• Try to avoid calculation mistake

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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-8 : Full Syllabus Test (Paper-II)

Name : ....

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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	41
Q.2	48
Q.3	
Q.4	34
Section-B	
Q.5	23
Q.6	44
Q.7	
Q.8	
Total Marks Obtained	190

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

Q.1 (a) A hydro-electric station is to be designed for a catchment area of 500 km^2, rainfall for which is 130 cm/annum. The head available is 30 m. Assume that 80% of the total rainfall is available, rest is lost to evaporation. Penstock efficiency is 97%, turbine efficiency is 87%, generator efficiency is 92% and the load factor is 60%. Determine the electricity generation capacity of the station.

[12 marks]

$$W = 500\times10^{6} \times \frac{130\times10^{-2}}{365} \times 0.8$$

$$= \cancel{142.46\times10^{4}}$$

$$\boxed{W = \cancel{1424.6\times10^{3}}}$$

$$P_{avg} = 9.81\times10^{-6} \times W \times H \times \eta$$

$$= 9.81\times10^{-6}\times1424.6\times10^{3}\times30\times0.97\times0.87\times0.92$$

$$P_{avg} = \cancel{325.50}\ \text{~~Watt~~ MW}$$

$$\text{load factor} = \frac{P_{avg}}{P_{max}}$$

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$$P_{max} = \frac{325.50}{0.6} = \underline{542.51}\ MW$$

Electricity generation capacity $= \cancel{542.51}$ MW

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Q.1 (b) A 3-phase long line has constants $A = 0.98\angle 3°$ and $B = 110\angle 75°$ ohm per phase.

(i) If the load is 50 MVA, 0.8 pf lagging, find the capacity of shunt compensation equipment if voltages at the two ends of the line are 132 kV each.

(ii) Find the capacity of shunt compensation equipment if the voltage at the two ends are to be maintained at 132 kV under no load condition.

[12 marks]

(i) $P_R = 50 \times 0.8 = 40$

$$P_R = \frac{V_s V_R}{B}\cos(\theta-\delta) - \left|\frac{A}{B}\right| V_R^2 \cos(\theta-\alpha)$$

$$40 = \frac{(132)^2}{110}\cos(75-\delta) - \frac{0.98}{110}(132)^2\cos(75-3°)$$

$$40 = 25090.56\cos(75-\delta) - 47.96$$

$$75-\delta = 56.26$$

$$\boxed{\delta = 18.73°}$$

$$Q_R = \frac{V_s V_R}{B}\sin(\theta-\delta) - \left|\frac{A}{B}\right| V_R^2 \sin(75-3°)$$

$$= \frac{(132)^2}{110}\sin(56.26) - \frac{0.98}{110}\times 132^2 \sin 72°$$

$$Q_R = 131.72 - 147.63$$

$$\boxed{Q_R = -15.90} \text{ MVAR}$$

Required shunt capacitance = 15.90 MVAR

(ii) Under No load $P_R = 0$

$$\frac{V_s \cancel{V_R}}{\cancel{B}}\cos(\theta-\delta) = \left|\frac{A}{\cancel{B}}\right| V_R^{\cancel{2}}\cos(\theta-\alpha)$$

$$\cos(\theta-\delta) = 0.98\cos(75-3)$$

$$\delta = 75 - 72.37 = 2.62°$$

$$Q_R = \frac{(132)^2}{110}\sin(75-2.62) - \frac{(132)^2 \times 0.98}{110}\sin 72^\circ$$

$$Q_R = 150.96 - 147.63$$

$$Q_R = 3.33 \text{ MVAR}$$

Required "shunt" compensation = 3.33 MVAR

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Good Approach

Q.1 (c) A DC motor has an armature resistance of 0.5 Ω and $K\phi$ of 3 V-sec. The motor is driven by a single-phase thyristorized full converter. The input to the converter is an AC source of 230 V, 50 Hz. The motor is used as a prime mover of a forklift. In the upward direction, the mechanical load is 69 Nm and the triggering angle is α = 15°. In the downward direction, the load torque is 180 Nm. Calculate the triggering angle required to keep the downward speed equal in magnitude to upward speed. Assume continuous motor current for all operation. Also calculate the triggering angle to keep the motor at holding position while it was moving upward.

[12 marks]

$I_1 \rightarrow$ current during upward dirn

$$I_1 = \frac{69}{K\phi} = \frac{69}{3} = 23 \text{ Amp}.$$

$$V_t = \frac{2V_m}{\pi}\cos\alpha = \frac{2\times 230\sqrt{2}}{\pi}\cos 15^\circ$$

$$= \underline{200.01 \text{ Volt}}$$

$$E_1 = V_t - I_{a_1} r_a = 200.01 - 23\times 0.5$$

$\boxed{E_1 = 188.51}$ → for upward motion.

$I_2 \rightarrow$ for down ward motion.

$$I_2 = \frac{180}{3} = \underline{60} \text{ Amp}.$$

$$V_t = \frac{2V_m}{\pi}\cos\alpha_2$$

$$E_2 = \left(\frac{2V_m}{\pi}\cos\alpha_2 + 60\times 0.5\right)$$

for downward speed = upward speed

$$188.51 = \frac{2\times 230\sqrt{2}}{\pi}\cos\alpha_2 + 30$$

$$218.51 = \frac{2\times 230\sqrt{2}}{\pi}\cos\alpha_2$$

$\boxed{\alpha_2 = 40.05°}$

for holding position $E = 0$

$$\frac{2V_m}{\pi} \cos\alpha = I_a r_a$$

$$\cos\alpha = \frac{23 \times 0.5 \times \pi}{2 \times 230\sqrt{2}}$$

$$\boxed{\alpha = 86.81^\circ}$$

at holding position.

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Q.1 (d) Find the z-transform of the discrete time signal, $x(n) = \sin(2\omega_0 n)\, u[n]$.

[12 marks]

$$x(n) = \left(\frac{e^{j2w_0 n} - e^{-j2w_0 n}}{2i}\right) u(n)$$

$$x(n) = \frac{1}{2i}\left[e^{j2w_0 n} u(n) - e^{-j2w_0 n} u(n)\right]$$

taking z transform of signal

$$X(z) = \frac{1}{2i}\left[\frac{1}{1-(e^{j2w_0})z^{-1}} - \frac{1}{1-(e^{-j2w_0})z^{-1}}\right]$$

$$= \frac{1}{2i}\left[\frac{z}{z-e^{j2w_0}} - \frac{z}{z-e^{-j2w_0}}\right]$$

$$= \frac{1}{2i}\left[\frac{z\left(z-\frac{1}{e^{j2w_0}}\right) - z\left(z-e^{j2w_0}\right)}{\left(z-e^{j2w_0}\right)\left(z-\frac{1}{e^{j2w_0}}\right)}\right]$$

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Good Approach

$$\Rightarrow \frac{1}{2i}\left(\frac{\cancel{z^2} - \frac{z}{e^{j2w_0}} - \cancel{z^2} + ze^{j2w_0}}{z^2+1-z\left(e^{j2w_0}+e^{-j2w_0}\right)}\right)$$

$$= \frac{z\left(\frac{e^{j2w_0}-e^{-j2w_0}}{2i}\right)}{z^2+1-2z\cos 2w_0}$$

$$\boxed{X(z) \Rightarrow \frac{z\sin 2w_0}{z^2-2z\cos 2w_0+1}}$$

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Q.1 (e) The truth table of XY flip flop is shown below. Design this flip flop using T-flip flops and additional logic gates.

Truth table

X	Y	Q_{n+1}
0	0	Q_n
0	1	$\bar{Q}_n$
1	0	0
1	1	1

[12 marks]

X	Y	Q_n	Q_{n+1}	T
0	0	0	0	0
0	0	1	1	0
0	1	0	1	1
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	1
1	1	1	1	0

T	Q_n	Q_{n+1}
0	0	0
0	1	1
1	0	1
1	1	0

T

$X \backslash YQ_n$	00	01	11	10
$\bar{X}$			1	1
X		1		1

$$T = \bar{X}Y + \bar{Y}\bar{Q}_n + X\bar{Y}Q_n$$

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Q.2 (a) The ohmic, hysteresis and eddy current losses in a transformer at 50 Hz are 1.6%, 0.9% and 0.6% respectively. For a steinmetz's coefficient of 1.6,

Find:

(i) The losses at 60 Hz, for the same system voltage and current.

(ii) The output at 60 Hz, for the total losses to remain the same as on 50 Hz.

[20 marks]

at 50 Hz

Ohmic loss = 1.6%

Hysteresis loss = 0.9% $\quad n = 1.6$

eddy current loss = 0.6%

at 60 Hz

Ohmic loss = 1.6% (Because ohmic loss is independent of frequency).

Hysteresis loss = $B_m^n f$

$$= \left(\frac{V}{f}\right)^n \times f \Rightarrow f^{1-n}$$

$$\frac{H_2}{H_1} = \frac{f_2^{1-n}}{f_1^{1-n}} = \left(\frac{60}{50}\right)^{1-n} \times H_1$$

$$= \left(\frac{6}{5}\right)^{(1-1.6)} \times H_1$$

$$= 0.896 \times H_1$$

$$\boxed{H_2 = 0.806\%}$$

eddy current loss = $B_m^2 f^2$

$$= \frac{V^2}{\cancel{f^2}} \times \cancel{f^2}$$

Hence eddy current loss is also constant

$$\boxed{E_2 = E_1 = 0.6\%}$$

(ii) The output at 60 Hz will be same as of 50 Hz if all the losses are same as on 50 Hz.

Assume Input at 50 Hz is 1 pu

output = Input − Losses

$= 1 - [0.016 + 0.009 + 0.006]$

$\boxed{\text{output} = 0.969 \text{ pu}}$

for 60 Hz

output = 0.969 pu

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Q.2 (b) A three phase, 50 Hz transmission line of length 80 km is having resistance and inductive reactance of 3.75 mΩ/km and 15.92 μH/km respectively. The line is delivering a load of 375 kVA per phase at 0.8 p.f. lagging while the sending end line to line voltage is maintained at 3300 V.

Determine:

(i) The receiving end voltage and receiving end line current.

(ii) Sending end power and power factor.

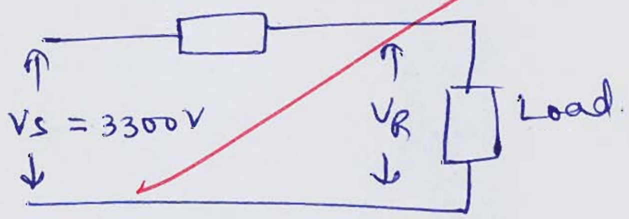
(iii) Voltage regulation of the line.

[20 marks]

(i) $R = 3.75\ m\Omega \times 80 = \underline{0.3\ \Omega}$

$jX = j\, 2\pi \times 50 \times 15.92 \times 10^{-6} \times 80 = j\underline{0.4}\ \Omega$

$R + jX = (0.3 + j0.4)\ \Omega$



$I_R = \dfrac{375 \times 10^3}{V_R} \angle -36.86$ ($V_R \to$ per phase voltage at Receiving end)

$V_S = V_R + (0.3 + j0.4) \times \dfrac{375 \times 10^3}{V_R} \angle -36.86$

$\left(\dfrac{3300}{\sqrt{3}}\right) = V_R + \dfrac{187500}{V_R} \angle 53.13 - 36.86$

$\dfrac{3300}{\sqrt{3}} = V_R + \dfrac{187500}{V_R} \angle 16.27$

$\left(\dfrac{3300}{\sqrt{3}}\right)^2 = V_R^2 + \left(\dfrac{187500}{V_R}\right)^2 + 2 \times 187500 \cos 16.27$

~~3600~~ $= V_R^2 + \dfrac{3.5156 \times 10^{10}}{V_R^2} + 359982.04$

3630000

$$V_R^4 + (359982.04 - 3630000)V_R^2 + 3.5156\times10^{10} = 0$$

$$V_R^4 - 3270017.96\,V_R^2 + 3.5156\times10^{10} = 0$$

$$V_R^2 = 3259233.215 \;,\; 10784.74$$

$$V_R = 1805.33 \;,\; 103.84 \;(\times)$$

$$\boxed{V_R\,(\text{phase}) = 1805.33} \text{ volts}$$

$$I_R(\text{phase}) = \frac{375\times10^3}{1805.33}$$

$$\boxed{I_R(\text{phase}) = 207.71\angle{-36.86^\circ}}$$

$$\boxed{\dot{I}_R(\text{line}) = I_R(\text{phase}) = 207.71\angle{-36.86^\circ}}$$

$$\boxed{V_R(\text{Line}) = 3126.92 \text{ volts}}$$

ii) $V_s = V_R + IZ$

$$= 1805.33 + 207.71\angle{-36.86} \times (0.3 + j0.4)$$

$$\boxed{V_s\,(\text{phase}) = 1905.24\angle{0.875^\circ}} \qquad V_s = 3300\angle{0.875^\circ}$$

$$P_{in} = \sqrt{3}\,V_L I_L \cos\phi_s$$

$$= \sqrt{3}\times3300\times207.71 \cos(0.875 + 36.86)$$

$$\boxed{P_{in} = 938.914 \text{ kwatt}}$$

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Input power factor

$\cos\phi_s = \cos(0.375 + 36.86)$

$\boxed{\cos\phi_s = \underline{\underline{0.790}}}$

(iii)

Voltage Regulation $= \frac{V_s - V_R}{V_S} \times 100$

$= \frac{3300 - 3126.92}{\cancel{3126.92}\ 3300} \times 100$

Voltage Regulation $= \underline{5.244\ \%}$

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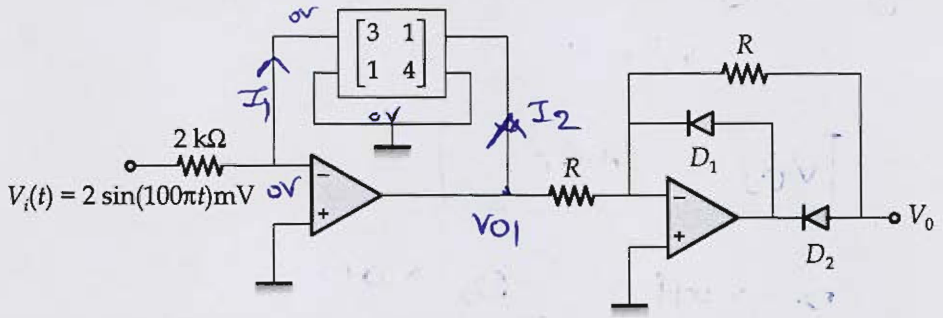
Q.2 (c) In the circuit shown in figure below, all the op-amps and diodes are ideal.



The two port network is characterized by the z-parameters (kΩ). Draw the output voltage (V_o) waveform. Also, calculate the average value of V_o.

[20 marks]

$V_1 = z_{11} I_1 + z_{12} I_2$

$V_2 = z_{21} I_1 + z_{22} I_2$ $\boxed{V_1 = 0}$

$0 = 3 I_1 + I_2$ $I_1 = \frac{V_i(t)}{2K}$

$V_{o1} = I_1 + 4 I_2$

$= I_1 + 4(-3I_1)$

$= I_1 - 12 I_1$

$V_{o1} = -11 I_1$

$V_{o1} = \left(-11 \times \frac{V_i(t)}{2K}\right)$ K

$\boxed{V_{o1} = -\frac{11}{2} V_i(t)}$

During +ve half cycle → $V_i(t) > 0$

$V_{o1} =$ (-ve)

hence $D_1 \rightarrow$ ON $D_2 \rightarrow$ off

$\boxed{V_o = 0}$

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During negative half cycle

$V_i < 0$

$$\boxed{V_{o1} = +ve}$$

$D_1 \rightarrow off$ $\quad$ $D_2 \rightarrow ON$

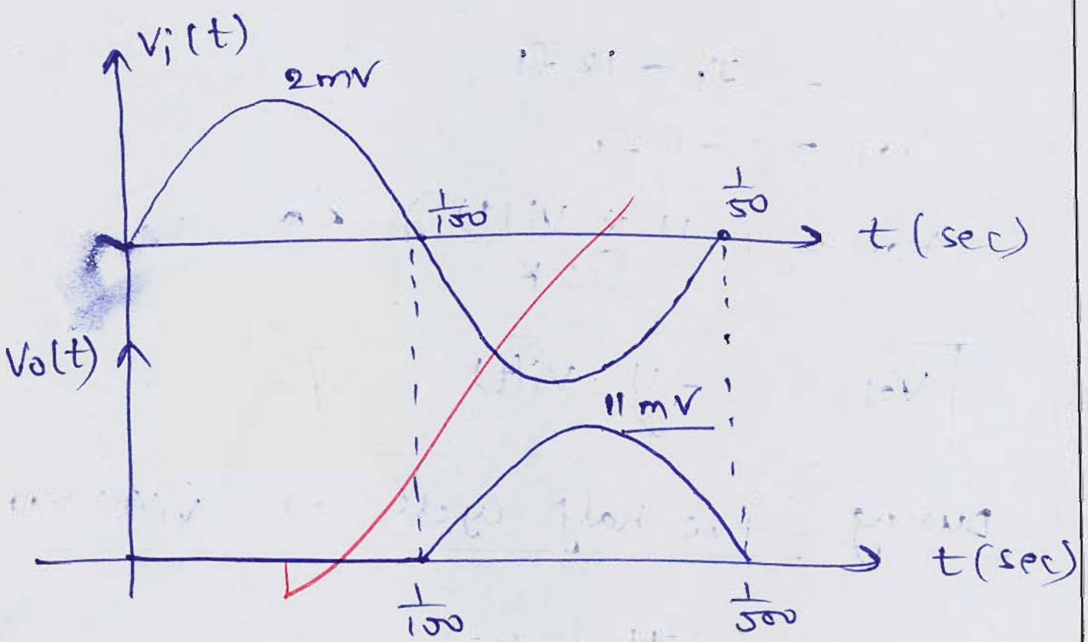
$$V_o = -\frac{R}{R} V_{o1}$$

$$= -V_{o1}$$

$$\boxed{V_o = \frac{11}{2} V_i(t)}$$

$$V_o = 5.5 \times 2 \sin(100\pi t) \text{ mV}$$

$$\boxed{V_o = 11 \sin(100\pi t) \text{ mV}}$$



Average value of V_0

$$= \frac{V_m}{\pi} = \frac{11}{\pi} = 3.50 \text{ m volt}$$

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Good
Approach

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Q.3 (a) Let $x[n]$ = IDFT $[X(k)]$ for $n, K = 0, 1, \ldots\ldots$ Apply below all properties to the sequence, $X(k) = \text{DFT}\{1, -j2, j, -j4\}$ by deriving the relationship between $x[n]$ and the IDFT's.

(i) $\text{IDFT}\{X^*(k)\}$.

(ii) $\text{IDFT}\left\{X(-k)_N\right\}$.

(iii) $\text{IDFT}\left\{\text{Re}\left[X(k)\right]\right\}$.

(iv) $\text{IDFT}\left\{\text{Im}\left[X(k)\right]\right\}$.

(Note : Use the result directly)

[20 marks]

Q.3 (b) A 10 kVA, 2500/250 V, single-phase transformer gave the following test results:

Open-circuit test (l.v.) :	250 V,	0.8 A,	50 W
Short-circuit test (h.v.) :	60 V,	3 A,	45 W

Calculate :

(i) The efficiency at $\frac{1}{4}$ of full load at 0.8 power factor.

(ii) The load (kVA output) at which maximum efficiency occurs and also the value of maximum efficiency at 0.8 power factor.

(iii) The voltage regulation and the secondary terminal voltage under rated load at power factor 0.8 lagging.

[20 marks]

Q.3 (c) Two 25 MVA, 11 kV identical synchronous generators are connected to a common bus-bar, which supplies a feeder. The star point of one of the generator is grounded through a resistance of 1 Ω while that of other generator is isolated. A line to ground fault occurs in phase '*a*' at the far end of feeder. Determine:

(i) Fault current.

(ii) The voltage of phase '*b*' and phase '*c*'.

(iii) Voltage of star point of the grounded generator with respect to ground.

The sequence impedances of each generator and feeder are given below:

	Generator (per unit)	**Feeder (ohm/phase)**
Positive sequence	$j0.2$	$j0.4$
Negative sequence	$j0.15$	$j0.4$
Zero sequence	$j0.08$	$j0.8$

[20 marks]

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Q.4 (a) **(i)** Briefly discuss the methods of power factor improvement in phase controlled rectifier.

(ii) A single-phase full converter in operated with symmetrical angle control, conduction angle $\beta = \frac{\pi}{3}$. If the load current, I_a is constant and ripple is negligible, determine the Fourier series expression of input current and the harmonic factor HF.

[20 marks]

(i) For power factor improvement

→ freewheeling diode across load terminal is used.

By using free wheeling diode load current does not become negative hence overall improvement in power factor occurs.

→ By using large inductor in load circuit to make current constant & ripple free.

→ By using semiconverter rectifier circuit. It also helps in improving power facter.

(ii)

$$I_{sr} = \frac{2\sqrt{2}\, I_0}{n\pi} \sin(n\omega_0 t - \phi)$$

$$g = \frac{I_{s1}}{I_0} = \frac{2\sqrt{2}}{\pi}$$

$I_{s1} \rightarrow$ fundamental component of I_{sr}

Harmonic factor $= \boxed{\frac{2\sqrt{2}}{\pi}} = g$

Total Harmonic distortion $= \sqrt{\frac{1}{g^2} - 1}$

$= \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1}$

$= 48\%$

10

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Q.4 (b) **(i)** Determine the damping ratio, undamped natural frequency of oscillations and % M_p for a unit step input given to a unity negative feedback system with open loop transfer function shown below:

$$\frac{C(s)}{E(s)} = \frac{1}{s(1+0.5s)(1+0.2s)}$$

(ii) The closed-loop transfer function of a unity negative feedback control system is given below:

$$\frac{C(s)}{R(s)} = \frac{Ks+\beta}{s^2+\alpha s+\beta}$$

Determine the steady state error for unit ramp input.

[10 + 10 marks]

(ii)

$$\frac{C(s)}{R(s)} = \frac{Ks+\beta}{s^2+\alpha s+\beta}$$

$G(s)H(s)$ OLTF $= \dfrac{Ks+\beta}{s^2+\alpha s+\cancel{\beta}-Ks-\cancel{\beta}}$

$$= \frac{Ks+\beta}{s^2+(\alpha-K)s} = \frac{Ks+\beta}{s(s+\alpha-K)}$$

$$e_{ss} = \lim_{s\to 0} \frac{sR(s)}{1+\dfrac{Ks+\beta}{s(s+\alpha-K)}}$$

for unit ramp input $R(s) = \frac{1}{s^2}$

$$= \lim_{s\to 0} \frac{s\times\frac{1}{s^2}}{1+\dfrac{Ks+\beta}{s(s+\alpha-K)}} \Rightarrow \frac{1}{s+\dfrac{Ks+\beta}{(s+\alpha-K)}}$$

$$= \frac{1}{\dfrac{\beta}{\alpha-K}}$$

$$\boxed{e_{ss} = \frac{\alpha-K}{\beta}}$$

10

Good Approach

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Q.4 (c) A 220 V, 50 Hz, 3-phase star-connected salient pole alternator has six poles. With a field current of 2.4 A, it produces rated terminal voltage on open circuit condition. On short circuit, it requires 0.8 A field current to produce an armature current of 27 A. The alternator has direct axis reactance (X_d) to quadrature axis reactance (X_q) ratio of 1.5. It is connected to bus bars of 220 V (line to line voltage) and its excitation required under this condition is 250 V. (Assuming negligible armature resistance)

Determine:

(i) The maximum power that the alternator can deliver and corresponding load angle with the excitation remaining unchanged.

(ii) The maximum power that the alternator can deliver if a sudden loss of excitation occurs during the synchronized condition.

(Assume linear magnetic circuit)

[20 marks]

$$X_s = \frac{V_{oc}}{I}$$

$$= \frac{220/\sqrt{3}}{27} = j4.70 \ \Omega$$

$$X_d + X_q = j4.7 \quad \text{—(1)}$$

$$\frac{X_d}{X_q} = 1.5$$

$$X_d = 1.5 X_q$$

$$2.5 X_q = j4.7$$

$$\boxed{X_q = 1.88j}$$

$$\boxed{X_d = 2.82j}$$

$$P = \frac{E_f V_t}{X_d}\sin\delta + \frac{V_t^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$$

$$= \frac{250 \times 220}{2.82}\sin\delta + \frac{(220)^2}{2}\left(\frac{1}{1.88} - \frac{1}{2.82}\right)\sin 2\delta$$

$$P = 19503.54\sin\delta + \cancel{24200} \times 4290.78 \sin 2\delta$$

for max power $\frac{dP}{d\delta} = 0$

$$\frac{dP}{d\delta} = 19503.54 \cos\delta + 4290.78 \times 2 \sin 2\delta = 0$$

$$= 19503.54 \cos\delta + 8581.56 \cos 2\delta = 0 .$$

$$19503.54 \cos\delta + 8581.56 \left[2\cos^2\delta - 1\right] = 0$$

$$17163.12 \cos^2\delta + 19503.54 \cos\delta - 8581.56 = 0$$

$$\cos\delta = +0.3389$$

$$\boxed{\delta = \cancel{109.80}^\circ} \; \boxed{70.19^\circ}$$

$$P_{max} = 18349.36 + 2736.046$$

$$\boxed{P_{max} = 21085.406 \text{ MW}}$$

(ii) sudden loss of Excitation $\Rightarrow E = 0$

$$P = 4290.78 \sin 2\delta$$

for maximum power

$$\boxed{\delta = 45^\circ}$$

$$\boxed{P_{max} = 4290.78 \text{ MW}}$$

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Section-B

Q.5 (a) The following assembly language program of an 8085 microprocessor, working with a clock frequency of 3 MHz is used to set up a delay of 10 ms:

```
      MVI B, wx H
      MVI C, yz H
L1:   DCX B
      JNZ L1
```

What is the minimum value of $(wxyz)_H$ in hexadecimal to obtain required delay?

[12 marks]

MVI B , 10 H
MVI C , 00 H

DCX B
JNZ L1

Minimum value of $(wxyz)_H$

$= \underline{(10\ 00)H}$

to obtain a

1

In complete Solution

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Q.5 (b) A message signal, X contains five symbols 'h', 'e', 'l', 'l', 'o' where each sample $x_i \in B^{D\times1}$ and $B \in \{0, 1\}$.

(i) Find the probability of the unique symbols in X.

(ii) Find the entropy of message signal, X.

(iii) Create a balanced Huffman tree for this message signal X.

(iv) Create the Huffman code book.

[12 marks]

(i) Probability of unique symbols

$$P_h = h \log\left(\frac{1}{h}\right)$$

$$P_e = e \log\left(\frac{1}{e}\right)$$

$$P_l = l \log\left(\frac{1}{l}\right)$$

$$P_o = o \log\left(\frac{1}{o}\right)$$

(ii) Entropy of message signal $= P_h + P_e + P_l + P_l + P_o$

$$= h \log\left(\frac{1}{h}\right) + e \log\left(\frac{1}{e}\right) + l \log\left(\frac{1}{l}\right) + l \log\left(\frac{1}{l}\right) + o \log\left(\frac{1}{o}\right)$$

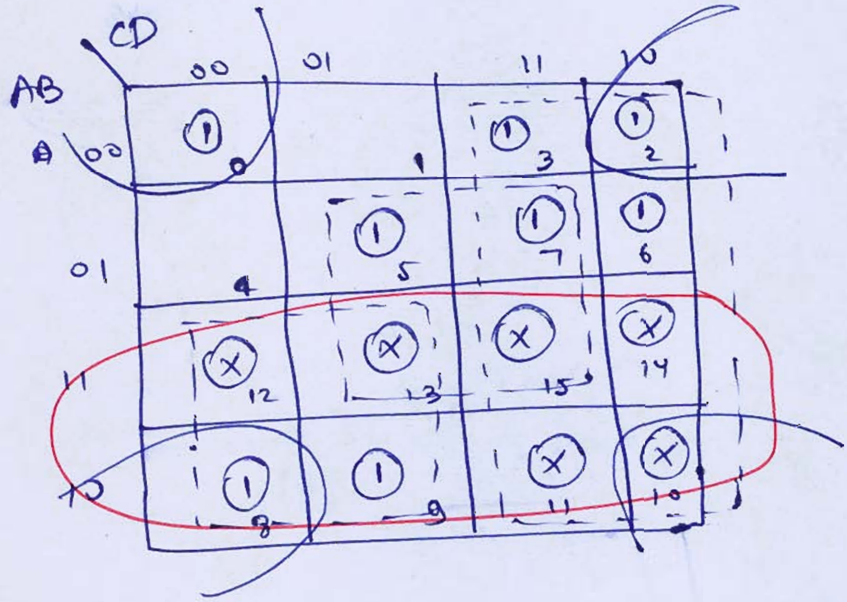
0

Incomplete Solution

Do not write in this margin

Q.5 (c) $f(A, B, C, D) = \Sigma m(0, 2, 3, 5, 6, 7, 8, 9) + \Sigma d(10, 11, 12, 13, 14, 15)$. Realize the minimized function using only NOR gates.

[12 marks]



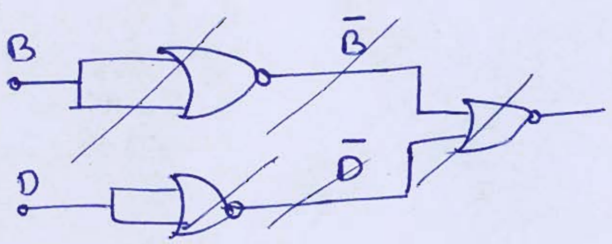
$f(A,B,D) = C + BD + \bar{C}A + \bar{D}\bar{B}$

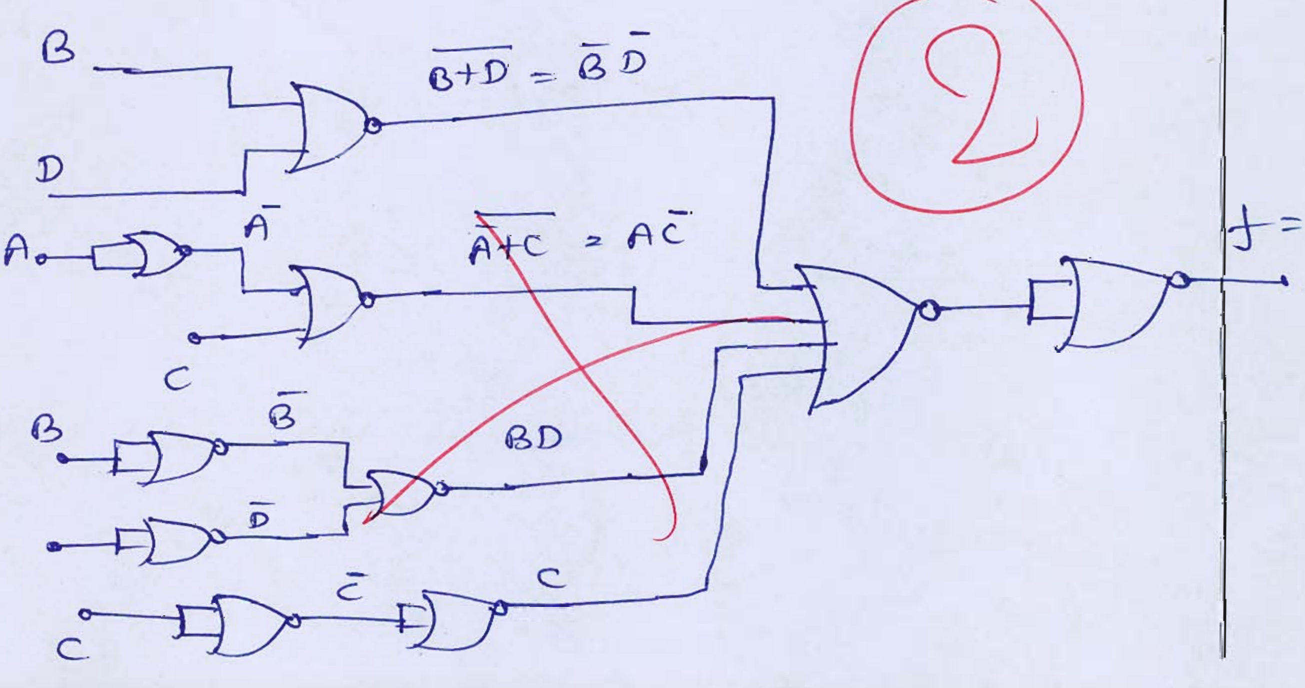
$f(A,B,C,D) = C + BD + A\bar{C} + \bar{B}\bar{D}$

$\bar{\bar{f}} = \cancel{\overline{\overline{C + BD + A\bar{C} + \bar{B}\bar{D}}}}$

$\Rightarrow \cancel{\overline{\bar{C} \cdot \overline{BD} \cdot \overline{A\bar{C}} \cdot \overline{\bar{B}\bar{D}}}}$

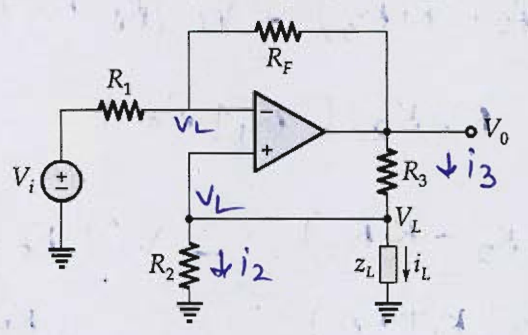
$\Rightarrow$





2

Q.5 (d) In the circuit shown below, obtain the equation of i_L (load current) independent of z_L.



[12 marks]

$$\frac{V_i - V_L}{R_1} = \frac{V_L - V_o}{R_F}$$

$$\frac{V_i}{R_1} = \frac{V_L}{R_1} + \frac{V_L}{R_F} - \frac{V_o}{R_F}$$

$$\frac{V_i}{R_1} + \frac{V_o}{R_F} = V_L\left[\frac{1}{R_1} + \frac{1}{R_F}\right]$$

$$V_i R_F + R_1 V_o = V_L (R_1 + R_F)$$

$$V_L = \frac{V_i R_F + V_o R_1}{R_1 + R_F} \quad \text{—— (1)}$$

$$i_L = i_3 - i_2$$

$$= \frac{V_o - V_L}{R_3} - \left[\frac{V_L}{R_2}\right]$$

$$= \frac{V_o - \left(\frac{V_i R_F + V_o R_1}{R_1 + R_F}\right)}{R_3} - \frac{V_i R_F + V_o R_1}{(R_1 + R_F) R_2}$$

$$\Rightarrow \frac{\cancel{V_o R_1} + V_o R_F - V_i R_F - \cancel{V_o R_1}}{(R_1 + R_F) R_3} - \frac{V_i R_F + V_o R_1}{(R_1 + R_F) R_2}$$

$$i_L \Rightarrow \frac{1}{R_1 + R_F}\left[\frac{V_o R_F R_2 - V_i R_F R_2 - V_i R_F R_3 - V_o R_1 R_3}{R_3 R_2}\right]$$

$$i_L = \frac{V_0 (R_F R_2 - R_1 R_3) - V_i (R_F R_2 + R_F R_3)}{R_3 R_2 (R_1 + R_F)}$$

$$i_L = \frac{V_0 (R_F R_2 - R_1 R_3)}{R_3 R_2 (R_1 + R_F)} - V_i \frac{(R_F R_2 + R_F R_3)}{(R_1 + R_F) R_2 R_3}$$

7

Do not write in this margin

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

$$G(s) = \frac{K}{s(s+3)(s^2+s+1)}.$$

Determine the values of K that will cause sustained oscillations in the closed-loop system. Also, find the oscillation frequency.

[12 marks]

Char. eq^n $\quad 1 + G(s)H(s) = 0$

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

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

$$s^4 + s^3 + s^2 + 3s^3 + 3s^2 + 3s + K = 0$$

$$s^4 + 4s^3 + 4s^2 + 3s + K = 0$$

s^4	1	4	K
s^3	4	3	
s^2	$\frac{16-3}{4}$	K	
s^1	$\frac{\frac{39}{4} - 4K}{\frac{39}{4}}$		
s^0	K		

$\boxed{K > 0}$

$$\frac{39}{4} - 4K > 0$$

$$K < \frac{39}{16}$$

$\boxed{K \leq 2.43}$

for sustained oscillation $\boxed{K = 2.43}$

$$\frac{13}{4}s^2 + 2.43 = 0$$

$$s^2 = \frac{-2.43 \times 4}{13} = \sqrt{0.7476}$$

$\boxed{s = j\omega_n = j0.86}$ $\quad \boxed{\omega_n = 0.86 \text{ rad/sec}}$

Do not write in this margin

$$\boxed{f = 0\cdot 1376 \text{ Hz}}$$

11

Good Approach

Do not write in this margin

Q.6 (a) (i) A 3-phase full-converter charges a battery from a three-phase supply of 240 V, 50 Hz. The battery emf is 190 V and its internal resistance is 0.6 ohm. On account of inductance connected in series with the battery, charging current is constant at 22 A. Calculate the firing angle and supply power factor.

(ii) If it is desired that power flows from dc source to ac source in part (i), calculate the firing angle delay for the same value of current.

[20 marks]

(i) $E = 190\,V \qquad r = 0.6$

$V_0 = E + I_0 r$

$= 190 + 22 \times 0.6$

$V_0 = 203.2$ volt

$\frac{3V_{ml}}{\pi}\cos\alpha = 203.2$

$\frac{3 \times 240\sqrt{2}}{\pi}\cos\alpha = 203.2$

$\cos\alpha = 0.6269$

$\boxed{\alpha = 51.175^\circ}$

Input power $= E \times I_0 + I_0^2 \times r$

$\sqrt{3} V_{sr} I_{sr} \cos\phi = 190 \times 22 + 22^2 \times 0.6$

$\sqrt{3} \times 240 \times I_0\sqrt{\frac{2}{3}} \times \cos\phi = 4470.4$

$\cos\phi = \frac{4470.4}{\sqrt{3} \times 240 \times 22\sqrt{\frac{2}{3}}} = 0.598$

$\boxed{\text{supply power factor} = 0.598}$

(ii) when power flow is reversed

$E \rightarrow -ve$

$V_0 = -E + I_0 R = -190 + 22 \times 0.6$

$= \underline{-176.8}$

$$\frac{3V_{ml}}{\pi}\cos\alpha = -176.8$$

$$\cos\alpha = \frac{-176.8}{3\times 240\sqrt{2}}\times\pi$$

$$\boxed{\alpha = 123.05^\circ}$$

Input power = output power

$$\sqrt{3}V_{sr}I_{sr}\cos\phi = -EI_o + I_o^2 r$$

$$= -190\times 22 + 22^2\times 0.6$$

$$\sqrt{3}V_{sr}I_{sr}\cos\phi = -3889.6$$

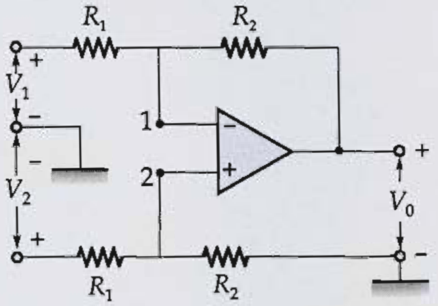
$$\boxed{\cos\phi = -0.52}$$

$$\boxed{\text{Input power factor} = -0.52}$$

18

Good Approach

Q.6 (b) (i) The differential input operational amplifier shown below consists of a base amplifier of infinite gain. Derive an expression for its output voltage, V_0.



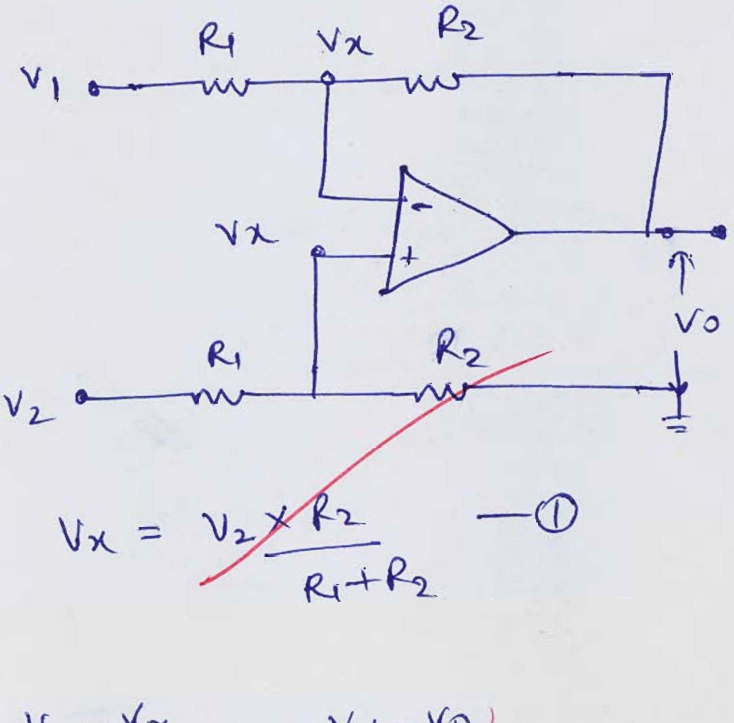
(ii) Draw the pin diagram of the 555 timer.
A 555 timer is connected for Astable operation with V_{CC} = 12 V. The component values are selected as R_A = 10 kΩ, R_B = 2.3 kΩ and C = 0.1 μF.

Calculate:

1. Output frequency.
2. Duty cycle.
3. Average power dissipated if 1 kΩ resistive load is connected between source and the output pin.

[8 + 12 marks]

(i)



$$V_x = \frac{V_2 \times R_2}{R_1 + R_2} \quad —(1)$$

$$\frac{V_1 - V_x}{R_1} = \frac{V_x - V_o}{R_2}$$

$$\frac{V_1}{R_1} = \frac{V_x}{R_1} + \frac{V_x}{R_2} - \frac{V_o}{R_2}$$

$$\frac{V_1}{R_1} = \frac{V_2 R_2}{R_1 + R_2}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{V_o}{R_2} \quad —(2)$$

$$\frac{V_1}{R_1} = \frac{V_2 \cancel{R_2}}{R_1 \cancel{R_2}} - \frac{V_0}{R_2}$$

$$\frac{V_1}{R_1} = \frac{V_2}{R_1} - \frac{V_0}{R_2}$$

$$\frac{V_0}{R_2} = \frac{(V_2 - V_1)}{R_1}$$

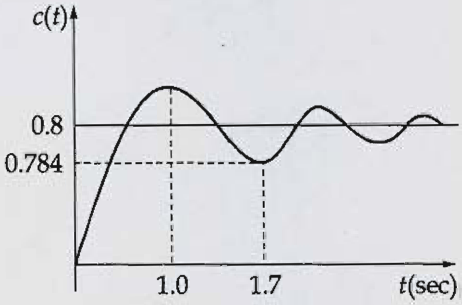
$$V_0 = \frac{R_2}{R_1}(V_2 - V_1)$$

$$\boxed{V_0 = \frac{-R_2}{R_1}(V_1 - V_2)}$$

8

Good Approach

Q.6 (c) (i) The unit step response of a second order underdamped system is shown in the figure below. Determine the transfer function of the system.



[8 marks]

undershoot

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

$$0.016 = e^{-\frac{2\xi\pi}{\sqrt{1-\xi^2}}}$$

$$0.6581 = \frac{\xi}{\sqrt{1-\xi^2}}$$

$$0.433 = \frac{\xi^2}{1-\xi^2}$$

$$0.433 - 0.433\,\xi^2 = \xi^2$$

$$1.433\,\xi^2 = 0.433$$

$$\xi^2 = 0.3022 \qquad \boxed{\xi = 0.549}$$

$$t_p = \frac{\pi}{w_d} = 1$$

$$w_d = \pi$$

$$w_n\sqrt{1-\xi^2} = \pi$$

$$w_n = \frac{\pi}{\sqrt{1-0.3022}} \qquad \boxed{w_n = 3.76 \text{ rad/sec}}$$

second order T/f

$$T/f = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

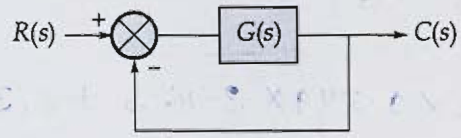
$$= \frac{(3.76)^2}{s^2 + 2 \times 0.549 \times 3.76\, s + (3.76)^2}$$

$$= \frac{14.14}{s^2 + 4.128\, s + 14.44}$$

$$\boxed{T/f = \frac{14.14}{s^2 + 4.128 s + 14.44}}$$

7

Q.6 (c) **(ii)** For the system shown in figure below, $G(s) = \dfrac{60s + K}{s^2(s^2 + 6s + 30)}$. Determine the range of values of K for which all the closed loop poles lie to the left of $s = -1$.



[12 marks]

for all the poles to lie in left of $\underline{s=-1}$

put $s \to (s+1)$

$$G(s) = \frac{60(s-1)+K}{(s-1)^2\left((s-1)^2+6(s-1)+30\right)}$$

$$= \frac{60s+(K-60)}{(s^2+1-2s)(s^2-2s+1+6s-6+30)}$$

$$= \frac{60s+(K-60)}{(s^2-2s+1)(s^2+4s+25)}$$

char. eq^n $\quad 1+G(s)H(s) = 0$

$$1+\frac{60s+(K-60)}{(s^2-2s+1)(s^2+4s+25)} \times 1 = 0$$

$$(s^2-2s+1)(s^2+4s+25) + 60s + K - 60 = 0$$

$$s^4 - 2s^3 + s^2 + 4s^3 - 8s^2 + 4s + 25s^2 - 50s + 25 + 60s + K - 60 = 0$$

$$s^4 + 2s^3 + 18s^2 + 14s + K - 35 = 0$$

s^4	1	18	$K-35$
s^3	2	14	
s^2	11	$K-35$	
s^1	$\frac{154-(2K-70)}{11}$		
s^0	$K-35$		

$154-2K+70>0$

$224 > 2K$

$K < \frac{224}{2}$

$\boxed{K < 112}$

$\boxed{K-35>0}$

$\boxed{K>35}$

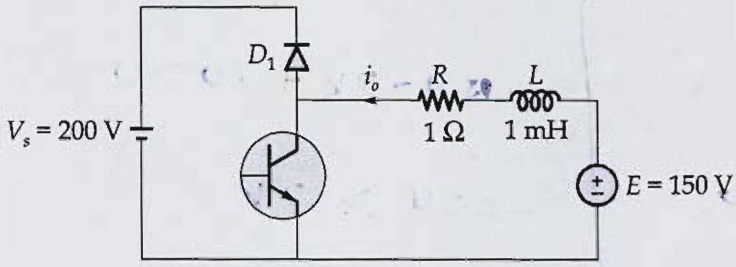
11

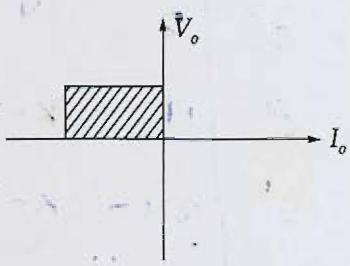
Range of K

Good Approach

$\boxed{35 < K < 112}$

Q.7 (a) A dc-to-dc chopper capable of second-quadrant is used in 200 V dc battery electric vehicle. The machine armature has 1 Ω in series with 1 mH inductance.





(i) The machine is used for regenerative braking. At a constant speed downhill, the back emf is 150 V, which results in 10 A braking current. What is the switch on-state duty cycle if the machine is delivering continuous output current? What is the minimum chopping frequency for these conditions?

(ii) At this speed (that is $E = 150$ V), determine the minimum duty cycle for continuous inductor current, if the switching frequency is 1 kHz. What is the average braking current at the critical duty cycle?

(iii) If the chopping frequency is increased to 5 kHz, at the same speed (that is $E = 150$ V), what is the critical duty cycle and corresponding average dc machine current?

[20 marks]

Q.7 (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]

7 (c) The fuel-cost function in Rs/hr of two thermal power plants are :

$$C_1 = 320 + 6.2P_1 + 0.004P_1^2$$
$$C_2 = 320 + 6P_2 + 0.003P_2^2$$

where P_1 and P_2 are in MW. The plant outputs are subjected to following limits (in MW):

$$50 \leq P_1 \leq 250$$
$$50 \leq P_2 \leq 350$$

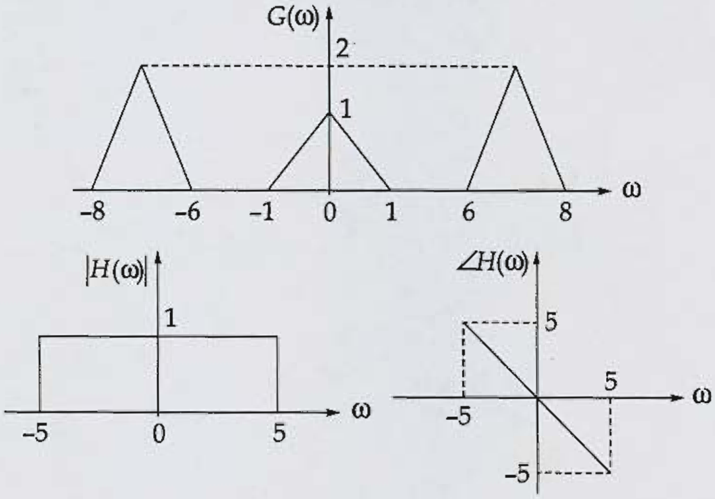
The per unit system real power loss with generation expressed in pu on a 100 MVA base are given by

$$P_L = 0.0125P_1^2 + 0.00625P_2^2$$

The total load is 412.35 MW. Determine the optimal load dispatch of generation. Start with an initial estimate of $\lambda = 7$ Rs/MWh. Use the gradient method of optimization for 3-iterations.

[20 marks]

Q.8 (a) (i) Suppose $g(t)$ is the input to an LTI system with transfer function $H(\omega)$ and $G(\omega)$ is the Fourier transformer of $g(t)$ as shown below:



Find the output of the LTI system, $y(t)$.

[10 marks]

Do not write in this margin

Q.8 (a) **(ii)** Find the inverse Laplace transform for $F(s) = \dfrac{1}{s^2(s+1)^2}$ using continuous convolution method.

[10 marks]

Q.8 (b) The open-loop transfer function of a feedback control system is

$$G(s)H(s) = \frac{K(1+2s)}{s(1+s)(1+s+s^2)}.$$

Find the restriction on K for stability. Find the value of K for the system to have a gain margin of 3 dB. With this value of K, find the phase cross over frequency and phase margin.

[20 marks]

char. eq^n

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

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

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

$$s^2 + s^3 + s^4 + s + s^2 + s^3 + K + 2sK = 0$$

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

$$\begin{array}{c|ccc} s^4 & 1 & 2 & K \\ s^3 & 2 & 1+2K & \\ s^2 & \frac{4-(1+2K)}{2} & K & \\ s^1 & \frac{\left(\frac{3-2K}{2}\right)(1+2K) - 2K}{\left(\frac{3-2K}{2}\right)} & & \\ s^0 & K & & \end{array}$$

$$\frac{4-1-2K}{2} > 0$$

$$\boxed{K > 0}$$

$$3 - 2K > 0$$

$$\boxed{K < 1.5}$$

$$(3-2K)(1+2K) - 4K > 0$$

$$3 - 2K + 6K - 4K^2 - 4K > 0$$

$$3 + \cancel{4K} - \cancel{4K} - 4K^2 > 0$$

$$K^2 < \frac{3}{4} \qquad \left(-\frac{\sqrt{3}}{2} < K < \frac{\sqrt{3}}{2}\right)$$

Range of K

$$\boxed{0 < K < 0.866}$$

GM = 3 dB

$$20\log\left(\frac{1}{x}\right) = 3\,dB$$

$$\frac{1}{x} = 1.41$$

$$\boxed{x = 0.707}$$

K

ω_{pc}

$+\tan^{-1}2\omega_{pc} - 90^\circ - \tan^{-1}\omega_{pc}$

3 (c) A single phase full bridge controlled rectifier is supplied from a single phase ac source of 230 V, 50 Hz. The converter is delivering power to an R-L load where $R = 20\ \Omega$ and $L = 0.2$ H. For the firing angle of 60°,

(i) check whether the load current is continuous or not.

(ii) determine the dc component of the load current.

(iii) determine the power absorbed by the load considering only first dominant harmonic.

[20 marks]

OOOO

Space for Rough Work

Space for Rough Work