MODEL ANSWER

WINTER - 2017 EXAMINATION

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

Important Instructions to examiners:

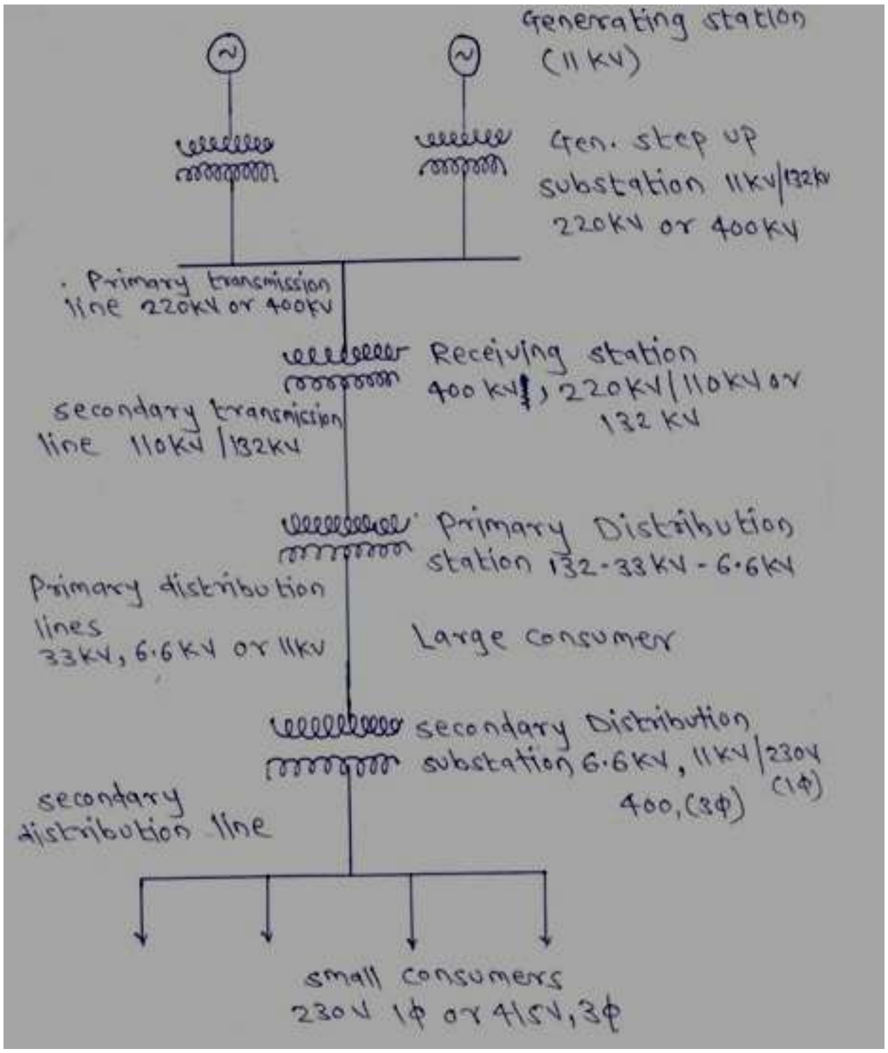
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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:** **Draw a single line diagram of power system.** **Single line diagram of power system:**	**12** **4M**

MODEL ANSWER

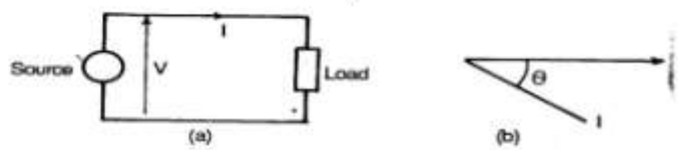
WINTER - 2017 EXAMINATION

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

			***2M voltage level*** ***2M line diagram***
	b) **Ans.**	**Prove that in power flow equation S = VI*.** In Electrical engineering,	**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

1M

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

$$S = VI^*$$
$$= |V|\,|I| \angle\theta$$
$$= |V|\,|I| \cos\theta + j|V|\,|I| \sin\theta = P + jQ$$

1M

That means in electrical engineering Q is positive when load is inductive and negative when load is capacitive.

In order to get the proper sign in power system analysis, for Q it is necessary to find out VI* instead of V*I which will reverse sign for Q. ***1M***

As if S= V*I = VI $\angle -\theta_1 + \theta_2$

$$= VI \angle -(\theta_1 - \theta_2)$$

$$= VI\cos(\theta_1 - \theta_2) - jVI\sin(\theta_1 - \theta_2)$$

$$= P - jQ$$

1M

Hence to get same sign in power system the complex power S is defined as S = VI* instead of V* I.

c) **Compare between AC and DC resistance in power system.** **4M**

Ans.

AC resistance	**DC resistance**
R_{ac} = Resistance offered for flow of AC Current	R_{dc} = Resistance offered for flow of DC Current
R_{ac} = Effective resistance = Average cu loss in conductor (watts)/ I^2rms	R_{dc} = Ohmic resistance = $\rho l/a$

Any 4 points 1M each

AC resistance is higher than DC resistance	DC resistance is lower than AC resistance
R_{ac} is higher as skin effect & proximity effect is present for AC current	R_{dc} is lower as DC current is uniformly distributed i.e. skin effect & proximity effect is absent for DC current.

d) **Write advantages of generalized circuit representation.** **4M**

Ans. **Advantages of generalized circuit representation:**

Any 4 advantages 1M each

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.

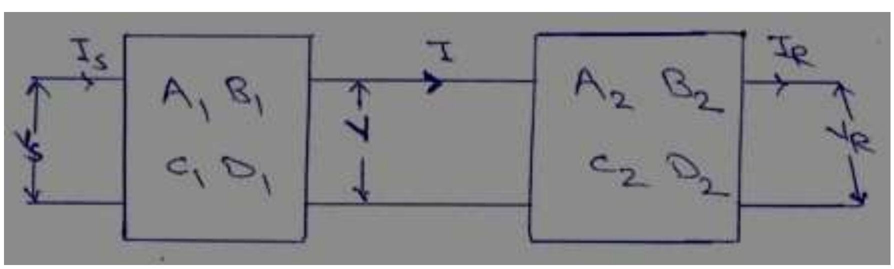
Input power = $V_S I_S$ Cos ϕ_S…………1ϕ..ckt.

= 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:

$$\begin{vmatrix} A & B \\ C & D \end{vmatrix} = \begin{vmatrix} A_1 & B_1 \\ C_1 & D_1 \end{vmatrix} \times \begin{vmatrix} A_2 & B_2 \\ C_2 & D_2 \end{vmatrix}$$

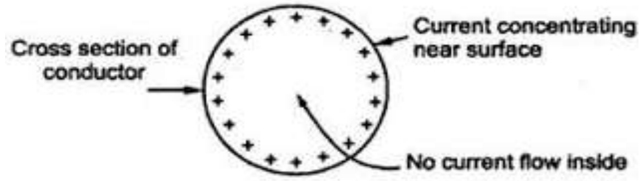
		7. When two transmission lines are connected in parallel then the resultant two part network can be easily obtained by $A = \dfrac{A_1B_2 + A_2B_1}{B_1 + B_2}$ $B = \dfrac{B_1B_2}{B_1 + B_2}$ $D = \dfrac{D_1B_2 + D_2B_1}{B_1 + B_2}$ $C = C_1 + C_2 - \dfrac{(A_1 - A_2)(D_2 - D_1)}{B_1 + B_2}$	
1.	**B)** **a)** **Ans.**	**Attempt any one of the following:** **Derive an expression for generalized circuit constants for two networks connected in series.**  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)	**6** **6M** ***1M*** ***1M***

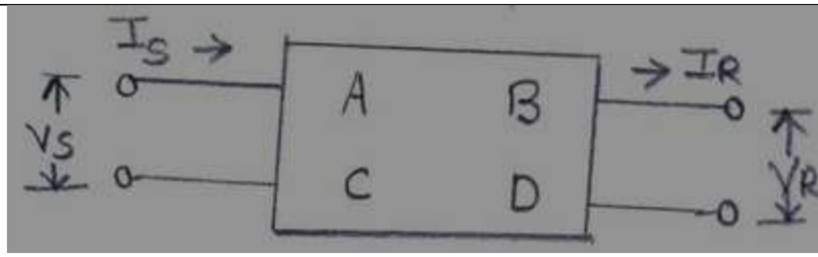
		For Network (2) $V = A_2.V_R + B_2.I_R$ ....(3) $I = C_2.V_R + D_2.I_R$ ....(4) Substitute equation (3) & (4) in equation (1) & (2) $V_S = A_1 (A_2.V_R + B_2.I_R) + B_1 (C_2.V_R + D_2.I_R)$ $V_S = A_1.A_2.V_R + A_1.B_2.I_R + B_1.C_2.V_R + B_1.D_2.I_R$ $V_S = (A_1.A_2 + B1.C_2) V_R + (A_1.B_2 + B_1.D_2) I_R$ Comparing with standard GCE (1) $\boxed{\begin{array}{l} A = A_1.A_2 + B_1.C_2 \\ B = A_1.B_1 + B_1.D_2 \end{array}}$ 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) $\boxed{\begin{array}{l} C = C_1.A_2 + D_1.C_2 \\ D = C_1.B_2 + D_1.D_2 \end{array}}$	***1M*** ***$1^{1/2}$M*** ***$1^{1/2}$M***
	b) **Ans.**	**Explain the skin effect and proximity effect in transmission lines.** **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.	**6M**

MODEL ANSWER

WINTER - 2017 EXAMINATION

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

		 **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 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	***Skin effect 3M*** ***Proximity effect 3M***
2.	**a)** **Ans.**	**Attempt any two of the following:** **i) Define generalized circuit and generalized circuit constants.** **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.	**16** **4M**

		 For Generalized circuit , Generalized Equations can be written as but $V_S = AV_R + BI_R$ $I_S = CV_R + DI_R$ **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) $D = \frac{IS}{IR}$; $V_R = 0$ 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.	***Generalized circuit 2M*** ***Generalized circuit constant 2M***
	Ans.	**ii) Write the advantages of circle diagram.** **Following are the advantages of circle diagram:** 1. Simple method to represent transmission line. 2. Easy to understand parameters of line. 3. Maximum power transferred can by easily determined. 4. The transmission line loss can be determined. 5. Less steps for calculation or analytical solution. 6. Rating of compensating equipment can be directly determined. 7. The torque angle δ can be determined.	**4M** ***Any 4 advantages 1M each***

		8. The transmission line performance can be studied at any load condition. 9. The nature of compensation of reactive power can be analyzed. 10. Any type of transmission line can be represented into circle diagram	
	b)	**Determine the inductance per km of a transposed double circuit 3ϕ line shown in Fig.1. Each circuit of the line remains on its own side. The diameter of the conductor is 2.532cm.**	**8M**

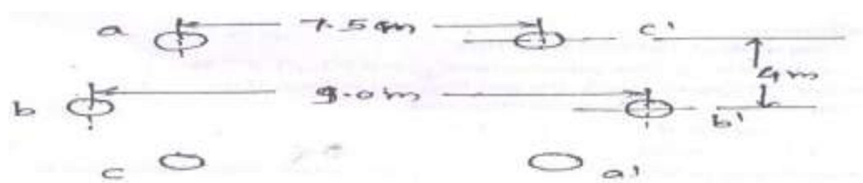
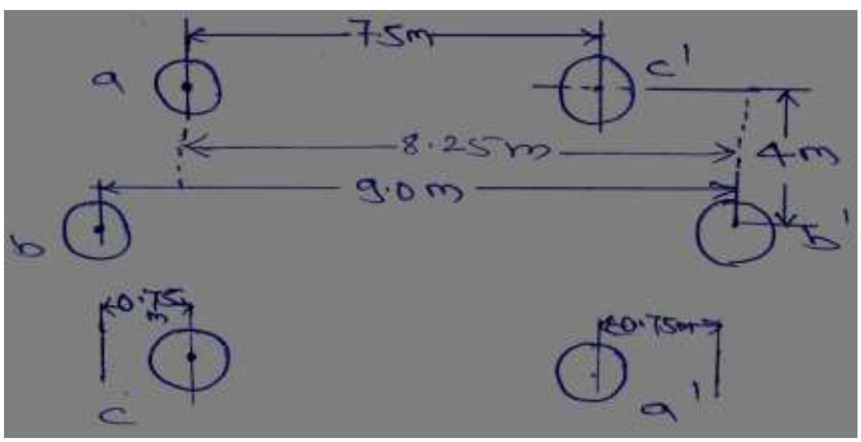


Fig. — 1

	Ans.	***(Note: Numerical is based on double circuit. Consider if student has attempted to solve).***	



			1M
		Given, d= 2.532cm $\therefore\ r = 0.001266m$ $\therefore r' = 0.7788 \text{ x } r$ $= 0.7788 \text{ X } 0.01266$ $= 9.85 \text{ X } 10^{-3}$ $D_{ab'} = D_{bc'} = D_{a'b} = D_{cb'} = \sqrt{4^2 + 8.25^2}$ = 9.16mt	***1M***

$D_{ab} = D_{bc} = D_{C'b'} = D_{b'a'} = \sqrt{4^2 + 0.75^2}$
$= 4.06$mt
$D_{aa'} = D_{cc'} = \sqrt{8^2 + 7.5^2} = 10.96$mt
$D_{mab} = 4\sqrt{(9.16 \text{ X } 4.06)^2} = \sqrt{9.16 \text{ X } 4.06} = 6.09$m
$D_{mbc} = 4\sqrt{(9.16 \text{ X } 4.06)^2} = \sqrt{9.16 \text{ X } 4.06} = 6.09$m
$D_{mac} = 4\sqrt{(8 \text{ X } 7.5)^2} = \sqrt{8 \text{ x } 7.5} = 7.74$m **2M**
$\therefore D_m = 3\sqrt{D_{mab} \,.\, D_{mbc} \,.\, D_{mac}}$
$= 3\sqrt{6.09 \text{ X } 6.09 \text{ X } 7.74}$
$= 6.59$mt

$D_{sa} = \sqrt{9.85 \text{ X } 10^{-3} \text{X } 10.96} = 0.328$m
$D_{sa} = D_{sc} = 0.328$m
$D_{sb} = \sqrt{9.85 \text{ X } 10^{-3} \text{X } 9} = 0.297$m

2M

Equivalent $D_s = 3\sqrt{D_{sa} \,.\, D_{sb} \,.\, D_{sc}}$
$= 3\sqrt{0.328 \text{ X } 0. \text{ X } 0.297}$ **1M**
$\therefore D_s = 0.317$m

$\therefore$ Inductance $= 2 \text{ X } 10^{-7} \log_e \frac{D_m}{D_s}$

$= 2 \text{ X } 10^{-7} \log_e \frac{6.59}{0.317}$ **1M**

$= 6.06 \text{ X } 10^{-7}$ H/mt/ph

$\therefore$ Inductance $= 6.06 \text{ X } 10^{-7}$ H/mt/ph

c) **A 3ϕ 132 KV overhead line delivers 50 MVA at 132 KV and power factor 0.8 lagging at its receiving end. The constants of the line are A = 0.98 ∠ 3⁰ and B = 110 ∠75⁰ Ω/phase. Find** **8M**
i) Sending end voltage and power angle.
ii) Sending end active and reactive power.
iii) Capacity of static compensation equipment at the receiving end to reduce the sending end voltage to 140 KV for the same load.

Ans. **i) Sending end voltage and power angle.**
Receiving End current

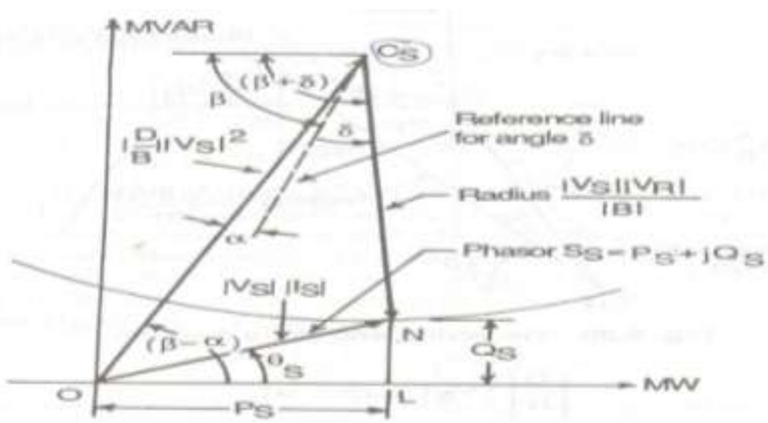
		$I_R = \frac{MVA\ X\ 10^{-6}}{\sqrt{3} X\ V_R X\ 10^3}$ $= \frac{50\ X\ 10^{-6}}{\sqrt{3} X\ 132 X\ 10^3}$ = 218.69A $o\angle$-36.86	***2M***
		calculate sending end voltage, $V_s = A.V_R + B.\ V_R$ $= \left[(0.98)\left(\frac{132\ X\ 10^3}{\sqrt{3}}\angle 0^0\right)\right] + [(110\angle 75^0)\ .\ (218.69\angle 36.86)]$ $= [74.68\ \angle 3^0] + [24.05\ \angle\ 38.14^0]$ $= 93.48 + j18.75$ $\therefore\ V_s = 95.34$ KV $\angle 11.34^0$ $\therefore V_s = 95.34$KV $\delta\ = 11.34^0$---------Power Angle Convert V_s into line voltage $\therefore V_s = \sqrt{3}$ X 95.34 $V_s = 165.13$KV $\angle 11.34^0$	
		ii) Calculate sending active & reactive power: $S_s = \frac{A.V_s^2}{B}\angle(B.\alpha) + \frac{V_s.V_R}{B}\angle(B-\delta)$ $=\left[\frac{(0.98)(165.13)^2}{110}\angle(75^0-3^0)\right] + \left[\frac{165.13\ X\ 132}{110}\angle(75^0-11.34^0)\right]$ $= [242.93\angle 72^0] + [198.15\ \angle 63.66]$ $= 75.06 + j\ 231.04 + 87.91\ j177.57$ $= 162.97 + j408.61$	***2M***

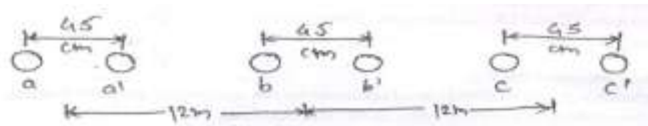
		Sending end Active power = 162.97MW Sending end Reactive power = 408.61MVAR **iii) Calculate capacity of static equipment:** $Q_s = \frac{A.V_S^2}{B}\sin(B - \alpha) + \frac{V_s.V_R}{B}\sin(B - \delta)$ $= \left[\frac{(0.98)(140)^2}{110}\sin(72)\right] - \left[\frac{140 \ X\ 132}{110}\sin(75 - 11.34)\right]$ = [174.61 X 0.95] – [168 X 0.89] = 165.87 – 149.52 = 16.35 MVAR Q_R = 50 X sin (36.86) = 30 MVAR ∴ capacity of static equipment, = Q_S - Q_R = 16.35 - 30 = -28.65 MVAR	*2M* *2M*
3.	**a)** **Ans.**	**Attempt any four of the following:** **Write the role of power system engineer in PS.** ***(Note: Any other relevant points shall 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.	**16** **4M** ***Any 4 points 1M each***

MODEL ANSWER

WINTER - 2017 EXAMINATION

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

		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.	
	b) **Ans.**	**Write the steps for drawing a sending end circle diagram with neat diagram.** i. Step-1: Draw the X-Y plane in which plane X represents the active power (MW) & axis-y-represents the Reactive power (MVA). With proper scale. ii. Step-2: The centre of sending end circle is located at the tip of phasor $\lvert D/B\rvert\ 1V_S\rvert^2 < \beta - \alpha$ drawing OC_S from positive MW axis. **OR** Locate X and Y coordinates of the centre are $\lvert D/B\rvert 1V_S\rvert^2 Cos\ (\beta - \alpha)$ and $\lvert D/B\rvert 1V_S\rvert^2\ Sin\ (\beta - \alpha)$ and mark the point Cs. Join OCs. iii. Step-3: Radius = $\lvert V_S\rvert\lvert V_R\rvert$ / $\lvert B$ Draw the Curve with the radius of sending end circle from centre Cs to the scale. iv. Step-4: Locate point Lon X axis such that OL represents Ps to the scale. Draw perpendicular at L to X axis which cuts the circle at point at N. Join NCs. N is the operating point of the system. Step-5: Complete the triangle ONL which represents power triangle at sending end.  	**4M** ***Steps 2M*** ***Diagram 2M***
	c)	**A 400 KV 3-phase bundled conductor line with two sub-conductors per phase has a horizontal configuration as shown in Fig.2. The radius of each sub-conductor is 1.6 cm. Find the inductance per phase per km of the line.**	**4M**

	Ans.	 Fig. - 2 Self GMD of each conductor $r' = 0.7788 \times r$ $= 0.7788 \times 1.6$ $= 1.25cm$ Let self GMD of each phase be $D_{s1} = D_{s2} = D_{s3} = D_s$ $D_{s1} = \sqrt[4]{(Daa'Daa)^2}$ $= \sqrt[4]{(1.25 \times 4.5)}$ $= 7.5cm = 0.075m$ Mutual GMD between a and b phase. $D_{ab} = \sqrt[4]{D_{ab} D_{ab'} D_{a'b} D_{a'b'}}$ $= \sqrt[4]{(D_{ab})^2 (D_{ab'})(D_{a'b})}$ $= \sqrt[4]{(12)^2 (12.45)(11.55)}$ $= 11.97m$ $D_{ab} = D_{bc} \quad 11.97m$ $D_{ac} = \sqrt[4]{D_{ac} D_{ac'} D_{a'c} D_{a'c'}}$ $= 4\sqrt{(24)(24.45)(23.55)(24)}$ $= 23.99$	***1/2M*** ***1/2M*** ***1/2M*** ***1/2M*** ***1/2M*** ***1/2M***

MODEL ANSWER

WINTER - 2017 EXAMINATION

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

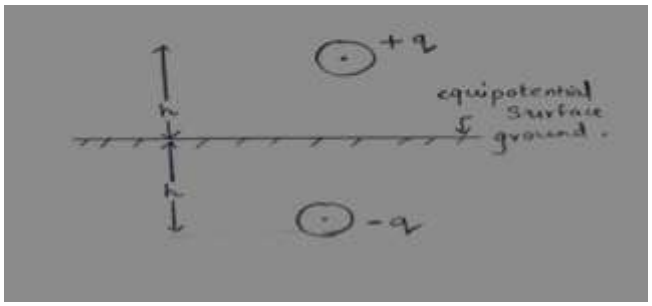
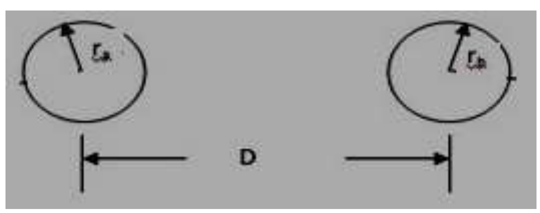
		$D_{eq} = 3\sqrt{D_{ab}\ D_{bc}\ D_{ac}}$ $= 3\sqrt{11.97 \text{ X } 11.97 \text{ X } 23.99}$ $= 15.09m$ $L = 2 \text{ X } 10^{-7} \log_e \frac{D_{eq}}{D_s}$ $= 2 \text{ X } 10^{-7} \log_e \frac{15.09}{0.075}$ $= 1.06MH/km$	***1/2M*** ***1/2M***
	d) **Ans.**	**A 3ϕ 132 KV line delivers 40 MVA at 0.8 p.f. lagging. The line constants are A = D = 0.98 $\angle 3^0$, B = 110 $\angle 75^0$, C = 5 X $10^{-4}\angle 88^0$. Find the capacity of phase modifier at full load. V_s = 140 KV, V_r = 132 KV.** cos ϕ 0.8 sin ϕ = 0.6 P_R = 40 X 0.8 = 32MW Q_R = 40 X 0.6 = 24 MVAR $P_R = \frac{V_s V_R}{B}\cos(\beta - \delta) - \frac{AV_R 2}{B}\cos(\beta - \alpha)$ $= \frac{140 \text{ X } 132}{110}\cos(\beta - \delta) - \frac{0.98 \text{ X } 132^2}{110}\cos(75 - 3)$ $32 = 168\cos(\beta - \delta) - 115.23\ \cos 72^0$ $32 = 168\cos(\beta - \delta) - 35.60^0$ $\cos(\beta - \delta) = 0.402$ $\beta - \delta = \cos^{-1}(0.402)$	**4M** ***1/2M*** ***1/2M*** ***1/2M*** ***1/2M***

MODEL ANSWER

WINTER - 2017 EXAMINATION

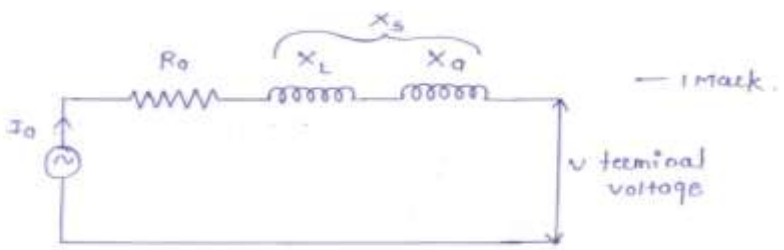
Subject: Power System Analysis **Subject Code: 17510**

		$\beta - \delta = 66.296$	½M
		$Q_R = \frac{V_s V_R}{B}\sin(\beta - \delta) - \frac{A V_R^2}{B}\sin(\beta - \alpha)$	½M
		$= \frac{140 \text{ X } 132}{110}\sin(66.296) - \frac{0.98 \text{ X } 132^2}{110}\sin(75 - 3)$	
		= 153.826 - 109.59	
		Q_R = 44.236 MVAR	½M
		Capacity of phase modifier = 44.236 – 24 = 20.236MVAR	½M
	e) **Ans.**	**Explain the effect of earth field on transmission line capacitance.** As earth is also a perfect conductor its electric field affect the outside electric field i.e. capacitance of the line conductor. For example 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 the conductor. Hence potential difference exists between the conductor and the earth. And the electric flux is perpendicular to the earth's equipotential surface. Since the surface is assumed to be a perfect conductor. Imagine a fictitious conductor of the same size and shape as the over head conductor lying directly below the original conductor at a distance equal to twice the distance of the conductor above the plane of the earth by a distance equal to the distance of the 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. Now the plane midway between the original conductor and the fictitious conductor is an equipotential surface and occupies the same position as that of the earth. Now the flux between the overhead conductor and this equipotential surface is the same as that which existed between the conductor and the earth. Thus for the calculation of the capacitance, the earth may be replaced by a conductor at a distance equal to that of the overhead conductor above the earth from	**4M** ***Explanation 4M***

		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 and is called the image conductor.  	
4.	**A)** **a)** **Ans.**	**Attempt any three of the following:** **Derive an expression for capacitance of two wire line.** **Capacitance of two wire line:** Consider two wire line as shown in fig. excited from single phase source. The line develops equal and opposite sinusoidal charges on the two conductors which can be represented as q_a and q_b so that $q_a = - q_b$.  The potential difference across conductors a & b as V_{ab} can be written in terms of the contribution made by q_a and q_b by applying superposition theorem As D >>>r , assume that D + r =D –r =D Thus $$V_{ab} = \frac{1}{2\pi k}\left(q_a \ln\frac{D}{r_a} + q_b \ln\frac{r_b}{D}\right)$$ Since $q_a = - q_b$, we have $$V_{ab} = \frac{q_a}{2\pi k} \left(q_a \ln\frac{D^2}{r_a r_b} \right)$$ The line capacitance C_{ab} is then	**12** **4M** ***1M*** ***1M***

		$$C_{ab} = \frac{q_a}{V_{ab}} = \frac{\pi k}{\ln(\frac{D}{(r_a r_b)^{1/2}})}\frac{F}{m} length\ of\ line$$ **OR** $$C_{ab} = \frac{0.0121}{\ln(\frac{D}{(r_a r_b)^{1/2}})}\frac{\mu F}{m}$$ If $r_a = r_b = r$ then $$C_{ab} = \frac{0.0121}{\ln(\frac{D}{r})}\frac{\mu F}{km}$$	***1M*** ***1M***
	b) **Ans.**	**A 275 KV, 3ϕ line has the following line parameters, A = 0.93 ∠1.5⁰, B = 115 ∠77⁰. If the receiving end voltage is 275 KV, determine the sending end voltage if the load of 250 MW at 0.85 lagging PF is being delivered at the receiving end.** $$given: V_R = 275KV, A = 0.93\angle 1.5^{\circ}, B = 115\angle 77^{\circ}$$ $$\text{Power delivered} - \text{PR} = 250\text{Mw}, 0.85\text{lag}$$ $$load = \sqrt{3}V_R I_R \cos\emptyset_R = 250\times 10^6 =$$ $$= \sqrt{3}x\ 275\times 10^3\times I_R\times 0.85$$ $$\therefore I_R = 617.49Amp$$ $$\emptyset_R = \cos^{-1}0.85 = 31.79$$ $$V_S = AV_R + BI_R$$ $$V_S = 0.93\angle 1.5\times\frac{275\times 10^3}{\sqrt{3}}\angle 0 + 115\angle 77\times 617.49\angle - 31.79$$ $$V_s = 204948.51\angle - 15.35^0$$ $$V_s\ (phase\ value) = 204.948KV$$ $$V_s\ (line\ value) = 342.31KV$$	**4M** ***1M*** ***1M*** ***1M*** ***1M***
	c) **Ans.**	**Draw the equivalent circuit diagram of** **i) Alternator ii) Transformer.**	**4M**

i) Equivalent circuit diagram of alternator:

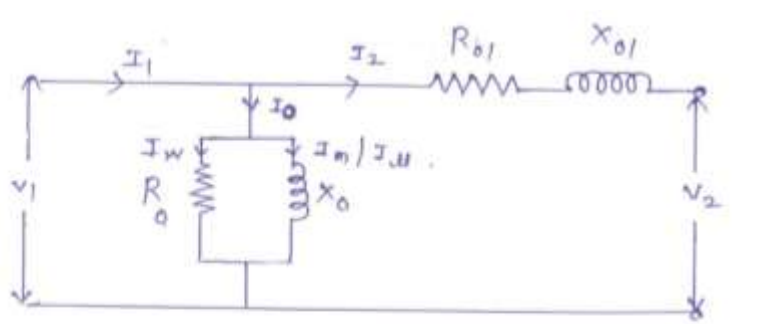


1M

Significance of term:
R_a = armature resistance
X_L = Leakage reactance
X_a = Armature reaction reactance
$X_s = X_L + X_a$ = synchronous reactance
E = Induced emf
V = terminal voltage

1M

ii) Equivalent circuit diagram of Transformer:



1M

V_1 = Primary voltage
I_1 = Primary current
R_{01} = No-Load Branch resistance
X_{01}= No-Load Branch reactance
$R_{01}= R_1 + R_2^1$ = Equivalent resistance reformed to primary
$X_{01}= X_1+ X_2^1$ = Equivalent reactance
I_w = Iron loss component
I_m/I_μ = Magnetizing current
I_o = No load current
V_2 = terminal voltage

1M

	d)	**State the expression for complex power at receiving end of transmission line. Derive the condition for max. power at receiving end.**	4M
	Ans.	**The expression for complex power at receiving end of transmission line……** $$P_R = \frac{V_S\,V_R}{B}\cos(\beta-\delta) - \frac{A V_R^{\,2}}{B}\cos(\beta-\alpha)$$ Where V_S , V_R – sending end and receive end voltages $A\angle\alpha$, $B\angle\beta$ – GCC of line δ - load angle	*1M*
		Condition for maximum power at receiving end can be obtained by Differentiate above equation with respect to variable load (δ) and equating it to zero. $$\frac{dP_R}{d\delta} = -\frac{V_S\,V_R}{B}\sin(\beta-\delta) + 0 = 0$$	*1M*
		$$\frac{V_S\,V_R}{B}\sin(\beta-\delta) = 0$$ $$\sin(\beta-\delta) = 0$$	*1M*
		$$(\beta-\delta) = 0$$ $$\boxed{\beta = \delta}$$	*1M*
4.	B)	**Attempt any one of the following:**	6
	a)	**Explain how generalized circuit constants are measured.**	6M
	Ans.	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 are shown below	*1M*

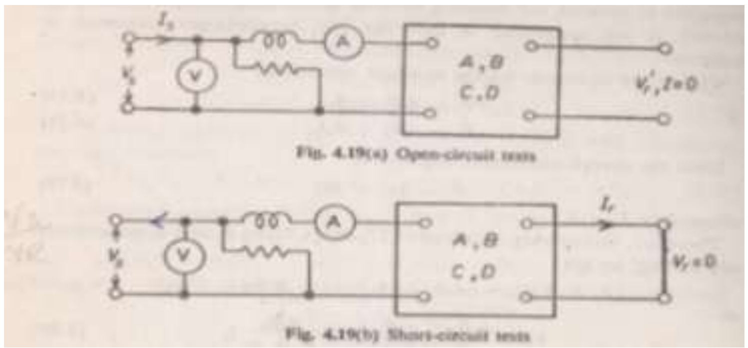


Fig. 4.19(a) Open-circuit tests

Fig. 4.19(b) Short-circuit tests

1M

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 $I_R = CV_R$

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

1M

-sending end impedance with receiving end open ckted.

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

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

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

1M

-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.

$\therefore$ 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 = D$V_s + BI_s \times$ (-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

1M

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)

$Z_{rs} = \frac{B}{A}$

or **B = A**$\boldsymbol{Z_{rs}}$ = $\boldsymbol{Z_{rs}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ ----------------(b)

$Z_{so} = \frac{A}{C}$

$\therefore$**C** = $\frac{A}{Z_{so}} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$ ----------------------(c)

$Z_{ro} = \frac{D}{C}$

1M

$\therefore$ **D = C**$\cdot$ $\boldsymbol{Z_{ro}} = \frac{Z_{ro}}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro}-Z_{rs}}}$

		$= Z_{ro}\sqrt{\frac{1}{(Z_{ro}-Z_{rs})Z_{so}}}$-----------(d) If $Z_{ro} = Z_{so}$ we get A = D for symmetric network	
	b) **Ans.**	**Explain the concept self G.M.D. and mutual G.M.D. in inductance for transmission line.** Expression:  Cond X m = 3 Cond Y n = 2 $D_m = \sqrt[mn]{\text{mn terms}}$ $= \sqrt[6]{(D_{aa'}\ D_{ab'})\ (D_{ba'}\ D_{bb'})(D_{ca'}\ D_{cb'})}$ $D_{sx} = \sqrt[m^2]{m^2 \text{ terms}}$ $= \sqrt[9]{(D_{ab}\ D_{aa}\ D_{ac})\ (D_{ba}\ D_{bb}\ D_{bc})(D_{ca}\ D_{cb}\ D_{cc})}$ $D_{sy} = \sqrt[4]{(D_{a'a'}\ D_{a'b'})\ (D_{b'b'}\ D_{b'a'})}$ $L_A = 2 \times 10^{-7} In \frac{Dm}{Ds} H/m$ **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	**6M** *1M* *1M* *1M* *1M*

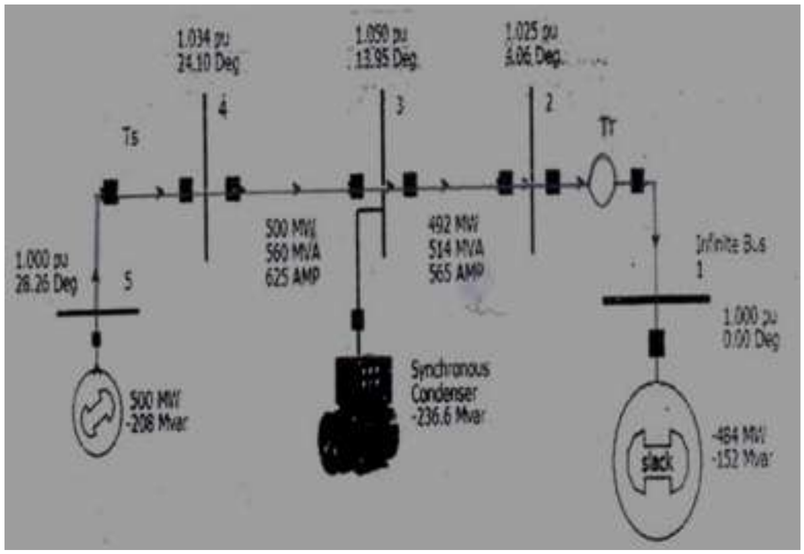
MODEL ANSWER

WINTER - 2017 EXAMINATION

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

		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.	*1M* *1M*
5.	**a)** **Ans.**	**Attempt any two of the following:** **A 132 KV, 50Hz, 3ϕ transmission line delivers a load of 50 Mw at 0.8 P.F. lagging at the receiving end. The generalized constants of the transmission line are A = 0.85 ∠1.6⁰, B = 100 ∠80⁰, C = 0.0018 ∠95⁰. Find sending end voltage, sending end current and % voltage regulation. Use nominal π method.** $given: V_R = 132KV, \quad A = 0.85\angle 1.6, \quad B = 100\angle 80$ $load = 50Mw, 0.8lag$ $load = \sqrt{3}V_R I_R \cos\emptyset_R = 50 \times 10^6$ $= \sqrt{3}\,X132 \times 10^3 \times I_R \times 0.8$ $\therefore I_R = 273.3666\,Amp$ $\emptyset_R = \cos^{-1} 0.8 = 36.86$ $V_S = AV_R + BI_{\boldsymbol{R}\ldots}$ $= 0.85\angle 1.6 \times 132 \times 10^3\angle 0 + 100\angle 80 \times 273.366\angle - 36.86$ $V_s = 133.89\angle 9.38\,KV$ $I_S = CV_R + DI_R$ 1M $= 0.0018\angle 95 \times 132 \times 10^3\angle 0 + 0.85\angle 1.6 \times 273.3666\angle - 36.86$ = 197.70∠31.25) **For nominal π circuit,** V_{RNL} is V_S/A	**16** **8M** *1M* *2M* *2M* *1M*

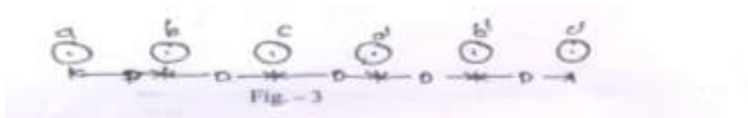
		Voltage regulation $= \dfrac{\frac{Vs}{A} - -V_{RFL}}{V_{RFL}}$ X 100 $= \dfrac{\frac{133.89}{0.85} - 132}{132}$ x 100 = 19.33%	***1M*** ***1M***
	b) **Ans.**	**Explain why reactive power compensation is necessary. Explain working of synchronous condenser in this.** **Need of Reactive power compensation:** 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 Q_s & reactive power consumed by load Q_r If $Q_s > Q_r$ --- V_r increases If $Q_s < Q_r$ -----V_r decreases If $Q_s = Q_r$ ----V_r flat cha So to maintain balance in Q_s &Q_r Reactive power compensation is required. **Synchronous condenser any 4 points 1 mark each** • It is synchronous motor operating at no load with over excitation • It is used for compensating large amount of reactive power • It is used in load dispatch center • It is dynamic/ rotating compensation equipment • It is costly & requires maintenance **OR**	**8M** ***4M*** ***Any 4 points 1M each***



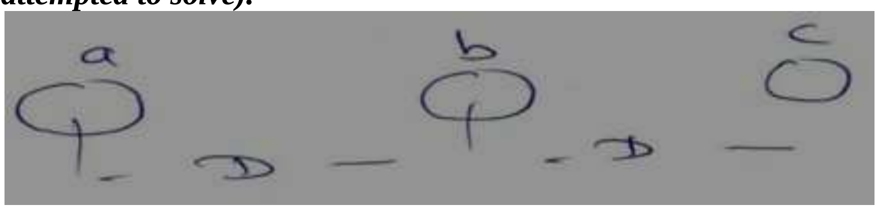
Synchronous Condenser: A synchronous condenser is a synchronous motor running under no-load condition, which delivers inductive or absorbs capacitive reactive power.

Synchronous condensers have played a major role in voltage and reactive power control for more than 50 years. Functionally, a synchronous condenser is simply a synchronous machine connected to the power system. After the unit is synchronized, the filed current is adjusted to either generate or absorb reactive power as required by the ac system. The machine can provide continuous reactive power control when used with the proper automatic exciter circuit. Synchronous condensers have been used at both distribution and transmission voltage levels to improve stability and to maintain voltages within desired limits under varying load conditions and contingency situations. However, synchronous condensers are rarely used today because they require substantial foundations and a significant amount of starting and protective equipment. They also contribute to the short circuit current and they cannot be controlled fast enough to compensate for rapid load changes. Moreover, their losses are much higher than those associated with static compensators, and the cost is much higher compared with static compensators. Their advantage lies in their high temporary overload capability.

c) **Find the susceptance to neutral/km of a double-circuit three phase line with transposition as shown in Fig.3. Given D = 7m and radius of each = 1.38cm.** **8M**



Ans. ***(Note: Numerical is based on double circuit. Consider if student has attempted to solve).***



Considering single circuit…..

$L = 2 \times 10^{-7} \log_e = \frac{D_{eq}}{D_s}$

$$D_{eq} = \sqrt[3]{D_{ab}\, D_{bc}\, D_{ca}}$$

$$= \sqrt[3]{D \times D \times 2D} = 8.819\text{m}$$

2M

$D_S = 0.7788r = 1.38 \times 0.7788 \times 10^{-2}$

$= 1.0744 \times 10^{-2}$

2M

$$\therefore L = 2 \times 10^{-7} \log_e \left(\frac{8.819}{1.0744 \times 10^{-2}}\right)$$

$= 1.34 \times 10^{-6}$ H/m/ph

$= 1.34$ mH/km/ph

2M

$X_L = 2\pi fL = 2 \times 51 \times 50 \times 1.34 \times 10^{-3}$

$= 420.97 \times 10^{-3}\ \Omega$/km/ph

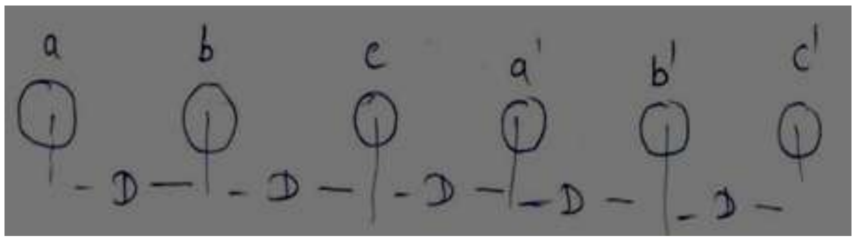
1M

Susceptance $= \frac{1}{X_L} = 2.37$ siemens/km/ph

1M

OR

Considering double circuit…..



D = 7m, r = 1.38cm

$D_S = r' = 0.7788r = 1.38 \text{ X } 0.7788 \text{ X } 10^{-2}$

$= 1.744 \text{ X } 10^{-2}$m

1M

$D_m = \sqrt[3]{D_{m_{ab}} D_{m_{bc\,1}} \; Dm_{ca'}}$

$Dm_{ab'} = \sqrt[4]{(Daa' Dab' \text{ X } Dba' Dbb')}$

$= \sqrt[4]{(3D \text{ X } 4D \text{ X } 2D \text{ X } 3D)}$

$= \sqrt[4]{(3 \text{ X } 4 \text{ X } 2 \text{ X } 3) \text{ X } D} = 2.917$

= 20.39m

$Dm_{bc}' = \sqrt[4]{(Dbb' Dbc' \text{ X } Dcb' Dcc')}$

$= \sqrt[4]{(3D \text{ X } 4D \text{ X } 2D \text{ X } 3D)}$

= 20.39m

$Dm_{ca}' = \sqrt[4]{(Dca' Dcc' \text{ X } Daa' Dac')}$

$= \sqrt[4]{(D \text{ X } 3D \text{ X } 3D \text{ X } 5D)}$

= 2.59 x 7 =18.13m

$D_m = \sqrt[3]{(20.39 \text{ X } 20.39 \text{ X } 18.13)}$

		$= 19.60m$ $D_{sa} = 4\sqrt{(DaaDaa'\ X\ Da'aDa'a')}$ $= 4\sqrt{(Daa\ X\ Daa')} = \sqrt{(Ds\ X\ Daa')}$ $= \sqrt{(1.0744\ X\ 10^{-2} X\ 3\ X\ D)}$ $= \sqrt{(1.0744\ X\ 10^{-2} X\ 3\ X\ 7)}$ $= 0.474m$ $D_{sb} = \sqrt{D_{bb}\ X\ D_{bb'}} = 0.474m$ $D_{sc} = \sqrt{D_{cc}\ X\ D_{cc'}} = 0.474$ $D_s = 3\sqrt{D_{sa}\ D_{sb}\ D_{sc}} = 0.474m$ Inductance = $2\ X\ 10^{-7} \log_e \frac{D_m}{D_s}$ $= 2\ X\ 10^{-7} \log_e\left(\frac{19.60}{0.474}\right)$ $= 7.44\ X\ 10^{-7} H/m$ $= 0.744mH\ km$ $X_L = 2\pi fL = 2\pi\ X\ 50\ X\ 0.744$ $= 233.734\ m\ \Omega/km/ph$ $\therefore$Susceptance $= \frac{1}{X_L} = 4.278$ siemens/km/ph	*2M* *1M* *2M* *1M* *1M*
6.	**a)**	**Attempt any four of the following:** **A 50Hz, 3ϕ, 275KV, 400 km x mission line has the following parameters: R = 0.035Ω /km/ph, L = 1.1 mH/km/ph, C = 0.012μ F/km/ph. If the line is supplied at 275 KV, determine the MVA rating of a shunt reactor having negligible losses. The receiving**	**16** **4M**

end volt. Is 275 KV when line is delivering no load. Use nominal π method.

Ans.

F=50Hz, V_s=275kv, L=300km, V_R=275kv,
R=0.0035Ω/km/ph,L=1.1mH/km/ph=$1.1X10^{-3}$H/km/ph,
C=0.012μF/km/ph=$0.012X10^{-6}$ F/km/ph
At no load condition i.ePr=0MVA Rating of shunt reactor?
Use nominal π

$A = 1 + \frac{YZ}{2}$ AND $B = Z$

$$Z = R + jX_L = \sqrt{R^2 + {X_L}^2}$$

$$X_L = 2\pi FL = 2 \times \pi \times 50 \times 1.1 \times 10^{-3} \times 300 = 2.072\Omega$$

$$R = 0.5 \times 300 = 1.05\Omega$$

$$Z = 1.05 + 2.072 = 2.322\angle 63.12\Omega$$

1M

$$Y = jwc = j \times 2\pi \times 50 \times 0.012 \times 10^{-6} \times 300$$

$$= 0.0011304 \times 10^{-6} = j0.0011304 = 0.0011304\angle 90^0$$

$$\therefore A = 1 + (0.0011304\angle 90, (2.322\angle 63.12)$$

$$= 1 + \frac{0.002624\angle 153.12}{2\angle 0}$$

$$= 1 + 0.00131\angle 153.12 = 1 + (-0.001168 + j0.000592)$$

$$= 0.9988 + j0.000592$$

$$= 0.9988\angle 0.0339^0$$

1M

$$B = Z = 2.322\angle 63.12\Omega$$

$$\therefore |A| = 0.9988\angle\alpha = 0.0339\angle\beta = 2.322\angle\beta = 63.12$$

Receiving end power is given by…..

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

At no load Pr $_{=0}$

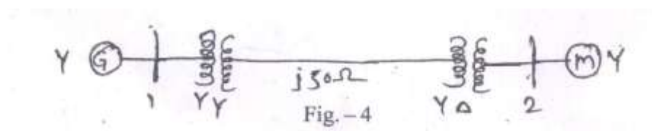
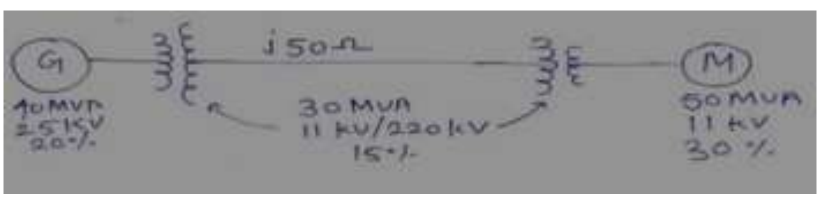
$$\therefore\ O = \frac{275 \times 275}{2.322}\cos(\beta - \delta) - \frac{0.9988 \times 275}{2.322}\cos(63.12 - 0.0339)$$

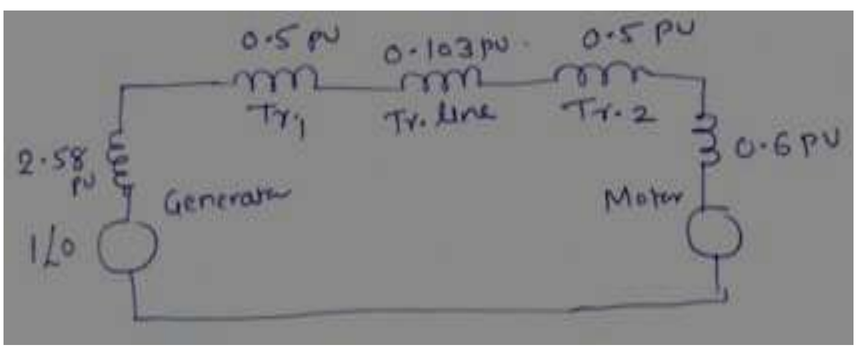
$$\therefore (\beta - \delta) = 63.12^0$$

Now substituting in equation for Q_r,

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

1M

		$= \frac{275 \times 275}{2.322}\sin(63.12) - \frac{0.9988 \times 275}{2.322}\sin(63.12 - 0.0339)$ $29050.011 - 29006.44$ $Q_r = 43.566 MVAR$ Thus the line supplies 43.66 MVAR lagging VAR at no load, thus the rating of shunt reactor 43.566MVAR	***1M***
	b) **Ans.**	**Draw the pu impedance diagram for the P.S. shown in Fig.4, Neglect resistance and use a base of 100 MVA, 220 KV in 50 Ω line. The ratings of the generator, motor and transformer are, generator – 40MVA, 25 KV, X = 20%, Motor = 50 MVA, 11 KV, X = 30%, Y-Y transformer = 40MVA, 30/220 KV, X = 15% Y - Δ transformer, 30 MVA, 11/220 KV, X = 15% Fig.4.**   Base – 100MVA Base KV – 220KV in tr. Line ∴ Base KV 11 KV for Gen.& Motor side. Calculation X_{pu} **(1) Generator -** X_{pu} new = X_{PU} old X $\frac{MVA_{new}}{MVA_{old}}$ X $\left(\frac{KV_{old}}{KV_{new}}\right)^2$ $= 0.20 \text{ X } \frac{100}{40} \text{ X } \left(\frac{25}{11}\right)^2$ $= 2.58_{pu}$ **(2) Transformer-**	**4M**

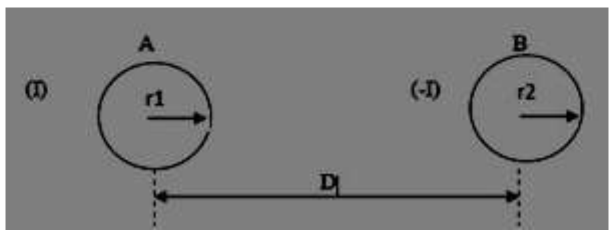
		X_{pu} new $= 0.15 \times \frac{100}{30} \times \left(\frac{11}{11}\right)^2$ ***OR*** $= 0.15 \times \frac{100}{30} \times \left(\frac{220}{220}\right)^2$ $= 0.5_{pu}$ **(3) Transmission line-** $X_{pu} = \frac{X_{actual}}{X_{Base}} = \frac{X_{actual}}{KV_B{}^2} \times MVA_B$ $= \frac{50}{(220)^2} \times 100 = 0.103_{pu}$ **(4) Motor-** $X_{pu\ new} = 0.30 \times \frac{100}{50} \times \left(\frac{11}{11}\right)^2$ $= 0.6_{pu}$ 	***1M*** ***1M*** ***1M*** ***1M***
	c) Ans.	**Derive the expression for inductance of single phase line composed of solid conductors and bundled conductors.** ***(Note: Derivation for solid conductors and bundled conductors is different. If students attempt any one, must be considered for 4 marks)*** Inductance of Single Phase to Line Composed of Solid Conductors:	4M

MODEL ANSWER

WINTER - 2017 EXAMINATION

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

Consider a single phase to line composed of two solid conductors A & B of radii r_1& r_2 mts .Respectively
and placed at a distance D mts. Apart.
Say conductor 'A' carries current in forward and 'B' carries current as return path
current through two conductors are equal but flow in opposite directions.



Flux linkage of each conductor depends upon the internal flux and external fluxes of both conductors. ψa total =ψ_{ai}nt + ψa ext.
ψ_{ai}nt – flux linkage due to internal fluxes = ½ x 10^{-7} I wbt/mt.

To simplify the calculations assume that, as D>>> r1 & r2 (the case in overhead line)

Zero current

$\therefore \Psi_{a\mathrm{ex}_1} = 2 \text{ X } 10^{-7} \text{ I} \log_e \frac{D}{r_1}$ **1M**

$\therefore \Psi_{a_{total}} = \Psi a_{\mathrm{int}} + \Psi a_{\mathrm{ext}}$

$= \frac{1}{2} \text{ X } 10^{-7} \text{ I} + 2 \text{ X } 10^{-7} \text{ I} \log_e \frac{D}{r_1'}$

$= \frac{1}{2} \text{ X } 10^{-7} \text{ I } \log_e \frac{De^{1/4}}{r_1}$

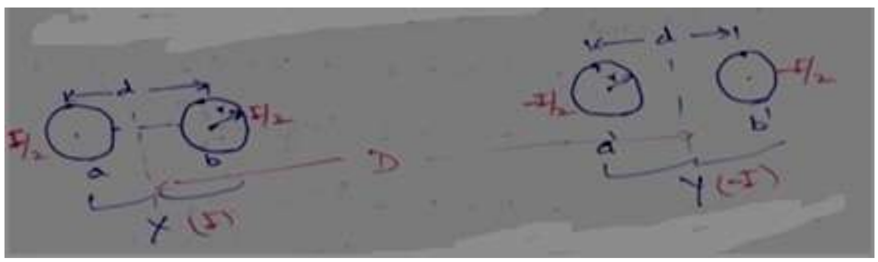
$= \frac{1}{2} \text{ X } 10^{-7} \text{ I } \log_e \frac{D}{e^{-1/4} r_1}$

$= \frac{1}{2} \text{ X } 10^{-7} \text{ I } \log_e \frac{D}{r_1'}$ where $r_1' = e^{-1/4} r_1$ **1M**

$\therefore L_a = \frac{\Psi_{a_{total}}}{I} = 2 \text{ X } 10^{-7} \log_e \frac{D}{r_1'}$ H/mt

Inductance of 1 Phase line i.e. complete loop is
L loop = La + Lb= 2(2 x 10 -7 $\log_e$ D/r')
= 4 x 10 $^{-7}$ $\log_c$ D/ r' H/mt**.**
Inductance of Bundled conductor — ***1M***
L= 2 x $10^{-7}\log_e$ Dm/Ds

OR — ***1M***



Let 'I' be the current through conductor 'X' which equally divides among 2 filaments 'a' & 'b' i.e. current through each filament is I/2 amp. Consider conductor 'y' forms the return path for the current.

Inductance of conductor 'x', L_x

$= \frac{1}{x} L_{ax}$

$= \frac{1}{2} X\ L_a$

Where L_a inductance of filament 'a'

$L_a = L_b$

n – no. of filament

= 2…. For duplex butid conductor

Net flux linkage with filament 'a' due to current through a, b, a[1], b[1] filaments

$$\psi = 2 \text{ x } 10^{-7} \left\{\frac{I}{2}\left(\log_e \frac{1}{r'} + \log_e \frac{1}{D_{ab}}\right) - \frac{I}{2}\left(\log_e \frac{1}{D_{aa'}} + \log_e \frac{1}{D_{ab'}}\right)\right\}$$

$$= 2 \text{ x } 10^{-7}\ I \log_e \frac{\sqrt{D_{aa'} \cdot D_{ab'}}}{\sqrt{D_{aa} . D_{ab}}} \text{where } D_{aa} = r'$$

$$\therefore\ L_a = \frac{y_a}{I/2} = 2 \text{ X } 10^{-7} \log_e \frac{D_{aa'} . D_{ab'}}{D_{aa} . D_{ab}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{H/mt}$$

III l_yL b = 2 X 10^{-7} $\log_e$

$$\frac{D_{ba'} . D_{bb^1}}{D_{ba} . D_{bb}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{H/mt}$$

		$\therefore L_{ax} = \dfrac{L_a + L_b}{2}$ $= 2 \times 10^{-7} \log_e \dfrac{\sqrt{Daa' \cdot Dab' \cdot Dbb' \cdot Dba'}}{\sqrt{Daa' \cdot Dab' \cdot Dbb \cdot Dba}}$ $\therefore L_x = \frac{1}{2} L_{ax}$ $= 2 \times 10^{-7} \log_e \dfrac{4\sqrt{Daa' \cdot Dab' \cdot Dbb' \cdot Dba'}}{4\sqrt{Daa \cdot Dab \cdot Dbb \cdot Dba}}$ $= 2 \times 10^{-7}$ $\log_e \frac{D_m}{Ds_x} \ldots\ldots\ldots\ldots\ldots {}^{H}/_{mt}$ llll$_y$ $L_y = 2 \times 10^{-}$ $^{7}\log_e \frac{D_m}{Ds_y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots {}^{H}/_{mt}$ where$Ds_{y=4\sqrt{Da'a' \cdot Db'b' \cdot Da'b' \cdot Db'a'}}$ $\therefore L_{loop}$ - Total inductance of 1ϕ line $= L_x + L_y$ $= 2 \times 10^{-7}\left[\log_e \frac{D_m}{Ds_x} + \log_e \frac{D_m}{Ds_y}\right]$ $= 2 \times 10^{-7} \log_e \frac{Dm^2}{Ds_x \cdot Ds_y}$ $= 2 \times 10^{-7} \log_e \frac{Dm^2}{Ds^2}$ where $D_s = Ds_x = Ds_y$ for duplex bundelled $= 4 \times 10^{-7} \log_e D_m/D_s$……….H/mt $L_{loop} = 4 \times 10^{-7} \log_e D_m/D_s$………H/mt	
	d) Ans.	**Write power flow equation in the terms of sending end and receiving end voltage.** Power flow equation at the receiving end is given by	4M ***1M***

		$S_R = \frac{V_R V_S}{B}\angle(\beta-\delta) - \frac{AV_R^2}{B}\angle(\beta-\propto)$..............................	½M
		$P_R = \frac{V_R V_S}{B}cos(\beta-\delta) - \frac{AV_R^2}{B}cos(\beta-\propto)$	½M
		$Q_R = \frac{V_R V_S}{B}Sin(\beta-\delta) - \frac{AV_R^2}{B}sin(\beta-\propto)$	1M
		Power flow equation at the sending end is given by $S_S = \frac{AV_S^2}{B}\angle(\beta-\propto) - \frac{V_s V_R}{B}\angle(\beta+\delta)$	½M
		$P_S = \frac{AV_S^2}{B}cos(\beta-\propto) - \frac{V_s V_R}{B}cos(\beta+\delta)$	½M
		$Q_S = \frac{AV_S^2}{B}sin(\beta-\propto) - \frac{V_s V_R}{B}sin(\beta+\delta)$ Where P_R= Real or active power in MW, Q_R= Reactive power in MVAR at receiving end P_s= Real or active power in MW, Q_s= Reactive power in MVAR at sending end 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	
	e) Ans.	**A medium transmission line has series impedance is (20+j52) Ω and shunt admittance is 316X10^{-6} S/ph. Calculate A, B, C, D constants of the line assuming nominal 'T' circuit.** $Z = 20 + j\,52\Omega$ $Y = 316\times10^{-6}S$ $for\ NominalT-circuit$ $A = D = 1+\frac{YZ}{2}, B = Z\left(1+\frac{yz}{4}\right), C = Y$ $A = D = \frac{1+yz}{2} = 1+[\frac{(316\times10^{-6})(20+j\ 52)}{2}]$ $A = 1+\frac{8.80\angle68.96}{2}$ $A = 1+4.108\ \times10^{-3}$	4M

		$A = 1.00\angle 0.23 = D$	***2M***
		$C = Y = 316 \times 10^{-6} mhos$	***1M***
		$B = Z\left(1 + \frac{yz}{4}\right) = 316 \times 10^{-6}\left[1 + \frac{(316 \times 10^{-6})(20 + j\,52)}{4}\right]$	
		$= 8.60 \times 10^{-4}\angle 48.92 siemens$	***1M***