Ignou Centre

Mention unit properly

Try to avoid calculation mistake

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India's Best Institute for IES, GATE & PSUs

ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-3 : Power Systems [All topics] +
Systems and Signal Processing-1 + Microprocessor-1
Electrical Circuits-2 + Control Systems-2 [Part Syllabus]

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	40
Q.2	50
Q.3	32
Q.4	
Section-B	
Q.5	42
Q.6	23
Q.7	
Q.8	
Total Marks Obtained	197

Signature of Evaluator: Saurabh Kumar

Cross Checked by: ....

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.

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Section A : Power Systems

Q.1 (a) A 66 kV concentric cable with intersheath has a core diameter of 1.6 cm. 3 mm thick dielectric materials constitute the three zones of insulation. Determine the maximum stress in each of the three layers if 20 kV is maintained across each of the inner two layers.

[12 marks]

Sol^n:

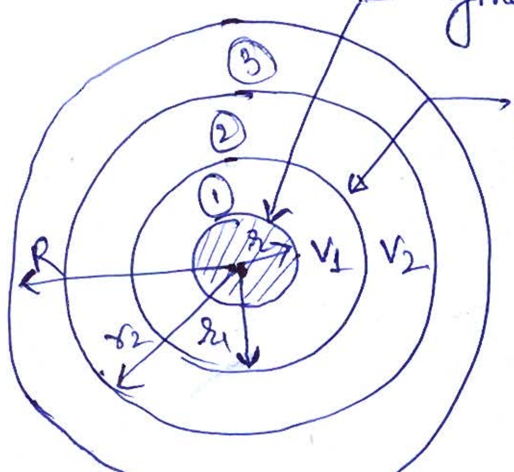

fig: core & dielectric

given

$r = \frac{1.6}{2} = 0.8\,cm$

$r = 8\,mm$

$r_1 = 8+3 = 11\,mm$

$r_2 = r_1 + 3 = 14\,mm$

$R = r_2 + 3 = 17\,mm$

given: $V_1 = V_2 = 20\,kV$

2

max. stress for innermost layer ①

$$g_{max1} = \frac{V_1}{r \ln \frac{r_1}{r}} = \frac{20}{8 \ln \frac{11}{8}}$$

$$\boxed{g_{max1} = 7.85 \frac{kV}{mm}}$$ Ans

max stress for layer ②

$$g_{max2} = \frac{V_2}{r_1 \ln \frac{r_2}{r_1}} = \frac{20}{11 \ln\left(\frac{14}{11}\right)}$$

$$\boxed{g_{max2} = 7.539 \frac{kV}{mm}}$$ Ans

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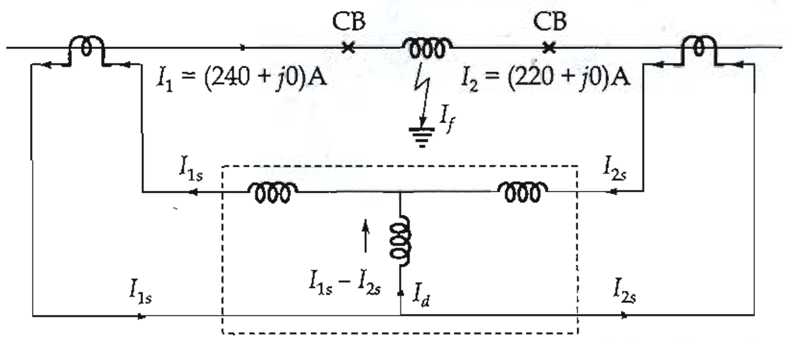
Q.1 (b) Figure below shows percentage differential relay is applied for the protection of a generator winding. The relay has 10% slope of its operating characteristic on $\frac{(I_{1s}+I_{2s})}{2}$ versus $(I_{1s}-I_{2s})$ diagram. A high resistance ground fault occurred near the grounded neutral end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding are shown in the figure below. Assuming CT ratio of 400/5 ampere, will the relay operate to trip the breaker?



[12 marks]

Sol^n:

CT ratio = 400/5 [given]

and K = 10% = 0.1

Now

$$I_{1S} = \frac{I_1}{400/5} = \frac{240}{80} = 3\text{ A}$$

and

$$I_{2S} = \frac{I_2}{400/5} = \frac{220}{80} = 2.75\text{ A}$$

operating current

$$I_{op} = I_{1S} - I_{2S} = 3 - 2.75$$

$$I_{op} = 0.25\text{ A}$$

restraining current

$$I_{res} = K\left(\frac{I_{1S}+I_{2S}}{2}\right) = 0.1\left(\frac{3+2.75}{2}\right)$$

$$= 0.2875\text{ A}$$

$\therefore$ $I_{op} < I_{res}$
(0.25A) (0.2875A)

So, relay will not operate to trip the breaker.

11

Good Approach

Q.1 (c) A 50 Hz, 4 pole, turbo-generator rated 100 MVA, 11 kV has an inertia constant of 8 MJ/MVA.

(i) Determine the stored energy in the rotor at synchronous speed.

(ii) If the mechanical input is suddenly raised to 80 MW for an electrical load of 50 MW, determine acceleration in elec-degree/sec^2, neglecting mechanical and electrical losses.

(iii) If the acceleration calculated in part (ii) is maintained for 10 cycle, determine the change in torque angle and rotor speed in revolutions per minute at the end of the period.

[2 + 5 + 5 marks]

Solⁿ: given: $f = 50\,Hz$

$p = 4$

Rating, $G = 100$ MVA

$V = 11$ KV

inertia constant, $H = 8 \frac{MJ}{MVA}$

i) stored energy:

$K.E. = GH$

$= 100 \times 8$

$= 800$ MJ Ans

ii) mech. input, $P_m = 80$ MW

electrical load, $P_e = 50$ MW

so, Acceleration power, $P_a = P_m - P_e$

$P_a = 80 - 50 = 30$ MW

In pu, $P_a = \frac{30}{100} = 0.3$ pu. → mention Base value

using swing eqⁿ: $\boxed{\frac{H}{\pi f} \frac{d^2\delta}{dt^2} = P_a}$ (in pu)

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_a$$

$$\alpha = \frac{d^2\delta}{dt^2} = \frac{P_a}{H}\times\pi f$$

$$\alpha = \frac{0.3}{8}\times\pi\times 50$$

$$\boxed{\alpha = 5.89 \ \frac{\text{elect-rad}}{s^2}}$$

$$\frac{H}{180 f}\cdot\frac{d^2\delta}{dt^2} = P_a$$

$$\alpha = \frac{d^2\delta}{dt^2} = \frac{P_a}{H}\times 180 f$$

$$\alpha = \frac{0.3}{8}\times 180^\circ\times 50$$

$$\boxed{\alpha = 337.5 \ \frac{\text{elect-deg}}{s^2}}$$

Ans.

(iii) $T = \frac{1}{f} = \frac{1}{50} = 0.02$ sec

for 10 cycles, $t = 10\times 0.02 = 0.2$ sec.

a) $\Delta\delta = \frac{1}{2}\alpha t^2$

$$\Delta\delta = \frac{1}{2}\times 5.89\times 0.2^2$$

$$\boxed{\Delta\delta = 0.1178 \ \text{elect rad}}$$ Ans

or $\Delta\delta = 0.1178\times\frac{180^\circ}{\pi}$ elect-deg

$$\boxed{\Delta\delta = 6.749^\circ \text{elect-deg}}$$

Ans

b) for rotor speed at end of 0.2 sec

$$f = f_0 + \frac{\alpha}{2\pi}\cdot t$$

$$f = 50 + \frac{5.89}{2\pi}\times 0.2$$

$$f = 50.1874 \ Hz$$

$$N = \frac{120 f}{P} = \frac{120\times 50.1874}{4}$$

$$\boxed{N = 1505.62} \text{ rpm}$$

Ans

11

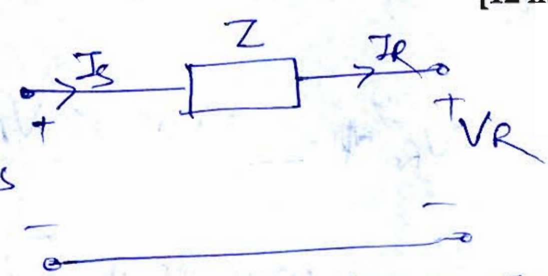
Good Approach

Use space properly

Q.1 (d) The per phase impedance of 3-ϕ short transmission line is $(0.3 + j0.4)\Omega$. The sending-end line to line voltage is 3300 V and the load at the receiving end is 300 kW per phase at 0.8 pf lagging. Calculate receiving end voltage and line current.

[12 marks]

Sol^n: short T/L:



given: $Z = 0.3 + j0.4\ \Omega$ | $I_S = I_R$

$V_{S(l-l)} = 3300V$

~~per~~ phase $|V_S| = \frac{3300}{\sqrt{3}} = 1905.25\ V$

and $P_R = 300\,kW$ @ 0.8 pf lagging

To find i) $V_R = ?$ ii) $I_S = I_R = ?$

5

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}\begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}^{-1}\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \frac{1}{AD-BC}\begin{bmatrix} D & -B \\ -C & A \end{bmatrix}\begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

$\because AD-BC = 1$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} 1 & -Z \\ 0 & 1 \end{bmatrix}\begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

$V_R = 1805.32$

So, $V_R = V_S - Z I_S$ —(1)

Let V_S as ref.

Let $I_S = I_R = I$

$$\boxed{V_R = 1905.25\angle 0 - (0.3 + j0.4) I}$$ —(1)

~~from~~ $P_R = \sqrt{3} V_R I_R \cos\phi$

$$\boxed{I_R = I = \frac{P_R}{\sqrt{3} V_R \cos\phi} = \frac{300 \times 10^3}{\sqrt{3} \times V_R \times 0.8}}$$ —(2)

~~I~~ =

on putting I in eqⁿ (1), we get

$$V_R = 1905.25\angle 0 - (0.3+j0.4) \times \frac{300\times10^3}{0.8\sqrt{3}\times V_R}$$

$$V_R^2 - 1905.25\, V_R + \frac{(0.3+j0.4)\times 300\times10^3}{0.8\sqrt{3}} = 0$$

$$V_R = \frac{1905.25 \pm \sqrt{(1905.25)^2 - 4\times\frac{(0.3+j0.4)\times 300\times10^3}{0.8\sqrt{3}}}}{2}$$

Calculation error

$$V_R = \frac{1905.25 \pm 1040.63\angle -2.934}{2}$$

1805.32 ✓

$$\boxed{V_R = 1072.32\angle -1.44^\circ \text{ V}}$$ or $\left(V_R = 57.81\angle 54.5\right.$ discard it

Receiving end voltage

$$\boxed{V_{R(l-l)} = \sqrt{3}\times 1072.32 = 3242.96 \text{ V}}$$ Ans

3127 ✓

Receiving end current

$$I_R = \frac{300\times10^3}{\sqrt{3}\times 1072.32\times 0.8}$$

1805.3

$$\boxed{I_R = 115.63 \text{ A}}$$ Ans

207.72 A

Go through the made easy solution

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Q.1 (e) A three phase generator delivers 1.0 p.u. power to an infinite bus through a transmission network when a fault occurs. The maximum power which can be transferred in pre-fault, during fault and post fault conditions are 1.75 p.u., 0.4 p.u and 1.25 p.u. respectively. Find the critical angle.

[12 marks]

Sol^n:

given: $P_m = 1 pu$

max power during prefault, $P_{max1} = 1.75 pu$

max power during fault, $P_{max2} = 0.4 pu$

max power during post fault, $P_{max3} = 1.25 pu$

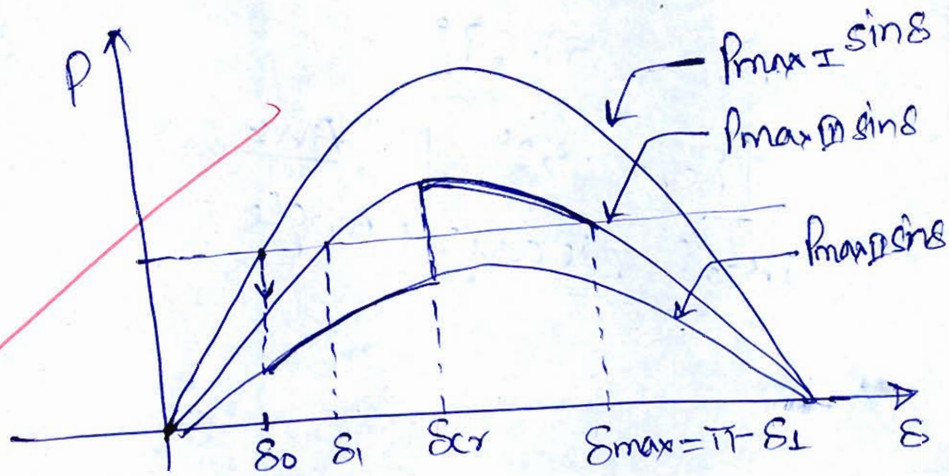


fig: P-δ curve

$$\delta_0 = \sin^{-1}\left(\frac{P_m}{P_{max1}}\right) = \sin^{-1}\left(\frac{1}{1.75}\right) = 34.85^\circ \text{ or } 0.608 \text{ rad}$$

$$\delta_{max} = \pi - \sin^{-1}\left(\frac{P_m}{P_{max\,III}}\right) = \pi - \sin^{-1}\left(\frac{1}{1.25}\right) = 126.87^\circ \text{ or } 2.214 \text{ rad}$$

using equal Area criteria

$$\int_{\delta_0}^{\delta_{max}} P_a \, d\delta = 0$$

$$\int_{\delta_0}^{\delta_{cr}} (P_m - P_{max\,II} \sin\delta)\, d\delta + \int_{\delta_{cr}}^{\delta_{max}} (P_m - P_{max\,III} \sin\delta)\, d\delta = 0$$

on ~~sol~~ simplying, we get -

$$\delta_{cr} = \cos^{-1}\left[\frac{P_m(\delta_{max} - \delta_0) + P_{max3}\cos\delta_{max} - P_{max2}\cos\delta_0}{P_{max3} - P_{max2}}\right]$$

$$\delta_{cr} = \cos^{-1}\left[\frac{1(126.87 - 34.85) \times \frac{\pi}{180} + 1.25\cos 126.87 - 34.85\cos 34.85}{1.25 - 0.4}\right]$$

$\delta_{cr} = 0.9005$ rad

$\delta_{cr} = 51.59°$

$\boxed{\delta_{cr} = 52°}$ Ans.

Critical clearing Angle.

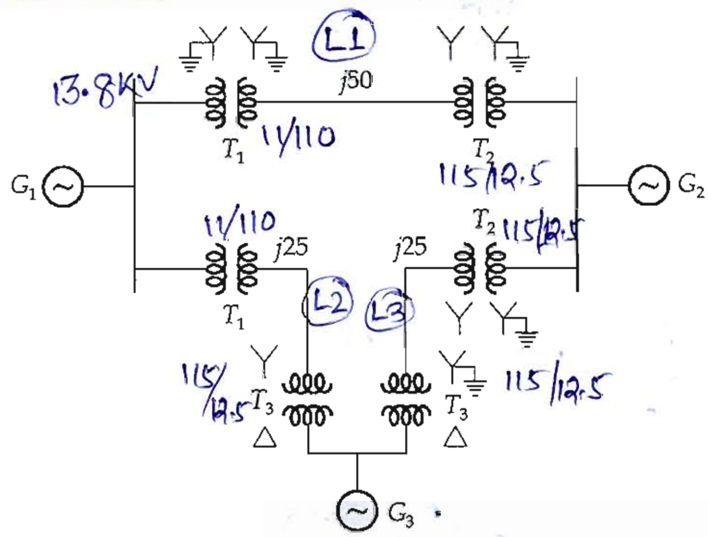
11

Good Approach

Q.2 (a) A 3-bus system is given in figure below. The ratings of the various components are listed below :

Generator 1 = 50 MVA;	13.8 kV;	$X'' = 0.15$ pu
Generator 2 = 40 MVA;	13.2 kV;	$X'' = 0.20$ pu
Generator 3 = 30 MVA;	11 kV;	$X'' = 0.25$ pu
Transformer 1 = 45 MVA,	11 kV Δ/110 kV Y,	$X = 0.1$ pu
Transformer 2 = 25 MVA,	12.5 kV Δ/115 kV Y,	$X = 0.15$ pu
Transformer 3 = 40 MVA,	12.5 kV Δ/115 kV Y,	$X = 0.1$ pu

The line impedances are shown in figure below. Determine the reactance diagram based on 50 MVA and 13.8 kV as base quantities in Generator 1.



[20 marks]

Sol^n:

Base MVA $S_B = 50$ MVA

Base voltage for gen 1 $V_B = 13.8$ KV

$$\boxed{X''_{G1} = 0.15 \text{ pu}}$$

For transformer 1

$S_{B,old} = \cancel{40}\ 45$ MVA | $S_{B,new} = 50$ MVA

$V_{B,old} = \cancel{13.2}\ 11$ KV | $V_{B,new} = 13.2$ KV

$$X_{T1} = X_{T1(old)} \times \left(\frac{V_{B,old}}{V_{B,new}}\right)^2 \times \frac{S_{B,new}}{S_{B,old}}$$

$$\boxed{X_{T1} = 0.1 \times \left(\frac{11}{13.2}\right)^2 \times \frac{50}{45} = 0.077 \text{ pu}}$$

For line 1 $\quad X_{L1} = \dfrac{X_{actual}}{X_{Base}} = \dfrac{j50}{380.88}$

$$X_{Base} = \frac{V_B}{I_B}$$

$$X_{Base} = \frac{V_B^2}{S_B}$$

$$X_{Base} = \frac{138^2}{50} = 380.88\ \Omega$$

$$\boxed{X_{L1} = j0.1313 \text{ pu}}$$

For line 2 $\quad \boxed{X_{L2} = \dfrac{j25}{380.88} = j0.0656 \text{ pu}}$

For T2

$$\frac{138}{V_{B,T2}} = \frac{115}{12.5}$$

$\boxed{V_{B,T2} = 15\,kV}$ on LT.

$$X_{T2} = 0.15 \times \left(\frac{12.5}{15}\right)^2 \times \frac{50}{25}$$

$$\boxed{X_{T2} = 0.2083}\ pu$$

For G2

$$\boxed{X_{G2} = 0.2 \times \left(\frac{12.2}{15}\right)^2 \times \frac{50}{40} = 0.1936\ pu}$$

for HT of T2

$V_{B,T2} = 138\,kV$

for Line 3

$$\boxed{X_{L3} = \frac{j25}{(138)^2} \times 50 = j0.0656\ pu}$$

For T3

$$\boxed{X_{T3} = 0.1 \times \left(\frac{115}{138}\right)^2 \times \frac{50}{40} = 0.0868\ pu}$$

For G3

for LT of T3

$V_{B,T3} = 15\,kV$

$$X_{G3} = 0.25 \times \left(\frac{11}{15}\right)^2 \times \frac{50}{30}$$

$$\boxed{X_{G3} = 0.224\ pu}$$

Now, as all the pu reactances are on same Base, we can shown them on reactance diagram.

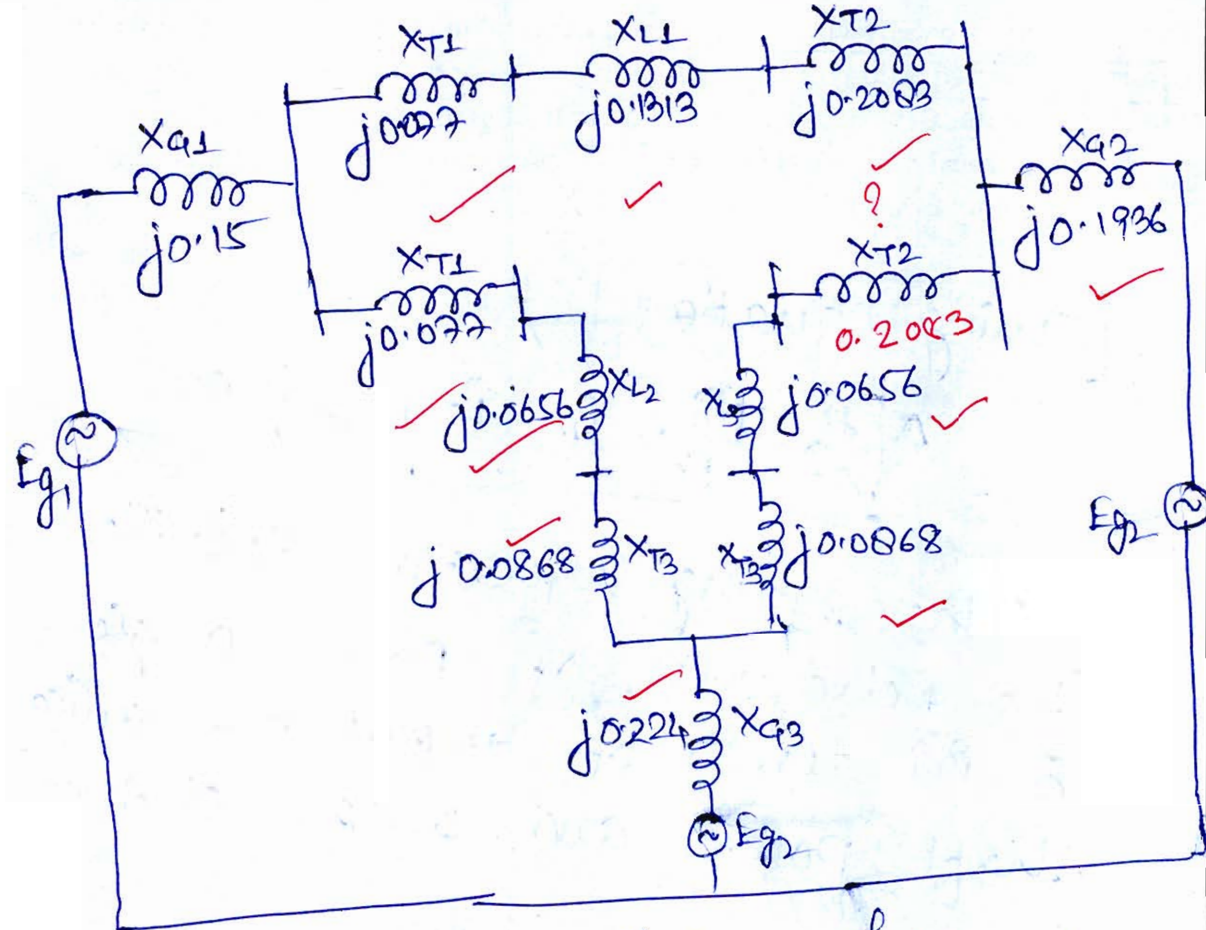


fig: reactance diagram of given system Ans

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Mention all value

X_{T2} is missing

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Q.2 (b) Explain briefly what is swing equation and use dynamics of angular motion with time to formulate the equation for a synchronous generator of inertia constant H in seconds run by a mechanical turbine with input power P_m in p.u. to deliver electrical power P_e in p.u. to the electrical network at f Hz in terms of power angle δ in radians measured from rotating reference of generator axis.

[20 marks]

Sol^n:

Swing equation

$$\boxed{\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_m - P_e}$$ (in pu)

The swing equation describes the behaviour of power angle δ in terms of input mechanical shaft power and output electrical power.

The swing eq^n is used in determining steady state stability of the sync. generator when disturbances is applied.

Derivation

$P_{sh} = P_m$ = shaft power or mechanical power

Mention motor and generator

T_m = mechanical torque

T_e = electrical torque

W_{sm} = sync. mechanical speed

W_s = sync. electrical speed

P = no. of poles, $W_{sm} = \frac{2W_s}{P}$

$$\boxed{J \frac{d^2\theta}{dt^2} = T_m - T_e} \quad \text{--- (1)}$$ ← Torque equation

$K.E = \frac{1}{2} J \omega_{sm}^2$

on converting in electrical domain

$K.E = \frac{1}{2} M \omega_s$
$= GH$

where,
M = inertia constant in $\frac{MJ\text{-sec}}{\text{electrical rad}}$

H = Inertia constant in $\frac{MJ}{MVA}$ or sec

from eqn (1), it can be written in terms of power as

$$\boxed{\frac{GH}{\pi f} \frac{d^2\delta}{dt^2} = P_m - P_e} \quad \text{--- (2)}$$ (in MW)

This eqn is known as swing eqn.

where, δ is power angle measured from rotating ref. of generator axis

eqn (2) can be written in per unit as

$$\boxed{\frac{H}{\pi f} \frac{d^2\delta}{dt^2} = P_m - P_e}$$ in pu

Hence derived.

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Q.2 (c) A 3-ϕ, 400 km, 50 Hz long transmission line with series impedance of $(0.15 + j0.78)\ \Omega/\text{km}$ and shunt admittance of $j5.0 \times 10^{-6}$ ℧/km. Determine *A*, *B*, *C*, *D* parameter of line assuming :

(i) The line could be represented by nominal-T.

(ii) The line could be represented by nominal-π.

(iii) The exact representation.

[20 marks]

Soln.

given length = 400 km

$f = 50\,Hz$

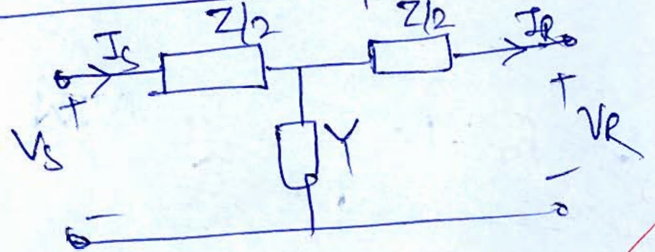
$z = (0.15 + j0.78)\ \frac{\Omega}{km}$

$y = j\,5\times10^{-6}\ \frac{℧}{km}$

$Z = z \times length = (0.15 + j0.78) \times 400 = 60 + j312\ \Omega$

$Y = y \times length = j5\times10^{-6} \times 400 = j2\times10^{-3}\ ℧$

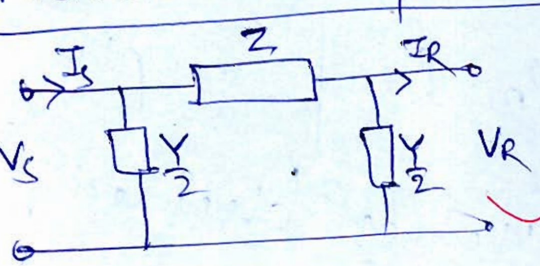
i) $\boxed{\text{Nominal T Representation}}$



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

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.690\angle 4.98^\circ & 268.3\angle 81.15^\circ \\ j2\times10^{-3} & 0.690\angle 4.98^\circ \end{bmatrix}$$ Ans

ii) $\boxed{\text{Nominal } \pi \text{ Representation}}$



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

$$= \begin{bmatrix} 0.690\angle 4.98^\circ & 317.7\angle 79.11^\circ \\ 1.689\times10^{-3}\angle 92.03^\circ & 0.690\angle 4.98^\circ \end{bmatrix}$$ Ans

iii) $\boxed{\text{exact Representation}}$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cosh\gamma l & Z_c \sinh\gamma l \\ \frac{1}{Z_c}\sinh\gamma l & \cosh\gamma l \end{bmatrix}$$

For Exact Representation Go Through the made easy Solution

$$\gamma l = l\sqrt{yz} = 400\sqrt{j5\times10^{-6}\times(0.15+j0.78)} = 0.7971\angle 84.55^\circ$$

$$\gamma l = \alpha l + j\beta l = 0.0757 + j0.7934$$

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$$Z_c = \sqrt{\frac{Z}{y}} = \sqrt{\frac{0.15+j0.78}{j5\times10^{-6}}} = 398.57\angle -5.44\,\Omega$$

$$\boxed{\cosh\gamma l = \frac{e^{\gamma l}+e^{-\gamma l}}{2} = 1.002\angle 0.059^\circ}$$

$$\boxed{\sinh\gamma l = \frac{e^{\gamma l}-e^{-\gamma l}}{2} = 0.077\angle 10.386^\circ}$$

$$e^{\gamma l} = e^{\alpha l + j\beta l} = e^{\alpha l}\angle\beta l = e^{0.0757}\angle 0.7934 = 1.078\angle 0.7934$$

$$e^{-\gamma l} = e^{-\alpha l - j\beta l} = e^{-\alpha l}\angle -\beta l = e^{-0.0757}\angle 0.7934 = 0.927\angle -0.7934$$

Do not write in this margin

$$Z_c \sinh\gamma l = (398.57\angle{-5.44})(0.077\angle 10.386)$$

$$Z_c \sinh\gamma l = 30.7\angle 4.94^\circ\ \Omega$$

$$\frac{\sinh\gamma l}{Z_c} = \frac{0.077\angle 10.386}{398.57\angle{-5.44}} = 1.93\times10^{-4}\angle 15.82^\circ$$

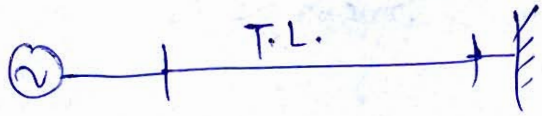
$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} \cosh\gamma l & Z_c \sinh\gamma l \\ \frac{1}{Z_c}\sinh\gamma l & \cosh\gamma l \end{bmatrix}$$

$$= \begin{bmatrix} 1.002\angle 0.059 & 30.7\angle 4.94 \\ 1.93\times10^{-4}\angle 15.82 & 1.002\angle 0.059 \end{bmatrix}$$

Q.3 (a) A 50 Hz generator is delivering 50% of the power that it is capable of delivering through a transmission line to an infinite bus. A fault occurs that increases the reactance between the generator and infinite bus to 400% of the value before the fault. When the fault is isolated, the maximum power that can be delivered is 80% of the original maximum value. Determine critical clearing angle for the condition described.

[20 marks]

Solⁿ:



Sol Prefault; $X_I = X$, P_{maxI}

during fault: $X_{II} = 4X$, P_{maxII}

post fault: $X_{III} =$, P_{maxIII}

prefault

$0.5 P_{maxI} = P_{maxI} \sin\delta_0$ (given)

$\boxed{\delta_0 = 30^\circ}$ and $P_{e1} = P_{maxI}\sin\delta$

$\boxed{\delta_0 = 0.5235 \text{ rad}}$ or $P_{e1} = \frac{EV}{X_I}\sin\delta$

during fault

$P_{e2} = P_{maxII}\sin\delta$

$P_{e2} = \frac{EV}{X_{II}}\sin\delta = \frac{EV}{4X_1}\sin\delta = 0.25\frac{EV}{X_1}\sin\delta$

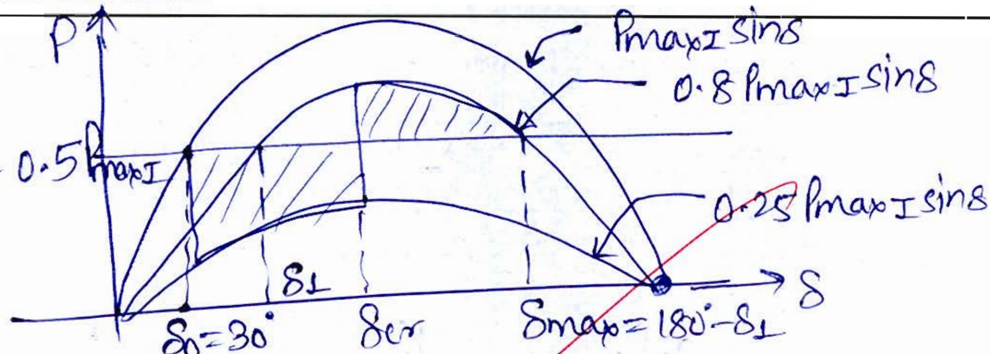
$\boxed{P_{e2} = 0.25 P_{maxI}\sin\delta}$

so, $P_{maxII} = 0.25 P_{maxI}$

Post ~~post~~ fault

given, $P_{maxIII} = 0.8 P_{maxI}$

P-δ



For δ_1 $\quad 0.5 P_{maxI} = 0.8 P_{maxI} \sin\delta_1$

$\boxed{\delta_1 = 38.68°}$ & so, $\delta_{max} = 141.31°$

$\boxed{\delta_{max} = 2.466 \text{ rad}}$

Equal Area Criteria

$$\int_{\delta_0}^{\delta_{max}} P_a d\delta = 0$$

$$\Rightarrow \int_{\delta_0}^{\delta_{cr}} (P_m - 0.25 P_{maxI}\sin\delta)\, d\delta + \int_{\delta_{cr}}^{\delta_{max}} (P_m - 0.8 P_{maxI}\sin\delta)\, d\delta = 0$$

on simplyfying, we get
critical angle

$$\delta_{cr} = \cos^{-1}\left[\frac{\overset{0.5 P_{maxI}}{P_m}(\delta_{max} - \delta_0) + P_{maxIII}\cos\delta_{max} - P_{maxII}\cos\delta_0}{P_{maxIII} - P_{maxII}}\right]$$

$$\delta_{cr} = \cos^{-1}\left[\frac{0.5 P_{max1}(2.466 - 0.5235) + 0.8 P_{max1}\cos 2.466 - 0.25 P_{maxI}\cos 0.5235}{0.8 P_{maxI} - 0.25 P_{maxI}}\right]$$

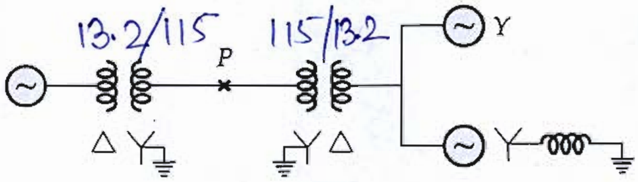
$\delta_{cr} = 1.3313$ rad

$\boxed{\delta_{cr} = 76.278°}$ Ans.

18

Good Approach

Q.3 (b) A 30 MVA, 13.8 kV, 3-phase alternator has a subtransient reactance of 15% and negative and zero sequence reactance of 15% and 5% respectively. The alternator supplies two motors over a transmission line having tensiometers of both-ends as shown on one line diagram. The motors having rated input of 20 MVA and 10 MVA both with 12.5 kV with 20% subtransient reactance and negative and zero sequence reactances are 20% and 5% respectively. Current limiting reactor of 2 Ω each are in the alternator and larger motor. The 3-phase transformers are both rated 35 MVA, 13.2 Δ - 115 Y kV with leakage reactance of 10%. Series reactance of the line is 80 Ω. The zero sequence reactance of the line is 200 Ω. Determine the fault current when (i) L-G, (ii) L-L, (iii) LLG and fault takes place at point *P*.



(Assume, V_f = 120 kV)

[20 marks]

Sol^n

given

G1

$X_{g1} = 0.15$

$X_{g2} = 0.15$

$X_{g0} = 0.05$

Assuming

Base MVA = 30 MVA (S_B)

Voltage Base G1, $V_B = 13.8$ kV

for T1 & T2

$X_T = 0.1 \times \left(\frac{13.2}{13.8}\right)^2 \times \frac{30}{35}$

$X_T = 0.0784$

for motors : 20 MVA, 12.5 kV

$X_{m1} = 0.2 \times \left(\frac{12.5}{13.8}\right)^2 \times \frac{30}{20} = 0.246$

$X_{m2} = X_{m1} = 0.246$

$X_{m0} = 0.05 \times \left(\frac{12.5}{13.8}\right)^2 \times \frac{30}{20} = 0.0615$

for Trans. Line

$V_{Base} = 120.22$ kV

$X_{L1} = \frac{80 \times 30}{(120.22)^2}$

$X_{L1} = 0.166 = X_{L2}$

8

$X_{L0} = \frac{200 \times 30}{(120.22)^2}$

$X_{L0} = 0.415$ pu

for motor 10 MVA, 12.5 kV

$X_{m1} = X_{m2} = 0.2 \times \left(\frac{12.5}{13.8}\right)^2 \times \frac{30}{10}$

$X_{m1} = X_{m2} = 0.4923$

$X_{m0} = 0.05 \times \left(\frac{12.5}{13.8}\right)^2 \times \frac{30}{10} = 0.123$

$X_{mL} = \frac{2}{\frac{(13.8)^2}{30}} = 0.315$

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It can be done , But too lengthy

Incomplete solution

Q.3 (c) (i) Give the methods of improving string efficiency for an insulator.

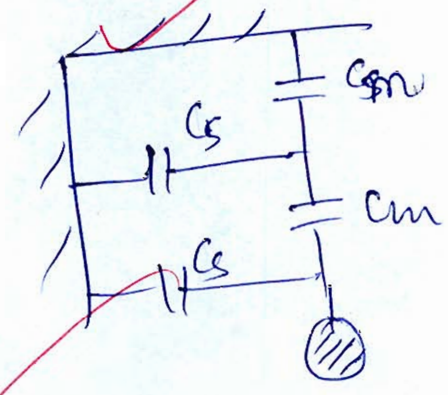
(ii) A transmission line has a span of 375 m between level supports. The conductor has an effective diameters of 1.96 c.m. and weight 0.865 kg/m. Its ultimate strength is 9060 kg. If the conductor has ice coating of radial thickness 1.27 c.m. and subjected to a wind pressure of 3.9 gm/cm^2 of projected area. Calculate sag for a safety factor of 2. (Weight of 1 c.c. of ice is 0.91 gm).

[8 + 12 marks]

Soln:

Methods to improve string efficiency

(1) By increasing the cross-arm length.



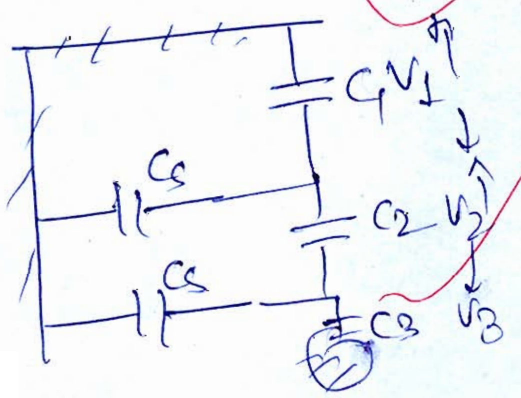
$m = \frac{Cm}{CS}$

As m increases.

η improves.

(2) By grading the dielectric ~~ttoo~~.
i.e. using different values Cm such that

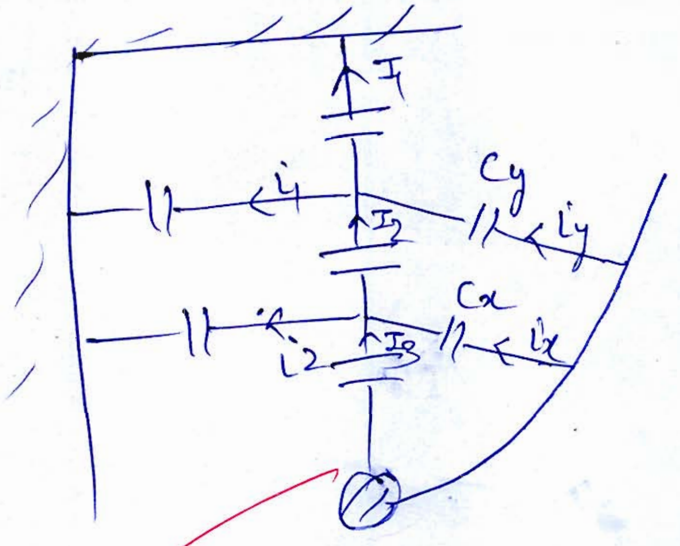
Choose C_1 & C_2, C_3 such that



$V_1 = V_2 = V_3$.

so, η $\uparrow$es. to 100%.

(2) By using ring



6

Such that $i_2 = i_x$
& $i_1 = i_y$

choose such angle / distance that would make C_x, C_y
$\rightarrow i_2 = i_x$
$i_1 = i_y$

this would res η to 100%

Write solution in detail.

Q.4 (a) A star connected 3-phase, 10 MVA, 6.6 kV alternator has a per phase reactance of 20%. It is protected by Merz-price circulating current principle not less than 170 A. Calculate of the value of earthing resistance to be provided in order to ensure that only 20% of the alternator winding remains unprotected.

[20 marks]

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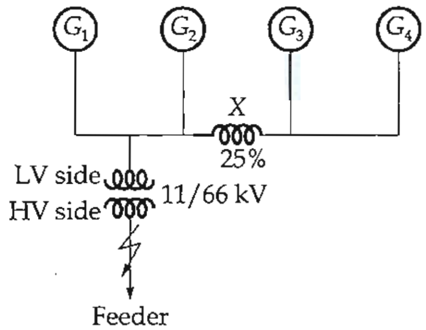
Q.4 (b) A generating station has four identical generators, G_1, G_2, G_3 and G_4 each of 20 MVA, 11 kV having 20% reactance. They are connected to a busbar which has a busbar reactor of 25% reactance on 20 MVA base, inserted between G_2 and G_3 as shown below. A 66 kV feeder is taken off from the bus bars through a 15 MVA, 11/66 kV transformer having 7.5% reactance. A symmetrical 3-phase fault occurs at the high voltage terminals of the transformers. Calculate the current fed into the fault.



[20 marks]

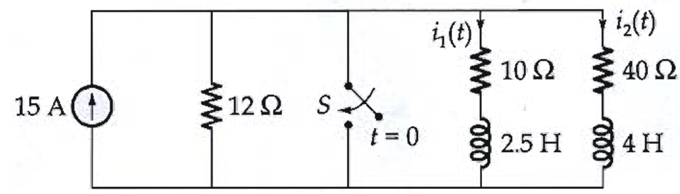
Do not write in this margin

Q.4 (c) A string of six insulation unit has mutual capacitance 10 times the capacitance to ground. Determine the voltage across each unit as a fraction of the operating voltage. Also, determine string efficiency.

[20 marks]

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

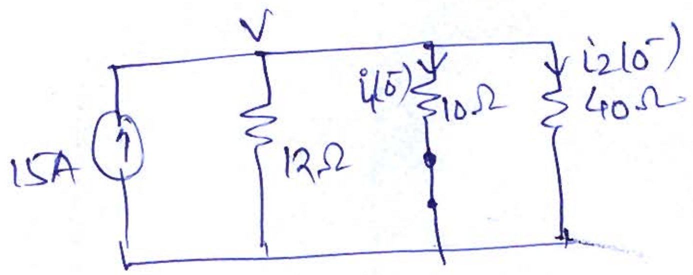
Q.5 (a) The switch 'S' in the circuit shown below is opened for a long time and closed at $t = 0$. Find the time domain expressions for currents $i_1(t)$ and $i_2(t)$ for $t > 0$.



[12 marks]

for t=0⁻ Assuming circuit in steady state

So



KCL
$$V\left(\frac{1}{12}+\frac{1}{10}+\frac{1}{40}\right)=15$$

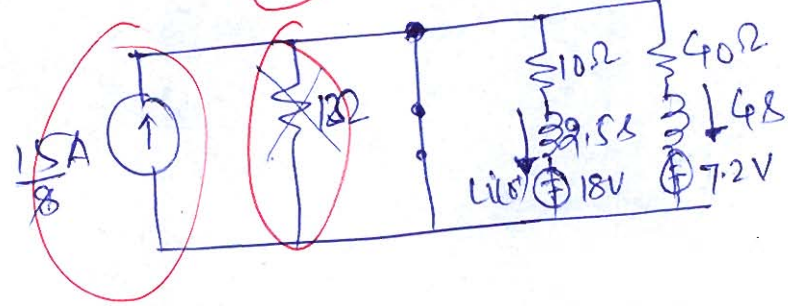
$$V = 72\,V$$

$$i_1(0^-) = \frac{72}{10} = 7.2\,A = i_1(0^+)$$

$$i_2(0^-) = \frac{72}{40} = 1.8\,A = i_2(0^+)$$

4

for t=0⁺
in s domain



Incomplete solution

Do not write in this margin

Q.5 (b) The open-loop transfer function of a unity feedback control system is given by

$$G(s) = \frac{K}{s(s+2)}$$

The system is to have 25% maximum overshoot and peak time 1.0 second. Determine the value of K and tachometer feedback constant K_t.

[12 marks]

Sol^n.

$\% M_p = 25\%$ $\quad M_p = 0.25$

$t_p = 1$ sec $\quad CLTF = \frac{K}{s^2+2s+K}$

so, $\boxed{\omega_n = \sqrt{K}}$

$2\xi\omega_n = 2$

$\boxed{\xi = \frac{1}{\omega_n} = \frac{1}{\sqrt{K}}}$

$M_p = e^{-\pi\xi/\sqrt{1-\xi^2}}$

$0.25 = e^{-\pi\xi/\sqrt{1-\xi^2}}$

$\boxed{\xi = 0.4037}$

$\therefore \boxed{K = \frac{1}{\xi^2} = 6.135}$ $\quad$ & $\omega_n = 2.476$ rad/sec

for

$t_p = \frac{\pi}{\omega_d} \Rightarrow \boxed{\omega_d = \frac{\pi}{t_p} = \frac{\pi}{1} = 3.14}$

$\omega_n\sqrt{1-\xi^2} = 3.14$

$\omega_n\sqrt{1-0.4037^2} = 3.14$

$\omega_n = 3.432$ rad/sec

so, given system can not provide $M_p = 25\%$ & $t_p = 1$ sec at the same time Now

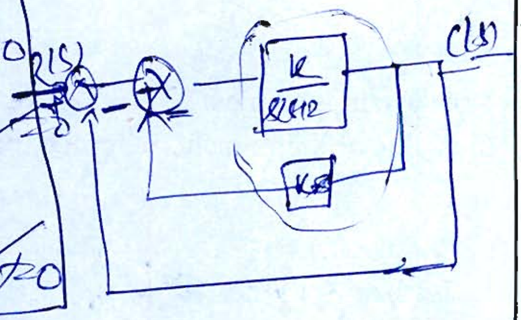
~~$H(s) = K_r \cdot s$~~

~~So, Ch. eq^n~~

~~$1 + G(s)H(s) = 0$~~

~~$1 + \frac{K}{s(s+2)} \cdot K_r s = 0$~~

~~$s^2 + 2s + K \cdot K_r s = 0$~~



$$G'(s) = \frac{\frac{K}{s(s+2)}}{1 + \frac{K}{s(s+2)} \cdot K_r s} = \frac{K}{s^2 + (2 + KK_r)s}$$

now:

$$\text{CLTF} = \frac{G'(s)}{1 + G'(s)} = \frac{K}{s^2 + (2 + KK_r)s + K}$$

So, $\boxed{\omega_n = \sqrt{K}}$ — ①

$2\xi\omega_n = 2 + KK_r$

$\boxed{\xi = \frac{2 + KK_r}{2\sqrt{K}}}$ — ②

for $\xi = 0.4037$ & $\omega_n = 3.432$

$\boxed{K = \omega_n^2 = 11.778}$ Ans

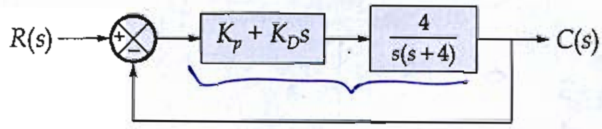
$$0.4037 = \frac{2 + 11.778 \times K_r}{2 \times 3.432}$$

$\boxed{K_r = 0.0654}$ Ans

11

Good Approach

Q.5 (c) A control system with PD controller is shown below :



Determine the value of K_P and K_D such that the damping ratio of the system will be 0.75 and the steady state error for unit ramp input will be 0.20.

[12 marks]

Soln:

$$G(s) = \frac{4(K_p + K_D s)}{s(s+4)}$$

$$T(s) = \frac{G(s)}{1+G(s)} = \frac{\frac{4(K_p + K_D \cdot s)}{s(s+4)}}{1 + \frac{4(K_p + K_D s)}{s(s+4)}}$$

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

$4K_p = \omega_n^2$

$\omega_n = 2\sqrt{K_p}$

on comparing

$2\xi\omega_n = 4 + 4K_D$ —(1)

$\boxed{2\xi\omega_n = 4(1+K_D)}$ —(1)

given $\xi = 0.75$

$\frac{2 \times 0.75 \times 2\sqrt{K_p}}{4} = 1 + K_D$

$\boxed{1 + K_D = 0.75\sqrt{K_p}}$ —(2)

for unit ramp

$K_v = \lim_{s \to 0} sG(s)$

$K_v = \lim_{s \to 0} s \cdot \frac{4(K_p + K_D \cdot s)}{s(s+4)} = K_p$

~~given~~ $e_{ss} = \frac{1}{K_v} = \frac{1}{K_p} = 0.2$ (given)

so, $\boxed{K_p = 5}$ Ans

put in eqn (2)

$1+K_D = 0.75\sqrt{5}$

$\boxed{K_D = 0.677}$ Ans

11

Good Approach

Q.5 (d) The Fourier transform $X(\omega)$ of a continuous time periodic signal $x(t)$ is given by

$$X(\omega) = j\delta\left(\omega - \frac{\pi}{3}\right) + 2\delta\left(\omega - \frac{\pi}{7}\right)$$

Determine :

(i) The fundamental frequency of the signal $x(t)$.

(ii) The complex Fourier series coefficients of the signal $x(t)$.

(iii) The time domain expression of $x(t)$.

[12 marks]

Sol^n: we know

$$\delta(t) \longleftrightarrow 1$$

using dual property

$$1 \longleftrightarrow 2\pi\delta(-\omega) \quad \text{or} \quad 2\pi\delta(\omega)$$

So,

$$1 \xrightleftharpoons{FT} 2\pi\delta(\omega)$$

$$\frac{1}{2\pi} \xrightleftharpoons{FT} \delta(\omega)$$

$$\frac{e^{-\pi/3\, t}}{2\pi} \xrightleftharpoons{FT} \delta\left(\omega - \frac{\pi}{3}\right) \quad \text{--- (1)}$$

$$\frac{e^{-\pi/7\, t}}{2\pi} \xrightleftharpoons{FT} \delta\left(\omega - \frac{\pi}{7}\right) \quad \text{--- (2)}$$

So,

$$X(\omega) = j\delta\left(\omega - \frac{\pi}{3}\right) + 2\delta\left(\omega - \frac{\pi}{7}\right)$$

$$X(\omega) \rightleftharpoons x(t) = j\frac{e^{-\frac{\pi}{3}t}}{2\pi} + 2\frac{e^{-\frac{\pi}{7}t}}{2\pi}$$

$j = e^{j\frac{\pi}{2}}$

$$\boxed{x(t) = \frac{e^{\left(-\frac{\pi}{3}t + j\frac{\pi}{2}\right)} + 2e^{-\frac{\pi}{7}t}}{2\pi}} \quad \text{Ans}$$

$e^{-t/\tau} \Rightarrow$ time period τ

So, $\omega_1 = \frac{\pi}{3}$, $\omega_2 = \frac{\pi}{7}$

fundamental freq., $\omega = HCF(\omega_1, \omega_2)$

$$\boxed{\omega = \frac{HCF(\pi, \pi)}{LCM(3,7)} = \frac{\pi}{21}} \text{ rad/sec}$$

$$2\pi f = \frac{\pi}{21}$$

$$\boxed{f = \frac{1}{42}} \text{ /sec}$$

6

6

Incomplete

Solution

Do not write in this margin

Q.5 (e) Explain the following instructions:

(i) XCHG (ii) IN (iii) OUT (iv) DAA

[12 marks]

Ans (i) XCHG: Change the content stored in (H, L) ~~and~~ with other register pair (D, E)

so, $(H, L) \leftrightarrow (D, E)$

ii) IN: To get the 8-bit data from the location which is connected as input devices.

$A \leftarrow IN(PORT)$

iii) OUT: To store the 8-bit data at the location which is connected as output device

$A \rightarrow OUT(Port)$

iv) DAA: Decimal Adjustment

When two BCD nos. are used in calculation; then DAA provides the valid BCD number after the calculation.

$A_7\ A_6\ A_5\ A_4\ A_3\ A_2\ A_1\ A_0$

$B_7\ B_6\ B_5\ B_4\ B_3\ B_2\ B_1\ B_0$ SUM

$\underbrace{S_7\ S_6\ S_5\ S_4}\ \underbrace{S_3\ S_2\ S_1\ S_0}$

If not valid BCD or Cy = 1 then Add 0110 0000

If not valid BCD or AC = 1 then Add 0000 0110

This work is done by DAA.

10

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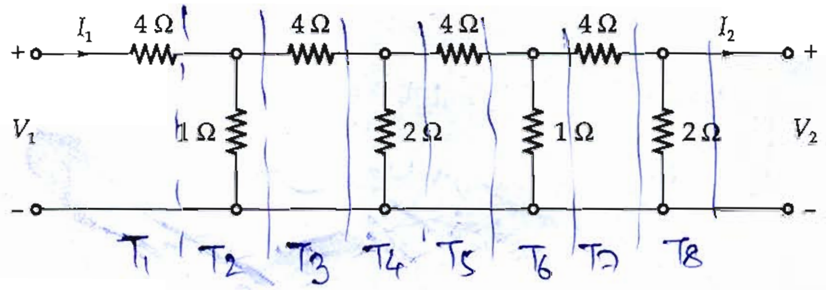
Q.6 (a) (i) Two 2-port network are connected in cascade. Prove that the overall transmission parameter matrix equals to the multiplication of individual transmission parameter matrices.

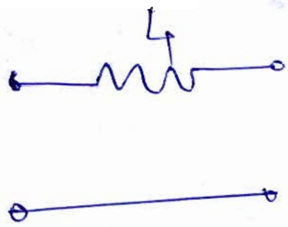
(ii) Determine the transmission parameters of the 2-port network shown in the figure below:



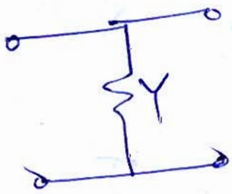
[20 marks]

Solⁿ:

(ii) ∵



$$\Rightarrow T = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 4 \\ 0 & 1 \end{bmatrix}$$



$$\Rightarrow T = \begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$$

So,

$$T = T_1 \cdot T_2\, T_3\, T_4 \cdot T_5 \cdot T_6 \cdot T_7 \cdot T_8$$

$$T = \underbrace{\begin{bmatrix} 1 & 4 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}}\underbrace{\begin{bmatrix} 1 & 4 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ \frac{1}{2} & 1 \end{bmatrix}}\underbrace{\begin{bmatrix} 1 & 4 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}}\begin{bmatrix} 1 & 4 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ \frac{1}{2} & 1 \end{bmatrix}$$

$$T = \underbrace{\begin{bmatrix} 5 & 4 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 3 & 4 \\ \frac{1}{2} & 1 \end{bmatrix}}\begin{bmatrix} 5 & 4 \\ 1 & 1 \end{bmatrix}\begin{bmatrix} 3 & 4 \\ \frac{1}{2} & 1 \end{bmatrix}$$

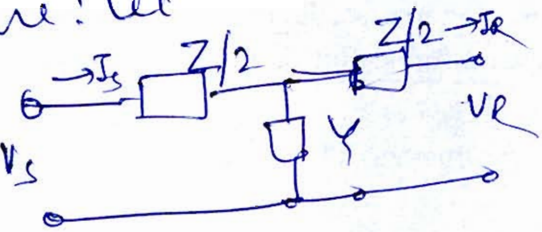
$$T = \begin{bmatrix} 17 & 24 \\ 3.5 & 5 \end{bmatrix}\begin{bmatrix} 17 & 24 \\ 3.5 & 5 \end{bmatrix}$$

$$\boxed{T = \begin{bmatrix} 373 & 520 \\ 77 & 109 \end{bmatrix}}$$ Ans.

10

(i)

To prove: let



on solving

$$T = \begin{bmatrix} 1+\frac{YZ}{2} & Z\left(1+\frac{YZ}{4}\right) \\ Y & 1+\frac{YZ}{2} \end{bmatrix}$$

Now let find

$T_1 \cdot T_2 \cdot T_3$

2

$$T_1 \cdot T_2 \cdot T_3 = \begin{bmatrix} 1 & Z/2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix} \begin{bmatrix} 1 & Z/2 \\ 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1+\frac{YZ}{2} & Z\left(1+\frac{YZ}{4}\right) \\ Y & 1+\frac{YZ}{2} \end{bmatrix} = T$$

Hence proved

Go through the made easy solution

Q.6 (b) (i) Explain the similarities and differences between :

1. JUMP and CALL instructions.
2. STA and STAX instructions.

[10 marks]

Ans

JUMP	CALL

Similarities → Both are used to change the normal flow of program.

Differences:
In JUMP → present Address of PC is not stored.

In CALL: PC is stored in STACK so possible to return back to program after serving subroutine

STA & STAX: Similarly Both are used to store the content of Accumulator in memory.

6

Diff: STA save the Accumulator content to given memory Address. (location) ← A

STAX: STAX saves the content of accumulator to that memory location whose Address is available in the register pair.

Q.6 (b) (ii) Write an assembly language program for an 8085 microprocessor, to find 2's complement of a 16-bit number. Write comments for selected instructions.

[10 marks]

Soln.

Algorithm

1) Store no. in register pair. (H,L)

2) XRA content A X L and save in DE.

3) ~~Add double Addition~~ Add 1 by INX D.

Now It has the 2's complement of given 16 bit no.

3

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Q.6 (c) Check whether given signal $x(t) = \sum_{n=-\infty}^{\infty} e^{-(2t-n)}u(2t-n)$ is periodic. If yes, compute its average power.

[20 marks]

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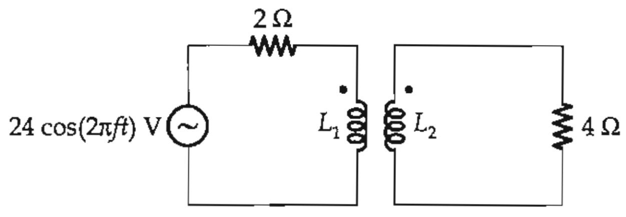
Q.7 (a) The coupled circuit shown below has a coefficient of coupling $K = 1$. Determine the energy stored in the mutually coupled inductor at $t = 5$ msec.

$L_1 = 3.185$ mH; $L_2 = 12.74$ mH; $f = 50$ Hz



[20 marks]

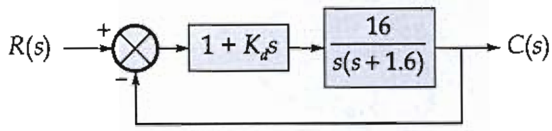
Q.7 (b) Obtain eigen values, eigen vectors and the state model in canonical form for a system described by

$$\dot{x}(t) = \begin{bmatrix} 0 & 1 & 0 \\ 3 & 0 & 2 \\ -12 & -7 & -6 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 0 \\ 2 \end{bmatrix} u(t)$$

$$y(t) = [1 \;\; 0 \;\; 0]\, x(t)$$

[20 marks]

Q.7 (c) A control system employing proportional and derivative control as shown below, has damping ratio equal to 0.8. Find the time instant at which the step response of system attains the peak value. Also find the percent maximum overshoot of system.



[20 marks]

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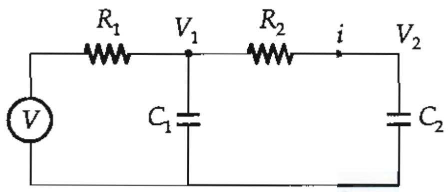
Q.8 (a) (i) Determine the state model for the network shown below considering $V_1 = x_1$; $V_2 = x_2$ and $y = i$.



[10 marks]

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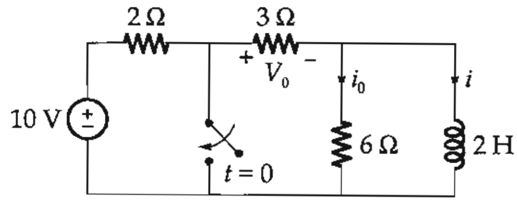
Q.8 (a) (ii) In the circuit shown below:



Find i_0, V_0 and i for all time, assuming that the switch was open for a long time.

[10 marks]

Do not write in this margin

Q.8 (b) Consider a discrete time system with input $x(n)$ and output $y(n)$ related by

$$y(n) = \sum_{k=n-n_0}^{n+n_0} x(k)$$

where n_0 is a finite positive integer

(i) Is this system linear?

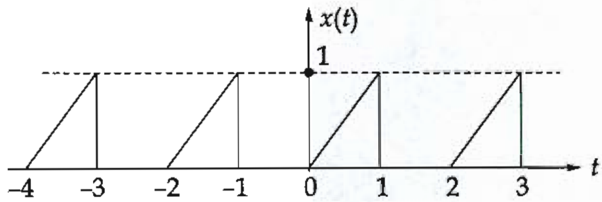
(ii) Is this system time-invariant?

(iii) If $x(n)$ is known to be bounded by a finite integer B_x [i.e. $|x(n)| < B_x$ for all n], it can be shown that $y(n)$ is bounded by a finite number C. We conclude that the given system is stable. Express C in terms of B_x and n_0.

[20 marks]

Do not write in this margin

Q.8 (c) Find the trigonometric Fourier series for the waveform shown in figure and sketch the line spectrum.



[20 marks]

OOOO

Space for Rough Work

Space for Rough Work