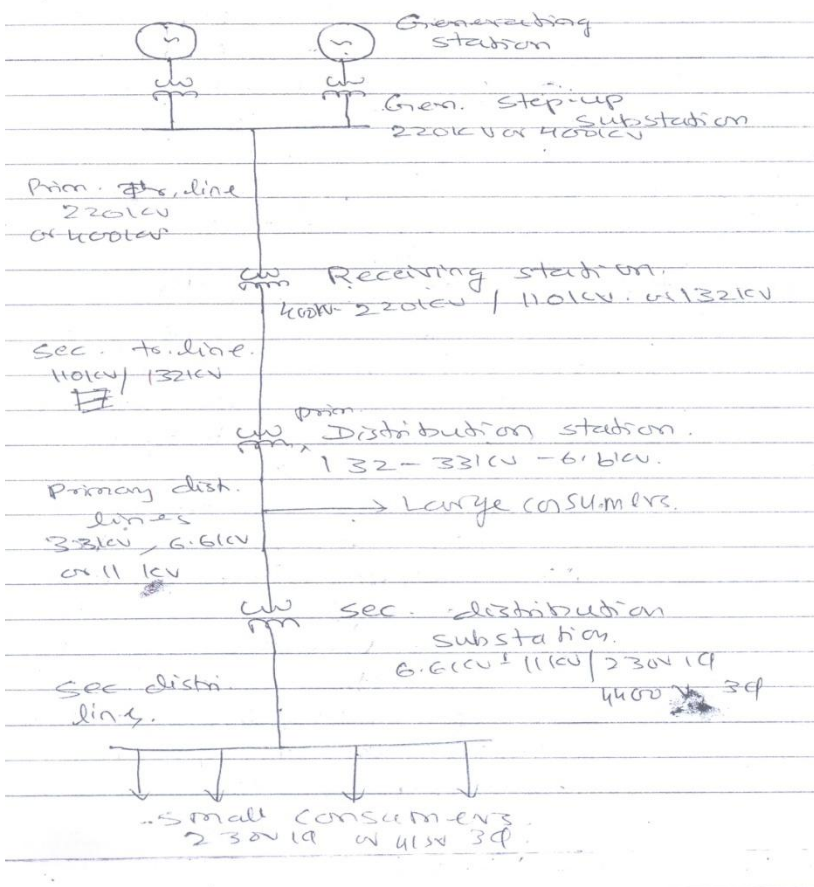
Important Instructions to examiners:

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] a) (4-marks for Correct diagram showing all voltage levels)



Q.1 A] b) (2-marks for description, 2-marks for Factors)

When d.c. current flows in the line conductor, the current is uniformly distributed across the section of the conductor whereas flow of alternating current is non-uniform. Maximum current flows through surface of 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. Consider for a moment that the conductor is composed of no. of annular filaments. The inner filaments carrying currents give rise to flux which links with the outer filaments as well as inner filaments. Whereas the flux setup by outer filaments does not enclose inner filaments. Therefore the inductance of the inner filament is higher as compared to the outer filaments. Because of this more current flows through outer filaments as they have less opposition.

Factors affecting:

1. Frequency: This effect depends upon the frequency. At radio frequency the skin effect6 becomes so permanent that the current resides mostly on the surface of the conduction. Even at 50 Hz skin effect is significant and causes a.c. resistance of a conductor to be higher than the d.c. resistance.
2. The skin effect increases with conductor cross section and frequency.
3. At 50 Hz due to skin effect increase in resistance is 3 to 5%

Q.1A] c) (1-mark for each point)

1. Due to capacitance effect, net reactance of transmission line decreases. So V drop decreases and regulation of line increases.

2. At no load due to capacitance effect receiving, and voltage increases than the sending end voltage (Ferranti effect) so regulation is negative.

3. Capacitance effect neutralizes inductance effect. So net reactance of line decreases. So losses decrease and efficiency increases.

4. Power = $V_S V_R$ / X so due to capacitance effect transmission capacity increases.

Q.1 A] d) (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 = $V_R I_R \cos \phi R$ 1ϕ ckt.

   = # $V_R I_R \cos \phi R$ for 3 ϕ ckt.

   Output power = $V_S I_S \cos \phi S$ 1ϕ ckt.

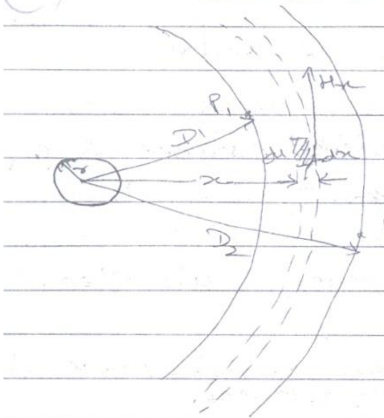
   = # $V_S I_S \cos \phi S$ for 3ϕ ckt.

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

5. By calculating input and output power can be calculated.

Q.1 B] a) (1-mark for Diagram, 2-marks for flux density,2-marks for flux linkage equation and substitution, 1-mark for final flux linkage equation.)

1 B (a) Flux linkages outside due to external flux.



• Consider two points P_1 & P_2 at a distance of D_1 & D_2 resply. from the centre of the conductor which carries a current of I amps & is having a return path at ∞. Hence flux set up outside conductor i.e. external flux are co-centric with the conductor and lies between two cylindrical surfaces passing thro' P_1 & P_2.

Let H_x be the field intensity tangential to the element.

By Ampere's law, we get

$$mmf = I$$

$$\text{mmf} = \oint H_x \cdot dl = H_x \cdot 2\pi x$$

$$\therefore I = H_x \cdot 2\pi x$$

$$\therefore H_x = \frac{I}{2\pi x}$$

Let B_x be the flux density of the flux element, which is constant

$$\therefore B_x = \mu H_x = \frac{\mu I}{2\pi x} \quad Wb/mt^2$$

Now total flux in tubular element of thickness 'dx' is given by,

$$d\phi = B_x \cdot dx$$

$$= \frac{\mu I}{2\pi x} \cdot dx \text{ --- Wb/m.}$$

This flux links with current I amp.

$\therefore$ Net flux linkage,

$$d\psi = d\phi$$

$$= \frac{\mu I}{2\pi x} \cdot dx \quad \text{WbT/m.}$$

Flux linkage with conductor due to external fluxes lying betwees between P_1 & P_2

$$\psi_{ext} = \int_{D_1}^{D_2} \frac{\mu I}{2\pi x} \cdot dx = \frac{\mu I}{2\pi} \left[\log_e x\right]_{D_1}^{D_2}$$

$$= \frac{\mu I}{2\pi} \left[\log_e D_2 - \log_e D_1\right]$$

$$\therefore = \frac{\mu I}{2\pi} \log_e \frac{D_2}{D_1} \text{ --- WbT/m.}$$

We know that,

$$\mu = \mu_0 \mu_r = 4\pi \times 10^{-7} \times 1$$

$$= 4\pi \times 10^{-7} \text{ --- H/m.}$$

$$\therefore \psi_{ext} = \frac{4\pi \times 10^{-7}}{2\pi} I \log_e \frac{D_2}{D_1}$$

$$= 2 \times 10^{-7} I \log_e \frac{D_2}{D_1}$$

$$\boxed{\psi_{ext} = 2 \times 10^{-7} I \log_e \frac{D_2}{D_1} \text{ -- WbT/m}}$$

If $D_2 = D$ mt.
$D_1 = r$ – radius of conductor.

Then flux linkage with a conductor due to external fluxes lying between the conductor surface & the circular path P at distance D mts from the centre of the conductor, is given by

$$\boxed{\psi_{ext} = 2 \times 10^{-7} \log_e \frac{D}{r} \quad H/m}$$

Q.1 B] b) (1-mark each)

1. Max receiving end power

2. KVAR rating of compensating equipment at receiving end – to maintain receiving end V.

3. Sending end voltage.

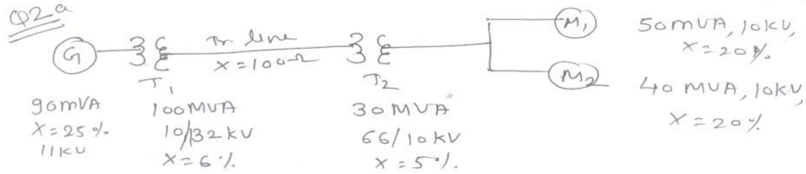
4. Sending end p. f, and sending end power.

5. Load angle δ.

6. Losses in line.

Q.2] a)

Q2 a



assuming base ~~kVA~~ MVA = 100
& base voltage 10 kV

p.u. reactance ~~impedance~~ of T_1 = 6 % — 1M

p.u. reactance of Gen. referred to base MVA & base V

$= X_{pu.old} \times \left(\frac{\text{Base MVA new}}{\text{Base MVA old}}\right) \times \left(\frac{\text{Base kV old}}{\text{Base kV new}}\right)^2$

$= 0.25 \times \left(\frac{100}{90}\right) \times \left(\frac{11}{10}\right)^2$

$= 0.336$ pu — (1M)

p.u. reactance of T_2 =

$= 0.05 \times \frac{100}{30} \times \left(\frac{10}{10}\right)^2$

$= 0.166$ pu. (1M)

p.u. reactance of M_1

$= 0.2 \times \frac{100}{50} \times \left(\frac{10}{10}\right)^2 = 0.4$ (1M)

p.u. reactance of M_2

$= 0.2 \times \frac{100}{40} \times \left(\frac{10}{10}\right)^2 = 0.5$ (1M)

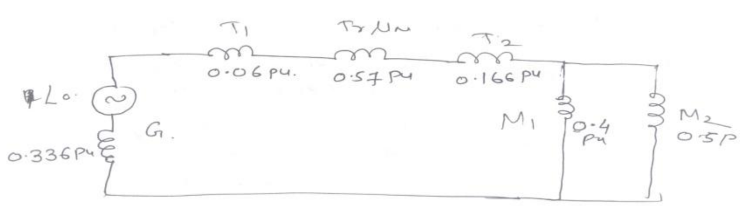
Base impedance of Tr. line

$= \frac{(\text{Base kV})^2 \times 1000}{\text{Base kVA}}$

$= \frac{(132)^2 \times \cancel{1000}}{100} = 174.24$

pu X of Tr. line $= \frac{X_{actual}}{X_{Base}}$

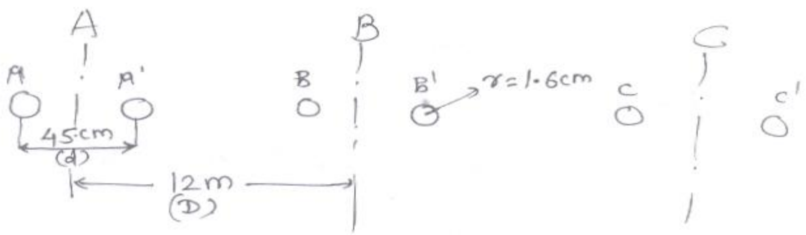
$= \frac{100}{174.24} = 0.57$ pu. (1M)



—(2M)

Q.2] b)

Q2 b.



$D = 12\,m$.

$d = 45\,cm = 45 \times 10^{-2}\,m$

$r = 1.6\,cm = 1.6 \times 10^{-2}\,m$

Let Self GMD of each phase be $D_{S1} = D_{S2} = D_{S3} = D_S$

$$D_S = \sqrt[4]{D_{AA'}\,D_{AA}} = \sqrt{D_{AA}\,D_{AA'}}$$

$$= \sqrt{(0.7788 \times 1.6) \times 45} = 7.488\ cm \quad (2M)$$

Mutual GMD bet A & B phase

$$D_{AB} = \sqrt[4]{D_{AB}\,D_{AB'}\,D_{A'B}\,D_{A'B'}}$$

$$= \sqrt[4]{(12)^2 \times (11.55) \times (12.45)} = \underline{\underline{11.996}}\ m$$

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

$$D_{AC} = \sqrt[4]{D_{AC}\,D_{AC'}\,D_{A'C}\,D_{A'C'}}$$

$$= \sqrt[4]{(24)^2 \times 23.55 \times 24.45} = \underline{\underline{23.998}}\,m \quad (3M)$$

$$D_{eq} = \sqrt[3]{D_{AB}\,D_{BC}\,D_{CA}} = \sqrt[3]{11.996 \times 11.996 \times 23.998}$$

$$= 15.115 \quad (1M)$$

$$L = 2 \times 10^{-7} \log_e \frac{D_{eq}}{D_S} = 2 \times 10^{-7} \log_e \left(\frac{15.115}{7.488}\right) \quad (2M)$$

$$= 1.4 \times 10^{-6}\ H/m = \boxed{1.4\ mH/km}$$

Q.2] c)

Q.2C

$Z = 52 + j\,200$ ohm

$Y = j1.5 \times 10^{-3}$ siemens.

ABCD constant for nominal π method.-

$A = D = 1 + \frac{YZ}{2}$

$\boxed{B = Z = 52 + j200}$ — (1M)

$C = Y\left(1 + \frac{YZ}{4}\right)$

$A = D = 1 + \frac{YZ}{2}$

$= 1 + \frac{\left[j1.5 \times 10^{-3} \times (52 + j200)\right]}{2}$

$= 1 + \frac{1.5 \times 10^{-3} \angle 90 \cdot 206.64 \angle 75.42}{2}$

$= 1 + 1.5498 \angle 165.42$

$= 1 + (-1.4998 + j\,0.39)$

$\boxed{A = D = 0.4998 + j0.39}$ (4M)

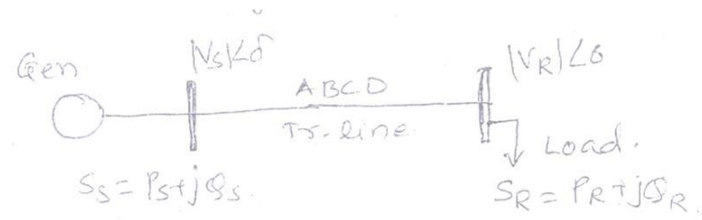
$C = Y + \left(1 + \frac{YZ}{4}\right)$

$= j1.5 \times 10^{-3} + (1 + 0.7749 \angle 165.42)$

$= j1.5 \times 10^{-3} + 1 + (-0.7499 + j\,0.195)$

$\boxed{C = 0.2501 + j0.21}$ (3M)

Q.3] a)



Consider a two bus system connected with generator and load at each bus. The parameters at generator and load bus are

$V_B = 1Vs \mid < \delta$ $S_B = Ps + JQ_S = V_S J_S$ (1)

$V_R = M_R \mid < \theta$ $S_R = P_R + JQ_R = V_R J_R$ (2)

SS and SR represents complex sending end and receiving end power. ***[1-mark]***

The receiving end and sending end currents can be represented as

$I_R = 1/B\ V_S - A/B\ V_R$ (3)

$I_S = D/B\ V_S - 1/B\ V_R$ (4)

Let A, B, D are transmission line constants written as $A = |A| < \alpha$, $B = |B| < \beta$, $D = |D| < \alpha$ ***[1-mark]***

Therefore we can write

$I_R = |1/B|\ 1V_S| < (\delta - B) - |A/B|\ 1V_R| < (\alpha - \beta)$

$I_S = |D/B|\ 1V_S| < (\alpha + \delta - B) - |1/B|\ 1V_R| < - \beta)$ ***[1-mark]***

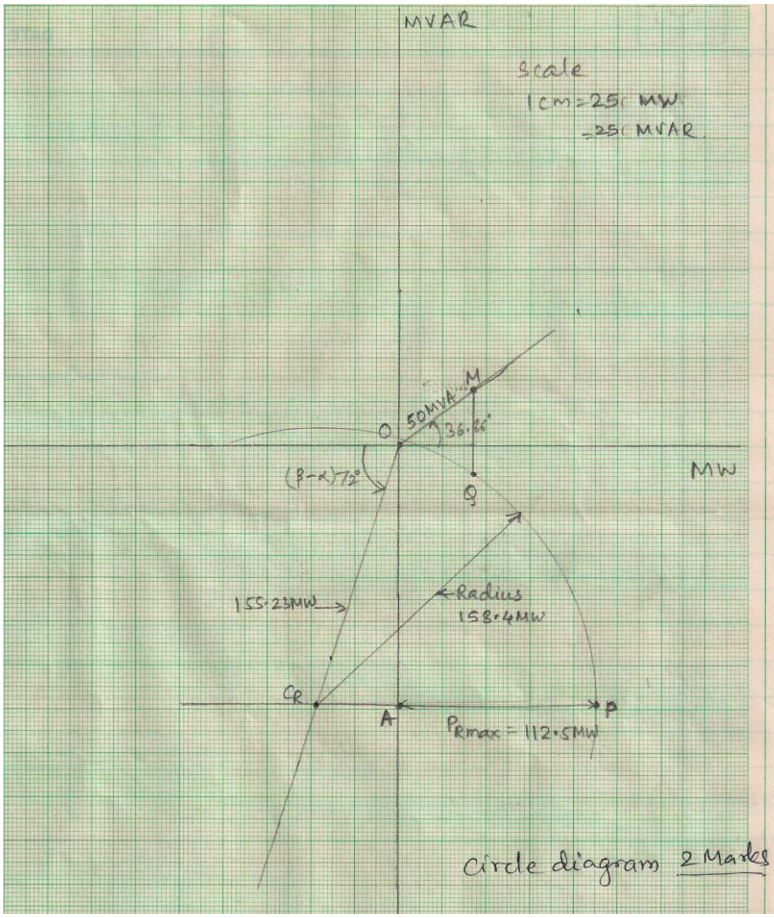
Substituting for IS in Equation 1 we get

$S_S = |D/B|\ 1VS|^2 < (\beta - \alpha) - |V_S||V_R| / |B| < \beta + \delta$

If VR and VS are expresse in KV line, the 3ϕ sending end complex power can be given by

$S_S = |D/B|\ |VS^{|2} < \beta - \alpha - |V_S||V_R| / |B| < \beta + \delta$ ***[1-mark]***

Q.3] b) (2-marks for Circle Diagram, 2-marks for steps)



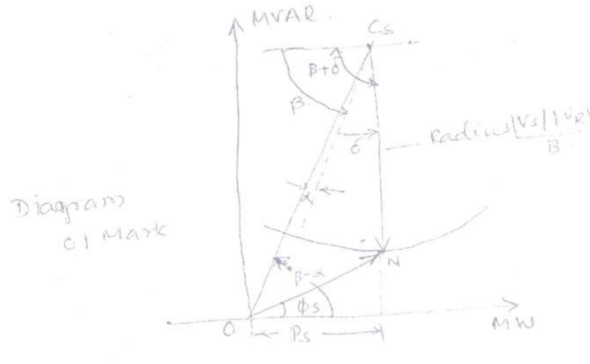
Steps:

i. 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.

The X and Y coordinates of the centre are $|D/B|1V_S|^2$ Cos $(\beta - \alpha)$ and $|D/B|1V_S|^2$ Sin $(\beta - \alpha)$

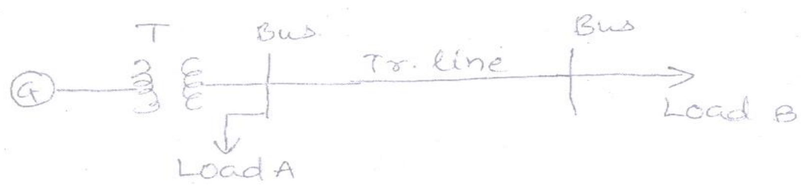
ii. The radius of sending end circle is drawn with $|V_S||V_R| / |B|$ from centre C_S

iii. The operating point N is located by measuring torque angle δ in the direction indicated from reference line of angle α

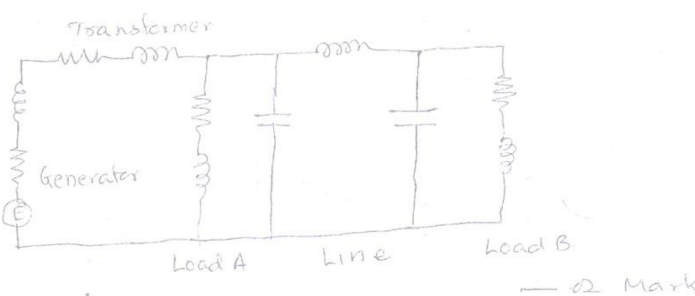


Q.3] c) Impedance diagram

In order to analyze a system it is necessary to draw its equivalent circuit known as impedance diagram.



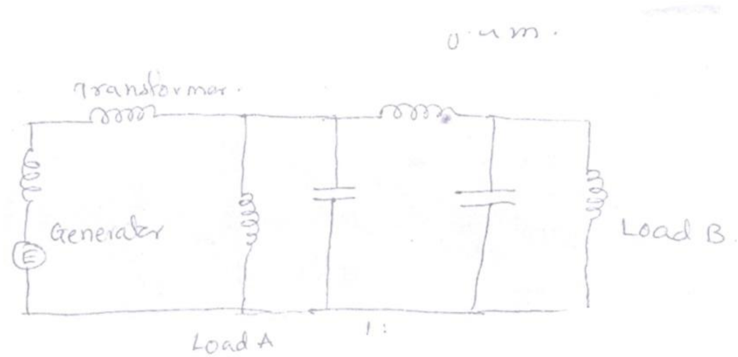
A generator is represented by an emf in series with an impedance. Transformers are represented by equivalent impedances. A short line is represented by series impedance. Medium and long lines are represented by equivalent π circuits. A static load is represented by a resistance and reactance in series. Motors are represented by their equivalent circuits. That will be called as impedance diagram.



[2-marks]

Reactance Diagram:

In equivalent circuit representation if the resistance components of impedances are neglected, an impedance diagram reduces to a reactance diagram.



The above diagram shows only reactance part of each component i.e. transformer, generator, transmission line, load etc. ***[2-marks]***

Q.3] d) (Any four 1-mark each)

Important aspects of power system analysis are as follows:

i. Planning the operation and control of power system.

ii. Load How analysis, short circuit analysis and stability analysis.

iii. Continuous monitoring of power system and making decisions.

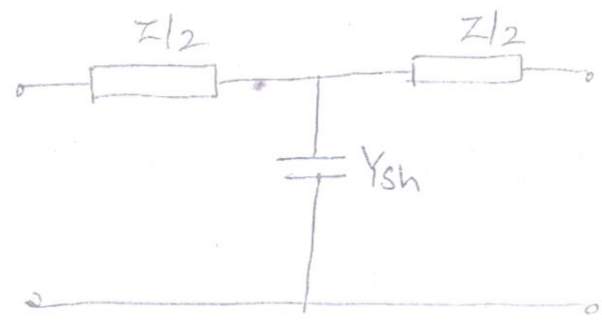
iv. Problems solving in case of power shortages, load management.

v. Economic and optimum load dispatch.

vi. Planning for improvement and expansion of a power system.

Q.3] e)

For a nominal T-network



ABCD constants are given by

A = 1+YZ / 2 , B = Z (1+ YZ / 2

C = Y D = 1 + YZ / 2 ***[2-marks]***

AD – BC = [(1+ YZ / 2)(1 + YZ / 2)] – [(Y)(Z (1+ YZ / 4))]

= [1+YZ / 2 + YZ / 2 + Y^2Z^2 / 4] – YZ + Y^2Z^2 / 4] ***[1-marks]***

= 1 + ~~2~~YZ / ~~2~~ + ~~Y^2Z^2 / 2~~ – YZ – ~~Y^2Z^2 / 4~~

= 1 + YZ – YZ

= 1

= R.H.S

Hence proved that AD – BC = 1 ***[1-mark]***

Q.4 A] a) (Any four 1-mark each)

Advantages of per unit system:

i. Manufacturers usually specify the impedance values of equipments in per unit of equipment rating.
ii. When expressed in P.U., system parameters tend to fall in relatively narrow numerical ranges.
iii. P. U. data representation yields important information about relative magnitudes.
iv. 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.
v. If base values are selected properly the P.U. impedance is same on both sides of transformers.

Q.4 A] b) (1-mark each)

Factors affecting proximity effect:

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

Q.4 A] c)

Given data

$V_S = V_R = 275$ KV, $A = 0.85 < 5^o$, $B = 300 < 75^o$

Then for unity power factor $Q_R = 0$

$\therefore$ $Q_R = |V_S||V_R| / |B| \sin(\beta - \delta) - |A| / |B| |V_R|^2 \sin(\beta - \alpha)$ ***[1-mark)***

Substituting all values we get

$0 = (275)(275) / 300 \sin(\beta - \delta) - (0.85)(275)^2 / 300 \sin(75 - 5)$

$0 = (252.083) \sin(\beta - \delta) = 0.798$

$B - \delta = 53^o$ ***[2-marks]***

Substituting this is in equation of P_R we get

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

$= (275)(275) / 300 \cos(53) - 0.85 \times (275)^2 / 300 \cos(75-5)$

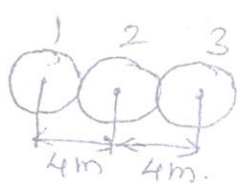
$= (252.083)(0.601) - (214.27)(0.342)$

$= 151.50 - 73.28$

$P_R = 78.22$ MW.

Unity power at receiving end is 78.22 MW ***[1-mark]***

Q.4 A] d)



$r = 2$ cm

$= 2 \times 10^{-2}$ m

Self GMD $D_S = 9\sqrt{(D_{11}\ D_{12}\ D_{13})(D_{21}\ D_{22}\ D_{23})(D_{31}\ D_{32}\ D_{33})}$ ***[1-mark]***

$D_{11} = D_{22} = D_{33} = 0.7788\ r = 0.0155$ m

$D_{12} = D_{23} = D_{32} = D_{21} = 4$m

$D_{13} = D_{31} = 8$m ***[1-mark]***

Self GMD DS = $9\sqrt{(0-0155)(4x8)x(4x0.0155\ x\ 8)x}(8x4x0.0155)$ ***[1-mark]***

$= 9\sqrt{(0.498)(0.498)(0.498)}$

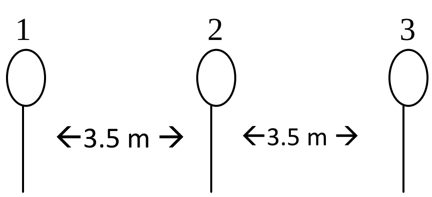
Self GMD = 0.792m ***[1-mark]***

Q.4 B] a)

Given data

d= 1.2 cm r =1.2/2 = 0.6 cm

VR = 132KV f = 50 Hz



$D_{eq} = (D_{12} \times D_{23} \times D_{31})^{1/3} = 4.40$ m ***[1-mark]***

Capacitance (line to line) $C_{line} = 0.01206 / \log (D_{eq} / r)$

$= 0.01206 / \log (4.40 \times 100 / 0.6)$

$= 4.2 \times 10^{-3}$ µF / phase ***[2-marks]***

Capacitance line to neutral $C_n = 2\ C_{line}$

$= 8.417 \times 10^{-3}$ µF / phase ***[1-mark]***

Capacitive reactance $Xc = 1 / 2\ \pi \times 50 \times 8.417 \times 10^{-3} \times 10^{-6}$

$= 378.17\ \Omega$ ***[1-mark]***

Charging current $I_C = V_{ph} / XC$

$= (132 / V\# \times 10^{-3}) / 378.17$

$= 201.52$ A / phase ***[1-mark]***

Q.4 B]b) b)

Given $A = 0.98 < 3^o$ $B = 110 < 75^o$

$V_R = 132KV$

Centre of receiving end circle is given by

$OC_R = |A|/ |B\ |V_R|^2$

$= 0.98 / 110\ (132)^2 = 155.23$ MW

Taking $(\beta - \alpha) = 75 – 3 = 72^o$ and scale

1cm = 250 MW locate centre OC_S on graph paper.

$OC_R = 3.10$ cm ***[1-mark]***

Load = 50 MVA. Cos $\phi_R = 0.8$ Load = 2cm

$\therefore \phi R = \text{Cos } -1\ (0.8) = 36.86$ o

Draw line from centre in first quadrant at < 36.86. locate point M with load 50 MVA on 36.86 line

[1-mark]

Draw circle for VS = VR = 132 KV condition with radius |VS||VR|/|B|

= 132 x 132 / 110

= 158.4 MW

= 6.33 cm ***[1-mark]***

Extend circle upto $\beta \neq \delta = \theta$ i.e. cutting

Positive X axis Mark point as P

Measure AP = $P_{R\ max}$ = 4.5cm = 112.5MW ***[1-mark]***

Draw vertical line parallel to Yaxis from M upto point Q on circle. Measure MQ = Reactive vars of shunt compensation = 1.9cm = 47.5MVAR ***[1-mark]***

Q.5] a)

For series connection,

$A = A_1A_2 + B_1C_2$

$= (0.98 < 2^o)(0.95 < 3^o) + (28 < 6\ j\ ^o)\ (0.0004 < 90^o)$

$= 0.931 < 5^o + 0.0112 < 15^o$

$= 0.9279 + j0.08114 – 0.0104 + j0.004013$

$= 0.917 + j0.08515$

$= 0.9209 < 5.3\ ^o$ ***[2-marks]***

$B = A_1B_2 + B_1D_2$

$= (0.98< 2^o)(40 < 85\ ^o) + (28 < 69^o)(0.95< 3^o)$

$= 39.2 < 87^o + 26.6 < 72^o$

$=10.27 + j64.44$

$= 65.26 < 80.95\ ^o\ \Omega$ ***[2-marks]***

$C = C_1A_2 + D_1C_2$

$= (0.0002 <80^o)\ (0.95 < 3^o) + (0.98 < 2^o)(0.0004 < 90^o)$

$= 0.00019 < 83^o + 0.000392 < 92^o$

$= 9.47 \times 10^{-6} + j5.8 \times 10^{-4}$

$= 5.8 \times 10^{-4} < 89.1\ ^o$ ***[2-marks]***

$D = C_1B_2 + D_1D_2$

$= (0.0002 < 80^o)(40 < 85^o) + (40 < 85^o)+(0.98 < 2^o)(0.95<3^o)$

$= 0.008 < 165^o + 931 < 5^o$

$= 0.92 + j0.083$

$=0.934 < 5.2\ ^o$ ***[2-marks]***

Q.5] b) (2-marks for Diagram, 2-marks sending end calculation, 2marks receiving end calculation, 2-marks calculation of A, B, C, D)

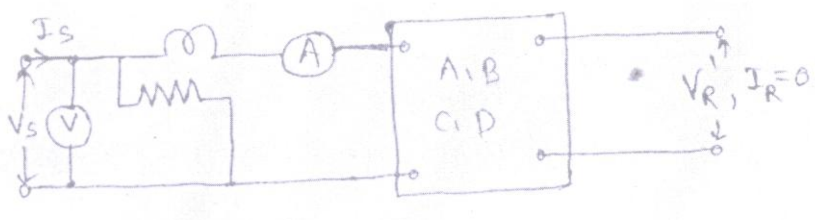


fig ⓐ o.c. tests

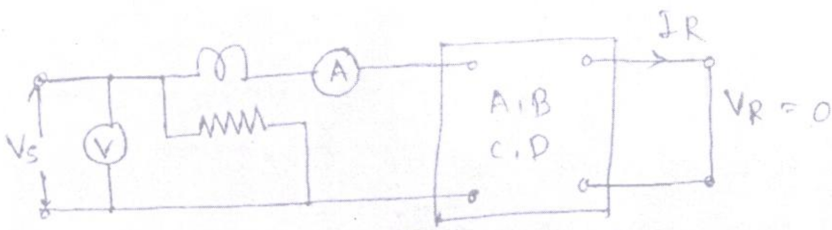


fig ⓑ s.c. tests.

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_RO = 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,

$V_R = 0$

$\therefore\ V_S = I_s Z_{SS}$

$Z_{SS} = V_S / I_S = B / D$ (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 $I_S = 0$

$\therefore$ ZRO = VR / IR = D / C (9) (From 7 and 8)

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

ZRS = B / A (10) (From 7 and 8)

iv. From equation 9 and 10

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

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

$\therefore a = \sqrt{}\ Z_{SO} / Z_{SO} – Z_{RS}$ (11)

Now, ZRS = B / A

$\therefore$ = A Z_{RS} = ZRS $\sqrt{}Z_{SO}$ / $Z_{RO} - Z_{RS}$ (12)

Z_{SO} = A/C

$\therefore$ C = A / Z_{SO} = 1 / Z_{SO} $\sqrt{}$ Z_{SO} / $Z_{RO} - Z_{RS}$ (13)

Z_{RO} = D/C

$\therefore$ D = CZ_{RO} = Z_{RO} / Z_{SO} $\sqrt{}$ Z_{SO} / $Z_{RO} - Z_{RS}$

= Z_{RS} x $\sqrt{}$ 1/ Z_{SO} ($Z_{RO} - Z_{RS}$)

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

$\therefore$ D =A $\sqrt{}$ Z_{SO} / Z_{RO} - Z_{RS}

Q.5] c)

(c) :

$$S_r = -\frac{|A||V_R|^2}{|B|}\angle(\beta-\alpha) + \frac{|V_S||V_R|}{|B|}\angle(\beta-\delta) \quad (1)$$

$$S_S = \frac{|A||V_S|^2}{|B|}\angle(\beta-\alpha) - \frac{|V_R||V_S|}{|B|}\angle(\beta+\delta) \quad (2)$$

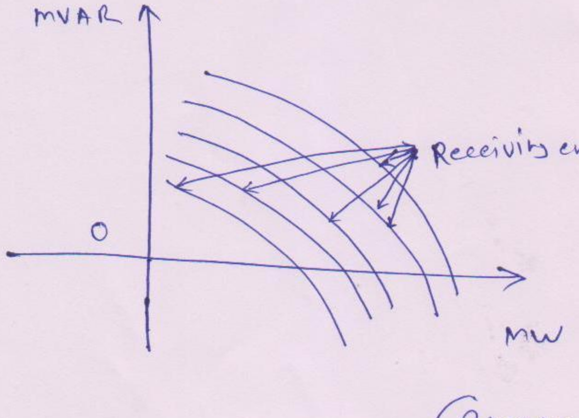
The above eqn's are the eqn for Receiving end Power & sending end power. — (2marks)

→ (1) for Receiving end circle diagram.

→ The ~~radius~~ center of the circle can be located by the eqn $-\frac{|A||V_R|^2}{|B|}$. if we change the value of V_R i.e. Receiving end voltage the center of circle may ~~vary~~ change depend upon value.

→ Similarly the radius of circle can be given by equation $\frac{|V_S||V_R|}{|B|}$. If we change the value of both voltage V_S & V_R then the circle radius may vary depending upon the value.

— So for variation in V_S & V_R the receiving end circle diagram is as follows.



(3marks)

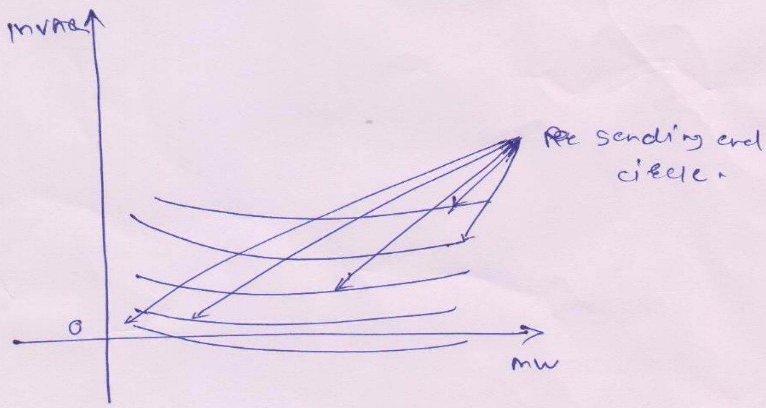
(8)

(2) Sending end circle :-

→ ~~for Va~~ The eqn for centre of circle is given by $\frac{|A||V_s|^2}{|B|}$. for variation in values of V_s the ~~the~~ centre of circle may shift.

→ Similarly for variation in values of V_s & V_R the radius of circle may change by the formula. $\frac{|V_R||V_s|}{|B|}$.

– The circle diagram for change in V_s & V_R are as follows.



(3 marks)

Q.6] a)

The d.c. resistanceof conductor is given by

Rdc = ρ l / A

The d.c resistance of a standard conductor is greater than the above value

The ac resistance is give by

R = Avg. power loss in conductor (W) / I^2 ***[1-mark]***

The effective resistance is usually referred as the effective resistance of the conductor. The increase in resistance due to skin effect increases with conductor cross section and frequency. ***[1-mark]***

The increase in resistance causes the increase in proximity effect incase of underground cables.

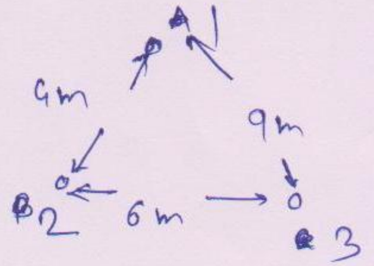
[1-mark]

The increase in temperature on the metal will cause increase in the resistance linearly. ***[1-mark]***

Q.6] b)

$\Rightarrow l = 500\,km$

$d = 1.8\,cm = 1.8 \times 10^{-2}\,m$



$D_{12} = 4m,\ D_{23} = 6m,\ D_{31} = 9m$

$r = \frac{1.8 \times 10^{-2}}{2} = 0.9 \times 10^{-2}\,m$

$L/ph/m = 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{\sqrt[3]{D_{12}D_{23}D_{31}}}{r}\right]$ (1 marks)

$= 10^{-7}\left[\frac{1}{2} + 2\log_e \frac{\sqrt[3]{4 \times 6 \times 9}}{\ldots}\right]$

$L/ph/km = 1.35 \times 10^{-6} \times 1000$

$= 1.35 \times 10^{-3}\,H$ — (2 marks)

for $l = 500\,km$

$L/ph = 1.35 \times 10^{-3} \times 500$

$= \underline{0.675\,H}$ — (1 marks)

Q.6] c) (1-mark each)

1. Due to capacitance effect, net reactance of transmission line decreases. So V drop decreases and regulation of line increases.

2. At no load due to capacitance effect receiving, and voltage increases than the sending end voltage (Ferranti effect) so regulation is negative.

3. Capacitance effect neutralizes inductance effect. So net reactance of line decreases. So losses decrease and efficiency increases.

4. Power = $V_S V_R / X$ so due to capacitance effect transmission capacity increases.

Q.6]d)

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

for max. power.

diff. the above eqn w.r.t. δ & equate to zero.

$\therefore \frac{dP_R}{d\delta} = -\frac{|V_S||V_R|}{|B|}\sin(\beta-\delta) = 0$

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

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

$\beta-\delta = 1$

$\boxed{\beta = \delta}$ — (3 marks).

This is the condition for max. Receiving end Power.

Q.6] e) (1-mark each)

1. Static Compensation

   a. Shant capacities

   b. Shant Reactor

   c. Series capacitor

2. Synchronous Compensators.

3. Control by transformers.

4. Top Changing transformer.