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 judgement 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)

i. **Write any four advantages of "per unit system". *(Any four 1-mark each)***

1. Manufacturers usually specify the impedance values of equipments in per unit of equipment rating.
2. When expressed in P.U., system parameters tend to fall in relatively narrow numerical ranges.
3. P. U. data representation yields important information about relative magnitudes.
4. The transformer connections in 3-ph circuits do not affect the per unit value impedance though base voltages on two sides do not depend upon connections.
5. If base values are selected properly the P.U. impedance is same on both sides of transformers.

ii. If $\bar{V} = 66\angle -10^0$ kV and $\bar{I} = 10\angle -30^0$amp, then find active power, apparent power and reactive power, using complex power equation.

$\boldsymbol{given}: \bar{V} = 66\angle -10KV, \bar{I} = 10\angle -30amp$

$complex\ power = VI^* \ldots\ldots\ldots\ldots (1M)$

$= 66\angle -10 \times 10\angle +30 = 660\angle 20KVA \ldots\ldots\ldots (\frac{1}{2}M)$

$\therefore apperent\ power = 660KVA \ldots\ldots. (\frac{1}{2}M)$

$active\ power = 660\cos 20 = 620.197KW \ldots\ldots.. (1M)$

$Reactive\ power = 660 \times \sin 20 = 225.733KVAR \ldots\ldots.. (1M)$

iii. Write effect of resistance of transmission line on voltages regulation and efficiency.

- The voltage regulation of the line is ratio of voltage drop online to the rated voltage
- i.e.$V.R. = \frac{I_r R\cos\phi_r + I_r \sin\phi_r}{V_r}$
- Due to increase in the resistance the voltage drop increases & hence regulation also increases. **(2Mark)**
- The line resistance will cause the line copper loss due to this copper loss the line transmission efficiency reduces.
- More the line resistance less is the efficiency & less is the line resistance less is the line efficiency. **(2Mark)**

iv. Define is A, B, C, D constants referred to transmission line.

GCE equation $V_S=AV_R+BI_R$ & $I_S=CV_R+DI_R$

Definition of Generalized Circuit Constant A,B,C& D ---

1) $A = \frac{V_S}{V_R}$; $I_R = O$

It is the ratio of the voltage impressed at the sending end to the voltage at the receiving end when the receiving end is open circuited. It is a dimension less quantity.

2) $B = \frac{V_S}{I_R}$; $V_R = O$

It is the volt impressed at the sending end to current of receiving end when receiving end is short circuited. It is known as Transfer impedance. It's unit is in ohms.

3) $C = \frac{I_S}{V_R}$; $I_R = O$

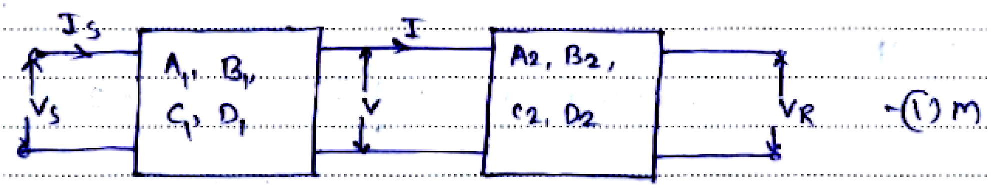
It is defined as the ratio sending end current to the receiving end voltage when receiving end is open circuited. It is known as Transfer admittance and it's unit mho.

4) $D = \frac{I_S}{I_R}$; $V_R = O$

It is the ratio of amperes impressed at the sending end to the ampere at the receiving end when the receiving end is short circuited. It is a pare quantity.

b) Attempt any ONE of the following:

i. If A_1, B_1, C_1, D_1 and A_2, B_2, C_2, D_2 are ABCD constants of two circuits. Find overall ABCD constants of resultant circuit, if these two circuits are connected in series.



Two n/w are said to be connected in series when the o/p of one n/w is connected to the i/p of other n/w.

Let the constants of these n/w be A1, B1, C1, D1 & A2, B2, C2, D2 which are connected in series as show in fig.

These two n/w could be two transmission line or a transformer connected in to transmission line from equation of $V_R=DV_S-BI_S$ &

$I_R=-CV_S+DI_S$

$\therefore V=D_1V_S-B_1I_S$ (1)

$I= -C_1V_S+A_1I_S$ (2)

& $V=A_2V_R+B_2I_R$ (3)

$I=C_2V_R+D_2I_R$ (4)

From equation (1) & (3) & equation (2) & (4) respectively.

$A_1 V_S - B_1 I_S = A_2 V_R + B_2 I_R$ — (5)
$-C_1 V_S + A_1 I_S = C_2 V_R + D_2 I_R$ — (6) — (1) m

multiply eqn (5) by A_1 & (6) by B_1 & adding the eqn.

$(A_1 D_1 - B_1 C_1) V_S + (-B_1 A_1 + B_1 A_1) I_S = (A_1 A_2 + B_1 C_2) V_R + (A_1 B_2 + B_1 D_2) I_R$

$(A_1 D_1 - B_1 C_1) V_S = (A_1 A_2 + B_1 C_2) V_R + (A_1 B_2 + B_1 D_2) I_R$ — (7) — (1) m

multiply eqn (5) by C_1 & (6) by D_1 & add

$(C_1 D_1 - D_1 C_1) V_S + (-B_1 C_1 + A_1 D_1) I_S = (A_2 C_1 + C_2 D_1) V_R + (B_2 C_1 + D_2 D_1) I_R$

$(A_1 D_1 - B_1 C_1) I_S = (A_2 C_1 + C_2 D_1) V_R + (B_2 C_1 + D_2 D_1) I_R$ — (8) (1) m

Since $A_1 D_1 - B_1 C_1 = 1$ ∴ from eqn (7)

∴ $V_S = (A_1 A_2 + B_1 C_2) V_R + (A_1 B_2 + B_1 D_2) I_R$ — (9)

from eqn (8) — (1) m

$I_S = (A_2 C_1 + C_2 D_1) V_R + (B_2 C_1 + D_2 D_1) I_R$ — (10)

but $V_S = A V_R + B I_R$ & — (11)

$I_S = C V_R + D I_R$ — (12)

from eqn (9), (10), (11) & (12) — (1) m

$A = A_1 A_2 + B_1 C_2$

$B = A_1 B_2 + B_1 D_2$ $D = B_2 C_1 + D_2 D_1$.

$C = A_2 C_1 + C_2 D_1$

ii. Explain each of the following terms self GMD, mutual GMD, significance of inductance in transmission line.

The concept of self GMD & Mutual GMD (2 marks for each definition.)

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

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 meandistance* (self GMD) of conductor A, and is abbreviated as D_{sA}. Sometimes, self GMD is also called *geometric mean radius* Similarly,

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.

Significance of inductance in transmission line :2mark (any 2,1 mark for each.)

- inductance causes voltage drop (IX_l) which affect regulation
- 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.
- Transmission line capacity depends on inductance

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

a.

i. Explain advantage of generalized circuit representation of transmission line in power system..(Any four points ,1 mark each)

Advantages of generalized circuit:

1. The generalized circuit equation 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 = $V_R I_R \cos \phi R$ 1ϕckt.
   = # $V_R I_R \cos \phi R$ for 3 ϕckt.
   Output power = $V_S I_S \cos \phi S$ 1ϕckt.
   = # $V_S I_S \cos \phi S$ for 3ϕckt.
   $\therefore$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 what circle diagram is in power system.

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)**

- 3ϕ sending end complex power can be given by
  $S_S = |D/B|\ |V_S|^2 < \beta - \alpha - |V_S||V_R|\ / |B| < \beta + \delta$
  The centre of sending end circle is located at the tip of phasor $|D/B|\ 1V_S|^2 < \beta - \alpha$ 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 3ϕreceiving 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 **----- (1 mark)**

b) Calculate inductanctive reactance per km. for the arrangement of three phase conductors shown below in figure No.1.
Write assumption made during the calculations.

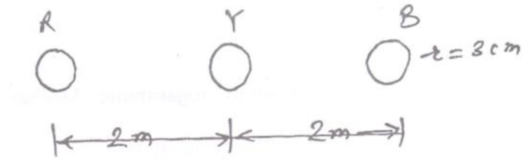


Fig. No. 1

$$L_x = L_y = L_B = 2 \times 10^{-7} \log_e \frac{D_{eq}}{r^1}$$
$$D_{eq} = \sqrt[3]{D_{RY} D_{RB} D_{BR}} = \sqrt[3]{2 \times 2 \times 4} = 2.519m$$
$$r^1 = 0.7788r = 0.7788 \times (3 \times 10^{-2}) = 0.023m \dots\dots (1M)$$

$$L_x = L_y = L_B = 2 \times 10^{-7} \log_e (\frac{2.519}{0.023}) \dots\dots (1M)$$

$$= 9.3922 \times 10^{-7} \frac{H}{M} = 0.939 \times 10^{-6}\ \frac{H}{M} = 0.936 \frac{mH}{Km} \dots\dots (1M)$$

$$inductive\ reactahnce X_L = 2\pi f L = 2 \times \pi \times 50 \times o.936 = 294.053\ \frac{m\Omega}{Km} \dots (1M).$$
$$\boldsymbol{assumption\ made\ durihng\ calculation} \dots\dots\dots. (\boldsymbol{4M, each\ 1M})$$

1. Lines are transposed.
2. Fluxes at distance equal to are more than ($D+r_2$) from the centre or conductor ‘A’ links net zero current.

3. External flux from (D-r_2) to (D-r_2) links a current whose magnitude reduces progressively from I to zero along this distance.
4. Fluxes beyond r_1 and less than (D-r_2) links all the current. I in conductor-A.

c) A 220kV 3 phase line has following parameters A=0.9∠1.5^{0,} B=100∠75^{0}. If the receiving end voltage is 220 kV, determine-

i. Sending end voltage if a load of 150MW at 0.85 lagging of connected at the receiving end

$$given: V_R = 220KV, A = 0.9\angle 1.5, B = 100\angle 75$$
$$load = 150Mw, 0.85lag$$
$$load = \sqrt{3}V_R I_R \cos\emptyset_R = 150\times 10^6 = \sqrt{3}\,220\times 10^3\times I_R\times 0.85$$
$$\therefore I_R = 463.11Amp \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(\mathbf{1M})$$
$$\emptyset_R = \cos^{-1} 0.85 = 31.79 \ldots\ldots\ldots\ldots\ldots\ldots.(\mathbf{1M})$$
$$V_S = AV_R + BI_R = 0.9\angle 1.5\times 220\times 10^3\angle 0 + 100\angle 75\times 463.11\angle -31.79 \ldots.(\mathbf{1M})$$
$$V_s = 220.42\angle -0.038KV \ldots\ldots\ldots\ldots\ldots(\mathbf{1M})$$

ii. Maximum power that can be delivered if sending end voltage is 230kV and receiving end voltage is220 kV.

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For max receiving end power condition is $\boldsymbol{B-\delta=0} \ldots\ldots\ldots\ldots(\mathbf{1M})$

$$\boldsymbol{P_{R_{max}} = \frac{V_S V_R}{B} - \frac{AV_R^2}{B}\cos(\beta-\alpha)} \ldots\ldots\ldots.(\mathbf{1M})$$

$$\boldsymbol{= \frac{230\times 220}{100} - \frac{0.9\times(220)^2}{100}\cos(75-1.5)} \ldots\ldots.(\mathbf{1M})$$

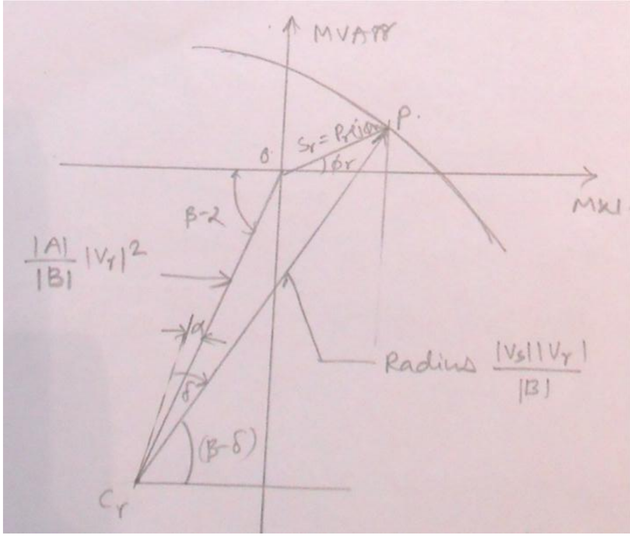
$$\boldsymbol{P_{R_{max}} = 382.283Mw} \ldots\ldots\ldots\ldots\ldots\ldots(\mathbf{1M})$$

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

a) If base voltage is 600 V and base apparent power is 100 kVA then find base impedance and base current.

$$Given\ base\ voltage = 600V = 0.6KV$$
$$base\ apparent\ power = 100KVA$$
$$\boldsymbol{Base\ current} = \frac{Base\ KVA}{\sqrt{3}\,(Base\ KV)} = \frac{100KVA}{\sqrt{3}\times 0.6KV} = 96.22A \ldots\ldots\ldots.(\mathbf{2M})$$
$$\boldsymbol{Base\ impedance} = \frac{(Base\ KV)^2\times 1000}{(Base\ KV)} = \frac{(0.6)^2\times 1000}{100} = 3.6\Omega \ldots\ldots(\mathbf{2M})$$

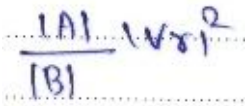
b) Along with diagram, write different steps for drawing receiving end circle diagram. (Labeled diagram 2M, 2Mexplanation)



The complex power at the receiving end of a line id given by

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

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



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 'c_r'.

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

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

c) Calculate inductance of a 3 phase line for the arrangement of conductors shown in figure No. 2 below. The conductor diameter is 0.6 cm.

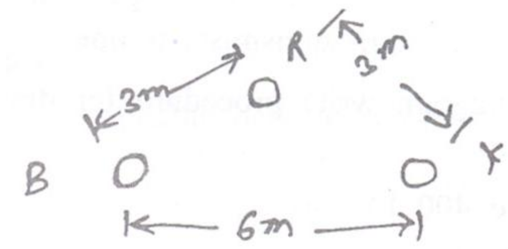


Fig. No. 2

$$The\ conductor\ diameter = 0.6cm$$

$$Radius\ r = \frac{0.6}{2} = 0.3cm = 0.3cm = 3 \times 10^{-3}m$$

$$mutual\ distance\ r^1 = 3 \times 10^{-3} \times 0.7788 = 2.33 \times 10^{-3}m \ldots\ldots (\boldsymbol{1M})$$

$$D_{RB} = D_{RY} = 3m\,, D_{BY} = 6cm.$$

$$the\ mutual\ GMD = D_m = \sqrt[B]{D_{RB}D_{RY}D_{BY}} = (3 \times 3 \times 6)^{\frac{1}{3}} = 3.78m = 0 \ldots . (\boldsymbol{1M})$$

$$Inductance = L = 0.4605 \log\frac{D_m}{r^1} = 1.478\frac{mH}{Km} \ldots . (\boldsymbol{2M})$$

d) A 220 kV transmission line has following generalized circuit constants A=0.75∠65^0, B=250∠65^0. Determine the power at unity power factor that can be received if the voltage at each end is maintained at 220 kV.

$$A = 0.75\angle 65^0 \quad B = 250\angle 65^0 \qquad V_r = 220kV \qquad V_s = 220kV$$

$$at\ unity\ p.f\ Q_r = 0$$

$$\therefore Q_r = \frac{|V_s||V_r|}{|B|}\sin(\beta - \delta) - \frac{|A||V_r|^2}{B}\sin(\beta - \alpha)$$

$$O = \frac{(220)(220)}{250}\sin(\beta - \delta)\frac{0.75}{250}(220)^2\sin(65 - 65) = 193.6\sin(\beta - \delta) - 123.80$$

$$take\ \alpha = 6.5\ instead\ of\ 65$$

$$\sin(\beta - \delta) = 0.639$$

$$(\beta - \delta) = 39.75 \ldots\ldots\ldots\ldots\ldots\ldots\ldots . (\boldsymbol{2M})$$

$$subsituting\ (\beta - \delta) = 39.65\ in\ equation\ of\ Pr$$

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

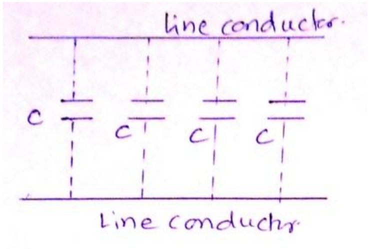
$$= \frac{(220)(220)}{250}cos(39.75) - \frac{0.75}{250}(220)^2\cos(65 - 65) = 148.84 - 75.86$$

$$P_r = 72.97MW\ at\ unity\ p.f \ldots\ldots\ldots\ldots . (\boldsymbol{2M})$$

Give marks for taking $\alpha = 65\ or\ assuming\ any\ value\ of\ \alpha$

e) Explain how capacitance is formed in transmission line. Also explain significance of capacitance in performance of transmission line.

- When any two conductors separated by an insulating material the capacitance is formed.
- Therefore when any two conductors of an overhead transmission line are separated by air which acts as an insulation, the capacitance is formed between the two overhead line conductors. The capacitance between the conductors is the charge per unit.



(2Marks)

➢ **significance of capacitance in performance of transmission line**

(2Marks)

- 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 line capacitance is responsible for boosting the voltage level under no load condition.

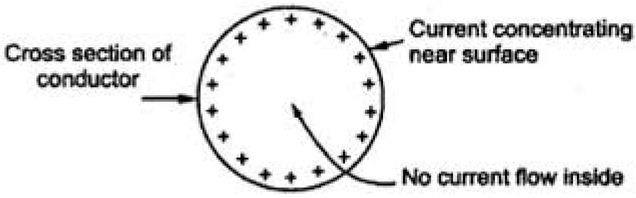
Q.4.

a) Attempt any Three of the following: (12M)

i. Explain skin effect and proximity effect referred to line conductors.

Skin Effect:

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.



Proximity effect

The alternating magnetic flux in a conductor cause by the current flowing in a neighboring conductor gives rise to circulating currents which cause an apparent increase in the resistance of a conductor. This phenomenon is called proximity effect.

OR

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”

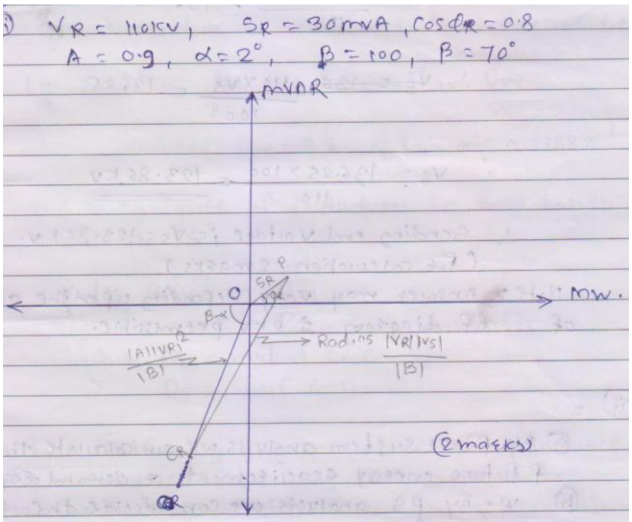
The proximity effect also result in non-uniform of current in the cross section of a conductor.

While considering skin effect it was assumed that is no other current carrying conductor near but when a current carrying conductor is nearby, its flux will link with the conductor under consideration and its effect to the nearer half of the conductor will be more than with the farther half.

If conductors carry in the opposite directions the magnetic fields set up will tend to cause an increase in the current density in the adjacent portions of the conductors while if the currents are in the same directions, the current density is increased in remote parts of the conductor.

ii. **A three phase 110kV transmission line delivers 30MVA at 0.8 pf lag. Draw receiving end circle diagram and find the sending end voltage. Given A=0.90$\angle 2^0$,B=100$\angle 70^0$**

Note: Answer may vary depending upon the accuracy of diagram$\pm 2KV$ *permissible*



The distance of centre OCR=$\frac{|A||V_R|^2}{|B|} = \frac{0.9\times 110^2}{100} 108.9MVA$

Take scale as 1cm=25MVA

$\therefore for\ 108.9MVA = 4.36$cm

$$also\angle\beta - \alpha = 70^0 - 2^0 = 68^0$$

Draw line OCR with angle68^0 & mag. 4.36cm now S_R=30MVA=1.2cm

$$\cos\emptyset_R = 0.8$$

$$\therefore \emptyset_R = 36.86^0$$

Draw line with angle $\emptyset_R = 36.86^0\ w.r.t + ve\ MW\ axis\ \&\ distance\ 1.2cm\ obtainpoint\ P.$

Now joint C_RP & measure it C_RP=5.45cm=136.25MVA the C_RP is Radius.

$$\therefore Radius\ C_RP = \frac{|V_R||V_S|}{|B|} = 13.25$$

$$\therefore \frac{110 \times V_S}{100} = 136.25$$

$$V_S = \frac{136.25 \times 100}{110} = 123.86KV$$

$$Sending\ end\ voltage\ is\ V_S = 123.86KV \ldots\ldots\ldots\ldots \boldsymbol{for\ calculation}\ (\mathbf{2}\ \boldsymbol{M})$$

iii. Explain the need of power system is analysis.
(1 Point 1M, 4M)

a. By power system analysis we can calculate the future energy requirement or demand requirement.
b. By PS analysis we can decide the source for generation.
c. We can calculate the pa value of different parameter to make calculations simple.
d. We can study the power system network for grid.
e. We can calculate the different parameter such as R, L &C for different line.
f. We can calculate the effect on transmission line skin effect, proximity effect.
g. We can calculate the how power is flowing in transmission line i.e. sending end and receiving end.
h. We calculate the losses in transmission line.
i. We can calculate the rating of compensation equipment to full fill the requirement of reactive power.

iv. Derive the conduction for maximum power at receiving end.

As the receive end side active power is given by,

$$P_R = \frac{|V_S||V_R|}{|B|}\cos(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta - \alpha) \ldots\ldots (\mathbf{1}\boldsymbol{M})$$

For max value differentiate above eq. w.r.t. 'δ' as V_S, V_R, A, B & α are constant.

$$\therefore \frac{dP_R}{d\delta} = \frac{d}{d\delta}\left[\frac{|V_S||V_R|}{|B|}\cos(\beta - \delta) - \frac{|A||V_R|^2}{|B|}\cos(\beta - \alpha)\right]$$

Equate this equation w.r.t. zero

$$\frac{dP_R}{d\delta} = \frac{|V_S||V_R|}{|B|}\frac{d}{d\delta}\cos(\beta - \delta) = 0 \ldots\ldots(\mathbf{1M})$$

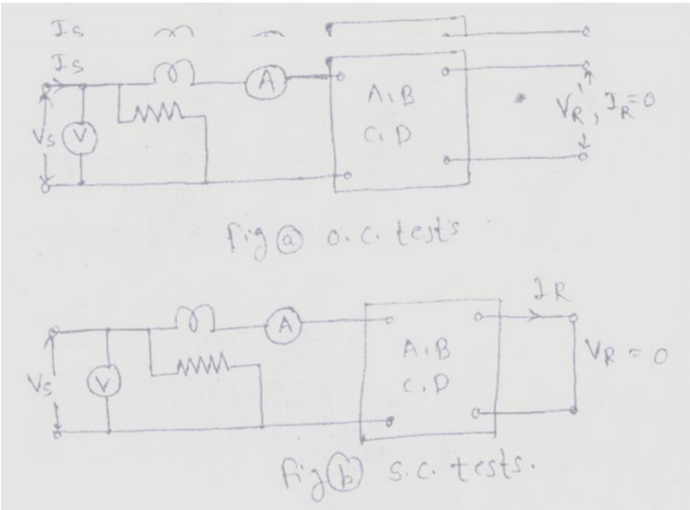
$$\sin(\beta - \delta) = 0$$

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

$$\beta = \delta \ldots\ldots(\mathbf{2M})$$

b) Attempt any one of the following:

i. Explain how a generalised circuit's constant of a transmission line is measured, which is connected in the system.



i. To find transmission like parameters the open circuit and short circuit tests at the two ends are done. The above fig a and fig b show the connection diagrams of o.c. and s.c. respectively.
Z_{SO} = Sending end impedance with receiving end open.
Z_{SS} = Sending end impedance with receiving end short.
Z_{R}o = Receiving end impedance with sending end open.
Z_{RS} = Receiving end impedance with sending end short.
ii. For making impedance measurement on sending end side, we use equation
$V_S = AV_{Rt}\ BI_R$ (1)
$I_S = CV_{Rt}\ DI_R$ (2)
Open circuit test, fig a
$V_S = I_S Z_{SO}$
$\therefore Z_{SO} = V_S / I_S = A / C$ (3) (from equation 1, 2 & fig a)

For short circuit test,
$V_R = 0$
$\therefore V_S = Is\ Z_{SS}$
$Z_{SS} = V_S / I_S = B / D$ (4) (From equation 1,2 and fig b)
The angle of complex quantities of impedance is calculated from wattmeter reading.
iii. To determine impedances on receiving end side, following equations are made use
$V_S = DV_S – BI_S$ (5)
$I_R = -CV_S + AI_S$ (6)

If we perform the test on receiving end side the directions of sending end current and receiving end current are reverse.

$\therefore V_R = DV_S - BI_S$ (7)

$-I_R = -CV_S - AI_S$

$I_R = CV_S + AI_S$ (8)

O.C. test on sending end $I_S = 0$

$\therefore Z_{RO} = V_R / I_R = D / C$ (9) (From 7 and 8)

S.C. test on sending end $V_S = 0$

$Z_{RS} = B / A$ (10) (From 7 and 8)

iv. From equation 9 and 10

$Z_{RO} - Z_{RS} = D /C - B /A = AD\text{-}BC / AC = 1 / AC$

$Z_{RO} - Z_{RS} / Z_{SO} = 1/AC \times C/A = 1/A^2$

$\therefore A = \sqrt{\frac{Z_{so}}{Z_{Ro}-Z_{Rs}}} \ldots\ldots.(11)$

Now, $Z_{RS} = B / A$

$\therefore B = A\, Z_{RS} = Z_{RS}\sqrt{\frac{Z_{so}}{Z_{Ro}-Z_{Rs}}} \ldots..(12)$

$Z_{SO} = A/C$

$\therefore C = A / Z_{SO} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{Ro}-Z_{Rs}}}$ (13)

$Z_{RO} = D/C$

$\therefore D = CZ_{RO} = \frac{Z_{Ro}}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{Ro}-Z_{Rs}}}$

$$= Z_{Rs} \times \sqrt{\frac{1}{Z_{so}(Z_{Ro} - Z_{Rs})}} \ldots\ldots(14)$$

For symmetric network $Z_{RO} = Z_{SO}$

$$\therefore D = A = \sqrt{\frac{Z_{so}}{Z_{Ro} - Z_{Rs}}}$$

ii. Explain difference between magnitude of inductance in solid conductor and magnitude of inductance in bundled conductor.

The magnitude of inductance in Solide conductor is

$L/m = 2\times10^{-7} \ln \frac{D}{r'}$ or $L = 2\times10^{-7} \ln \frac{D_m}{D_s}$

where $D_m = D$ & $D_s = r' = 0.7788r$ } 1 mark

The magnitude of inductance in ~~solid~~ bundled conductor is

$L/m = 2\times10^{-7} \ln \frac{D_m}{D_s}$

where D_m = mutual GMD.
D_s = self GMD. } 1 mark

While calculating the magnitude of inductance for solid conductor only the distance between two conductor is considered as Dm & i.e. mutual distance and the G.M.R. is considered as the self GMD. i.e. $D_s=r^1=0.7788r$.
Where r is the radius of the conductor. **(2M)**

While calculating the magnitude of inductance in bundled conductor the mutual GMD (DM) is taken as the mutual distance between the conductors. Which will be not equal to the only distance between two but distance between all the bundled conductors.
The self GMD(D_s) will be the self distance between the same bundled.

for eg. a a' b b' c c'

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

where $D_{aa} = D_{a'a'} = 0.7788r$.
(2marks)

While calculating the magnitude of inductance in bundled conductor the mutual GMD (DM) is taken as the mutual distance between the conductor which will be not equal to the only distance between two but distance between two but distance between all the bundled conductors.
The self GMD(Ds) will be the self distance between the same bundled**.**

for eg. a a' b b' c c'

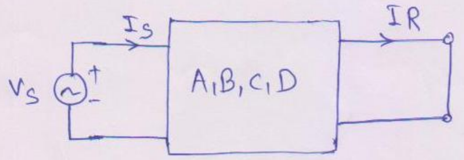
$D_s = (D_{aa} \times D_{aa'} \times D_{a'a'} \times D_{a'a})^{1/4}$

where $D_{aa} = D_{a'a'} = 0.7788r$.
(2marks)

(if student write ans. by some ~~dif~~ diff. assumption Please consider ~~it~~ it by your assumptions.)

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

a) Prove AD-BC=1 where A, B, C, D are generalized circuit constants of a medium transmission line.



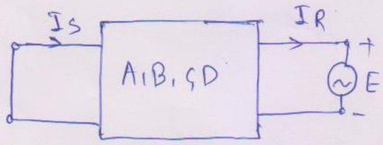
– (1 mark)

Consider fig. where a 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 the other end is S.C.

The eqn is

$V_S = E = 0 + BI_R$ — (1 mark)

or $I_R = \frac{E}{B}$ –(i)



–(1 mark)

Now, S.C. the sending end and connect the generator at the receiving end shown in fig. The positive directions of flow of current are shown in fig. –(1 mark)

$\therefore 0 = AE + BI_R$ –(ii)

Since line is a linear passive bilateral &

$I_S = -I_R = CE + DI_R$ –(iii)

eliminating I_R from eqn (ii) & (iii)

$I_R = -AE/B$

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

from (i) $I_R = \frac{E}{B}$ from (iv)

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

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

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

$\therefore \boxed{AD - BC = 1}$

} 4 marks.

b) Along with diagram write procedure for drawing sending end circle diagram.

Steps: for sending end power circle diagram (**3marks for step, 3 marks for diagram)**

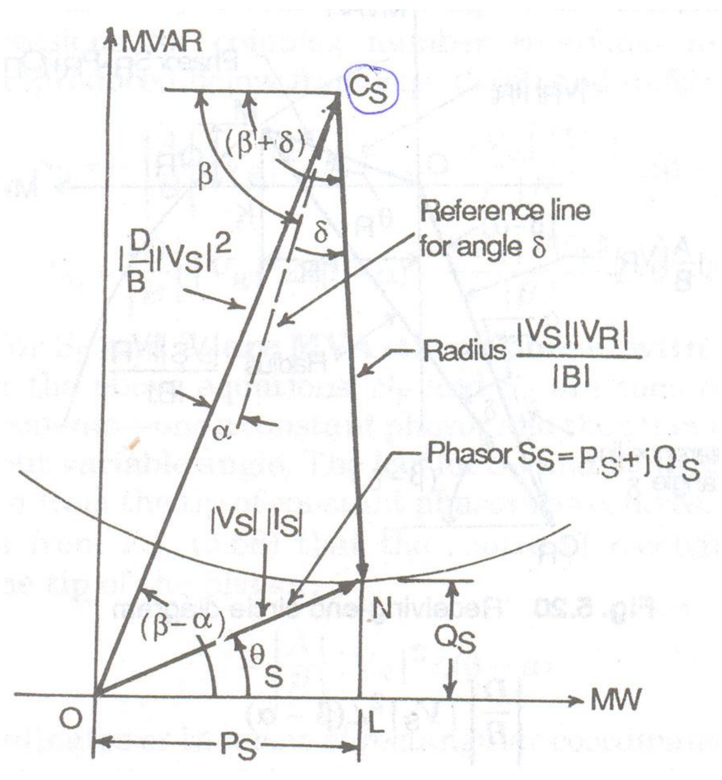
i. Step-1: Draw the X-Y plane in which plane X represents the active power (MW) & axis-y-represents the Reactive power (MVA). with proper scale.

ii. Step-2: The centre of sending end circle is located at the tip of phaser $|D/B|\ 1V_S|^2 < \beta - \alpha$ drawing OC_S from positive MW axis.
OR
locate X and Y coordinates of the centre are $|D/B|1V_S|^2$ Cos (β - α) and $|D/B|1V_S|^2$ Sin (β - α) and mark the point Cs. Join OCs.

iii. Step-3: Radius = $|V_S||V_R|$ / |B
Draw the Curve with the radius of sending end circle from centre Cs to the scale.

iv. Step-4: Locate point Lon X axis such that OL represents Ps to the scale. Draw perpendicular at L to X axis which cuts the circle at point at N. Join NCs. N is the operating point of the system.

v. Step-5: Complete the triangle ONL which represents power triangle at sending end.



c) A three phase 400 kV, 500 km transmission line has following parameters
Resistance=0.025 ohms/km/phase
Inductance=1mH/km/phase
Capacitance=0.020μF/km/phase
Calculate ABCD constants. Use nominal π method.

$R = 0.025\Omega/K$/ph

$L = 1\ mH\ /\ Km\ /ph$

$c = 0.020\mu F\ /\ Km\ /ph$

$for\ 500Km\ line$

$R = 0.025 \times 500 = 12.5\Omega$

$X = 2\pi fL = 2\pi \times 50 \times 1 \times 10^{-3} \times 250 = 78.53\Omega \ldots\ldots\ldots.(1M)$

$Z = R + jX = 12.5 + j78.53 = 79.51\angle 80.95^o\Omega \ldots\ldots\ldots(1M)$

$Y = jwcL = 314 \times 0.020 \times 10^{-6} \times 250 = \angle 90^0 = 1.57 \times 10^{-3}\angle 90^0 \ldots\ldots(1M)$

$for\ Nominal\ \pi - circuit$

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

$$A = D = \frac{1+yz}{2} = 1 + [\frac{(1.57\times 10^{-3}\angle 90^0).(79.51\angle 80.95^o)}{2}$$
$$A = 1 + \frac{0.12\angle 170.95}{2}$$
$$A = 1 + 0.06\angle 170.95$$
$$A = 1 - 0.059 + j9.43\times 10^{-3} = 0.941 + j9.437\times 10^{-3} = 0.941\angle 0.57^0 = D \ldots (2M)$$
$$B = Z = 79.51\angle 80.95^0\Omega \ldots\ldots.(1M)$$
$$C = Y\left(1+\frac{yz}{4}\right) = 1.57\times 10^{-3}\angle 90^0\left[1+\frac{(1.57\times 10^{-3}\angle 90^0)(79.51\angle 80.95^0)}{4}\right]$$
$$= 1.57\times 10^{-3}\angle 90^0[1 + 0.03\angle 170.95^0]$$
$$= 1.57\times 10^{-3}\angle 90^0[1 - 0.029 + j4.718\times 10^{-3}]$$
$$= 1.57\times 10^{-3}\angle 90^0[0.971 + j4.718\times 10^{-3}]$$
$$= 1.57\times 10^{-3}\angle 90^0[0.971\angle 0.278]$$
$$= 1.524\times 10^{-3}\angle 90.278\ siemens \ldots..(2M)$$

Q.6. Attempt any Four of the following:

a) A 400V, 50Hz, 3 phase line delivers 100 kW at 0.85 pf lagging. If power factor of this line is to be increased to 0.95 lagging, then calculate value of shunt capacitances if they are connected in

i. star

ii. delta

This question is not from syllabus so that mark can be given.

$\boldsymbol{Given}$:

$\boldsymbol{Voltage\ (V)}$ =**400V**

$\boldsymbol{Frequency\ (f)}$ =**50 Hz**

$\boldsymbol{power\ (P) = 100KW}$

$\textbf{Power factor} = \boldsymbol{\cos\emptyset_1 = 0.85}$

$\boldsymbol{Improved\ power\ factor = 0.95}$

$\boldsymbol{Solution}$:

$\boldsymbol{1)\ \cos\emptyset_1 = 0.85}$

$\boldsymbol{\therefore \emptyset_1 = \cos^{-1}(0.85)}$

$\boldsymbol{\emptyset_1 = 31.788^0}$

$\boldsymbol{2)\ \tan\emptyset_1 = \tan(31.788)}$

$\boldsymbol{\tan\emptyset_1 = 0.619}$

$\boldsymbol{3)\ \cos\emptyset_2 = 0.95}$

$\boldsymbol{\emptyset_1 = 18.19^0}$

$\boldsymbol{4)\ \tan\emptyset_2 = \tan(18.19)}$

$\boldsymbol{\tan\emptyset_1 = 0.328}$

after improving the power factor to 0.95, rating 1shunt capaitance

$$\boldsymbol{= P(\tan\emptyset_1 - \tan\emptyset_2) = 100(0.619 - 0.328) = 29.1KVAR \ldots\ldots\ldots\ldots.(2M)}$$

$\boldsymbol{1)\ capacitor\ connected\ in\ star}$

$$\boldsymbol{C_S = \frac{KVAR\times 10^3}{\omega(V)^2} = \frac{29.1\times 10^3}{2\times\pi\times 50\times(400)^2} = 578.926\mu F \ldots\ldots\ldots..(1M)}$$

$\boldsymbol{2)\ Delta\ \ connection\ (C_d)}$

$$\boldsymbol{C_d = \frac{KVAR\times 10^3}{3\omega(V)^2} = \frac{29.1\times 10^3}{3\times 2\pi\times 50\times(400)^2} = 192.975\mu F \ldots\ldots\ldots.(1M)}$$

b) Write any eight functions that a power system engineer has to perform.
(For each function ½ M)

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

(Note: any other relative points may be consider)

c) Write meaning of each of following terms internal flux, external flux, flux linkage, isolated conductor.(1M for each)

Internal flux:
When AC current flow through a conductor it set up magnetic field surrounding the conductor as well as inside the conductor. The magnetic flux set up by the current inside the conductor and concentric with the conductor is called as internal flux.

External flux:
When AC current flow through a conductor it set up magnetic field surrounding the conductor as well as inside the conductor. The magnetic flux set up by the current outside the conductor and concentric with the conductor is called as External flux.

Flux linkage:
The external flux setup by a current carrying conductor which links with the same conductor or neighboring conductor is called as Flux Linkage.

Isolated conductor:
A current carrying conductor which develops its own field surrounding it and the lines of fluxes are concentric & perpendicular with the conductor in absences of any neighboring field in the viscidity of the conductor. Such conductor is called as isolated conductor.

d) State the advantages of circle in power system analysis.
(1M to each point any 4, related point can be considered)

1. In power system AC transmission real & reactive powers can be theoretically calculated by using complex power expressions. The same calculators are performed graphically by circle dia. which reduces no. of calculations.
2. The performance of the transmission line at various load condition can be studied for the circle diagram.
3. By drawing circle diagram we can calculate sending end voltages.
4. By drawing circle diagram we can calculate rating of compensation equipment.
5. The diagram is useful in calculating the line losses.
6. The diagram is use full in calculating the power max. Power angle.
7. In one diagram we can calculate all parameters.
8. The results obtained can be accurate
9. No. of parameters can be calculated for same system using same circle diagram.

10. If any changes are made in tr. line parameters the same can be implemented on circle dia. Just by changing scale.
11. The calculation is fast.

e) A short transmission line has series impedence of (10+j25)Ω. Calculate A, B, C, D generalized circuit constants.

$Z = 10 + j25\Omega$

$for\ short\ line,$

$A = 1 \dots \dots . (\boldsymbol{1M})$

$B = Z = 10 + j25\Omega = 26.92\angle 1.19^0\Omega \dots \dots . (\boldsymbol{1M})$

$C = 0 \dots \dots \dots (\boldsymbol{1M})$

$D = 1 \dots \dots (\boldsymbol{1M})$