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

WINTER – 2019 EXAMINATION
MODEL ANSWER

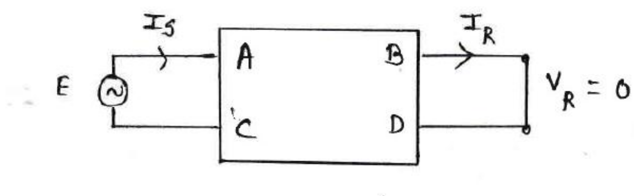
Subject: Power System Analysis **Subject Code: 17510**

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)** **(a)** **Ans.**	**Attempt any THREE of the following:** **State the role of Power System Engineer.** **The role of Power System Engineer:** 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.	**12** **4M** ***Any four points 1M each***

	(b) Ans.	**Justify 'AC resistance is always higher than DC resistance'.** When dc current flow in line conductor, the current is uniformly distributed across the section of the conductor whereas flow of alternating current is non-uniform over the cross section in the manner that current density is higher at the surface of the conductor compared to the current density at its centre. This effect is more pronounced as frequency increases this phenomenon is called as skin effect. It causes power loss for given rms AC than the loss when same value of DC is flowing through the conductor. Therefore AC resistance is greater than DC resistance.	**4M** ***Explanation 4M***
	(c) Ans.	**State the expression for complex power, real power and reactive power at sending end of transmission line.** $\text{Complex powe} - S_S = \frac{\lvert A\rvert\lvert V_S\rvert^2}{\lvert B\rvert}(\angle\beta-\propto) - \frac{\lvert V_R\rvert\lvert v_S\rvert}{\lvert B\rvert}(\angle\beta+\delta)$ $\text{Real power} - P_S = \frac{\lvert A\rvert\lvert V_S\rvert^2}{\lvert B\rvert}\cos(\beta-\propto) - \frac{\lvert V_R\rvert\lvert v_S\rvert}{\lvert B\rvert}\cos(\beta+\delta)$ $\text{Reative power} - Q_S = \frac{\lvert A\rvert\lvert V_S\rvert^2}{\lvert B\rvert}\sin(\beta-\propto) - \frac{\lvert V_R\rvert\lvert v_S\rvert}{\lvert B\rvert}\sin(\beta+\delta)$ Parameters of above expressions…. -*Sending end voltage* $- \lvert V_S\rvert\angle\delta$ -Receiving end voltage$-\lvert V_R\rvert\angle\delta$ -GCC -A $\angle\propto$, B$\angle\beta$,	**4M** ***1M*** ***1M*** ***1M*** ***1M***
	(d) Ans.	**Write advantages of generalised circuit representation.** **Advantages of generalized circuit representation:** 1. The generalized circuit equations are well suited to transmission lines. Hence for given any type of the transmission line (short, medium, long). The equation can be written by knowing the values of A B C D constants. 2. Just by knowing the total impedance and total admittance of the line the values of A B C D constants can be calculated. 3. By using the generalized circuit equations V_{RNL} can also be calculated. $\therefore V_S = AV_R + BI_R$ i.e. when $I_R = 0$	**4M** ***Any four advantages 1M each***

		$V_{RNL} = V_S/\ A$ Now the regulation of the lin0e can be immediately calculated by % regu = V_S / A– V_R / V_R x 100 4. Output power = $V_R\ I_R$ Cos ϕR 1ϕckt. = # $V_R\ I_R$ Cos ϕR for 3ϕckt. Output power = $V_S I_S$ Cos ϕS 1ϕckt. = # $V_S\ I_S$ Cos ϕS 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 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:** **For a generalised circuit prove that AD - BC =1** Consider two terminal pair network with parameters A, B, C, D is connected to an ideal voltage source with zero internal impedance at one end and at the other end is short ckted.	**6** **6M**



1M

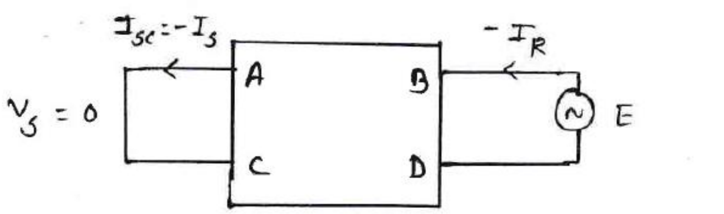
To represent this condition in equation form we get

$$V_s = AV_R + BI_R$$

$$I_R = \frac{V_S}{B} [\because V_R = 0]$$ ***1M***

$I_{sc} = \frac{E}{B}$ ....(1) ***1M***

Now connect above ideal source at the receiving end and short circuited the sending end.



1M

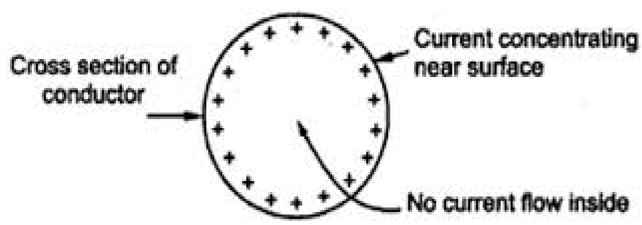
Now $V_s = AV_p + BI_R$

$0 = A.E + B(-I_R)$

$$I_R = \frac{AE}{B}$$

Since transmission line is a linear, passive bilateral network

$I_s = -I_{Sc} = (V_R + DIR - I_{Sc} = CE + D\left(\frac{AE}{B}\right)$ ***1M***

		Substituting value of I_{Sc} in above equation $$\frac{-E}{B} = CE - D\frac{AE}{B}$$ $\frac{-\cancel{E}}{B} = \left(C - \frac{AD}{B}\right)\cancel{E}$ $$\frac{-1}{\cancel{B}} = \frac{BC - AD}{\cancel{B}}$$ AD - BC = 1	*1M*
	(b) Ans.	**Describe skin effect and proximity effect. State the 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	**6M** *2M for statement* *1M for factors*

		• Material of conductor **Proximity Effect:** 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 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 for statement*** ***1M for factors***
2.	**(a) (i)** **Ans.**	**Attempt any TWO of the following:** **Write advantages of circle diagram.** **Advantages of circle diagram:** 1. Simple method to represent performance transmission line. 2. Easy to understand variation of performance parameters of line. 3. Maximum power transferred can by easily determined. 4. The transmission line loss can be determined. 5. Provides graphical solution. 6. Rating of compensating equipment can be directly determined. 7. The torque angle δ can be determined. 8. The transmission line performance can be studied at any load& any p.f.condition. 9. The nature of compensation of reactive power can be analyzed. 10. Any type of transmission line can be represented into circle diagram	**16** **4M** ***Any four advantages 1M each***
	(a) (ii) **Ans.**	**Define generalised circuit constants.** 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.	**4M** ***1M for each constant***

		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 $=\frac{IS}{IR}$; $V_R = 0$ 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) Ans.	**A 3-ph line has following parameters:** **A = D = 0.9 $\lfloor 0.4^0$ B = 99 $\lfloor 76.86^0$ load angle = 9^0, sending end voltage and receiving end voltage are maintained at 220 kV. Calculate sending end active and reactive power. Also, calculate active and reactive power at receiving end.** Given, A = 0.9, D = 0.9 B = 99, Vs = V_R = 220V $\alpha = 0.4, \quad \beta = 76.86 \;\; \& \;\; \delta = 9^0$ **1) Sending end Active Power:** $Ps = \left\|\frac{A}{B}\right\| \|V_s\|^2 \cos(\beta - \alpha) - \frac{\|V_S\|\|V_R\|}{\|B\|}\cos(\beta + \delta)$ $= \left\|\frac{0.9}{99}\right\| \|220\|^2 \cos(76.86 - 0.4) - \left\|\frac{220^2}{99}\right\| \cos(76.86 + 9^0)$ = 103.01 – 35.29 = 67.71MW Ps = 67.71MW **2) Reactive power at sending end:** $Qs = \left\|\frac{A}{B}\right\| \|V_s\|^2 \sin(\beta - \alpha) - \frac{\|V_S\|\|V_R\|}{\|B\|}\sin(\beta + \delta)$ $= \left\|\frac{0.9}{99}\right\| \|220\|^2 \sin(76.86 - 0.4) - \frac{\|220\|^2}{99}\sin(76.86 + 9)$	8M *2M* *2M*

= 427.77 – 487.61

= 59.84

$\therefore$ Qs = 59.84 MVAR

3)Receiving end Active Power:

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

$$= \left|\frac{220^2}{99}\right| \cos\,(76.86 - 9^0) - \left|\frac{0.9}{99}\right| |220|^2 \; cos\;(76.86 - 0.4)$$

2M

= 184.248 - 103.014

= 81.234MW

4) **Receiving and reactive power:**

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

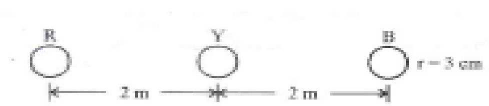
$$= \left|\frac{220^2}{99}\right| \sin\,(76.86 - 9^0) - \left|\frac{0.9}{99}\right| |220|^2 \; sin\;(76.86 - 0.4)$$

2M

= 452.84 - 427.77

= 25.07MVAR

(c) **Calculate Inductance and inductive reactance/ km for arrangement of 3-ph conductors shown in fig.** **8M**

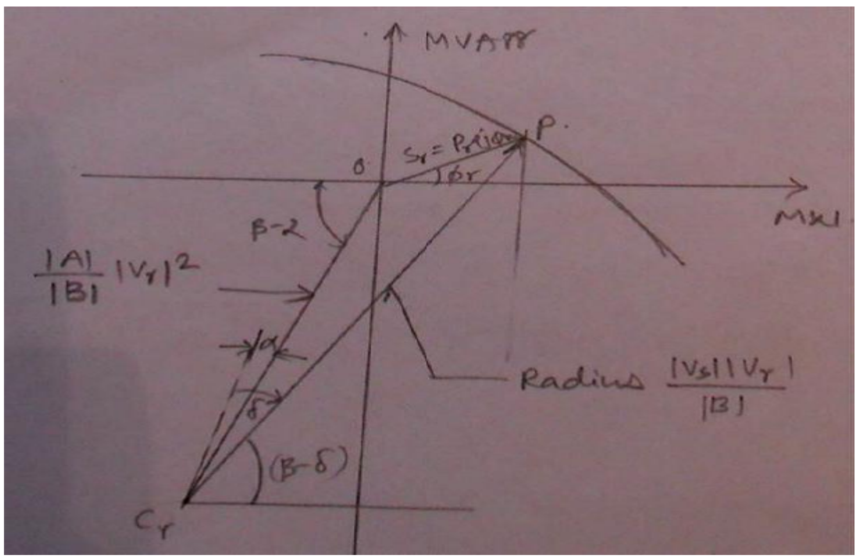


Ans.

$$D_{RY} = D_{YB} = 2\text{m}$$

$$D_{RB} = 4\text{m}$$

		$$D_{eq} = \sqrt[3]{2 \times 2 \times 4} = 2.51$$	*1M*
		r = 3cm = 0.03m	
		$$r' = 0.7788 \times r$$	*1M*
		= 0.7788 x 0.03	
		= 0.0233m	
		$$L = 2 \times 10^{-7} \log_e \left(\frac{D_{eq}}{r'}\right)$$	*3M*
		$= 2 \times 10^{-7} \log_e \left(\frac{2.51}{0.0233}\right)$	
		$= 9.359 \times 10^{-7}$ H/m	
		$= 9.359 \times 10^{-4}$ H/m	
		= 0.9359 mH/km	
		$$X_L = 2\pi FL$$	*3M*
		$= 2\pi \times 50 \times 0.9359$	
		= 294.021 mΩ/km	
3.		**Attempt any FOUR of the following:**	**16**
	(a)	**Write any four advantages of PU system.**	**4M**
	Ans.	**Advantages of PU system:** 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	***Any four advantages 1M each***

		unit value impedance through base voltages on two sides do not depend upon connections of windings.. 5. If base values are selected properly the P.U. impedance is same on both sides of transformer.	
	(b) **Ans.**	**Write the steps for drawing a receiving end circle diagram with neat diagram.**  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). $\frac{\|A\|}{\|B\|}\|V_r\|^2$ Step-2: To draw the center of the circle take the distance equal to & angle equal to (β-α) & draw the line in third quadrant & locate the point '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	**4M** ***Labeled diagram 2M*** ***Explanation 2M***
	(c)	**Explain the effect of earth field on transmission line capacitance by method mirror image.**	**4M**

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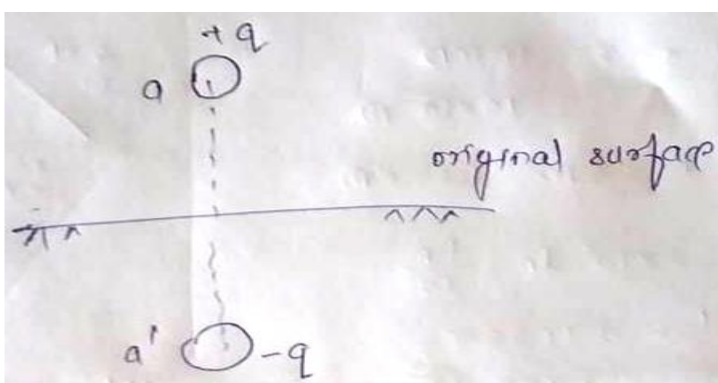
	Ans.	As earth is also a perfect conductor, its electric field affect the outside electric field i.e. capacitance of the line conductor. E.g. Consider a circuit consisting single over head conductor with a return path through the earth. Assume the earth as a perfectly horizontal sheet of infinite extent which therefore acts like an equipotential surface. Now the earth has a charge equal in magnitude and opposite to that of conductors. Hence potential difference exist between the conductor and the earth. And the electric flux is perpendicular to earths equipotential surface. Since the surface is assume to be a perfect conductor. Imagine a fictitious conductor of same size and shape as the over head conductor lying directly below the original conductor at a distance equal to twice the distance of conductor above the plane of earth by a distance equal to the distance of overhead conductor above the earth. Suppose the earth is removed and a charge equal and opposite to that on the overhead conductor is assumed on the fictitious conductor is an equipotential surface is the same as that which existed between the conductor and earth. Thus for the calculation of the capacitance, the earth may be replaced by conductor at a distance equal to that of overhead conductor above the earth from the earth below it. i.e. earth is replaced by a equipotential surface and a conductor. This conductor has a charge equal in magnitude and opposite in sign to that of the original conductor is called as image conductor. 	***Explanation 3M*** ***Diagram 1M***
	(d)	**A 3-ph 110kV transmission line delivers 30 MVA at 0.8 p.f. lagging. Draw receiving end circle diagram and find sending end voltage. Given A = 0.90 $\angle 2^0$ B = 100 $\angle 70^0$.**	**4M**

Ans.

(Note: Answer may vary depends upon accuracy of graph)

The distance of centre OC_r $from\ origin = \frac{|A|}{|B|}|V_R|^2$

$= \frac{0.90}{100} x\ 110^2 = \frac{108.9}{30} = 3.63MVA$

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

Take scale as 1 cm = 30 MVA ***1M***

Draw line OC_r with angle 68^0 and mag. $\frac{108.9}{30} = 3.63cm$

To Locate pt. P …draw a line OP ***1M***

$\therefore$ for 30 MVA $= 1cm$

$\therefore p.f - \cos \emptyset_R = 0.8$

$\therefore \emptyset_R = 36.86^0$

Now join C_rP and measure C_rP = 4.5 cm = 4.5 x 30 = 135 MVA

$\therefore$ C_rP is radius

$\therefore$ radius $= \frac{|V_R||V_s|}{B}$ = 135 MVA ***1M***

$$\therefore \frac{110\ x\ V_s}{100} = 135$$

$\therefore$ Sending end vtg V_S = 118.18kV

V_S = 118.18kV

(Note : Graph may be drawn by defining coordinates of the circle)

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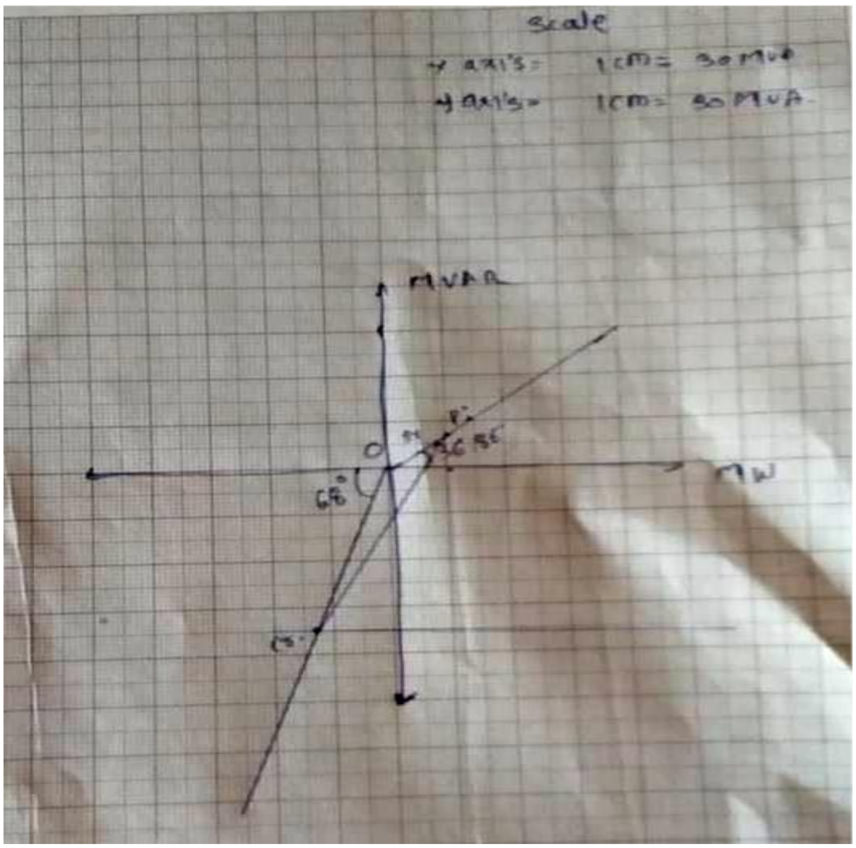
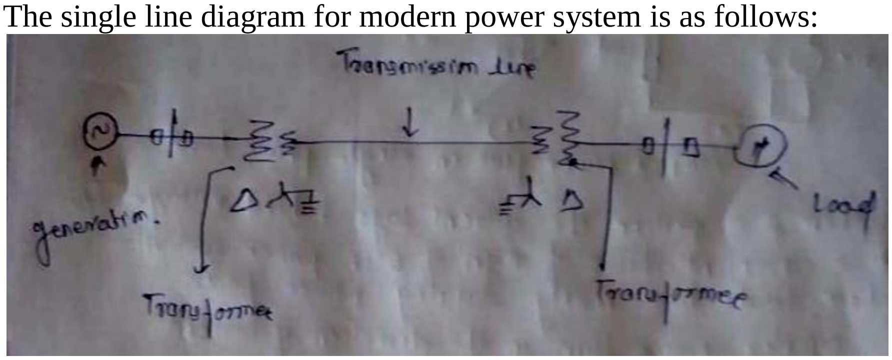
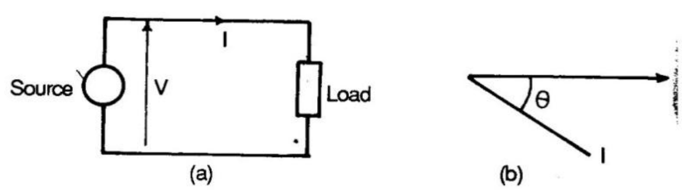
			*1M*
	(e) **Ans.**	**Determine inductance /km of a 3-ph line using 20 mm diameter conductor. When conductors are situated at corners of triangle with spacing 4 M, 5 M, 6 M. Condutors are regularly transposed.** 	**4M**

		d = 20mm, r = 10m $= 10 \times 10^{-3}$m $D_r = 4$m, $D_2 = 5$m, $D_3 = 6$m 1) $L = 2 \times 10^{-7} l_n \frac{D_m}{D_s}$ $\therefore D_s = 0.7788r$ $= 7.788 \times 10^{-3}$	
		$D_m = \sqrt[3]{D_1 D_2 D_3}$ $= (4 \times 5 \times 6)^{13}$ = 4.93m	*1M* *1M*
		$L = 2 \times 10^{-7} l_n \frac{4.93}{7.788 \times 10^{-3}}$ $L = 1.2901 \times 10^{-6}$ H/m...	*1M*
		$L = 1.290 \times 10^{-3}$ H/km...	*1M*
4.	**(A)** **(a)** **Ans.**	**Attempt any THREE of the following:** **Draw single line diagram of modern Power System.** The single line diagram for modern power system is as follows: 	**12** **4M** ***Correct diagram 4M***

	(b) **Ans.**	**Prove that in power flow equation S = VI*.** 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 θ in power systems where loads have mostly lagging power factors. Complex power flow in the direction of current indicated is givenb 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 signnifies rating of equipments (generators, transformers) $P = \|V\|\|I\| \cos\theta = \text{real (active) power (watts, kW, MW)}$ $Q = \|V\|\|I\| \sin\theta = \text{realactive power}$ = voltamperes reactive (VAR)	**4M** *1M* *1M* *1M*

= kilovoltampress reactive (kVAR)

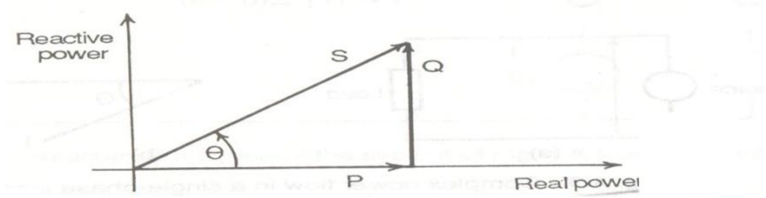
= megavoltamperes reactive (MVAR)

It immediately follows from equation that Q, the reactive power, is positive for lagging current (lagging power factor load) and negative for leading currnt (leading power factor load0. With the direction of current indicated in Fig, $S = P + jQ$ is supplied by the source and is absorbed by the load.

1M

$\theta = \tan^{-1}\frac{Q}{P}$ = 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

(c) **Calculate the capacitance of a 100 km long 3-ph 50 Hz overhead transmission line consisting of 3 conductors each of diameter 2 cm spaced 2.5 m at the corners of equilateral triangle.** **4M**

Ans.

Give D = 2.5m

d = 2cm r = 1cm = 1×10^{-2}m

$r^{'} = 0.7788r = 07788 \times 1 \times 10^{-2}$

		$\therefore \text{capacitance} = \frac{2\pi \in}{\log \frac{D}{r'}}$	*1M*
		$= \frac{2\,\pi \text{ x } 8.85 \text{ x } 10^{-12}}{\log \frac{2.5}{(0.7788 \text{ X } 10^{-2})}}$	*1M*
		$C = 9.634 \text{ x } 10^{-12}$ F/m	*1M*
		$C = 9.634 \text{ x } 10^{-9}$ F/km ∴ for 100 km long F/m line. $C = 9.634 \text{ x } 10^{-9} \text{ x } 100$ $C = 9.634 \text{ x } 10^{-7}$ F/km	*1M*
	(d) Ans.	**A 275 kV, 3ϕ line has the following parameters A = 0.93 $\lfloor 1.5^0$, B = 115 $\lfloor 77^0$. If receiving end voltage is 275 kV, determine the sending end voltage if load of 25 MW at 0.85 lagging P.F. is being delivered at the receiving end.** V_R = 275 kV A = D = 0.93∠ 1.5 B = 115 ∠77^0 V_R = 275 kV load = 25MW Receiving end circle diagram X - coordinates = $\frac{-AV_R{}^2}{B} \cos(\beta - \alpha)$	4M *1M*

$= \frac{-0.93 \text{ X } 275^2}{115} \cos\ (77-15)$

= -153.126 MW

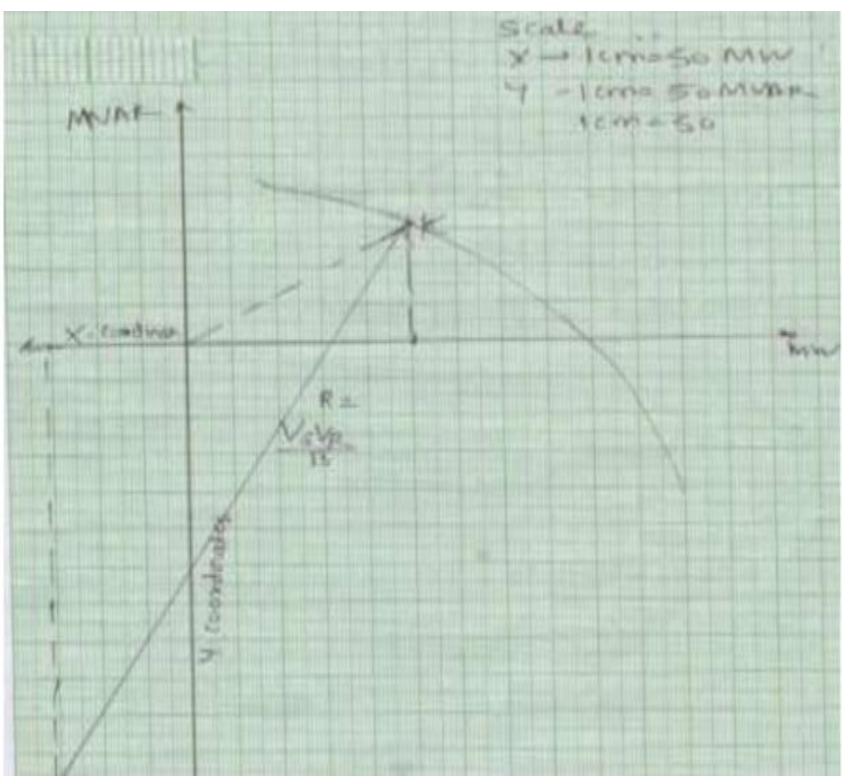
Y - coordinates = $\frac{-AV_R{}^2}{B} \sin\ (\beta - \alpha)$ ***1M***

$= \frac{-0.93 \text{ X } 275^2}{115} \sin\ (77-15)$

= - 592.09 MVAR

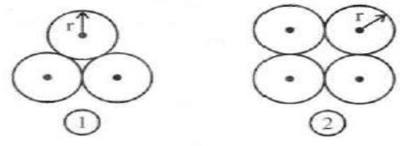
Scale X axis = km = 50 MW

Y axis = km = 50MVAR



1M

		$\therefore$ from graph radius = 17.1cm = 17.1 x 50 = 855 MVA $$\therefore\ 855 = \frac{V_S V_R}{B} = \frac{V_s\ X\ 275}{115}$$ $\therefore V_s = 357.54\ kV$	*1M*
4.	(B) (a) Ans.	**Attempt any ONE of the following:** **A 3-ph 50 Hz 100 km line as resistance of 10Ω, inductance 0.1H, c = 0.9 μF delivers load of 35 MW, 132 kV, 0.8 p.f. lagging using π method, calculate ABCD parameters.** Given, R = 10Ω, C = 0.9μF, L = 0.1H l = 100km V_R = 132kV, 0.8 P.F. lagging Z = (R + i2πFL) = (10 + i2π50 x 0.1) = (10 + i31.41) = 32.96 ∠ 72.34Ω Y = j2πFC = j2π x 50 x 0.9 x 10^{-6} = j 2.83 x 10^{-4}∠ 90^0 = 2.83 x 10^{-4}∠ 90^0 S $\therefore$ Considering π method $D = A = 1 + \frac{YZ}{2}$ $= 1 + \frac{(2.83 \times 10^{-4}\angle 90)(32.96\angle 72.34)}{2}$ $= 1 + \frac{9.3276 \times 10^{-3}\angle 162.34}{2}$ = 1+ 4.66 x 10^{-3}∠162.34	**6** **6M** *1M*

		$= 1 - 4.44 \times 10^{-3} + j\,1.41 \times 10^{-3}$ $= 1 - 0.0044 + j0.00141$ $A = D = 0.9956 + j0.00141$ $\boxed{A = D = 0.995\angle 0.081}$ $B = Z = 32.96\angle 72.34^0$ $C = Y\left(1 + \frac{Yz}{4}\right)$ $C = \frac{Y^2 z}{4} + y$ $= \frac{(j2.83 \times 10^{-4})^2 (32.96\angle 72.34)}{4} + (j2.83 \times 10^{-4})$ $= \frac{(-8.0086 \times 10^{-8})(32.96\angle 72.34)}{4} + (j2.83 \times 10^{-4})$ $= (2.002 \times 10^{-8})(32.96\angle 72.34) + j2.83 \times 10^{-4}$ $= 5.93 \times 10^{-8}\angle 72.34 + (2.83 \times 10^{-4}\angle 90)$ $= 1.79 \times 10^{-8} + j5.6 \times 10^{-8} + i2.83 \times 10^{-4}$ $= 1.79 \times 10^{-8} + i2.83 \times 10^{-4}$ $\boxed{C = 2.83 \times 10^{-4}\angle 89.99^0 \text{ S}}$	***2M*** ***1M*** ***2M***
	(b)	**Find self GMD for arrangement shown in fig. if r = 0.1 cm.** 	**6M**

	Ans.	The self GMD for figure 1 is given by $= D_{12} = D_{21} = D_{23} = D_{31} = 2r$ $D_{13} = D_{31} = 4r$ $D_{11} = D_{22} = D_{33} = 0.77886$ $D_s = \sqrt[3]{(D_{11}D_{12}D_{13})(D_{21}D_{22}D_{23})(D_{31}D_{32}D_{33})}$ $D_s = \sqrt[9]{(r)^3(2r)^4(4r)^2}$ $= \sqrt[9]{(0.7788)^3(r)^3(2r)^4(4r)^2}$ $= 1.703r = 1.703 \text{ x } 0.1 = 0.17\text{cm}$ The self GMD for figure 2 is given by $= D_{11} = D_{22} = D_{33} = D_{44}$ $D_{11} = D_{22} = D_{33} = D_{44}$ $\therefore D_{12} = D_{23} = D_{34} = D_{41} = D_{21} = D_{32} = D_{43} = D_{44} = 2r$ $= D_{13} = D_{24} = D_{31} = D_{42} = \sqrt[2]{2r}$ $D_s = \sqrt[16]{\begin{matrix}(D_{11}D_{12}D_{13}D_{14})(D_{21}D_{22}D_{23}D_{24})(D_{31}D_{32}D_{33}D_{34})\\(D_{41}D_{42}D_{43}D_{44})\end{matrix}}$ $D_s = \sqrt[16]{(0.7788)^4(2r)^4\left(\sqrt[2]{2r}\right)^4}$ $D_s = 1.7999r = 1.799 \text{ x } 0.1 = 0.1799\text{cm}$	*1M* *1M* *1M* *1M* *1M* *1M*
5.	**(a)**	**Attempt any TWO of the following:** **Two transmission line network are connected in series. Determine A, B, C, D constant of overall n/w.**	**16** **8M**

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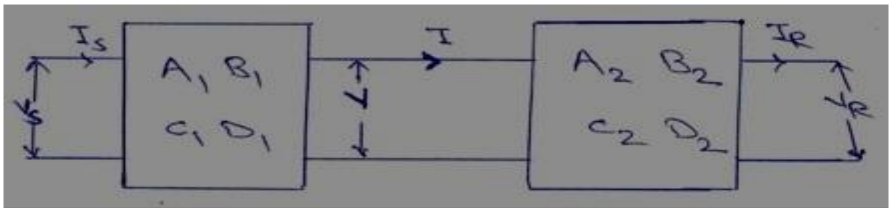
Ans.



1M

Applying generalized circuit equation for network (1)

GCE (1) = $V_S = A.V_R + B.I_R$

GCE (2) = $I_S = C.V_R + D.I_R$

1M

For Network (1)

$V_S = A_1V + B_1I$....................................(1)

$I_S = C_1V + D_1I$.....................................(2)

For Network (2)

$V = A_2.V_R + B_2.I_R$ ....(3)

$I = C_2.V_R + D_2.I_R$ ....(4)

1M

Substitute equation (3) & (4) in equation (1) & (2)

$V_S = A_1 (A_2.V_R + B_2.I_R) + B_1 (C_2.V_R + D_2.I_R)$

$V_S = A_1.A_2.V_R + A_1.B_2.I_R + B_1.C_2.V_R + B_1.D_2.I_R$

$V_S = (A_1.A_2 + B1.C_2) V_R + (A_1.B_2 + B_1.D_2) I_R$

1M

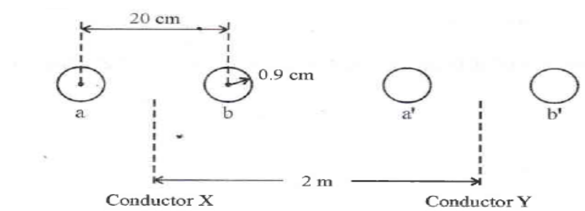
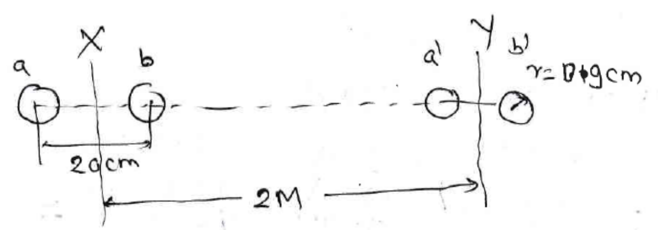
Comparing with standard GCE (1)

$A = A_1.A_2 + B_1.C_2$

$B = A_1.B_1 + B_1.D_2$

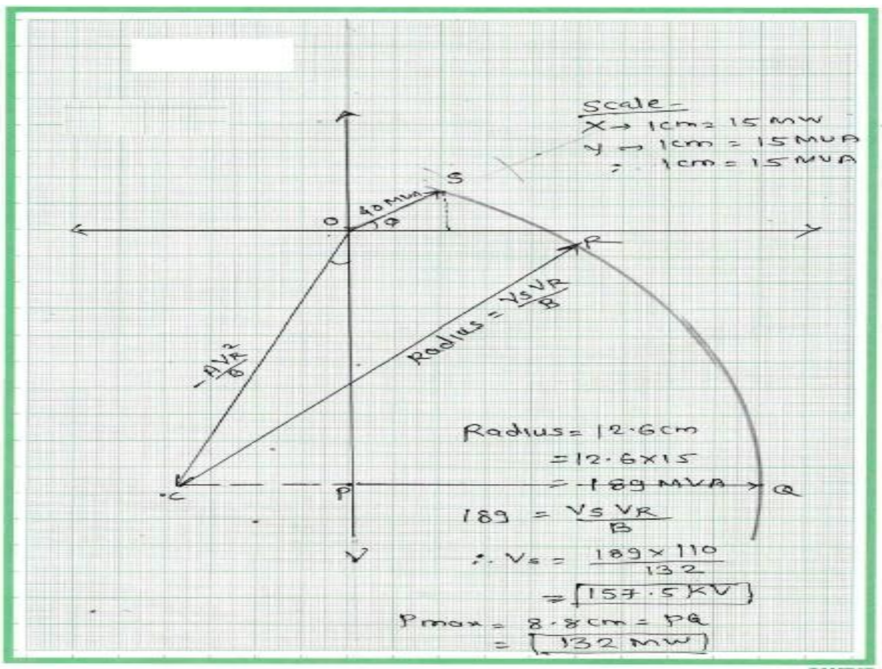
2M

Substitute equation (3) & (4) in equation (2)

		$I_S = C_1 (A_2.V_R + B_2.I_R) + D_1 (C_2.V_R + D_2.I_R)$ $= C_1A_2.V_R + C_1.B_2.I_R + D_1.C_2.V_R + D_1.D_2.I_R$ Comparing with GCE (2) $C = C_1.A_2 + D_1.C_2$ $D = C_1.B_2 + D_1.D_2$	*2M*
	(b) **Ans.**	**Calculate inductance & inductive reactance of 1-ph transmission line shown in fig.**   $D_{sx} = D_{sy} = 4\sqrt{(D_{ab} X\ D_{aa})^2}$ $= \sqrt{(D_{ab} D_{aa})}$ $= \sqrt{(20 \text{ x } 10^{-2} \text{ x } 0.9 \text{ x } 0.7788 \text{ x } 10^{-2})}$ $= 0.037M$ $D_m = 4\sqrt{(Daa^1\ Dab^1 Dba^1 Dbb^1)}$ $= 4\sqrt{((2 \text{ x } 2.2 \text{ x } 1.8 \text{ x } 2)}\ = 1.99M$	**8M** *2M* *2M*

		$L_x = 2 \times 10^{-7} \log_e \left(\frac{D_m}{D_s}\right)$ $= 2 \times 10^{-7} \log_e \left(\frac{0.037}{1.99}\right)$ $= 2 \times 10^{-7} \log_e \left(\frac{1.99}{0.037}\right)$ $= 7.97 \times 10^{-7}$ H/m = 0.797 mH/km $L_x = L_y = 0.797$ mH/km Inductive reactance $X_L = 2\pi f L = 2 \times \pi \times 50 \times 0.797$ = 250.38mΩ/km	***2M*** ***1M*** ***1M***
	(c) Ans.	**A 3ϕ 132 kV. tr. line delivers 40 MVA at 0.8 P.F. lagging. Determine sending end voltage with the help of circle diagram. Given A = 0.98∠3⁰, B = 110∠72⁰. Also, find max power delivered at receiving end.** Given data $V_R = 132$kV Load 40MVA, 0-8pf A= 0.98∠3 B=110∠72 X coordinates = $\frac{-AV_R^2}{B}$ Cos (β – α) $= \frac{-0.98 \times 132^2}{110} Cos(72-3)$ = 55.63 MW = 3.70 cm------------------------------------ Y coordinates = $\frac{-AV_R^2}{B}$ Sin (β – α) $= \frac{-0.98 \times 132^2}{110} Sin(72-3)$ = - 144.92 MVAR- = 9.7 cm -----------------------------	**8M** ***1M*** ***1M***

Selecting scale on X-axis 1cm=15 MW
Y-axis 1cm = 15 MVAR
∴ 1cm = 15 MVA ----------------------------- *1M*



2M

From Graph Radius = CR = 12.6 cm
=189 MVA ---------------------------------- *1M*

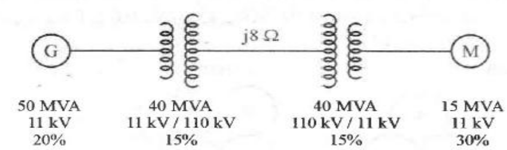
$= \frac{V_S V_R}{B}$

$$189 = \frac{V_{S\ x\ 132}}{110}$$

$\therefore V_S = 157.5\ kV$ --------------------------------- *1M*
Maximum power = PQ = 8.8 cm = 132MW----------------------------- *1M*

6. **Attempt any FOUR of the following:** **16**

(a) **Draw reactance diagram for following power system assuming generator as base:** **4M**



Ans.

Base – 50 MVA
Base KV – 110KV in tr. Line
∴ Base KV 11 KV for Gen.& Motor side.
Calculation X_{pu}

(1) Generator -

$$X_{pu}\text{ new} = X_{PU}\text{ old X } \frac{MVA_{new}}{MVA_{old}} \text{ X } \left(\frac{KV_{old}}{KV_{new}}\right)^2$$

$$= 0.20 \text{ X } \frac{50}{50} \text{ X } \left(\frac{11}{11}\right)^2$$

$= 0.2_{pu}$----------------------- ***1M***

(2) Transformer-

$$X_{pu}\text{ new} = 0.15 \text{ X } \frac{50}{40} \text{ X } \left(\frac{11}{11}\right)^2$$

OR

$$= 0.15 \text{ X } \frac{50}{40} \text{ X } \left(\frac{110}{110}\right)^2$$

$= 0.1875_{pu}$---------------------------- ***1M***

(3) Transmission line-

$$X_{pu} = \frac{X_{actual}}{X_{Base}} = \frac{X_{actual}}{{KV_B}^2} \text{ X } MVA_B$$

$$= \frac{8}{(110)^2} \text{ X } 50 = 0.033 \text{ PU}$$---------------------------- ***1M***

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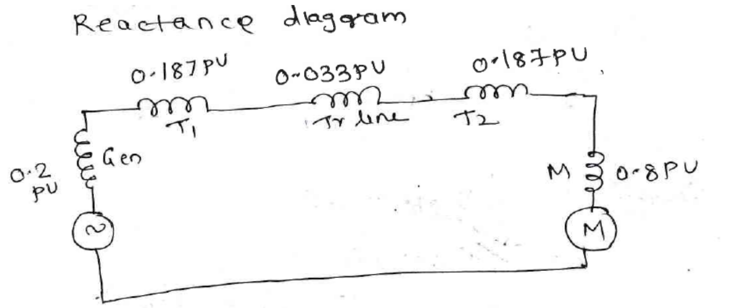
(4) Motor-

$X_{punew} = 0.30 \text{ X } \frac{40}{15} \text{ X } \left(\frac{11}{11}\right)^2$

$= 0.8_{pu}$ -- *1M*



	(b) Ans.	**Define self GMD and Mutual GMD with example.** Expression:	**4M**

Cond X — m = 3

Cond Y — n = 2

$D_m = \sqrt[mn]{mn \text{ terms}}$

$= \sqrt[6]{(D_{aa'} D_{ab'})(D_{ba'} D_{bb'})(D_{ca'} D_{cb'})}$

$D_{sx} = \sqrt[m^2]{m^2 \text{terms}}$

Each definition 1M

Each example 1M

		$= \sqrt[9]{(D_{ab}D_{aa}D_{ac})(D_{ba}D_{bb}D_{bc})(D_{ca}D_{cb}D_{cc})}$ $D_{sy} = \sqrt[4]{(D_{a'a'}D_{a'b'})(D_{b'b'}D_{b'a'})}$ $L_A = 2 \times 10^{-7} In \frac{Dm}{Ds} H/m$ **Ds --GMR: Self GMD:** The denominator of the argument of the logarithm in above Equation is the 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. The denominator is defined as the self-geometric mean distance (self GMD) of conductor A, and is abbreviated as D_{sA}. Sometimes, self GMD is also called geometric mean radius. Similarly, **Dm --GMD: Mutual GMD** The numerator of the argument of the logarithm in above Equation is the $(mn)^{th}$ 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.	
	(c) **Ans.**	**A balanced 3-ph load of 30 MW is supplied at 132kV 50 Hz 0.8 P.F. lagging z =20 tj 52Ω and y = 315 x $10^{-6}\lfloor \underline{90^0}$ siemens /ph. Use nominal T method. Calculate ABCD constant.** $Z = (20 + j\,52)\,\Omega$ $Y = 315 \times 10^{-6} \angle 90^0$ $for\ Nominal\ \pi - circuit$ $A = D = 1 + \frac{YZ}{2}, B = Z, C = Y\left(1 + \frac{YZ}{4}\right)$ $A = D = \frac{1+YZ}{2} = 1 + [\frac{(315 \times 10^{-6} \angle 90^0\ X\ (20+\ j\,52))}{2}]$ -------------------------------- $A = 1 + \frac{0.0175\ \angle 158.9}{2}$ $A = 1 + 0.00877\ \angle 158.9$ $A = 0.992 + j0.00315 = 0.992\ \angle 0.181 = D$	**4M** ***2M***

		$B = Z = (20 + \ j\,52) = 55.71\angle 68.98\,\Omega$ ------------- ---------------------- $C = Y\left(1+\frac{YZ}{4}\right) = 315\times10^{-6}\angle 90^0\left[1+\frac{\left((315\times10^{-6}\angle 90^0)(20+\ j\,52)\right)}{4}\right] = 3.137\times 10^{-4}\angle 90.09 siemens)$---	*1M* *1M*
	(d) **Ans.**	**State the need of reactive power compensation. Name the devices used for reactive power compensation.** **Need of reactive power compensation:** i. Most of the power system components are to be operated with voltage profile of 15%. But during power transfer a voltage drop of less than 10% occurs which is due to flow of reactive power. Moreover reactive currents contribute for I^2R losses in the system. ii. Most of the loads absorb lagging Vars to supply the magnetizing current of equipment such as transformers, induction motors etc. At any moment the maximum Vars which can be transferred over the line are fixed by voltage profile. iii. At peak loads the Vars demanded by the loads greatly exceeds Vars which can be transmitted over the lines. Flow of reactive power through the line causes voltage drop in the line and varies the voltage profile at important buses. Therefore additional equipment is necessary to generate lagging Vars at load centers to meet the reactive power requirements. iv. At light loads the lagging Vars produced by the lines are much larger than required by load. This surplus lagging Vars must be absorbed by additional equipment to keep voltage profile within limits. If it is not done the system voltage at some of the buses is likely to become higher then nominal value. From the above discussion it follows that it is necessary to compensate reactive power. **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 center Auto transformer – substations	**4M** ***Any two points 1M each*** ***Any two devices 1M each***
	(e) **Ans.**	**Give significance of inductance resistance and capacitance parameters of tr. line.** **Significance of inductance:**	**4M**

		1) It causes IX_L drop in transmission line which affects regulation 2) It is the only parameter which decides power transmission capacity of line i.e. if inductance decreases power transmission capacity increases. 3) It causes voltage drop which affects the voltage regulation of the line.	***1½M***
		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.	***1½M***
		Significance of capacitance: 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.	***1M***