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(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

WINTER – 12 EXAMINATION
Subject Code : 12153 Model Answer Page No : 1 / N

Q.1 (a)

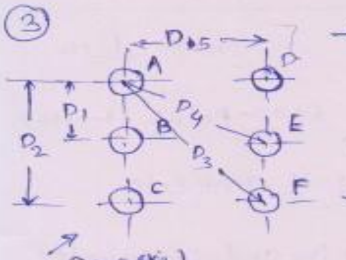
(each point 1 marks)

1. i) How much electricity to generate
   ii) Where, when & by using what fuel it generate.
   iii) To find line parameter's
   iv) To solve the problems of planning and coordinated operation of vast and complex power N/w.
   v) To find the line losses.
   vi) To model the power system & to simulate for result.
   vii) To calculate the rating the compansating equipment.

2. - The A.C. resistance is higher in value compared to D.C. resistance.
   - The A.C. resistance is given by
   $$R = \frac{\text{Avg. power loss}}{I^2}$$
   - For small change in temp., the resistance increases with temp. in accordance with the relation.
   $$R_t = R_0(1+\alpha_0 t)$$
   - A.C resistance is equal to D.C. resistance only if the current distribution is uniform throughout the conductor.

(each point 1 marks)

(3)



→ Consider a group of long straight conductors A, B, C etc. operating at potentials such that charges q_A, q_B, q_c etc. c/m length exist on the respective conductors.

→ Potential at A due to it's own charge (i.e. q_A)

(1 marks)

$$= \int_r^{\infty} \frac{q_A}{2\pi\varepsilon_0 x}\, dx \quad - (i)$$

- Potential at conductor A due to charge q_B

$$= \int_{d_1}^{\infty} \frac{q_B}{2\pi x\varepsilon_0}\, dx \quad - (ii)$$

Potential at conductor A due to charge q_c

$$= \int_{d_2}^{\infty} \frac{q_c}{2\pi x\varepsilon_0}\, dx \quad - (iii) \quad \text{— (1 marks)}$$

overall p.d. betn conductor A & infinite neutral plane is

$$V_A = (i) + (ii) + (iii) \ldots$$

$$= \int_r^{\infty} \frac{q_A}{2\pi x\varepsilon_0}\, dx + \int_{d_1}^{\infty} \frac{q_B}{2\pi x\varepsilon_0}\, dx + \int_{d_2}^{\infty} \frac{q_c}{2\pi x\varepsilon_0}\, dx$$

$$= \frac{1}{2\pi\varepsilon_0}\left[q_A(\ln_e \infty - \ln_e r) + q_B(\ln_e \infty - \ln d_1) + q_c(\ln \infty - \ln d_2) + \cdots \right]$$

$$= \frac{1}{2\pi\varepsilon_0}\left[q_A \ln\frac{1}{r} + q_B \ln\frac{1}{d_1} + q_c \ln\frac{1}{d_2} + \ln\infty(q_A + q_B + q_c) + \cdots \right]$$

Assume balance condition $q_A + q_B + q_c = 0$

$$V_A = \frac{1}{2\pi\varepsilon_0}\left[q_A \ln\frac{1}{r} + q_B \ln\frac{1}{d_1} + q_c \ln\frac{1}{d_2} + \cdots \right]$$

(2 marks).

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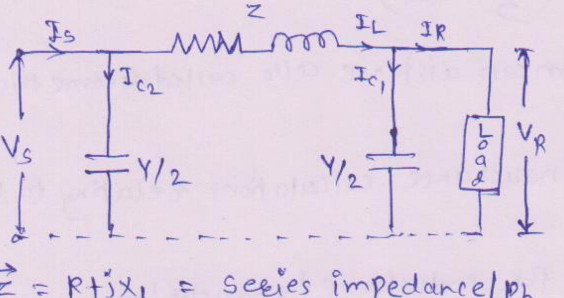
(4)



— (1 marks)

$\vec{Z} = R + jX_L$ = Series impedance/ph

$\vec{Y} = j\omega C$ = Shunt admittance

$\vec{I}_s = \vec{I}_L + \vec{I}_{C_2}$

or $\vec{I}_s = \vec{I}_L + \vec{V}_s \vec{Y}/2$ — (i)

Also $\vec{I}_L = \vec{I}_R + \vec{I}_{C_1}$

$= \vec{I}_R + \vec{V}_R \vec{Y}/2$ — (ii)

Now $\vec{V}_S = \vec{V}_R + \vec{I}_L \vec{Z}$

$= \vec{V}_R + (\vec{I}_R + \vec{V}_R \vec{Y}/2)\vec{Z}$

$= \vec{V}_R \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{I}_R \vec{Z}$ — (iii) — (1 marks)

Also $\vec{I}_S = \vec{I}_L + \vec{V}_S \vec{Y}/2$

$= (\vec{I}_R + \vec{V}_R \vec{Y}/2) + \vec{V}_s \vec{Y}/2$

Put value of V_s

$\therefore \vec{I}_S = \vec{I}_R + \vec{V}_R \vec{Y}/2 + \vec{Y}/2 \left[\vec{V}_R \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{I}_R \vec{Z}\right]$

$= \left(\vec{Y}/2 + \vec{Y}/2 + \frac{\vec{Y}^2 \vec{Z}}{4}\right)\vec{V}_R + \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\vec{I}_R$

$= \left(\vec{Y} + \frac{\vec{Y}^2 \vec{Z}}{4}\right)\vec{V}_R + \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\vec{I}_R$

$\vec{I}_S = \vec{Y}\left(1 + \frac{\vec{Y}\vec{Z}}{4}\right)\vec{V}_R + \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\vec{I}_R$ — (iv) — (1 marks)

compare eq^n (iii) & (iv) with following eqn

$\vec{V}_s = \vec{A}\vec{V}_R + \vec{B}\vec{I}_R$

$\vec{I}_s = \vec{C}\vec{V}_R + \vec{D}\vec{I}_R$

$\therefore \vec{A} = \vec{D} = 1 + \frac{\vec{Y}\vec{Z}}{2}$, $\vec{B} = \vec{Z}$, $\vec{C} = \vec{Y}\left(1 + \frac{\vec{Y}\vec{Z}}{4}\right)$ — (1 marks) b)

1) = Self GMD:- (3 marks)

- Self Geometrical mean distance also called Geometrical mean radius (GMR).
- It simplifies inductance calculations relating to multiconductor arrangements.
- In the expression for inductance / conductor / m

$= 2\times10^{-7}\left[\frac{1}{4} + \ln\frac{d}{r}\right]$

$= 2\times10^{-7}\times\frac{1}{4} + 2\times10^{-7}\ln\frac{d}{r}$ -(i)

In this eqn the term $2\times10^{-7}\times\frac{1}{4}$ is the inductance due to flux within the solid conductor. For many purposes it's desirable to eliminate this term by the introduction of self GMD.

- If we replace the solid conductor by hollow conductor then the current to the conductor R is zero, also flux & inductance at centre is zero. The term $2\times10^{-7}(1/4)$ shall be eliminated. To remove this term & to use the hollow conductor the self GMD term is used.

Self GMD (D_s) = $0.7788r$ & hence the above eqn is L/conductor/m $= 2\times10^{-7}\ln D/D_s$

Mutual GMD :- (3 marks).

- The mutual GMD is the geometrical mean of the distances from one conductor to the other and therefore must be between the largest and smallest such distances.
- It represents the equivalent geometrical spacing.

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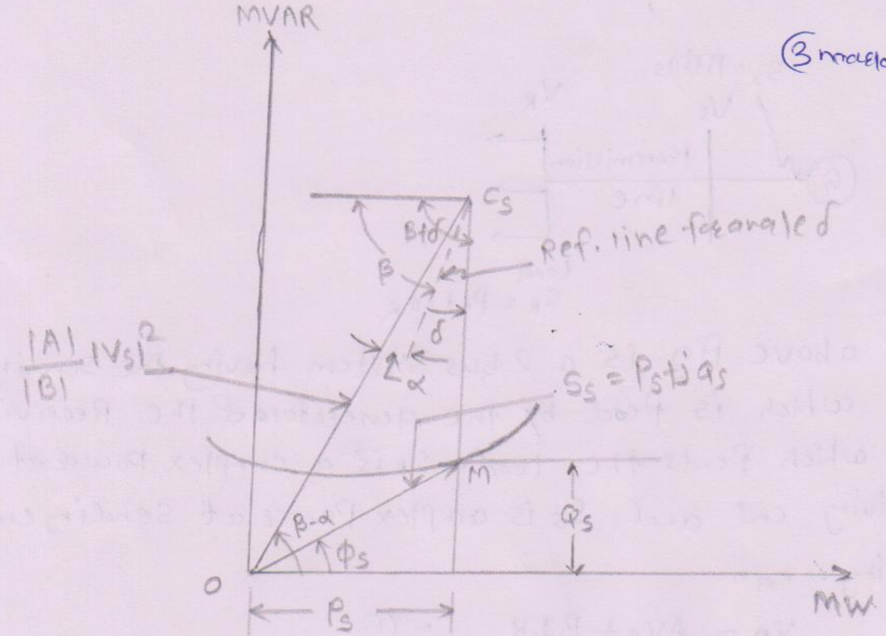
- The mutual-GMD between two conductors is equal to the distance between their centre i.e.

D_m = Spacing between conductors.

(2)

(3 marks)



(1) $S_s = P_s + jQ_s = \frac{|A||V_s|^2}{|B|}\angle(\beta-\alpha) - \frac{|V_R||V_s|}{|B|}\angle\beta+\delta$.

The centre of sending end circle is located at the tip of the phasor $\frac{|A||V_s|^2}{|B|}\angle\beta-\alpha$.

(2) Draw the MW & MVAR axis. ~~To draw~~ ~~centre~~ circle of ~~of~~ ~~circle~~

(3) To plot centre of circle take distance equal to $\frac{|A||V_s|^2}{|B|}$ & angle equal to $\angle(\beta-\alpha)$ to the positive x-axis. i.e. point C_s.

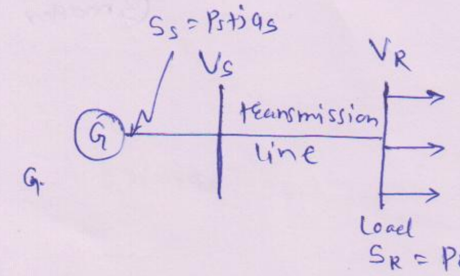
(4) With C_s as centre & distance equal to (i.e. radius) $\frac{|V_R||V_s|}{|B|}$

Draw the sending end circle.

⑤ The operating point m is located by drawing the line Csm inclined at an angle δ w.r.t. reference line. (to draw ref. line take angle equal to α & base equal to OC_s).

⑥ (each point $\frac{1}{2}$ marks).

Q. 3
①



— The above fig. is a 2 bus system having the sending end bus which is feed by the generator & the Receiving end bus which feeds the load. S_R is a complex power at receiving end and S_s is complex power at sending end.

— using eqn

$$V_S = AV_R + BI_R \quad - ①$$

$$I_S = CV_R + DI_R \quad - ②$$

&

$$V_R = DV_S - BI_S \quad - ③$$

$$I_R = -CV_S + AI_S \quad - ④ \qquad \text{— ① marks}$$

the current I_R & I_S can be expressed in terms of V_R & V_S as

$$I_R = \frac{1}{B}V_S - \frac{A}{B}V_R - ⑤$$

$$\& \; I_S = \frac{D}{B}V_S - \frac{1}{B}V_R$$

$$= \frac{A}{B}V_S - \frac{1}{B}V_R - ⑥$$

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Let $V_R = |V_R|\angle 0$, $V_S = |V_S|\angle\delta$

$D = A = |A|\angle\alpha$, $B = |B|\angle\beta$

Then, $$I_R = \frac{|V_S|\angle\delta}{|B|\angle\beta} - \frac{|A|\angle\alpha}{|B|\angle\beta}|V_R|\angle 0$$

$$= \frac{|V_S|}{|B|}\angle\delta-\beta - \frac{|A|}{|B|}|V_R|\angle\alpha-\beta \quad -(7)$$ – (1 marks)

& $$I_S = \frac{|A||V_S|}{|B|}\angle(\alpha+\delta-\beta) - \frac{|V_R|}{|B|}\angle-\beta \quad -(8)$$

The conjugates of I_R & I_S are

$$I_R^* = \frac{|V_S|}{|B|}\angle\beta-\delta - \frac{|A||V_R|}{|B|}\angle\beta-\alpha$$

$$I_S^* = \frac{|A||V_S|}{|B|}\angle(\beta-\alpha-\delta) - \frac{|V_R|}{|B|}\angle\beta \quad -(9)$$ – (1 marks)

The complex power/ph at the receiving end & sending end, are

$$S_R = P_R + jQ_R$$
$$= V_R I_R^*$$
$$= |V_R|\angle 0\left[\frac{|V_S|}{|B|}\angle(\beta-\delta) - \frac{|A||V_R|}{|B|}\angle(\beta-\alpha)\right]$$
$$= \frac{|V_R||V_S|}{|B|}\angle\beta-\delta - \frac{|V_R|^2|A|}{|B|}\angle(\beta-\alpha)$$
$$= \frac{|V_S||V_R|}{|B|}\angle(\beta-\delta) - \frac{|A||V_R|^2}{|B|}\angle(\beta-\alpha) \quad -(10)$$

$$\therefore P_R = \frac{|V_S||V_R|}{|B|}\cos(\beta-\delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta-\alpha)$$

$$Q_R = \frac{|V_S||V_R|}{|B|}\sin(\beta-\delta) - \frac{|A||V_R|^2}{|B|}\sin(\beta-\alpha)$$ – (1 mark).

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(2) =

(i) Sending end Voltage (V_S)
(ii) Receiving end voltage (V_R)
(iii) Generalised circuit constants ~~A&B~~ $|A|\angle\alpha$ & $|B|\angle\beta$
(iv) The Power angle δ.
(v) The Receiving end load & p.f.
(each point 1marks).

(3)

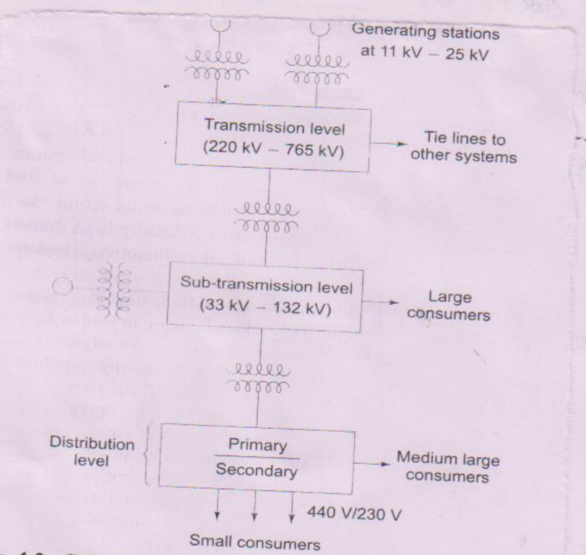

Fig. 1.3 Schematic diagram depicting power system structure

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(4) Single line diagram :- (2 marks)

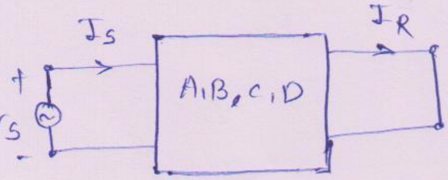
- It is easy to represent ~~3 phase~~ single phase structure instead of 3ϕ.
- It is easy to understand rather than complicated 3ϕ line.

Equivalent circuit representation :- (2 marks)

- The circuit is reduces to small ckt.
- The calculation is easy
-

(~~for each~~ point)

(5)

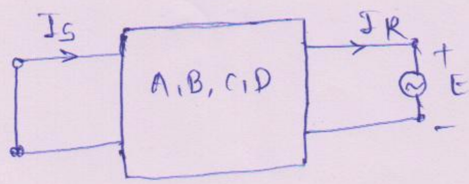


consider fig. where a two terminal pair N/w with parameter. A, B, C & D is connected to an ideal voltage source with zero internal impedance at one end & the other end is S.C.

The eq^n is

$V_S = E = 0 + BI_R$ — (1 marks)

or $I_R = \frac{E}{B}$ — (1)



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Now S.C. the sending end and connect the generator at the receiving end shown above fig. The positive directions of flow of current are shown in fig.

$\therefore 0 = AE + BIR$ — (2) — (1 marks)

Since line is a linear passive bilateral N/w

& $I_S = -I_R = CE + DI_R$ — (3)

eliminating I_R from eqn (2) & (3)

$-I_R = CE + D\left(\frac{-AE}{B}\right)$ — (4) (1 marks)

from eqn (1) $I_R = \frac{E}{B}$ .. (from (4))

$$\frac{-E}{B} = CE + D\left(\frac{-AE}{B}\right)$$

$$\frac{-1}{B} = C - \frac{DA}{B}$$

$$\frac{-1}{\cancel{B}} = \frac{BC - AD}{\cancel{B}}$$

$$\therefore \boxed{AD - BC = 1}$$ (1 marks).

Q.2 (1) (Any 4 points- 1 mark for each point)

Per unit value of a quantity is the ratio of the actual value of that quantity to an arbitrary selected value of that quantity. This arbitrary selected value is called as 'Base Value'.

$$\text{Per unit value} = \frac{\text{Actual value}}{\text{Base value}}$$

In power system there are 4 quantities- KVA, KV, current & impedance. Base value of KVA & KV can be selected from which we can calculate Base value of current & impedance as follows.

$$\text{Base current} = \frac{\text{Base KVA}}{\text{Base KV}} \quad \text{--- phase current}$$

$$\text{Base current} = \frac{3\phi \text{ Base KVA}}{\sqrt{3}\ \text{Base KV}_{l-l}} \quad \text{--- line current}$$

1m

$$\text{Base impedance} = \frac{(\text{Base KV})^2}{\text{Base KVA}} \times 1000 = \text{---}\ \Omega$$

* $\text{Per unit KVA} = \dfrac{\text{actual KVA}}{\text{Base KVA}}$
* $\text{Per unit KV} = \dfrac{\text{actual KV}}{\text{Base KV}}$

1 mar

* $\text{Per unit impedance} = \dfrac{\text{actual impedance}}{\text{Base impedance}}$
* $\text{Per unit current} = \dfrac{\text{actual current}}{\text{Base current}}$

1m

we can also calculate Z p.u. reffer to new base values as

$$Z_{p.u.\,new} = Z_{pu\,old} \times \left(\frac{\text{Base KV}_{old}}{\text{Base KV}_{new}}\right)^2 \times \frac{\text{Base KVA}_{new}}{\text{Base KVA}_{old}}$$

Advantages of per unit method (Any 4 points- 1 mark for each point)

1. Manufacturers: Usually specify the impedance of a piece of apparatus in percent or per unit on the bases of the nameplate rating.
2. The Zpu of machine of the same type but having widely different ratings usually lie within a narrow range. Although the Ω value differ with the ratings. Hence when the impedance of the machine is not known, the table in which av values for different machines re given.

3. The per unit impedance once expressed on the proper base, is same referred to either side of any transformers, because Base KV is selected in the same ratio as the transformer ratio.

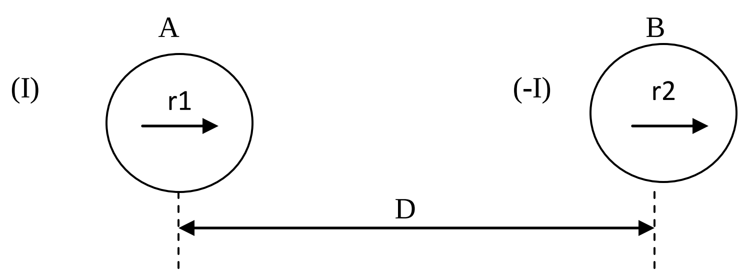
4. The way in which transformers are connected in 3-phase circuits of the transformer, although it determine the relation between the base voltage on the two sides of the transformer.

5. Per unit values of quantities simplifies the calculations to greater extent. More over since system data is available in per unit values hence it is always convenient to adopt per unit calculations.

Q.2 (i)

Inductance of Single Phase to Line

Composed of Solid Conductors: Consider a single phase to line composed of two solid conductors A & of radii r1 & r2 mts. Respectively and placed at a distance D mts. Apart. Say conductor ‘A’ carries current in forward and ‘B’ carries current as return path I.e. current through two conductors are equal but flow in opposite directions.



Flux linkage of each conductor depends upon the internal flux and external fluxes of both conductors.

Ψa total = Ψa int + Ψa ext.

Ψa int – flux linkage due to internal fluxes = ½ x $^{10\ -7}$ I wbt/mt.

To calculate Ψa ext. following points are to be considered:-

- Fluxes at distance = D + r2 from the centre of conductor ‘ A’ links net zero current ($\therefore$ it encloses both conductor A & B)

- Fluxes from (D-r2) to (D+r2) links a current whose magnitude reduces progressively from I to zero.

- Fluxes beyond r1 & less than (D-r2) links all the current I in conductor ‘A’.

Hence to simplify the calculations assume that, as D>>> r1 & r2 (the case in overhead line) the fluxes from

$(D-r_2)$ to the centre of conductor 'B' (3)
links with full current I amps.
whereas the fluxes from centre of conductor 'B' upto $D+r_2$ links with zero current.

$\therefore \Psi_{a\,ext} = 2\times10^{-7} I \log_e \frac{D}{r_1'}$ → 1 mark.

~~where $r_1' = 0.7788\, r_1$~~ $= e^{-1/4} r_1$

$\therefore \Psi_{a\,total} = \Psi_{a\,int} + \Psi_{a\,ext}$

$= \frac{1}{2}\times10^{-7} I + 2\times10^{-7} I \log_e \frac{D}{r_1'}$

$= 2\times10^{-7} I \log_e \frac{D e^{1/4}}{r_1}$

$= 2\times10^{-7} I \log_e \frac{D}{e^{-1/4} r_1}$

$= 2\times10^{-7} I \log_e \frac{D}{r_1'}$ where $r_1' = e^{-1/4} r_1$

$\therefore L_a = \frac{\Psi_{a\,total}}{I} = 2\times10^{-7} \log_e \frac{D}{r_1'}$ H/mt. → 1 mark

Since currents in conductor A & B flows in opposite directions, mag-flux set up by both current between the conductors are in same direction. ∴ The resulting mmf is the sum of mmfs of both conductors.

$\therefore \cancel{L_a} L_b = 2\times10^{-7} \log_e \frac{D}{r_2'}$ ... H/mt.

complete

$\therefore$ Inductance of IQ line i.e. complete loop is

$$L_{loop} = L_a + L_b = 2 \times {}^{10^{-7}} \log_c \frac{D2}{r1r2}$$

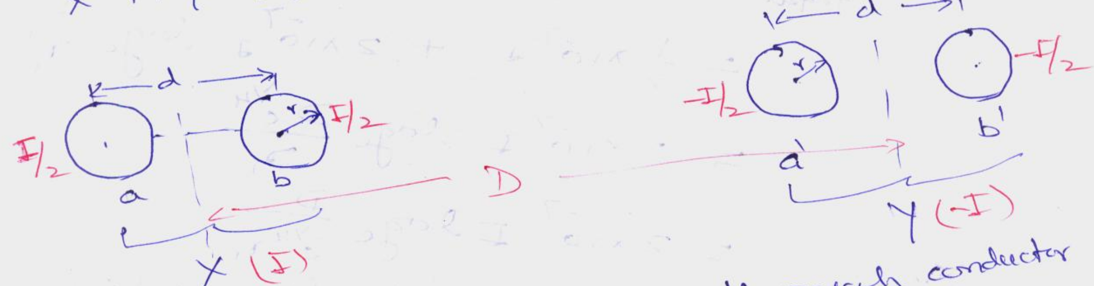
$$= 4 \times 10^{-7} \log_c d/r1 \quad h/mt.$$

Where $r1 = \sqrt{r1r2}$ (4 –marks)

Q.2 (ii)

(ii) Inductance of Single phase tr. line composed of bundled conductors.

Consider a 1ϕ tr. line composed of duplex bundled conductors X & Y as shown in fig.



Let 'I' be the current through conductor 'X' which equally divides among 2 filaments 'a' & 'b' i.e. current thro' each filament is $I/2$ amp. Consider conductor 'Y' forms the return path for the current.

1 mark

Inductance of conductor 'X', L_x

$= \frac{1}{n} L_{av}$

$= \frac{1}{2} \times L_a$

where L_a - inductance of filament 'a'

$L_a = L_b$.

n - no. of filament

$= 2$ -- for duplex bund. conductor.

Net flux linkage with filament 'a' due to current thro' a, b, a', b' filaments

$$\psi_a = 2\times10^{-7}\left\{\frac{I}{2}\left(\log_e\frac{1}{r_1}+\log_e\frac{1}{D_{ab}}\right)-\frac{I}{2}\left(\log_e\frac{1}{D_{aa'}}+\log_e\frac{1}{D_{ab'}}\right)\right\}$$

4

$$= 2\times10^{-7} I \log_e \frac{\sqrt{D_{aa'}\cdot D_{ab'}}}{\sqrt{D_{aa}\cdot D_{ab}}}$$ where $D_{aa} = r'$

$$\therefore L_a = \frac{\psi_a}{I/2} = 2\times10^{-7}\log_e \frac{D_{aa'}\cdot D_{ab'}}{D_{aa}\cdot D_{ab}} \;\ldots\; H/mt.$$

|||ly $$L_b = 2\times10^{-7}\log_e \frac{D_{ba'}\cdot D_{bb'}}{D_{ba}\cdot D_{bb}} \;\ldots\; H/mt.$$

$$\therefore L_{ave} = \frac{L_a+L_b}{2}$$
$$= 2\times10^{-7}\log_e \frac{\sqrt{D_{aa'}\cdot D_{ab'}\cdot D_{bb'}\cdot D_{ba'}}}{\sqrt{D_{aa}\cdot D_{ab}\cdot D_{bb}\cdot D_{ba}}}$$

$$\therefore L_x = \frac{1}{2} L_{ave}$$
$$= 2\times10^{-7}\log_e \frac{\sqrt[4]{D_{aa'}\cdot D_{ab'}\cdot D_{bb'}\cdot D_{ba'}}}{\sqrt[4]{D_{aa}\cdot D_{bb}\cdot D_{ab}\cdot D_{ba}}}$$
$$= 2\times10^{-7}\log_e \frac{D_m}{D_{sx}} \;\ldots\; H/mt.$$ → 1 mark

|||ly $$L_y = 2\times10^{-7}\log_e \frac{D_m}{D_{sy}} \;\ldots\; H/mt.$$

where $D_{sy} = \sqrt[4]{D_{a'a'}\cdot D_{b'b'}\cdot D_{a'b'}\cdot D_{b'a'}}$ → 1 mark.

$\therefore L_{loop}$ – total inductance of 1φ line

$$= L_x + L_y$$
$$= 2\times10^{-7}\left[\log_e \frac{D_m}{D_{sx}} + \log_e \frac{D_m}{D_{sy}}\right]$$
$$= 2\times10^{-7}\log_e \frac{D_m^2}{D_{sx}\cdot D_{sy}}$$

where $D_s = D_{sx} = D_{sy}$ for duplex bundled co

$$= 2\times10^{-7}\log_e \frac{D_m^2}{D_s^2}$$

= 4 x $^{10\,-7}$ logc Dm / Ds ….H/mt.

L $_{loop}$ = 4 x $^{10\,-7}$ logc Dm / Ds ….H/mt.

.2 (iii)

Q. No. 2

(3)

(2)

Given → 3φ line

$V_{R_{L-L}} = 110\,kV \qquad V_{R\,ph} = \frac{110 \times 10^3}{\sqrt{3}} = 63508.5\ V/ph$

$P_R = 50 \times 10^6\ VA = \sqrt{3}\, V_L I_L \qquad \cos\phi_R = 0.8$ lag, $\therefore \phi_R = -36.88^\circ$

$\therefore 50 \times 10^6 = \sqrt{3} \times 110 \times 10^3 \times I_L$

$\therefore I_R = \frac{50 \times 10^6}{\sqrt{3} \times 110 \times 10^3} = 262.43\,A \angle -36.88^\circ$

$A = D = 0.98 \angle 3^\circ \quad B = 110 \angle 75^\circ\ \Omega \quad C = 0.0005 \angle 88^\circ\ ℧$

G.C.E. states that

$V_S = A V_R + B I_R$

$= 0.98 \angle 3^\circ \times 63508.5 \angle 0^\circ + 110 \angle 75^\circ \times 262.4 \angle -36.88^\circ$

$= 84917.2 \angle 2.198^\circ$ volt/ph.

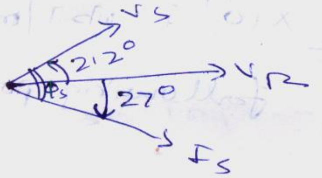
$V_S = \sqrt{3}\, V_{ph} = 147.08\ kV$ // — 2 marks

$I_S = C V_R + D I_R$

$= 0.0005 \angle 88^\circ \times 63508.5 + 0.98 \angle 3^\circ \times 262.4 \angle -36.88^\circ$

$= 246.02$ Amp. $\angle -27^\circ$ // — 2 marks

vector diagram



$\therefore \phi_S = 2.2 + 27^\circ = 29.2^\circ$

$\therefore \cos\phi_S = \cos 29.2^\circ = 0.873$ — 1 mark

Power at sending end $P_S = 3 V_S I_S \cos\phi_S$

$= 3 \times 84917.2 \times 246.02 \times 0.873$

$= 54.71\ MW$ — 1 mark

Transmission efficiency $= \frac{P_R}{P_S} \times 100$

$= \frac{50}{54.71} \times 100$

$= 91.39\ \%$ — 2 mark.

Vs – Sending end voltage = 147.08KV

Is – Sending end current = 246.02AMP

Ps – Sending end power = 54.71Mw

η - Transmission efficiency = 91.39 %

Q.No 4(a) (i)

Role of power system engineer

Power system engineer plays an important role in designing, operating of power system network. He has to face a variety of challenging tasks which he can meet only by keeping abreast of the recent scientific advances and the latest techniques. On the planning side, he has to make decisions on how much electricity is to be generated - where, when and by using what fuel. He has to be involved in construction tasks of great magnitude both in generation and transmission. He has to solve the problems of planning and co-ordinated operation of a vast and complex power network, so as to achieve a high degree of economy and reliability. In a country like India, he has to additionally face the perennial problem of power shortages and to evolve strategies for energy conservation and load management. He should know the methods of making load studies, fault analysis, stability

(4 marks for any 4 points)

studies and the principles of eco
-nomic dispatch because such stu
effect the design and operat
of the system and the selection
apparatus for its control.

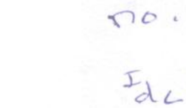
Q No. 4 (a)

(3) Skin effect in transmission line →

Based on type of current we have A.C. transmission system & D.C. transmission system.

When d.c. current flows in tr. line conductor the current is uniformly distributed across the conductor whereas when A.C. current flows through ~~the~~ it max. current flows through the surface of the conductor i.e. non-uniform distribution of current across the conductor. This effect is known as skin effect.

Skin effect is mainly due to magnetic flux set up by a.c. current inside the conductor. Assume that the conductor is composed of no. of annular filaments, The inner filaments



carrying current give rise to flux which links with the outer filaments as well as inner filaments whereas flux set up by outer filaments links with outer filaments only, i, the inductance of inner filament is higher than outer filament. Hence impedance of inner filament is compairatively higher than outer filament. Hence more current flows thro' surface of the conductor.

(2 marks)

(6)

Factors affecting / influencing skin effect →

(i) Frequency of the current. (At radio freq. skin effect is more prominent) It is significant at 50 Hz. freq.

(ii) diameter of the conductor, or C.S. area " "

(iii) material of the conductor. permeability of the conductor material.

(iv) voltage of the conductor.

(2 marks for any two)

Q.No 4 (a) (4)

$A\angle\alpha = 0.85\angle 5^\circ$ $B\angle\beta = 300\angle 75^\circ\ \Omega$ $V_R = V_S = 275\ kV$

$p.f. = \cos\phi_R = 1$ $P_R = ?$

At unity p.f. $\sin\phi_R = 0$ $\therefore Q_R = 0$ → 1 mark

Reactive power ~~$S_R = P_R + jQ_R$~~ P_R at receiving end

$$Q_R = \frac{V_S V_R}{B}\sin(\beta-\delta) - \frac{A}{B}V_R^2\sin(\beta-\alpha)$$

$$0 = \frac{275\times 275}{300}\sin(75^\circ-\delta) - \frac{0.85}{300}\times 275^2\sin(75^\circ-5^\circ)$$

$\therefore \sin(75^\circ-\delta) = \sin 70^\circ \times 0.85 = 0.7987$

$\therefore 75^\circ - \delta = 53^\circ$ $\therefore \delta = 75^\circ - 53^\circ = 22^\circ$ → 1 mark

substituting in eqn. for P_R

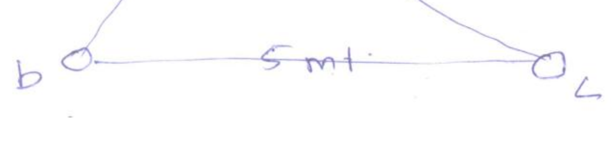
$$P_R = \frac{V_S V_R}{B}\cos(\beta-\delta) - \frac{A}{B}V_R^2\cos(\beta-\alpha)$$ — 1 mark

$$= \frac{275\times 275}{300}\cos(75^\circ-22^\circ) - \frac{0.85}{300}\times 275^2\cos(75^\circ-5^\circ)$$

$= 78.42\ MW.$

$\boxed{P_R = 78.42\ MW}$ → 1 mark.

Q.No. 4 (a) (2)



$$D_{eq} = \sqrt[3]{D_{ab}\cdot D_{bc}\cdot D_{ac}}$$

$$= \sqrt[3]{4\times 5\times 6}$$

$= 4.93\ mt$

→ 1 mark

$$r' = 0.7788\, r$$
$$= 0.7788\left(\frac{2}{2}\right) \times 10^{-2}\ mt$$
$$= 0.007788\ mt.$$ 1 mark

$$L = 2\times10^{-7} \log_e \frac{Deq}{r'}$$
$$= 2\times10^{-7} \log_e \frac{4.93}{0.00788}$$
$$= 12.9\times10^{-7}\ H/mt.$$
$$= 1.29\times10^{-6}\ H/mt.$$
$$= 1.29\ mH/kmt.$$

2 mark

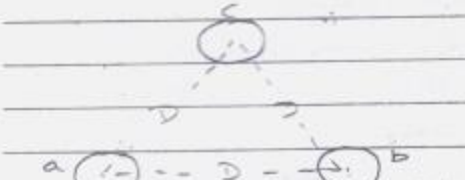
$$\boxed{L = 1.29\ mH/kmt}$$

Q. No. 4 (b)

(1)

Attach - A (7)

Capacitance of a 3φ line with equilateral spacing.



Consider a 3φ line composed of 3 identical solid conductors of radius 'r' and spacing between them 'D' mt.

Assume that there is no charges in the vicinity of the conductors and voltages of charges are sinusoidal and there is negligible effect of the earth field. Hence the charges are uniformly distributed ∀ $q_a + q_b + q_c = 0$

Since $I_a + I_b + I_c = 0$ — 1 mark

Now the p.d. between a & b conductors due to charges on all conductors is

$$v_{ab} = \frac{1}{2\pi k}\left[q_a \log_e \frac{D}{r} + q_b \log_e \frac{r}{D} + q_c \log_e \frac{D}{D}\right]$$

$$= \frac{1}{2\pi k}\left[q_a \log_e \frac{D}{r} + q_b \log_e \frac{r}{D}\right] \quad \text{—(1)}$$

IIIly p.d. between a & c conductors

$$v_{ac} = \frac{1}{2\pi k}\left[q_a \log_e \frac{D}{r} + q_b \log_e \frac{D}{D} + q_c \log_e \frac{r}{D}\right]$$

$$= \frac{1}{2\pi k}\left[q_a \log_e \frac{D}{r} + q_c \log_e \frac{r}{D}\right] \quad \text{—(2)}$$

Adding eqns (1) & (2), we get

$$v_{ab} + v_{ac} = \frac{1}{2\pi k}\left[2 q_a \log_e \frac{D}{r} + (q_b + q_c)\log_e \frac{r}{D}\right]$$

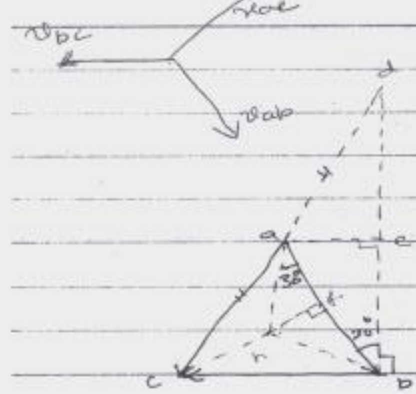
since $q_a + q_b + q_c = 0$

$$= \frac{1}{2\pi k}\left[2 q_a \log_e \frac{D}{r} - q_a \log_e \frac{r}{D}\right]$$

$$= \frac{1}{2\pi k} 3 q_a \log_e \frac{D}{r} \quad \text{—(3)}$$

2 marks.

Draw the vectors v_{ab}, v_{bc} & v_{ac} as shown in fig. Now produce V_{ca} up to d such that ac = ad & we get bd ⊥ bc. Now drop ae ⊥ to bd. Let 'n' the pt. where internal angles bisector meets. Now drop nf ⊥ to ab.



From vector diagram,

$$\vec{v}_{ab} + \vec{v}_{ac} = \vec{v}_{ad} + \vec{v}_{ab}$$
$$= \vec{v}_{bd}$$

3 marks

$$= 2\, v_{be}$$
$$= 2\, v_{ab} \cdot \cos 30^\circ$$

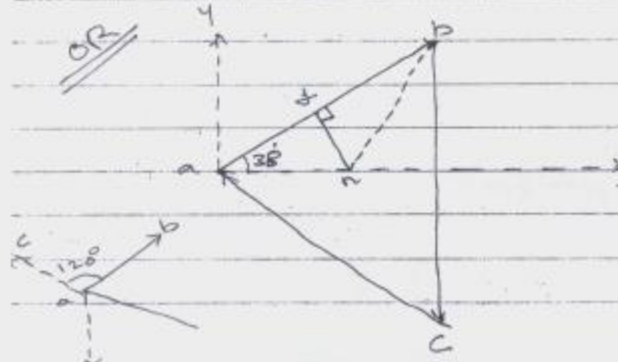
But from Δ anb,

$$v_{ab} = 2\, v_{af} = 2 \cdot v_{an} \cos 30^\circ$$

Substituting in above eqn.

$$\therefore \vec{v}_{ab} + \vec{v}_{ac} = 2 \left(2\, v_{an} \cos 30^\circ\right) \cos 30^\circ$$
$$= 4\, v_{an} \cdot \cos^2 30^\circ$$
$$= 4 \cdot v_{an} \cdot \left(\frac{\sqrt{3}}{2}\right)^2$$
$$= 3\, v_{an} \quad \text{(Le)}$$

OR



Having the vector diagram for 3φ line 120° displacement and taking origin at pt. 'a' and x-axis as reference axis. From fig. we get

$$\vec{v}_{ab} = 2\, v_{af}$$
$$= 2\, v_{an} \cos 30^\circ$$
$$= \sqrt{3}\, v_{an}$$

(8)

$|||^{ly}$ $\vec{V_{ac}} = 2V_{an} \cos 30^\circ = \sqrt{3} V_{an}$

$\therefore \vec{V_{ab}} + \vec{V_{ac}} = \sqrt{3} V_{an} \angle 30^\circ + \sqrt{3} V_a \angle -30^\circ$

$= \sqrt{3} V_{an} \{ \cos 30^\circ + j \sin 30^\circ + \cos 30^\circ - j \sin 30^\circ$

$= \sqrt{3} V_{an} \cdot 2 \cdot \cos 30^\circ$

$= \sqrt{3} V_{an} \cdot 2 \cdot \frac{\sqrt{3}}{2} = 3 V_{an}$

$\vec{V_{ab}} + \vec{V_{ac}} = 3 V_{an}$ —— (4)

3 marks.

From —— (3) & (4)

$3 V_{an} = \frac{3\, q_a}{2\pi k} \log_e \frac{D}{r}$

$\therefore V_{an} = \frac{q_a}{2\pi k} \log_e \frac{D}{r}$

$\therefore$ line to neutral capacitance

$$\boxed{C_n = \frac{q_a}{V_{an}} = \frac{2\pi k}{\log_e D/r} \; F/mt}$$

$V_S = 240\,kV \qquad V_R = 235$

load = 90 MW at 0.8 p.f lag.

$A = 0.97 \angle 0.3^\circ \qquad B = 85.2 \angle 72^\circ$

→ To locate centre 'n'

X co-ordinate $= 0a = -\frac{A V_R^2}{B} \cos(\beta - \alpha)$

$= -\frac{0.97 \times 235^2}{85.2} \cos(72 - 0.3)$

$= -197.41\ MW$

Y co-ordinate $= 0b = -\frac{A V_R^2}{B} \sin(\beta - \alpha)$

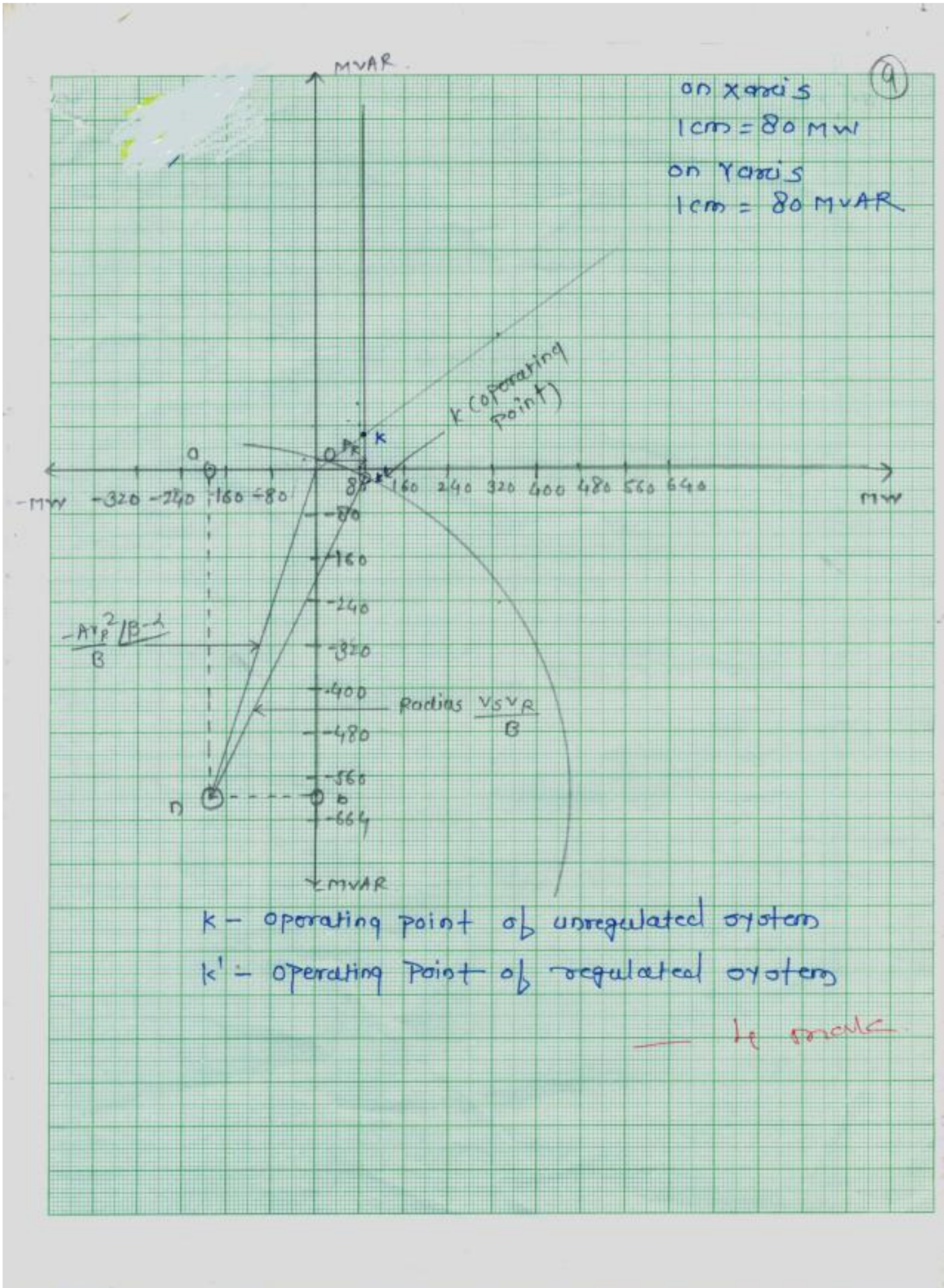
$= -\frac{0.97 \times 235^2}{85.2} \sin(72 - 0.3)$

$= -596.93\ MVAR$

Radius $= \frac{V_S V_R}{B} = \frac{240 \times 235}{85.2} = 661.97\ MVA$.

centre of circle = (−197.41 MW, −596.93 MVAR) → 1 mark

Radius of circle = 661.97 MVA. → 1 mark


MVAR
on x axis
1cm = 80 MW
on Y axis
1cm = 80 MVAR
K (operating point)
-MW
-320 -240 -160 -80
80 160 240 320 400 480 560 640
MW
-80
-160
-240
-320
-400
-480
-560
-664
Radius $\frac{V_S V_R}{B}$
$\frac{-A V_R^2}{B} \angle \beta - \alpha$
-MVAR
K – operating point of unregulated system
K' – operating Point of regulated system

Q.5 Attempt any two 16 Marks.

a) To measure G.C.C. of a given line O.C. and S.C. tests are carried out on both sending and and recieving end side. The connection circuit diagram for both tests are as follows:

Fig 4.19 (a) & (b) Page 88

Electrical Power Systems – C.L. Wadhwa – ~~2 Marks~~ (2 Marks)

In the connection diagrams are similarly 2M made for performing these tests on both sides. After performing the O.C. and S.C. test on both sides ~~both sides~~ the impedances are determined for each tests.

Z_{so} = sending end impedance with recieving end open circuited.

Z_{ss} = sending end impedance with recieving end short circuited.

Z_{ro} = Recieving end impedance with sending end open circuited.

Z_{rs} = Receiving end impedance with sending end short circuited. 2 Marks

Here

$$Z_{so} = \frac{V_s}{I_s} = \frac{A}{C} \text{ for } I_r = 0 \text{ (open circuit test)} \quad (1)$$

$$Z_{ss} = \frac{V_s}{I_s} = \frac{B}{D} \text{ for } V_r = 0 \text{ (short circuit test)} \quad (2)$$

$$Z_{ro} = \frac{V_r}{I_r} = \frac{D}{C} \text{ for } I_s = 0 \text{. (~~short~~ open circuit test)} - (3)$$

$$Z_{rs} = \frac{V_r}{I_r} = \frac{B}{A} \text{ for } V_s = 0 \text{ (short circuit test)} - (4)$$

From equations (1), (2), (3) and (4)

$$Z_{ro} - Z_{rs} = \frac{D}{C} - \frac{B}{A} = \frac{AD - BC}{AC} = \frac{1}{AC}.$$

$$\frac{Z_{ro} - Z_{rs}}{Z_{so}} = \frac{1}{AC} \cdot \frac{C}{A} = \frac{1}{A^2}.$$

$$\therefore A = \sqrt{\frac{Z_{so}}{Z_{ro} - Z_{rs}}} \quad \text{——— (5)} \qquad \text{— 1 Mark}$$

$$B = A Z_{rs} = Z_{rs} \sqrt{\frac{Z_{so}}{Z_{ro} - Z_{rs}}} \quad \text{——— (6)} \quad \text{— 1 Mark}$$

$$Z_{so} = \frac{A}{C}$$

$$C = \frac{A}{Z_{so}} = \frac{1}{Z_{so}} \sqrt{\frac{Z_{so}}{Z_{ro} - Z_{rs}}} \quad \text{——— (7)} \quad \text{1 Mark}$$

$$Z_{ro} = \frac{D}{C}.$$

$$D = C Z_{ro} = \frac{Z_{ro}}{Z_{so}} \sqrt{\frac{Z_{ro}}{Z_{ro} - Z_{rs}}}.$$

$$= Z_{ro} \sqrt{\frac{1}{Z_{so}(Z_{ro} - Z_{rs})}} \quad \text{——— (8). 1 Mark}$$

~~2 Marks~~.

From equations (5), (6), (7) & (8) we can get GCC. for the given line.

2). Procedure to draw receiving end circle diagram can be as follows.

a). Locate the centre OC_r of receiving end circle diagram on graph paper at $\frac{|A|}{|B|}|V_r|^2$ inclined at $\angle(\beta-\alpha)$ in the ~~positive direction~~ negative x-axis.

b) From center C_r the receiving end circle is drawn with radius $\frac{|V_s||V_r|}{|B|}$.

c) The operating point P is located on the circle by considering the real power (load) delivered i.e. P_r.

d) The torque angle δ can be represented and read from positive direction of reference line drawn with help of angle α.

(1 Mark each, ~~2 Marks~~ 4 Marks)

Fig 5.20 Page 148 Modern power system Analysis – Nagrath Kothari

Information obtained from receiving end circle diagram :

a) Rating of reactive power compensating equipment

b) Maximum receiving end power $P_r max$.

c) Line losses.

d) Sending end voltage.

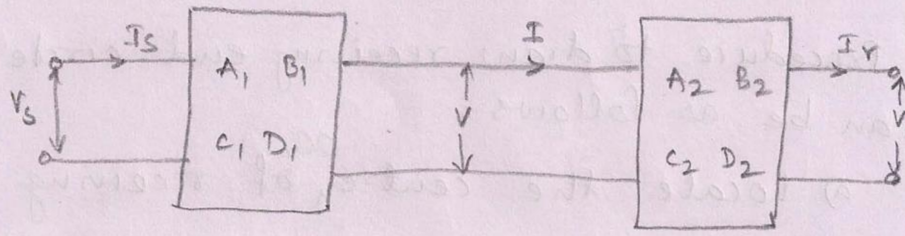
e) Voltage regulation and efficiency of the line

(4 Marks)
(1 Mark each)

3) Overall ABCD constants for two transmission lines connected in series :

Let the constants of two transmission line networks be A_1, B_1, C_1, D_1 and A_2, B_2, C_2, D_2

which are connected in series.



— 1 Mark

The net constants of the system can be found as follows:

$$V = D_1 V_s - B_1 I_s \quad \text{—— (1)}$$

$$I = -C_1 V_s + A_1 I_s \quad \text{—— (2)}$$ (1 Mark.)

and

$$V = A_2 V_r + B_2 I_r \quad \text{—— (3)}$$

$$I = C_2 V_r + D_2 I_r \quad \text{—— (4)}$$

From ~~equations (1) & (4)~~ above equations we get

$$D_1 V_s - B_1 I_s = A_2 V_r + B_2 I_r. \quad \text{—— (5)}$$

$$-C_1 V_s + A_1 I_s = C_2 V_r + D_2 I_r \quad \text{—— (6)}$$ (2 Marks)

Multiplying equation (5) by A_1 and (6) by B_1 and adding the resulting equations we get

$$(A_1 D_1 - B_1 C_1) V_s = (A_1 A_2 + B_1 C_2) V_r + (A_1 B_2 + B_1 D_2) I_r \quad \text{—— (7)}$$

Multiplying equation (5) by C_1 and (6) by D_1 and adding resulting equations.

(2 Marks)

$$(A_1 D_1 - B_1 C_1) I_s = (A_2 C_1 + C_2 D_1) V_r + (B_2 C_1 + D_1 D_2) I_r \quad \text{—— (8)}.$$

Since $A_1 D_1 - B_1 C_1 = 1$ the constants of the two networks are

$$A = A_1 A_2 + B_1 C_2$$

$$B = A_1 B_2 + B_1 D_2$$

$$C = A_2 C_1 + C_2 D_1$$

(1/2 Mark each 2 Mark).

$D_1 = B_2C_1 + D_1D_2$

Q.6 Attempt any four

1) Data given

diameter $d = 2cm$.

spacing between conductor $= 2.5 m = D$.

radius $= 2/_1 = 1cm$. — 1 Mark

capacitance of 3ϕ line is given by

$$C_{ab} = \frac{0.0242}{\log D/r} \qquad \text{— 1 Mark}$$

$$= \frac{0.0242}{\log(2.5/1\times10^{-2})}$$

$$= \cancel{60}\ \cancel{0.6}\ 6.08\times10^{-2}$$

— 1 Mark

$Cab|_{pn} =$ 608 μF/km.

$Cab\ |_{pn} = 608 \times 100 \times 10^{-6} = 608\times10^{-4}$ F

$= \cancel{608}$ 60.8 μF.

— 1 Mark.

Capacitance line to neutral

$$C_{an} = \frac{1}{2} Cab = \frac{1}{2}\times 60.8 = 30.4 \ \mu F.$$

2). Effect of resistance on efficiency:

The resistance of transmission line conductors is the most important cause of power loss in a transmission line. The power loss is given by equation

$D_1 = B_2C_1 + D_1D_2$

Q.6 Attempt any four

1) Data given

diameter $d = 2cm$.

spacing between conductor $= 2.5\ m = D$.

radius $= 2/_1 = 1cm$. — 1 Mark

Capacitance of 3ϕ line is given by

$$C_{ab} = \frac{0.0242}{\log D/r} \quad \text{— 1 Mark}$$

$$= \frac{0.0242}{\log(2.5/1\times10^{-2})}$$

$$= \cancel{60}\ \cancel{0.6}\ 6.08\times10^{-2}$$

— 1 Mark

$C_{ab}|_{ph} = 608\ \mu F/km$.

$C_{ab}|_{ph} = 608\times100\times10^{-6} = 608\times10^{-4}\ F$

$= \cancel{608}\ 60.8\ \mu F$.

— 1 Mark.

Capacitance line to neutral

$$C_{an} = \frac{1}{2}C_{ab} = \frac{1}{2}\times60.8 = 30.4\ \mu F.$$

2). Effect of resistance on efficiency:

The resistance of transmission line conductors is the most important cause of power loss in a transmission line. The power loss is given by equation

$P = I^2 R$ Watt

In transmission line major part of ~~losses~~ total losses is power loss i.e. I^2R. Therefore the amount of resistance of conductor will decide the amount of current and therefore the power loss. ~~The amount~~

As Resistance is inversly propotional to current $R \propto \frac{1}{I}$, more the resistance less will be current flowing and the decrease in losses. The efficiency of transmission line depends upon ~~output~~ losses as

$$\eta = \frac{o/p}{o/p + losses}$$

Therefore more the resistance of transmission line more the losses and lesser will be efficiency of transmission line and vice versa.

(2 Marks each)

* Effect of resistance on voltage regulation.

Voltage regulation of the transmission line is given by

% voltage regulation = ~~NL No load V_R = Full loa~~

$$= \frac{\text{No load } V_R - \text{Full load } V_R}{\text{Full load } V_R} \times 100.$$

$$= \cancel{IR\cos\phi_R} \frac{V_S - V_R}{V_R} \times 100.$$

$$= \cancel{\frac{IR\cos\phi_R + IX_L\sin\phi_R}{V_R} \times 100}.$$

$$= \frac{\sqrt{(V_r \cos\phi_r + IR)^2 + (V_r \sin\phi_r + I X_L)^2} - V_R}{V_R} \times 100.$$

Here amount of Vs depends upon current resistance and reactance of line.

Therefore change in value of resistance will change the value of current as well as sending end voltage Vs. Therefore it will affect on voltage regulation of the line.

(2 Marks)

3) Condition for ~~Pmax~~: Prmax:

The expression for Receiving end active Power Pr is given as

$$P_r = \frac{|V_s||V_r|}{|B|}\cos(\beta-\delta) - \frac{|A||V_r|^2}{|B|}\cos(\beta-\alpha) \quad \text{--- (1)}.$$

~~Mark~~

For ~~obt~~ deriving maximum value of Pr derivating above equation w.r.t δ we get

$$\frac{dP_r}{d\delta} = \frac{d}{d\delta}\left[\frac{|V_s||V_r|}{|B|}\cos(\beta-\delta) - \left|\frac{A}{B}\right| |V_r|^2 \cos(\beta-\alpha)\right]$$

$$= \left[\frac{|V_s||V_r|}{|B|}\sin(\beta-\delta)\right](-1) - 0.$$

$$= -\frac{|V_s||V_r|}{|B|}\sin(\beta-\delta) \quad \text{--- (2)}.$$

Equating above expression to zero we get Prmax

$$-\frac{|V_s||V_r|}{|B|}\sin(\beta-\delta)=0$$

$$\therefore \sin(\beta-\delta)=0$$

$$\therefore \beta-\delta=\sin^{-1}(0)$$

$$\beta-\delta=0$$

$$\therefore \beta=\delta$$

Therefore at $\beta=\delta$ we get the maximum power P_r max.

(01 Mark for each step)

4) Methods of reactive power Compansation:

For compansation of reactive power following methods are adopted.

i) static compansation: It consists of shunt capaciters, shunt reactors and series capacitors.

shunt capacitors are small banks of capacitors arranged in 3-phase star or delta. They have to be switched on at times of peak loads and switched off at times of light loads.

shunt reactors are used to abscrb the lagging vars generated by line during light load conditions. The inducter may be coreless type or gagged core type.

ii) Synchronous compansators: It is essentially a synchronous motor with no mechanical output. They are usually salient pole design. It delivers lagging vars when its excitation is large and delivers leading vars when excitation is small.

iii) Tap changing ~~Control by~~ transformers: Transformers are provided with taps on windings to adjust transformation ratio. Tap changing, by altering the in-phase component of the system voltage, affects the distribution of vars in a system and may be used to control the flow of reactive power.

iv) Regulating transformer: A special type of transformer designed for small adjustments of voltage is known as regulating transformer. The MVA rating of regulating transformer is quite small and it can be used to change the voltage at a point by small amount. It can be brought into the circuit by closure of relay whose operation can be controlled by system voltage or system current. A regulating transformer can be used for voltage magnitude control and reactive power control.

(1 Mark each method)

5) Advantages of generalised circuit representation:
A transmission line is represented in generalised circuit form gives following advantages

a) Any type of transmission line can be represented in a generalized circuit form.

b). Complicated circuits are represented in simpler form.

c) Performance of transmission line canbe easily studied.

d) Sending end voltage, current & p.f. canbe ~~directed~~ determined.

e). Efficiency and regulation of transmission line can be easily determined.

~~5th~~. (1 Mark each)

6). Effect of temperature on transmission line resistance:

Generally transmission line conductors are metals like copper, aluminium ~~et~~ The resistance of metals increases with increase in temperature. since the value of ρ is given at a specific temperature and line operates at a higher temperature, the actual resistance is higher than the value found by equation → 01 Mark

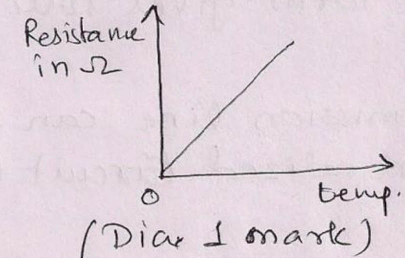
$$R_t = R_0(1 + \alpha_0 t).$$

where R_t = Resistance at $t°C$

R_0 = Resistance at $0°C$

α_0 = temp. Coefficient of resistance at $0°C$ → (01 Mark).

For small changes in temperature, the resistance increases linearly with temperature. ~~and resistance~~



(Diar 1 mark)

The temperature of conductor increases due to heat, losses and atmospheric conditions. Also it decreases due to atmospheric condition-which affects the line resistance. (1 mark)