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

MODEL ANSWER

SUMMER – 2018 EXAMINATION

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:** **Explain the role of power system engineer in operation of power system.** **Role of power system engineer in operation of power system:** i. For operation of the power system he has to plan for generation of electricity where, when and by using what fuel. ii. He has to plan for expansion of the existing grid system and also for new grid system. iii. He coordinated operation of a vast and complex power network, so as to achieve a high degree of economy and reliability. iv. He has to be involved in constructional task of great magnitude both in generation and transmission. v. He has to solve problem of power shortages. vi. He has to evolve strategies for energy conservation and load management. vii. For solving the power system problems he has to develop new method.	**(12)** **4M** ***Any 4 points 1M each***

	b) **Ans.**	**What is proximity effect? State the factors on which it depends.** When the alternating current is flowing through a conductor alternating magnetic flux is generate surrounding the conductor. This magnetic flux associates with the neighboring conductor and induce emf which opposes current through the conductor. This phenomenon is considered as rise in resistance of conductor. This complete phenomenon is called as, "proximity effect". **Factors affecting proximity effect:** 1. Conductor size (diameter of conductor) 2. Frequency of supply current. 3. Distance between conductors. 4. Permeability of conductor material	**4M** ***Stateme nt 2M*** ***Factors ½ M for each***
	c) **Ans.**	**List the advantages of generalized circuit representation. (any 4 points)** **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} $V_S = AV_R + BI_R$ i.e. when $I_R = 0 V_{RNL} = V_S / A$ Now the regulation of the line can be immediately calculated by % Voltage Regulation = $V_S / A - V_R / V_R$ X 100 4. Output power = $V_R I_R \cos \phi_R$ for ….1ϕ…ckt. = $3V_R I_R \cos \phi_R$ for ….3ϕ ……..ckt. Input power = $V_S I_S \cos \phi_S$…………1ϕ..ckt. = $3 V_S I_S \cos \phi_S$ …………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	**4M** ***Any 4 points 1M each***

		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 obtained 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 two transmission lines are connected in parallel then the resultant two part network can be easily obtained by $$A = \frac{A_1B_2 + A_2B_1}{B_1 + B_2}$$ $$B = \frac{B_1B_2}{B_1 + B_2}$$ $$D = \frac{D_1B_2 + D_2B_1}{B_1 + B_2}$$ $$C = C_1 + C_2 - \frac{(A_1 - A_{2)}(D_2 - D_1)}{B_1 + B_2}$$	
	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 Q_R If Qs > Q_R --- V_R increases If Qs < Q_R ----- V_R decreases If Qs = Q_R ------- V_R flat cha So to maintain balance in Qs & Q_R Reactive power compensation is needed. **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	**4M** ***Need 2M*** ***Devices 2M***

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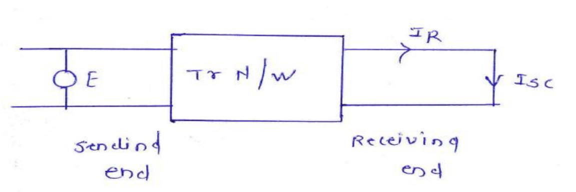
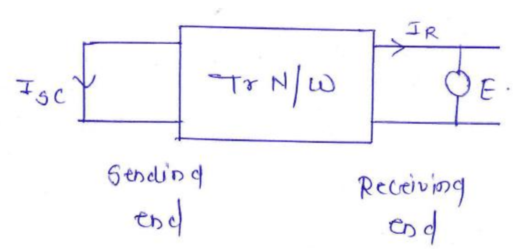
1.	**B)** **a)** **Ans.**	**Attempt any one of the following:** **State the effect of capacitance and inductance on the performance of transmission line.** **Effect of capacitance on performance of transmission line:** • Capacitance of a transmission line is the result of the potential difference between the conductors; it causes them to be charged in the same manner as the plates of a capacitor when there is a potential difference between them. • The capacitance between conductors is the charge per of potential difference between the lines. • Capacitance is also formed between line conductor and ground. • When an alternating voltage is applied to the line the line capacitance draws a leading sinusoidal current called charging current. The flow of current through the conductor gives rise to a magnetic field and charging of a conductor results in an electric field. A charge if brought in the vicinity of this electric field experiences a force. • Capacitance also affects voltage drop and voltage regulation of the line. • Under low load condition V_R is greater than V_S, voltage regulation is negative. • Ferrenti effect is observed in long tr. Lines due to existence of Capacitance. **Effect of inductance parameter**: • Voltage drop in the series impedance (IX_l) • Due to lagging p. f. V_S is always greater than V_R, , hence regulation is always positive. • As p. f. increases regulation also increases. • The voltage drop is the same in the series impedance of the line in all case, but because of the different power factor the voltage drop is added to the receiving end voltage a different angle in each case.	**(6)** **6M** ***Any 3 points of effect of capacitance 1M each*** ***Effect of inductance parameter 1M each***
	b) **Ans.**	**For a generalised circuit prove AD – BC = 1** Consider fig where two terminal pair N/W with parameters A, B, C & D is connected to an ideal voltage source with zero internal impedance with receiving end shorted. $V_S = 0$, $V_R = 0$, $I_R = I_{SC}$ Standard GCE 1	**6M** ***1M***

$V_S = A.V_R + B.I_R$
$E = A.0 + B.I_{SC}$
$I_{SC} = \frac{E}{B}$ ----------- (2)



Now apply ideal voltage source on receiving end and short circuit sending



$V_S = 0$, $V_R = E$, $I_R = - I_R$, $I_S = -I_{SC}$ ***1M***
Standard GCE 2

$I_S = C.V_R + D.I_R$
$-I_{SC} = C.E + D.-I_R$ ---------------- (3)

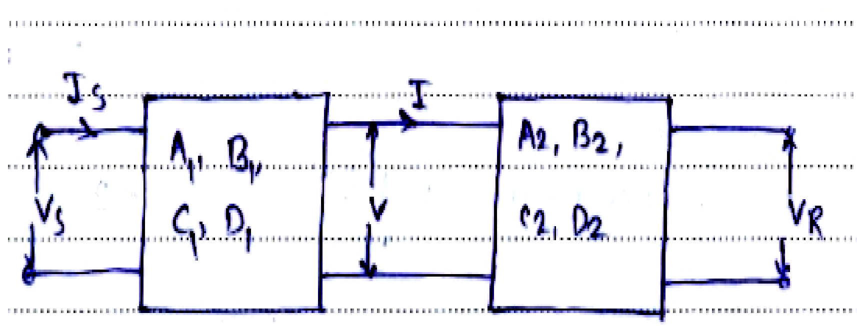
$V_S = A.V_R + B.I_R$

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

$I_R = \frac{AE}{B}$ ----------------- (4) ***1M***
Substituting equation (2) and (4) in equation (3)
$\frac{\cancel{E}}{B} = C*\cancel{E} - D\frac{A\cancel{E}}{B}$

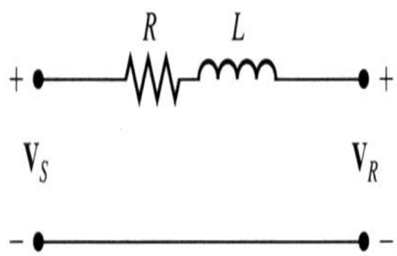
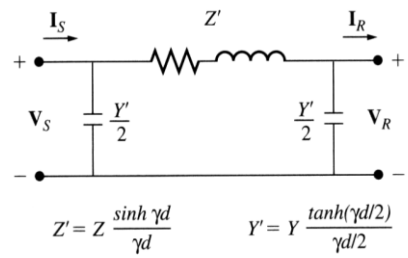
Multiplying with B on both side ***1M***
-1 = BC- AD
AD- BC = 1
Hence proved.

2.		**Attempt any two of the following:**	**(16)**
	a)	**State the factors to be considered to draw reactance diagram from impedance diagram of modern power system.**	**8M**
	Ans.	**Factors to be considered to get reactance diagram from impedance diagram:** 1. The resistance in the impedance diagram is neglected, through it leads to error, the results may be satisfactory. 2. Because the inductance reactance of the system is much larger than resistance of the system. i.e. R<<X and also z=R+ jX and not R+X 3. $Z^{'} = R + jX$ $= \sqrt{R^2 + X^2}$ $= \sqrt{X^2}\ as\ R \ll X$ $= X$ 4. Loads in the system if also not involve rotating machinery them they have little effect over the line current under fault condition. 5. For fault calculations always synchronous motor are to be considered because their excitation has considerable effect over the line current under fault condition. 6. If the line current is to be calculated just after occurrence of the fault then induction motor loads are represented by a generated emf in series with the inductive reactance. 7. If the line current is to be calculated few cycle after the occurrence of the fault then induction motor is to be neglected or omitted because the current dies out quickly after the I.M. is short circuited. 8. Since the magnetizing current i.e.I_0 insignificant compared with full load current (I_O<<I_F i.e. 10% of I_F) hence the magnetizing circuit of the transformer is omitted.	***1M for each point***
	b)	**Three conductors of 3ϕ, 3 wire system are arranged at the corners of equilateral triangle of side 2M each, diameter of each conductor is 2 cm. Calculate inductance and capacitance of each conductor.**	**8M**
	Ans.	Given D = 2m d = 2cm r = 1cm = 00.1m	

		1) $L = 2 \times 10^{-7} \log\frac{D}{r^1}$	*1M*
		$R^1 = 0.7788 X\ r$	
		$= 0.7788 X 0.01$	
		$= 7.788 X 10^3$ m	*1M*
		$L = 2 \times 10^{-7} \log\frac{2}{7.7788\ \ X\ 10^{-3}}$	*1M*
		$= 1.109 X 10^{-6}$ H/m	*1M*
		= 1.10mH/Km	*1M*
		2) $C_{an} = \frac{2\pi\epsilon}{\log\frac{D}{r}}$	*1M*
		$= \frac{2\pi\ X\ 8.85\ X\ 10^{-12}}{\log\frac{2}{0.01}}$	*1M*
		$= 10.49\ X\ 10^{-12}$ F/m	*1M*
		$C_{an} = 10.49\ X\ 10^{-13}\ \mu$F/Km	
	c) Ans.	**Derive overall ABCD constants of network where two transmission line are seriesly connected.** 	8M

		Applying generalized circuit equation for network (1) GCE (1) = $V_S = A.V_R + B.I_R$ GCE (2) = $I_S = C.V_R + D.I_R$ 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) Substitute equation (3) & (4) in equation (1) & (2) $V_S = A_1 (A_2.V_R + B_2.I_R) + B_1 (C_2.V_R + D_2.I_R)$ $V_S = A_1.A_2.V_R + A_1.B_2.I_R + B_1.C_2.V_R + B_1.D_2.I_R$ $V_S = (A_1.A_2 + B_1.C_2) V_R + (A_1.B_2 + B_1.D_2) I_R$ Comparing with standard GCE (1) $A = A_1.A_2 + B_1.C_2$ $B = A_1.B_2 + B_1.D_2$ Substitute equation (3) & (4) in equation (2) $I_S = C_1 (A_2.V_R + B_2.I_R) + D_1 (C_2.V_R + D_2.I_R)$ $= C_1 .A_2.V_R + C_1 .B_2.I_R + D_1.C_2.V_R + D_1.D_2.I_R$ Comparing with GCE (2) $C = C_1.A_2 + D_1.C_2$ $D = C_1.B_2 + D_1.D_2$	*1M* *1M* *1M* *1M* *1M* *1M* *1M* *1M*
3.	**a)** **Ans.**	**Attempt any four.** **Compare short and long transmission line. (Any four points)**	**(16)** **4M** ***Any 4points 1M each***

Short transmission line	**long transmission line**
Length shorter than 80 km	Length 250 Kms or above
Shunt Capacitance effect is very small	Capacitance effect is more
Equivalent circuit consist resistance & inductance	Equivalent circuit consist resistance, capacitance & inductance
Shunt Capacitance neglected in performance calculation	Capacitance must be considered in performance calculation
Ferranti effect is not observed	Ferranti effect is not observed

	
Overhead transmission lines shorter than 80 km (50 miles) can be modeled as a series resistance and inductance, since the shunt capacitance can be neglected over short distances.	For long lines, it is not accurate enough to approximate the shunt admittance by two constant capacitors at either end of the line. Instead, both the shunt capacitance and the series impedance must be treated as distributed quantities;
A = 1, B = Z, C = 0 and D = 1	A = coshδl B = $Z_C$sinhδl C = sinhδl ⁄ Z_C D = coshδl

b) **Ans.**

Define self GMD and mutual GMD. **4M**

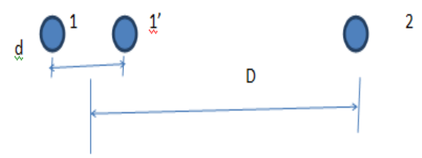
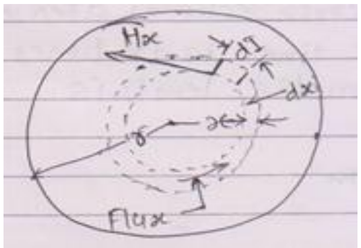
Definition of Self & mutual GMD

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

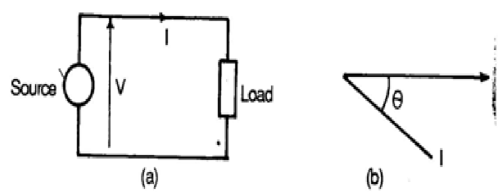
$$L_A = 2\times 10^{-7} In\frac{Dm}{Ds} H/m$$

Ds --GMR: 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

Self GMD 2M

		conductor A, and is abbreviated as D_{sA}. Sometimes, self GMD is also called *geometric mean radius* Similarly, Dm --GMD: The numerator of the argument of the logarithm in above Equation is the $m'n$th root of the $m'n$ terms, which are the products of all possible mutual distances from the n filaments of conductor A to m' filaments of conductor B. It is called ***mutual geometric mean distance*****(mutual GMD)** between conductor A and B and abbreviated as D_m. 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 = $\sqrt{D_{12}D_{1'2}}$ = $\sqrt{\left(\frac{d}{2}+D\right) x\, (D-\frac{d}{2})}$	***Mutual GMD 2M***
	c) **Ans.**	**Obtain the expression for flux linkages of an isolated current carrying conductor due to internal flux only.**  Figure Shows the cross-section of a long cylindrical conductor of radius r carrying a Sinusoidal current of r.m.s. value I. The magnetic lines of flux are	**4M**

		concentric with the Conductor. Let, the field intensity at a distance x meters from the centre of the conductor be Hx. Since the field is symmetrical, Hx is constant for all point equidistant from the centre. If Ix is the current enclosed upto distances x, then $\oint$ H$x.dl$ = Ix…………………………….(i) or $2\pi x$ Hx= Ix…………………………….(ii)	***1M***
		For finding the value of Ix, the current is assumed to be uniformly distributed over the cross-section of the conductor. Then $\mathrm{I}x = \left(\frac{\pi x^2}{\pi r^2}\right)$ I = $\left(\frac{x^2}{r^2}\right)$ I …………..(iii)	***1M***
		From equation (ii) & (iii) $\mathrm{H}x = \frac{\mathrm{I}x}{2\pi r^2}$ AT/m………………(iv) The flux density B$x$at a distance x from the centre is Bx =$\mu \mathrm{H}x = \frac{\mu \mathrm{I}x}{2\pi r^2}\,\omega$b/m^2………(v)	***1M***
		For finding flux linkages, a tabular element of thickness dx may be considered. The cross-sectional area of the element, normal to the flux line is dx times the axial length. The flux per meter length is $\mathrm{d}\emptyset = \frac{\mu \mathrm{I}x}{2\pi r^2}\mathrm{d}x$ ωb/m A flux line positioned at x links with $\frac{\pi x^2}{\pi r^2}$ of the total current. Thus the flux linkage for flux d$\emptyset$ is given by dΨ = $\frac{\pi x^2}{\pi r^2}$. d$\emptyset$ = $\frac{\mu I x^3}{2\pi r^4}$ d$x\omega$b-T/m………………(vi)	***1M***
		For computing the total internal flux linkages Ψ int we integrate equation (vi) from The centre to surface of the conductor.	

		$\Psi \text{ int} = \int^{r} \frac{\mu I x^3}{2\pi r^4} dx = \frac{\mu I}{8\pi}\ \omega\text{b-T/m}$	***1M***
	d) Ans.	**Prove that complex power in power system is VI* and not V*I.** Consider a single-phase load fed from a source as in Fig. Let $V = \lvert V\rvert \angle \delta$ $I = \lvert I\rvert \angle (\delta - \theta)$  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 $S = VI^*$ $= \lvert V\rvert\, \lvert I\rvert \angle \theta$ $= \lvert V\rvert\, \lvert I\rvert \cos\theta + j\lvert V\rvert\, \lvert I\rvert \sin\theta = P + jQ$ **OR** $\lvert S\rvert = (P^2 + Q^2)^{1/2}$ Here S =Complex power (VA, kVA, MVA) $\lvert \boldsymbol{S}\rvert$ = apparent power (VA, kVA, MVA); it signifies rating of equipment (generators, transformers) $P = \lvert V\rvert\, \lvert I\rvert \cos\theta$ = real (active) power (watts, kW, MW)	**4M**

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$$Q = |V|\,|I| \sin\theta = \text{reactive power}$$

= voltamperes reactive (kVAR)

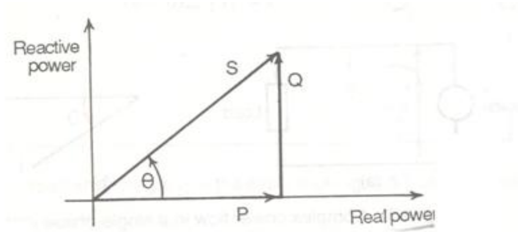
= kilovoltamperes reactive (kVAR)

= 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 F.g. $S = P + jQ$ is supplied by the source and is absorbed by the load.

$$\theta = \tan^{-1}\frac{Q}{P} = \text{positive for lagging current}$$

= 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
</td><td>

2M

2M
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Ans.</td><td>Describe the stepwise procedure for drawing receiving end circle diagram.</td><td>4M</td></tr>
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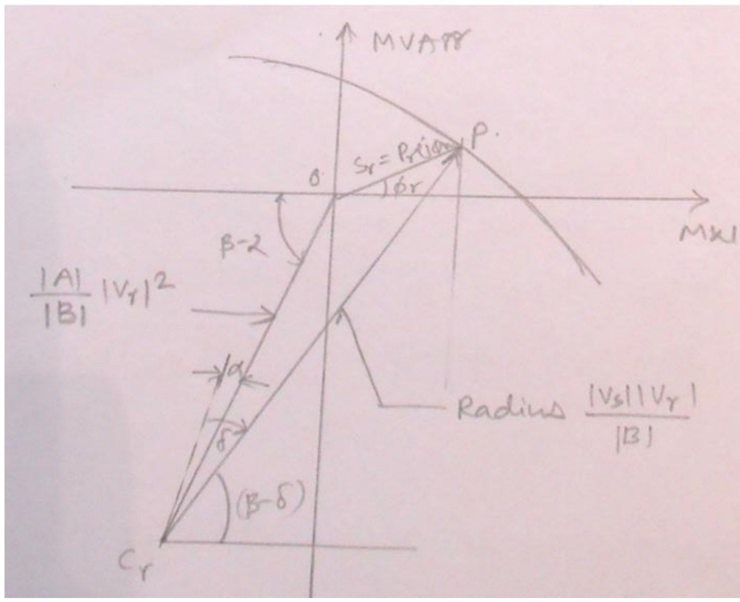


Labeled diagram 2M

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).

Explanation 2M

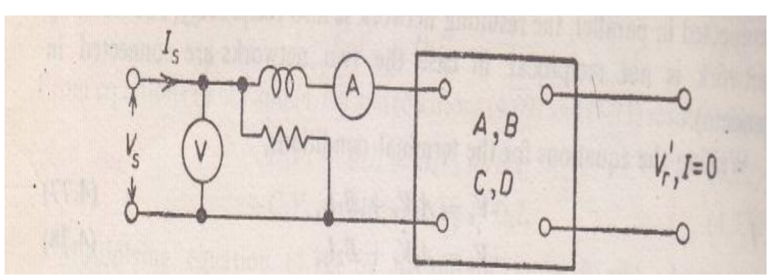
$$\frac{|A|}{|B|}\,|V_r|^2$$

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 1st 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

4.	**A)**	**Attempt any three of the following:**	**(12)**
	a)	**"AC resistance of a conductor is more than DC resistance". Justify.**	**4M**

	Ans.	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. **OR** **AC resistance is always higher than DC resistance due to-** **1) 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………………………………………………………***(2M)*** **2) 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". ……………………………………………………***(2M)***	***Explanation 4M***
	b) **Ans.**	**Explain how ABCD constants are measured for the erected transmission line.**  **Figure a: Open-circuit tests**	**4M**

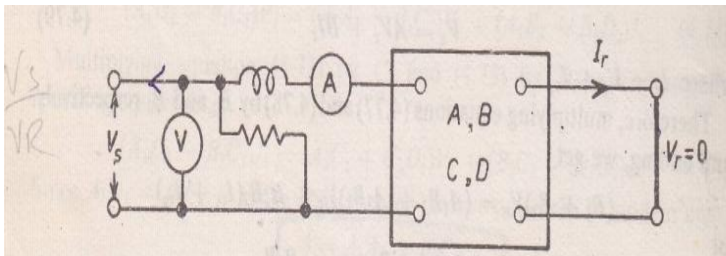


Figure b: Short-circuit tests

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.

The test is conducted on sending end side.

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

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

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

We to get, as $I_R = CV_R$

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

-sending end impedance with receiving end open ckted.

From S.C. test as $V_R = 0$

$V_s = B\, I_R \times I_s = D\, I_R$

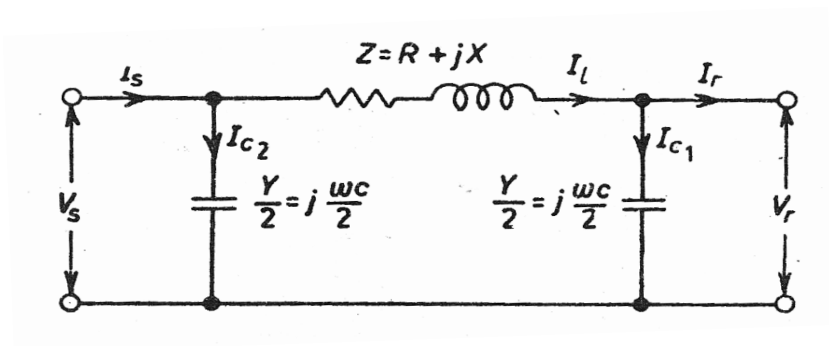
$\therefore Z_{ss} = \frac{V_s}{I_s} = \frac{B}{D}$

-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 = DV_s − BI_s I_R = − CV_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) = $-(V_s + A(-I_s)$ ∴ $-I_R = -CV_s - AI_s$ $I_R = CV_s + AI_s$ 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, $\frac{Z_{ro}-Z_{rs}}{Z_{so}} = \frac{1}{AC} \cdot \frac{C}{A} = \frac{1}{A^2}$ ∴A $= \sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ -------------(a) $Z_{rs} = \frac{B}{A}$ or B = AZ_{rs} = $Z_{rs}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ ----------------(b) $Z_{so} = \frac{A}{C}$ ∴C = $\frac{A}{Z_{so}} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ --------------© $Z_{ro} = \frac{D}{C}$ ∴ D = C· $Z_{ro} = \frac{Z_{ro}}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$	***2M***

		$= Z_{ro}\sqrt{\frac{1}{(Z_{ro}-Z_{rs})Z_{so}}}$-----------(d) If $Z_{ro} = Z_{so}$ we get A = D for symmetric network	***2M***
	c) **Ans.**	**State the expression for complex power at receiving end of transmission line. Derive the condition for maximum power at the receiving end.** **Derivation for condition for maximum power at receiving end.** As the receive end side active power is given by, $$P_R = \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\cos(\beta-\delta) - \frac{\lvert A\rvert\lvert V_R\rvert^2}{\lvert B\rvert}\cos(\beta-\alpha)$$ **For max value differentiate above eq. w.r.t. 'δ'** as V_S, V_R, A, B & α are constant. $$\therefore \frac{dP_R}{d\delta} = \frac{d}{d\delta}\left[\frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\cos(\beta-\delta) - \frac{\lvert A\rvert\lvert V_R\rvert^2}{\lvert B\rvert}\cos(\beta-\alpha)\right]$$ **Equate this equation w.r.t. zero** $$\frac{dP_R}{d\delta} = \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\frac{d}{d\delta}\cos(\beta-\delta) = 0$$ $$\sin(\beta-\delta) = 0$$ $$\beta-\delta = \sin^{-1}(0) = 0$$ $$\beta = \delta$$	4M ***1M*** ***1M*** ***2M***
	d) **Ans.**	**State the advantages of circle diagram (any 4 points).** ***(Note: Any other related point shall be considered).*** **Advantages of circle diagram:** 1. In power system AC transmission real & reactive powers can be theoretically calculated by using complex power expressions. The same calculators are performed graphically by circle dia. which reduces no. of calculations. 2. The performance of the transmission line at various load condition can be studied for the circle diagram. 3. By drawing circle diagram we can calculate sending end voltages.	4M ***Any 4 points 1M each***

		4. By drawing circle diagram we can calculate rating of compensation equipment. 5. The diagram is useful in calculating the line losses. 6. The diagram is useful in calculating the power max. Power angle. 7. In one diagram we can calculate all parameters. 8. The results obtained can be accurate 9. No. of parameters can be calculated for same system using same circle diagram. 10. If any changes are made in tr. line parameters the same can be implemented on circle dia. Just by changing scale. 11. The calculation is fast.	
4.	**B)** **a)** **Ans.**	**Attempt any one of the following:** **Draw nominal π and T networks. And write the expression for ABCD parameters for nominal π and T network.** **Nominal Pi –network:**  for Nominal π − circuit ABCD constants are given by $A = D = 1 + \frac{YZ}{2}, B = Z, C = Y\left(1 + \frac{yz}{4}\right)$ **Nominal T method:** Figure shows the nominal T method with capacitance is connected at centre of line, the line resistance and reactance is halfly tempered on both side.	**(6)** **6M** ***Diagram 1M*** ***Explana tion 2M***

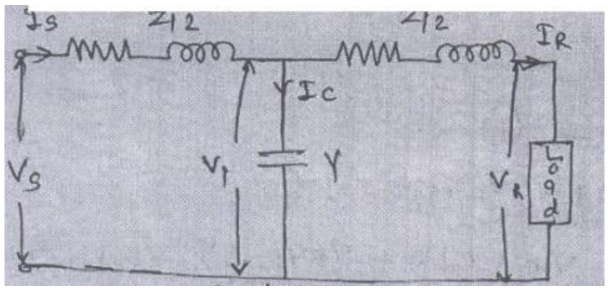


Diagram 1M

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

Explanation 2M

b) **Calculate self GMD for following configuration:** **6M**

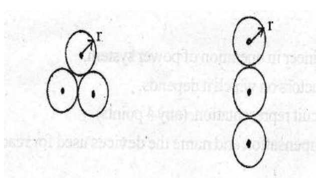


Fig.1 Fig.2

Ans. **Fig. 1**

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

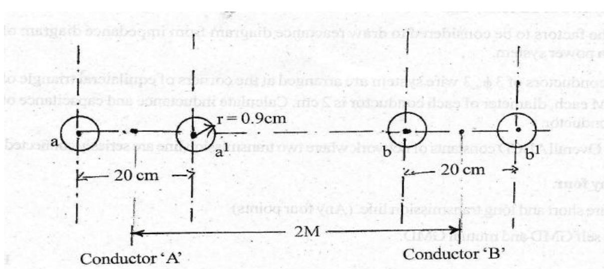
$D_{11} = D_{22} = D_{33} = 0.7788$ r

$D_{12} = D_{23} = D_{32} = D_{21} = D_{31} = D_{23} = 2$r

$D_S = \sqrt[9]{(0.7788\ r)^3(2r^6)}$

= 1.46r

3M

		Fig. 2 Self GMD $D_S = \sqrt[9]{(D_{11}D_{12}D_{13})(D_{21}D_{22}D_{23})(D_{31}D_{32}D_{33})}$ $D_{11} = D_{22} = D_{33} = 0.7788$ r $D_{12} = D_{23} = D_{32} = D_{21} = 2r\ (D_{11}D_{12}D_{13})^2$ $D_{13} = D_{31} = 4r$ Self GMD DS = $\sqrt[9]{(D_{11}D_{12}D_{13})^2(D_{21}D_{22}D_{23})}$ = $\sqrt[9]{(0.7788r\ X\ 2R\ X\ 4r\ )^2(2r\ X\ 0.7788\ r\ X\ 2r)}$ = $\sqrt[9]{(r\ )^9(120.92)}$ **Self GMD = 1.70 r cm**	*3M*
5.		**Attempt any two of the following:**	**(16)**
	a)	**Determine inductive reactance of 1 ϕ line arrangement shown in fig.** 	**8M**
	Ans.	Self GMD $D_{sa} = D_{sb}$ $= \sqrt[4]{(D_{aa}\ Daa^1)^2} = \sqrt{D_{aa}\ Daa^1}$ $= \sqrt{0.7788\ X\ 0.9\ X\ 10^{-2}\ \ X\ 20\ X\ 10^{-2}}$ = 0.037M $D_m = \sqrt[4]{D_{aa}\ Dab^1\ Da^1b\ \ Da^1\ b^1}$ $= \sqrt[4]{(2\ X\ 2.2\ X\ 1.8\ X\ 2)}$	*2M*

		= 1.995M $L_a = L_b = 2 \text{ X } 10^{-7} \log_e \frac{D_m}{D_s}$ $= 2 \text{ X } 10^{-7} \log_e \frac{1.995}{0.037}$ $= 7.97 \text{ X } 10^{-7} \frac{H}{m}$ = 0.797 mH/Km $X_L = 2\pi fL = 2 \text{ X } \pi \text{ X } 50 \text{ X } 0.797 \text{ X } 10^{-6}$ $= 2.50 \text{ X } 10^{-4}\ \Omega$	***2M*** ***1M*** ***2M*** ***1M***
	b) **Ans.**	**A 3ϕ, 50Hz, 100km transmission line has resistance 10 Ω, inductance 0.1H and capacitance 0.9µF delivers a power of 35MW, 132KV, 0.8 pf lagging. Use nominal π method. Derive ABCD parameters, efficiency and regulation** $R = 10\ \Omega$ $L = 0.1\ H$ $c = 0.9\ \mu F$ $X = 2\pi fL = 2\pi \times 50 \times 0.1 = 31.42\ \Omega$ $Z = R + jX = 10 + j\ 31.42 = 32.97\angle 72.34\ \Omega$ $Y = jwc = j314 \times 0.9 \times 10^{-6} = 2.826 \times 10^{-4}\angle 90^0$ $for\ Nominal\ \pi - circuit$ $A = D = 1 + \frac{YZ}{2}, B = Z, C = Y\left(1 + \frac{yz}{4}\right)$ $A = D = \frac{1+yz}{2} = 1 + [\frac{(2.826\times 10^{-4}\angle 90^0).(32.97\angle 72.34)}{2}]$ $A = 1 + \frac{9.317x10^{-4}\angle 162.34}{2}$	**8M** ***1M*** ***1M***

		$A = 0.9955 + j1.4132 = 0.9955\angle 0.08 = D$ $B = Z = 32.97\angle 72.34\ \Omega$ $C = Y\left(1+\frac{yz}{4}\right) = 2.826\times10^{-4}\angle 90^0\left[1+\frac{(2.826\times10^{-4}\angle 90^0)(32.97\angle 72.34)}{4}\right]$	*1M*
		$= 1\times10^{-3}\angle 90^0 x 0.9566\angle 0.697$ $= 2.819\ \times 10^{-4}\angle 90.04 siemens$ $given: V_R\ = 132KV,$ $load = 35\ Mw, 0.8lag$	
		$load = \sqrt{3}V_R I_R \cos\emptyset_R = 35\times10^6 = \sqrt{3}\,X132\times10^3\times I_R\times0.8$	*1M*
		$\therefore I_R = 191.366\ Amp$ $\emptyset_R = \cos^{-1}0.8 = 36.86$ $V_S = AV_R + BI_R = 0.9955\angle 0.08\times132/\sqrt{3}\times10^3\angle 0 + 32.97\angle 72.34 \times 191.366\angle -36.86 ....$ $V_s\ = 81.0926\ \ \angle 2.66\ KV$ $I_S = CV_R + DI_R$ $= 2.819\ \times10^{-4}\angle 90.04\times\frac{132}{\sqrt{3}}\times10^3\angle 0 + 0.9955\angle 0.08\times\ 191.366\angle -36.86$	
		= 178.36∠-31.25 Amp	*1M*
		Voltage regulation = $\frac{\frac{Vs}{A} - -V_{RFL}}{V_{RFL}}$ X 100	
		$= \frac{\frac{81.0926}{0.9955} - 132/\sqrt{3}}{132/\sqrt{3}}$ x 100 = 6.88%	*1M*

		Efficiency = $\frac{load}{\sqrt{3}V_s\, x I_{S\ x\ pf}} = \frac{35\times10^6}{3x\ 81.0926\ x\ 10^3 x\ 178.36\ x\cos(2.66+31.25)}$x 100 = 97.19%	*1M* *1M*
	c) **Ans.**	**A 33KV, single circuit, 3 phase transmission line has the ABCD parameters A=D = 01 $\angle 0^0$, B = 11.18 $\angle 63.43^0$ Ω and the receiving end voltage is 32 KV (line to line). How much active and reactive power is to be dispatch from sending eng?** Taking receiving end phase voltage as reference phase or we have $V_R = \frac{32{,}000}{\sqrt{3}} \angle 0^0 = 18{,}475 \angle 0^0$ V Receiving end current $I_R = \frac{S_R \text{ MuA X } 10^6}{\sqrt{3}\, V_{RL}} = \frac{7.5 \text{ X } 10^6}{\sqrt{3} \text{ X } 32{,}000}$ $I_{\mathbf{R}} = 135.32$A Receiving end power fact or cos ϕ_R = 0.85 lagging **OR** $\phi_R = \cos^{-1} 0.85 = 31.8^0$ So $\boxed{I_R = 135.32 \angle{-31.8^0}}$ Line parameters. A = D = 1 $\angle$ 0^0 and B = 11.18 $\angle$ 63.43^0 Ω C = $\frac{AD\ -1}{B} = \frac{1-1}{B} = 0$ Sending end voltage, $V_s = AV_R + BI_R$ = $1\angle 0^0$ X $18{,}475 \angle 0^0 + 11.18 \angle 63.43^0$ X $13{,}532 \angle -31.8^0$ = 18475 $\angle$ 0^0 + 1512.88 $\angle$ 31.63^0 = 19763.2 + j793.4 = 19.7779 $\angle$ 2.3^0 Sending end current $I_s = CV_R + DI_R$ = 0 + 1 $\angle 0^0$ X 135.32 $\angle -31.8^0$	8M *1M* *2M* *2M*

		$= 135.32 \angle -31.8^0 A$	
		Phase angle, $\phi_s = 2.3^{\mathbf{0}} - (-31.8^{\mathbf{0}}) = 34.1^{\mathbf{0}}$	*1M*
		Active power despatched $= \frac{3V_s\ I_S \cos \phi\ \mathbf{s}}{10^6}$	
		$= \frac{(3 \text{ X } 19779\ \text{ x } 135.32 \text{ x} \cos\ 34.1^0)}{10^6}$	*1M*
		= 6.65 MW	
		Reactive power despatched $= \frac{3V_s\ I_S \sin\ \phi\ \mathbf{s}}{10^6}$	
		$= 3 \text{ X } 19779\ \text{ x } 135.32 \text{ x } \sin 34.1^0 \text{ X } 10^{-6}$	
		= 4.5 MVAR	*1M*
6.		**Attempt any four of the following:**	**(16)**
	a)	**State any four advantage of P.U. Calculations.**	**4M**
	Ans.	**Advantages of PU calculations:** 1. Manufacturers: Usually specify the impedance of a piece of apparatus in percent or per unit on the bases of the nameplate rating. 2. The Zpu of machine of the same type but having widely different ratings usually lie within a narrow range although the value differ with the ratings. Hence, when the impedance of the machine is not known, the table in which values for different machines are given can be referred. 3. The per unit impedance once expressed on the proper base, is same referred to either side of any transformers, because Base KV is selected in the same ratio as the transformer ratio. 4. The way in which transformers are connected in 3-phase circuits of the transformer, although it determine the relation between the base voltages on the two sides of the transformer. 5. Per unit values of quantities simplifies the calculations to greater extent. More over since system data is available in per unit values hence it is always convenient to adopt per unit calculation. **OR** 1. Manufacturers usually specify the impedance values of equipments in per unit of equipment rating.	***Any 4 points 1M each***

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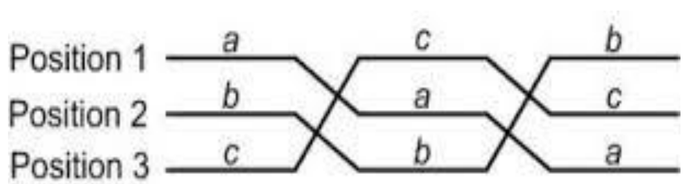
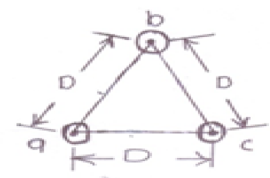
		2. When expressed in P.U., system parameters tend to fall in relatively narrow numerical ranges. 3. P. U. data representation yields important information about relative magnitudes. 4. The transformer connections in 3-ph circuits do not affect the per unit value impedance though base voltages on two sides do not depend upon connections. 5. If base values are selected properly the P.U. impedance is same on both sides of transformers.	
	b) **Ans.**	**What is transposition of conductors in 3ϕ system? 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  **Advantages of transposition:** 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. 1) The transposition 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) Transposition results in balanced receiving end voltages when sending end voltages and line currents are balanced. 3) Voltages induced in the adjacent communication lines will be zero.	**4M** ***Transposition 2M*** ***Any 2 advantages 1M each***
	c) **Ans.**	**Derive the expression for inductance of 3ϕ line (single circuit) composed of solid conductor symmetrical spacing.**	**4M**

		Inductance of a 3 line with symmetrical spacing: Figure shows a 3 phase line with conductors a, b and c spaced at corners of an equilateral triangle, each side is 'D'. The conductors each of radius 'r'  The three-conductors occupy the corners of an equilateral triangle. If the 3 ϕ system, then $\overline{I_a}, \overline{I_b}$ and $\overline{I_c}$ are displaced by 120^0 and $\overline{I_a} + \overline{I_b} + \overline{I_c} = 0$	*1M*
		$$\Psi a = 2 \text{ X } 10^{-7} \left[I_{a.} \ln\left(\frac{1}{ra^1}\right) + I_{b.} \ln\left(\frac{1}{D}\right) + I_{c.} \ln\left(\frac{1}{D}\right) \right] \frac{\text{wb.T}}{\text{m}}$$	*1M*
		$$= 2 \text{ X } 10^{-7} \left[I_{a.} \ln\left(\frac{1}{ra^1}\right) - I_{a.} \ln\left(\frac{1}{D}\right) \right] \frac{\text{wb.T}}{\text{m}}$$ $$\therefore I_b + I_c = -I_a$$ $$= 2 \text{ X } 10^{-7} . I_a . \ln \frac{\left\{\frac{1}{ra^1}\right\}}{\left\{\frac{1}{D}\right\}} \frac{\text{wb.T}}{\text{m}}$$	
		$$= 2 \text{ X } 10^{-7} . I_a . \ln\left(\frac{D}{ra^1}\right) \frac{H}{m}$$ $$\therefore L_a = \frac{\Psi_a}{I_a} = 2 \text{ X } 10^{-7} \ln\left(\frac{D}{ra^1}\right) \frac{H}{m}$$ Inductance per conductor or inductance /phase	*1M*
		$$L_a = 2 \text{ X } 10^{-7} \ln\left(\frac{D}{r^1}\right) \frac{H}{m}$$ $$\boxed{L_a = 0.2 \ln\left(\frac{D}{r^1}\right) \frac{mH}{km}}$$	*1M*
	d) **Ans.**	**State the comparison between synchronous condenser and capacitor bank (any four points) used in power system.**	**4M**

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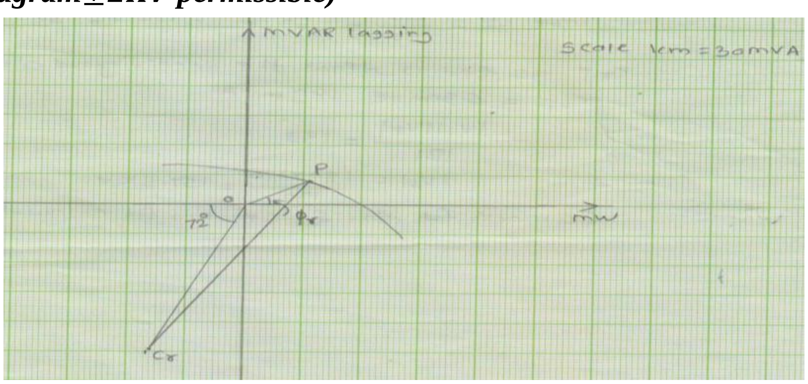
Sr. No.	Synchronous Condenser	Capacitor Bank
1	Synchronous condenser Can supply lagging as well as leading VARs	Capacitor Bank Can supply only leading VARs
2	The control of synchronous condenser is fast and continuous	The control of Capacitor Bank is slow
3	The failure of synchronous condenser means loss of complete unit	The failure of one unit of capacitor bank affects that unit only.
4	Synchronous condenser can be overloaded for short periods	Capacitor bank cannot be overloaded.
5	No switching problems present in synchronous condenser	Due to switching problems present in Capacitor Bank harmonics are produced.
6	For large VAR requirement synchronous condenser is economical	For small VAR requirement capacitor banks are economical.

Any 4 points 1M each

e) **A 3 phase 132 KV over head transmission line delivers 40 MVA at 0.8 p.f. log at receiving end. The line constants are A = 0.98 $\angle 3^0$, B = 110 $\angle 75^0$ Ω with the help of circle diagram determine sending end voltage.** **4M**

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

Ans.



1M

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		The distance of centre OCR= $\frac{\lvert A\rvert\lvert V_R\rvert^2}{\lvert B\rvert} = \frac{0.98\times 132^2}{110} = 155.23\ MVA$ Take scale as 1cm=30 MVA $\therefore for\ 40MVA = 1.33$ cm $also\ \angle\beta - \alpha = 75^0 - 3^0 = 72^0$ Draw line OCR with angle 72^0& mag. 5.17 cm now S_R=40MVA=1.33 cm $\cos\emptyset_R = 0.8$ $\therefore \emptyset_R = 36.86^0$ Draw line with angle $\emptyset_R = 36.86^0\ w.r.+ve\ MW\ axis\ \&\ distance\ 1.33\ cm\ obtainpoint\ P.$ Now joint C_RP & measure it C_RP= 6.3 cm=189 MVA the C_RP is Radius. $\therefore Radius\ C_RP = \frac{\lvert V_R\rvert\lvert V_S\rvert}{\lvert B\rvert} = 189$ $\therefore \frac{132\ \times V_S}{110} = 189$ $V_S = \frac{189\ \times 110}{132} = 157.5\ KV$ Sending end voltage is $V_S = 157.5\ KV$	***1M*** ***1M*** ***1M***