MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

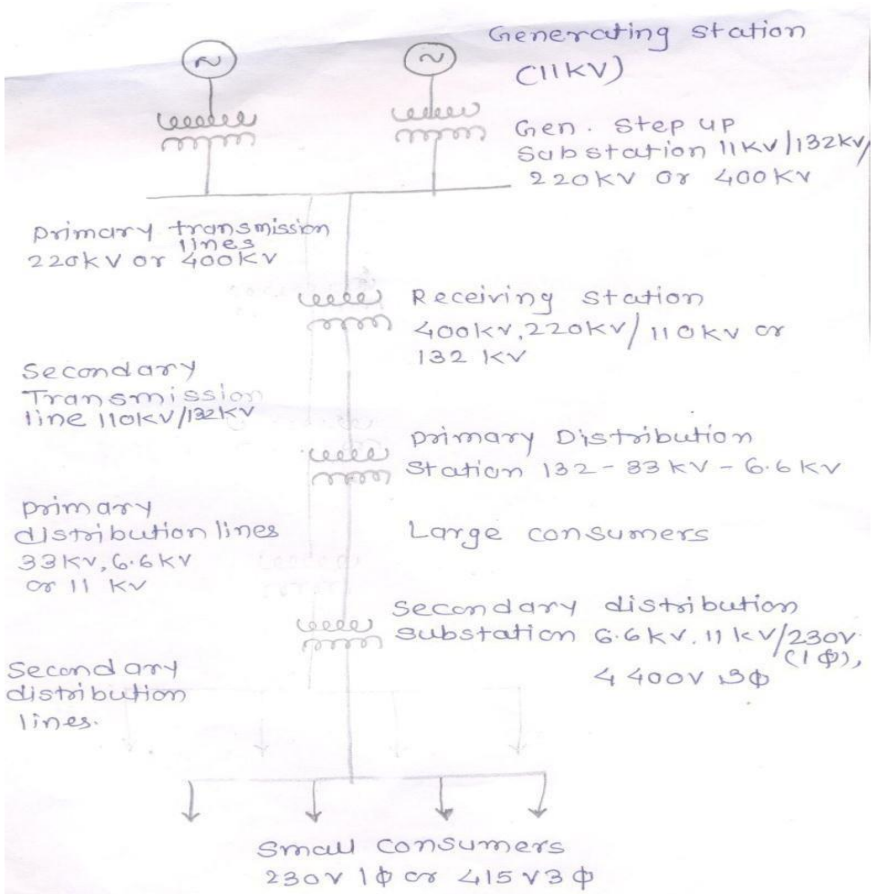
WINTER – 2016 EXAMINATION

Model Answer **Subject Code: 17510**

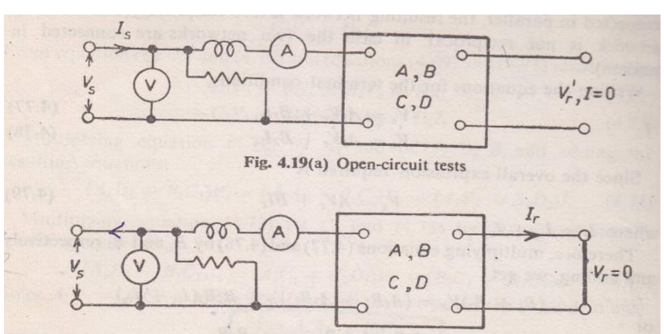
Important Instructions to examiners:

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.

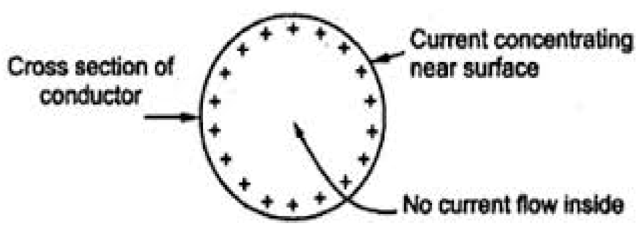
Q. No.	Sub Q.N.	Answer	Marking Scheme
1.	**A)**	**Attempt any three of the following:**	**12**
	a)	**Draw a basic structure of power system showing different voltage levels.**	***4M***
	Ans.		

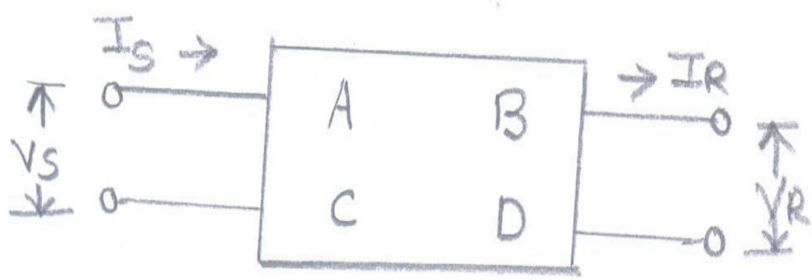
			***2M voltage levels*** ***2M line diagram***
	b) Ans.	**Give the expression for complex power, active power and reactive power at receiving end.** Complex power at the receiving end is given by $S_R = V_R I_R^*$ …………………………. $P_R = \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\cos(\beta - \delta) - \frac{\lvert A\rvert\lvert V_R\rvert^2}{\lvert B\rvert}\cos(\beta - \delta)$ …….. $Q_R = \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\sin(\beta - \delta) - \frac{\lvert A\rvert\lvert V_R\rvert^2}{\lvert B\rvert}\sin(\beta - \delta)$. … Where P_R= Real or active 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	***4M*** ***1M*** ***1M*** ***1M*** ***1M***

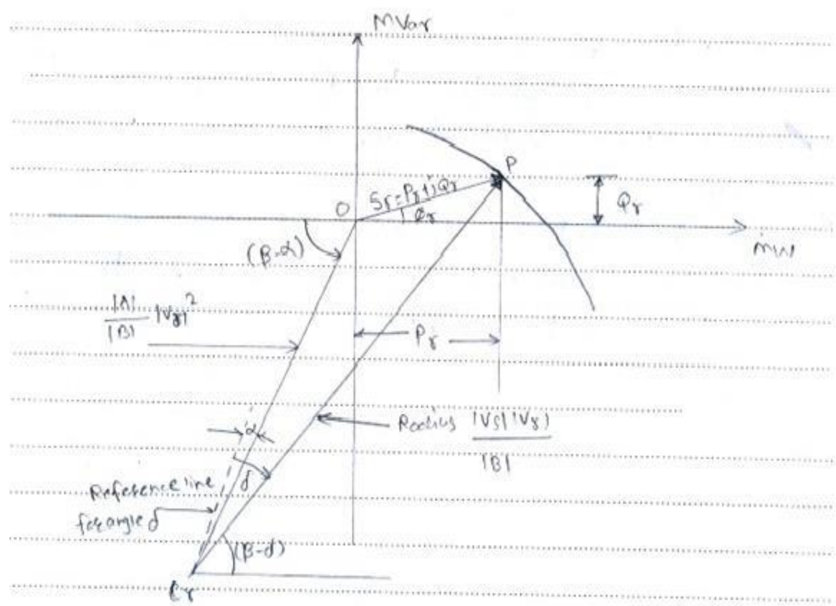
	c) Ans.	**State the significance of resistance parameter on performance of transmission line.** **Significance of resistance:** 1. Resistance causes voltage drop IR 2. Voltage drop in transmission line affects regulation 3. Resistance causes I^2R losses, which affects efficiency. 4. Temperature of line increases due to resistance.	***4M*** ***1M for each point***
	d) Ans.	**List the advantages of generalised circuit representation.** **Advantages of generalized:** 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 VRNL $V_S = AV_R + BI_R$ i.e. when IR = 0VRNL = V_S /A Now the regulation of the line can be immediately calculated by % Voltage Regulation = V_S / A - V_R / V_R X 100 4. Output power = V_R I_R Cos ϕ_R for ….1ϕ…ckt. = 3V_R I_R Cos ϕ_R for ….3ϕ ……..ckt. Input power = $V_S I_S$ Cos ϕ_S…………1ϕ..ckt. = 3 $V_S I_S$ Cos ϕ_S …………3ϕ..ckt. losses in the line = input – output 5. By calculating input and output power efficiency 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: $$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} A_1 & B_1 \\ C_1 & D_1 \end{vmatrix} \times \begin{vmatrix} A_2 & B_2 \\ C_2 & D_2 \end{vmatrix}$$	***4M*** ***Any 4 advantages 1M each***

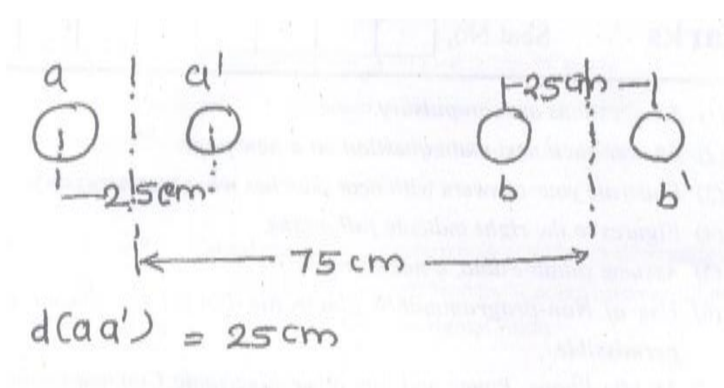
		7. When two transmission lines are connected in parallel then the resultant two part network can be easily obtained by $A = \frac{A_1B_2 + A_2B_1}{B_1 + B_2}$ $B = \frac{B_1B_2}{B_1 + B_2}$ $D = \frac{D_1B_2 + D_2B_1}{B_1 + B_2}$ $C = C_1 + C_2 - \frac{(A_1 - A_2)(D_2 - D_1)}{B_1 + B_2}$	
1.	**B)** **a)** Ans.	**Attempt any one of the following:** **Explain the procedure for measurement of generalised circuit constants.** 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…………………………………………….. The connection diagram is shown below:  The test is conducted on sending end side. Now, $V_s = AV_R + BI_R$------- (1) $I_s = CV_R + DI_R$ ------- (1)	**6** ***6M*** ***1M*** ***2M***

		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 $I_R \times I_s$ = D I_R $\therefore Z_{ss} = \frac{V_s}{I_s} = \frac{B}{D}$ sending end impedance with receiving end s.c.ed ………………… 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 = DV_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) $Z_{rs} = \frac{B}{A}$	**1M** **1M**

		or B = AZ_{rs} = $Z_{rs}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ ----------------(b) $Z_{so} = \frac{A}{C}$ ∴ C = $\frac{A}{Z_{so}} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ --------------(c) $Z_{ro} = \frac{D}{C}$ ∴D = C· $Z_{ro} = \frac{Z_{ro}}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ = $Z_{ro}\sqrt{\frac{1}{(Z_{ro}-Z_{rs})Z_{so}}}$-----------(d) If $Z_{ro} = Z_{so}$ we get A = D for symmetric network ……..………..	*1M*
	b) Ans.	**Define skin effect and proximity effect. State factors on which skin effect and proximity effect depends.** **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. **Skin effect depends on factors:** • Current • Permeability of material • Frequency • Conductor diameter • Diameter • Material of conductor **PROXIMITY EFFECT:** When the alternating current is flowing through a conductor alternating magnetic flux is generate surrounding the conductor. This	*6M* *2M* ***Any 2, ½ M for each***

		magnetic flux associates with the neighboring conductor and generate circulating currents. This circulating currents increases resistance of conductor. This 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	***2M*** ***Any 2, ½ M for each***
2.	**a)** **i)** Ans.	**Attempt any two of the following:** **Define generalised circuit and generalised circuit constant.** **Generalized Circuit**: An passive, linear, bilateral network with two port terminals is known as generalized circuit. A transmission line is a 2 port network, two input terminals where power enters & two output terminals where power leaves the network.  **Generalized Circuit Constant:** 1) A = $\frac{VS}{VR}$; I_R= 0 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 =$\frac{VS}{IR}$; V_R= 0 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. Its unit is in ohms. 3) C = $\frac{IS}{VR}$; I_R= 0 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 its unit mho. 4) D =$\frac{IS}{IR}$; V_R= 0	**16** ***4M*** ***Definition of generalised circuit 1M*** ***Generalisation circuit constant 3M***

		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.	
	ii) Ans.	**Explain the procedure for receiving end circle diagram with usual notation.**  $S_r = \frac{-\lvert A\rvert \lvert V_r\rvert^2}{\lvert B\rvert} \angle(\beta-\alpha) + \frac{\lvert V_s\rvert \lvert V_r\rvert}{\lvert B\rvert} \angle(\beta-\delta)$ **Step-1:** Draw the X-Y plane in which plane X represents the active power (MW) & axis-y-represents the Reactive power (MVA). $\frac{\lvert A\rvert}{\lvert B\rvert} \lvert V_r\rvert^2$ **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 |Vs| |Vr| & draw a circle in 1st quadrant.	***4M*** ***Diagram 2M*** ***Explanation 2M***

		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 Sr=Pr+jQr& the corresponding value of Qr 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'.	
2.	**b)** Ans.	**Determine inductive reactance of 1 φ tr. Line arrangement shown in fig.1 per mt. length. The dia. of each conductor is 1cm and current is equally shared by two parallel conductors.** 	***8M***

$d = 1cm \quad \therefore r = 0.5cm = 0.5 \times 10^{-2} m$

$\frac{L}{M} = 2 \times 10^{-7} \ln \frac{D_m}{D_s}$

Self GMR $= 0.7788r$
$= 0.7788 \times 0.5 \times 10^{-2}$
$= 3.894 \times 10^{-3}$ — 2 mark

$\therefore D_{aa} = D_{a'a'} = D_{bb} = D_{b'b'} = 3.894 \times 10^{-3}$ GM.

$\therefore D_s = (D_{aa} \times D_{a'a'} \times D_{aa'} \times D_{a'a})^{1/4}$
$= (3.894 \times 10^{-3} \times 3.894 \times 10^{-3} \times 0.25 \times 0.25)^{1/4}$
$= (3.894 \times 10^{-3} \times 0.25)^{1/2}$
$= 0.0312 m$ — 2 mark

$D_m = (D_{ab} \times D_{ab'} \times D_{a'b} \times D_{a'b'})^{1/4}$
$= (0.75 \times 1.0 \times 0.5 \times 0.75)^{1/4}$
$= (0.281)^{1/4}$
$= 0.728 m$ — 2 mark

$\frac{L}{m} = 2 \times 10^{-7} \ln \frac{D_m}{D_s}$
$= 2 \times 10^{-7} \ln \frac{0.728}{0.0312}$
$= 6.299 \times 10^{-7}$

$\frac{L}{km} = 6.299 \times 10^{-7} \times 1000$
$= 629.9 \times 10^{-6} H$ — 1 mark

$\therefore X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 629.9 \times 10^{-6}$
$= 0.1977 \Omega / km$ — 1 mark

2.	**c)**	**If A and B constants of a 3 φ tr. Line are 0.9 $\angle 1^0$ and 100 $\angle$ 85^0 respectively. Determine the receiving end current and power supplied to load. Assume both sending end and receiving end voltages are 200 kV with phase dift. of 8^0 between them.**	***8M***
	Ans.	$A = 0.9 \angle 1^\circ \qquad \delta = 8^\circ$ $B = 100 \angle 85^0$ $\lvert V_S \rvert = \lvert V_R \rvert = \frac{200}{\sqrt{3}}$ kV — 1 mark Now $V_S = AV_R + BI_R$ — 1 mark $I_R = \frac{V_S}{B} - \frac{AV_R}{B}$ — 1 mark $I_R = \frac{200 \times 10^3 \angle 8}{\sqrt{3}\, 100 \angle 85} - \frac{0.9 \angle 1 \times 200 \times 10^3 \angle 0}{\sqrt{3}\, 100 \angle 85}$ $= 1154.70 \angle -77 - 1039.23 \angle -84$ $I_R = 259.75 - j\,1125.10 - 108.62 + j\,1033.53$ $= 151.13 - j\,91.51$ $= 176.70 \angle -31.21^\circ$ — 2 mark $3\phi S_R = \frac{V_S V_R}{B} \angle \beta - \delta - \frac{A V_R^2}{B} \angle \beta - \alpha$ — 1 mark $= \frac{200 \times 200}{100} \angle 85 - 8 - \frac{0.9 \times 200^2}{100} \angle 85 - 1$ $= 400 \angle 77^\circ - 360 \angle 84^\circ$ $P_R = 400 \cos 77^\circ - 360 \cos 84^\circ$ $= 89.98 - 37.63$ $= 52.345$ MW — 2 mark	

3. **Attempt any four of the following:** **16**

a) **Draw the reactance diagram of given power system as shown in fig.2 select generator rating as the common base value.** ***4M***

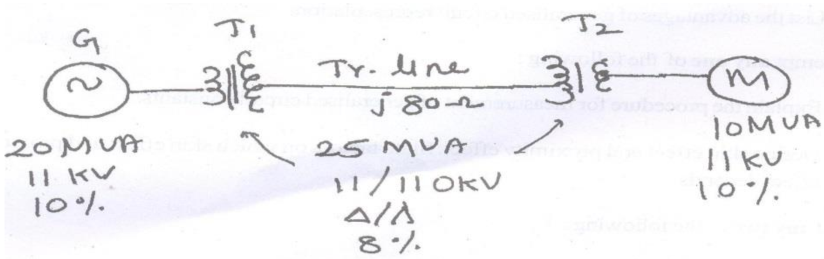


Fig. 2

Ans.

Assuming Gen as base

$\therefore$ Base MVA = 20

Base V = 11 kV for Gen. side

= 110 kV for Tr. line side

& 11 kV for motor side

Calculation of X_{pu} →

① Generator → $X_{pu\,new} = X_{pu\,old} = \underline{0.1\ pu}$

② Transformer T_1 & T_2

$$X_{pu\,new} = X_{pu\,old} \times \frac{MVA_{new}}{MVA_{old}} \times \left(\frac{kV_{old}}{kV_{new}}\right)^2$$

$$= 0.08 \times \frac{20}{25} \times \left(\frac{11}{11}\right)^2 = \underline{0.064\ pu}$$

③ Motor

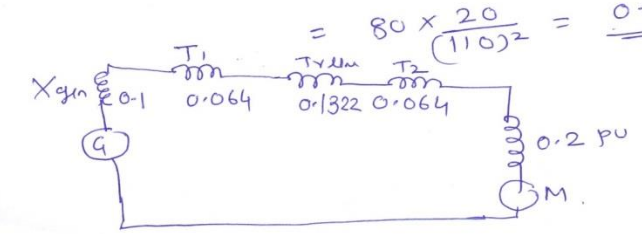
$$X_{pu\,new} = 0.1 \times \frac{20}{10} \times \left(\frac{11}{11}\right)^2 = \underline{0.2\ pu}$$

} 2M

④ Tr. line -

$$X_{pu} = \frac{X_{actual}}{X_{Base}} = X_{actual} \times \frac{MVA_{Base}}{(kV_{Base})^2}$$

$$= 80 \times \frac{20}{(110)^2} = \underline{0.1322\ pu}$$ → 1M



} – 1M

	b) Ans.	**Give the expression for coordinates for centre and radius for sending end and receiving end circle dia.** The centre of Receiving end circle is located at the tip of phaser $\|A/B\|$ $1V_r\|^2 < \beta - \alpha$ drawing OC_S from negative MW axis. 1. The X and Y coordinates of the centre are $\|A/B\|\ 1V_r\|^2$ Cos $(\beta - \alpha)$ and $\|A/B\|\ 1V_r\|^2$ Sin $(\beta - \alpha)$ 2. The radius of sending end circle is drawn with $\|V_S\|\|V_R\| / \|B\|$ from centre C_S 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. 3. The X and Y coordinates of the centre are $\|D/B\|1V_S\|^2$ Cos $(\beta - \alpha)$ and $\|D/B\|1V_S\|^2$ Sin $(\beta - \alpha)$ 4. The radius of sending end circle is drawn with $\|V_S\|\|V_R\| / \|B\|$ from centre C_S	*4M* *2M* *2M*
	c) Ans.	**Determine the inductance of 3 φ line operating at 50Hz and conductors are arranged at triangle of sides 1.6m, 3.2m and 1.6m. The conductor diameter is 0.8 cm.** $L_x = L_y = L_B = 2 \times 10^{-7} \log_e \frac{D_{eq}}{r^1}$ $D_{eq} = \sqrt[3]{D_{RY}D_{RB}D_{BR}} = \sqrt[3]{1.6 \times 3.2 \times 1.6} = 2.0158m$ $r^1 = 0.7788r = 0.7788 \times (0.8 \times 10^{-2}) = 0.00623m$ $L_x = L_y = L_B = 2 \times 10^{-7} \log_e(\frac{2.0158}{0.00623}$ $= 1.156 \times 10^{-6} \frac{H}{M} = 1.156 \frac{mH}{Km}$	*4M* *1M* *1M* *1M* *1M*
	d) Ans.	**A250kV transmission line has following GCC-A = 0.85 ∠7^0, B = 300 ∠75^0 Ω/phase. Determine power at unity P.F. that can be received if voltage at each end is maintained at 250kV.** Given data $V_S = V_R = 250$ KV, A = 0.85 <7 ^{o}, B = 300 < 75 ^{o}	*4M*

Then for unity power factor $Q_R = 0$

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

Substituting all values we get

$0 = (250)X(250)/ 300 \sin(\beta - \delta) - (0.85)(250)^2 / 300 \sin(75 - 7)$

$0 = 208.33 \sin(\beta - \delta) - 164.188$

$\sin(\beta - \delta) = 0.788$

$\beta - \delta = 52^o$ ***2M***

Substituting this is in equation of P_R we get

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

$= (250)(250) / 300 \cos(52) - 0.85 \times (250)^2 / 300 \cos(75-7)$

$= (208.33)(0.616) - (177.083)(0.375)$

$= 128.33 - 66.406$

$P_R = 61.924$ MW.

Unity power at receiving end is 61.924 MW ***1M***

e) **Derive an expression for capacitance of 1 φ tr. line compose of solid conductor.** ***4M***

Ans.

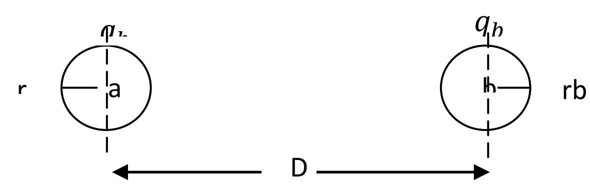


Diagram 1M

Capacitance of a 1φ line is defined as the charge on the conductor /unit of a p. d between them.

$$c = \frac{q}{v} \text{ F/mt}$$

Where q – change on the conductor in coulombs / m t

V – p. d between the conductors in volts. ***Explanation 1M***

Consider a 1 φ line excited from 1 φ A.C source. The line develops equal and opposite sinusoidal charges on the two conductors. Let q_a&q_b be the changes on the conductors 'a'& 'b' whose radii are r_a, r_b respectively.

Derivation 2M

Since the conductor 'b' for mc a return path for the current through' conductor 'a', the change 'q_b' on conductor 'b' is equal &opposite to conductor 'a'.

i.e.$q_a = -q_b$ or $q_b = -q_a$

Assume that charges on each conductor are distributed uniformly around its periphery and length.

Consider the conductor ‘a’ alone with the charge and ‘b’ without any charge. Now the p. d between the conductors a & b is

$$\vartheta_{ab} = \frac{q_a}{2\,\pi k}\log_e \frac{D}{ra}l \quad \text{- - v/mt - (1)}$$

Similarly consider b with charge and ‘a’ without any charge. Then the p. d. between the conductors b & a is given by

$$\vartheta_{ba} = \frac{qb}{2\pi k}\log_e \frac{D}{r_b}\text{-(2)}$$

p. d. between a & b can be written as,

$$\vartheta_{ab} = -\vartheta_{ba} = \frac{-q_b}{2\,\pi k}\log_e \frac{D}{r_b}\text{-(3)}$$

Now by super position theorem, the net p. d. between a & b when both the conductors are charged equally oppositely can be written by adding the eq. ----------- (1) & (3)

$$\vartheta_{ab} = \vartheta_{ab}{}' + \vartheta_{ab}{}''$$

$$= \frac{q_a}{2\,\pi k}\log_e \frac{D}{r_a} - \frac{q_b}{2\Pi k}\log_e \frac{D}{r_b}$$

$$\cdot\frac{q_a}{2\,\pi k}\log_e \frac{D}{r_a} + \frac{q_b}{2\Pi k}\log_e \frac{D}{r_b}$$

Since $q_a = -q_b$

$$= \frac{q_a}{2\,\pi k}\left[\log_e \frac{D}{r_a} + loge \frac{D}{r_b}\right]$$

$$= \frac{q_a}{2\,\pi k}\log_e \frac{D^2}{r_a r_b}{}^2$$

If $r_a = r_b = r$

$$\vartheta = \frac{q_a}{2\,\pi k}\log_e \frac{D^2}{r^2}$$

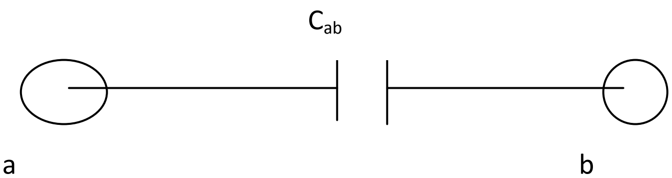
$$= \frac{2\,q_a}{2\,\pi k}\log_e \frac{D}{r}$$

$$\vartheta = \frac{q_a}{\pi k}\log_e \frac{D}{r} \quad \text{-----------------v/mt. ....(4)}$$

Capacitance between two conductors i.e. line capacitance
Can be written as—

$$C_{ab} = \frac{q_a}{V_{ab}} = \frac{\pi k}{loge^{D}/_{r}} \quad \text{------------F/Mt. ---(5)}$$

And it is represented as

		 	
4.	**A)** **a)** Ans.	**Attempt any three of the following:** **Define self GMD and mutual GMD.** **Mutual GMD:** If conductor A has ‘n’ no of sub conductor & conductor B has ‘m’ no of subconductor, then *mn*th root of the *mn* 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 $D_{m.}$ Similarly, **Self GMD**: or GMR n^2th 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. It 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* (GMR). Example let radius of conductor X & Y is = r  Self GMD of conductor X = $\sqrt[4]{D_{11}D_{1'1},D_{11},D_{1'1}}$ = $\sqrt[4]{r' x\, r' x\, d\, x\, d}$ =$\sqrt{r' x d}$ Self GMD of conductor Y = r’ Mutual GMD between conductor X & Y = $\sqrt{D_{12}D_{1'2}}$ = $\sqrt{\left(\frac{d}{2}+D\right) x\ (D-\frac{d}{2})}$	**12** ***4M*** ***2M each***

	b) Ans.	**A275kV 3 φ line has following parameter A = 0.91 ∠ 1.5^0, B = 115 ∠77^0. If the receiving end voltage is 275kV determine the max. power that can be delivered if sending end V is held at 295 kV.** Given data V_R = 275KV , A=D= 0.91 ∠1.5 , B = 115 ∠ 77 Ω P_{RMAX}= ?when V_R= V_s = 275 KV **For max receiving end power condition is** $\boldsymbol{B-\delta=0}$ ……………………………………………………… **So** $P_{RMAX}=\frac{V_S V_R}{B}-\frac{A}{B}VR^2\cos(\beta-\alpha)$ ……………………………. $\frac{275\ X\ 275}{115}-\frac{0.91}{115}\ X\ (275)^2\ \ \cos(77-1.5)$ = 507.775 MW	*4M* *1M* *1M* *2M*
	c) Ans.	**Explain the role of power system engineer.** ***(Note: any other relative points may be consider)*** 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./ outage of line vii. He has to evolve strategies for energy conservation and load management. viii. For solving the power system problems he has to update with new technology method.	*4M* *Any 4 1M each*
	d) Ans.	**State the need of reactive power compensation and name the devices used for reactive power compensation.** **Need of Reactive power compensation:** Power system is well designed when it gives good quality of reliable supply i.e variation at receiving end is within limit (+/- 5 %). If variation is more performance of equipment is affected. Variation in Voltage indicates unbalance in reactive power generated Qs & reactive power consumed by load Qr If Qs >Qr --- Vr increases If Qs < Qr -----Vr decreases	*4M* *Need of reactive power compensation 2M*

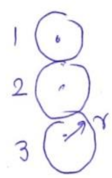
		If Qs = Qr ---- Vr flat cha So to maintain balance in Qs & Qr Reactive power compensation is required. **Devices for of Reactive power compensation:** 1) shunt capacitor bank –substation & medium Tr. line 2) Inductance reactor bank- long HV tr. line 3) Syn. condenser- load centre 4) Auto transformer – substations	***Devices for of reactive power compensation 2M***
4.	**B)** **a)** Ans.	**Attempt any one of the following:** **A 50Hz 3 φ tr. line is 250 km long. It has a total series impedance of 35 + j40 Ω and shunt admittance of 930 x 10^{-4} Ω. It delivers 40,000 kW with 90% p.f. lag. Find ABCD constant considering medium line having nominal T circuit regulation of line.** $Z = 35 + j40 \quad Y = 930 \times 10^{-4}$ ℧ $I_R = \frac{40{,}000}{\sqrt{3} \times 220 \times 0.9} = 342.95 \text{ Amp} \angle -25.84$ ABCD Constant for T ckt. $A = (1 + \frac{YZ}{2}) = 1 + \frac{(930 \times 10^{-4} \angle 90)(35 + j40)}{2}$ $= 1 + (-1.85 + j1.627)$ $= 1.84 \angle 117.85 = D$ → (1M) $B = Z(1 + \frac{YZ}{4}) = (35 + j40)(1 + \frac{930 \times 10^{-4} \angle 90 \times (35 + j40)}{4})$ $= 43.41 \angle 133.89$ → (1m) $C = Y = 930 \times 10^{-4} \angle 90$ → (1m) $V_S = A V_R + B I_R$ $= 1.84 \angle 117 \times \frac{220 \times 10^3}{\sqrt{3}} \angle 0 + 43.41 \angle 133.89 \times 342.95 \angle -25.84$ $= 248{,}428.38 \angle 116.46$ $= 248.42 \text{ kV}$ → (2m) $\% \text{Reg} = \frac{\frac{V_S}{A} - V_R}{V_R} \times 100$ $= \frac{\frac{248.42}{1.84} - 220/\sqrt{3}}{220/\sqrt{3}} \times 100 = 6.29\%$ (1M)	**6** ***6M***

	b)	**Find self GMD for arrangement as shown in fig.3 If r = 0.1cm.**	***6M***

Fig. 3

Ans.

Self GMD if $r = 0.1\,cm$



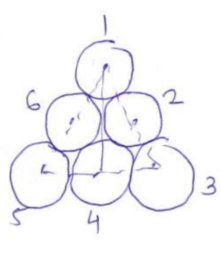
$$D_s = \sqrt[9]{(D_{11}D_{12}D_{13})(D_{21}D_{22}D_{23})(D_{31}D_{32}D_{33})}$$

$$= \sqrt[9]{(D_{11}D_{12}D_{13})^2(D_{21}D_{22}D_{23})} \quad (\rightarrow 1M)$$

$$= \sqrt[9]{(0.7788r \times 2r \times 4r)^2(2r \times 0.7788r \times 2r)} \quad \rightarrow (1M)$$

$$= \sqrt[9]{r^9}\,\sqrt[9]{120.92}$$

$$= 1.70r = \underline{0.17\,cm} \quad \rightarrow (1M)$$



$$D_{14} = \sqrt{(4r)^2 - (2r)^2} \quad \sqrt{12}\,r$$

$$D_s = \sqrt[36]{(D_{11}D_{12}D_{13}D_{14}D_{15}D_{16})^3 \cdot (D_{21}D_{22} \ldots D_{23}D_{24}D_{25}D_{26})^3} \quad \rightarrow (1M)$$

$$D_s = \sqrt[12]{(D_{11}D_{12}D_{13}D_{14}D_{15}D_{16})(D_{21}D_{22}D_{23}D_{24}D_{25}D_{26})}$$

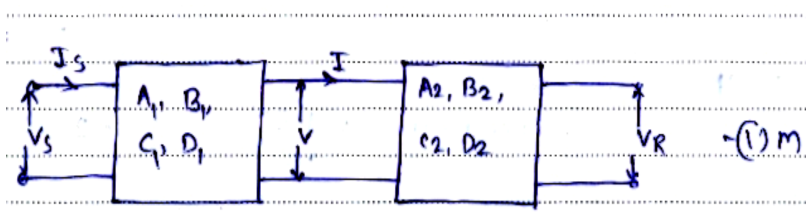
$$= \sqrt[12]{(0.7788r \times 2r \times 4r \times \sqrt{12}\,r \times 4r \times 2r)(2r \times 0.7788r \times 2r \times 2r \times \sqrt{12}\,r \times 2r)} \quad \rightarrow (1M)$$

$$= 2.102r = \underline{0.210\,cm} \quad \rightarrow (1M)$$

5. **Attempt any two of the following:** **16**

a) **Derive overall ABCD constants of series connected two transmisson line networks.** ***8M***

Ans.



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. ***2M***

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) $I_S = (A_2 C_1 + C_2 D_1) V_R + (B_2 C_1 + D_2 D_1) I_R$ —(10) —(1)m 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) $A = A_1 A_2 + B_1 C_2$ $B = A_1 B_2 + B_1 D_2$ $D = B_2 C_1 + D_2 D_1$. $C = A_2 C_1 + C_2 D_1$ (1)m	
	b) Ans.	**A 3 φ line has following constants. A = D = 0.9 ∠ 0.5^0, B = 99 ∠78^0 Ω. The sending end and receiving end voltages are maintained at 220kV. Calculate load angle when power fed at sending end is 400MW using sending end circle diagram. Also determine maximum power delivered at receiving end.**	*8M*

X - co-ordinate =

$$\frac{A V_S^2}{B} \cos(\beta - \alpha)$$

$$= \frac{0.9 \times 220^2}{99} \cos(78 - 0.5)$$

$$= 95.233 \text{ MW} \rightarrow (1M)$$

Y - co-ordinate =

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

$$= \frac{0.9 \times 220^2}{99} \sin(78 - 0.5)$$

$$= 429.570 \text{ MVAR} \rightarrow (1M)$$

Radius of circle $= \frac{V_S V_R}{B}$

$$= \frac{220 \times 220}{99} = 488.88 \text{ MVA} \rightarrow (1M)$$

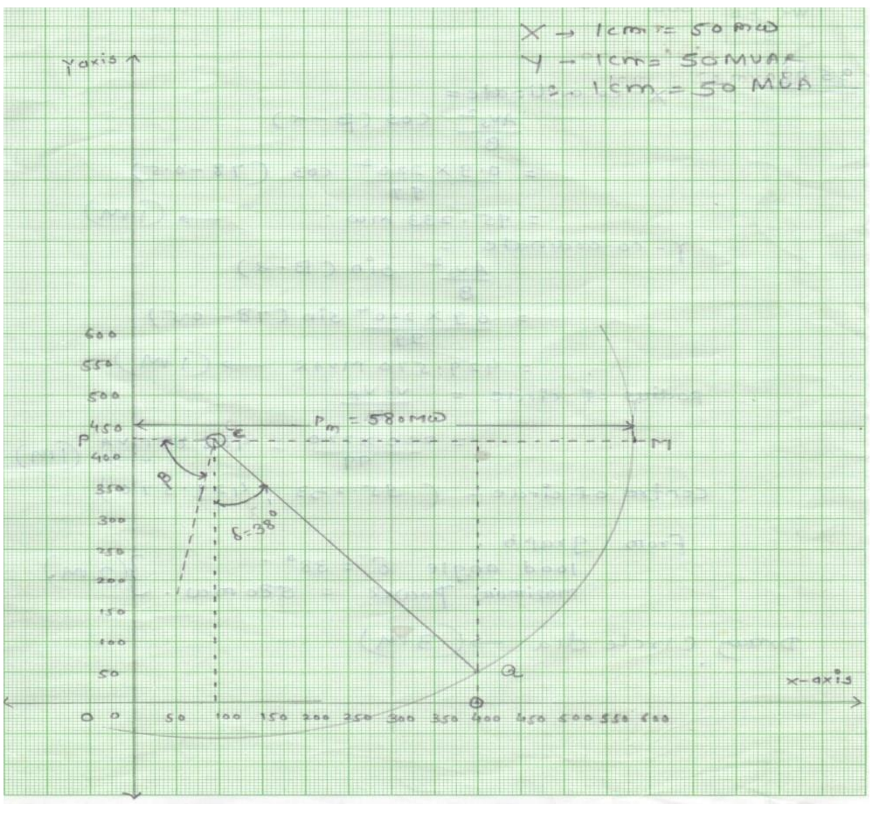
centre of circle = (95.233, 429.570)

From graph:

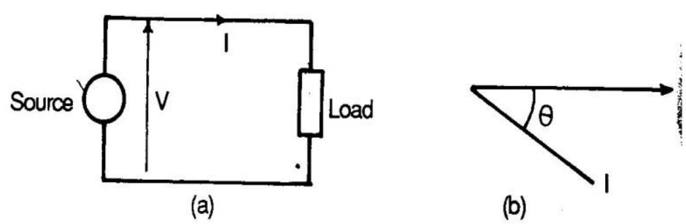
load angle $\delta = 38°$

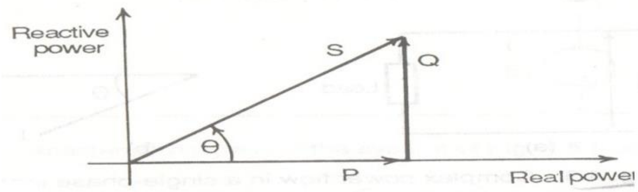
Maximum Power = 580 MW. } (2M)

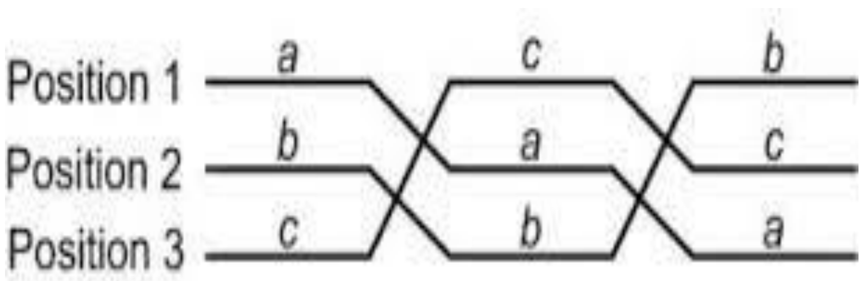
Draw Circle dia → (3M)



	c) Ans.	**A 3 φ line with equilateral spacing 3mt is to be rebuilt with horizontal spacing as D_{13} = $2D_{12}$ = $2D_{23}$. The conductors are to be fully transposed. Find the spacing between adjacent conduct as such that new line has the same inductance as original value.** 3 phase line with equilateral spacing $L = 2X10^{-7} \log_e \frac{D}{r\prime} = 2X10^{-7} \log_e \frac{3}{r\prime}$- -------------Eq 1 With horizontal spacing …………………….. …………………… $2X10^{-7} \log_e \frac{Deq}{r\prime}$ ---eq 2 $Deq = \sqrt[3]{D12}$x D23X D31 Inductance L remains same Equating eq 1 &eq 2 $L = 2X10^{-7} \log_e \frac{D}{r\prime} = 2X10^{-7} \log_e \frac{Deq}{r\prime}$…………………………….. $\frac{D}{r'} = \frac{Deq}{r'}$ D = Deq = $\sqrt[3]{(D12}$x D23X D31) 3 = $\sqrt[3]{((D12)^2\ X\ (2D12))}$ 3 = $\sqrt[3]{2X(D12)^3}$ D12 = $\frac{3}{\sqrt[3]{2}}$= 2.381 m ……………………………………………………...	*8M* *1M* *1M* *3M* *3M*
6.	a) Ans.	**Attempt any four of the following:** **Prove that complex power in power system is S = VI*.**	**16** *4M*

		Consider a single-phase load fed from a source as in Fig. . Let $V = \|V\| \angle\delta$ $I = \|I\| \angle(\delta - \theta)$  Complex power flow in a single-phase load When θ is positive, the current lags behind voltage. This is a convenient choice of sign of θ in power systems where loads have mostly lagging power factors. Complex power flow in the direction of current indicated is given by $S = VI^*$ $= \|V\|\,\|I\| \angle\theta$ $= \|V\|\,\|I\| \cos\theta + j\|V\|\,\|I\| \sin\theta = P + jQ$ or $\|S\| = (P^2 + Q^2)^{1/2}$ Here S = complex power (VA, kVA, MVA) $\|S\|$ = apparent power (VA, kVA, MVA); it signifies rating of equipments (generators, transformers) $P = \|V\|\,\|I\| \cos\theta$ = real (active) power (watts, kW, MW) $Q = \|V\|\,\|I\| \sin\theta$ = reactive power = voltamperes reactive (VAR) = kilovoltamperes reactive (kVAR) = megavoltamperes reactive (MVAR) It immediately follows from Eq. that Q, the reactive power, is positive for lagging current (lagging power factor load) and negative for leading current (leading power factor load). With the direction of current indicated in Fig. , $S = P + jQ$ is supplied by the source and is absorbed by the load.	4M

		$\theta = \tan^{-1}\frac{Q}{P}$ = positive for lagging current = negative for leading current  Phasor representation of complex power (lagging pf load) In Electrical engineering S=P+jQ. Where Q is positive and it is inductive reactive power which lags i.e. due to lagging current. Q is negative when capacitive reactive power. i.e. due to leading current. The same concept is obtained when we consider S=VI* & not when considered S=V*I	
	b) Ans.	**List the advantages of PU system.** **Advantages of PU calculations:-** 1. Manufacturers specify impedance of apparatus in % or P.U. values on basis of name plate rating. 2. p.u. impedance of machine of same type having different ratings usually lay within narrow range though actual values differs with rating. Hence if impedance is not known, we can consider value from table in which avg. value for different type of machine are given. 3. P.u values are same referred to either side of transformer. 4. Type of connection of 3Φ transformer in 3Φcircuit does not affect p.u. values.	***4M*** ***Any 4 each advantage 1M***
	c) Ans.	**What is transposition of 3 φ line? State its advantages.** **Transposition** of conductors means exchanging the positions of the conductors at regular intervals along the line such that each conductor occupies the original position of every other conductor over equal distance. Unsymmetrical Spacing in the transmission line causes the flux linkages and therefore the inductance of each phase to be different resulting in unbalanced receiving end voltages even when sending end voltages and line currents are balanced. Also voltages will be induced in the adjacent communication lines when the line currents are balanced. This problem is reduced by transposition.	***4M*** ***1M*** ***1M***

		Advantages: **1.** This arrangement causes each conductor to have the same average inductance over the transposition cycle. Over the length of one transposition cycle the total flux linkages is zero. **2.** Results in balanced receiving end voltages when sending end voltages and line currents are balanced. **3.** No voltages will be induced in the adjacent communication lines when the line currents are balanced. 	*1M* *1M*
	d) Ans.	**Derive the expresssion for complex power at receiving end in simple two bus power system.** Complex power at receiving end tr. line GCE→ $V_s = AV_R + BI_R$ $\therefore I_R = \frac{V_S}{B} - \frac{A}{B} V_R$ let $V_R = \|V_R\|\angle 0$, $V_S = \|V_S\|\angle \delta$	*4M*

		$D = A = A\angle\alpha \quad B = B\angle\beta$ $\therefore I_R = \frac{V_S\angle\delta}{B\angle\beta} - \frac{A\angle\alpha\, V_R\angle 0}{B\angle\beta} \rightarrow (1m)$ $= \frac{V_S}{B}\angle\delta-\beta - \frac{AV_R}{B}\angle(\alpha-\beta)$ $I_R^* = \frac{V_S}{B}\angle\beta-\delta - \frac{AV_R}{B}\angle(\beta-\alpha) \rightarrow (1m)$ Let S_R be complex power at receiving end. $S_R = V_R I_R^*$ $= \frac{V_R V_S}{B}\angle\beta-\delta - \frac{AV_R^2}{B}\angle\beta-\alpha \rightarrow (1m)$ $= P_R + jQ_R$ $\therefore P_R = \frac{V_R V_S}{B}\cos(\beta-\delta) - \frac{AV_R^2}{B}\cos(\beta-\alpha)$ $Q_R = \frac{V_R V_S}{B}\sin(\beta-\delta) - \frac{AV_R^2}{B}\sin(\beta-\alpha)$ $\rightarrow (1m)$	
	e) Ans.	**A balanced load of 50 MVA is supplied at 132 kV, 502Hz, 0.8pf lag by means of tr. line. The series impedance is 180 $\angle 75^0$ Ω /ph and shunt admittance is 1 X 10^{-3} $\angle 90^0$ S/ph calculate ABCD constants using nominal ∏ method.** $Z = 180\angle 75^o \Omega$ $Y = 1 \times 10^{-3}\angle 90^0$ $for\ Nominal\ \pi - circuit$ $A = D = 1 + \frac{YZ}{2}, B = Z, C = Y\left(1 + \frac{yz}{4}\right)$ $A = D = \frac{1+yz}{2} = 1 + [\frac{(1\times10^{-3}\angle 90^0).(180\angle 75^o)}{2}]$ $A = 1 + \frac{0.18\angle 165}{2}$ $A = 1 + 0.09\angle 165$ $A = 0.913 + j0.02329 = 0.913\angle 1.46 = D$	*4M* *2M*

		$B = Z = 180\angle 75^o \Omega$ $C = Y\left(1+\frac{yz}{4}\right)$ $= 1\times 10^{-3}\angle 90^0\left[1+\frac{(1\times 10^{-3}\angle 90^0)(180\angle 75^o)}{4}\right]$ $= 1\times 10^{-3}\angle 90^0 x 0.9566\angle 0.697$ $= 9.566\ \times 10^{-4}\angle 90.697 siemens$	***2M***