Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1) A) Attempt any three of the following: **12M**

a) Explain the role of a power system engineer in operation of power system.

(Any 4 point 1M for each point)

Note: Any other relevant point shall be considered.

Ans.

i. For operation of the power system he has to plan for generation of electricity where, when and by using what fuel.
ii. He has to plan for expansion of the existing grid system and also for new grid system.
iii. He coordinated operation of a vast and complex power network, so as to achieve a high degree of economy and reliability.
iv. He has to be involved in constructional task of great magnitude both in generation and transmission.
v. He has to solve problem of power shortages.
vi. He has to evolve strategies for energy conservation and load management.
vii. For solving the power system problems he has to develop new method.

b) What is proximity effect? State the factors on which it depends.

(Statement 2M & factors ½M for each)

Ans.

When the alternating current is flowing through a conductor alternating magnetic flux is generate surrounding the conductor. This magnetic flux associates with the neighboring conductor and induce emf which opposes current through the conductor. This phenomenon is considered as rise in resistance of conductor. This complete phenomenon is called as, "proximity effect".

Factors affecting proximity effect:

1. Conductor size (diameter of conductor)
2. Frequency of supply current.
3. Distance between conductors.
4. Permeability of conductor material

c) Explain the concept of circle diagram.

Ans. Circle diagram:

Complex power supplied at sending end & at receiving end can be calculated by line equations. Same calculations can be carried out graphically.

- Locus of complex power is a circle. Circles are convenient to draw & circle diagrams are useful aid to visualize the load flow over a transmission line
- Locus of complex power is a circle drawn from tip of constant phasor as a centre& with radius equal to constant magnitude of second vector ……………………..**(2mark)**

Sending end complex power can be given by

$S_S = |D/B|\ |VS|^2 < \beta - \alpha - |V_S||V_R| / |B| < \beta + \delta$

The centre of sending end circle is located at the tip of phasor $|D/B|\ ||V_S|^2 < \beta - \alpha$ drawing OC_S from positive MW axis.

The radius of sending end circle is drawn with $|V_S||V_R| / |B|$ from centre CS……(**1 mark)**

Similarly receiving end complex power can be given by

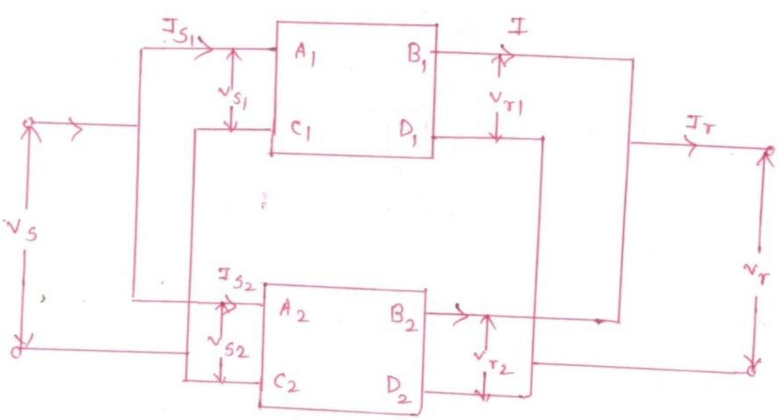
$S_R = |V_S||V_R| / |B| <(\beta - \delta) - |A| / |B|\ |V_R|^2 < (\beta - \alpha)$

Centre of sending end circle is located at the tip of phasor $- |A| / |B|\ |V_R|^2 < (\beta - \alpha)$

The radius of receiving end circle is drawn with |VS||VR| / |B| from centre……..**(1mark)**

d) Derive generalized circuit constants of two networks connected in parallel.

Ans.



(1 Mark)

The above fig show the two network in parallel, for deriving this consider the reciprocal networks writing the equations for the terminal conditions.

We get,

$V_{S1} = V_{S2} = V_S$ and $V_{r1} = V_{r2} = V_r$

Also $I_r = I_{r_1} + I_{r_2}$

$V_S = A_1 V_r + B_1 I_{r_1} \ldots\ldots\ldots\ldots\ldots\ldots..(i)$

$V_S = A_2 V_r + B_2 I_{r_2} \ldots\ldots\ldots\ldots\ldots\ldots..(ii)$…………both (i) and (ii) for………***(1 Mark)***

Multiplying eq. (i) and (ii) by B_2, B_1 respectively and adding, we get

$$(B_1 + B_2)V_s = (A_1B_2 + A_2B_1)V_r + B_1B_2(I_{r_1} + I_{r_2})$$

$$V_S = \frac{(A_1B_2 + A_2B_1)}{B_1 + B_2}V_r + \frac{B_1B_2}{B_1 + B_2}(I_{r_1} + I_{r_2})$$

$$V_S = \frac{(A_1B_2 + A_2B_1)}{B_1 + B_2}V_r + \frac{B_1B_2}{B_1 + B_2}I_r - - - - (iii)$$

GCE for resultant Generalized network can be expressed as,

$$V_s = AV_r + BI_r - - - - - (iv)$$
$$I_s = CV_r + DI_r - - - - - (iv)$$

Comparing eq. (iii) and (iv) we get,

$$A = \frac{(A_1B_2 + A_2B_1)}{B_1 + B_2}, \& B = \frac{B_1B_2}{B_1 + B_2} - - - - - (v)$$

Since transmission line is a symmetrical network,

A=D=$\frac{(A_1B_2+A_2B_1)}{B_1+B_2}$=$\frac{(D_1B_2+D_2B_1)}{B_1+B_2}$------(Vi)--***(1 Mark)***

Now,

$$IS_1 = C_1V_R + D_1I_{R1}$$
$$IS_2 = C_2V_R + D_1I_{R2}$$
$$\therefore IS = IS_1 + IS_2 = (C_1 + C_2)V_R + D_1I_{R1} + D_2I_{R2} - - - (i)$$

$$from = (i) I_{R1} = \frac{V_S - A_1V_R}{B_1} \text{and} I_{R2} = \frac{V_S - A_2V_R}{B_2}$$

$$\therefore IS = (C_1C_2)V_R + \frac{D_1V_s - A_1D_1V_R}{B_1} + \frac{D_2V_s - A_2D_2V_R}{B_2}$$

$$= \left(C_1 + C_2 - \frac{A_1 D_1}{B_1} - \frac{A_2 D_2}{B_2}\right) V_R + \frac{D_1}{B_1} + \frac{D_2}{B_2} V_s$$

$$Subssituting the value of V_s$$

$$= \left(C_1 + C_2 - \frac{A_1 D_1}{B_1} - \frac{A_2 D_2}{B_2}\right) V_R + \left(\frac{D_1}{B_1} + \frac{D_2}{B_2}\right)\left(\frac{A_1 B_2 + A_2 B_1}{B_1 + B_2}\right) V_R + \left(\frac{D_1}{B_1} + \frac{D_2}{B_2}\right)\left(\frac{B_1 B_2}{B_1 + B_2}\right) I_R$$

Comparing with $I_s$eqn.iv and simplifying C……

$$C = C_1 + C_2 - \frac{A_1 D_1}{B_1} - \frac{A_2 D_2}{B_2} + \left(\frac{D_1}{B_1} + \frac{D_2}{B_2}\right)\left(\frac{A_1 B_2 + A_2 B_1}{B_1 + B_2}\right)$$

$$= C_1 C_2 - \frac{A_1 D_1}{B_1} - \frac{A_2 D_2}{B_2} + \frac{(D_1 B_2 + D_2 B_1)(A_1 B_2 + A_2 B_1)}{B_1 B_2 (B_1 + B_2)}$$

$$\therefore C_1 + C_2 - \left(\frac{A_1 D_1 + A_2 D_2 - A_1 D_2 - A_2 D_1}{B_1 + B_2}\right)$$

$$C = C_1 + C_2 + \frac{(A_1 - A_2)(D_1 - D_2)}{B_1 + B_2} - - - - - - - - - - - - \quad (\mathbf{1\ Mark})$$

Q.1) B) Attempt any one of the following: **6M**

a) Explain the concept of self G.M.D. and mutual G.M.D. in the calculation of transmission line inductance.

Ans.

$$L_A = 2 \times 10^{-7} In \frac{[(D_{11'}...D_{1j'}...D_{1m'})...(D_{i1'}...D_{ij'}...D_{im'})...(D_{n1'}...D_{nj'}...D_{nm'})]^{1/m'n}}{[(D_{11}...D_{1i}...D_{1n})...(D_{i1}...D_{ii}...D_{in})...(D_{n1}...D_{ni}...D_{nm})]^{1/n^2}} H/m$$

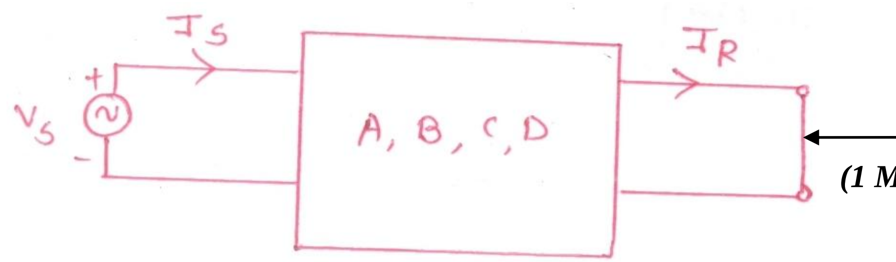
(2 Marks)

GMD: The numerator of the argument of the logarithm in above Equation is the *m'n*th root of the *m'n* terms, which are the products of all possible mutual distances from the n filaments of conductor A to m' filaments of conductor B. It is called *mutual geometric mean distance* (mutual GMD between conductor A and B and abbreviated as $D_{m.}$(***2 Marks)***
Similarly,

GMR: The denominator of the argument of the logarithm in above Equation is the $n^2 th$ root of n^2 product terms (n sets of n product terms each). Each set of n product term pertains to a filament and consist of r' (D_{ii}) for that filament and $(n-1)$ distances from that filament to every other filament in conductor A. The denominator is defined as the *self-geometric mean distance* (self GMD) of conductor A, and is abbreviated as D_{sA}. Sometimes, self GMD is also called *geometric mean radius* (GMR). ***(2 Marks)***

b) For a generalized circuit power prove that AD – BC = 1.

Ans.

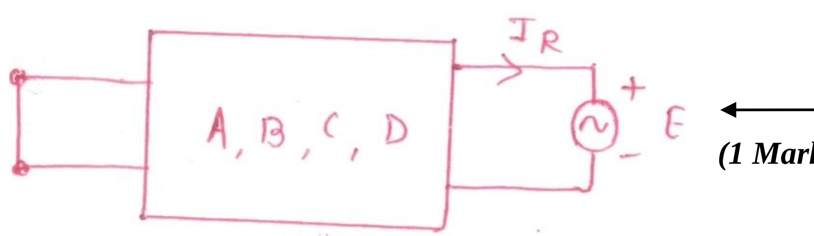


(1 Mark)

Consider fig where two terminal pair N/W with parameters A, B, C & D is connected to an ideal voltage source with zero internal impedance at one end and other end is S.C.

The equation is $V_s=E=0+BI_R$

Or $I_R= E/B$ ---------- (i) **……………………………………………….*(1 Mark)***



(1 Mark)

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

$\therefore 0 = AE + BI_R$--------- (ii)

Since line is a linear passive bilateral &

$I_S= -I_R= CE + DI_R$---------- (iii)

Eliminating IR from equation (ii) & (iii)

$I_R = - AE/B$

$-I_R = CE + D (-AE/B)$------- (iv)

From equation (i) IR= E/B put in equation (iv)

$-E/B = CE + D (-AE/B)$

$- 1/ B = C – DA/B$

- 1/ ~~B~~ = C – DA/~~B~~

$\therefore AD – BC =1$

(3Mark)

Q.2) Attempt any two of the following: 16M

a) A single 3-phase line operated at 50Hz is arranged as shown in Fig No.1. The conductor diameter is 0.6 cm. Find the inductance and capacitance per km. The line is regularly transposed.

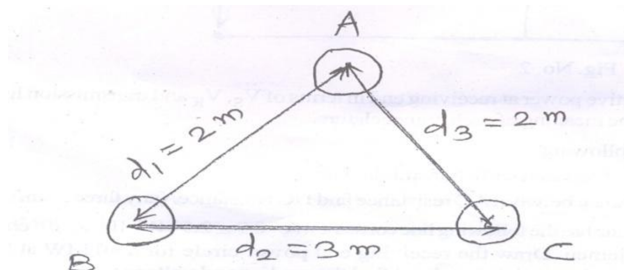


Fig No. 1

Ans. For calculating inductance:

$r^1 = 0.7788 \text{ X } 0.3 \text{ X } 10^{-2}$

$= 0.0023\text{m}$………………………………………………..***(1 Mark)***

$D_{eq} = \sqrt[3]{2 \text{ X } 2 \text{ X } 3} = \sqrt[3]{12} = 2.2894$………………………..***(1 Mark)***

$L = 2 \text{ X } 10^7 \log_e \frac{D_{eq}}{r'}$…………………………………………***(1 Mark)***

$= 2 \text{ X } 10^7 \log_e \frac{2.2894}{0.0023}$

$= 2 \text{ X } 10^7 \text{ X } 6.9031$…………………………………………***(1 Mark)***

$L = 1.380 \text{ X } 10^{-6} \text{ H/m}$

$= 1.380 \text{ X } 10^{-9} \text{ H/km}$……………………………………..***(1 Mark)***

For calculating capacitance

$r = 0.3 \text{ X } 10^{-2}\text{m}$

$C = \frac{\pi\, \varepsilon 0}{\log_e \frac{D_{eq}}{r}}$………………………………………………***(1 Mark)***

$= \frac{\pi \text{ X } 8.85 \text{ X } 10^{-12}}{\log_e \frac{2.2894}{3 \text{ X } 10^{-3}}}$…………………………………………***(1 Mark)***

$= \frac{\pi \text{ X } 8.85 \text{ X } 10^{-12}}{6.6374}$

$= 4.188 \text{ X } 10^{-12} \text{ F/m}$

$= 4.188 \text{ X } 10^{-15} \text{ F/km}$…………………………………………***(1 Mark)***

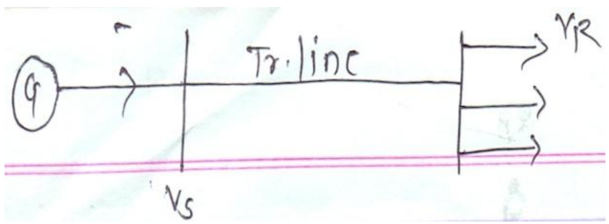
b) Derive the equation of a receiving end power circle diagram in terms of general circuit constants. Show how this diagram can be used to determine the maximum power that can be transmitted under given operating condition.

Ans.

Consider a single line diagram of 3∅ tr. Line i.e. having two bus system – sending end bus which is fed by generator and the receiving end bus which feeds the load.

Now from G C E S.

$$V_S = AV_R + BI_R$$



(1 Mark)

$$\therefore \ I_R = \frac{V_s}{B} - \frac{A}{B}V_R$$

$$\text{Let } V_R = |V_R|\angle 0 \quad V_S = |V_S|\angle\delta$$

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

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

$$= \frac{V_S}{B}\angle\delta - \beta - \frac{AV_R}{B}\angle\alpha - \beta$$

$$\therefore \ I_R^* = \frac{V_S}{B}\angle\beta - \delta - \frac{AV_R}{B}\angle\beta - \alpha$$

Let S_R betne complex power at the receiving end

$$\therefore \ S_R = V_R I_R^*$$

$$S_R = \frac{V_R V_S}{B}\angle\beta - \delta - \frac{AV_R^2}{B}\angle\beta - \alpha$$ ....***(1 Mark)***

$$= P_R + jQ_R$$

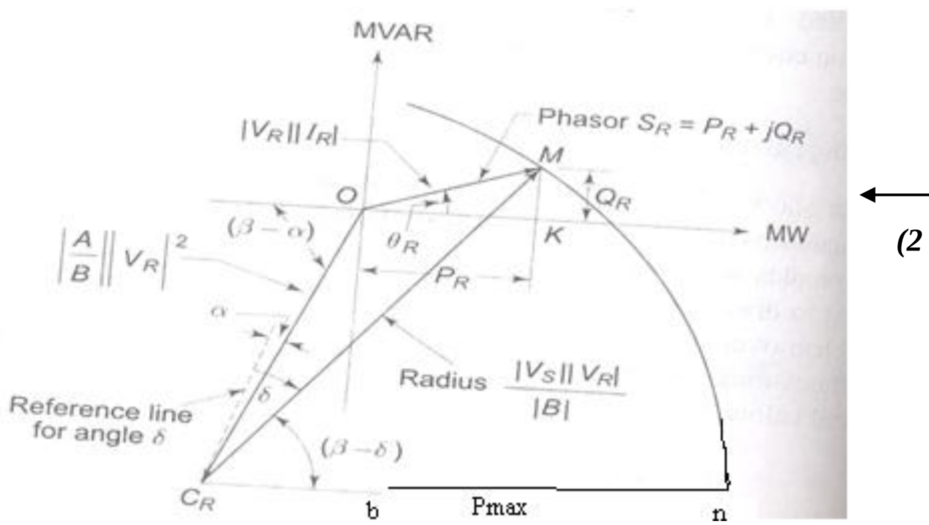
$$\text{Now } P_R = \frac{V_R V_S}{B}\cos(\beta - \delta) - \frac{AV_R^2}{B}\cos(\beta - \alpha)$$ ....***(1 Mark)***

The centre of receiving –end circle is located at the tip of the phasor.

$- \left|\frac{A}{B}\right| |V_R|^2 \ (\beta - \propto)$ ……………………………………*(1/2 Mark)*

In polar coordinates or in terms of rectangular coordinates, Horizontal coordinate of the centre

$= - \left|\frac{A}{B}\right| |V_R|^2 \ cos(\beta - \propto)$ MW…………………………*(1/2 Mark)*



(2 Mark)

Vertical coordinate of the centre

$= - \left|\frac{A}{B}\right| |V_R|^2 \ sin(\beta - \propto)$ MVAR

The radius of the receiving-end circle is

$\frac{|v_S||v_R|}{B}$ MVA

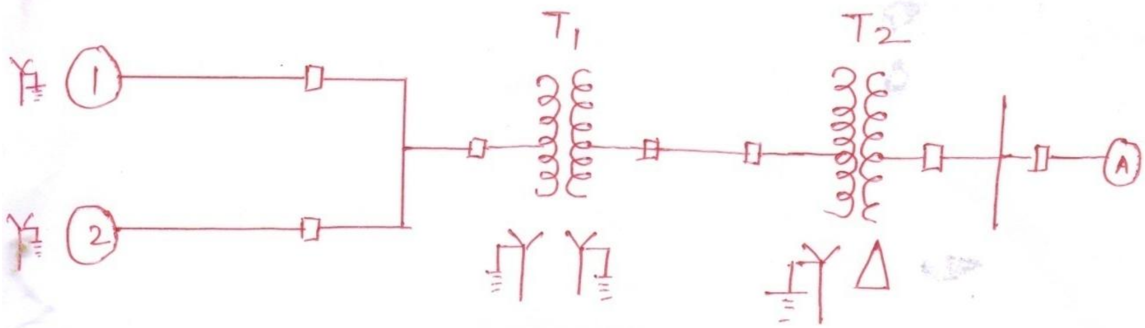
The receiving-end circle diagram is drawn. The centre is located by drawing OC_R at an angle$(\beta - \propto)$ in the positive direction from the negative MW-axis. From the centreC_R the receiving-end circle is drawn with the radius $|V_S||V_R|/|B|$. The operating point *M* is located on the circle by means of the received real power P_R.

- Extend the arc till it cuts extended line C_Rb. Now bn represents P_{max}. Determine P_{max} using the power scale (1cm = --MW). ……………………………..*(2 Mark)*

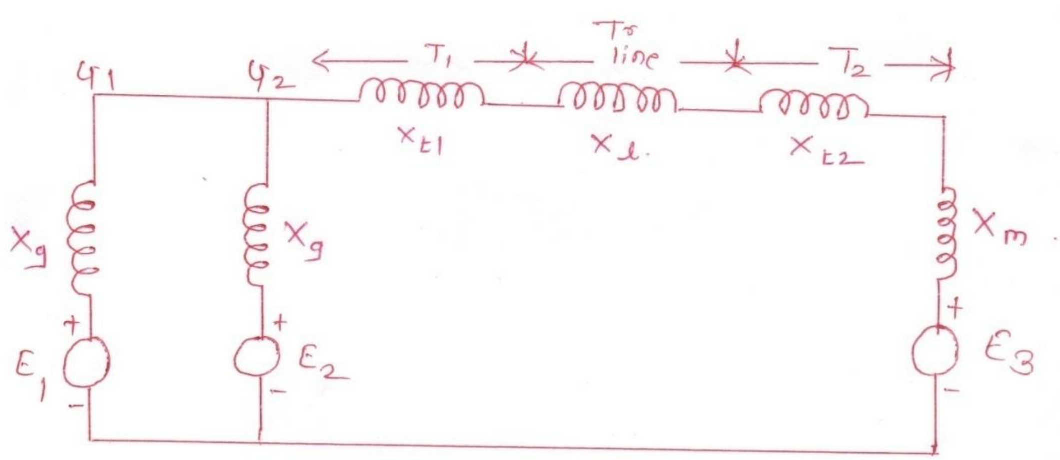
c) Draw a single line labeled diagram and reactance diagram showing the essential components of modern power system.

(Diagram of Single line diagram of simple power system 4M, Reactance diagram 4M)

Ans.



single line diagram of simple power system.



Reactance Diagram.

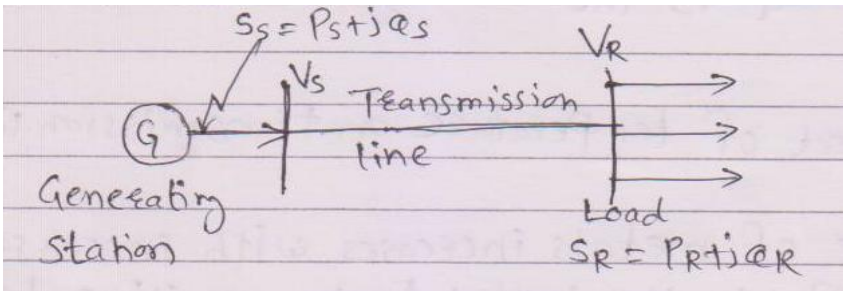
1, 2 → Generator.

A → motor.

Q.3) Attempt any four of the following: 16M

a) Obtain the equation for complex power at sending end of transmission line.

Ans:



(1 Mark)

Figure shows the single line diagram of a 3∅ transmission line.

- In the figure two bus system having the sending end bus which is fed by the generator and the receiving end bus which feeds the load.
- S_R is the complex power of the receiving end and S_S is the complex power at the sending end.
- Using the current I_S can be expressed in terms of V_R and V_S as:

$I_S = \frac{D}{B}V_S - \frac{1}{B}V_R = \frac{A}{B}V_S - \frac{1}{B}V_R$.......(i)......................***(1 Mark)***

Let, $V_R = |V_R|\angle 0, V_S = |V_S| \angle 0,\ D = A = |A| \angle \propto,\ B = |B| \angle B$

Then $I_S = \frac{|A||V_S|}{B}(\angle \propto + \delta - \beta) - \frac{|V_R|}{B} - \angle B$

The conjugates of I_S are

$Is^* = \frac{|A||V_S|}{B}(\angle \beta - \propto - \delta) - \frac{|V_R|}{B} \angle B$......................***(1 Mark)***

The complex power/phase at the sending end are

$$S_S = P_S + jas = V_S I_S^*$$

$$S_S = |V_S| \angle \delta \left[\frac{|A||V_S|}{|B|}(\beta \angle \propto - \delta) - \frac{|V_R|}{|B|} \angle B\right]$$

$S_S = \frac{|A||V_S|^2}{|B|} \angle(\beta - \propto) - \frac{|V_R||v_S|}{|B|} \angle(\beta + \delta)$............***(1 Mark)***

The above equation is the sending end side complex power.

b) A 3-phase overhead transmission line has a total series impedance per phase of 200 $\angle 80^0$ohms and total shunt admittance of 0.0013 $\angle$ 90^{0}siemen per phase. Determine the value of A and B constants.
(Any one method can be used)

Ans.

Z ph = 200 $\angle 80^0\ \Omega$, Y = 0.0013 $\angle \mathbf{90^0}$ S/ph

A = ?, B = ?

Since line type is not mention. We assume the line

(i) Nominal π

$$A = 1 + \frac{YZ}{2} = 1 + \frac{(0.0013\angle 90^0)(200\angle 80^0)}{2\angle 0}$$

$$= 1 + \frac{0.26\angle 170}{2\angle 0}$$

$$= 1 + 0.13\angle 170^0 = 1 + (-0.128 + j0.0225)$$

= 0.872 + j0.0225

= 0.8722$\angle$1.47^0……………………………………..*(2 Mark)*

B = Z = 200$\angle$80$^0\Omega$……………………………......*(2 Mark)*

OR

(ii) For nominal T

$A = 1 + \frac{YZ}{2}$ = 0.8722$\angle$ 1.47^0 (similar to π)……………….………......*(2 Mark)*

$B = Z\left(1 + \frac{YZ}{4}\right)$ = 200$\angle$80^0$\left(1 + \frac{0.0013\angle 90}{4\angle 0}\right)$

= 200$\angle$80^0 (1 + 0.065$\angle$170)

= (200$\angle$ 80^0) (-0.936 + j 0.011)

= (200$\angle$ 80^0) (0.936 $\angle$0.673)

B = 187.2 $\angle$80.673 Ω……………………………………………......*(2 Mark)*

c) Explain the effect of temperature on transmission line resistance.
(4 points 4M)

Ans.

The resistance of conducting materials increases with increase in temperature. That is material used in transmission line having positive temperature coefficient.
The resistance of insulators increases with decrease in temperature. They are having negative temperature coefficient.

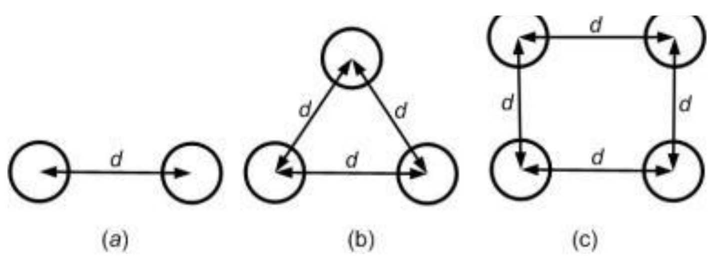
The resistance of alloy's increase or decrease with change in temperature.

1. As I increases temperature of line increases and there by R of line also increases.
2. As R increases, I^2R losses increases and in turn temperature of line increases.
3. Over all losses in line increases and efficiency decreases.
4. As temperature of line increases breakdown voltage of surrounding air increases. Therefore corona loss also increases.

d) Explain what is a bundled conductor and why is it used.
(Explanation 2M, uses 2M)

Ans.

Bundled conductors consist of several parallel cables connected at intervals by spacers, often in a cylindrical configuration. The optimum number of conductors depends on the current rating .It is a group of conductors
For transmission of power across long distances, high voltage transmission is employed. Transmission higher than 132 kV poses some problems, such as the corona effect, which cause significant power loss and interference with communication circuits. In order to reduce this corona effect, it is preferable to use more than one conductor per phase, or bundled conductors



a-Duplex
b- triplex
c- quadraplex

Advantages of use of bundled conductor

- Bundled conductors reduce the voltage gradient in the vicinity of the line. This reduces the possibility of corona discharge.

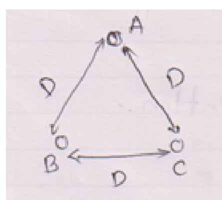
- An improvement in the transmission efficiency as loss due to corona effect is countered.
- Bundled conductor lines will have higher capacitance in comparison with single lines. Thus, they will have higher charging currents, which help in improving power factor.
- A bundle conductor also has lower reactance, compared to a single conductor.
- Additionally, bundled conductors cool themselves more efficiently due to the increased surface area of the conductors, further reducing line losses.
- The increased GMR reduces line reactance and inductance.

e) Calculate the capacitance of a 100km long 3-phasae, 50Hz overhead transmission line consisting of three conductors, each of diameter 2 cm spaced 2.5 m at the corners of equilateral triangle.

Ans:

l = 100km, d = 2cm, $r = \frac{2}{2} = 1 \text{ X } 10^{-2}$ m, D = 2.5m

∴∴



$C/ph = \frac{\pi\varepsilon 0}{\ln\frac{D}{r}}$ …… ……………………………….**(1 *Mark*)**

$= \frac{8.85 \text{ X } 10^{-12}}{5.521} = 5.035 \text{ X } 10^{-12}$F/m……………………………….**(1 *Mark*)**

C/ph/km = $5.035 \text{ X } 10^{-12} \text{ X } 1000$

= $5.035 \text{ X } 10^{-9}$ F/km……………………………………………………**(1 *Mark*)**

For l = 100km

C/ph = $5.035 \text{ X } 10^{-9} \text{ X } 100$
= $5.035 \text{ X } 10^{-7}$ F ………………………………………….……………**(1 *Mark*)**

Q.4) a) Attempt any three of the following: 12M

a) Write the equation for converting the per unit impedance expressed in one base to another. List the two advantages of per unit computation.
(Formula 2M, Advantages each 1M)

Ans: Per unit impedance referred to new base:

$$= \begin{bmatrix}\text{per unit impedance} \\ \text{referred to old base}\end{bmatrix} \text{ X } \left[\frac{\text{Base KV old}}{\text{Base KV new}}\right] \text{ X } \left[\frac{\text{Base KVA new}}{\text{Base KVA old}}\right]$$

$Z_{new} = Z_{old} \text{ X } \frac{KV_{old}}{KV_{new}} \text{ X } \frac{KVA_{new}}{KVA_{old}}$

Advantages:

1. Manufactures usually specify the impedance values of equipments in per unit of the equipments rating. If the data is not available it is easier to assume its per unit value than its numerical value.
2. When expressed in per unit, system parameters tend to fall in relatively narrow numerical ranges. Therefore, any data can be identified.
3. Per unit data representation gives important information about relative magnitudes.
4. Power systems contain a large no. of transformers. The ahmic value of impedance as referred to secondary is different from the value as referred to primary. The per unit values are same on the two side of the transformer.
5. The transformer connections in 3∅ circuits do not affect the per unit value of impedance although the base voltages on the two sides do depend on the connections.

b) Obtain the expression for flux linkages of an isolated current carrying conductor due to internal flux only.

Ans:

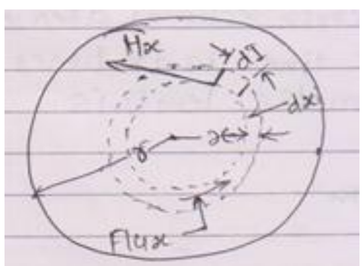


Figure Shows the cross-section of a long cylindrical conductor of radius r carrying a sinusoidal current of r.m.s. value I. The magnetic lines of flux are concentric with the conductor.

Let, the field intensity at a distance x meters from the centre of the conductor be Hx.

Since the field is symmetrical, Hx is constant for all point equidistant from the centre. If Ix is the current enclosed upto distances x, then……………………………….***(1Mark)***

$\oint Hx.dl = Ix$……………………………….(i)

or $2\pi x\, Hx = Ix$…………………………….(ii)

For finding the value of Ix, the current is assumed to be uniformly distributed over the cross-section of the conductor. Then

$Ix = \left(\frac{\pi x^2}{\pi r^2}\right) I = \left(\frac{x^2}{r^2}\right) I$ …………..(iii) ……………..***(1Mark)***

From equation (ii) & (iii)

$\mathrm{H}x = \frac{\mathrm{I}x}{2\pi r^2}$ AT/m……………….(iv)

The flux density B$x$at a distance x from the centre is

Bx =μH$x = \frac{\mu \mathrm{I}x}{2\pi r^2}\omega$b/m^2………(v)………………..***(1 Mark)***

For finding flux linkages, a tabular element of thickness dx may be considered. The cross-sectional area of the element, normal to the flux line is dx times the axial length. The flux per meter length is

$d\emptyset = \frac{\mu \mathrm{I}x}{2\pi r^2}dx$ ωb/m

A flux line positioned at x links with $\frac{\pi x^2}{\pi r^2}$ of the total current. Thus the flux linkage for flux d∅ is given by

$d\Psi = \frac{\pi x^2}{\pi r^2} . d\emptyset$

$= \frac{\mu I x^3}{2\pi r^4}$ d$x\omega$b-T/m……………..(vi)

For computing the total internal flux linkages Ψ int we integrate equation (vi) from The centre to surface of the conductor.

Ψ int $= \int_0^r \frac{\mu \mathrm{I} x^3}{2\pi r^4}dx = \frac{\mu \mathrm{I}}{8\pi}$ ωb-T/m…………………***(1 Mark)***

c) A simple circuit of Fig. No. 2 consists of single shunt admittance. Find the A, B, C, D constants from fundamental formulae.

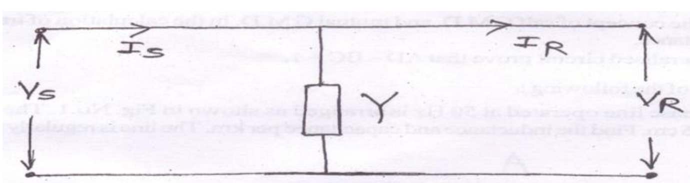
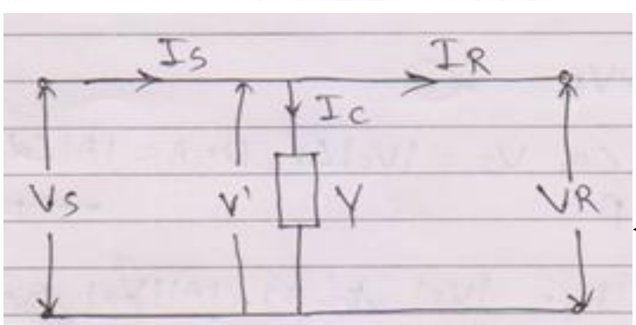


Fig. No. 2

Ans.



(1 Mark)

For the above circuit

$V^1 = V_R$……………………….(i)

$I_c = V^1Y = V_RY$………………(ii)……………………..*(1 Mark)*

$I_S = I_R + I_C = I_R + YV_R$

$I_S = YV_R + I_R$…………………(iii)……………………..*(1 Mark)*

$V_S = V^1 = V_R$ ………………..(iv)

$\therefore A = 1, \ B = 0, \ C = Y, \ D = 1$………………………..*(1 Mark)*

OR

For nominal T circuit, GCC are given as

$A = D = 1 + \frac{YZ}{2}$……………………………………………*(1 Mark)*

$C = Y$…………………………………………………*(1 Mark)*

$B = Z\left(1 + \frac{YZ}{4}\right)$ ………………………………………*(1 Mark)*

put $Z = 0$

$A = 1, \ B = 0, \ C = Y, \ D = 1$………………………..*(1 Mark)*

d) Express real and reactive power at receiving end in terms of V_S, V_R and transmission line constants. Mention the meaning of each nomenclature.

Ans:

$P_R = \frac{|V_S||V_R|}{|B|}\cos(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta - \delta)$……………………….*(1$^{1/2}$ Mark)*

$Q_R = \frac{|V_S||V_R|}{|B|}\sin(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\sin(\beta - \delta)$……………………….*(1$^{1/2}$ Mark)*

Where P_R= real power in MW, Q_R = Reactive power in MVAR
V_S = Sending end voltage per phase in KV
V_R = Receiving end voltage per phase in KV
δ = Power angle
A, B = Generalized Circuit Constant
(1 Mark)

Q.4) b) Attempt any one of the following: 6M

a) i) Write significance of capacitance in transmission line.
(Any 3 points 1M each)

Ans.

- The capacitance is uniformly distributed along the whole length of the line and may be regarded as a uniform series of capacitors connected between the conductors.
- When an alternating voltage is applied sinusoidal current called the charging current which is drawn even when the line is open circuit at the far end.
- The line capacitance being proportional to its length, the charging current is negligible for lines less than 100km long. For longer lines the capacitance becomes increasingly important and significant for performance of 1 transmission line.
- Line capacitance creates a voltage drop in the line due to its reactance value.
- In EHV lines capacitance is responsible for boosting the voltage level under no load condition.
- C depends on length and voltage of line. Hence, classification of line is done based on length and voltage.
- Effect of C depends on length and voltage and hence they are neglected in short transmission line.
- Effect of C on performance of line is considerable in medium transmission line. Hence assumed to be lumped at 1 or 2 points in the line.
- Effect of C on performance of transmission line is high. So, it is considered to be distributed uniformly throughout the length of the line.

ii) Explain the difference between AC resistance and DC resistance. (any three point).
(Each 1M)

Ans.

AC resistance	DC resistance
Rac = Resistance offered for flow of AC Current	Rdc = Resistance offered for flow of DC Current
Rac = Effective resistance = Average cu loss in conductor (watts)/ I^2rms	Rdc = Ohmic resistance = ρ l/a
AC resistance is higher than DC resistance	DC resistance is lower than AC resistance
Rac is higher as skin effect & proximity effect is present for AC current	Rdc is lower as DC current is uniformly distributed i.e. skin effect & proximity effect is absent for DC current.

b) A 132 kv three phase line has the following line constants: A = 0.9, $\angle 2.5^0$, B = 100 $\angle 70^0$ ohm, C = 0.0006 $\angle 80^0$siemen. Draw the receiving end power circle for a 40 MW at 0.8 power factor lagging at the receiving end and find the sending end voltage.

Ans.

Co-ordinates of Centre 'C':

X-coordinate $= \frac{-AVR^2}{B}\cos(\beta-\alpha)$

$= \frac{-(0.9)(132)^2}{100}\cos(70-2.5)$

$= -156.816 \cos(67.5)$

$= -60.01$MW……………………………………………………(1 Mark)

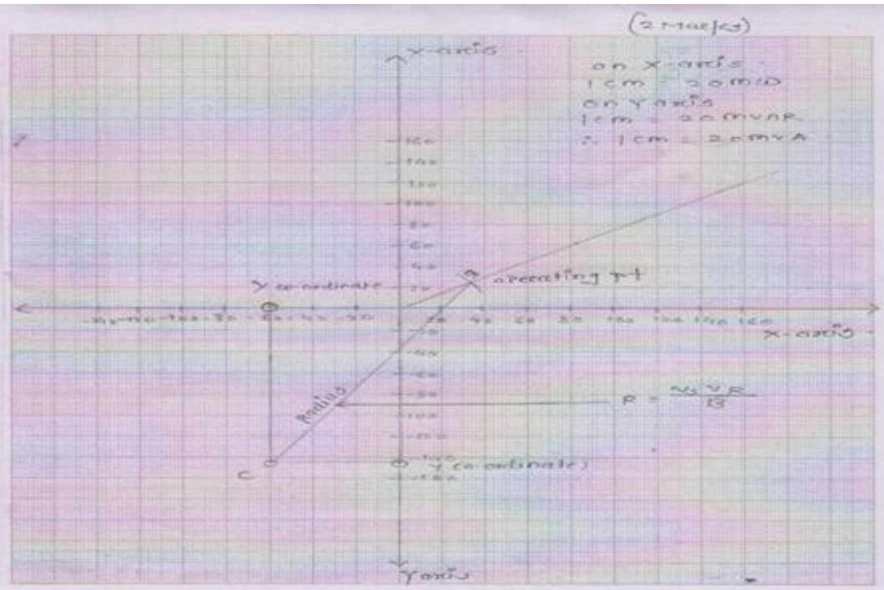
Y-coordinate $= \frac{-AVR^2}{B}\sin(\beta-\alpha)$

$= \frac{-(0.9)(132)^2}{100}\sin(70-2.5)$

$= -156.816 \sin(67.5)$

$= -144.87$ MVAR…………………………………………(1 Mark)

(2 Marks)



Radius R = CA= 9.7 * power scale

$\doteq$ 9.7* 20

= 194 MVA……………………………………(1Mark)

And…….Rradius $= \frac{V_S V_R}{B}$

$194 = \frac{V_S \times 132}{100}$

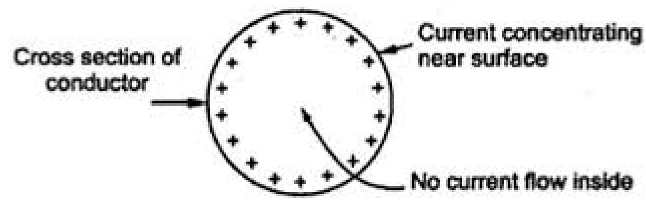
$V_S = 146.96$ kV………………………………………………(1 Mark)

Q.5) Attempt any two of the following: 16M

a) i) Explain skin effect. State different factors on which it depends.

Ans.

The distribution of current throughout the cross section of a conductor is uniform when DC is passing through it. But when AC is flowing through a conductor, the current is non-uniformly distributed over the cross section in a manner that the current density is higher at the surface of the conductor compared to the current density at its center. This phenomenon is called skin effect.



(2 Marks)

Effects of Skin Effect:

It causes larger power loss for a given rms AC than the loss when same value of DC is flowing through the conductor. Consequently the effective conductor Skin effect depends on following resistance is more for AC then for DC.

Skin effect depends on factors: (***2 Mark)***

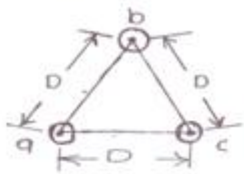
- Current
- Permeability of material
- Frequency
- Conductor diameter
- Diameter
- Material of conductor

ii) Derive the expression for inductance of three phase line (single circuit) composed of solid conductors with symmetrical spacing.

Ans.

Inductance of a 3φ line with Symmetrical spacing :-

Figure shows a 3 phase line with conductors a, b and c spaced at corners of an equilateral triangle, each side is 'D'. The conductors each of radius 'r'



The three-conductors occupy the corners of an equilateral triangle. If the 3φ system, then $\bar{I}_a$, $\bar{I}_b$ and $\bar{I}_c$ are displaced by 120° and $\bar{I}_a + \bar{I}_b + \bar{I}_c = 0$.

(1 Mark)

$$\psi_a = 2\times10^{-7}\left[I_a\cdot\ln\left(\frac{1}{r_a'}\right) + I_b\cdot\ln\left(\frac{1}{D}\right) + I_c\ln\left(\frac{1}{D}\right)\right]\frac{wb.T}{m}$$

$$= 2\times10^{-7}\left[I_a\cdot\ln\left(\frac{1}{r_a'}\right) - I_a\cdot\ln\left(\frac{1}{D}\right)\right]\frac{wb.T}{m}$$

$$\because I_b + I_c = -I_a$$

$$= 2\times10^{-7}\cdot I_a\cdot\ln\frac{\left\{\frac{1}{r_a'}\right\}}{\left\{\frac{1}{D}\right\}}\frac{wbT}{m} \quad \because I_b + I_c = -I_a$$

$$= 2\times10^{-7}\cdot I_a\cdot\ln\left\{\frac{\frac{1}{r_a'}}{\frac{1}{D}}\right\}\frac{wbT}{m}$$

$$= 2\times10^{-7}\cdot I_a\cdot\ln\left(\frac{D}{r_a'}\right)\frac{H}{m}$$

$$\therefore L_a = \frac{\psi_a}{I_a} = 2\times10^{-7}\ln\left(\frac{D}{r_a'}\right)\frac{H}{m}$$ ***(2 Mark)***

Inductance per conductor or inductance / phase.

$$L_a = 2\times10^{-7}\ \ln\left(\frac{D}{r'}\right)\frac{H}{m}$$

$$\boxed{L_a = 0.2\ \ln\left(\frac{D}{r'}\right)\frac{mH}{km}}$$ ***(1 Mark)***

b) i) Write four advantages of generalized circuit representation.
(Any four points, 1M each)

Ans. Advantages of generalized circuit:

1. The generalized circuit equations are well suited to transmission lines. Hence for given any type of the transmission line (short, medium, long). The equation can be written by knowing the values of A B C D constants.
2. Just by knowing the total impedance and total admittance of the line the values of A B C D constants can be calculated.
3. By using the generalized circuit equations V_{RNL} can also be calculated.

$\therefore V_S = AV_R + BI_R$

i.e. when $I_R = 0$

$V_{RNL} = V_S/\ A$

Now the regulation of the line can be immediately calculated by

% regu = V_S / A– V_R / V_R x 100

4. Output power = $V_R\ I_R$ Cos ϕR 1ϕ ckt.

= # $V_R\ I_R$ Cos ϕR for 3ϕ ckt.

Output power = $V_S I_S$ Cos ϕS 1ϕ ckt.

= # $V_S\ I_S$ Cos ϕS for 3ϕ ckt.

$\therefore$ losses in the line = input – output

5. By calculating input and output power can be calculated.
6. Series circuit: when two lines are connected such that the output of the first line serves as output to the second line and the output of the second line is fed to the load, the two lines behave as to parts networks in cascade. Its ABCD constants can be obtain by using following matrix

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} A_1 & B_1 \\ C_1 & D_1 \end{vmatrix} \times \begin{vmatrix} A_2 & B_2 \\ C_2 & D_2 \end{vmatrix}$$

7. When to $t_r$lines are connected in parallel then the resultant two part network can be easily obtained by

$$A = \frac{A_1B_2 + A_2B_1}{B_1 + B_2}$$

$$B = \frac{B_1B_2}{B_1 + B_2}$$

$$D = \frac{D_1B_2 + D_2B_1}{B_1 + B_2}$$

$$C = C_1 + C_2 - \frac{(A_1 - A_{2)}(D_2 - D_1)}{B_1 + B_2}$$

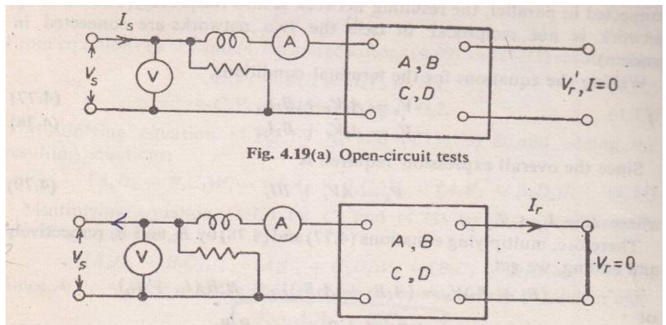
ii) Explain how ABCD constant are measured for a transmission line.

Ans.

Measurement of Generalized Circuit Constants can be done by conducting Open circuit and short circuit test.

If a transmission line is already erected, the constants can be measured by conducting the open circuit and short circuit test on the two ends of the line. Consider a transmission line and determine the impedances which are complex quantities. The magnitudes are obtained by ratio of the voltages and currents and the angle with the help of wattmeter reading……………………………………………………………………..(*1 Mark)*

The connection diagram is shown below:



(*1 Mark)*

Diagram: Short-circuit tests

The test is conducted on sending end side.

Now, $V_s = AV_R$ + BI_R------- (1)

$I_s =$ CV_R + DI_R ------- (1)

From these = n. s. under o. c test

We to get, as I_R = CV_R

$\therefore Z_{so} = \frac{V_s}{I_s} = \frac{AV_R}{CV_R} = \frac{A}{C}$

-sending end impedance with receiving end open ckted.

From S.C. test as V_R = 0

V_s = B I_R×I_s = D I_R

$\therefore Z_{ss} = \frac{V_s}{I_s} = \frac{B}{D}$

-sending end impedance with receiving end s.c.ed ………………….*(1 Mark)*

Note – These impedances $Z_{ss,} Z_{so}$ are complex quantities, the magnitudes are obtained by the ratio of the voltages and currents. The angle is obtained with the help of wattmeter.

Similarly the same tests can be named out on receiving end side.

∴ From o.c. test –

Generalized = O.C can be written

As V_R = D$V_s -$ BI_s

$I_R = -$ C$V_s +$ AI_s

Since the direction of sending end current according to the network whereas while performing the tests on receiving end side, the direction of the current will be leaving the network, therefore these equations become

V_R = D$V_s +$ BI_s× (-I_R) = $-(V_s + A(-I_s)$

$\therefore -I_R = -$C$V_s - AI_s$

I_R = C$V_s + AI_s$

From O. C. test, I_s = O

$Z_{ro} = \frac{V_R}{I_R} = \frac{DV_S}{CV_S} = \frac{D}{C}$

$-$receving end impedance with sending end open clcted.

From S.C. test, V_S=O

$Z_{rs} = \frac{V_R}{I_R} = \frac{BI_S}{AI_S} = \frac{B}{A}$

−receving end impedance with sending end s.ced

Now,

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

$= \frac{1}{AC}[ASAD - BC = 1]$

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

$\therefore A = \sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ -------------(a)

$Z_{rs} = \frac{B}{A}$

or $B = AZ_{rs} = Z_{rs}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ ----------------(b)

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

$\therefore C = \frac{A}{Z_{so}} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ --------------(c)

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

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

$= Z_{ro}\sqrt{\frac{1}{(Z_{ro}-Z_{rs})Z_{so}}}$-----------(d)

If $Z_{ro} = Z_{so}$ we get A = D for symmetric network ……..………..*(1 Mark)*

c) A220 Kv, 50Hz, 3-phase overhead transmission line delivers a load of 75,000kW at 0.8 p.f. lagging at the receiving end and has the following constants.
A = D = 0.9∠ 0.6^0; B = 153.2 ∠ 84.6^0 ohm and C = 0.0012∠90^0 S calculate the sending end parameters.

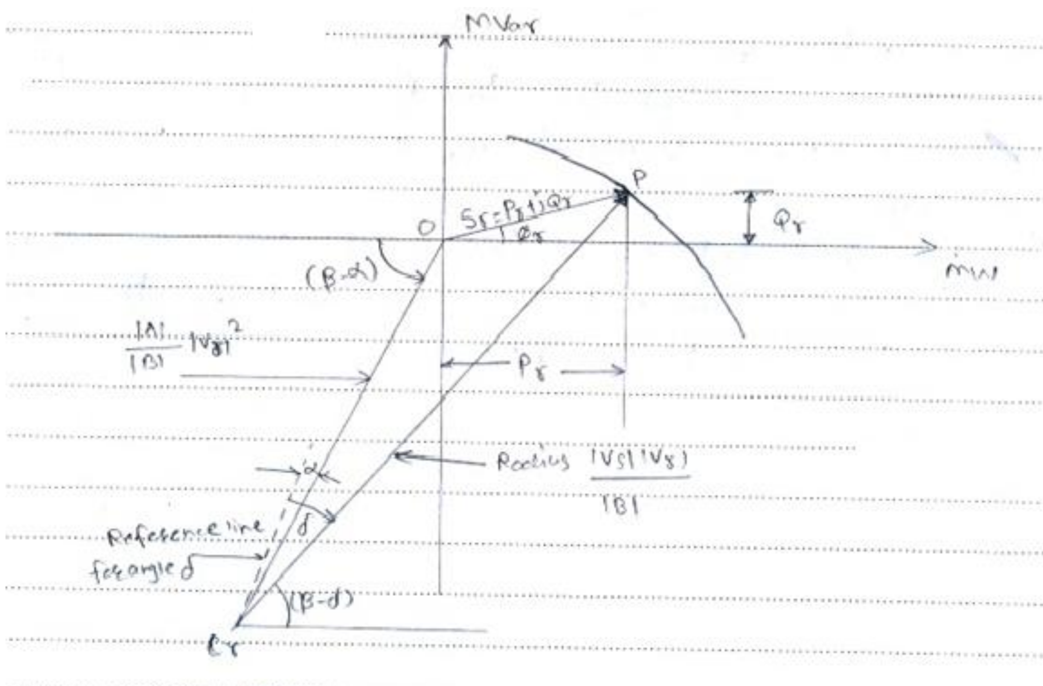
Ans.

$$given: V_R = 220KV, A = 0.9\angle 0.6, B = 153.2\angle 84.6$$
$$load = 75Mw, 0.8lag$$
$$load = \sqrt{3}V_R I_R \cos\emptyset_R = 75 \times 10^6 = \sqrt{3}\, 220 \times 10^3 \times I_R \times 0.8$$
$$\therefore I_R = 246.03\ Amp \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(\mathbf{1M})$$
$$\emptyset_R = \cos^{-1} 0.8 = 36.86 \dots\dots\dots\dots\dots\dots.(\mathbf{1M})$$
$$V_S = AV_R + BI_R \dots\dots\dots(\mathbf{1M})$$
$$= 0.9\angle 0.6 \times 220 \times 10^3\angle 0 + 153.2\angle 84.6 \times 246.03\angle - 36.86 \dots.(\mathbf{1M})$$
$$V_s = 225.33\angle 7.64KV \dots\dots\dots\dots\dots(\mathbf{1M})$$
$$I_S = CV_R + DI_R \dots\dots\dots(\mathbf{1M})$$
$$= 0.0012\angle 90 \times 220 \times 10^3\angle 0 + 0.9\angle 0.6 \times 246.03\angle - 36.86 \dots.(\mathbf{1M})$$
$$I_s = 222.66\angle 36.69\ Amp \dots\dots\dots\dots\dots(\mathbf{1M})$$

Q.6) Attempt any four of the following: 16M

a) Explain the stepwise procedure for drawing receiving end circle diagram.
(2M --- diagram & 2M—steps)

Ans. Steps for drawing Receiving End Circle diagram:-



$$S_r = \frac{-|A||V_r|^2}{|B|}\angle(\beta-\alpha) + \frac{|V_s||V_r|}{|B|}\angle(\beta-\delta)$$

Step-1: Draw the X-Y plane in which plane X represents the active power (MW) & axis-y-represents the Reactive power (MVA).

$$\frac{|A|}{|B|}|V_r|^2$$

Step-2 To draw the center of the circle take the distance equal to & angle equal to (β-α) & draw the line in third quadrant & locate the point 'n'.

Step-3 To draw the circle the radius is taken equal to $|V_s|\,|V_r|$ & draw a circle in 1st quadrant.

$|B|$

Step-4) The operating point p on the circle is located by the amount of real power delivered to the load i.e.pr

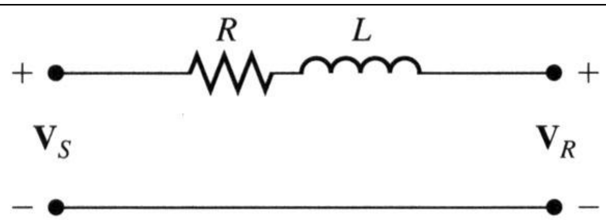
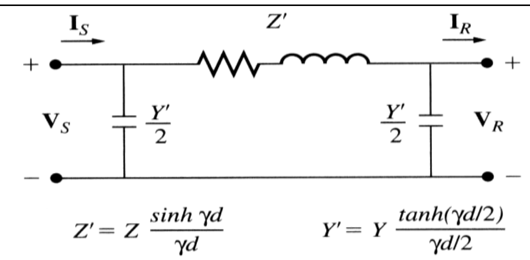
Step-5) Joint the 'op'& draw the line parallel from point P to Y-axis. 'op' represents the true power

$S_r=P_r+jQ_r$& the corresponding value of Q_r can be read from the diagram.

Step-6) Draw the reference line w.r.t. 'on' at an angle α. The power angle is the angle between the ref. line shown & phasor 'np'.

b) Compare short and long transmission line (any four point).
(Any 4points -1M each)

Ans..

Short transmission line	**long transmission line**
Length shorter than 80 km	Length 250 Kms or above
Shunt Capacitance effect is very small	Capacitance effect is more
Equivalent circuit consist resistance & inductance	Equivalent circuit consist resistance, capacitance & inductance
Shunt Capacitance neglected in performance calculation	Capacitance must be considered in performance calculation
Ferranti effect is not observed	Ferranti effect is not observed
	
Overhead transmission lines shorter than 80 km (50 miles) can be modeled as a series resistance and inductance, since the shunt capacitance can be neglected over short distances.	For long lines, it is not accurate enough to approximate the shunt admittance by two constant capacitors at either end of the line. Instead, both the shunt capacitance and the series impedance must be treated as distributed quantities;
A = 1, B = Z, C = 0 and D = 1	A = cosh δl B = Z_C sinh δl C = sinh δl ⁄ Z_C D = cosh δl

c) Explain the effect of inductance on performance of the transmission line.
(Effect of inductance parameter 1M for each)

Ans.

- voltage drop in the series impedance (IX_l)
- due to lagging p.f. V_S is always greater than $V_{R,}$, hence regulation is always positive.
- As p.f. increases regulation also increases.

- The voltage drop is the same in the series impedance of the line in all case, but because of the different power factor the voltage drop is added to the receiving end voltage a different angle in each case.

d) Write four advantages of circle diagram.
(Any 4 advantage ----1M each)

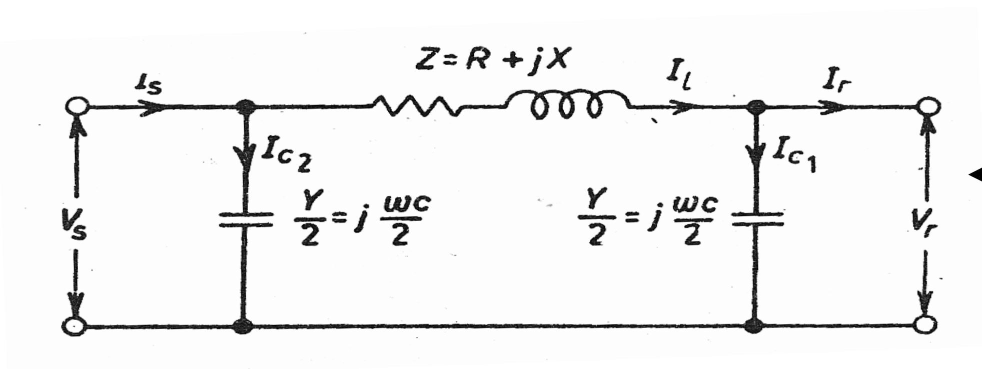
Ans. Following are the advantages of circle diagram:

1. Simple method to represent transmission line.
2. Easy to understand parameters of line.
3. Maximum power transferred can by easily determined.
4. The transmission line loss can be determined.
5. Less steps for calculation or analytical solution.
6. Rating of compensating equipment can be directly determined.
7. The torque angle δ can be determined.
8. The transmission line performance can be studied at any load condition.
9. The nature of compensation of reactive power can be analyzed.
10. Any type of transmission line can be represented into circle diagram

e) Draw and explain medium transmission line.

Ans. Medium transmission line is a transmission line whose length is greater than 150km and less than 300km.
Voltage level is greater than 20KV and less than 100KV. ***(1 Mark)***

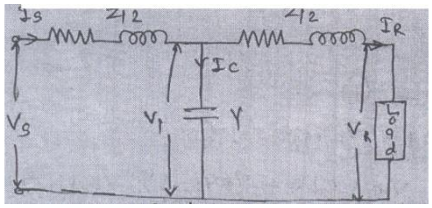
- **Nominal π representation of transmission line:**



(1 Mark)

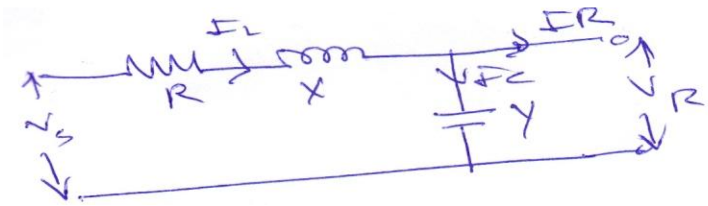
- **Nominal T representation.**

Figure shows the nominal T method with capacitance is connected at centre of line, the line resistance and reactance is halfly tempered on both side



(1 Mark)

- **End condenser representation**:



(1 Mark)