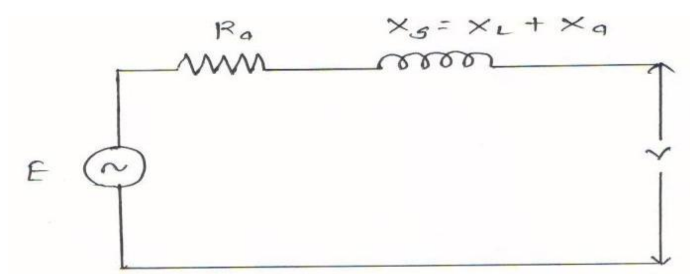
MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

WINTER – 2019 EXAMINATION
MODEL ANSWER

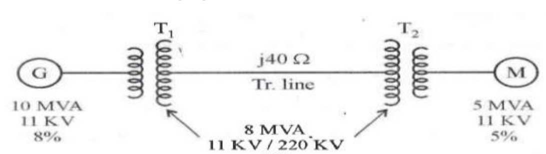
Subject: Power System Analysis (Elective-I) **Subject Code: 22529**

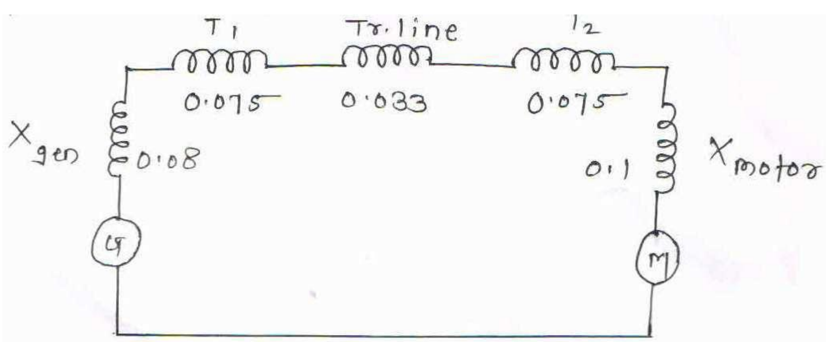
Important Instructions to examiners:

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.1
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)** **Ans.**	**Attempt any FIVE of the following:** **Draw equivalent circuit of alternator.**  E = Induced emf V = Terminal voltage R_a= Armature resistance X_L = Leakage reactance X_o = Armature reaction reactance	**10** **2M** ***Correct diagram 2M***

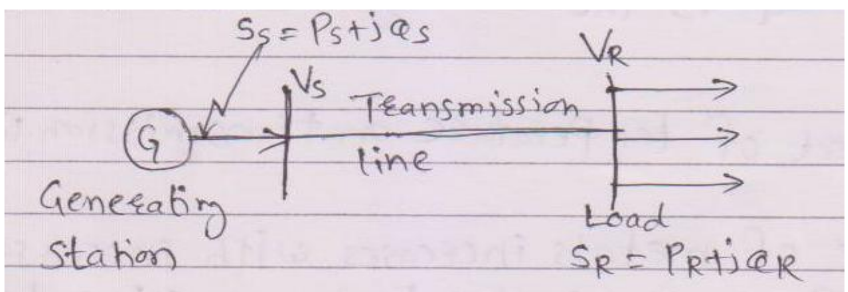
		X_s = Synchronous reactance $R_a + jx_s = Z_s$ $R_a + j(X_L + X_a) = Z_s$	
	(b) **Ans.**	**Define impedance diagram and reactance diagram.** **Impedance diagram:** Impedance diagram is the simplified equivalent circuits of single line or one line diagrams of power system in which all components are represented by their equivalent circuit. **Reactance diagram:** The reactance diagram is the simplified equivalent circuit of power system in which the various components of power system are represented by their reactance. **or** **Reactance diagram** is the simplification of impedance diagram in which resistive components, capacitive parameters of tr. Line, magnetizing circuit of transformer, rotating machines and impedance of protective element of the machines are neglected and is used only for fault current calculation is called reactance diagram.	**2M** ***Each definition 1M***
	(c) **Ans.**	**List out factors affecting proximity effect.** **Factors affecting proximity effect:** 1. Conductor size (diameter of conductor) 2. Frequency of supply current. 3. Distance between conductors. 4. Permeability of conductor material	**2M** ***Any two factors 1M each***
	(d) **Ans.**	**State the impact of inductance and resistance on transmission line performance.** **Impact of inductance on transmission line:** 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. **Impact of resistance on transmission line:** 1) It causes voltage drop, so it affects regulation. 2) It causes I^2R loss which affects efficiency and temperature rise. 3) Whatever power loss occurs in transmission line is only due resistive parameter. 4) Though value of resistance is very small, it causes losses,	**2M** ***Impact of inductance any one 1M*** ***Impact of resistance any one 1M***

		temperature rise& poor voltage regulation so it cannot be neglected	
	(e) Ans.	**Give the expression for ABCD constant of T model.** Expression for ABCD constants of T model: $$A = D = 1 + \frac{YZ}{2}$$ $$B = Z\left(1 + \frac{YZ}{4}\right)$$ $$C = Y$$	**2M** ***½M for each constant***
	(f) Ans.	**Determine ABCD constant of short transmission line having impedance (20 + j50)Ω.** ABCD constants of short transmission line having impedance 20 +j 50 ohm are as follows: A = 1 B = Z= 20 +j50 **Ω** C = 0 D = 1	**2M** ***½M for each constant***
	(g) Ans.	**Recall X & Y coordinates for centre of sending and circle diagram.** X and Y co-ordinates for centre of sending end circle diagram are as follows: $X - co - ordinate = \frac{DV_S^2}{B}\cos(\beta - \alpha)$ ...MW $Y - co - ordinate = \frac{DV_S^2}{B}\sin(\beta - \alpha)$ ....MVAR	**2M** ***1M for each***
2	 (a)	**Attempt any THREE of the following:** **Develop a reactance diagram for structure of power system (Refer Fig.1) considering generator as base.**  **Fig. 2 (a)**	**12** **4M**

	Ans.	Assuming generator RATING as base Base MVA = 10 MVA Base voltage – 11 kV for generator side 220 kV for transmission line side	*½M*
		Calculation of X_{pu} 1) Generator: $X_{pu\ new} = X_{pu\ old} = 0.8$ pu	*½M*
		2) Transformer T_1 and T_2: $X_{pu\ new} = X_{pu\ old} X \left(\frac{MVA_{new}}{MVA_{old}}\right) X \left(\frac{kV_{old}}{kV_{new}}\right)^2$	*½M*
		$= 0.06 X \left(\frac{10}{8}\right) X \left(\frac{11}{11}\right)^2 = 0.075$pu	*½M*
		3) Motor $X_{pu\ new}$ $= 0.05 X \left(\frac{10}{5}\right) X \left(\frac{11}{11}\right)^2 = 0.1$ pu	*½M*
		4) Transmission line X_{pu} $= \frac{X_{actual}}{X_{Base}} = X_{actual}\ X\ \frac{MVA_{Base}}{(kV_{Base})^2}$ $= 40 X \left(\frac{10}{(110)^2}\right) = 0.033$ pu	*½M*
		Reactance Diagram:  	*1M*

	(b) Ans.	**Define self GMD & Mutual GMD with the help of example.** **Self GMD**: It is n^2th root of n^2 product terms where n is the no. of filaments in a conductor. **OR** It is the n^2th root of product of distances of a filament from itself and from other filaments of same conductor. **OR** Each set of n product term pertains to a filament and consist of r' (D_{ii}) for that filament and $(n-1)$ distances from that filament to every other filament in conductor A. It is defined as the *self-geometric* mean distance (self GMD) of conductor A, and is abbreviated as D_{sA}. Sometimes, self GMD is also called *geometric mean radius* (GMR). **Mutual GMD:** If conductor A has 'n' no of sub conductor & conductor B has 'm' no of sub conductor, then *mn* th root of the *mn* terms, which are the products of all mutual distances from the each filaments of conductor A to m' filaments of conductor B. It is called *mutual geometric mean distance* (mutual GMD between conductor A and B and abbreviated as D_m. Similarly, **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 = $\sqrt{D_{12}D_{1'2}}$ $= \sqrt{\left(\frac{d}{2}+D\right) x\ (D-\frac{d}{2})}$	4M *Each Definition 1M* *Example 2M*

	(c)	**3ϕ transmission line with impedance 32.9 ∠ 72.35 Ω/ph and admittance j2.827 x 10^{-4}∠ 90 Ω/ph delivers load of 35 MW, 132 KV, 0.8 P.F. lag. Use π method and determine ABCD constants.**	**4M**
	Ans.	$Z = 32.9 \angle 72.35 \frac{\Omega}{ph}$ $Y = 2.827 \times 10^{-4}\angle 90$ mho/ph By using π method $A = 1 + \frac{YZ}{2}$ $= 1 + \frac{(2.827 \text{ X } 10^{-4}\angle 90)\ (32.9\angle 72.35)}{2}$ $= 1 + \frac{9.300 \text{ X } 10^{-3}\ \angle 162.35}{2}$ $= 1 + (4.65\text{x } 10^{-4}\angle 162.35)$ $= 1 - 4.431 \times 10^{-4} + j1.409 \times 10^{-4}$ $= 0.999 + j\ 1.409 \times 10^{-4}$ $= 0.999 + \angle\ 8.08 \times 10^{-3}$ $A = D = 1 + \frac{YZ}{2} = 0.999 + \angle\ 8.08 \times 10^{-3}$ $B = Z = 32.9 \angle 72.35^0\ \Omega/$ $C = Y\left(1 + \frac{YZ}{4}\right)$ $= 2.827 \times 10^{-4}\angle\ 90 \left(1 + \frac{(2.827 \times 10^{-4}\angle\ 90)(32.9\angle 72.35)}{4}\right)$	*1M for each constants*

		$= 2.827 \times 10^{-4}\angle 90 \left(1 + \frac{9.300 \times 10^{-3}\angle 162.35}{4}\right)$ $= 2.827 \times 10^{-4}\angle 90$ ($1 + 2.325 \times 10^{-3}\angle 162.35$ $= 2.827 \times 10^{-4}\angle 90$ ($1 + (-2.215 \times 10^{-3} + j7.049 \times 10^{-4})$) $= 2.827 \times 10^{-4}\angle 90$ ($0.997 + j7.049 \times 10^{-4}$) $= (2.827 \times 10^{-4}\angle 90)(0.997\ \angle 0.040)$ $= 2.818 \times 10^{-4}\angle 90.04$ mho	
	(d) **Ans.**	**Derive the expression for complex power, active and reactive power at sending end.**  Figure shows the single line diagram of a 3Ø transmission line. - In the figure two bus system having the sending end bus which is fed by the generator and the receiving end bus which feeds the load. - S_R is the complex power of the receiving end and S_S is the complex power at the sending end. - Using the current I_S can be expressed in terms of V_R and V_S as: $I_S = \frac{D}{B}V_S - \frac{1}{B}V_R = \frac{A}{B}V_S - \frac{1}{B}V_R$…….(i) Let, $V_R = \|V_R\|\angle 0$, $V_S = \|V_S\|\angle 0$, D = A = $\|A\|\angle \propto$, B = $\|B\|\angle\beta$	**4M** *1M* *1M*

<table>
<tr><td></td><td></td><td>Then $I_S = \frac{|A||V_S|}{B}(\angle\propto + \delta - \beta) - \frac{|V_R|}{B} - \angle\beta$

The conjugates of I_S are

$$Is^* = \frac{|A||V_S|}{B}(\angle\beta - \propto - \delta) - \frac{|V_R|}{B}\angle\beta$$

The complex power/phase at the sending end are
$$S_S = P_S + jas = V_S I_S^*$$
$$S_S = |V_S|\angle\delta\left[\frac{|A||V_S|}{|B|}(\beta\angle\propto - \delta) - \frac{|V_R|}{|B|}\angle\beta\right]$$
$$S_S = \frac{|A||V_S|^2}{|B|}(\angle\beta - \propto) - \frac{|V_R||v_S|}{|B|}(\angle\beta + \delta)$$
$$P_S = \frac{|A||V_S|^2}{|B|}\cos(\beta - \propto) - \frac{|V_R||v_S|}{|B|}\cos(\beta + \delta)$$
$$Q_S = \frac{|A||V_S|^2}{|B|}\sin(\beta - \propto) - \frac{|V_R||v_S|}{|B|}\sin(\beta + \delta)$$

The above equation is the sending end side complex power.</td><td>1M

1M</td></tr>
<tr><td>3.</td><td>(a)
Ans.</td><td>Attempt any THREE of the following:
Summerise the role of power system engineer.
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</td><td>12
4M

Any four roles 1M each</td></tr>
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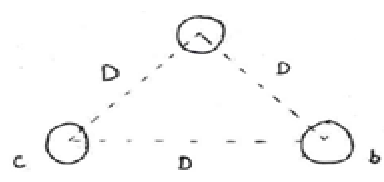
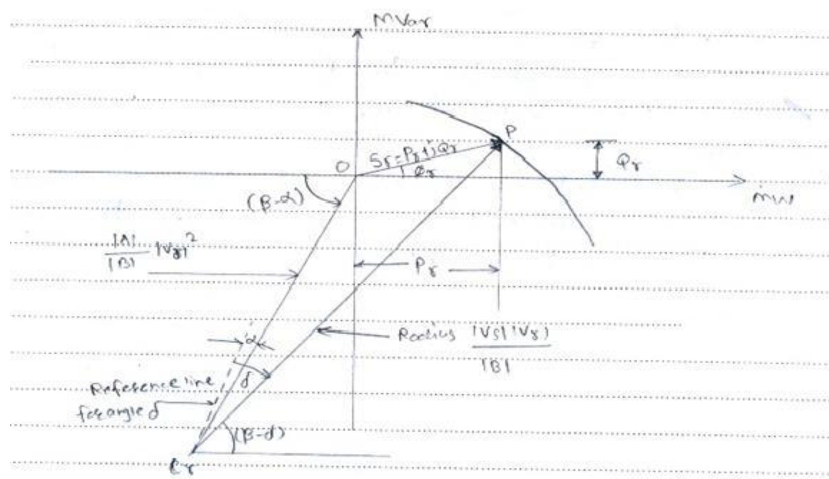
		new technology method. ***(Note: Any other relative points shall be considered)***	
	(b) **Ans.**	**Derive the expression for inductance of 3ϕ line with symmetrical arrangement.** Inductance of a 3ϕ with symmetrical spacing:	**4M**
			***1M for diagram***
		Figure shows a 3ϕ line with conductors a, b and c spaced at corners of an equilateral triangle each side is 'D'. The conductors each of radius 'r'.	***1M***
		The three-conductors occupy the corners of an equilateral triangle. If the 3ϕ system, then, $\overline{I_a}$, $\overline{I_b}$ and $\overline{I_1}$ and $\overline{I_c}$ are displayed by 120^0 Flux linkage with a conductor considering fluxes set by all conductors is, $\Psi a = 2 \text{ x } 10^{-7}.\left[I_a.l_n\left(\frac{1}{ra^1}\right) + I_b.l_n\left(\frac{1}{D}\right) + I_c.l_n\left(\frac{1}{D}\right)\right] \frac{wb.T}{m}$ $= 2 \text{ x } 10^{-7}.\left[I_a.l_n\left(\frac{1}{ra^1}\right) - I_a.l_n\left(\frac{1}{D}\right)\right] \frac{wbT}{m}$ $\therefore I_b + I_c = -I_a$ $= 2 \text{ x } 10^{-7}.I_a.l_n \frac{\left\{\frac{1}{ra^1}\right\}}{\left\{\frac{1}{D}\right\}} \frac{wbT}{m}$ For a balanced system $I_a + I_b + I_c = 0$ $\therefore I_b + I_c = -I_a$	***1M***

		$\Psi a = 2 \times 10^{-7} . I_a . l_n \left\{ \frac{\frac{1}{ra^1}}{\frac{1}{D}} \right\} \frac{wbT}{m}$ $= 2 \times 10^{-7} . I_a . l_n \left(\frac{D}{ra^1} \right) \frac{H}{m}$ $\therefore L_a = \frac{\Psi_\phi}{I_\phi} = 2 \times 10^{-7} l_n \left(\frac{D}{ra^1} \right) \frac{H}{m}$ Inductance per conductor or inductance/ phase $L_a = 2 \times 10^{-7} l_n \left(\frac{D}{r^1} \right) \frac{H}{m}$ $\boxed{L_a = 0.2 \, l_n \left(\frac{D}{r^1} \right) \frac{mH}{Km}}$	*1M*
	(c) Ans.	**Define Generalised circuit constants.** For Generalized circuit , Generalized Equations can be written as: $V_S = AV_R + BI_R$ $I_S = CV_R + DI_R$ **Generalized Circuit Constant:** 1) $A = \frac{V_s}{V_R}$ when $I_R = 0$ 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) $B = \frac{V_s}{I_R}$; $V_R = 0$ 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) $C = \frac{I_s}{V_R}$; $I_R = 0$ 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) $D = \frac{I_s}{I_R}$; $V_R = 0$ 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.	4M ***Each definition 1M***

	(d)	**A 200 kV line with GCC A = 0.86 $\angle 7^0$, B = 300 $\angle 75^0 \Omega$. Determine real power at unity P.F. that can be received if voltage at both end is maintained at 200kV.**	**4M**
	Ans.	Given data $V_S = V_R = 200$ KV, A = 0.86 $\angle 7^o$, B = 300 $\angle 75^o$ Then for unity power factor $Q_R = 0$ $\therefore Q_R = \|V_S\|\|V_R\| / \|B\| \sin(\beta - \delta) - (\|A\| / \|B\|)\|V_R\|^2 \sin(\beta - \alpha)$	***1M***
		Substituting all values we get $0 = (200)X(200)/ 300 \sin(\beta - \delta) - ((0.86)(200)^2 / 300) \sin(75 - 7)$ $0 = 133.33 \sin(\beta - \delta) -106.32$ $\sin(\beta - \delta) = 0.797$ $\beta - \delta = 52.88^0$	***1M***
		Substituting this is in equation of P_R we get $P_R = (\|V_S\|\|V_R\| / \|B\|)\cos(\beta - \delta) - (\|A\| / \|B\|)\|V_R\|^2 \cos(\beta - \alpha)$ $= \{(200)(200) / 300 \}\cos(52.88) - \{0.86 \times (200)^2 / 300 \}\cos(75-7)$	***1M***
		$= 80.46 - (114.67)(0.37)$ $P_R = 38.03$ MW. Unity power at receiving end is 38.03 MW	***1M***
4.		**Attempt any THREE of the following:**	**12**
	(a)	**Give the stepwise procedure for drawing circle diagram at receiving end.**	**4M**
	Ans.		



$$S_r = \frac{-|A||V_r|^2}{|B|}\angle(\beta-\alpha) + \frac{|V_s||V_r|}{|B|}\angle(\beta-\delta)$$

Diagram 1M

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 'n'.

Step-3: To draw the circle the radius is taken equal to |Vs| |Vr| & draw a circle in 1st quadrant.

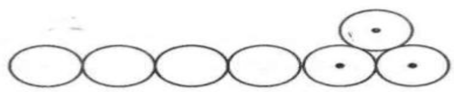
Step-4: The operating point p on the circle is located by the amount of real power delivered to the load i.e.pr

Step-5: Joint the 'op'& draw the line parallel from point P to Y-axis. 'op' represents the true power Sr=Pr+jQr& the corresponding value of Qr can be read from the diagram.

Step-6: Draw the reference line w.r.t. 'on'at an angle α. The power angle is the angle between the ref. line shown & phasor 'np'.

Procedure 3M

(b) Calculate self GMD for conductors (Refer Fig.2). **4M**



(i) (ii)

Fig. 4 (b)

Ans. Case i)

(i)

$D_{11} = r^1$, $D_{12} = 2r$, $D_{13} = 4r$, $D_{14} = 6r$ ***1M***

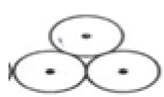
$D_{21} = 2r$, $D_{22} = r^1$, $D_{23} = 2r$, $D_{24} = 4r$

Self GMD $D_S = \sqrt[16]{(D11D12D13D14)^2(D21D22D23D24)^2}$ ***1M***

$$\sqrt[8]{(0.7788r\ X\ 2rX\ 4r\ x\ 6r)\quad(2r\ X\ 0.7788\ r\ X\ 2r\ x\ 4r)}$$

$D_s = 2.155r$

ii)

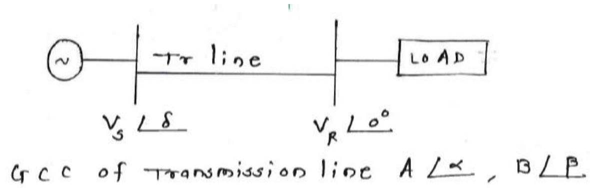


$D_{11} = D_{22} = D_{33} = 0.7788\ r$ ***1M***

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

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

		$D_S = \sqrt[9]{(0.7788\ r)^3 (2r^6)}$ = 1.46r	
	(c) Ans.	**A 3ϕ 50 Hz line has resistance of 20 Ω, inductance 0.2 H and capacitance 1μF. Determine ABCD constants of line considering π model.** **A 3ϕ 50 Hz** $R = 20\ \Omega$ ph $L = 0.2\ H$ $c = 1\ pf = 1 \times 10^{-12}$ f $X = 2\pi f L = 2\pi \times 50 \times 0.2 = 62.83\ \Omega.$ $Z = R + jX = 20 + j\ 62.83 = 65.94\angle 72.34^o\ \Omega$ $Y = jwc = 314 \times 1 \times 10^{-12}\angle 90^0 = 314 \times 10^{-12}\angle 90^0$ $Z = 65.94\angle 72.34^o\ \Omega$ $Y = 314 \times 10^{-12}\angle 90^0$ $\boldsymbol{for\ Nominal\ \pi - circuit}$ $A = D = 1 + \frac{YZ}{2}, B = Z, C = Y\left(1 + \frac{yz}{4}\right)$ $A = \frac{1+YZ}{2} = 1 + [\frac{314\times10^{-12}\angle 90^0\ x\ 65.94\angle 72.34^o)}{2}]$ $A = 1 + \frac{2.07\ \ x10^{-8}\ \ \angle 162.34}{2}$ $A = 1 + 1.03\ \ x10^{-8}\ \ \angle 162.34$ $A = 0.999 + j\ \ 3.124\ \ X10^{-9}\ \ = 0.999\ \angle 1.79\ x10^{-7}$ $A = D = \frac{1+YZ}{2} = 1 + [\frac{314\times10^{-12}\angle 90^0\ x\ 65.94\angle 72.34^o)}{2}]$	4M *1M* *1M* *1M*

		$B = Z = 20 + j\,62.83 = 65.94\angle 72.34^o\,\Omega$ $C = Y\left(1+\frac{YZ}{4}\right) = 314\times10^{-12}\angle 90^0\left[1+\frac{\left(\left(314\times10^{-12}\angle 90^0\right)(20+j\,62.83\right)}{4}\right]$ $= 3.14\times10^{-10}\angle 90^0\ S$	*1M*
	(d) Ans.	**Derive the condition for maximum power at sending end.** **Condition for maximum power at SENDING end.** **For a simple two bus power system represented as**	4M
			*1M*
		As the sending end side active power is given by, $$P_S = \frac{\lvert A\rvert\lvert V_s\rvert^2}{\lvert B\rvert}\cos(\beta-\alpha) - \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\cos(\beta+\delta)$$	*1M*
		For given system ABCD remains constant and maintaining voltages at sending end as well as receiving end constant, P_S varies with load angle δ. For max value of P_S differentiate above eq. w.r.t. 'δ' and equate it to zero. $\therefore \frac{dP_s}{d\delta} = \frac{d}{d\delta}\left[\frac{\lvert A\rvert\lvert V_s\rvert^2}{\lvert B\rvert}\cos(\beta-\alpha) - \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\cos(\beta+\delta)\right] = 0$ $$\therefore \frac{dP_s}{d\delta} = \frac{\lvert V_S\rvert\lvert V_R\rvert}{\lvert B\rvert}\frac{d}{d\delta}\cos(\beta+\delta) = 0$$ $$\sin(\beta+\delta) = 0$$ $$\beta+\delta = \sin^{-1}(0) = 0$$ $$\beta+\delta = 0$$	*1M* *1M*

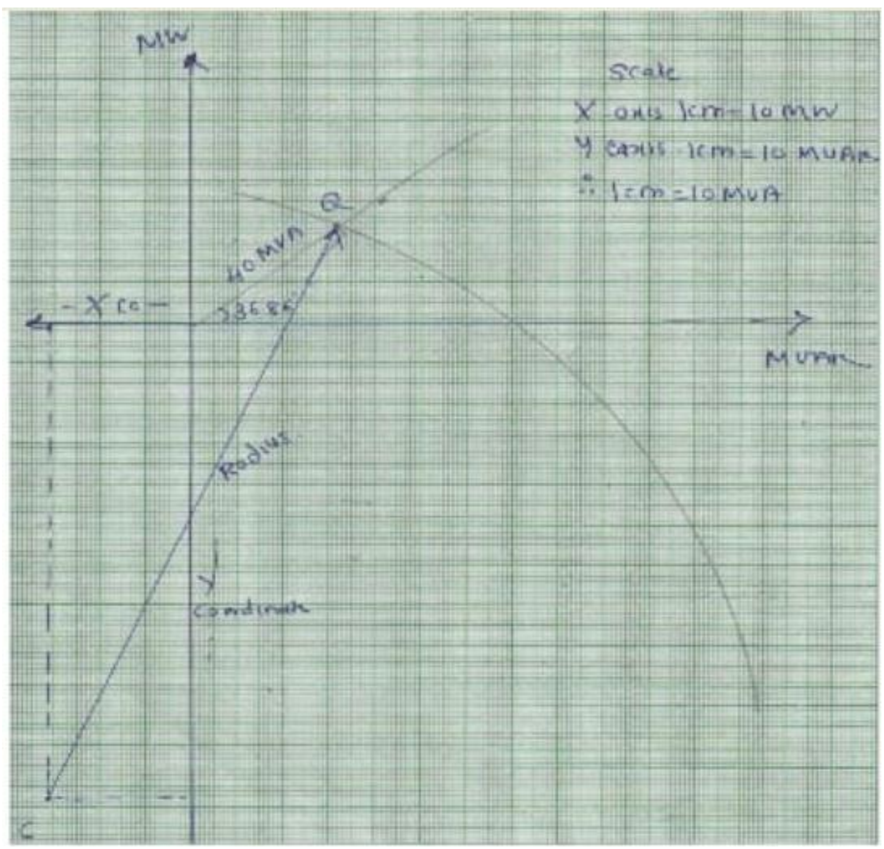
	(e)	**3ϕ line with GCC A = 0.99∠0.08^0, B = 10 + j31.42, C = 2.79 x 10^{-4}∠90.04^0 supplies load of 35 MW, 132kV, 0.8lag. Determine regulation of line.**	**4M**
	Ans.	$given: V_R = 132KV,$ $A = 0.99\angle 0.08,\ B = (10 + j31.42)\ \Omega$ $load - P_R = 35Mw, 0.8lag$ $P_R = \sqrt{3}V_R I_R \cos\emptyset_R = 35 \times 10^6 = \sqrt{3}\,X132 \times 10^3 \times I_R \times 0.8$ $\therefore I_R = 191.36Amp$ $\emptyset_R = \cos^{-1} 0.8 = 36.86$ $V_S = AV_R + BI_R$ $= 0.99\angle 0.08 \times 132 \times \frac{10^3}{\sqrt{3}}\angle 0 + (10 + j31.42) \times 191.36\angle -36.86$ $V_s\ phase = 80.674\ \angle 2.68\ KV$ $V_s\ line = 139.73\ KV$ Voltage regulation = $\frac{\frac{Vs}{A} - -V_{RFL}}{V_{RFL}}$ X 100 $= \frac{\frac{139.73}{0.99} - 132}{132}$ x 100 = 6.93 %	*1M* *1M* *1M* *1M*
5.		**Attempt any TWO of the following:**	**12**
	(a)	**Determine Inductance & Capacitance of 3ϕ line operating at 50 Hz and conductors are arranged at corners of symmetrical triangle with side 3.4 m & diameter of each conductor is 0.8 cm.**	**6M**
	Ans.	Given D = 3.4m d = 0.8cm r = 0.4cm = 0.4 x 10^{-2}m ∴ Inductance L = 2 x 10^{-7}log $\frac{D}{r^1}$ $r^1 = 0.7788 \times 10^{-2} \times 0.4$ m $r^1 = 0.7788 \times 4 \times 10^{-3}$ m	*1M* *1M*

		$\therefore L = \frac{2 \times 10^{-7} \log^{3.4}}{0.7788 \times 4 \times 10^{-3}}$ $\therefore L = 6.075 \times 10^{-7} H/m$ 2) $C = \frac{2\pi\in}{\log\frac{D}{r1}}$ $= \frac{2\pi\, 8.85 \times 10^{-12}}{\log\frac{3.4}{0.7788 \times 4 \times 10^{-3}}}$ $C = 830 \times 10^{-11}$ F/m	*1M* *1M* *1M* *1M*
	(b) Ans.	**A 3ph 132kV transmission line delivers 40 MVA at 0.8 pf lag. Draw receiving end circle diagram and determine sending end voltage for $A = 0.98 \angle 3^0$, $B = 140 \angle 78^{0.}$** $V_R = 132$ Kv Load – 40MVA, 0.8 pf $A = 0.98\angle 3^0$ $B = 140 \angle 78^{0.}$ X coordinates $= \frac{-AVR^2}{B} \cos(\beta - \alpha)$ $= \frac{-0.98 \times 132^2}{140} \cos(78 - 3)$ = 31.57 MW Y coordinates $= \frac{-AVR^2}{B} \sin(\beta - \alpha)$ $= \frac{-0.98 \times 132^2}{140} \sin(78 - 3)$ = 117.81 MVAR	6M *1M* *1M*

Selecting scale on X- axis 1cm = 10MW

Y- axis 1cm = 10MVAR

$\therefore$ 1cm = 10 MVA



2M

From graph Radius = CQ = 15.5cm

= 155 MVA

1M

T calculate sending end voltage V_S

1M

$$155 = \frac{V_S\ V_R}{B} = \frac{V_S \ X\ 132}{140}$$

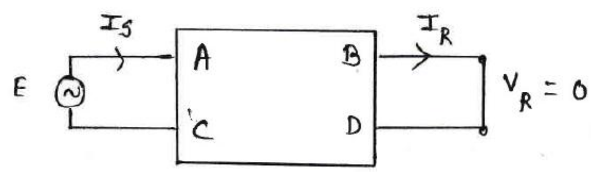
$\therefore\ V_S = 164.39$ kV

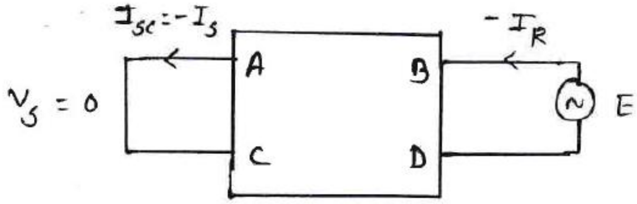
	(c)	**A 3ϕ line has following parameters A = D = 0.9 ∠0.4°, B = 99 ∠76.86° load angle is 9°. If sending end and receiving end voltages are maintained at 22kV, calculate sending end complex power, active power and reactive power.**	6M
	Ans.	Given, A = 0.9, D = 0.9 B = 99, Vs = V_R = 220V $\alpha = 0.4, \quad \beta = 76.86 \ \& \ \delta = 9^0$ **1) Complex power at sending end:** $Ss = \left\|\frac{D}{B}\right\| \|V_s\|^2 \angle \beta - \alpha - \frac{\|V_S\|\,\|V_R\|}{\|B\|} \angle \beta + \delta$ $= \left\|\frac{0.9}{99}\right\| \|220\|^2 \angle [76.86 - 0.4] - \frac{\|220\|^2}{\|99\|} \angle 76.86 + 9^0$	1M
		= 440 ∠ 76.46 – 488.89 ∠85.86 103.01 + i427.77- (95.29 + j487.61) Ss = 67.72 – i60MVA	1M
		2) Active Power: $Ps = \left\|\frac{D}{B}\right\| \|V_s\|^2 \ cos\,(\beta - \alpha) - \frac{\|V_S\|\,\|V_R\|}{\|B\|} \cos\,(\beta + \delta)$ $= \left\|\frac{0.9}{99}\right\| \|220\|^2 \ cos\,(76.86 - 0.4) - \left\|\frac{220^2}{99}\right\| \cos\,(76.86 + 9^0)$	1M
		= 103.01 – 35.29 = 67.71MW Ps = 67.71MW	1M
		3) Reactive power at sending end:	

		$Qs = \left\|\frac{D}{B}\right\| \|V_s\|^2 \sin(\beta - \alpha) - \frac{\|V_S\|\|V_R\|}{\|B\|} \sin(\beta + \delta)$	
		$= \left\|\frac{0.9}{99}\right\| \|220\|^2 \sin(76.86 - 0.4) - \frac{\|220\|^2}{99} \sin(76.86 + 9)$	*1M*
		= 427.77 – 487.61	
		= 59.84	
		∴ Qs = 59.84 MVAR	*1M*
6.		**Attempt any TWO of the following:**	**12**
	(a)	**3ϕ line has parameter A = D = 0.9 ∠0.4^0, B = 99 ∠76.86^0, sending end & receiving end voltages are maintained at 200kV. Calculate maximum power supplied at sending end.**	**6M**
	Ans.	A = D = 0.9 ∠ 0.4 B = 99 ∠ 76.86^0 ∴ $\alpha = 0.4$ $\beta = 76.86$	*1M*
		Vs = V_R = 220kV	*1M*
		For **maximum power supplied at sending end condition** P_{max} is , $\beta + \delta = 180^0$	*1M*
		Now maximum power P_{max} **supplied is given by,** $P_{max} = \frac{AVs^2}{B}\cos(\beta - \alpha) + \frac{V_s V_R}{B}$	
		$= \frac{0.9 \text{ X } 220^2}{99}\cos(76.86 - 0.4) + \frac{220^2}{99}$	*2M*
		Ps_{max} = 591.90MW	*1M*
		OR	
		Note : It can be solved by Circle diagram	***Marks at the discretion of examiner***

	(b) Ans.	**State the necessity of reactive power compensation equipment. List out the devices used for reactive power compensation and give application of each device.** **Necessity of reactive power compensation equipment** : i. Due to reduction in reactive power flow there is reduction in tr. Line current & reduction in line losses. So to improve the performance efficiency of system improves power transmission becomes more economical. ii. Due to reduction in line losses heating of line reduces thereby ageing of insulation reduces & life of equipments, cable or line increases. ii. Wear – tear of the switchgear equipment reduces due to reduction in operation. v. By local provision of reactive power KVA load on the line reduces and hence additional load can be connected or additional power can be transmitted without any additional generating equipment or resource. That means loading capacity of line/generator increases. So to main balance in Qs & Qr reactive power compensation is required **Or** 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	**6M** ***Necessity 3M***

<table>
<tr><td></td><td></td><td>likely to become higher then nominal value.

Devices for reactive power compensation
1. Shunt compensation equipments - Shunt reactor , shunt capacitor& static var system
2. Series compensation equipments - Series reactors
3. Synchronous compensation equipments - Synchronous condenser</td><td>Any 3 device with application 1M each</td></tr>
<tr><td></td><td>(c)
Ans.</td><td>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.


To represent this condition in equation form we get
$V_s = AV_R + BI_R$
$I_R = \frac{V_S}{B}$ $[\because V_R = 0]$
$I_{sc} = \frac{E}{B}$ ....(1)
Now connect above ideal source at the receiving end and short circuited the sending end.


Now $V_s = AV_p + BI_R$</td><td>6M

1M

1M

1M

1M</td></tr>
</table>

WINTER – 2019 EXAMINATION
MODEL ANSWER

Subject: Power System Analysis (Elective-I) **Subject Code: 22529**

		$0 = A.E + B(-I_R)$	
		$I_R = \frac{AE}{B}$	
		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	
		$\frac{-E}{B} = CE - D\frac{AE}{B}$	***1M***
		$\frac{-\cancel{E}}{B} = \left(C - \frac{AD}{B}\right)\cancel{E}$	
		$\frac{-1}{\cancel{B}} = \frac{BC - AD}{\cancel{B}}$	
		$\boxed{AD - BC = 1}$	