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ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-15: Full Syllabus Test

Paper-II

Name : Kartikeya Singh

Roll No : E B 1 9 M B D L A 7 3 2

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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. 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.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	41
Q.2	53
Q.3	53
Q.4	
Section-B	
Q.5	47
Q.6	57
Q.7	
Q.8	
Total Marks Obtained	251

Signature of Evaluator: K. Sudharshan
Cross Checked by: K. Sudharshan

32875

32

98·621

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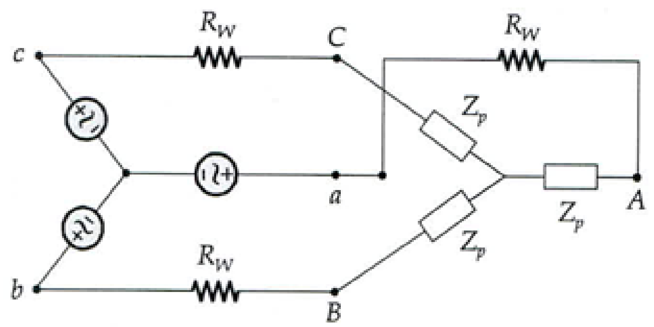
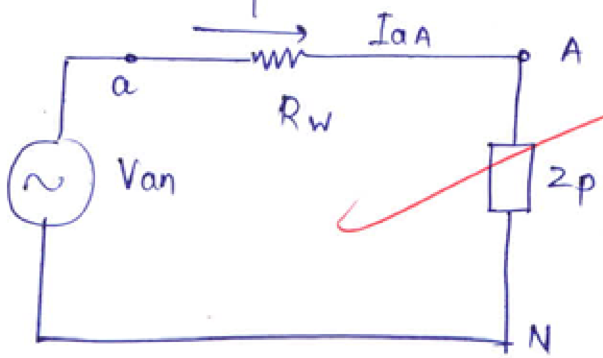
Section-A

a) Let $V_{an} = 2300\angle 0°$ V rms in the balanced system shown in figure below, and set $R_W = 2\,\Omega$. Assume positive phase sequence with the source supply a total complex power of $S = (100 + j30)$ kVA. Find **(i)** I_{aA} **(ii)** V_{AN} **(iii)** Z_p and **(iv)** the transmission efficiency.



[12 marks]

per phase equivalent circuit



Now

Total Complex power = (100 + j30) KVA

$3 V_{ph} I_{ph}^* = 104.40 \angle 16.69$ KVA

$3 \times V_{an} I_{aA}^* = 104.40 \angle 16.69$ KVA

$I_{aA}^* = \dfrac{104.40 \times 10^3}{3 \times 2300} \angle 16.69$

$\boxed{I_{aA} = 15.13 \angle -16.69 \text{ Amp}}$

Complex input power supplied = Power consumed (Complex)

$(100 + j30) \times 10^3 = (15.13)^2 (2 + Z_p) \times 3$

$Z_p = 143.613 + 43.68j\ \Omega$

$\boxed{Z_p = 150.108 \angle 16.917\Omega}$

$V_{AN} = \dfrac{V_{an} \times Z_p}{Z_p + R_W}$

$V_{AN} = \dfrac{2300 \times (150.108 \angle 16.917)}{2 + 150.108 \angle 16.917}$

$\boxed{V_{AN} = 2271.083 \angle 0.219 \text{ Volts.}}$

Do not write this

Transmission efficiency = $\frac{\text{Real power at load}}{\text{Real power supplied.}} \times 100$

$= \frac{3 \times 15.13^2 \times 143.613}{100 \times 10^3} \times 100$

$= \underline{98.625\%}$

12

Q.1 (b) A 24-slot (2 layers), 2 pole dc machine with 18 turns per coil has wave winding. The average flux density per pole is 1 T. The effective length of machine is 20 cm and radius of armature is 10 cm. The magnetic poles are designed to cover 80% of the armature periphery. If armature angular velocity is 183.2 rad/sec,

Determine:

(i) The induced emf in the armature winding.

(ii) The induced emf per coil.

(iii) Induced emf per turn.

(iv) The induced emf per conductor.

[12 marks]

i) Induced EMF = $\frac{P\phi NZ}{60A}$

for wave winding => $P = A$

$E = \frac{\phi NZ}{60}$

for double layer winding

No. of slots = No. of coils

24 = Coils

hence No. conductors

$Z \Rightarrow 24 \times 18 \times 2$

$= 864$

$N = 183.2 \times \frac{60}{2\pi} = 1749.43$ rpm

ϕ (per pole) = B × Area per pole

$= 1 \times \frac{\pi D l}{P} \times 0.8$

$= \frac{1 \times \pi \times 20 \times 10^{-2} \times 20 \times 10^{-2}}{2} \times 0.8$

$= 0.8 \times 0.06283$ Wb $= \underline{0.05026 \text{ Wb}}$

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hence $E = 0.05026 \times 1749.43 \times 864/60$

$E =$ ~~1582.8 Volts~~ 1266.24 Volts.

→ EMF per coil $= \dfrac{\text{Total EMF}}{\text{No. of coils per parallel path.}}$

$= \dfrac{1266.24}{(24/2)}$ (A = 2, Coils = 24)

$= 105.511$ Volts

→ EMF per turn $= \dfrac{\text{EMF of coil}}{\text{No. of turns in coil}}$

$= \dfrac{105.511}{1.8}$

$= 5.8617$ Volts

12

→ EMF per conductor $= \dfrac{\text{EMF of turn}}{2}$

$= \dfrac{5.8617}{2}$

$= 2.9308$ volts

Do not write this

Q.1 (c) In a single phase full bridge PWM inverter, the input DC voltage varies in a range of 295 – 325 V. Because of low distortion required in the output V_0, $m_a \le 1.0$.

(i) What is the highest V_{01} that can be obtained and stamped on its name plate as its voltage rating?

(ii) Its volt ampere rating is specified as 2000 VA, that is, $V_{01} \times I_0 = 2000$ VA where i_0 is assumed to be sinusoidal.

Calculate the combined switch utilization ratio when the inverter is supplying its rated volt amperes.

[12 marks]

(i) $V_{01} = m_A \times V_{DC}$

V_{01} (higthest) $= (m_A \times V_{DC})$ highest

$= (1 \times 325)$

$= 325$ Volt (peak)

$\frac{V_{01p} I_{01p}}{2} = 2000$

$I_{01(peak)} = \frac{4000}{325}$

$I_{01(peak)} = I_{SW} = 12.307$

(ii) Switch utilization ratio.

$SUR \Rightarrow \frac{(V_0 \cdot I_0)}{n(V_{sw}\ I_{sw})} \times 100$

n = number of switches.

V_{sw} = max voltage across

I_{sw} maximum current through switch

$SUR \Rightarrow \frac{2000}{n \times V_{SW} \times I_{sw}} \times 100$

$SUR = \frac{2000}{4 \times 325\ I_{sw}} \times 100.$

$SUR = 0.125 \times 100$

$SUR = 12.5\%$

$\frac{~~1.5384~~}{~~12.307~~}$

$\frac{~~1.5384~~}{~~8.7028~~}$

$= ~~0.176~~$

~~$I_{orms} \times V_{orms}$~~

~~$I_{supply\,rms}$~~

$= \frac{~~2000~~}{~~325~~}$

$= ~~6.1538~~$

~~I_{omax}~~ $= I_{sw(peak)}$

$= ~~8.7028~~$

~~$I_{orms\,peak} \times V_{rms\,pe}$~~

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d) (i) SBI bank hyderabad branch vault has 3 locks with a different key for each lock. Each key is owned by different person. In order to open the door atleast two people must insert their keys into the assigned locks. The signal lines, A, B and C are 1 if there is a key inserted into lock 1, 2 or 3 respectively. Find Boolean expression for the variable Z which is 1 if the door is open?

[8 marks]

To open the door at least 2 Keys are required / 2 people

A	B	C	Z (o/p)
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

8

hence preparing K map

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	0	1	1 3	2
A	4	1 5	1 7	1 6

$$\boxed{Z = AC + BC + AB}$$

Do writ this

Q.1 (d) **(ii)** Give the limitations of *K*-map?

[4 marks]

K map is powerful tool to solve the boolean expression but it has following limitation.

→ K map becomes very tidious to solve when no. of variables in the expression are more than 4 or 5.

→ K map can't precisely obtain the multiple expression if possible(

→

4

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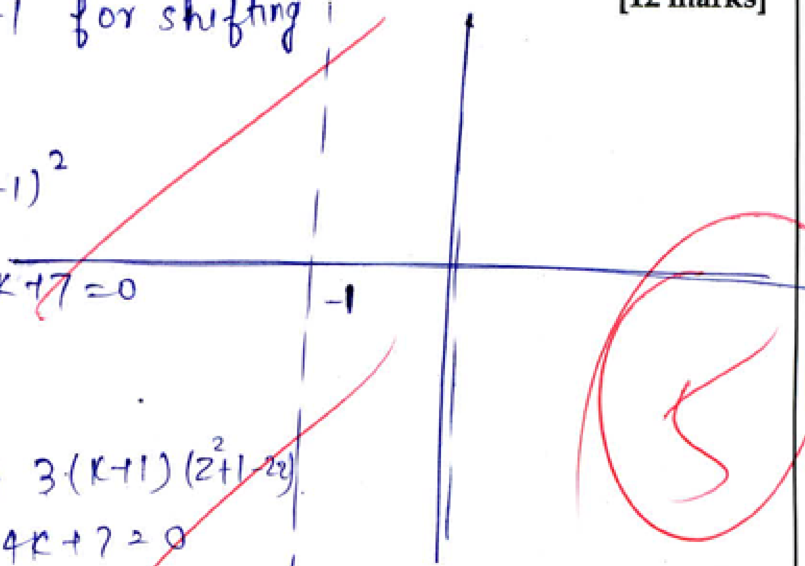
e) Determine the range of values of K ($K > 0$) such that the following characteristic equation has roots more negative than $s = -1$.

$$s^3 + 3(K+1)s^2 + (7K+5)s + (4K+7) = 0$$

[12 marks]

Replace s by $z-1$ for shifting to axes at $s = -1$



$(z-1)^3 + 3(K+1)(z-1)^2 + (7K+5)(z-1) + 4K+7 = 0$

$z^3 - 1 - 3z(z-1) + 3(K+1)(z^2+1-2z) + (7K+5)(z-1) + 4K+7 = 0$

$z^3 - 3z^2 + 3z - 1 + 3(K+1)z^2 + 3(K+1) - 6(K+1)z + (7K+5)z - (7K+5) + 4K+7 = 0$

$z^3 + 3Kz^2 + (7K+5-6K-6+3)z + 3K+3 + 4K+7 - (7K+5) = 0$

$z^3 + 3Kz^2 + (K+2)z + 5 = 0$

preparing routh hurtwitz table

z^3	1	$K+2$
z^2	$3K$	5
z^1	$\frac{3K(K+2)-5}{3K}$	0
z^0	5	

Neccessary conditions $3K > 0$, $K > 0$ $\quad K+2 > 0$, $K > -2$

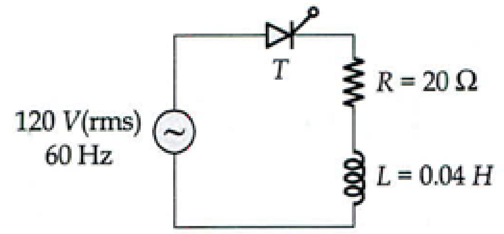
sufficient condition $3K(K+2) - 5 > 0$

$3K^2 + 6K - 5 > 0 \Rightarrow K > .6329$, $K < -2.632$

hence common condition is

$K > 0.6329$

Q.2 (a) For the circuit shown below:



If the delay angle is 45°,
then determine:

(i) an expression for $i(\omega t)$.

(ii) the average load current.

(iii) the power absorbed by the load.

(iv) the power factor.

[20 marks]

When SCR is ON $\qquad \omega = 120\pi$ rad/sec

$$120\sqrt{2}\sin\omega t = Ri + L\frac{di}{dt}$$

$$120\sqrt{2}\sin\omega t = 20i + 0.04\frac{di}{dt}$$

Now

$$i = \frac{120\sqrt{2}\sin\left(\omega t - \tan^{-1}\left(\frac{15.079}{20}\right)\right)}{\sqrt{(20)^2 + (120\pi \times 0.04)^2}} + Ae^{-t/\tau}$$

$$i(\omega t) = 6.775\sin(\omega t - 37.014°) + Ae^{-\omega t/\omega\tau}$$

$$i(\omega t) = 6.775\sin(\omega t - 0.646^R) + Ae^{-\omega t/0.7539}$$

at $\omega t = \alpha$ $\qquad i(\omega t) = 0$
$= 45°$

$$0 = 6.775\sin(45 - 37.014) + Ae^{-\frac{45° \times \pi}{180 \times 0.7539}}$$

$$A = -2.6677$$

hence

$$\boxed{i(\omega t) = 6.775\sin(\omega t - 0.646^R) - 2.6677e^{-\frac{\omega t}{.7539}}}$$

Now at $\omega t = \beta$ current becomes zero

$$0 = 6.775 \sin(\beta - 0.646) - 2.6677 e^{-\beta/.7539}$$

$$\beta = \cancel{0.7853} \quad 3.7849 \text{ Rad}$$

$$\beta = 216.85^\circ$$

Average load current

$$i_{av} = \frac{1}{2\pi}\int_\alpha^\beta i(\omega t)\, d(\omega t)$$

$$i_{av} = \frac{1}{2\pi}\int_{\pi/4}^{3.7849}\left(6.77 \sin(\omega t - 0.646) - 2.667 e^{-\omega t/.7539}\right) d(\omega t)$$

$$i_{av} = \frac{12.788}{2\pi} = 2.035 \text{ Amp.}$$

$$i_{rms} = \left[\frac{1}{2\pi}\int_\alpha^\beta i^2(\omega t)\, d(\omega t)\right]^{1/2}$$

$$i_{rms} = \left[\frac{1}{2\pi}\int_{\pi/4}^{3.7849}\left[6.775 \sin(\omega t - .646) - 2.667 e^{-\omega t/.7539}\right]^2 d(\omega t)\right]^{1/2}$$

$$i_{rms} = \left[\frac{1}{2\pi} \times 66.87\right]^{1/2} = 3.2625 \text{ Amp}$$

20

Power delivered to load $= i_{rms}^2 \times R$

$$= (3.2625)^2 \times 20$$

$$= 212.87 W$$

$$Pf = \frac{I_{rms}^2 R_L \quad \cancel{V_{rms} I_{rms}}}{V_{srms} I_{srms}} = \frac{I_{rms}^2 R_L}{V_{srms} I_{srms}}$$

$$Pf = \frac{3.2625 \times 20}{120} = 0.54375$$

$270 - \tan^{-1}\omega/2$

Q.2 (b) A control system is represented by unity feedback control system $G(s) = \frac{Ks^3}{(s+1)(s+2)}$.

Draw Nyquist plot for above system. At what value of ω does Nyquist plot interests the negative real axis. Comment on stability of system by analysis of drawn Nyquist plot for different values of K. Find whether system is stable for $K = 2$ or not.

[20 marks]

270

$$G(j\omega) = \frac{K(j\omega)^3}{(j\omega+1)(j\omega+2)}$$

$$G(j\omega) = \frac{-Kj\omega^3}{-\omega^2+2+3j\omega}$$

$$G(j\omega) = -j\frac{K\omega^3(1-j\omega)(2-j\omega)}{(\omega^2+1)(\omega^2+4)}$$

$$G(j\omega) = \frac{-j K\omega^3[2-3j\omega-\omega^2]}{(\omega^2+1)(\omega^2+4)}$$

$$G(j\omega) = \frac{-jK\omega^3(2-\omega^2)}{(\omega^2+1)(\omega^2+4)} - \frac{3K\omega^4}{(\omega^2+1)(\omega^2+4)}$$

at $\omega = 0$

$$G(j\omega) = -0 - 0j$$

at $\omega = \infty$

$$G(j\omega) = \left(\frac{+jK\omega^5}{\omega^4} - \frac{3K\omega^4}{\omega^4}\right)_{\omega\to\infty}$$

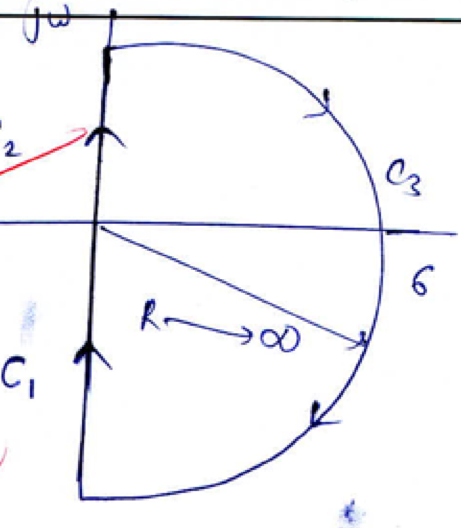
$$= j\infty - 3K$$

and when $\omega^2 = 2$ Nyquist plot intersects real axis

$$\boxed{\omega = \sqrt{2} \text{ rad/sec}}$$

$$G(j\omega) = \frac{-3K\times 4}{(2+1)(2+4)} = -\frac{2}{3}K$$

Nyquist contour for above problem.

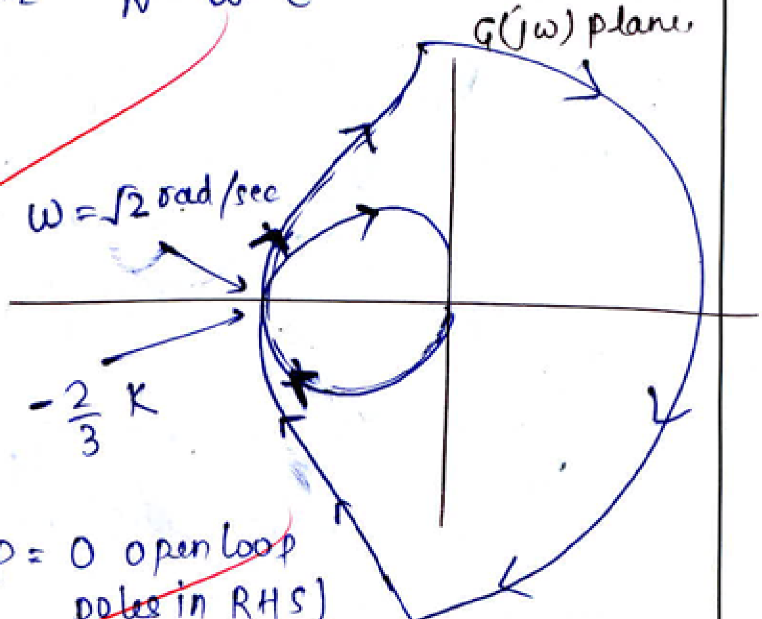


C_2 maps to $G(j\omega)$ plane as polar plot and C_1 is mirror image of it.

for C_3 $\quad s \longrightarrow Re^{j\theta} \quad R \to 0$

→ $G(Re^{j\theta}) = \dfrac{KR^3 e^{j3\theta}}{R^2 e^{j2\theta}} = KRe^{j\theta} = \infty e^{j\theta}$

$= \infty e^{j\pi/2}$ to $\infty e^{-j\pi/2}$



→ When

$\frac{2}{3}K > 1$

$K > 3/2$

then $N = -2$

hence $N = P - 2$ $\quad$ ($P = 0$ open loop poles in RHS)

$Z = 2$ (unstable with 2 closed loop poles in RHS)

→ When $\frac{2}{3}K < 1$

$K < 3/2$

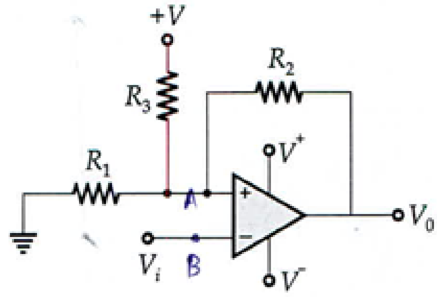
$N = 0$, $Z = 0$ stable

hence system is stable for $K < 3/2$

→ so for $K = 2$ system is unstable.

20

Q.2 (c) Consider the bistable circuit shown in the figure below:



The op-amp's positive-input is connected to positive voltage source V through a resistor R_3.

(i) Derive expressions for the threshold voltage V_{TH} and V_{TL} in terms of the op-amp's saturation levels V^+, V^-, resistors R_1, R_2 and source voltage V.

(ii) Let $V^+ = -V^- = 13$ V, $V = 15$ V, and $R_1 = 10$ kΩ. Find the values of R_2 and R_3 that results in $V_{TL} = +4.9$ V and $V_{TH} = +5.1$ V.

[20 marks]

When Output $V_o = V^+$

~~hence~~ V_A = then applying KCL at Node A

$$\frac{V - V_A}{R_3} = \frac{V_A}{R_1} + \frac{V_A - V_o}{R_2}$$

$$\frac{V}{R_3} + \frac{V_o}{R_2} = V_A\left[\frac{1}{R_2} + \frac{1}{R_1} + \frac{1}{R_3}\right]$$

$$V_A = \frac{\left[V \times R_2 + V^+ R_3\right] R_1}{R_2 R_3 + R_1 R_3 + R_2 R_1}$$

hence

$$V_{TH} \text{ (upper threshold)} = \frac{\left[V R_2 + V^+ R_3\right] R_1}{R_2 R_3 + R_1 R_3 + R_2 R_1}$$

When output is $V_o = V^+$

then lower threshold

$$V_{TL} = \frac{\left[V R_2 + V^- R_3\right] R_1}{R_2 R_2 + R_1 R_3 + R_1 R_2}$$

When $V^+ = 13\,V$ $\quad V_{TH} = 5.1\,V$

$V^- = -13\,V$ $\quad V_{TL} = 4.9$

$V = 15\,V$

$R_1 = 10\,k\Omega$

Solving eq ① and ⑪

$$\boxed{\begin{aligned} 25.694\,k\Omega &= R_2 \\ R_3 &= 8.511\,k\Omega \end{aligned}}$$

Ans

13

$$V_{TH} = 5.1 = \frac{[15 \times R_2 + 13 \times R_3] \times 10000}{1000(R_2 + R_3) + R_2 R_3}$$

$$5.1\,[10000(R_2 + R_3) + R_2 R_3] = 150000 R_2 + 130000 R_3$$

$$99000 R_2 + 79000 R_3 = 5.1 R_2 R_3$$

$$\cancel{144900 R_2 + 124900 R_3 = 5.1 \times R_2 R_3} \quad \text{—— ①}$$

$$V_{TL} = 4.9 = \frac{(15 R_2 - 13 R_3) \times 10000}{1000(R_2 + R_3) + R_2 R_3}$$

$$4.9\,(10000(R_2 + R_3) + R_2 R_3) = 150000 R_2 - 130000 R_3$$

$$101000 R_2 \; [illegible] \; 179000 R_3 = 4.9 R_2 R_3 \quad \text{—— ⑪}$$

$$\cancel{4.9 R_2 R_3 = 145100 R_2 - 125100 R_3}$$

$$(4.9 R_2 + 125100)\, R_3 = 145100 R_2$$

$$R_3 = \frac{\cancel{10100 R_2}}{\cancel{4.9 R_2 + 17900}} \qquad \frac{145100 R_2}{4.9 R_2 + 125100}$$

from eq ①

$$144900 R_2 = \frac{(5.1 R_2 - 124900) \times 145100 R_2}{4.9 R_2 + 125100}$$

Solving we get

$$\cancel{\frac{99}{101}(4.9 R_2 + 17900) = 5.1 R_2 - 7900}$$

$$\boxed{R_2 = 25\,k\Omega \qquad R_3 = 14.65\,k}$$

$$\cancel{R_2 = 2.569\,k\Omega} \quad \text{and} \quad \cancel{R_3 = 8511\,k\Omega}$$

Q.3 (a) The T1 carrier system used in digital telephony multiplexes 24 voice channels based on 8 bit PCM. Each voice signal is usually put through a low pass filter with the cut off frequency of about 3.4 kHz. The filtered voice signal is sampled at 8 kHz. In addition, a single bit is added at the end of the frame for the purpose of synchronization.

Calculate:

(i) the duration of each bit,

(ii) the resultant transmission rate, and

(iii) the minimum required transmission bandwidth (Nyquist bandwidth).

[20 marks]

→ $f_s = 8000$ samples / sec

~~bit Rate~~ = $\cancel{n f_s \times N}$

Total No. of bits in a frame

$= (nN + 1)$

$= 8 \times 24 + 1 = 193$ bits

→ bit rate / Transmission Rate.

1.93 bits → 1 sample or ~~1 frame~~

$R_b = 193 \times 8000$

$R_b = 1544000$ bit/sec $= 1.544$ Mbps

→ Duration of each bit

$\Rightarrow \frac{1}{R_b} = 6.4766 \times 10^{-7}$ sec

$= 0.647\ \mu sec$

→ Minimum bath width

$BW_{min} = (nN+1) f_{s_{min}}$

$f_{s_{min}} = 2f_m$ (Nyquist band width)

$BW_{min} = (8 \times 24 + 1) \times 2 \times 3.4 \times 10^3$

$= 1312400$ Hz $\Rightarrow$ 1312.4 KHz

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(b) **(i)** Two dc shunt generators are rated at 250 kW and 150 kW, 400 V. Their full load voltage drops are 3% and 6% respectively. They are excited to no load voltages of 410 V and 420 V respectively. How will they share a load of 1000 A and determine the corresponding bus voltage?

(ii) In above question, the two generators are excited to equal no load voltages. What should be the percentage voltage drop of 150 kW generator in order that they share load in proportion to the ratio of their ratings? What is the no load voltage for a bus voltage of 400 V and load current of 1000 A?

[20 marks]

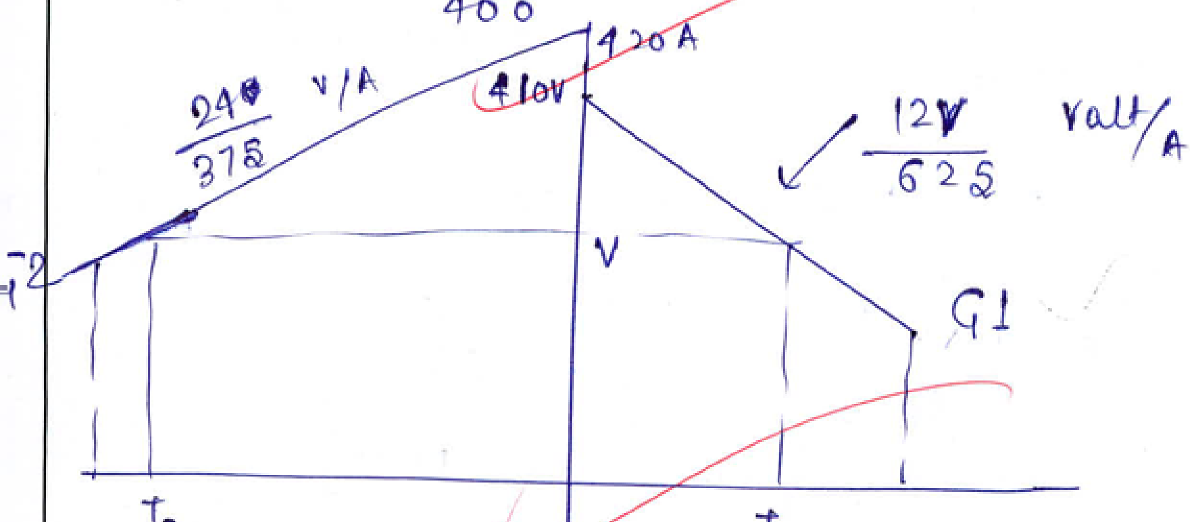
Voltage drop ① G1 $= \frac{3\times400}{100} =$

$\Rightarrow 3\times4 = 12\text{ V}$

Voltage drop of $G_2 = \frac{400\times6}{100} = 24\text{ V}$

$I_{fl_1} = \frac{250\times10^3}{400} = 625\text{ A}$

$I_{fl_2} = \frac{150\times10^3}{400} = 375\text{ A}$



let system voltage is V

so $\frac{24}{375} = \frac{420-V}{I_2}$ | $\frac{12}{625} = \frac{410-V}{I_1}$

$I_2 = \frac{375}{24}(420-V)$ | $I_1 = \frac{625}{12}(410-V)$

and $I_1 + I_2 = 1000\text{ A}$

$\frac{375}{24}(420-V) + \frac{625}{12}(410-V) = 1000$

$V = 397.538$ Volt.

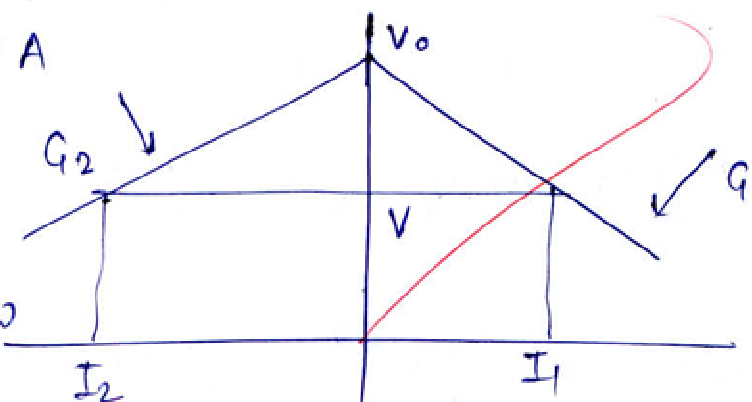
and $I_1 = \frac{625}{12}(410 - 397.538) = 649.03$ A

$I_2 = \frac{375}{24}(420 - 397.538) = 350.9687$ A

→ (ii) Sharing is in proportion to ratio

$I_1 = \frac{1000 \times 625}{625 + 375} = 625$ A

$I_2 = 375$ A



Now for generator (2) which is 150 kW generator

for proportional load sharing voltage drop should be same for both generator

hence % drop for G_2 = % drop of G_1 = 3%

$\frac{V_0 - V}{I_1} = \frac{\Delta V}{I_{r}}$

$\frac{V_0 - V}{I_2} = \frac{\Delta V}{I_{r}}$

$I_1 = I_{rate} \frac{\Delta V}{V_0 - V}$

Now given

$I_1 = 625$ A, $V = 400$ V

hence $\frac{V_0 - V}{\cancel{I_{rated}}\ I_1} = \frac{\Delta V}{I_{rated}}$,

$V_0 - V = \frac{3 \times 400}{1000} \times \cancel{\frac{625}{625}}$

$\frac{12}{I} = \frac{12}{I_{rat}}$

$V_0 = 400 + 12$

$\boxed{V_0 = 412 \text{ Volts.}}$

20

(c) A 15 MVA, 6.6 kV star connected generator has positive, negative and zero sequence reactance of 20%, 20% and 10% respectively. The neutral of the generator is grounded through a reactor with 5% reactance based on generator rating. A line to line fault occurs at the terminals of the generator when it is operating at rated voltage. Find current in the line and also in the generator reactor.

(i) When the fault does not involve the ground.

(ii) When the fault is solidly grounded.

[20 marks]

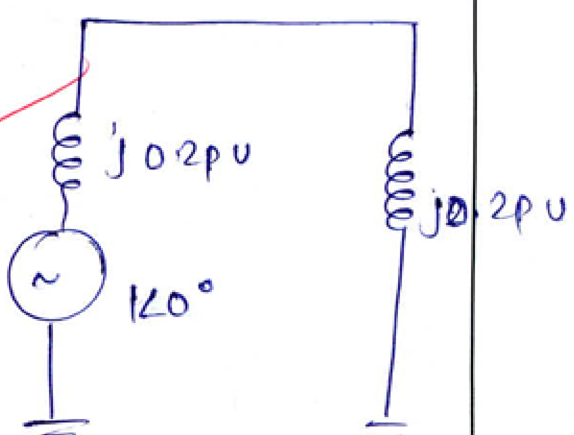
given $X_1 = j0.2 pu$ $\quad X_n = j0.05 pu$

$X_2 = j0.2 pu$

$X_0 = j0.1 pu$

(1) L-L fault.

$$I_{fault} = \left| \frac{\sqrt{3} \times V_{pu}}{X_1 + X_2} \right|$$



$$I_{fault} = \left| \frac{\sqrt{3} \times 1\angle 0^\circ}{j0.2 + j0.2} \right|$$

$$I_{fault} = \underline{4.33 pu}$$

~~hence~~ $I_{Base} = \dfrac{15 \times 10^6}{\sqrt{3} \times 6.6 \times 10^3} = 1312.15A$

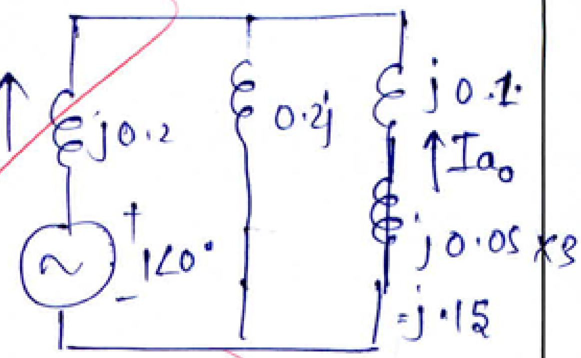
hence $I_{fault}(I_{line}) = 1312.15 \times 4.33$

$$\boxed{I_b = I_c = 5681.60 \text{ Amp}}$$. and $I_a = 0$

→ Since fault does not involve ground hence

$$\boxed{I_{reactor} = 0 A}$$

(ii) LLG fault.



$$I_{a_1} = \frac{1\angle 0^\circ}{0.2j + 0.2j \parallel 0.25j}$$

$$I_{a_1} = -3.214j \text{ pu}$$

hence $I_{a_0} = \dfrac{-I_{a_1} \times 0.2j}{0.2j + 0.25j}$

$$I_{a_0} = \frac{+3.214j \times 0.2j}{0.2j + .25j} = 1.42857j \text{ pu}$$

$$I_{a_2} = 1.7854j \text{ pu}$$

Now $I_{f(pu)} = 3I_{a_0} = 4.284 \text{ pu}$

hence current in the reactor

$= 4.284 \times 1312.15$

$$\boxed{I_{reactor} = 5621.25 \text{ Amp}}$$

Now $I_b = I_{a_0} + \alpha^2 I_{a_1} + \alpha I_{a_2}$

$I_b = j1.42857 + 1\angle{-120} \times (-3.214j)$
$+ 1.7854j \times 1\angle 120$

$I_c = I_b = 2.914 \text{ pu}$

3.05

hence $\boxed{I_b = I_c = 2.914 \times 1312.15 = 3823.6051 \text{ A}}$

$I_a = 0$

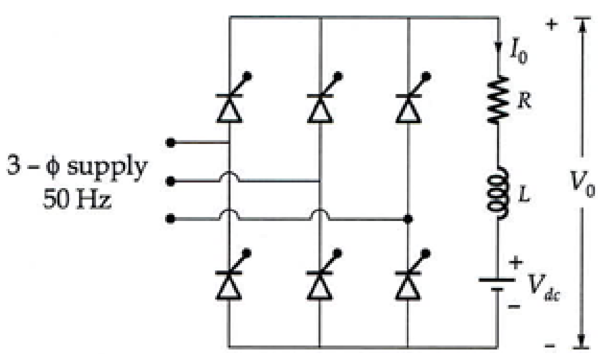
20

(a) The six pulse converter shown below has a delay angle $\alpha = 120°$. The three phase AC system is 4160 V (rms) line to line. The DC source is 3000 V, R = 2 Ω and L is large enough to consider the current to be purely DC.

(i) Determine the power transferred to the AC source from the DC source.

(ii) Determine the value of L such that the peak to peak variation in the load current is 10 percent of the average load current.

(Assume normalized harmonic voltage $\dfrac{V_6}{V_{mL}} = 0.28$, for $n = 6$)



[20 marks]

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(b) **(i)** Consider a plant given by,

$$\dot{X} = Ax + Bu$$

where, $A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

The system uses state feedback control $u = -Kx$. Let the desired closed loop poles are

$$s = -2 + j4, s = -2 - j4, s = -10$$

Determine the state feedback gain matrix K using transformation matrix T.

[10 marks]

Do not write in this margin

Q.4 (b) (ii) A unity feedback system has the forward path transfer function

$$G(s) = \frac{K_1(2s+1)}{s(5s+1)(s+1)^2}$$

The input $r(t) = (1 + 4t)u(t)$ is applied to the system. Determine the minimum value of K_1 if the steady state error is to be less than 0.1.

[10 marks]

(c) Consider the following transfer function of an IIR system:

$$H(z) = \frac{(1-z^{-1})^3}{\left(1-\frac{1}{2}z^{-1}\right)\left(1-\frac{1}{8}z^{-1}\right)}$$

Realize this system using cascade and parallel forms.

[20 marks]

Do not write in this margin

Section-B

(a) A Buck-boost converter has the following parameters:

$V_S = 24$ V $\quad D = 0.4 \quad R = 5\ \Omega$

$L = 20\ \mu$H $\quad C = 80\ \mu$F $\quad f = 100$ kHz

Determine the output voltage, inductor average current, $I_{L,\max}$ and $I_{L,\min}$ and the output ripple voltage.

[12 marks]

Output voltage

$$V_o = \frac{D}{1-D} \times V_s$$

$$V_o = \frac{0.4}{0.6} \times 24 = 16\text{ V}$$

$$(i_L)_{avg} = I_o + I_s = \cancel{I_o} +$$

$$\cancel{= \frac{V_o}{R}} +$$

$$I_o = \frac{V_o}{R} = \frac{16}{5} = 3.2\text{A}$$

$$I_s = \frac{V_o I_o}{V_s} = \frac{16 \times 3.2}{24} = 2.133\text{ A}$$

$$(i_L)_{avg} = 3.2 + 2.133 = 5.33\text{ A}$$

$$(\Delta I_L) = \frac{\alpha V_s}{fL} = \frac{0.4 \times 24}{100 \times 10^3 \times 20 \times 10^{-6}}$$

$$(\Delta I_L) = 4.8\text{ A}$$

$$i_{Lmax} = (i_L)_{avg} + \frac{\Delta I_L}{2}$$

$$= 5.33 + 2.4 = 7.73\text{A}$$

$$i_{Lmin} = (i_L)_{avg} - \frac{\Delta I_L}{2}$$

$$= 2.93\text{ A}$$

Output ripple voltage

$$\Delta V_c = \frac{I_o \times T_{ON}}{C}$$

$$= \frac{I_o \alpha}{fC}$$

$$= \frac{3.2 \times 0.4}{100 \times 10^3 \times 80 \times 10^{-6}}$$

$$= 0.16\text{ Volt}$$

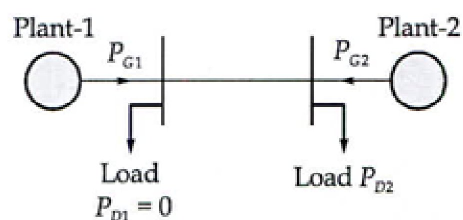
8

12

Q.5 (b) A two bus system is shown in figure. If 100 MW is transmitted from plant 1 to the load, a transmission loss of 10 kW is incurred. Find the required generation for each plant and the power received by the load when the system cost is Rs 25/MWh. The incremental fuel costs of the two plants are:

$$IC_1 = \frac{dF_1}{dP_{G1}} = 0.02P_{G1} + 16 \text{ Rs/MWh}$$

$$IC_2 = \frac{dF_2}{dP_{G2}} = 0.04P_{G2} + 20 \text{ Rs/MWh}$$



[12 marks]

$B_{21} = 0$

$B_{12} = 0$

Load is on plant 2, hence $B_{22} = 0$,

hence $B_{11} = \frac{P_L}{P_1^2} = \frac{10 \times 10^3}{100 \times 10^6}$

$B_{11} = \underline{1 \times 10^{-4}}$

$\frac{\partial P_L}{\partial P_1} = 2 B_{11} P_1$

for economic load despatch

$IC_1 L_1 = IC_2 L_2 = 25$

$IC1 \times \frac{1}{1 - \frac{\partial P_L}{\partial P_1}} = 1 \times IC_2 = 25$

$IC_2 = 25$

$0.04 \times P_{G_2} + 20 = 25$

$P_{G_2} = 125 \text{ MW}$

and $\frac{0.02 P_{G_1} + 16}{1 - 2 \times 10^{-4} \times P_{G_1}} = 25$

$0.02 P_{G_1} + 16 = 25 - 2 \times 10^{-4} \times 25 P_{G_1}$

$0.025 P_{G_1} = 9$

$P_{G_1} = 360 \text{ MW}$

$P_L = B_{11} P_{G_1}^2 = 1 \times 10^{-4} \times (360)^2 = 12.96 \text{ MW}$

Power to load $= P_1 + P_2 - P_L$

$= 360 + 125 - 12.96 = \underline{472.04 \text{ MW}}$

5

(c) A 10 kW, 400 V, 3-phase induction motor has full-load efficiency of 87% and power-factor of 0.85. At standstill and at rated voltage, the motor draws 5 times its full-load current and develops a starting torque of 1.5 times its full-load torque. An autotransformer is installed to reduce the starting current and to give full-load torque at starting. Neglecting exciting current of autotransformer, determine at the time of starting.

(i) the voltage applied to the motor terminals.

(ii) the current drawn by the motor and

(iii) the line current drawn from the supply mains.

[12 marks]

→ When rated voltage is applied

$$S_{fl} \cdot \left(\frac{I_{sc}}{I_{fl}}\right)^2 = \frac{T_{st}}{T_{fl}}$$

$$1.5 = (5)^2 S_{fl}$$

$$S_{fl} = 0.06$$

→ When autotransformer of ratio x is used

$$\left(\frac{T_{st}}{T_{fl}}\right) = x^2 \left(\frac{I_{sc}}{I_f}\right)^2 S_{fl}.$$

$$1 = x^2 \times 25 \times 0.06$$

$$\boxed{x = 0.816}$$

12

→ Voltage at the terminal of motor

$$\Rightarrow xV = 0.816 \times 400 = 326.4 \text{ Volts (L-L)}$$

→ $I_{fl} = \dfrac{10 \times 10^3}{0.87 \times \sqrt{3} \times 400 \times 0.85} = 19.518\text{ A}$

current drawn by motor

$$= x I_{sc} = 0.816 \times 5 \times 19.518$$

$$= 79.634 \text{ Amp}$$

→ Current drawn from supply $= x^2 I_{sc}$

$$= 0.816 \times 79.634$$

$$= 64.981 \text{ Amp.}$$

Q.5 (d) **(i)** By using the appropriate Fourier transform properties, find the Fourier transform of $g(t) = te^{-|t|}$.

(ii) By using the result of part (i), along with the duality property, determine the Fourier transform of $y(t) = \dfrac{4t}{(1+t^2)^2}$.

[12 marks]

$$e^{-t}u(t) \xrightarrow{FT} \frac{1}{1+j\omega}$$

$$e^{+t}u(-t) \xrightarrow{FT} \frac{1}{1-j\omega} \quad \text{(time reversal)}$$

$$e^{-t}u(t) + e^{t}u(-t) \xrightarrow{FT} \frac{1}{1+j\omega} + \frac{1}{1-j\omega} \quad \text{(linearity)}$$

$$e^{-|t|} \xrightarrow{FT} \frac{2}{1+\omega^2}$$

$$te^{-|t|} \xrightarrow{FT} (j)\frac{d}{d\omega}\left(\frac{2}{1+\omega^2}\right) \quad \text{(multiplication by } t \text{ in time domain)}$$

$$te^{-|t|} \xrightarrow{FT} (j) \times \frac{2 \times -1 \times 2\omega}{(1+\omega^2)^2}$$

$$te^{-|t|} \xrightarrow{FT} -\frac{4j\omega}{(1+\omega^2)^2}$$

By duality

t replace by $-\omega$

ω replace by t

$$-\frac{4jt}{(1+t^2)^2} \xrightarrow{FT} -\omega e^{-|\omega|} \times 2\pi$$

$$\frac{4t}{(1+t^2)^2} \xrightarrow{FT} -j2\pi\omega e^{-|\omega|}$$

12

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(e) Draw the architecture of Intel 8086 and mention the special functions associated with its registers.

[12 marks]

→ 8086 has following registers.

GPR
AL & AH
BL & BH
CL & CH
DL & DH

Pointers.
IP – Instruction point.
BP – Base pointer
SP – Stack pointer

and segment registers
CS – Code segment
DS – Data segment
ES – Extra segment
SI/DI –

→ General purpose registers can be used as 8 bit or 16 bit registers when combind

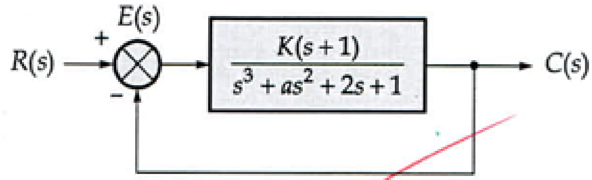
→ IP is similar to PC and contains address of Next instruction

→ BP is the register which contains offset address of

AH	AL
BH	BL
CH	CL
DH	DL

6

a) (i) A system oscillates with frequency ω having poles at $s = \pm j\omega$ and no poles in the right-half of the s-plane. Determine the values of K and a so that the system shown in figure below oscillates at a frequency of 2 rad/sec.



[10 marks]

Characteristic equation

$$1 + \frac{K(s+1)}{s^3+as^2+2s+1} = 0$$

$$s^3 + as^2 + (2+K)s + K+1 = 0$$

preparing routh array.

s^3	1	$2+K$
s^2	a	$K+1$
s^1	$\frac{a(2+K)-K+1}{a}$	
s^0	$K+1$	

for system to oscillation s^1 coefficient = 0

$$a = \frac{K+1}{2+K}$$

Now auxiliary eq

$$as^2 + (K+1) = 0$$

$$\frac{K+1}{K+2}s^2 + K+1 = 0$$

$$s^2 = -(K+2)$$

given $s = \pm j2$ rad/sec

$$s^2 = -4$$

$$-(K+2) = -4$$

$$\boxed{K = 2}$$

and

$$a = \frac{2+1}{2+2}$$

$$a = \frac{3}{4}$$

$$\underline{a = 0.75}$$

10

Q.6 (a) (ii) A first-order system and its response to a unit step input are shown below in figure (i) and figure (ii) respectively, determine the system parameters a and K.

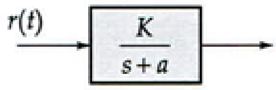


Fig. (i)

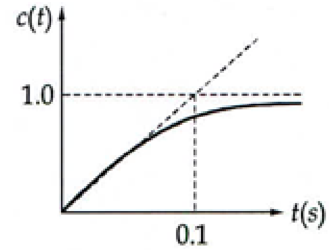


Fig. (ii)

[10 marks]

$$\frac{C(s)}{R(s)} = \frac{K}{(s+a)}$$

$$C(s) = \frac{K}{s(s+a)} \qquad \left[R(s) = 1/s \text{ step response} \right]$$

$$C(s) = \frac{K}{a}\left(\frac{1}{s} - \frac{1}{s+a}\right)$$

taking inverse LT —

$$c(t) = \frac{K}{a}\left(1 - e^{-at}\right)$$

as $t \longrightarrow \infty$ $\quad c(\infty) = K/a = 1$

hence $K = a$

and

$$\left.\frac{dc(t)}{dt}\right|_{t=0} = \left.\frac{K}{a} \times a e^{-at}\right|_{t=0}$$

$$\Rightarrow K$$

$$K = \frac{1}{0.1} = 10$$

hence $\underline{a = 10}$

10

(b) Determine the efficiency and regulation of a 3-phase, 50 Hz, 150 km long transmission line having 3 conductors spaced 3.5 metres delta formation when the receiving end delivers 25 MVA at 120 kV and pf 0.9 lagging. The resistance of the conductor is 0.25 ohm per km and the dia is 0.75 cm. Neglect leakage and use Nominal-*T*.

[20 marks]

$$L = 2\times10^{-7}\ln\left(\frac{D}{r'}\right) \text{ H/m/phase}$$

$$L = 2\times10^{-7}\ln\left[\frac{3.5}{\frac{0.75}{2}\times10^{-2}\times0.7788}\right]$$

$$L = 1.4177\times10^{-6} \text{ H/m/phase}$$

$$L = 1.4177\times150\times10^{3} \text{ H/phase} = 0.21266 \text{ H/phase}$$

$$C = \frac{2\pi\epsilon_0}{\ln D/r} = \frac{2\pi\times8.85\times10^{-12}}{\ln\left(\frac{3.5}{.5\times.75\times10^{-2}\times.7788}\right)} \text{ F/m/phase}$$

$$C = 8.13\times10^{-12} \text{ F/m/phase}$$

$$C = 1.2196 \ \mu\text{F/phase}$$

for Nominal T —

$$Z = R + j\omega L = 0.25\times150 + j\times100\pi\times.21266$$

$$= 76.61\angle60.69\ \Omega$$

$$Y = j\omega C = j\times100\pi\times1.2196\times10^{-6}$$

$$= 3.8314\times10^{-4}\angle90\ \mho$$

Now $A = D = 1 + \frac{YZ}{2} = 0.9872\angle0.41697$

$$B = Z\left(1+\frac{YZ}{4}\right) = 76.120\angle60.89\ \Omega$$

$$C = Y = 3.8314\times10^{-4}\angle90\ \mho$$

$$I_R = \frac{25 \times 10^6}{\sqrt{3} \times 120 \times 10^3} \angle -\cos^{-1} 0.9$$

$$I_R = 120.28 \angle -25.84 \text{ A}$$

hence

$$V_s = AV_R + BI_R = 0.9872 \angle 0.41697 \times \frac{120 \times 10^3}{\sqrt{3}} + 120.28 \angle -25.84 \times 76.61 \angle 60.69$$

$$V_s = 75862.722 \angle 4.35$$

$$V_s = 75.862 \angle 4.35 \text{ KV/phase.}$$

$$I_s = CV_R + DI_R = 3.8314 \times 10^{-4} \angle 90 \times \frac{120 \times 10^3}{\sqrt{3}} + .9872 \angle .41697 \times 120.28 \angle -25.84$$

$$I_s = 109.989 \angle -12.83 \text{ A}$$

Sending end power $P = 3 V_{s_{ph}} I_s \cos\phi$

$$= 3 \times 75.86 \times 10^3 \times 109.989 \cos(4.35 + 12.83)$$

$$= \underline{23.914 \text{ MW}}$$

$$\text{efficiency} = \frac{P_R}{P_s} \times 100$$

$$= \frac{25 \times .9}{23.914} \times 100 = 94.08\%$$

No load voltage at receiving end

$$V_{RNL} = \frac{V_s}{A} = \frac{75.86}{0.9872} = 76.84 \text{ KV/ph}$$

V Regulation

$$\frac{V_{NL_R} - V_{FL_R}}{V_{FL_R}} \times 100$$

$$\frac{76.84 - \frac{120}{\sqrt{3}}}{\frac{120}{\sqrt{3}}} \times 100 = \underline{10.9\%}$$

17

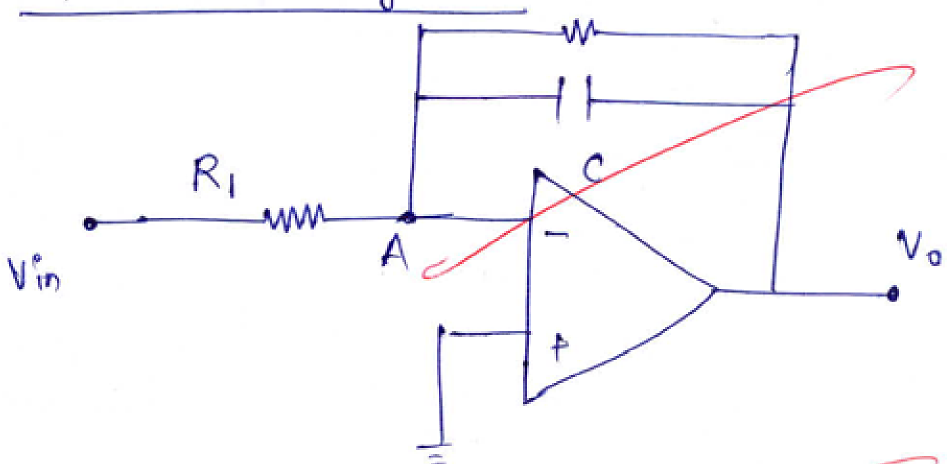
) **(i)** Derive the expression for corner frequency of practical integrator.

(ii) For a practical integrator, the component values are $R_1 = 120\ \text{k}\Omega$, $R_F = 1.2\ \text{M}\Omega$ and the capacitor $C_F = 10\ \text{nF}$.

Determine the safe frequency above which true integration will take place and the DC gain. Also find the peak of the output voltage for a sine wave input with 5 V peak and 10 kHz frequency.

[20 marks]

<u>practical integrator</u>



KCL at node A

$$\frac{V_{in} - 0}{R_1} = \frac{0 - V_o}{R_F} + (0 - V_o)\, CS$$

$$\frac{V_{in}}{R_1} = -V_o\left[\frac{1 + R_F CS}{R_F}\right] \Rightarrow \frac{V_o}{V_{in}} = -\frac{R_F/R_1}{1 + R_F CS}$$

hence carnor frequency

$$f_c = \frac{1}{2\pi R_F C}$$

→ (ii) DC gain $= \frac{-R_F}{R_1}$

$$= -\frac{1.2 \times 10^6}{120 \times 10^3}$$

$$= -10$$

$|DC\ gain| = 10$

and $f_c = \frac{1}{2\pi \times 1.2\times10^6 \times 10\times10^{-9}}$

$f_c = 13.2629$ Hz

20

→ When input ⇒ $5 \sin(2\pi \times 10^4 t)$ Volts

$$H(j\omega) = \frac{-10}{1 + 0.012 j\omega}$$

at $\omega = 2\pi \times 10^4$ rad/sec

$$H(j\omega) = \frac{-10}{1 + 0.012 \times 2\pi \times 10^4 j} = -0.01329 \angle -89.92$$

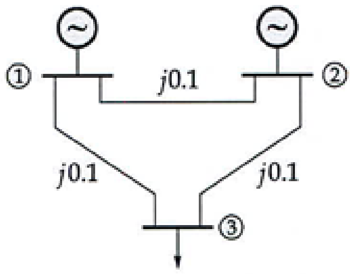
hence

$V_0 = H(j\omega) \times V_{in}$

$= -0.0663 \sin(2\pi \times 10^4 t - 89.92^\circ)$ Volts

$=$

Q.7 (a) Using Gauss Seidal load flow method, find bus voltages at the end of one iteration for the following 2 - bus system. Line reactances are shown in figure below. Ignore resistance and line charging. Assume initial voltage at all buses to be $1.0\angle 0°$. Use 1.0 as acceleration factor.



The bus data is given in the table below:

Bus No.	Specified P (p.u.)	Injections Q (p.u.)	Specified voltage (p.u.)
1.	–	–	1.0
2.	0.3	–	1.0
3.	0.5	0.2	–

[20 marks]

) The system function of an analog filter is given by,

$$H_a(s) = \frac{s+0.1}{(s+0.1)^2+9}$$

Convert this analog filter into a digital IIR filter by means of the impulse invariance method. Take the sampling interval as $T = 0.1$ s. Realize the resultant digital filter using direct from-II structure.

[20 marks]

c) Three similar single phase transformer have the primary and secondary windings connected in star and the tertiary winding in delta. In each transformer, secondary and tertiary turns are equal and ratio of primary to secondary turns is 2. The primary is fed at rated voltage by three wires.

(i) A single phase load, taking 24 A at unity power factor, is connected between one line and neutral of the secondary. Calculate the currents in each winding of the three transformers.

(ii) In addition to the single phase load of part (a), the secondary is now connected to a 3-phase balanced load requiring a line current of 40 A at 0.8 pf lag. Determine the current in each winding of three transformers.

[20 marks]

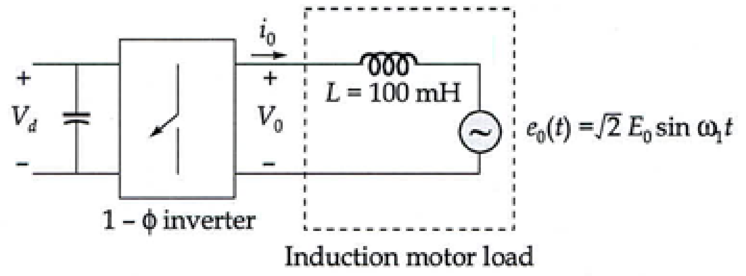
a) The open loop transfer function of a unity negative feedback system is given by,

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

Where K and T are positive constants. By what factor should the amplifier gain K be reduced so that peak overshoot of the unit step response of the system is reduced from 80% to 20%?

[20 marks]

(b) Consider the problem of ripple in the current of a single phase full bridge inverter as shown below:



Assume $V_{01} = 220$ V at a frequency of 47 Hz. If the inverter is operating in a square wave mode, calculate the peak value of ripple current.

Draw the waveforms of V_{ripple} and i_{ripple}.

[20 marks]

(i) Determine the root-mean-square value of the individual harmonics components and of the total induced emf per phase of a 50 Hz, 3 phase alternator from the following data: Number of poles, 10: slots per pole per phase is 2; conductors per slot (2 layers) is 4; coil span is $150°$; flux per pole (fundamental) is 0.12 Wb. The analysis of the gap flux density shows a 20% third harmonic. All the coils of a phase are connected in series.

[10 marks]

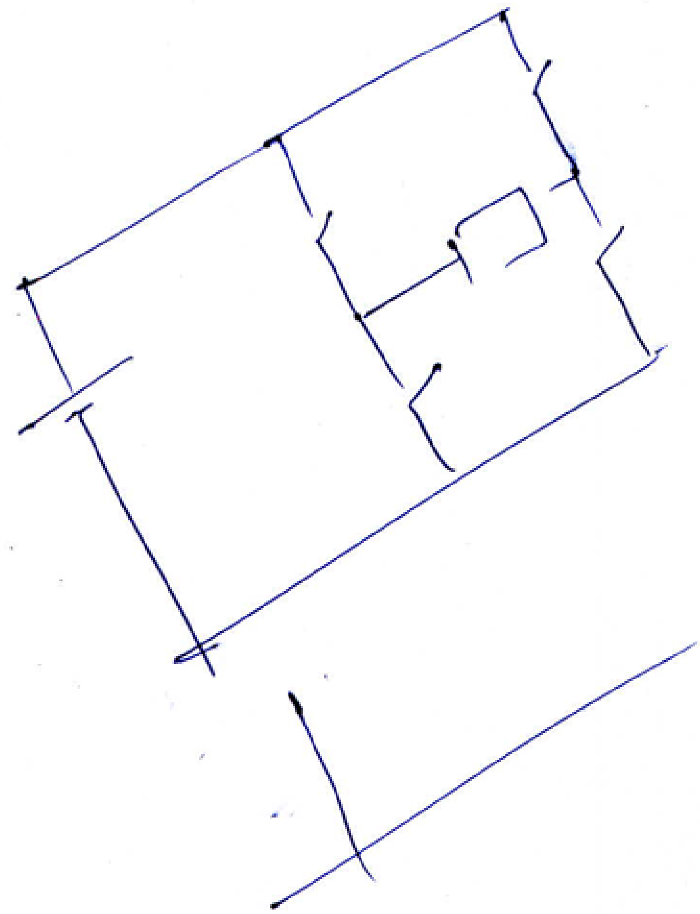
Q.8 (c) (ii) A compensated dc machine has 12000 armature ampere turns per pole. The ratio of pole arc to pole pitch = 0.60. Interpolar air gap length and flux density are 1 cm and 0.3 Wb/m^2 respectively. For the rated armature current of 800 A, calculate the number of compensating winding conductors per pole and number of turns on each interpole. Take $\mu_0 = 4\pi \times 10^{-7}$ H/m.

[10 marks]

OOOO

Space for Rough Work

Space for Rough Work



$s^2 + 3s + 2 + Ks^3$

$Ks^3 + s^2 + 3s + 2$

$2K < 3$

$K < 3/2$

$$5.1 = \frac{(15R_2 + 15R_3) \times 10000}{10000(R_2 + R_3) + R_2R_3}$$

$51000R_2 + 51000R_3 + \frac{R_2R_2}{5.1} = 150000R_2 + 150000R_3$

99000

$99000R_2$

$= \frac{(5.1R_2 - 79000)10100}{4.9R_2 + 179000}$

$\frac{99}{101}(4.9R_2 + 179000)$

$= 5.1R_2 - 79000$