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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-3 : Power Systems + Systems and Signal Processing-1 + Microprocessors-1 + Electrical Circuits-2 + Control Systems-2

Name : ....

Roll No :

Test Centres				Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐		
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	38
Q.2	
Q.3	48
Q.4	39
Section-B	
Q.5	48
Q.6	
Q.7	37
Q.8	
Total Marks Obtained	210

Signature of Evaluator: Saurabh kumar

Cross Checked by: ....

Corp. office : 44 - A/1, Kalu Sarai, New Delhi-110016 | **Ph:** 9021300500 | **Web:** www.madeeasy.in

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A : Power Systems

Q.1 (a) A 66 kV, 60 km long, transmission line delivers a load of 25 MW at 0.8 lagging power factor. If the line have series resistance and inductance of 0.08 Ω/km and 1.25 mH/km respectively, compute

(i) Sending end voltage and current

(ii) Voltage regulation

(iii) Transmission efficiency. Assume a power frequency of 50 Hz.

[12 marks]

25mw
0.8 pf lag
66kV

taking $f = 50Hz$

$R_1 = 0.08\ \Omega/km$

$L_1 = 1.25mH/km$

$\therefore\ Z = (R_1 + j\omega L_1)\, l = 24.05 \angle 78.48^\circ\ \Omega$

for short TL. T-parameters are

$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 24.05 \angle 78.48^\circ \\ 0 & 1 \end{bmatrix}$$

we know, $V_S = AV_R + BI_R$

taking V_R as reference, $V_R = \frac{66}{\sqrt{3}} \angle 0^\circ$ KV

$\therefore\ V_S = 1 \cdot \frac{66}{\sqrt{3}} \angle 0$ KV $+ 24.05 \angle 78.48\ I_R$

given $P_R = 25mw$

$\therefore\ \sqrt{3} \times 66 \times 10^3 \times I_L \times 0.8 = 25 \times 10^6$

$I_R = 273.37$

$\tilde{I}_R = 273.37 \angle -36.87^\circ$

Do not write in this margin

$\therefore \quad V_S = 43.24 \angle 5.79^\circ \text{ kV}$

$V_S \text{ line} = 74.896 \text{ kV}$

i) $V_S = 74.896 \text{ kV}$ line

$I_S = I_R = 273.37 \text{ A}$

ii) $VR = \dfrac{\frac{|V_S|}{|A|} - V_R}{V_R} = \dfrac{\frac{74.896}{1} - 66}{66} \times 100$

$= 13.48\ \%$

iii) $P_S = 3 V_S I_S \cos\phi_S = 3 \times 43.24 \times 10^3 \times 273.37 \times \cos(5.79 + 36.87)$

$= 26.08 \text{ MW}$

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$\therefore \quad \eta = \dfrac{P_R}{P_S} \times 100$

$= \dfrac{25}{26.08} \times 100$

$= 95.86\ \%$

Good Approach

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Q.1 (b) A hydroelectric station is to be designed for catchment area of 150 km^2, rainfall for which is 120 cm/annum. The head availability is 30 m. 72% of total rainfall is available, rest is lost to evaporation. Penstock efficiency is 95%. Turbine efficiency is 85% and generator efficiency is 90% and load factor is 40%. Determine the capacity of the station.

[12 marks]

$$\left.\begin{aligned} \eta_{penstock} &= 0.95 \\ \eta_{turbine} &= 0.85 \\ \eta_{generator} &= 0.9 \end{aligned}\right\} \Rightarrow \eta_{overall} = \eta_1 \eta_2 \eta_3 = 0.72675$$

area = 150 km^2

rainfall = 120 cm/annum

head = 30m

only 72% available

$$\text{volume of water stored / annum} = 120 \times 10^{-2} \times 150 \times 10^{6} = 180 \times 10^{6} \text{ m}^3/\text{annum}$$

$$\rho_{water} = 1000 \text{ kg/m}^3$$

$$\therefore \text{mass of water stored} = 10^3 \times 180 \times 10^6 \text{ kg} = 180 \times 10^9 \text{ kg / annum}$$

head = 30m

$$\Rightarrow \text{PE stored} = mgh = 52.92 \times 10^{12} \text{ J / annum}$$

as only 72% is available

$$\therefore \text{PE stored}_{actual} = 0.72 \times 52.92 \times 10^{12} = 38.1 \times 10^{12} \text{ J/annum}$$

load factor $= \dfrac{\text{avg demand}}{\text{max demand}}$

as $\eta = 0.72675$

$\Rightarrow$ actual o/p $= 0.72675 \times 38.1 \times 10^{12}$ J / annum

$= 27.69 \times 10^{12}$ J / annu

Power $= \dfrac{\text{Energy}}{\text{time}}$

for 1 year

$P = \dfrac{27.69 \times 10^{12}}{365 \times 24 \times 60 \times 60}$

$= 0.878$ MW

as $lf = 0.4$

$\Rightarrow$ capacity $= 2.195$ MW

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Good Approach

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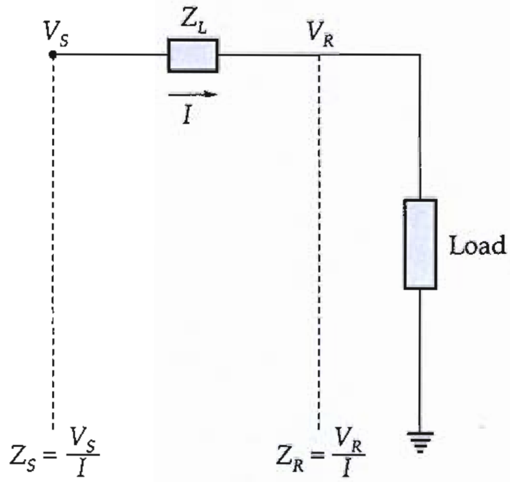
Q.1 (c) Consider the transmission line as shown in figure, with series impedance Z_L, negligible shunt admittance and a load impedance Z_R at the receiving end.



(i) Calculate Z_R for the given condition of $V_R = 1.0$ pu and $S_R = 2 + j0.8$ pu.

(ii) Construct the impedance diagram in R-X plane for $Z_L = (1 + j0.3)$ pu.

(iii) Find Z_S for this condition and angle between Z_S and Z_R.

[12 marks]

i) $S_R = (2 + j0.8)$ pu

$V_R = 1$ pu (taking V_R as reference $V_R = 1\angle 0^\circ$)

we know, $S_R = V_R I_R^*$

$$I_R = \frac{V_R}{Z_R}$$

$$\therefore S_R = V_R \cdot \left(\frac{V_R}{Z_R}\right)^*$$

$$S_R = \frac{|V_R|^2}{Z_R^*}$$

$$Z_R^* = \frac{|V_R|^2}{S_R} = \frac{1^2}{2 + j0.8}$$

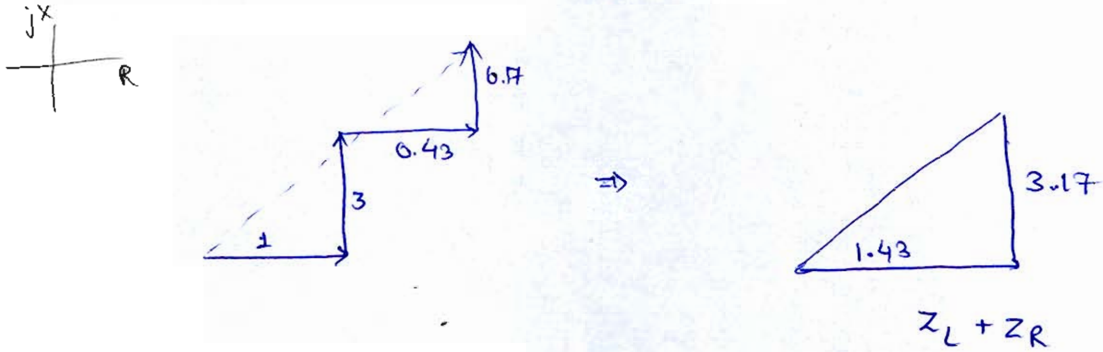
3

$$\Rightarrow Z_R = 0.464 \angle 21.8^\circ \text{ pu}$$

$$= 0.43 + j0.17 \text{ pu}$$

ii) $Z_L = 1 + j3$

$Z_R = 0.43 + j0.17$



iii) $Z_S = Z_L + Z_R$

$= 1.43 + j3.17$

$= 3.478 \cancel{\angle 65.72^\circ}$

$\therefore$ angle b/w Z_s & Z_R

$\cancel{= 65.72 - 21.8}$

$\cancel{= 43.92^\circ}$

Q.1 (d) A 3-ϕ, 765 kV, 50 Hz, 300 km, completely transposed line has the following positive sequence impedance and admittance :

$$z = 0.0165 + j0.3306 = 0.3310\angle 87.14° \ \Omega/\text{km}$$
$$y = 4.674 \times 10^{-6} \ \text{S/km}$$

Assuming positive sequence operation, calculate exact *ABCD* parameters of long line equation. Compare the exact *B* parameter with nominal π-circuit.

[12 marks]

$$Z_1 = (0.0165 + j0.3306)\ \Omega/\text{km}$$
$$Y_1 = (0 + j4.674 \times 10^{-6})\ \mho/\text{km}$$

for long line

$$\cancel{Z_C = \sqrt{Z_1 Y_1} =}$$

$$Z_C = \sqrt{\frac{Z_1}{Y_1}} = \left(\frac{0.3310\angle 87.14}{4.674\times 10^{-6}\angle 90}\right)^{1/2} = 266.12\angle -1.43°$$

$$y = \sqrt{Z_1 Y_1} = \sqrt{1.547\times 10^{-6}\angle 177.14°} = 1.24\times 10^{-3}\angle 88.57°$$

$$A = D = \cosh(ly) = \cosh(9.28\times 10^{-3} + j0.37)$$
$$= \cosh(9.28\times 10^{-3})\cos(0.37) + j\sinh(9.28\times 10^{-3})\sin(0.37)$$
$$= 1\angle 0.0034°$$

$$B = Z_C \sinh ly = Z_c \sinh(9.28\times 10^{-3} + j0.37)$$
$$= Z_C\left[\sinh(9.28\times 10^{-3})\cos(0.37) + j\cosh(9.28\times 10^{-3})\sin(0.37)\right]$$
$$= Z_C(0.011\angle 34.83°)$$
$$= 3\angle 33.4° \ \Omega$$

$$C = \frac{\sinh \gamma l}{Z_c} = \frac{0.011 \angle 34.83}{Z_c}$$

$$= 4.25 \times 10^{-5} \angle 36.26^\circ \quad ℧$$

$\therefore$ for long TL

$$\begin{bmatrix} 1 \angle 0.0034^\circ & 3 \angle 33.4^\circ \\ 4.25 \times 10^{-5} \angle 36.26^\circ & 1 \angle 0.0034^\circ \end{bmatrix}$$

2

for π n/w

$$B = Z = Z_1 l = 99.3 \angle 87.14^\circ$$

Do not write in this margin

Q.1 (e) Consider a 3-phase, Δ-Y connected, 30 MVA, 33 : 11 kV transformer with differential relay protection. If the CT ratios are 500 : 5 on primary side and 2000 : 5 on secondary side, compute the relay current setting for faults drawing upto 200% of rated transformer current.

[12 marks]

30 MVA
33/11 kV
3ϕ
Δ/Y

CT
Y / Δ
$\frac{500}{5}$ $\frac{2000}{5}$

as T/F is Δ/Y
⇒ CT must be Y/Δ

$$I_{L\,py} = \frac{30 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 524.86 \text{ A}$$

$$I_{L\,sy} = \frac{30 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 1574.59 \text{ A}$$

given $I_f = 200\%\ I_{rated}$

$\therefore I_{f\,py} = 1049.72$ A

$I_{f\,sy} = 3149.18$ A

using CT rations, computing current in CT sy

$$I_{ph} = 1049.72 \times \frac{5}{500} = 10.497 \text{ A}$$

$$I_{ph} = 3149.18 \times \frac{5}{2000} = 7.87 \text{ A}$$

$I_L = I_{ph} = 10.497$ A

$I_L = \sqrt{3}\ I_{ph} = 13.636$ A

Do not write in this margin

$\Rightarrow$ relay current

$= |I_{L_1} - I_{L_2}|$

$= |10.497 - 13.636|$

$= 3.139$ A

$\therefore$ relay current setting $= 3.139$ A

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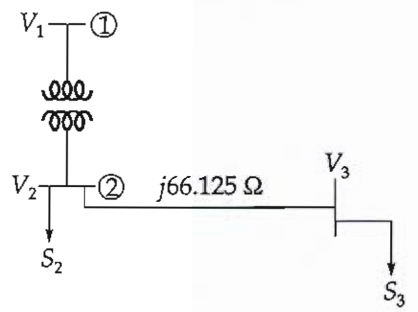
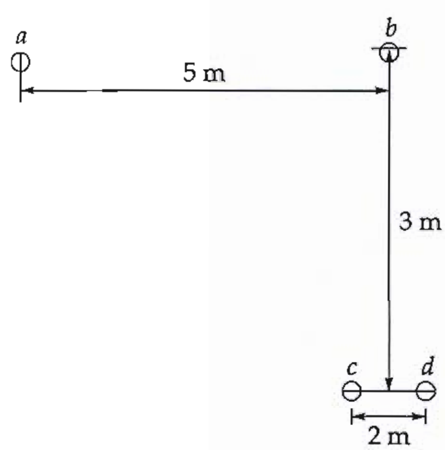
Good Approach

Q.2 (a) (i) The single line diagram of 3-phase power system is shown in figure. The transformer reactance is 20% on the base of 100 MVA, 23/115 kV and line impedance of $Z = j66.125\ \Omega$. The load at bus–2 is S_2 = 184.8 MW + j6.6 MVAR and at bus-3 is S_3 = 0 MW + j20 MVAR. It is required to hold the voltage at bus-3 at $115\angle 0°$ kV. Determine the voltages at bus-1 and bus-2.



(ii) A 50 Hz, 1-ϕ power line and telephone line are parallel to each other as shown in figure. The telephone line is symmetrically positioned directly below phase b. The power line carries a current of 226 A. Assume zero current flows in ungrounded telephone wires. Find the magnitude of voltage per km induced in the telephone line.



[10 + 10 marks]

Q.2 (b) **(i)** A 400 MVA synchronous machine has $H_1 = 4.6$ MJ/MVA and 1200 MVA machine has $H_2 = 3.0$ MJ/MVA. The two machines operate in parallel in a power plant. Find out H_{eq}, relative to a 100 MVA base.

(ii) The per unit bus impedance matrix for a power system is given by

$$Z_{bus} = j\begin{bmatrix} 0.0450 & 0.0075 & 0.030 \\ 0.0075 & 0.06375 & 0.030 \\ 0.030 & 0.030 & 0.21 \end{bmatrix}$$

A 3-ϕ fault occurs at bus-3 through a fault impedance of $Z_f = j0.19$ per unit. Using the bus impedance matrix, calculate the fault current, bus voltages and line currents during fault. Assume the pre-fault voltages at each bus is 1.0 pu.

[10 + 10 marks]

Q.2 (c) A single area consists of two generating units, rated at 400 MVA and 800 MVA with speed regulation of 4% and 5% on their respective ratings. The units are operating in parallel, sharing 700 MW. Unit-1 supplies 200 MW and unit-2 supplies 500 MW at 1.0 pu (60 Hz). The load increased by 130 MW.

(i) Assume there is no frequency-dependent load, i.e., $D = 0$. Find the steady-state frequency deviation and the new generation on each unit.

(ii) The load varies 0.804% for every 1% change in frequency, i.e., $D = 0.804$. Find the steady-state frequency deviation and the new generation on each unit.

[20 marks]

Q.3 (a) A 3-ϕ overhead line has resistance and reactance per phase 5 Ω and 25 Ω respectively. The load of receiving end 15 MW, 33 kV, 0.8 pF lagging. Find the compensation equipment needed to deliver this load with sending end voltage of 33 kV.

Calculate the extra load of 0.8 lagging power factor delivered with the compensating equipment (of capacity as calculated above) installed, if the receiving end voltage is permitted to drop to 28 kV.

[20 marks]

$R = 5\ \Omega$

$X = 25\ \Omega$

15 mw

33 kv

0.8 pf lag

$Z = 5 + j25 = 25.5\angle 78.69^\circ\ \Omega$

$A = D = 1,\quad C = 0,\quad B = Z$ (for short line)

let V_R be reference $\quad V_R = \frac{33}{\sqrt{3}}\angle 0$ kV

$V_S = \frac{33}{\sqrt{3}}\angle \delta$ kV

$I_R = \frac{15\times 10^6}{\sqrt{3}\times 33\times 10^3 \times 0.8} = 328.04\angle -36.87^\circ$

$I_S = I_R = 328.04\angle -36.87^\circ$

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

$15 = \frac{33\times 33}{25.5}\cos(78.69 - \delta) - \frac{33^2}{25.5}\cos(78.69)$

$\Rightarrow \delta = 21.876^\circ$

$$\therefore \quad Q_R = \frac{V_S V_R}{B} \sin(\beta - \delta) - \frac{A V_R^2}{B} \sin(\beta - \alpha)$$

$$= \frac{33^2}{25.5} \sin(78.67 - 21.876) - \frac{33^2}{25.5} \sin(78.69 - 0)$$

$$= -5.64 \text{ MVAR}$$

load requirement of reactive power $= \frac{15}{0.8} \times 0.6 = 11.25$ MVAr

$\therefore$ let Q amount of MVAR is supplied bey the shunt element

$$\therefore \quad -5.64 + Q = 11.25$$

$$Q = 16.89 \text{ MVAR}$$

$\therefore$ a shunt capacitor bank is required to compensate with $Q_c = 16.89$ MVAR

Now, as the receiving end voltage can drop to 28 kV

$$\therefore \quad \Delta V = (33 - 28) = 5 \text{kV}$$

$\therefore$ we know $\Delta Q = \frac{V \Delta V}{B}$

$$\Rightarrow \Delta Q = \frac{33 \times 5}{25.5} = 6.47 \text{ MVAR}$$

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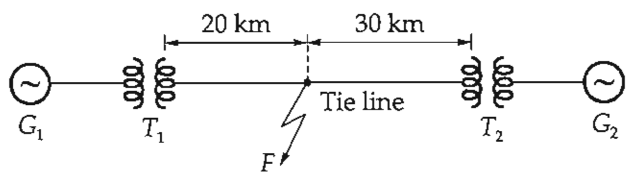
as $\cos\phi = 0.8$ lag

$$\Rightarrow P = 8.63 \text{ MW}$$

Q.3 (b) Generator G_1 and G_2 are identical and rated 11 kV, 20 MVA and have a transient reactance of 0.25 p.u at own MVA base. The transformers T_1 and T_2 are also identical and are rated 11/66 kV, 5 MVA and have a reactance of 0.06 p.u. to their own MVA base. The tie line is 50 km long, each conductor has a reactance of 0.848 Ω/km. The three phase fault is assumed at F, which is 20 km away from transformer T_1 as shown below. Find the short circuit current.



[20 marks]

G_1, G_2: 20 MVA, 11 kV, $X = 0.25$

T_1, T_2: 5 MVA, 11/66 kV, $X = 0.06$

$X_{line} = 0.848\ \Omega/\text{km}$

Let the MVA base of the system be 20 MVA and kV base be 11 kV on gen side

$\therefore$ kV base line $= 66$ kV

$X_{gen\ new} = 0.25$ pu

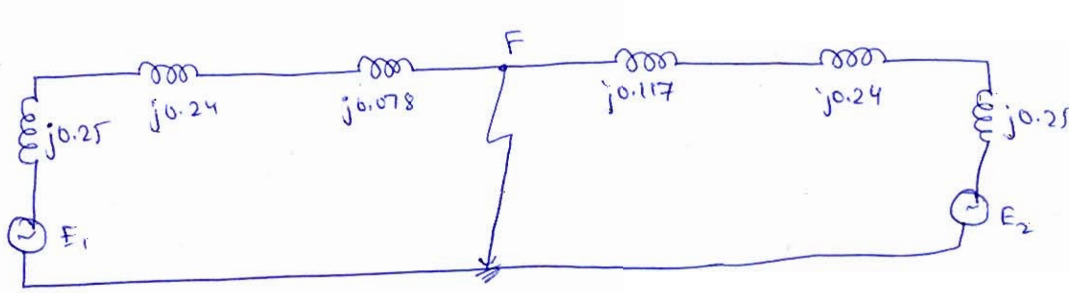
$X_{T/f\ new} = 0.06 \times \left(\frac{20}{5}\right) = 0.24$ pu

$Z_{base\ line} = \frac{kV^2}{MVA} = \frac{66^2}{20} = 217.8\ \Omega$

$X_{line\ 20km} = 0.848 \times 20 = 16.96\ \Omega = 0.078$ pu

$X_{line\ 30km} = 0.848 \times 30 = 25.44\ \Omega = 0.117$ pu

$\therefore$ Reactance diagram of system is



Assuming pre fault the system was unloaded

$\therefore E_1 = 1\angle 0$ pu

$E_2 = 1\angle 0$ pu

$$\therefore I_f = \frac{E_1}{j0.25 + j0.24 + j0.078} + \frac{E_2}{j0.25 + j0.24 + j0.178}$$

$$= \frac{1\angle 0}{j0.568} + \frac{1\angle 0}{j0.667}$$

$$= 3.41 \angle -90^\circ \text{ pu}$$

$\therefore$ I_f

$$I_{base\ line} = \frac{MVA_{base}}{\sqrt{3}\, V_{L\,base}} = \frac{20\times10^6}{\sqrt{3}\times 66\times10^3}$$

$$= 174.95 \text{ A}$$

$$\therefore I_f = 3.41 \times 174.95$$

$$= 596.59 \text{ A}$$

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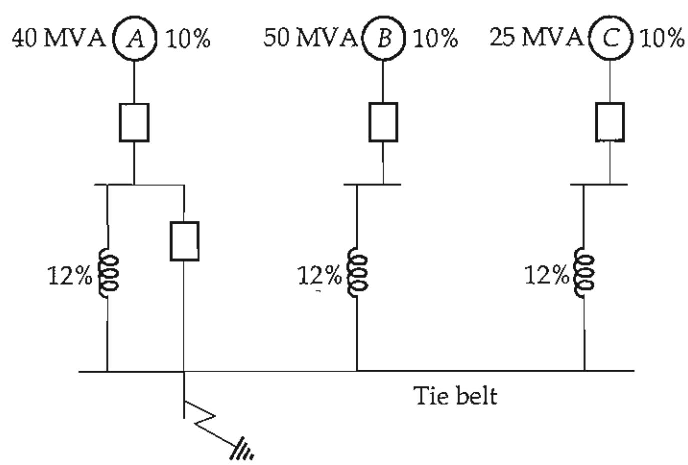
Good Approach

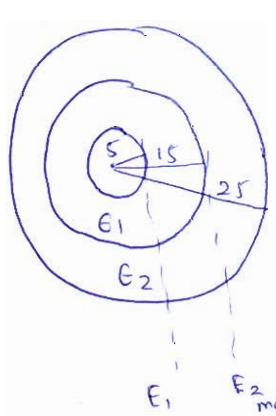
Q.3 (c) **(i)** A single-core, lead sheathed cable joints has a conductor of 10 mm diameter and two layers of different insulating materials, each 10 mm thick. The relative permittivities are 3 (inner) and 2.5 (outer). Calculate the potential gradient at the surface of conductor when the potential difference between the conductor and the lead sheath is 60 kV.

(ii) Three 6.6 kV generators A, B and C, each of 10%, leakage reactance and MVA rating 40, 50 and 25 respectively are interconnected electrically as shown in figure, by a tie bar current limiting reactor, each of 12% reactance based upon the rating of machine to which it is connected. A 3-ϕ feed is supplied from the bus-bar of generator A at a line voltage of 6.6 kV. The feeder has resistance of 0.06 Ω/ph and an inductive reactance of 0.12 Ω/ph. Estimate the maximum MVA there can be fed into symmetrical short circuit at the far end of the feeder.



[8 + 12 marks]

(i)



$r_o = 5\text{mm}$

$t = 10\text{mm}$

$\therefore \; r_1 = 15 \text{ mm}$

$r_2 = 25 \text{ mm}$

$\epsilon_1 = 3$

$\epsilon_2 = 2.5$

we know

$$V = E_{1\,max}\, r_0 \ln \frac{r_1}{r_0} + E_{2\,max}\, r_1 \ln \frac{r_2}{r_1}$$

$$\therefore \; 60 = E_{1\,max} \times 5 \ln \frac{15}{5} + E_{2\,max}\, 15 \ln \frac{25}{15}$$

$\therefore\ 60 = 5.5\ E_{1max} + 7.66\ E_{2max}$ — (i)

where E_1, E_2 are in kV/mm

also $E_{1max}\ \epsilon_1 r_0 = E_{2max}\ \epsilon_{r2} r_1$

$\Rightarrow 15\ E_{1max} = 37.5\ E_{2max}$ — (ii)

Solving (i) & (ii) we get

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$E_{1max} = 7$ kV/mm

$E_{2max} = 2.8$ kV/mm

(ii) Let MVA base be 100 MVA

$\therefore$ Gen A $\Rightarrow$ $X_{new} = 0.1 \times \frac{100}{40} = 0.25$

$X_{tie} = 0.12 \times \frac{100}{40} = 0.3$

$X_{feeder} = (0.06 + j0.12) \times \frac{100}{6.6^2} = 0.31 \angle 63.43^\circ$

$= 0.14 + j.275$

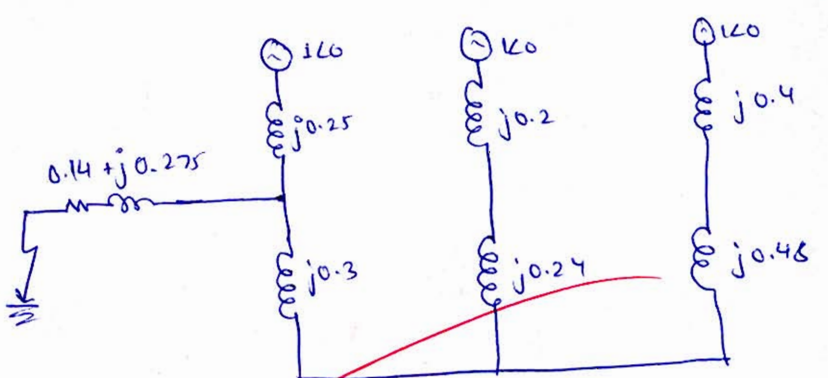
Gen B $\Rightarrow$ $X_{new} = 0.1 \times \frac{100}{50} = 0.2$

$X_{tie} = 0.12 \times \frac{100}{50} = 0.24$

Gen C $\Rightarrow$ $X_{new} = 0.1 \times \frac{100}{25} = 0.4$

$X_{tie} = 0.12 \times \frac{100}{25} = 0.48$

$\therefore$ Reactance diagram (assuming no load pre fault condition)



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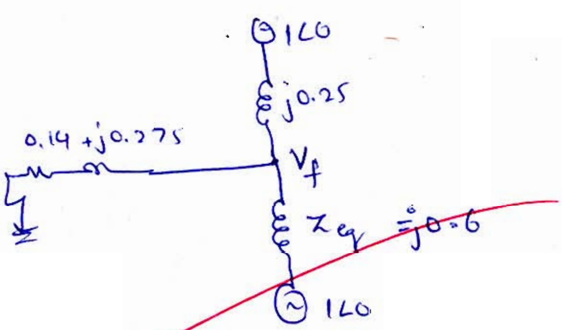


$Z_{eq} = j\{(0.2+0.24) \| (0.4+0.48)\} + 0.3$

$= j\,0.6$

$\therefore \frac{1-V_f}{j0.6} + \frac{1-V_f}{j0.25} = \frac{V_f}{0.14+j0.275}$

$\Rightarrow V_f = 0.65 \angle -9.75^\circ$ pu

$$\therefore \quad I_f = \frac{V_f}{0.14 + j0.275} = 2.1156 \angle -72.77^\circ \ pu$$

we know

$$SC_{mVA_{pu}} = I_{f_{pu}}$$

$$\therefore \quad SC_{mVA_{pu}} = 2.1156$$

$$\therefore \quad SC \ mVA = 2.1156 \times 100$$

$$= 211.56 \ mVA$$

11

Good Approach

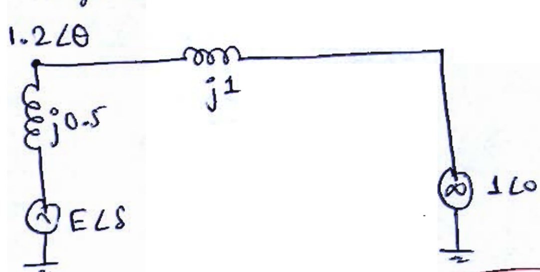
Q.4 (a) **(i)** Find the steady state power limit of a system consisting of a generator with equivalent reactance 0.50 pu connected to an infinite bus through a series reactance of 1 pu. The terminal voltage of generator held at 1.20 pu and voltage of infinite bus is 1.0 pu.

(ii) Determine the corona characteristics of a 3-phase line 160 km long. Conductor diameter 1.036 cm, 2.44 m delta spacing, air temperature 26.67°C, altitude 2440 m, corresponding to an approximate barometric pressure of 73.15 cm, operating at 110 kV at 50 Hz. Surface irregulating factor is 0.85 and $m_V = 0.72$.

[10 + 10 marks]

(i) The one line diagram is shown below

reactance diagram



for steady state power limit $\delta = 90^\circ$

∴ power flow is $\frac{E \times 1.2}{0.5} \sin(90-\theta) = \frac{1.2 \times 1}{1} \sin\theta = \frac{E \times 1}{1.5} \sin\delta$

$\Rightarrow \quad 2.4\, E \cos\theta = 1.2 \sin\theta = \frac{2E}{3}$

$\therefore \quad 2.4\, E \cos\theta = \frac{2E}{3}$

$\cos\theta = \frac{5}{18} \quad \Rightarrow \quad \theta = 73.87^\circ$

$\therefore \quad E = 1.73$ pu

$\therefore \quad S^3 L = \frac{E\,V}{X}$

$= \frac{1.73 \times 1}{(1+0.5)} = 1.15$ pu

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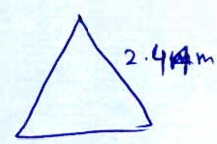
(ii) $d = 1.036 \times 10^{-2}$ m

$l = 160$ km

$T = 26.67°$

altitude $= 2440$ m

$b = 73.15$ cm



$d = 2.44$

$V_L = 110$ KV

$f = 50$ Hz

$m_o = 0.85$

$m_v = 0.72$

4

$\delta = \frac{1.32\, b}{273 + T} = 0.32$

$V_c = m_o\, g\, r\, \delta\, \ln\left(\frac{d}{r}\right)$

$V_v = m_v\, g\, r\, \delta \left(1 + \frac{0.3}{\sqrt{r\delta}}\right) \ln\left(\frac{d}{r}\right)$

taking $g = 21.1$ kV/cm

$\Rightarrow V_C = 18.3\ kV$

& $V_V = 31.78\ kV$

$V_L = 110 kV$

$\Rightarrow V_{ph} = 63.51\ kV$

Here V_C = critical disruptive voltage = 18.3 kV

is less than V_{ph}

$\Rightarrow$ corona loss occurs

$$P_L = (242.2 \times 10^{-5}) \left(\frac{f+25}{\delta}\right) (V_{ph} - V_c)^2$$

$$= 1160.26\ kW/km/ph$$

Total loss $= 3 \times 160 \times P_L$

$= 0.56$ MW

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Q.4 (b) A 50-Hz, 100 MVA, 4-pole, synchronous generator has inertia constant of 3.5 sec and supply 0.16 pu power on a system base of 500 MVA. The input to the generator is increased to 0.18 pu. Determine :

(i) Kinetic energy stored in the rotor.

(ii) Acceleration of the generator.

(iii) If acceleration continues for 7.5 cycles, calculate the change in rotor angle.

(iv) Speed in rpm at the end of the acceleration.

[20 marks]

$H = 3.5$ s

$P_m = 0.16$ pu on 500MVA (under steady state)

$\therefore P_e = 0.16$ pu

on m/c rating ie on ~~100 MVA~~ base

$P_e = 0.032$

now P_m becomes 0.18 on 500 MVA base

$\therefore P_m = 0.036$ on m/c rating

(i) ~~KE~~ $H = \dfrac{KE\ \cancel{rotor}}{m/c\ rating}$

$\therefore KE = 3.5 \times 100 = 350$ J

(ii) using swing eq^n

$$\frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = P_m - P_e$$

$$\frac{2\times 3.5}{2\pi\times 50}\frac{d^2\delta}{dt^2} = 0.036 - 0.032$$

$\therefore \quad \alpha = \frac{d^2\delta}{dt^2} = 0.179$ ~~elec rad~~ $/s^2$

(iii) $\frac{d^2\delta}{dt^2} = 0.179$

integrating we get

$\frac{d\delta}{dt} = 0.179t + C$

$\omega - \omega_s = 0.179t + C$

as speed can't change suddenly

$\therefore \quad \omega = \omega_s$ at $t = 0^-$ & $t = 0^+$

$\Rightarrow \quad C = 0$

$\Rightarrow \quad \frac{d\delta}{dt} = 0.179t$

integrating again

$\delta - \delta_0 = \frac{0.179t^2}{2}$ $\Big\{$ for 7.5 cycles

$\therefore \quad \Delta\delta = \frac{0.179}{2}(7.5 \times 0.02)^2$

$= 0.002$ rad elec

$= 0.115^\circ$ degree elec

(iv) as $\omega - \omega_s = 0.179t$

for 7.5 cycles

$\omega - \omega_s = 0.179 \times (7.5 \times .02)$

$= 0.02685$

$\omega = 0.02685 + \omega_s$

$= 314.186$ elec rad/s

$\omega_m = \frac{2}{P}\omega$ mech rad/s

$= 157.09$ mech rad/s $(P = 4)$

$\therefore N = \omega_m \times \frac{60}{2\pi}$

$= 1500.128$ rpm

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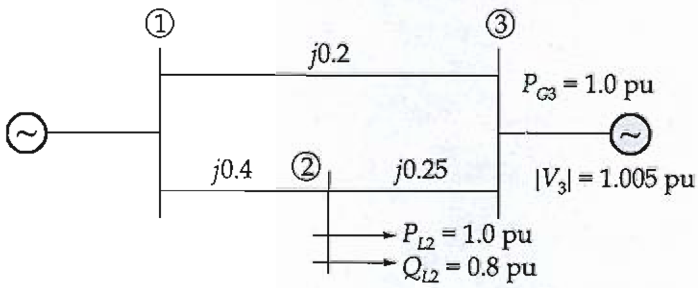
Q.4 (c) For the power system network shown in figure, compute the bus voltages using the Gauss-Seidel iteration method. Line reactances and loads are shown in figure. Bus-1 is the slack bus ($V_1 = 1.04\angle 0°$) and bus-2 and bus-3 are the load and voltage-control buses respectively. Assume tolerance equal to 1×10^{-5}.

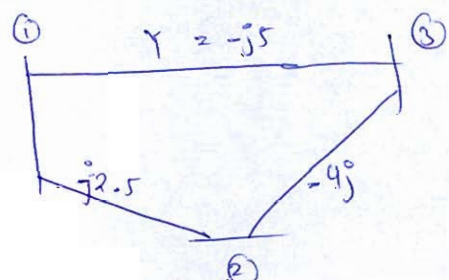


Compute V_1, V_2 and V_3 upto one iteration.

[20 marks]

Bus	P	Q	|V|	δ	initial V∠δ guess
1 - slack	P_1	Q_1	1.04	$0°$	
2 - PQ	-1	-0.8	V_2	δ_2	$1\angle 0°$
3 - PV	1	Q_3	1.005	δ_3	$1.005\angle 0°$

To form Y bus



$\therefore Y_{11} = -j5 - j2.5 = -j7.5$

$Y_{22} = -j2.5 - j4 = -j6.5$

$Y_{33} = -4j - j5 = -j9$

$Y_{12} = Y_{21} = j2.5$

$Y_{13} = Y_{31} = j5$

$Y_{23} = Y_{32} = j4$

$$Y = \begin{bmatrix} -j7.5 & j2.5 & j5 \\ j2.5 & -j6.5 & j4 \\ j5 & j4 & -j9 \end{bmatrix}$$

as Bus 1 is slack bus no need to find V_1

$\therefore$ for V_2

$$V_2' = \frac{1}{Y_{22}} \left[\frac{S_2^*}{V_2^{0*}} - Y_{21} V_1 - Y_{23} V_3 \right]$$

$$= 0.91 \angle -9.75^\circ$$

before going to V_3 we need to calculate Q_3

$$\therefore S_3^* = V_3^* \left(Y_{31} V_1^0 + Y_{32} V_2' + Y_{33} V_3^0 \right)$$

$$= 0.619 - j\,0.259$$

$$\Rightarrow Q_3 = 0.259$$

$\therefore$ for V_3'

$$V_3 = \frac{1}{Y_{33}} \left[\frac{S_3^*}{V_3^{0*}} - Y_{31} V_1 - Y_{32} V_2' \right]$$

$$= 1.005 \angle 2.397^\circ$$

$\therefore$ after 1^{st} iteration

$V_1 = 1.04 \angle 0^\circ$ pu (slack bus $\therefore$ no change)

$V_2' = 0.91 \angle -9.75^\circ$ pu

$V_3' = 1.005 \angle 2.397^\circ$ pu

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Section B : Systems and Signal Processing-1 + Microprocessor-1 + Electrical Circuits-2 + Control Systems-2

Q.5 (a) Calculate the delay in the following loop, assuming the system clock frequency is 3 MHz.

```
        LXI B, 12FFH
DELAY : DCX B
        XTHL
        XTHL
        NOP
        NOP
        MOV A, C
        ORA B
        JNZ DELAY
```

[12 marks]

$f_{clock} = 3\,MHz$

$[BC] = 12FF + 1 = (4863)_{10}$

Instr.	T-state
LXI	10
DCX	6
XTHL	16
NOP	4
MOV	4
ORA	4
JNZ	10/7

The loop 'DELAY' executes until (BC) comes to 0000H

∴ loop runs for 4663 times

out of which 4662 times condition is true.

$\therefore$ Total no of T- states

$$= 10 + 4662\,[6 + 16 + 16 + 4 + 4 + 4 + 4 + 10] + 1\,[6 + 16 + 16 + 4 + 4 + 4 + 4 + 7]$$

count = 298439

$$\therefore T_{delay} = 298439 \times T_{clock}$$

$$= 298439 \times \frac{1}{f_{clock}}$$

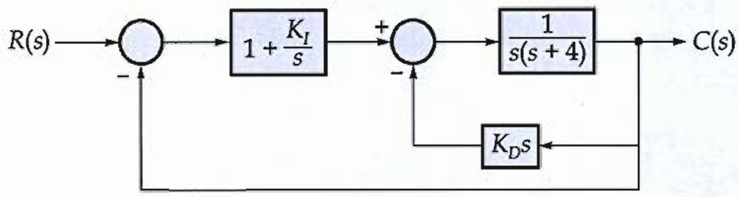
$$= 298439 \times \frac{1}{3 \times 10^6}$$

$$= 0.09947967 \text{ sec}$$

$$= 99.48 \text{ msec}$$

4

Q.5 (b) Determine the ranges of controller gains (K_D, K_I) so that the system shown in figure below remains stable. Also determine the type of the system. Plot the region of stability.



[12 marks]

The inner feedback loop becomes
$$\frac{\frac{1}{s(s+4)}}{1 + \frac{1}{s(s+4)} K_D s}$$

$$= \frac{1}{s(s+4) + sK_D} = \frac{1}{s(s+4+K_D)}$$

$$\therefore \text{OLTF} = \left(1 + \frac{K_I}{s}\right)\left(\frac{1}{s(s+4+K_D)}\right)$$

$$= \frac{(s+K_I)}{s^2(s+4+K_D)}$$

as two poles at origin in OLTF

$\Rightarrow$ Type 2 system

as the system is unity feedback

$$\therefore q(s) = s^2(s+4+K_D) + (s+K_I)$$

$$= s^3 + (4+K_D)s^2 + s + K_I$$

for stability $4 + K_D > 0$ & $K_I > 0$

$$\therefore K_D > -4 \qquad K_I > 0$$

Constructing RH table we get

s^3	1	1
s^2	$4+K_D$	K_I
s	$\frac{4+K_D-K_I}{4+K_D}$	0
s^0	K_I	

for stability ⇒ no sign change in 1^{st} column

$\therefore$ $4+K_D>0$ $\quad$ $4+K_D-K_I>0$ $\quad$ $K_I>0$

$K_D>-4$ $\quad$ $K_D>K_I-4$ $\quad$ $K_I>0$

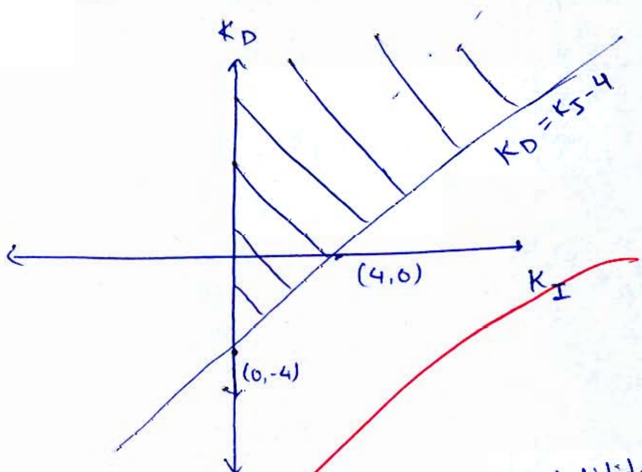
as $K_I>0$ & $K_D>K_I-4$ ⇒ $K_D>-4$

$\therefore$ for stability

$K_I>0$

$K_D>K_I-4$

11



Region of stability

Q.5 (c) The reduced incidence matrix of an oriented graph is given as :

$$\begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 \\ -1 & 0 & 1 & 0 & -1 & 0 \\ 0 & -1 & -1 & 1 & 0 & 0 \end{bmatrix}$$

(i) Draw its graph.

(ii) Determine the number of trees are possible for this graph.

[12 marks]

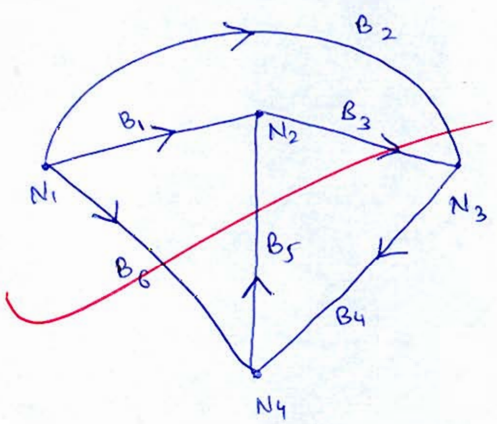
forming the incidence matrix A

row 4 = 0 − (Σ row 1,2,3 elements) as sum of row = 0

(i)

$$A = \begin{array}{c|cccccc} & B_1 & B_2 & B_3 & B_4 & B_5 & B_6 \\ \hline N_1 & 1 & 1 & 0 & 0 & 0 & 1 \\ N_2 & -1 & 0 & 1 & 0 & -1 & 0 \\ N_3 & 0 & -1 & -1 & 1 & 0 & 0 \\ N_4 & 0 & 0 & 0 & -1 & 1 & -1 \end{array}_{4\times 6}$$

as $A \equiv 4\times 6 \Rightarrow$ 4 nodes, 6 branches



taking +ve as outgoing
−ve as incoming

(iii) No of possible trees is given by $|A_a A_a^T|$

$$\therefore A_a A_a^T = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 \\ -1 & 0 & 1 & 0 & -1 & 0 \\ 0 & -1 & -1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 3 & -1 & -1 \\ -1 & 3 & -1 \\ -1 & -1 & 3 \end{bmatrix}$$

$$\therefore |A_a A_a^T| = 16$$

$\therefore$ no of trees possible $= 16$

Good Approach

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Q.5 (d) A continuous-time linear system S with input $x(t)$ and output $y(t)$ yields the following input-output pairs.

$$x(t) = e^{j2t} \xrightarrow{S} y(t) = e^{j3t}$$

$$x(t) = e^{-j2t} \xrightarrow{S} y(t) = e^{-j3t}$$

(i) If $x_1(t) = \cos(2t)$, determine the corresponding output $y_1(t)$ for system S.

(ii) If $x_2(t) = \cos(2t - 1)$, determine the corresponding output $y_2(t)$ for system S.

[12 marks]

(i) $x_1(t) = \cos 2t$

$$= \frac{e^{j2t} + e^{-j2t}}{2}$$

now $e^{j2t} \xrightarrow{S} e^{j3t}$

$e^{-j2t} \xrightarrow{S} e^{-j3t}$

$\therefore \frac{1}{2}\left(e^{j2t} + e^{-j2t}\right) \xrightarrow{S} \frac{1}{2}\left(e^{j3t} + e^{-j3t}\right)$ LTI system property

$A_1 x_1(t) + A_2 x_2(t) \xrightarrow{S} A_1 y_1(t) + A_2 y_2(t)$

when $x_1(t) \xrightarrow{S} y_1(t)$

$x_2(t) \xrightarrow{S} y_2(t)$

$\therefore$ o/p $y_1(t) = \frac{e^{j3t} + e^{-j3t}}{2}$

$$= \frac{2\cos 3t}{2}$$

$$= \cos 3t$$

(ii) $x_2(t) = \cos(2t-1)$

$= \cos\left(2\left(t-\frac{1}{2}\right)\right)$

$= x_1\left(t-\frac{1}{2}\right)$

$= \dfrac{e^{j(2t-1)} + e^{-j(2t-1)}}{2}$

$= \dfrac{e^{-j}}{2}\left(e^{j2t}\right) + \dfrac{e^{j}}{2}\left(e^{-j2t}\right)$

$\therefore$ for LTI system

$x(t) \xrightarrow{S} y(t)$

$x(t-t_0) \xrightarrow{S} y(t-t_0)$

$\therefore$ $x_1(t) \xrightarrow{S} y_1(t) = \cos 3t$

$x_1(t-\frac{1}{2}) \xrightarrow{S} \cos 3(t-\frac{1}{2})$

$\therefore$ $y_2(t) = \cos(3t-1.5)$

Now for e^{j2t}

o/p $= e^{j3t}$

for e^{-j2t}

o/p $= e^{-j3t}$

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Good Approach

$\therefore$ using linear property of system

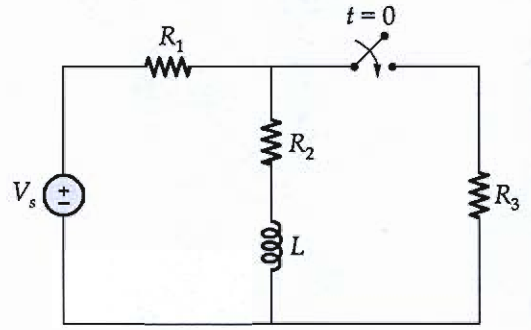
$\dfrac{e^{-j}}{2} e^{j2t} + \dfrac{e^{j}}{2} e^{-j2t} \xrightarrow{S} \dfrac{e^{-j}}{2} e^{j3t} + \dfrac{e^{j}}{2} e^{-j3t}$

$= \dfrac{e^{j(3t-1)} + e^{-j(3t-1)}}{2}$

$= \cos(3t-1)$

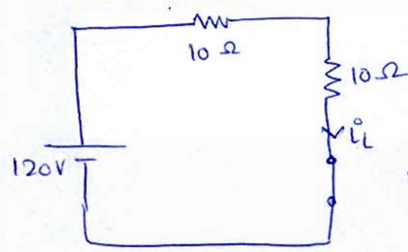
$\therefore$ $y_2(t) = \cos(3t-1)$

Q.5 (e) The switch in the circuit given below closes at $t = 0$, after being open for a long time. Find the inductor current $i_L(t)$, if $R_1 = R_2 = R_3 = 10\ \Omega$, $L = 0.01$ H and $V_s = 120$ V.



[12 marks]

befor $t = 0$ $(t < 0)$ circuit is in steady state, so



$L \rightarrow SC$

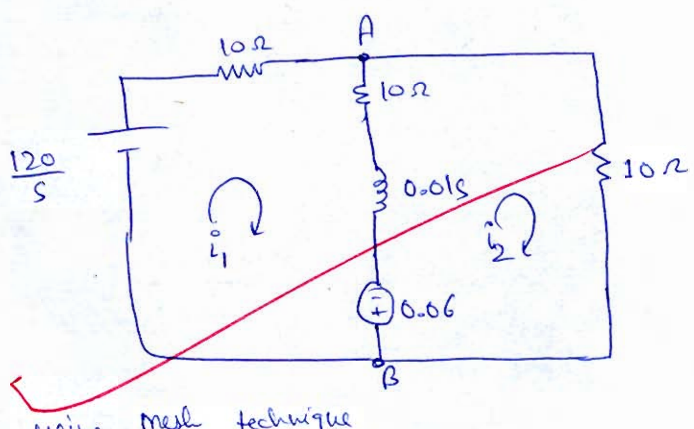
$i_L(0^-) = \dfrac{120}{10+10}$

$= 6$ A

as inductor current can't change suddenly

$\therefore$ $i_L(0^+) = i_L(0^-) = 6$A

Now for $t > 0$, drawing ckt in s-domain



$V_L = L\, i_L(0^+)$

$= 0.01 \times 6$

$= 0.06$ V

$\therefore$ using mesh technique

$$-\frac{120}{s} + 10\, I_1(s) + (10 + 0.01s)(I_1 - I_2) - 0.06 = 0$$

~~$20\ I_1(s)\ + 0.01$~~

$$(20 + 0.01s)\, I_1(s) - (10 + 0.01s)\, I_2(s) = 0.06 + \frac{120}{s} \quad (1)$$

$$10\, I_2(s) + 0.06 + (10+0.01s)\left(I_2(s) - I_1(s)\right) = 0$$

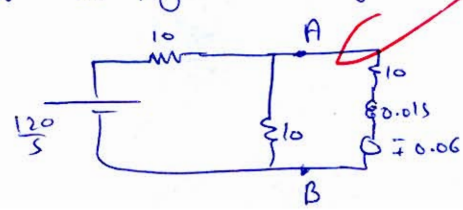
$$-(10+0.01s)\, I_1(s) + (20+0.01s)\, I_2(s) + 0.06 = 0$$

$$I_2(s) = \frac{(10+0.01s)\, I_1 - 0.06}{20+0.01s} \quad \text{— (ii)}$$

putting (ii) in (i)

$$(20+0.01s)\, I_1(s) - (10+0.01s)\frac{[(10+0.01s)\, I_1 - 0.06]}{20+0.01s} = 0.06 + \frac{120}{s}$$

or simply using Thevenin's theorem,

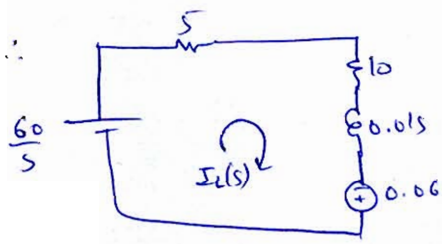


11

Good Approach

$$V_{th_{AB}} = \frac{120}{s} \times \frac{10}{10+10} = \frac{60}{s}, \quad Z_{th_{AB}} = 10 \| 10 = 5\,\Omega$$

∴



$$\Rightarrow \quad I_L(s) = \frac{\frac{60}{s} + 0.06}{5 + 10 + 0.01s}$$

$$= \frac{60 + 0.06s}{0.01s^2 + 15s}$$

$$= \frac{6000 + 6s}{s(s+1500)}$$

$$= \frac{4}{s} + \frac{2}{s+1500}$$

$$\Rightarrow \quad i_L(t) = \left(4 + 2e^{-1500t}\right) u(t)$$

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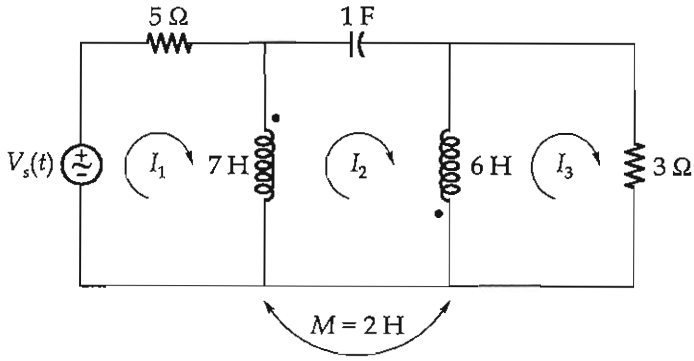
Q.6 (a) For the magnetically coupled circuit shown in figure, find the loop current I_1, I_2 and I_3, if $V_s(t) = 2\cos(2t)$.



[20 marks]

Q.6 (b) Write a program to arrange first 10 numbers from memory address 2040H in ascending order. Write the comment of each instruction.

[20 marks]

Q.6 (c) A system is represented by the state model,

$$\dot{X} = \begin{bmatrix} 0 & 2 \\ -3 & -5 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} r(t) \text{ and } y = [1 \quad -1]X$$

If the initial state vector is $X[0] = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$, find the zero input response, zero state response and total output response for a unit step input.

[20 marks]

Q.7 (a) Consider the cascade of the following systems S_1 and S_2, as depicted in figure,

$$x(n) \longrightarrow \boxed{S_1} \xrightarrow{w(n)} \boxed{S_2} \longrightarrow y(n)$$

S_1 : Causal LTI

$$w(n) = \frac{1}{2}w(n-1) + x(n)$$

S_2 : Causal LTI

$$y(n) = \alpha y(n-1) + \beta w(n)$$

The difference equation relating $x(n)$ and $y(n)$ is

$$y(n) = \frac{-1}{8}y(n-2) + \frac{3}{4}y(n-1) + x(n)$$

(i) Determine α and β.

(ii) Find the impulse response of the cascaded connection S_1 and S_2.

[20 marks]

$$w(n) = \frac{1}{2} w(n-1) + x(n)$$

applying z-T

$$W(z) = \frac{1}{2} W(z) z^{-1} + X(z)$$

$$W(z)\left[1 - \frac{z^{-1}}{2}\right] = X(z)$$

$$\frac{W(z)}{X(z)} = \frac{1}{1 - z^{-1}/2} \quad -(1)$$

now $\quad y(n) = \alpha\, y(n-1) + \beta\, w(n)$

applying z T

$$Y(z) = \alpha\, Y(z) z^{-1} + \beta\, W(z)$$

$$Y(z)(1 - \alpha z^{-1}) = \beta\, W(z)$$

$$\frac{Y(z)}{W(z)} = \frac{\beta}{1 - \alpha z^{-1}} \quad -(11)$$

multiplying eq^n ① & ⑪ we get

$$\frac{Y(z)}{X(z)} = \cancel{1}\left(\frac{1}{1-\frac{z^{-1}}{2}}\right)\cdot\left(\frac{\beta}{1-\alpha z^{-1}}\right) \quad \text{— (III)}$$

now using the eq^n

$$y(n) = -\frac{1}{8}\,y(n-2) + \frac{3}{4}\,y(n-1) + x(n)$$

applying ZT

$$Y(z) = -\frac{1}{8}\,Y(z)\,z^{-2} + \frac{3}{4}\,Y(z)\,z^{-1} + X(z)$$

$$Y(z)\left[1 - \frac{3}{4}z^{-1} + \frac{1}{8}z^{-2}\right] = X(z)$$

$$\frac{Y(z)}{X(z)} = \frac{1}{\left(1-\frac{3}{4}z^{-1} + \frac{1}{8}z^{-2}\right)}$$

$$= \frac{1}{\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{1}{4}z^{-1}\right)} \quad \text{— (IV)}$$

comparing eq^n (III) & (IV), we get

$$\frac{1}{\left(1-\frac{1}{2}z^{-1}\right)}\cdot\frac{1}{\left(1-\frac{1}{4}z^{-1}\right)} = \frac{1}{\left(1-\frac{1}{2}z^{-1}\right)}\cdot\frac{\beta}{\left(1-\alpha z^{-1}\right)}$$

$$\boxed{\beta = 1, \quad \alpha = \frac{1}{4}}$$

from eq ①

$$H_1(z) = \frac{1}{1 - \frac{z^{-1}}{2}}$$

applying inverse ZT

$$h_1(n) = \left(\frac{1}{2}\right)^n u(n)$$

from eq^n ⑪

$$H_2(z) = \frac{\beta}{1-\alpha z^{-1}} = \frac{1}{1-\frac{1}{4}z^{-1}}$$

applying inverse ZT

$$h_2(n) = \left(\frac{1}{4}\right)^n u(n)$$

$\therefore$ h(n) for S_1 = $\left(\frac{1}{2}\right)^n u(n)$

h(n) for S_2 = $\left(\frac{1}{4}\right)^n u(n)$

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Q.7 (b) The open loop transfer function of a unity feedback system is $G_p(s) = \dfrac{K}{s(s+2)}$. Design a lead compensator to have a velocity-error constant of $20s^{-1}$ and a phase margin of at least 50°.

$$G_C(s) = \frac{1+Ts}{1+\alpha Ts};\ \alpha < 1$$

[20 marks]

$$\text{OLTF} = G_p(s) \cdot G_c(s)$$

$$= \left(\frac{1+Ts}{1+\alpha Ts}\right)\left(\frac{K}{s(s+2)}\right)$$

$$= \frac{K(1+Ts)}{s(s+2)(1+\alpha Ts)}$$

system is type 1

∴ velocity error exist

$$K_v = \lim_{s \to 0} s\,(\text{OLTF})$$

$$20 = \lim_{s \to 0} \frac{K(1+Ts)}{(s+2)(1+\alpha Ts)}$$

$$20 = \frac{K}{2} \Rightarrow \boxed{K = 40}$$

To obtain phase margin of 50°, we need to get ω_{gc} first

such that $|\text{OLTF}|_{\omega_{gc}} = 1$

also $\angle \text{OLTF}_{\omega_{gc}} + 180 = 50 \Rightarrow \angle \text{OLTF}|_{\omega_{gc}} = -130°$

$$\therefore \; |OLTF| = \left. \frac{40\sqrt{1+T^2\omega^2}}{\omega\sqrt{\omega^2+4}\,\sqrt{1+\alpha^2T^2\omega^2}} \right|_{\omega gc} = 1$$

or $$1600\,(1+\omega^2T^2) = \omega^2(\omega^2+4)\,(1+\alpha^2T^2\omega^2)$$

also $$\angle OLTF = \tan^{-1}\omega T - 90 - \tan^{-1}\frac{\omega}{2} - \tan^{-1}\alpha\omega T = -130^\circ$$

$$\tan^{-1}\omega T - \tan^{-1}\frac{\omega}{2} - \tan^{-1}\alpha\omega T = -40^\circ$$

$$\tan^{-1}\omega T - \tan^{-1}\frac{\omega}{2} = \tan^{-1}\alpha\omega T + 40^\circ$$

10

$$\frac{\omega T - \frac{\omega}{2}}{1 + \omega T\frac{\omega}{2}} = \frac{\alpha\omega T + 0.839}{1 - 0.839\,\alpha\omega T}$$

given $\alpha < 1$, let us take $\boxed{\alpha = 0.5}$

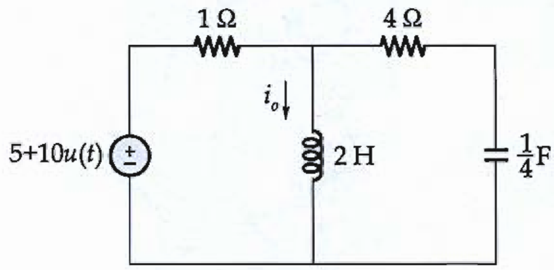
$$\therefore \; \frac{\omega T - \frac{\omega}{2}}{1 + \frac{\omega^2 T}{2}} = \frac{0.5\omega T + 0.839}{1 - 0.419\,\omega T}$$

$$\omega T - 0.419\,\omega^2T^2 - \frac{\omega}{2} + \frac{0.419\,\omega^2 T}{2} = 0.5\omega T + 0.839 + 0.25\,\omega^3T^2 + 0.419\,\omega^2 T$$

Incomplete solution

Do not write in this margin

.7 (c) (i) Determine the current i_o in the circuit shown below :



(ii) Differentiate between memory mapped I/O and I/O mapped I/O.

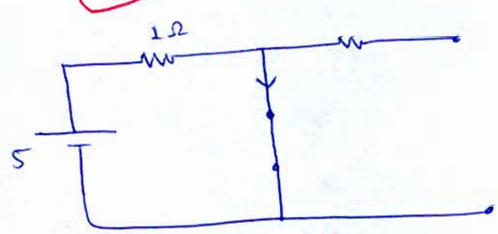
[15 + 5 marks]

(i) given source is $5 + 10u(t)$

$\therefore$ for $t < 0$ source $= 5$ V

for $t > 0$ source $= 15$ V

$t < 0^-$



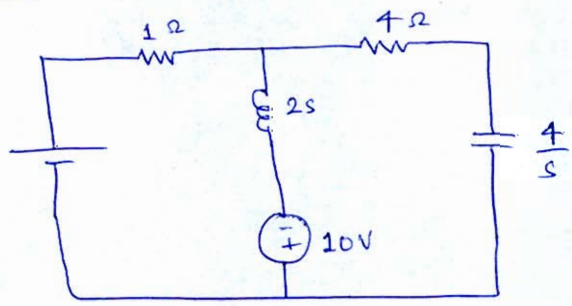
L – SC

C – OC

$i_L(0^-) = 5A$, $V_C(0^-) = 0V$

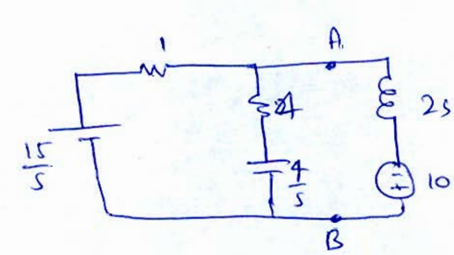
$\Rightarrow$ $i_L(0^+) = 5A$, $V_C(0^+) = 0V$

$t > 0$ circuit in s-domain



$V_L = L\, i(0^+)$
$= 2 \times 5 = 10V$

or



Using Thevenin's theorem across AB

$$V_{th} = \frac{15}{s} \times \frac{4 + 4/s}{4 + 4/s + 1}$$

$$= \frac{15}{s} \cdot \frac{4(1 + 1/s)}{5 + 4/s}$$

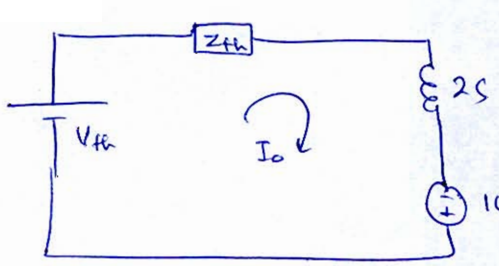
$$= \frac{15}{s} \frac{4(s+1)}{5s+4}$$

$$= \frac{60(s+1)}{s(5s+4)}$$

$$Z_{th} = 1 \parallel \left(4 + \frac{4}{s}\right)$$

$$= \frac{4 + \frac{4}{s}}{5 + \frac{4}{s}} = \frac{4(s+1)}{(5s+4)}$$

6



$$I_o(s) = \frac{V_{th} + 10}{Z_{th} + 2s} = \frac{\frac{60(s+1)}{s(5s+4)} + 10}{\frac{4(s+1)}{(5s+4)} + 2s}$$

$$= \frac{60(s+1) + 10s(5s+4)}{4s(s+1) + 2s^2(5s+4)}$$

$$= \frac{50s^2 + 100s + 60}{s(4s+4 + 10s^2 + 8s)} = \frac{50s^2 + 100s + 60}{s(10s^2 + 12s + 4)}$$

$$I_o(s) = \frac{50s^2 + 100s + 60}{s(10s^2 + 12s + 4)} \; A \quad \text{for } t>0$$

$$\& \; I_o(t) = 5 \; A \quad \text{for } t<0$$

In complete solution

(ii) In m/m mapped I/O, the I/O devices are treated as m/m location only, the processor does not know that I/O devices are being communicated.

address – 16 bit address

$\therefore 2^{16}$ max possible devices

signals – $\overline{MEMR}$, $\overline{MEMW}$, ~~I/O~~ $(IO/\bar{m} = 0)$

instructions – MOV A, M   MOV M, A   STA   LDA ...

In I/O mapped I/O devices, the processor knows that I/O devices are being communicated and theres no connect. b/w I/O & m/m.

address – 8 bit address

$\therefore 2^8$ max possible devices

signals – $\overline{IOR}$ $\overline{IOW}$ $(IO/\bar{m} = 1)$

instructions – IN #8bit   OUT #8bit

4

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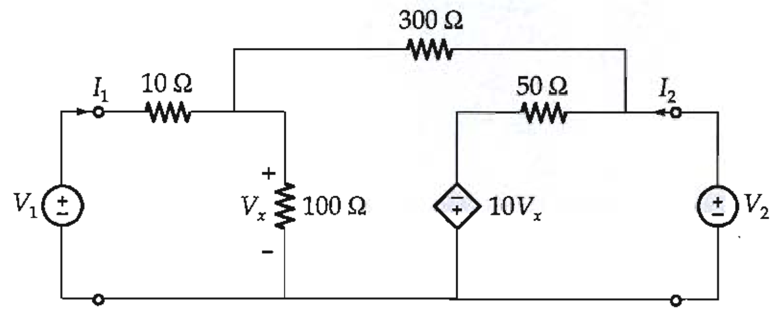
Q.8 (a) Obtain the h-parameter of the two-port network shown in figure below :



[20 marks]

Do not write in this margin

3 (b) (i) A system is represented by a state model as

$$\dot{x}_1 = -2x_1 - x_2 - 3x_3 + 2r$$
$$\dot{x}_2 = -2x_2 + x_3 + r$$
$$\dot{x}_3 = -7x_1 - 8x_2 - 9x_3 + 2r$$

The output, $y = 4x_1 + 6x_2 + 8x_3$

Check the controllability and observability of the system.

(ii) Explain the following instruction sets of 8086 microprocessor with example.

1. ROL; 2. ROR; 3. RCR; 4. RCL

[12 + 8 marks]

(c) Consider a signal $x(t)$ with Fourier transform $X(j\omega)$. Suppose we are given the following facts :

1. $x(t)$ is real and non-negative.
2. $F^{-1}\{(1 + j\omega)X(j\omega)\} = Ae^{-2t}u(t)$, where A is independent of t.
3. $\int_{-\infty}^{\infty} |X(j\omega)|^2 \, d\omega = 2\pi$

Determine a closed-form expression of $x(t)$.

[20 marks]

OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

$$H\left(\frac{\frac{E_1}{X_1}+\frac{E_2}{X_2}}{\frac{1}{X_1}+\frac{1}{X_2}}\right)$$

$\cos(2t-1)$

$$\frac{e^{j(2t-1)}+e^{-j(2t-1)}}{2}$$

$P \times t = E$

$$e^{j2t}e^{-j}+e^{-j2t}e^{j}$$

$$\frac{e^{-j}}{2}e^{j3t}+\frac{e^{-j3t}e^{j}}{2}$$

$$e^{j(3t-1)}$$

ΔQ

$$Q=\frac{V^2}{X}$$

$$\Delta Q=\frac{V\Delta V}{X}$$