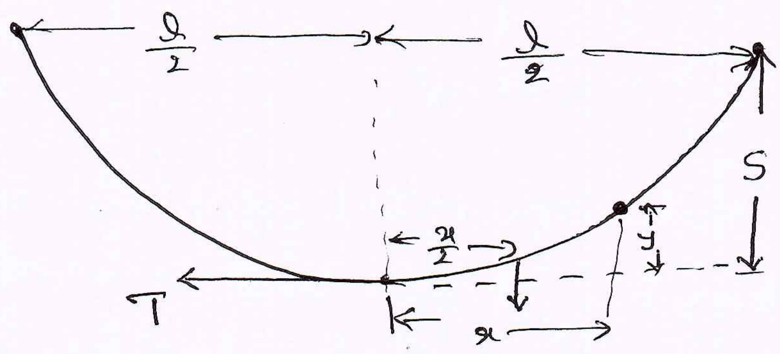
Distributer → It makes connectivity between feeder & service mains. Distributer utilizes distribution transformer with scheme of Δ-Y.

Service Mains → Service mains consists 4 wires for 3ϕ supply, Three phases (RYB) & Neutral (N). For 1ϕ user Phase & neutral wire. from the secondary side of transformer to energy meter service mains connected.

b) Define Sag. With usual notations derive an expression for the sag of a transmission line when the supports are at equal level. 8M

Ans:- "The difference in level between points of supports & the lowest point on the conductor is called sag".

Sag calculation when supports are at equal level



l = length of span

w = weight per unit length of conductor

T = Tension in the conductor

Consider a point P on the conductor. Taking the lowest point O as the origin, let the co-ordinates of point P be x & y. Assuming that the curvature is so small that curved length is equal to its horizontal projection, the two forces acting on the portion OP of the conductor are:

i] The weight wx of conductor acting at a distance $\frac{x}{2}$ from O

ii] The tension T acting at O.

$$Ty = wx \times \frac{x}{2}$$

$$y = \frac{wx^2}{2T}$$

$x = \frac{l}{2}$ & $y = S$

Sag $S = \frac{wl^2}{8T}$

c) Compare pin & suspension insulator

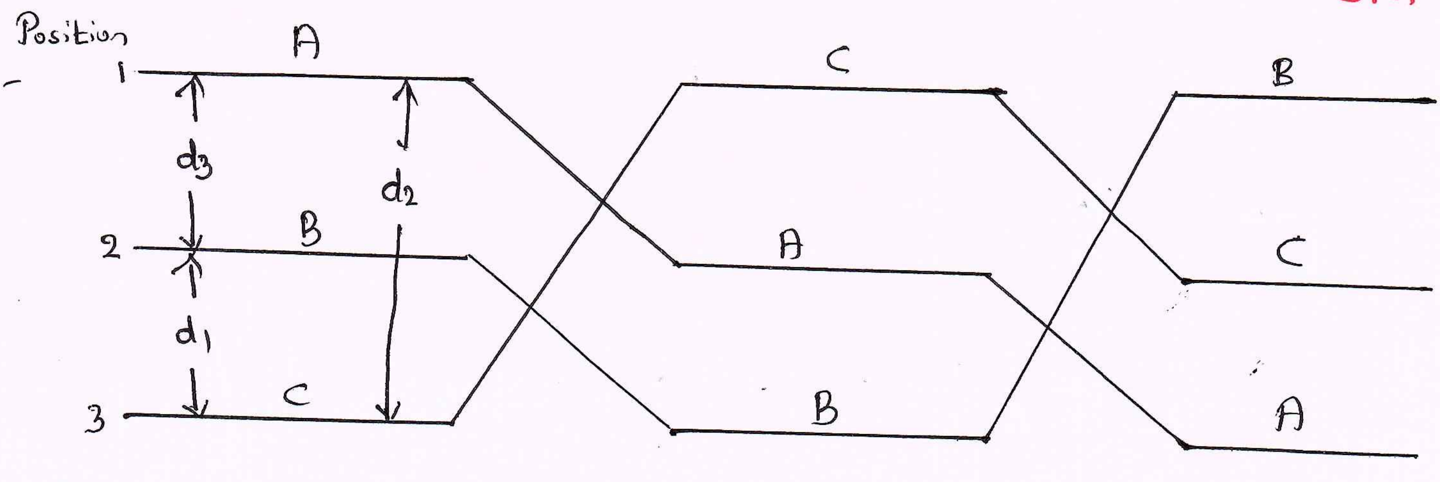
4M

Pin type	Suspension type
1] These are costlier than the suspension type.	1] For higher voltages, these are cheaper than pin type.
2] Use is restricted upto 33kV only.	2] Each unit is designed for 11kV & string can be designed for any higher voltage level
3] The replacement work is difficult.	3] Replacement work is easy as only
4] Chance of getting affected by lightning is more.	4] Less affected by lightning.

Q3 a) Derive an equation for inductance of 3 phase - un-symmetrically spaced but transposed transmission line /km

8M

Ans:-



$$I_A = I(1+j0)\ A$$

$$I_B = I(-0.5-j0.866)\ A$$

$$I_C = I(-0.5+j0.866)\ A$$

The total flux linkages per metre length of conductor A

$$\psi_A = \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4}-\log_e r\right)I_A - I_B\log_e d_3 - I_C\log_e d_2\right]$$

$$\psi_A = \frac{\mu_0}{2\pi}\left[\left(\frac{1}{4}-\log_e r\right)I - I(-0.5-j0.866)\log_e d_3 - I(-0.5+j0.866)\log_e d_2\right]$$

$$= \frac{\mu_0}{2\pi}\left[\frac{I}{4} - I\log_e r + 0.5\,I\log_e d_3 + j0.866\log_e d_3 + 0.5\,I\log_e d_2 - j0.866\,I\log_e d_2\right]$$

$$= \frac{\mu_0}{2\pi}\left[\frac{I}{4} - I\log_e r + 0.5\,I(\log_e d_3 + \log_e d_2) + j0.866\,I(\log_e d_3 - \log_3 d_2)\right]$$

$$= \frac{\mu_0}{2\pi}\left[\frac{I}{4} - I\log_e r + I\log_e\sqrt{d_2 d_3} + j0.866\,I\log_e\frac{d_3}{d_2}\right]$$

$$= \frac{\mu_0 I}{2\pi}\left[\frac{1}{4} + \log_e\frac{\sqrt{d_2 d_3}}{r} + j0.866\log_e\frac{d_3}{d_2}\right]$$

- Inductance of a conductor A

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

$$= \frac{\mu_0}{2\pi}\left[\frac{1}{4} + \log_e\frac{\sqrt{d_2 d_3}}{r} + j0.866\log_e\frac{d_3}{d_2}\right]$$

$$L_A = \frac{4\pi \times 10^{-7}}{2\pi}\left[\frac{1}{4} + \log_e \frac{\sqrt{d_2 d_3}}{r} + j0.866 \log_e \frac{d_3}{d_2}\right] H/m$$

$$= 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{\sqrt{d_2 d_3}}{r} + j1.732 \log_e \frac{d_3}{d_2}\right] H/m$$

$$L_B = 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{\sqrt{d_3 d_1}}{r} + j1.732 \log_e \frac{d_1}{d_3}\right] H/m$$

$$L_C = 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{\sqrt{d_1 d_2}}{r} + j1.732 \log_e \frac{d_2}{d_1}\right] H/m$$

Inductance of each line conductor

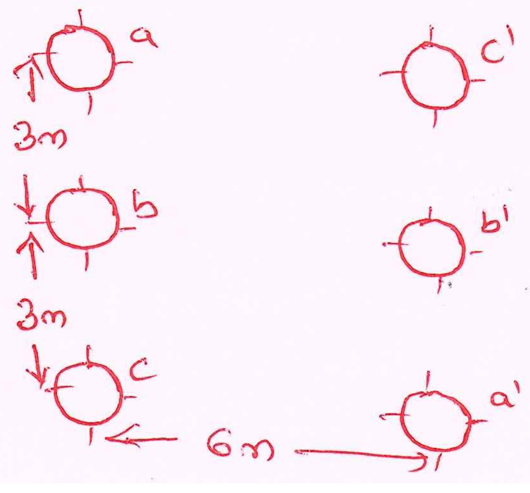
$$= \frac{1}{3}\left[L_A + L_B + L_C\right]$$

$$= \left[0.5 + 2\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}\right] 10^{-7} \times 10^{3} \; H/km$$

$$= \left[0.5 + 2\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}\right] 10^{-4} \; H/km$$

3b) Fig shows the spacings of a double circuit 3 phase - double circuit overhead line. The conductor radius is 1.3cm and line is transposed. Calculate the inductance per phase per kilometer.

6M



Ans:- GMR of conductor $= 1.3 \times 0.7788 = 1.01 cm$

Distance a to b' $= \sqrt{6^2+3^2} = 6.7 m$

Distance a to a' $= \sqrt{6^2+6^2} = 8.48 m$

$$D_s = \sqrt[3]{D_{s1} \times D_{s2} \times D_{s3}}$$

$$D_{s1} = \sqrt[4]{D_{aa} \times D_{aa'} \times D_{a'a'} \times D_{a'a}}$$

$$= \sqrt{(1.01 \times 10^{-2})^2 \times 8.48^2} = 0.292 m = D_{s3}$$

$$D_{s2} = \sqrt[4]{D_{bb} \times D_{bb'} \times D_{b'b'} \times D_{b'b}}$$

$$= \sqrt[4]{(1.01 \times 10^{-2})^2 \times 6^2} = 0.246 m$$

$$D_s = \sqrt[3]{0.292 \times 0.246 \times 0.292} = 0.275 m$$

$$D_{AB} = \sqrt[4]{D_{ab} \times D_{ab'} \times D_{a'b} \times D_{a'b'}} = \sqrt[4]{3^2 \times 6.7^2} = 4.48 m$$

$$D_{AB} = D_{BC}$$

$$D_{CA} = \sqrt[4]{D_{ca} \times D_{ca'} \times D_{c'a} \times D_{c'a'}} = \sqrt[4]{6 \times 6 \times 6 \times 6} = 6 m$$

$$D_m = \sqrt[3]{D_{AB} \times D_{BC} \times D_{CA}} = \sqrt[3]{4.48 \times 4.48 \times 6} = 4.94 m$$

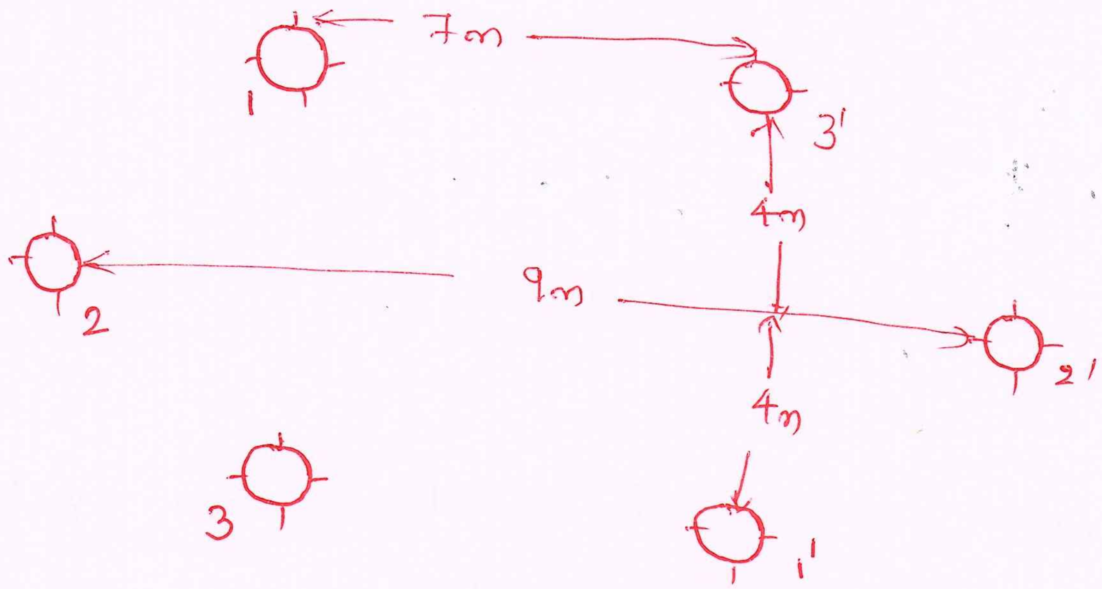
Inductance /phase / ~~metre~~ km length

$$= 10^{-7} \times 2 \log_e D_m/D_s = 10^{-7} \times 2 \log_e \frac{4.94}{0.275}$$

$$= 5.7 \times 10^{-7} \times 10^3$$

$$= 0.57 mH$$

c) The six conductors of a double circuit 3ϕ line are shown in Fig Q3 (c). The diameter of conductor is 2.5cm. Find the capacitance to neutral assuming that the line is transposed.



Ans:- $D_{12} = \sqrt{4^2+1^2} = \sqrt{17} = 4.12m$

$D_{12'} = \sqrt{4^2+8^2} = \sqrt{16+64} = 8.94m$

$D_{11'} = \sqrt{8^2+7^2} = \sqrt{113} = 10.63m$

$D_{12} = (D_{12} \times D_{12'} \times D_{21} \times D_{21'})^{1/4} = ((4.12)^2 \times (8.94)^2)^{1/4} = 6.12m$

$D_{23} = (D_{23} \times D_{23'} \times D_{32} \times D_{33'})^{1/4} = ((4.12)^2 \times (8.94)^2)^{1/4} = 6.12m$

$D_{31} = (D_{31} \times D_{31'} \times D_{13} \times D_{13'})^{1/4} = (8^2 \times 7^2)^{1/4} = 7.48m$

$D_m = (D_{12} \times D_{23} \times D_{31})^{1/3} = (6.12 \times 6.12 \times 7.48)^{1/3} = 6.54m$

$D_{s1} = (D_{11} \times D_{1'1} \times D_{11'} \times D_{1'1'})^{1/4} = \left(\left(\frac{2.5 \times 10^{-2}}{2}\right)^2 \times (10.63)^2\right)^{1/4} = 0.364m$

$$D_{S2} = (D_{22} \times D_{22'} \times D_{2'2} \times D_{2'2'})^{1/4} = \left(\left(\frac{2.5\times10^{-2}}{2}\right)^2 \times (8.95)^2\right)^{1/4} = 0.334m$$

$$D_{S3} = (D_{33} \times D_{33'} \times D_{3'3} \times D_{3'3'})^{1/4} = \left(\left(\frac{2.5\times10^{-2}}{2}\right)^2 \times (10.63)^2\right)^{1/4} = 0.364m$$

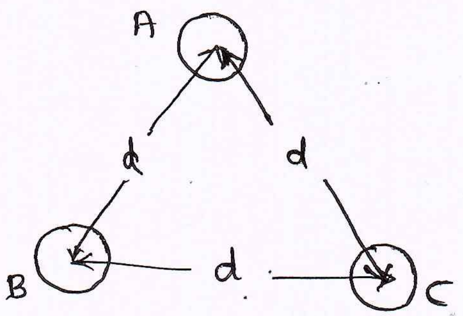
$$D_S = (D_{S1} \times D_{S2} \times D_{S3})^{1/3} = (0.364 \times 0.334 \times 0.364)^{1/3} = 0.354m$$

$$C_n = \frac{2\pi\varepsilon}{\ln \frac{D_m}{D_S}} = \frac{2\pi \times 8.854\times10^{-12}}{\ln\left[\frac{6.543}{0.354}\right]}$$

$C_n = 0.019\ nF/m$

Q4a) Derive an expression for capacitance of a 3ϕ single circuit line with equilateral spacing. 8M

Ans:-



A, B & C are 3 conductors in a 3ϕ single circuit, the charges Q_A, Q_B & Q_C per metre length respectively. Let the distance between conductors are 'd' metres.

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

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

$$V_A = \frac{1}{2\pi\varepsilon_0}\left[q_A \log_e \frac{1}{r} + q_B \log_e \frac{1}{d} + q_C \log_e \frac{1}{d}\right]$$

$$= \frac{1}{2\pi\varepsilon_0}\left[q_A \log_e \frac{1}{r} + (q_B + q_C) \log_e \frac{1}{d}\right]$$

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

Capacitance of conductor A w.r.t. neutral

$$C_A = \frac{q_A}{V_A} = \frac{q_A}{\frac{q_A}{2\pi\varepsilon_0} \log_e \frac{d}{r}}$$

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

b) Calculate the loop inductance per km of a 1ø line, comprising of 2 parallel conductors 1metre apart 1cm in diagmeter, when the material of conductor is i] copper ii] steel of relative permittivity 50. Prove the formula used. 8M

Ans:- $d = 100$ m $\quad r = 0.5$ cm

i] Copper conductor $(\mu_r = 1)$

$$\text{Loop inductance/km} = 10^{-4}\left(\mu_r + 4 \log_e \frac{d}{r}\right) \text{ H/km}$$

$$= 10^{-4}\left(1 + 4 \log_e \frac{100}{0.5}\right)$$

ii] Steel conductor ($\mu_r = 50$)

Loop inductance / km $= 10^{-4}\left(50 + 4 \log_e \frac{100}{0.5}\right)$

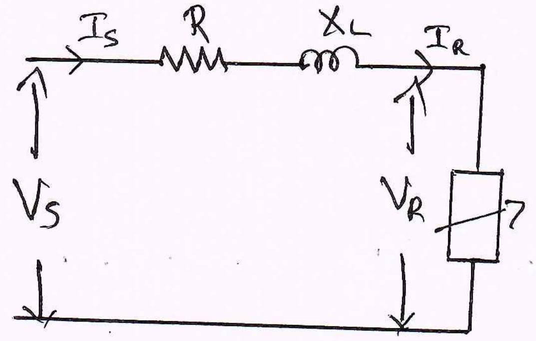
c) Compare single circuit & double circuit arrangement of transmission lines. 4M

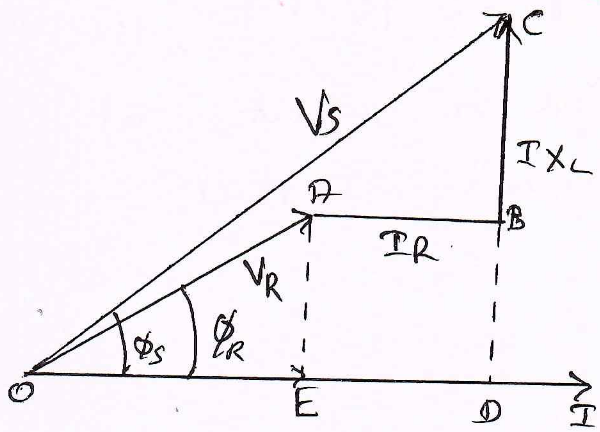
Ans:-

Single Circuit arrangement	Double Circuit arrangement
1] Less dangerous during repair work.	1] Comparatively dangerous
2] From continuity of supply point of view, the circuit is less reliable.	2] With reference to continuity of supply, the circuit is much reliable.
3] Spacing of conductors required is greater	3] Spacing of conductors required is less.
4] Required less foundation	

5a) Deduce an expression for voltage regulation & transmission efficiency of 1φ short transmission line by developing the vector diagram. 10M

Ans:-





$$OC^2 = OD^2 + DC^2 = (OE+ED)^2 + (CB+BD)^2$$

$$V_S^2 = (V_R\cos\phi_R + IR)^2 + (V_R\sin\phi_R + IX_L)^2$$

$$V_S = \sqrt{(V_R\cos\phi_R + IR)^2 + (V_R\sin\phi_R + IX_L)^2}$$

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

$$\text{Sending end p.f } \cos\phi_S = \frac{OD}{OC} = \frac{V_R\cos\phi_R + IR}{V_S}$$

$$\text{Power delivered} = V_R I_R \cos\phi_R$$

$$\text{Line losses} = I^2 R$$

$$\text{Power sent} = V_R I_R \cos\phi_R + I^2 R$$

$$\% \text{ Transmission efficiency } \eta_T = \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$$

I = Load current

R = loop ressistance.

V_S = Sending end voltage

X_L = Loop inductance

V_R = Receiving end voltage

$\cos\phi_R$ = P.f of receiving end

$\cos\phi_S$ = " " Sending end

5b) A 110kV, 50Hz, 3ϕ transmission line delivers a load of 40MW at 0.85 lagging p.f. at the receiving end. The generalised constants of the transmission line are $A = D = 0.95\angle 1.4°$, $B = 96\angle 78° \Omega$, $C = 0.0015\angle 90° \mho$. Find the regulation of the line & charging current use nominal T method. 10M

Ans:- Receiving end voltage/phase $V_R = \frac{110k}{\sqrt{3}} = 63.5kV$

Receiving end current/phase $I_R = \frac{P_R}{\sqrt{3} V_R \cos\phi_R} = \frac{40M}{\sqrt{3} \times 63.5k \times 0.85}$

$I_R = 247A$

$\vec{I_R} = 247\angle -\cos^{-1} 0.85 = 247\angle -31.78$ A

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

$= (0.95\angle 1.4 \times 63.5k) + (96\angle 78 \times 247\angle -31.78)$

$\vec{V_S} = 78942.3\angle 13.62°$ V

$V_S = 78.94kV$

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

$\vec{I_S} = (0.0015\angle 90° \times (63.5k)) + (0.95\angle 1.4° \times 247\angle -31.78)$

$\vec{I_S} = 203.7\angle -6.59$ A

$\vec{I_S} = \vec{I_C} + \vec{I_R}$

$\vec{I_C} = \vec{I_S} - \vec{I_R} = [(203.7\angle -6.59) - (247\angle -31.78)]$

$\vec{I_C} = 106.93\angle 94.04$ A

% Voltage regulation $= \dfrac{V_{Ro} - V_R}{V_R} \times 100$

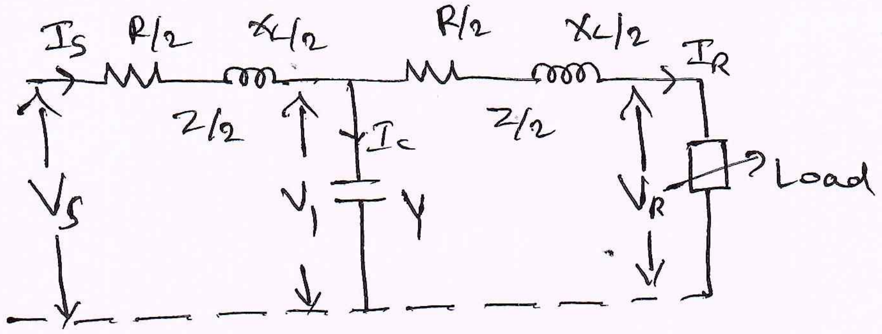
$= \dfrac{(V_S/A) - V_R}{V_R} \times 100$

$= \dfrac{(78.94k/0.95) - 63.5k}{63.5k} \times 100$

$= 30.86\%$

Q6a) Derive expression for ~~voltage~~ the generalised A, B, C, D constants for equivalent T network. 10M

Ans:-



$$\vec{V_S} = \vec{V_1} + \vec{I_S}\frac{\vec{Z}}{2} \qquad \vec{V_1} = \vec{V_R} + \vec{I_R}\frac{\vec{Z}}{2}$$

$$\vec{I_c} = \vec{I_S} - \vec{I_R} = \vec{V_1}\vec{Y} = \vec{Y}\left(\vec{V_R} + \frac{\vec{I_R}\vec{Z}}{2}\right)$$

$$\vec{I_S} = \vec{I_R} + \vec{Y}\vec{V_R} + \vec{Y}\frac{\vec{I_R}\vec{Z}}{2}$$

$$\vec{V_S} = \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\vec{V_R} + \left(\vec{Z} + \frac{\vec{Y}\vec{Z}^2}{4}\right)\vec{I_R}$$

$$\vec{A} = \vec{D} = 1 + \frac{\vec{Y}\vec{Z}}{2} \qquad \vec{B} = \vec{Z}\left(1 + \frac{\vec{Y}\vec{Z}}{4}\right) \qquad \vec{C} = \vec{Y}$$

$$\vec{A}\vec{D} - \vec{B}\vec{C} = \left(1 + \frac{YZ}{2}\right)^2 - Z\left(1 + \frac{YZ}{4}\right)Y$$

$$\vec{A}\vec{D} - \vec{B}\vec{C} = 1$$

6 b) Determine the efficiency & regulation of a 3ϕ 100km, 50Hz transmission line delivering 20MW at a p.f of 0.8 lag & 66kV to a balanced load. The conductors are of copper, each having resistance of 0.10 Ω per km, 1.5m outside diameter spaced equilaterally 2m between centres. Neglect leakage. Use nominal π method.

Ans:- $r = \frac{1.5}{2} = 0.75 \times 10^{-2} m$ $r' = 0.7788 r = 0.7788 \times 0.75 \times 10^{-2}$

$= 5.84 \times 10^{-3} m$

$L_A = 2 \times 10^{-4} \ln\left(\frac{D}{r'}\right) H/km = 2 \times 10^{-4} \ln\left(\frac{2}{5.84 \times 10^{-3}}\right) = 1.16 \times 10^{-3} H/km$

Capacitance per phase $C_{an} = \frac{2\pi\varepsilon}{\ln\left(\frac{D}{r}\right)} = \frac{2\pi \times 8.854 \times 10^{-12}}{\ln\left(\frac{2}{0.75 \times 10^{-2}}\right)}$

$C_{an} = 9.96 \, nF/m$

X_L for 100km $= 2\pi f L_A \times 100 = 2\pi \times 50 \times 1.16m \times 100$

$X_L = 36.66 \Omega$

X_c for 100km $= \frac{1}{2\pi \times 50 \times 9.95 \times 10^{-7} \times 100} = 3.19 k\Omega$

$\vec{Y_c} = j\frac{1}{X_c} = j\frac{1}{3196.13} = j\, 3.128 \times 10^{-4} \mho$

$\frac{\vec{Y_c}}{2} = j\, 1.5643 \times 10^{-4} \mho$

$\vec{V_R} = \frac{66k}{\sqrt{3}} = 38.10 kV \angle 0°$

$I_R = \frac{P_R}{\sqrt{3} V_R \cos\phi} = \frac{20M}{\sqrt{3} \times 66k \times 0.8} = 218.98A$

$\vec{I_R} = I_R \angle -\cos^{-1}\phi_R = 218.69 \angle -36.86^\circ$ A

$\vec{I_{C_1}} = \frac{Y_C}{2} \times \vec{V_R} = j1.56 \times 10^{-4} \times 38.10k \angle 0^\circ = j5.96A$

$\vec{I_L} = \vec{I_R} + \vec{I_{C_1}} = 218.69 \angle -36.86 + j5.96$

$= 215.16 \angle -35.58^\circ$ A

$\vec{V_S} = \vec{V_R} + \vec{I_L}\vec{Z}$

$\vec{V_S} = 38.1k + j0 + (215.16 \angle -35.58^\circ)(10 + j36.66)$

$\vec{V_S} = 44743.6 \angle 6.62^\circ$ V

Line value of $V_S = \sqrt{3} \times 44.74 = 77.5$ kV

$\vec{I_{C_2}} = \left[\frac{Y_C}{2}\right]\vec{V_S} = j1.56 \times 10^{-4} \times [44444.72 + j5163.09]$

$= 7 \angle 96.62^\circ$ A

$\vec{I_S} = \vec{I_{C_2}} + \vec{I_L} = 7 \angle 96.62^\circ + 215.16 \angle -35.58^\circ$

$= 210.52 \angle -34.17$ A

% Voltage regulation $= \frac{V_S - V_R}{V_R} \times 100 = \frac{44.74 - 38.10}{38.10} \times 100 = 17.41\%$

Total line loss $= 3I_L^2 R = 3 \times 215.16^2 \times 10 = 1388.8$ kW

% Transmission efficiency $= \frac{P_R}{P_R + \text{Losses}} \times 100$

$= \frac{20M}{20M + 1338.3k} \times 100$

$= 93.5\%$

Module - 4

7a) Explain the phenomena of Corona. List the factor affecting Corona.

10M

Ans:- The phenomenon of corona is accompanied by a hissing sound, production of ozone, power loss & radio interference. The higher the voltage is raised, the larger & higher the luminous envelope becomes & greater are the sound, the power loss & the radio noise. "The phenomenon of violet glow, hissing noise & production of ozone gas in an overhead transmission line is called as corona".

factors affecting Corona

* Atmosphere
* Conductor size
* Spacing between conductors.
* Line voltage

7b) A 33kV, 3ϕ underground cable 4km long uses 3 core cables. Each of the conductor has a diameter of 2.5cm & the radial thickness of insulation 0.5cm. the relative permittivity of the dielectric is 3. Calculate

1] Capacitance of the cable /ph
2] Charging current/ph
3] Total charging kVAR

Ans:- $d = 2.5 cm$ $t = 0.5 cm$ $\varepsilon_r = 3$

i] Capacitance of cable/ph/m = $\frac{2\pi\varepsilon_0\varepsilon_r}{\ln\left(\frac{D}{d}\right)}$ F/m

$$= \frac{2\pi \times 8.854\times10^{-12}\times 3}{\ln\left(\frac{3.5}{2.5}\right)}$$

$$= 4.96\times10^{-10} \text{ F/m}$$

$$C = 1.984\ \mu F/ph$$

ii] Charging current/ph $I_c = \frac{V_{ph}}{X_c} = \frac{33/\sqrt{3}\times10^3}{\frac{1}{2\pi\times50\times1.984\times10^{-6}}}$

$$= 11.87\ A$$

iii] Total charging kVAR = $3\ V_{ph} I_c$

$$= 3\times19.05k\times11.87$$

$$= 678.58\ kVAR$$

Q8a) Explain 1] Disruptive critical voltage 2] Visual critical voltage 3] Power loss

Ans:- 1] Disruptive Critical Voltage

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

$$g = \frac{V}{r\log_e\frac{d}{r}} \text{ v/cm}$$

$$g_0 = \frac{V_c}{r\log_e\frac{d}{r}}$$

$g_0 = 30$ kV/cm (max), 21.2 kV/cm (rms)

$V_c = g_0 r \log_e \frac{d}{r}$

δ = air density factor = $\frac{3.92b}{273+t}$

$V_c = g_0 \delta r \log_e \frac{d}{r}$

$V_c = m_0 g_0 \delta r \log_e \frac{d}{r}$ kV/ph

2] Visual Critical voltage

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

$$V_v = m_v g_0 \delta r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \log_e \frac{d}{r} \text{ kV/ph}$$

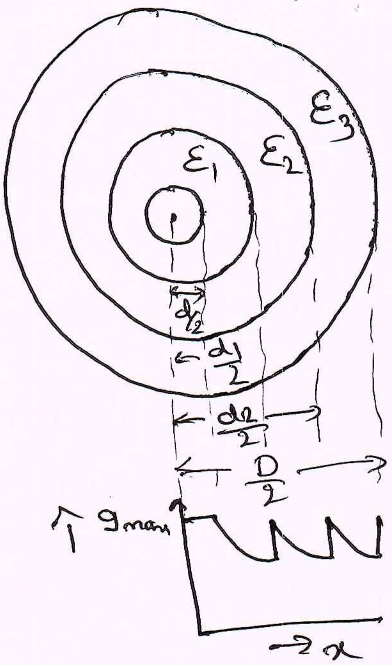
3] Corona Power loss

Corona ~~[illegible]~~ introduce the power loss due to hissing noise, violet light production.

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

b) Analyze grading of cables using capacitance grading method.

Ans:- The process of achieving uniformity in the dielectric stress by using layers of different dielectrics is known as capacitance grading.



The homogeneous dielectric is replaced by a composite dielectric. different permittivity dielectric is used $\varepsilon_1, \varepsilon_2$ & ε_3. highest permittivity being used near core.

$$\varepsilon_1 > \varepsilon_2 > \varepsilon_3$$

$$\frac{1}{\varepsilon_1 d} = \frac{1}{\varepsilon_2 d_1} = \frac{1}{\varepsilon_3 d_2}$$

$$\varepsilon_1 d = \varepsilon_2 d_1 = \varepsilon_3 d_2$$

Potential difference across the inner layer

$$V_1 = \int_{\frac{d}{2}}^{\frac{d_1}{2}} g\, dx = \int_{\frac{d}{2}}^{d_1/2} \frac{Q}{2\pi \varepsilon_0 \varepsilon_1 x}\, dx$$

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

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

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

$$V = V_1 + V_2 + V_3$$

$$= \frac{g_{max}}{2} \left[d \log_e \frac{d_1}{d} + d_1 \log_e \frac{d_2}{d_1} + d_2 \log_e \frac{D}{d_2} \right]$$

c) The inner & outer diameter of a cable are 3cm & 9cm respectively. The cable is insulated with the two materials having permittivities of 5 & 4 respectively with corresponding maximum possible stresses of 30 kV/cm & 20 kV/cm respectively. Calculate the radial tickness of each insulating layer & the safe working voltage of the cable. 4M

Ans:- $g_{1max} = \frac{Q}{\pi \varepsilon_1 d}$

$$Q = g_{1max} \pi \varepsilon_1 d = \frac{30k \times \pi \times 5 \times 3 \times 10^{-2}}{1 \times 10^{-2}}$$

$$Q = 1.4137 \times 10^{6}\ C$$

$$g_{2max} = \frac{Q}{\pi \varepsilon_2 d_1}$$

$$\frac{20 \times 10^3}{1 \times 10^{-2}} = \frac{1.4137 \times 10^6}{\pi \times 4 \times d_1}$$

$$d_1 = 0.05625 m = 5.625 m$$

Radial thickness of first dielectric $= \frac{d_1 - d}{2} = \frac{5.625 - 3}{2} = 1.31 cm$

" " " second " $= \frac{D - d_1}{2} = \frac{9 - 5.625}{2}$

$= 1.6875$ cm

$$q_{imax} = \frac{2V}{d\left[\ln\frac{d_1}{d} + \frac{\varepsilon_1}{\varepsilon_2}\ln\frac{D}{d_1}\right]}$$

$$\frac{30\times10^3}{1\times10^{-2}} = \frac{2V}{3\times10^{-2}\left[\ln\frac{5.625}{3} + \frac{5}{4}\ln\frac{9}{5.625}\right]}$$

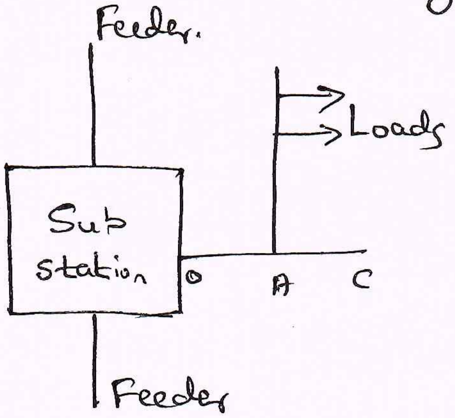
$$V = 54.725\ V$$

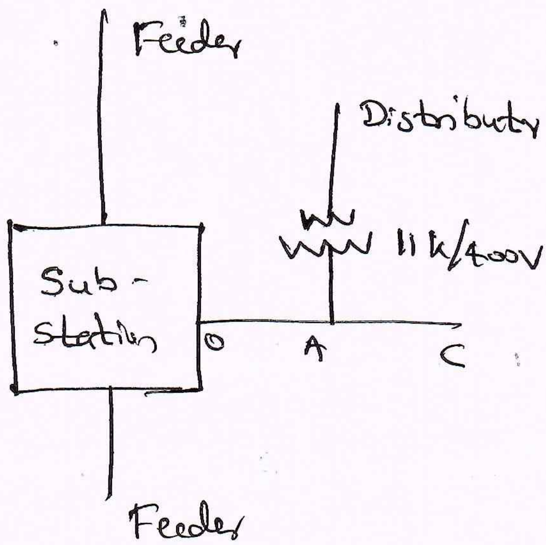
$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{54.725}{\sqrt{2}} = 38.7\ kV$$

Module 5

Q9a) Explain i] Radial distribution System
ii] Ringmain distribution system along with neat diagram. 10M

Ans:- i] Radial Distribution System





In this system, separate feeders radiate from a single substation feed the distributors at one end only. O C is a ~~distributor~~ feeder at point A, load is tapped. In ac distributor step down transformer is used.

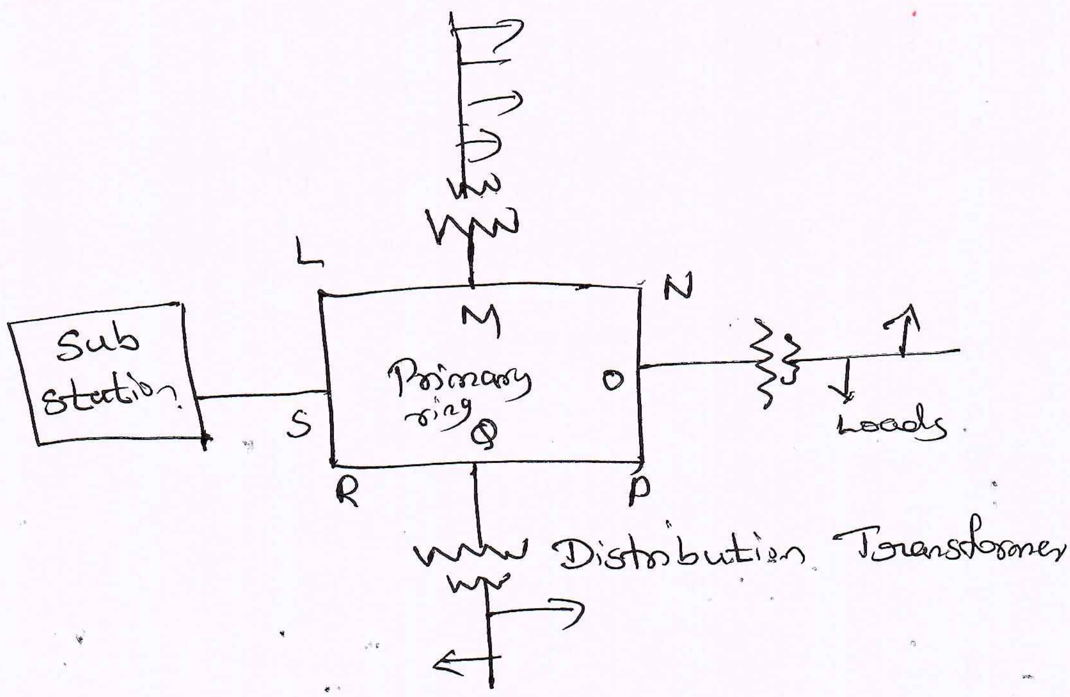
Drawbacks:-

1] The end of the distributor nearest to the feeding point will be heavily loaded.

2] The consumers are dependent on a single feeder & single distributor.

3] The consumer at the distant end of the distributor suffers from voltage fluctuation.

2] Ring Main System



All the ~~distribu~~ Feeders are interconnected in this configuration. Suppose one feed is faulty other feeds can resume the supply to that area.

Merits:-

1] Less voltage fluctuation.

2] System is reliable.

b) Define Reliability. Explain different probability distribution.

10M

Ans:- The reliability associated with a power system is a measure of the overall ability of the system to satisfy the customer demand for electrical energy.

Types of probability distribution

1] Binomial Distribution

The rules to find probability of different values of r out of n devices is given by Bernoulli's theorem.

$$P(x=r) = {}^{n}C_{r}\, p^{r} q^{n-r}$$

$x = r = 0, 1 \ldots \ldots n.$

$$\sigma = \sqrt{npq} \quad \& \quad \mu = np$$

2] Poisson Distribution

If p is small & np is very large then Poisson distribution is used to find the probability of occurance.

$$P(x=r) = \frac{e^{-np}(np)^{r}}{r!}$$

$$= \frac{e^{-\mu}(\mu)^{r}}{r!}$$

$$\sigma = \sqrt{np} = \sqrt{\mu}$$

3] Normal Distribution

Probability by normal distribution can be found as

$$P(x=r) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{1}{2}\left(\frac{r-m}{\sigma}\right)^2}$$

10a) A two wire distributor 1200m long is loaded as shown in fig. 'B' is the midpoint. The power factor of two load points refer to the voltage at 'C'. The impedance of each line is $(0.10+j0.2)\Omega$. Calculate the sending end voltage, current & power factor. The voltage at point 'C' is 220V.

Ans:- $\vec{Z}_{AB} = \vec{Z}_{BC} = (0.1+j0.2)\,\Omega$

$V_c = 220\angle 0^\circ$ V

$\vec{I}_2 = I_2(\cos\phi_2 - j\sin\phi_2) = 100(0.8 - j0.6) = (80-j60)$A

$\vec{I}_{BC} = (80-j60)$ A

$\vec{I}_1 = I_1(\cos\phi_1 - j\sin\phi_1) = 60(0.9 - j0.4358) = (54-j26.15)$A

$\vec{I}_{AB} = \vec{I}_1+\vec{I}_2 = (80-j60)+(54-j26.15)$

$= 134-j86.15$

$= 159\angle -32.73^\circ$ A

$\vec{V_{BC}} = \vec{I_{BC}}\,\vec{Z_{BC}} = (80 - j60) \times (0.1 + j0.2) = 22.36 \angle 26.65^\circ V$

$\vec{V_{AB}} = \vec{I_{AB}}\,\vec{Z_{AB}} = 159.3 \angle -32.73 \times (0.1 + j0.2) = 35.62 \angle 30.69^\circ V$

Total sending end voltage $= \vec{V_C} + \vec{V_{AB}} + \vec{V_{BC}}$

$= (220 + j0) + (30.63 + j18.18) + (20 + j10)$

$= 272.09 \angle 5.94 \ V$

$V_A = 272.09 \ V$

Angle between $\vec{I_{AB}}$ & $\vec{V_A} = [-32.73 - 5.94] = -38.68$

Sending end power factor $= \cos(-38.68) = 0.7806$ lagging

b) Analyze the effect of disconnection of neutral in 3ø 4 wire system. 6M

Ans:- Normally star point of the load is joined to the star point of distribution transformer or generator. If the neutral is disconnected opened or lost at any of its one side then looses its reference ground point.

Effects of disconnection of neutral are;

1] The potential of neutral point is always changing & not fixed

2] The neutral point floats upto line voltage.

3] It causes large changes in the currents & phase voltage.

4] The connected load may get damaged

5] The customers may receive serious shocks if they touch the equipment body.

c) Explain any 4 limitations of distribution system. 4M

Ans:- Limitations of distribution system are

1] Thermal limit

Temperature determines the limiting load current. The loading for typical system elements are set by temperature rather than mechanical considerations.

2] Economic limit

Heat is dissipated in the system components which is termed as losses. It leads to increase in cost.

3] Voltage drop

Thermal & economic limits are directly related to the magnitude of the load.

4] Over voltage

Apart from voltage drops, components must be capable of withstanding voltage surges generated from within the system.

SM Hegde