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ESE-2021
(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

ELECTRICAL ENGINEERING

PAPER-II

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ELECTRICAL ENGINEERING

ESE_MAINS_2021_PAPER – II

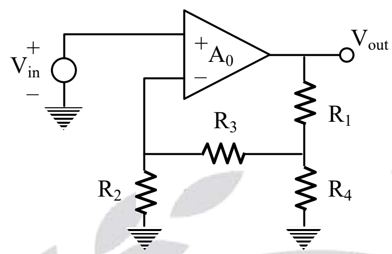
Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

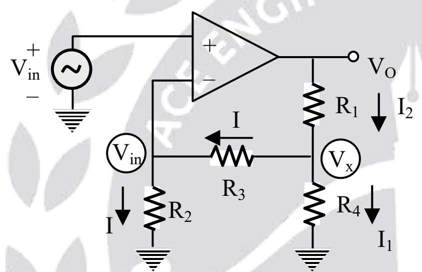
S.No	NAME OF THE SUBJECT	Marks
01	Analog and Digital Electronics	58
02	Systems and signal processing	66
03	Control systems	104
04	Electrical Machines	104
05	Power Systems	64
06	Power Electronics	84

SECTION – A

1(a) For a non-inverting amplifier with $A_0 = \infty$, calculate the closed loop gain. What happens to the result when $R_1 \to 0$ and $R_3 \to 0$? **[12M]**



Solution:



$$I = \frac{V_{in}}{R_2} \to V_x = I \,.\, R_3 + I.R_2$$

$$V_x = \frac{V_{in}}{R_2}\,[R_3 + R_2] \;\ldots\ldots (1)$$

$$I_1 = \frac{V_x}{R_4} = \frac{\frac{V_{in}}{R_2}[R_2 + R_3]}{R_4} = \frac{V_{in}}{R_4}\left[1 + \frac{R_3}{R_2}\right] \ldots\ldots.(2)$$

$$I_2 = I_1 + I = \frac{V_{in}}{R_4}\left[1 + \frac{R_3}{R_2}\right] + \frac{V_{in}}{R_2}$$

$$V_0 = \left[\frac{V_{in}}{R_4}\left[1 + \frac{R_3}{R_2}\right] + \frac{V_{in}}{R_2}\right] R_1 + \frac{V_{in}}{R_4}\left[1 + \frac{R_3}{R_2}\right] R_4$$

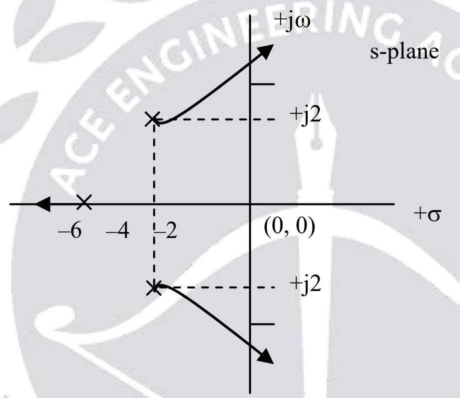
$$\frac{V_0}{V_{in}} = \left[\frac{R_1}{R_4}\left(1 + \frac{R_3}{R_2}\right) + \frac{R_1}{R_2}\right] + \left(1 + \frac{R_3}{R_2}\right)$$

$$\frac{V_0}{V_{in}} = \frac{R_1}{R_2} + \left(1+\frac{R_3}{R_2}\right)\left(1+\frac{R_1}{R_4}\right)$$

If $R_1 \to 0, \qquad R_3 \to 0$

Then, $\dfrac{V_0}{V_{in}} = 1$

1(b) The accompanying figure depicts the locus of closed loop poles of a system for $0 < K < \infty$. From the plot, determine the frequency with which the system is likely to exhibit sustained oscillation. Determine the value of K at which one of the closed loop poles lie at s = –8. [12M]



Solution:

$$G(s)\,H(s) = \frac{k}{(s+2-j2)(s+2+j2)(s+6)}$$

$$= \frac{k}{\left((s+2)^2+2^2\right)(s+6)}$$

$$GH(s) = \frac{k}{(s^2+4s+8)(s+6)}$$

CE : $1 + G(s)\,H(s) = 0 \Rightarrow (s^2 + 4s + 8)\,(s+6) + k = 0$

$s^3 + 4s^2 + 8s + 6s^2 + 24s + 48 + k = 0$

$s^3 + 10s^2 + 32s + (k + 48) = 0$

$$\begin{array}{c|cc}
s^3 & 1 & 32 \\
s^2 & 10 & k+48 \\
s^1 & \left[\dfrac{320-(k+48)}{10}\right] = MS & \\
s^0 & (k+48) &
\end{array}$$

For MS $\rightarrow$ 320 = (k + 48)

K = 272 the system generate sustain oscillations

Frequency of oscillation

AE : $10s^2 + (k + 48) = 0$

$$10s^2 + (272 + 48) = 0$$

$$10s^2 + 320 = 0$$

$$s = \pm j\sqrt{32}$$

$w_n = \sqrt{32} = 5.656$ rad/sec

k value at s = –8

$$|G(s)H(s)|_{s=-8} = 1$$

$$\left|\frac{k}{[(-8)^2 + 4(-8) + 8][-8 + 6]}\right| = 1$$

$$\left|\frac{k}{(64 - 32 + 8)(-2)}\right| = 1 \quad \Rightarrow k = 80$$

1(c) A 220 V, 8-pole, 4.5 kW, 1100 rpm, lap connected dc generator has 1200 conductors. Each conductor has a resistance of 100 mΩ. The generator is run at half rated speed and is delivering rated current to load. Find the induced emf and corresponding terminal voltage under this condition. Assume constant field flux and no magnetic saturation of the machine during operation. [12M]

Solution:

Given data:

V = 220V, P = 8, 4.5 KW, N = 1100 rpm,

A = P = 8, Z = 1200. R/c=100mΩ = 0.1Ω

No. of conductors in each parallel path $= \frac{1200}{8} = 150$

$\therefore$ Resistance of each parallel path = 150× 0.1 = 15Ω

$$\therefore\ R_a = \frac{15}{8} = 1.875\Omega$$

$$\text{Rated, } I_a = \frac{4.5\times10^3}{220} = 20.45\text{A}$$

$$\therefore\ Eg_1 = V + I_aR_a = 220 + 20.45 \times 1.875$$

$$Eg_1 = 258.43\text{ V} \rightarrow N_1 = 110\text{ rpm}$$

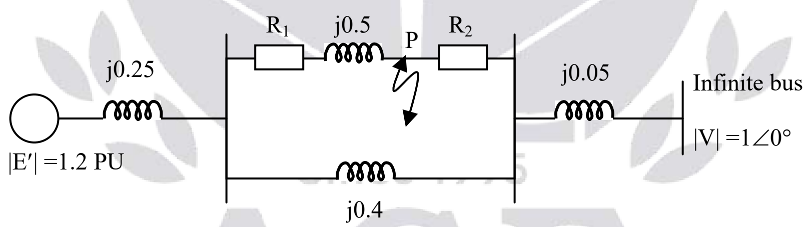
$\therefore Eg_2 = ?$ @ $N_2 = 550$ rpm

Emf @ half rated speed,

$$\frac{Eg_2}{Eg_1} = \frac{N_2}{N_1} \Rightarrow Eg_2 = \frac{550}{1100}\times 258.43 = 129.17\text{V}$$

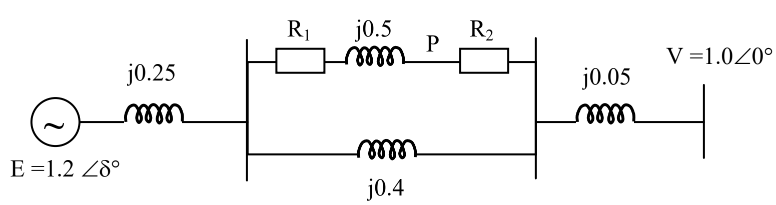
$$\therefore\ V = Eg_2 - I_aR_a = 129.17 - 20.45 \times 1.875 = 90.83\text{V}$$

1(d) For a system shown in the figure, a three phase fault occurs at point P which is followed by simultaneous opening of the circuit breakers R_1 and R_2. [12M]



If the generator was delivering 1.0 PU power prior to fault, find the power angle δ in pre-fault condition and the maximum permissible angle δ_{max} post-fault after clearing by removing the faulted line by breakers.

Solution:



Power delivered before fault is $P_{e1} = 1.0$ pu

Mechanical input $(P_s) = P_{e1} = 1.0$

$$P_{m1} = \frac{EV}{X_{1eq}} = \frac{1.2\times1.0}{0.25+0.05+\frac{0.5\times0.4}{0.9}}$$

$$P_{m1} = \frac{1.2\times1.0}{0.3+0.22} = \frac{1.2\times1.0}{0.52} = 2.3$$

Before fault

$P_s = P_{e1} = 1.0$

$1.0 = P_{e1} = P_{m1}\sin\delta_0$

$$\delta_0 = \sin^{-1}\left(\frac{1.0}{P_{m1}}\right) = \sin^{-1}\left(\frac{1.0}{2.3}\right)$$

$\delta_0 = 25.46°$

After fault cleared: Minimum power transfer is

$$P_{m3} = \frac{EV}{X_{3eq}}$$

$$= \frac{1.2\times1.0}{0.25+0.4+0.05}$$

$$= \frac{1.2\times1.0}{0.7}$$

$P_{m3} = 1.71$

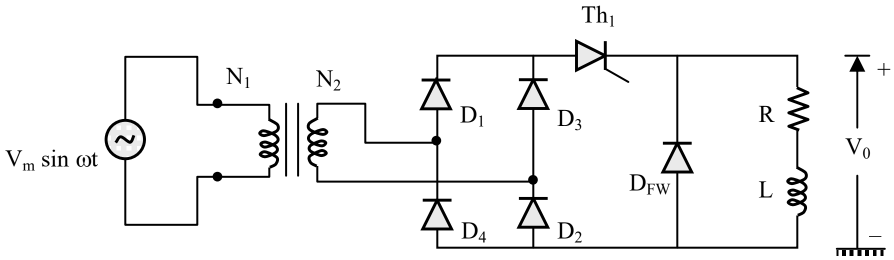
$P_s = 1.0$

$$\delta_{max} = 180-\sin^{-1}\left(\frac{P_s}{P_{m3}}\right)$$

$$\delta_{max} = 180-\sin^{-1}\left(\frac{1.0}{1.71}\right)$$

$= 144.26°$

1(e)



For the circuit shown in the figure,

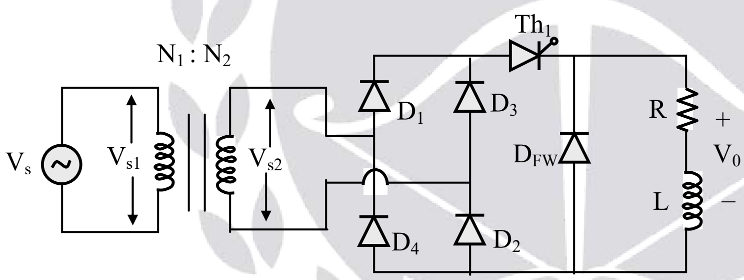
(i) Draw the output voltage $V_{0(+)}$ waveform.

(ii) Obtain the expression of $V_{0,av}$, i.e., average output voltage

(iii) Discuss limitations and application area

Assume thyristors are fired at α with $2f_s$ frequency, where $f_s = \omega/2\pi$ and ω is the synchronous supply frequency **[12M]**

Solution:



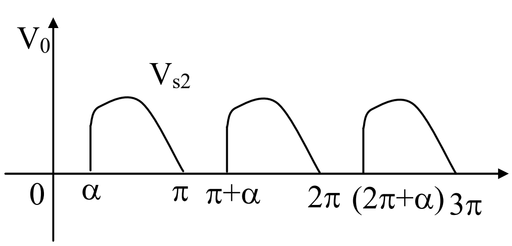
$$V_s = V_m \sin(\omega t) = V_{s1}$$

$$K = \frac{N_2}{N_1} = \frac{V_{s2}}{V_{s1}}$$

$$V_{s2} = \left(\frac{N_2}{N_1}\right)V_{s1}$$

$$V_{oavg} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_{s2}\, d\omega t$$

(i)



(ii) $V_{0avg} = \frac{1}{\pi}\int_{\alpha}^{\pi}\left(\frac{N_2}{N_1}\right)V_m \sin(\omega t).d\omega t$

$$= \frac{N_2}{N_1} \times V_m \times [-\cos(\omega t)]_{\alpha}^{\pi}$$

$$V_{0avg} = \frac{N_2}{N_1} \times V_m \times [1+\cos\alpha]$$

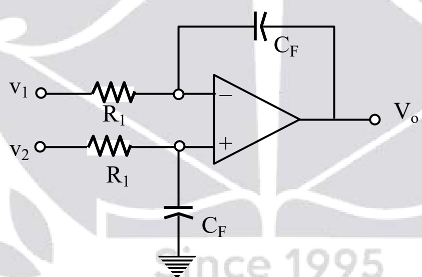
(iii)Limitations:

In this full wave rectifier circuit using single thyristor, as there are three power devices conducting together at the same time there is more conduction voltage drop and an increase in 'ON' state conduction losses and hence efficiency also reduces.

Applications:

1. This type of converter is suitable for motoring applications in D.C motor drives

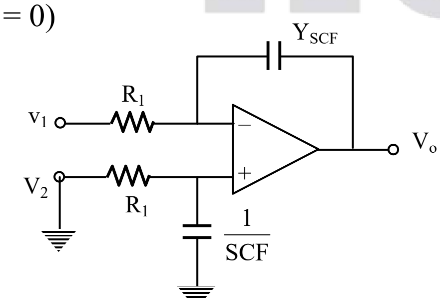
2(a) (i) Analytically prove that the following Op-Amp circuit does the function of differential integrator: [8M]



Solution:

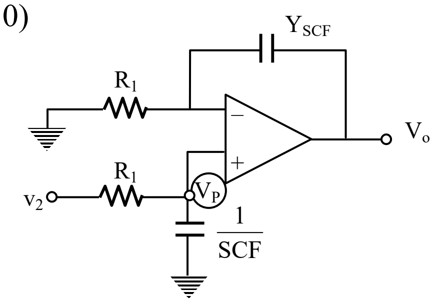
Let us apply super position

V_1 alone ($V_2 = 0$)



$$\frac{V_0(s)}{V_1(s)} = \frac{-1}{\frac{SCF}{R_1}} = \frac{-R_1}{SCF}$$

V_2 alone ($V_1 = 0$)



$$V_0(S) = \left[1 + \frac{1/SCF}{R_1}\right] V_P$$

$$= \left[1 + \frac{1}{SCF\,R_1}\right] \frac{\left(1/SCF\right)}{R_1 + \frac{1}{SCF}} V_2(S)$$

$$V_0(S) = \left[\frac{SCF\,R_1 + 1}{SCF\,R_1}\right] \frac{V_2(S)}{(1 + SCF\,R_1)}$$

$$V_0(S) = \frac{V_2(S)}{SCF\,R_1}$$

$$V_0(S) = \left[\frac{-1}{R_1 CF}\right] \frac{1}{S} V_1(S) + \frac{V_2(S)}{S[R_1 CF]}$$

$$= \left[\frac{1}{R_1 CF}\right] \frac{1}{S} [V_2(S) - V_1(s)]$$

$$\therefore\ V_0(t) = \frac{1}{R_1 CF} \int_0^t [V_2(t) - V_1(t)]dt$$

The circuit functions as a differential integrator.

2(a) (ii) A. What is the full scale output of a R–2R ladder for 4-bit numbers with R_F= 3R and state $0 \to 0V$ state $1 \to 5$ V?

B. What is the output of above converter with input: 1001?

C. An analog signal sensed by a sensor needs to be digitized. The range of analog signal is 0–2V, it is desired that variation of 0.01 V be detected. Assuming maximum frequency content in analog signal is not more than 2 kHz samples, calculate conversion time and resolution required. [12M]

Solution:

A. $\frac{V_R}{2^n}.\frac{R_f}{R}[1.2^3 + 1.2^2 + 1.2^1 + 1.2^0]$

$$= \frac{5V}{2^4}\frac{3R}{R}[8+4+2+1]$$

$$= \frac{15\times15}{16}V$$

$$= 14.0625\ V$$

B. The voltage for 1001

$$= \frac{5V}{2^4}\frac{3R}{R}[8+0+0+1]$$

$$= \frac{15\times9}{16}V$$

$$= 8.4375\ V$$

C. $0 \rightarrow 2V$

0.01 V variation should detected

f_m (max) = 2 kHz

f_s (max) = 2. $f_{m\ max}$

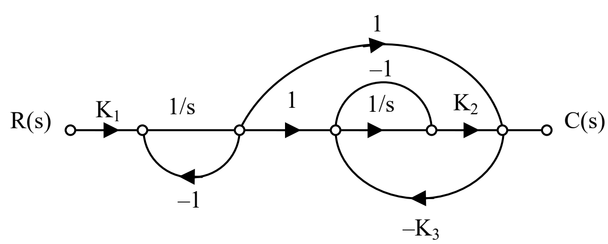
$= 2 \times 2$ kHz

$= 4$ kHz

$$f_s(\max) = \frac{1}{t_A} \Rightarrow t_A = \frac{1}{f_{s(\max)}} = \frac{1}{4\text{kHz}}$$

$t_A = 0.25$ ms

2(b) (i) For the signal flow graph shown in the figure, determine overall transfer function M(s) = $\frac{C(s)}{R(s)}$ **[12M]**



Solution:

No. of forward paths = 2

$$\therefore \frac{C(s)}{R(s)} = M(s) = \frac{\sum_{K=1}^{2} M_K D_K}{D}$$

$$M_1 = K_1.\frac{1}{s}.1.\frac{1}{s}.K_2 = \frac{K_1K_2}{s^2}$$

$$M_2 = K_1.\frac{1}{s}.1.1 = \frac{K_1}{s}$$

No. of loops = 3

$$L_1 = \frac{-1}{s},\ L_2 = \frac{-1}{s},\ L_3 = \frac{-K_2K_3}{s}$$

Two non-touching loops = $L_1L_2 = \frac{1}{s^2}$

$$L_1L_3 = \frac{K_2K_3}{s^2}$$

Three non-touching loops = 0

$$\therefore \Delta = 1 - (L_1 + L_2 + L_3) + (L_1L_2 + L_1L_3)$$

$$= 1 - \left(\frac{-1}{s} - \frac{1}{s} - \frac{K_2K_3}{s}\right) + \left(\frac{1}{s^2} + \frac{K_2K_3}{s^2}\right)$$

$$\Delta_1 = 1$$

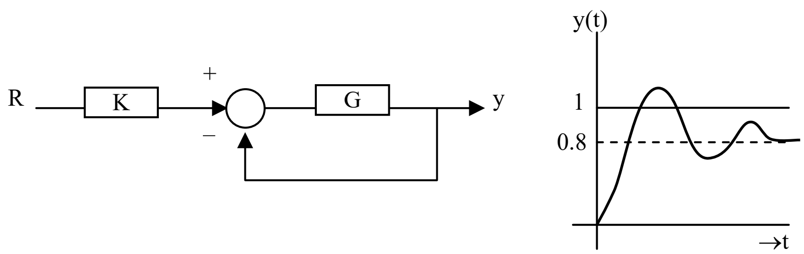
$$\Delta_2 = 1 - \left(\frac{-1}{s}\right) = 1 + \frac{1}{s}$$

$$M(s) = \left[\frac{K_1K_2}{s^2} + \frac{K_1}{s}\left(1+\frac{1}{s}\right)\right] \div \left[1 + \frac{2+K_2K_3}{s} + \frac{1}{s^2} + \frac{K_2K_3}{s^2}\right]$$

$$= \frac{\dfrac{K_1K_2 + K_1s\left(1+\dfrac{1}{s}\right)}{s^2}}{\dfrac{s^2 + 2s + K_2K_3s + 1 + K_2K_3}{s^2}}$$

$$M(s) = \frac{K_1s + K_1K_2 + K_1}{s^2 + (K_2K_3 + 2)s + K_2K_3 + 1}$$

2(b) (ii) For a system represented in the figure, response to a unit step with K = 1 is given. For what value of K does the steady state error become zero? [8M]



Solution:

With K > 1 steady state value = 0.8

Steady state value = 0.8 K (in terms of K)

Error = Input – output

$= 1 - 0.8K = 0$ (zero error)

$$K = \frac{1}{0.8} = 1.25$$

2(c) A three-phase, 6-pole, 50 Hz salient pole alternator is directly connected to 3500 V, 3-phase supply mains to deliver power. It has $X_d = 8.0\Omega$, $X_q = 6.0\Omega$ on per phase basis. The excitation is so adjusted to achieve an equivalent per phase internal generated voltage of 1500 V at a load angle of 15 degrees. Find the delivered power, armature current and power factor under this condition.

Now the alternator is made to deliver maximum power under the same value of excitation voltage. Find the new value of load angle and delivered power under this situation. [20M]

Solution:

A three phase, 6 – pole, 50 Hz salient pre alternates connected to 3500 V, 3 – Phase supply.

Assume star connected alternates

$$\therefore V_L = 3500\text{ V} \Rightarrow V_ph = \frac{3500}{\sqrt{3}} = 2020.72\text{V}$$

$X_d = 8.0\ \Omega$ /ph

$X_q = 6.0\ \Omega$ /ph

Excitation emf (or) internal generated voltage E_{ph} = 1500 V at load angle δ = 15°.

Find the delivered power, P

Armature current, I_a power factor, P.F.

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

$$= \frac{1500 \times 2020.72}{8}\sin 15^\circ + \frac{2020-72^2}{2}\left(\frac{1}{6} - \frac{1}{8}\right)\sin 2\times 15^\circ$$

= 98062.65 + 42534.47

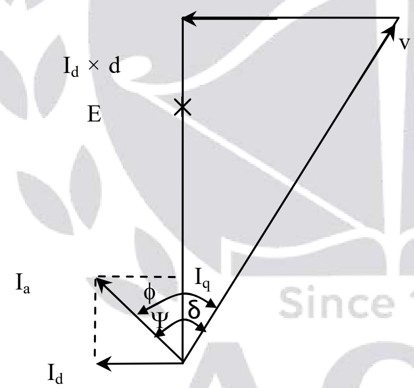
= 140597.12 W

P = 140.597 kW/Ph

Power for 3 – phase, P = 3 × 140.597 = 421.79 kW

P = 421.79 kW

Sin E < V ∴ alternator operate at LEAD PF the phasor diagram is



From the Phasor Diagram

$E = V\cos\delta - I_d \times d$

$1500 = 2020.72\cos 15^\circ - I_d \times 8$

$I_q \times q = V\sin\delta$

$$I_q = \frac{v\sin\delta}{X_q} = \frac{2020.72\sin 15^\circ}{6} = 87.166$$

Armature current $I_a = \sqrt{Id^2 + I_q^2}$

$I_a = \sqrt{56.48^2 + 87.166^2} = 103.864\text{A}$

$\therefore$ I_a = 103.864 A

$I_d = I_a \sin\Psi$

$56.48 = 103.864 \sin\Psi$

$\sin\Psi = 0.5437$

$\Psi = 32.94°$

$\Psi = \phi \pm \delta$ ‘+’ leg PF, ‘–’ lead P1[2]

$\Psi = \phi - \delta$

$32.94 = \phi - 15°$

$\therefore$ $\phi = 32.94 + 15° = 47.94°$

$\therefore$ P.F = $\cos\phi = \cos 47.94° = 0.6699$ Lead

$\simeq$ 0.67 Lead

P.F = 0.67 Lead

$\Rightarrow$ Now the alternator is made to deliver maximum power under the same value of execution.

i.e. E_{ph} = 1500 V

Find the new value of load angle (δ) and delivered power

$$P = \frac{EV}{X_d}\sin\delta + \frac{v^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 25$$

At maximum power output condition

$$\frac{dp}{d\delta} = 0$$

$$\frac{dp}{d\delta} = \frac{EV}{X_d}\cos\delta + v^2\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\cos 25 = 0$$

$$= \frac{1500 \times 2020.72}{8}\cos\delta + 2020.72^2\left(\frac{1}{6} - \frac{1}{8}\right)\cos 25 = 0$$

$= 378885 \cos\delta + 170137 \cos 2g = 0$

= 378885 cosδ +170137 (2cos²δ–1) = 0

= 378885 cosδ + 340274cos²δ – 170137 = 0

= cos²δ + 1.1134 cosδ – 0.5 = 0

$$\cos\delta = \frac{-1.1134 \pm \sqrt{1.1134^2 - 4\times 1(-0.5)}}{2\times 1}$$

cosδ = 0.343

δ = cos⁻ (0.343) = 67.92°

∴ At max power deliver, load angle δ = 69.92°

Maximum Power delivered

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

$$= \frac{1500\times 2020.72}{8}\sin 69.92^\circ + \frac{2020.72^2}{2}\left(\frac{1}{6} - \frac{1}{8}\right)\sin 2\times 69.92$$

= 355854 + 5486.3

P = 410717 W/Ph = 410.717 kW

∴ Total Power for 3 – phases

$P_{(total)}$ = 3 × 410.717

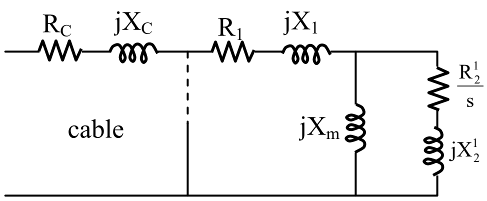
= 1232.151 kW

3(a) An induction motor of 1.5 kW, 3-PHASE, 415 v, 50 Hz, 1440 rpm is to undergo blocked rotor and no load tests. The motor is located away from the supply panel and the per phase impedance of the connecting cable is (5 + j 2.5) Ω. The metering is done at the panel end. The motor draws 0.7 A current and takes 150 W input power under no load condition at rated voltage. For blocked rotor condition, it draws a current of 2.5 A and takes input power of 250 W when 75 V (L–L) is applied from the panel. Calculate the machine equivalent circuit parameter referred to stator side.

(Assume equal distribution of resistance and leakage reactance between rotor and stator, negligible rotation losses and star connected stator of the machine). [20M]

Solution:

Equivalent circuit refer to stator



At no load

$N_r \approx N_s$

$S \approx 0$

$\frac{R_2^1}{S} \approx 0$

Cable impedance

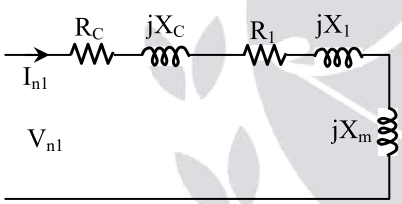
$Z_c = 5 + j2.5$

$= r_c + jx_c$

$R_c = 5\Omega$

$X_c = 2.5\ \Omega$

The equivalent circuit



$P_{n1} = 150W$

No-load power

$V_{n1} = 415V$; $I_0 = 0.7A$

No-load impedance

$$Z_{n1} = \frac{V_1/ph}{I_1/ph} \qquad X_{n1} = X_m + X_1 + X_c$$

$$= \frac{415/\sqrt{3}}{0.7}$$

$= 342.28\Omega$

$= R_{n1} + jx_{n1}$

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$R_{n1} = \dfrac{150}{3\times 0.7^2}$

$= 102.04\Omega$

$X_{n1} = \sqrt{Zn_1^2 - Rn_1^2}$

$= \sqrt{342.28^2 - 102.04^2}$

$= 326.7\ \Omega$

Blocked rotor loss:

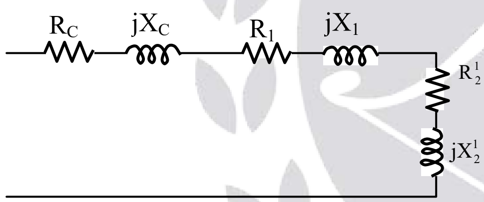
$I_{BR} = 2.5$ A

P_{BR}=250 W

$V_{BR} = 75$V

During blocked rotor loss

$N_r = 0$; S=1; $\dfrac{R_2^1}{S} = R_2^1$



$Z_{br} = \dfrac{75/\sqrt{3}}{2.5}$

$= 17.32\ \Omega$

$R_{br} = \dfrac{250}{3\times 2.5^2}$

$= 13.33\ \Omega$

$X_{br} = \sqrt{Z_{br}^2 - R_{br}^2}$

$= 11.05\ \Omega$

$X_{br} = X_c + X_1 + X_2^1$

Given $X_1 = X_2^1$

$X_{br} = X_c + 2X_1$

$2X_1 = 11.05 - 2.5\ \Omega$

$= 8.55$

$X_1 = 4.275\ \Omega$

$X_1 = X_2^1 = 4.275\ \Omega$

$X_m = X_{n1} - X_1 - X_L$

$= 326.7 - 4.275 - 2.5$

$= 319.925\ \Omega$

$R_1 = R_2^1$

$R_1 + R_2^1 = R_{01}$

Let $X_2 = X_m + x_2^1$

$= 319.925 + 4.275$

$= 324.2$

$$R_{br} = R_c + R_1 + R_2^1\left(\frac{X_m}{X_2}\right)^2$$

$$= R_c + R_1 + R_1\left(\frac{319.25}{323.275}\right)^2$$

$= R_c + R_1 + R_1 \times 0.979$

$R_{br} = R_c + 1.979\ R_1$

$R_{br} - R_c = 1.979\ R_1$

$$\frac{13.33 - 5}{1.979} = R_1$$

$R_1 = 4.209$

$R_2^1 = 4.209$

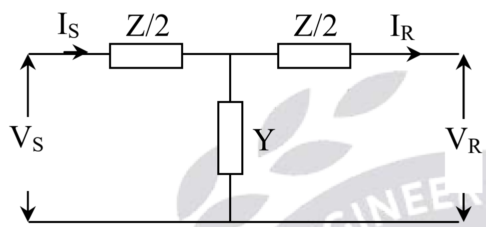
3(b) A three-phase, 50 Hz transmission line has a span of 250 km. It supplies a balanced load of 25 MVA at 0.8 lagging power factor. The receiving end load voltage is 132 kV. The line conductors are spaced equilaterally 3m apart. The conductor resistance is 0.11 ohm/km and its effective diameter is 1.6 cm. Using the nominal-T method, find sending end voltage and current. Also determine the voltage regulation at receiving end of transmission line. [20M]

Solution:

Nominal-T parameter:

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

Nominal-T circuit shown below.



V_S = sending end voltage

I_S = sending end current

V_R = receiving end voltage

I_R = receiving end current

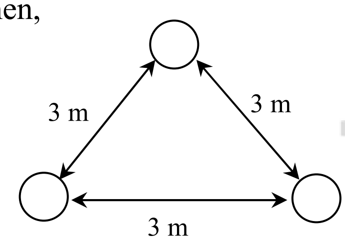
$\sqrt{3}\, V_R I_R = 25$

$I_R = \dfrac{25\times10^6}{\sqrt{3}\times132\times10^3} = 109.35$ A

Then,

$I_R = 109.35\angle{-36.86°}$

Then,



GMR = $0.8\times10^{-2}\times0.7788$

GMD = 3 m

$L = 0.2\ln\dfrac{GMD}{GMR}$ mH/km

$L = 0.2\ln\dfrac{3}{0.8\times0.7788\times10^{-2}}$

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L = 1.235 mH/km

L = 1.235 × 250 mH

L = 308.75 mH

$X_L = 308.75 \times 10^{-3} \times 2\pi \times 50$

$X_L = j96.95\ \Omega$

$R = 27.5\ \Omega$

$$C = \frac{0.02412}{\log \frac{GMD}{r}}\ \mu F/km$$

$$C = \frac{0.02412}{\log \frac{3}{(0.8 \times 10^{-2})}}$$

C = 9.37 nF/km

$C_{eq} = 2342.5$ nF

$Y = j2\pi fC$

$= j(100 \times 3.14 \times 2342.5 \times 10^{-9})$

$Y = j0.00074$

$V_S = AV_R + BI_R$

$I_S = CV_R + DI_R$

$$D = A = 1 + \frac{YZ}{2} = 1 + \frac{(j0.00074) \times (27.5 + j96.96)}{2}$$

$= 0.9641 + j0.01$

$A = 0.9641 + j0.01$

$A = 0.9642\angle 0.594$

$$B = Z\left(1 + \frac{YZ}{4}\right)$$

$$B = (27.5 + j96.96)\left[1 + \frac{j0.00074(27.5 + j96.96}{4}\right]$$

$$B = (27.5 + j96.96)[(0.982) + j0.0051]$$

$B = 100.78\angle 74.16[0.982\angle 0.298]$

$B = 98.965\angle 74.46$

C = Y = j0.00074

$$V_S = 0.9642\angle 0.594\left(\frac{132\times10^3}{\sqrt{3}}\right) + 98.965\angle 74.46 \times 109.35\angle -36.86$$

$V_S = 82051.98 + j7364.67$

$V_S = 82,381.83\angle 5.129$ V

$I_S = CV_R + DI_R$

$$I_S = j0.00074\times\left(\frac{132\times10^3}{\sqrt{3}}\right) + 0.9642\angle 0.594(109.35\angle -36.86)$$

$I_S = 85.014 - j5.97$

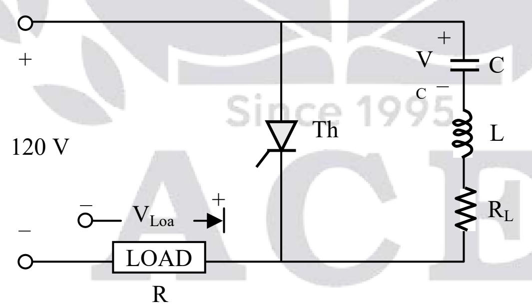
$I_S = 85.014 - j5.97$ A

Calculation of voltage Regulation:

$$VR = \frac{\left|\frac{V_S}{A}\right| - |V_R|}{|V_R|}\times 100 = \frac{\frac{142.69}{0.9642} - 132}{132}\times 100$$

%VR = 12.11%

3(c)



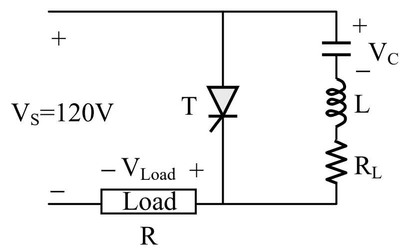
R_L = series/stray resistance of inductor L

C assumed ideal with ESR

The circuit shown in the figure is in steady state with thyristor OFF for a long time. Find the suitable values of L and C for the circuit so that current pulse across the load R = 550Ω is approximately of 1 ms. The circuit is designed to generate a pulse of 0.75 T, where T is period of resonant circuit. It is assumed that subsequent firing of thyristor occurs after 1 ms and inductor is ideal, i.e., $R_L = 0$. Derive all expressions with $R_L \neq 0$.

Also, plot the time variation of $V_{C(+)}$ and $V_{Load(+)}$ for one cycle. **[20M]**

Solution:



R = 550 Ω

Load current pulse = $t_p = 1 \times 10^{-3}$ sec

Assumptions:

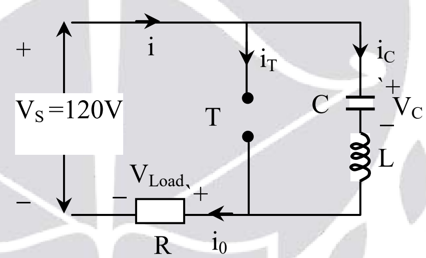
(i) Thyristor is initially OFF (t < 0)

(ii) Thyristor is triggered at t = 0

(iii) $R_L = 0$;

(iV) constant load current

For t < 0 , Thyristor $\Rightarrow$ OFF



$i_T = 0$ A; $i = i_c = i_0$

Capacitor charges

KVL to loop;

$$+V_S - \frac{1}{C}\int i dt - L.\frac{di}{dt} - Ri = 0$$

$$V_S = \frac{1}{C}\int i dt + L.\frac{di}{dt} + Ri$$

Taking Laplace Transform,

$$\therefore \ \frac{V_S}{s} = \left[\frac{1}{Cs} + Ls + R\right] I(s)$$

$$\therefore \ I(s) = \frac{\left(\frac{V_S}{s}\right)}{\left[R + sL + \frac{1}{Cs}\right]}$$

$$= \frac{Cs\left(\frac{V_s}{s}\right)}{\left[RCs + s^2LC + 1\right]}$$

$$= \frac{C.V_s}{LC \times \left[s^2 + s\frac{R}{L} + \frac{1}{LC}\right]}$$

$$= \frac{\left(\frac{V_s}{L}\right)}{\left[s^2 + s.\frac{R}{L} + \frac{1}{LC}\right]}$$

$$= \frac{\left(\frac{V_s}{L}\right)}{s^2 + s\frac{R}{L} + \frac{1}{LC} + \left(\frac{R}{2L}\right)^2 - \left(\frac{R}{2L}\right)^2}$$

$$= \frac{\left(\frac{V_S}{L}\right)}{\left(s + \frac{R}{2L}\right)^2 + \left[\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}\right]^2}$$

$$= \frac{A}{(s+\delta)^2 + \omega^2}$$

Where,

$$A = \frac{V_S}{L};\ \delta = \frac{R}{2L};\ \omega = \sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}$$

ω is natural frequency.

$$\therefore\ I(s) = \frac{A}{\omega} \times \frac{\omega}{(s+\delta)^2 + \omega^2}$$

Taking inverse Laplace Transform

$$i(t) = \frac{A}{\omega} \times e^{-\delta t}\sin(\omega t)$$

$$\therefore\ i(t) = i = \frac{V_S}{\omega L} \times e^{\frac{R}{2L}t}\sin(\omega t)$$

Now;

Voltage across capacitor

$V_C = V_S - V_{Load} - V_L$

$\therefore\ V_C = V_S - iR - L\dfrac{di}{dt}$

$\therefore\ V_C = V_S - R\dfrac{A}{\omega}e^{-\delta t}\sin(\omega t) - L\dfrac{d}{dt}\left[\dfrac{A}{\omega}e^{-\delta t}\sin\omega t\right]$

$\therefore\ V_C = V_S - \dfrac{R.A}{\omega}.e^{-\delta t}\sin(\omega t) - L\dfrac{A}{\omega}\times\left[e^{-\delta t}.A.\cos\omega t - \delta e^{-\delta t}.\sin\omega t\right]$

$\therefore\ V_C = V_S - \dfrac{A}{\omega}.e^{-\delta t}\left[R.\sin\omega t + \omega L.\cos\omega t - L.\delta\sin\omega t\right]$

$\therefore\ V_C = V_S - \dfrac{A}{\omega}e^{-\delta t}\left[R\sin\omega t + \omega L\cos\omega t - L.\dfrac{R}{2L}.\sin\omega t\right]$

$\therefore\ V_C = V_S - \dfrac{A}{\omega}.e^{-\delta t}\left[\dfrac{R}{2}\sin(\omega t) + \omega L.\cos\omega t\right]$

Substituting 'A' and 'δ' in above expression.

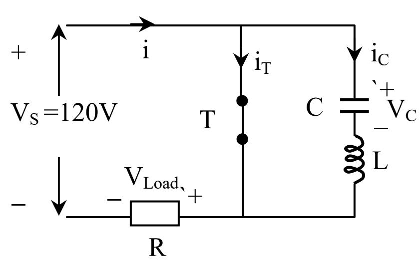
$\therefore\ V_C = V_S - \dfrac{V_S}{\omega L}.e^{\frac{-R}{2L}t}\left[\dfrac{R}{2}\sin(\omega t) + \omega L.\cos(\omega t)\right]$

$\therefore\ V_C = V_S - \dfrac{V_S}{\omega}\times e^{\frac{-R}{2L}t}\times\left[\dfrac{R}{2L}.\sin(\omega t) + \omega\cos(\omega t)\right]$

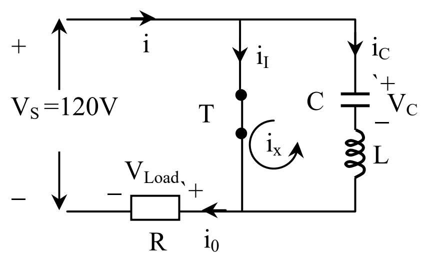
$\therefore$ As time changes from $-\infty$ to 0^- capacitor charges to voltage $V_C = V_S$ and circuit current reaches zero value.

At t = 0; thyristor turns ON

$\therefore$ For t > 0;



During t = 0 to t = t_1



Capacitor discharges and charges to reverse polarity;

$$\therefore\ i_x = V_s\sqrt{\frac{C}{L}}\sin(\omega_0 t)$$

Where, $\omega_0 = \dfrac{1}{\sqrt{LC}}$

$$\therefore\ i_C = -i_x = -V_s\sqrt{\frac{C}{L}}\sin(\omega_0 t)$$

$$\therefore\ i_C = -I_{C\ peak}\ .\ \sin(\omega_0 t)$$

Where $I_{C\ peak} = V_S\sqrt{\dfrac{C}{L}}$

$$i_0 = \frac{V_S}{R} = \frac{120}{550} = 0.218\text{ A}$$

$V_{Load} = V_S = 120$ V

$$V_C = \frac{1}{C}\int i_C dt = \frac{1}{C}\int -V_S\sqrt{\frac{C}{L}}.\sin(\omega_0 t)dt$$

$$\therefore\ V_C = \frac{1}{C}\times V_S\times\sqrt{\frac{C}{L}}.\frac{\cos\omega_0 t}{\omega_0}$$

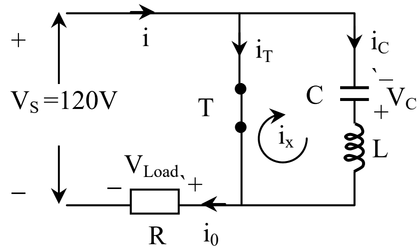
$$= V_S\sqrt{\frac{1}{LC}}\times\frac{\cos(\omega_0 t)}{\left(\frac{1}{\sqrt{LC}}\right)}$$

$V_C = V_S\cos(\omega_0 t)$

At t = t_1

$V_C = -V_S$; $i_C = 0$

During t = t_1 to t_2



$V_{Load} = V_S = 120$ V

$i_C = I_{C\ peak}.\sin(\omega_0 t)$

$V_C = -V_S.\cos(\omega_0 t)$

Where; $I_{C\ peak} = V_S\sqrt{\frac{C}{L}}$

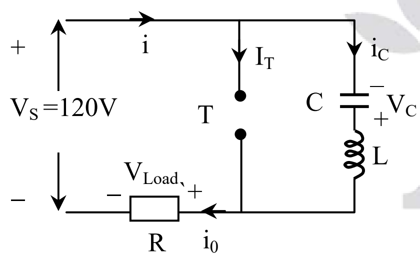
$\omega_0 = \frac{1}{\sqrt{LC}}$

When $i_C = i_x = i_0 = 0.218$ A; Thyristor turns OFF

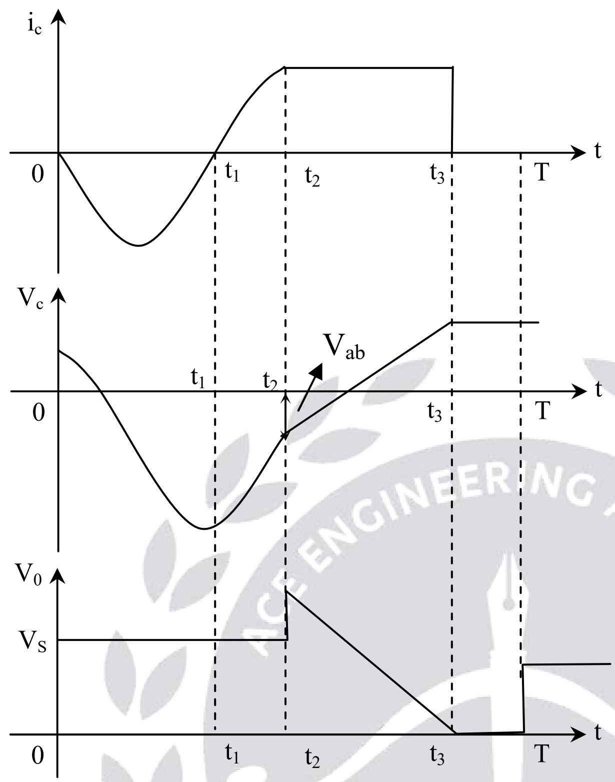
At t = t_2; Thyristor turns OFF

$V_C = -V_{ab}$

During t = t_2 to t_3:



Capacitor discharges through load and charges to reverse polarity



$t_3 = L \times 10^{-3}$ sec

$t_3 = 0.75\ T = 1 \times 10^{-3}$

$\therefore\ T = 1.33 \times 10^{-3}$ sec

$$t_1 = \frac{\pi}{\omega_0}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$\therefore\ t_1 = \pi\sqrt{LC}$

At $t = t_2$; $V_C = V_{ab}$

$V_C = V_{ab} = V_S\cos[\omega_0(t_2 - t_1)]$

$$\omega_0(t_2 - t_1) = \sin^{-1}\left(\frac{I_0}{I_P}\right)$$

$\therefore\ \omega_0(t_2 - t_1) = \sin^{-1}\left(\dfrac{0.218}{V_S\sqrt{\dfrac{C}{L}}}\right)$

Neglecting circuit turn OFF time of thyristor;

During t = t_2 to t_3

$i_C = I_0$

$C.\dfrac{dV_C}{dt} = I_0$

$\therefore\ C \times \dfrac{V_S}{(t_3 - t_2)} = I_0$

$\therefore\ t_3 - t_2 = C.\dfrac{V_S}{I_0}$

Assume C = 1 μF

$\therefore\ t_3 - t_2 = \dfrac{1\times10^{-6}\times120}{0.218}$

$\therefore\ t_3 - t_2 = 0.55 \times 10^{-3}$ sec

$\therefore\ t_2 = 1 \times 10^{-3} - 0.55 \times 10^{-3}$

$= 0.45 \times 10^{-3}$ sec

At t = t_2 ; $V_C = 0$

$V_C = 0 = V_S \times \cos[\omega_0(t_2 - t_1)]$

$\therefore\ \omega_0(t_2 - t_1) = \dfrac{\pi}{2}$

$\therefore\ (t_2 - t_1) = \dfrac{\pi}{2\omega_0} = \dfrac{\pi}{2}\times\sqrt{LC}$

Now,

$t_3 = t_1 + (t_2 - t_1) + t_3 - t_2)$

$1 \times 10^{-3} = \pi\sqrt{LC} + \dfrac{\pi}{2}\sqrt{LC} + 0.55\times10^{-3}$

Put $\quad C = 1 \times 10^{-6}$ F

$0.45 \times 10^{-3} = \dfrac{3\pi}{2}\times\sqrt{L\times(1\times10^{-6})}$

$\therefore\ L = 9.1178$ mH

4(a) Let x(t) be the rectangular pulse as shown in Figure (1). Express the signal y(t) shown in Figure (2) in terms of rectangular pulse x(t). **[20M]**

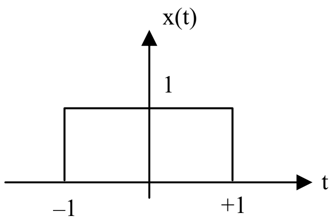


Figure (1)

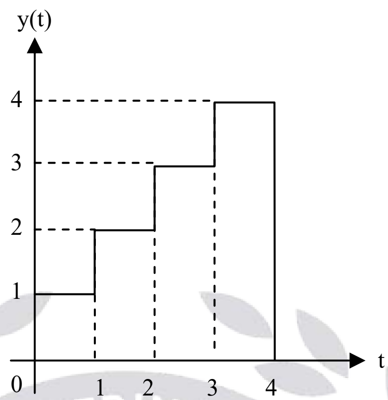
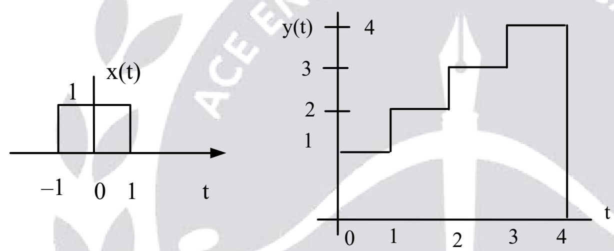


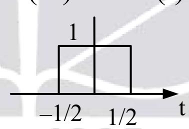
Figure (2)

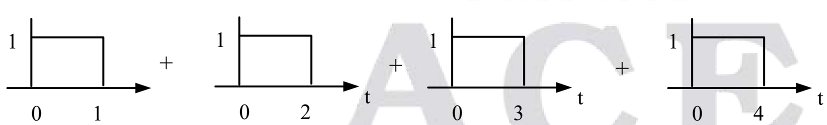
Solution:



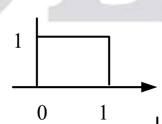
Assume x(t) = rect(t/2)

x(2t) = rect(t)

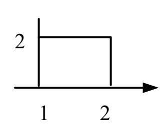




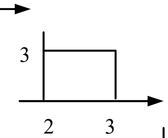
$$y(t) = x\left[2\left(t-\frac{1}{2}\right)\right]$$



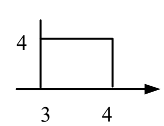
$$+\ 2x\left[2\left(t-\frac{3}{2}\right)\right]$$



$$+\ 3x\left[2\left(t-\frac{5}{2}\right)\right]$$

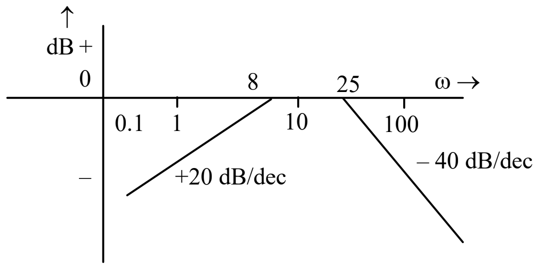


$$+\ 4x\left[2\left(t-\frac{7}{2}\right)\right]$$



y(t) = rect (t–1/2)+2rect(t–3/2)+3rect(t–5/2)+4rect(t–7/2)

4(b) (i) From the Bode asymptotic magnitude plot of a minimum phase system, determine the open loop transfer function. What is the gain margin of resulting unity negative feedback closed loop system? [10M]



Solution:

Initial slope = 20 dB/dec

Portion of the OLTF G(s) = Ks

Change in slope at the CF 1 = $\frac{1}{T_1}$ = ω_1 = 8,

= 0 – 20 = –20 dB/dec

$$\therefore G(s) = \frac{Ks}{(1+sT_1)}$$

Chance in slope at the CF 2 = $\frac{1}{T_2}$ = ω_2 = 25

= –40 – (0) = –40 dB/dec

$$\therefore G(s) = \frac{Ks}{(1+sT_1)(1+sT_2)^2}$$

$|Ks|_{\omega=8} = 1$ (i.e., 0 dB)

$K\omega = 1$

$K8 = 1$

$K = 2^{-3}$

$$\therefore G(s) = \frac{2^{-3}s}{\left(1+\frac{s}{8}\right)\left(1+\frac{s}{25}\right)^2}$$

$$= \frac{(8)(25)^2(2^{-3})s}{(s+8)(s+25)^2}$$

$$G(s) = \frac{625s}{(s+8)(s+25)^2}$$

The above system is always stable system

$\therefore$ GM = ∞

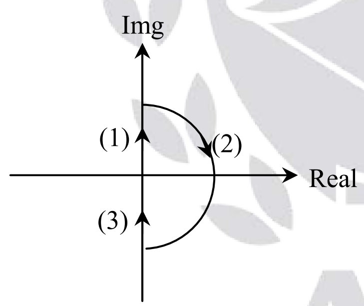
4(b) (ii) Given the open loop transfer function

$$\mathbf{G(s)\ H(s)} = \frac{K}{(s+4)(s-8)}$$

Using Nyquist stability criteria, determine the condition for closed loop stability. Verify the result using Routh-Hurwitz test. [10M]

Solution:

$$G(s)H(s) = \frac{K}{(s+4)(s-8)}$$



Mapping of section (1) of NC

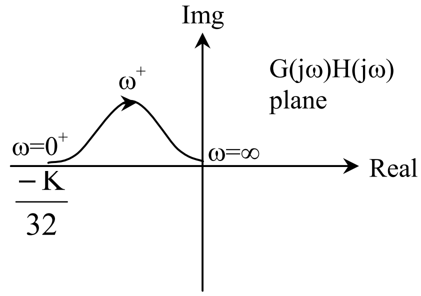
G(s)H(s) plane: Sub $s = j\omega$ $\quad 0 \le \omega C \le \infty$

$$G(j\omega)H(j\omega) = \frac{K}{(j\omega+4)(j\omega-8)}$$

$$M = \frac{K}{\sqrt{(\omega^2+16)(\omega^2+64)}}$$

$$\phi = -\left[\tan^{-1}\frac{\omega}{4} + 180 - \tan^{-1}\frac{\omega}{8}\right]$$

W	M	ϕ
0	$\dfrac{K}{32}$	$-180°$
.		
.		
.		
∞	0	$-180°$

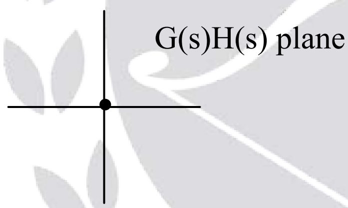


Mapping of section (2) of NC

Sub $\quad s = \lim\limits_{R\to\infty} Re^{j\theta}$ $\quad$ [θ is from 90° to −90°]

$$G(Re^{j\theta}) = \frac{K}{(Re^{j\theta}+4)(Re^{j\theta}-8)}$$

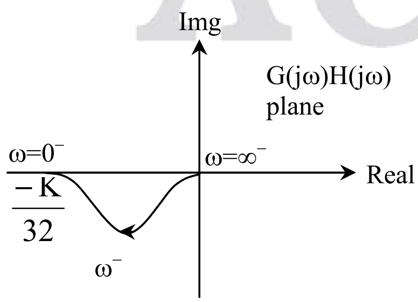
This section merges with the origin in G(s)H(s) plane



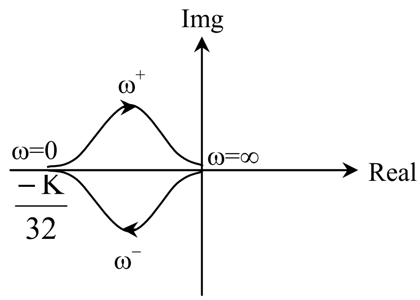
Mapping of section (3) of NC

Sub $\quad s = j\omega \quad -\infty \le \omega \le 0$

It is the mirror image of section (1) and is drawn such that the Nyquist plot is symmetrical wrt real axis.



Combining all the above three sections the Nyquist plot is shown below.



Let $\frac{K}{32} < 1$ (Given P = 1)

i.e., K < 32

N = 0

Z = P – N

= 1 – (0) = 1

Z = 1, closed loop

System is unstable with one right half of s plane pole

Let $\frac{K}{32} > 1$ i.e., K > 32 (Given P = 1)

N = –1

Z = P – N

= 1 – (–1)

Z = 2 closed loop system is unstable with two right hand poles

R.H. criterion

Characteristic equation $1+\frac{K}{(s+4)(s-8)} = 0$

$s^2 - 4s - 32 + K = 0$

R.H. tabulation

s^2	1	K –32
s^1	–4	
s^0	K – 32	

What ever 'K' value is chosen there are sign changes in the 1st column of RH tabulation.

System is always unstable.

K < 32, one sign changes i.e., one right hand pole exists.

K > 32, two sign changes i.e., two right hand poles exists.

4(c) A single phase ac controller supplied from a source, V_{in} = 220 sin 314.28 t produces an rms output voltage of 110 V for a resistive load of 10 Ω at a firing angle α. Determine

(i) the value of α, [4M]

(ii) the amplitude of the seventh harmonic current for α= π/6, and [8M]

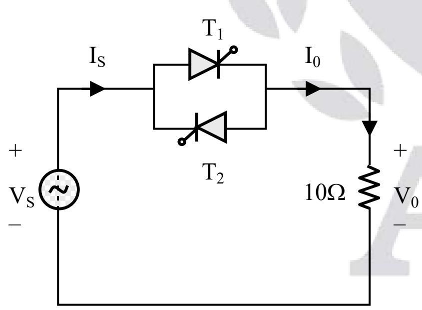
(iii) the input power factor [8M]

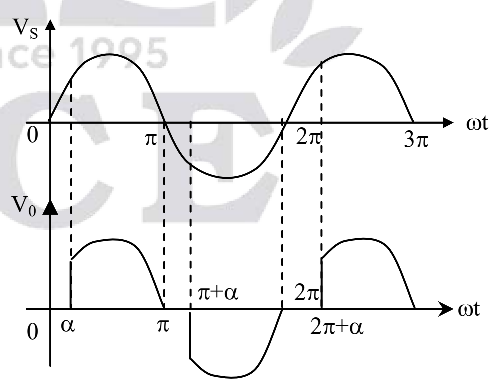
Solution:

$V_{in} = V_s = 220\ \text{Sin}\ (314.28t)\ \text{V}$

$V_{0rms} = 110\ \text{V}$

$R = 10\Omega$





$$V_{0rms} = \left[\frac{1}{\pi}\int_{\alpha}^{\pi} V_m^2 \text{Sin}^2(\omega t)d\omega t\right]^{1/2}$$

$$V_{0rms} = \frac{V_m}{\sqrt{2\pi}} \times \left[\pi - \alpha + \frac{\sin(2\alpha)}{2}\right]^{1/2}$$

$$110 = \frac{220}{\sqrt{2\pi}} \times \left[(\pi - \alpha) + \frac{\sin(2\alpha)}{2}\right]^{1/2}$$

$$(1.2533)^2 = (\pi-\alpha) + \frac{\sin(2\alpha)}{2}$$

$$1.5708 = (\pi-\alpha) + \frac{\sin(2\alpha)}{2}$$

$$\therefore\ \alpha - \frac{\sin(2\alpha)}{2} = 1.5708$$

$$\therefore\ \alpha = \pi/2 \text{ rad}$$

(ii) $\alpha = \pi/6$

$$a_n = \frac{V_m}{2\pi R} \times \left[\frac{2}{(n+1)}\{\text{Cos}(n+1)\alpha - 1\} - \frac{2}{(n-1)}\{\text{Cos}(n-1)\alpha - 1\}\right]$$

$$\therefore a_7 = \frac{220}{2\pi\times 10} \times \left[\frac{2}{(7+1)}\left\{\text{Cos}(7+1)\frac{\pi}{6} - 1\right\} - \frac{2}{(7-1)}\left\{\text{Cos}(7-1)\frac{\pi}{6} - 1\right\}\right]$$

$$\therefore\ a_7 = 3.5014 \times \left[\frac{2}{8}\times(-1.5) - \frac{2}{6}\times(-2)\right]$$

$$a_7 = 0.2917$$

$$b_n = \frac{V_m}{2\pi R} \times \left[\frac{2}{(n+1)}\{\sin(n+1)\alpha - 1\} - \frac{2}{(n-1)} \times \{\sin(n-1)\alpha - 1\}\right]$$

$$\therefore b_7 = \frac{220}{2\pi\times 10} \times \left[\frac{2}{(7+1)}\left\{\sin(7+1)\times\frac{\pi}{6} - 1\right\} - \left\{\frac{2}{(7-1)} \times \{\sin(7-1\}\frac{\pi}{6} - 1\right\}\right]$$

$$= 3.5014 \times \left[\frac{2}{8}\times(-1.866) - \frac{2}{6}\times(-1)\right]$$

$$B_7 = 0.467$$

$$\therefore\ C_7 = \sqrt{(a_7)^2 + (b_7)^2}$$

$$\therefore C_7 = \sqrt{(0.2917)^2 + (-0.467)^2}$$

$$C_7 = 0.5506$$

$\therefore$ Amplitude of 7th harmonic current = 0.5506 A

(iii) Input power factor = $\dfrac{V_{0rms}}{V_{srms}}$

$$\therefore \text{ IPF} = \frac{\frac{V_m}{\sqrt{2\pi}}\left[(\pi-\alpha)+\frac{\sin(2\alpha)}{2}\right]^{1/2}}{\left(V_m/\sqrt{2}\right)}$$

$$\text{IPF} = \frac{\left[(\pi-\alpha)+\frac{\text{Sin}(2\alpha)}{2}\right]^{1/2}}{\sqrt{\pi}}$$

At $\alpha = \pi/2$

i.p.f = 0.707 (lag)

SECTION B

5(a) Consider the FIR filter described by the equation

$y(n) = x(n) + x(n-4)$.

Determine its response to the input

$x(n) = \cos\left(\frac{\pi}{2}n\right) + \cos\left(\frac{\pi}{4}n\right), -\infty < n < \infty$.

Comment on the results obtained. **[12M]**

Solution:

FIR filter $y(n) = x(n)+x(n-4)$

$\downarrow$ Z.T

$Y(z) = X(z)[1+z^{-4}]$

$$\text{T.F } H(z) = \frac{Y(z)}{X(z)} = 1 + z^{-4}$$

$H(e^{jw}) = 1+e^{-j4\omega}$

$$x(n) = \cos\left(\frac{\pi n}{2}\right) + \cos\left(\frac{\pi n}{4}\right) \rightarrow H(e^{j\omega}) = 1+e^{-j4\omega}$$

$H(e^{j\pi/2}) = 1+e^{-j2\pi} = 2$

$H(e^{j\pi/4}) = 1+e^{-j\pi} = 0$

$\therefore y(n) = 2\cos(\pi n/2)$

input $x(n) = A\cos(w_0 n + \theta)$

$H(e^{j\omega}) = 1$

$H^{(ej\omega)} \angle H^{(ej\omega)}$

Steady state O/P = $A\,|H^{(ej\omega)}|\cos(\omega_0 n + \theta + \angle H^{(ej\omega)}$

5(b) Forward path transfer function of a unity negative feedback system is $G(s) = \dfrac{25}{s(s+20)^2}$.

Without drawing graph, analytically determine the gain margin. [12M]

Solution:

$$G(s) = \frac{25}{s(s+20)^2}$$

$$\angle\frac{25}{j\omega(j\omega+20)^2} = -180°\Bigg|_{\omega=\omega_{pc}}$$

$$-\left[90 + 2\tan^{-1}\frac{\omega_{pc}}{20}\right] = -180°$$

$$\omega_{pc} = 20$$

$$|G(j\omega_{pc})| = \frac{25}{\omega_{pc}.\left(\omega_{pc}^2 + 400\right)} = \frac{25}{16000}$$

$$GM = \frac{1}{|G(j\omega_{pc})|} = \frac{16000}{25} = 640$$

GM = 640 (or) 20 log(640) = 56 dB

5(c) A transformer of 150 kVA with 1% resistance and 4% leakage reactance is operating in parallel with another 300 kVA transformer having 1% resistance and 6% leakage reactance. The combination is delivering a load of 450 kVA at 400 V and unity power factor. Find the kVA loading on the 150 kVA transformer and the additional reactance to be connected in series with it to provide rated kVA loading on this transformer. [12 M]

Solution:

$T_1 \Rightarrow 150 \text{ kVA} \Rightarrow \%Z_1 = (1+j4)\ \%$

$T_2 \Rightarrow 300 \text{ kVA} \Rightarrow \%Z_2 = (1+j6)\%$

Load kVA = S_L = 450 kVA @ UPF

kVA Loading of T_1

$$\therefore S_1 = 450\angle 0 \times \frac{1+j6}{(3+j14)}$$

Let common base kVA = 300 kVA

$$\therefore \%Z_1 = \frac{300}{150}\times(1+j4) = (2+j8)\%$$

$$\%Z_2 = (1+j6)$$

$$\therefore S_1 = 450\angle 0 \times \frac{1+j6}{(3+j14)}$$

$$= 191.1\angle 2.63^\circ$$

$\therefore$ Additional Reactance to be connected in series with T_1 to provide Rated kVA loading on transformer is,

Z_1(p.u) = Z_2(p.u)

[1+j(4+X]=[1+j6]

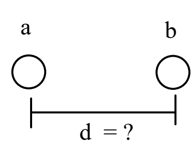
$\therefore$ X = 2% (or) (X = 0.02 p.u)

5(d) (i) A single phase overhead transmission line of 50 km length is to be designed with copper conductor of 5.04 cm diameter. It is expected to have a maximum line reactance of 31.4Ω. Determine the optimal spacing between the conductors. [6M]

Solution:

l = 50 km

$$r = \frac{5.04}{2} = 2.52 \text{ cm}$$



X_L = 31.4 Ω

$\omega L = 31.4$

$2\pi\, f\, L = 31.4$

$$L = \frac{31.4}{2\pi \times 50} = 0.1\text{ H}$$

$L = 0.4 \ln\left(\frac{d}{r^1}\right)$mH/km [Since, loop inductance to be considered]

$$L = \left[0.4\ln\left(\frac{d \times 100}{0.7788 \times 2.52}\right)\right] \times 10^{-3}\text{ H/km}$$

$$L = 0.4\ln\left(\frac{d \times 100}{0.7788 \times 2.52}\right) \times 10^{-3} \times 50\text{ H}$$

$$0.1 = 0.4\ln\left(\frac{d \times 100}{0.7788 \times 2.52}\right) \times 10^{-3} \times 50$$

$d = 291.27$ cm

5(d) (ii) Discuss the impact on line reactance if the conductors in the above case are replaced by stranded bundle conductors of the same outer diameter and line spacing. Assume an ACSR conductor with 6 conductors of Aluminum of 1.68 cm diameter each around one central steel conductor for your analysis. [6M]

Solution:

For bundled conductor

$$L = 0.2\ln\left(\frac{\text{GMD}}{\text{self GMD}}\right)\text{ mH/km/ph}$$

As self GMD >> GMR

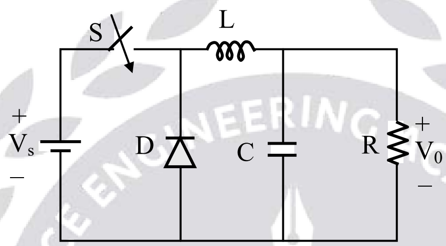
Inductance gets increases

$X_L = \omega L$

Inductive reactance also gets increases.

5(e) A buck converter is operating from a 24 V dc input voltage with variation of ± 10%. The required output voltage is 9 V dc with allowable voltage ripple of 100mV. The converter has rated capacity of 20 W and is operating at a switching frequency of 40 kHz. Find the minimum values of inductance and capacitance to be provided in the output filter for (i) Keeping the inductor current peak to peak ripple at 0.5 A, and (ii) inductor current to be just continuous. (Assume the converter is operating at rated power). [12M]

Solution:



$V_s = 24\text{V} \pm 10\ \%$

$V_0 = 9\text{V}$

$\Delta V_0 = 100 \times 10^{-3} = 0.1\ \text{V}$

$P_0 = 20\ \text{W}$;

$f_s = 40 \times 10^3\ \text{Hz}$

L_{min} and C_{min} = ?

(i) $\Delta I_L = 0.5\ \text{A}$

(ii) I_L is just continuous.

$$D = \frac{V_0}{V_s} = \frac{9}{24} = 0.375$$

(i) $\Delta I_L = \frac{V_s}{L} \times D(1-D) \times T$

$$\therefore\ L = \frac{V_s}{\Delta I_L} \times D \times (1-D) \times T$$

For L_{min}; $V_s = V_{smin} = 24 - 24 \times 0.1$

$= 21.6\ \text{V}$

$$\therefore\ L_{min} = \frac{21.6}{0.5} \times 0.375 \times (1-0.375) \times \left[\frac{1}{40 \times 10^3}\right]$$

$\therefore\ L_{min} = 253.125\ \mu H$

$\Delta V_0 = \dfrac{V_s}{8\times f^2 \times LC}\times D\ (1–D)$

$\therefore\ C_{min} = \dfrac{V_s}{\Delta V_0 \times f^2 \times L_{min}} \times D(1–D)$

$= \dfrac{21.6\times 0.375(1-0.375)}{0.1\times\left(40\times 10^3\right)^2 \times 253.125\times 10^{-6}}$

$C_{min} = 125\ \mu F$

(ii) $L = \dfrac{(1-D)\times RT}{2}$

$P_0 = \dfrac{V_0^2}{R}$

$R = \dfrac{V_0^2}{P_0} = \dfrac{9^2}{20} = 4.05\Omega$

$L = \dfrac{(1-D)\times\left[\dfrac{V_0^2}{P_0}\right]\times T}{2}$

$L = \dfrac{(1-0.375)\times\left[\dfrac{(9)^2}{20}\right]\times\left[\dfrac{1}{40000}\right]}{2} = 31.64\ \mu H$

$C = \dfrac{(1-D)}{16f^2\times L} \quad = \dfrac{(1-0.375)}{16\times\left(40\times 10^3\right)^2\times\left(31.64\times 10^{-6}\right)}$

$C = 0.77\ \mu F$

6(a) Consider the function Y (A,B, C) given in the truth table.

A	B	C	Y(A,B,C)
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

(i) Write a logic expression for Y(A,B,C)

(ii) Implement Y (A,B,C) using only 2-input gates.

(iii) Implement Y (A,B,C) using only 2-input NAND gates. **[20M]**

Solution:

	A	B	C	Y(A, B, C)
0	0	0	0	1
1	0	0	1	0
2	0	1	0	0
3	0	1	1	0
4	1	0	0	1
5	1	0	1	1
6	1	1	0	0
7	1	1	1	1

(i) $Y(A, B, C) = \Sigma m(0, 4, 5, 7)$

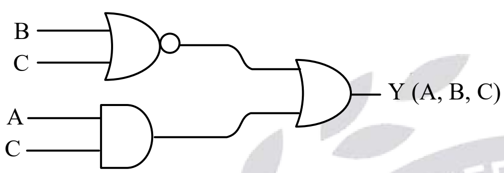
$= \pi M(1, 2, 3, 6)$

A \ BC	00	01	11	10
0	1			
1	1	1	1	

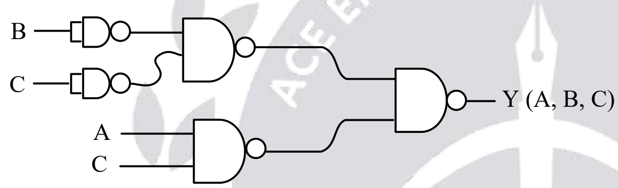
A \ BC	00	01	11	10
0		0	0	0
1				0

$$Y(A, B, C) = \overline{B}\,\overline{C} + AC\ ; \quad Y(A, B, C) = (A + \overline{C})(\overline{B} + C)$$

(ii)



(iii)



6(b) (i) Find the resolution and the bit rate in the sampling of signal with dynamic range of 1 volt if the sampling rate is F_s = 20 samples/sec and an 8-bit A/D converter is used. Determine the maximum frequency that can be present in resulting digital signal. [6M]

Solution:

$$\text{Resolution} = \frac{V_{max}}{2^n - 1} = \frac{\text{Dynamic Range}}{2^n - 1}$$

$$\text{Resolution} = \frac{1}{2^8 - 1} = \frac{1}{225} = 3.921 \text{ mV}$$

$$\text{Bit rate} = nf_s = 8 \times 20$$

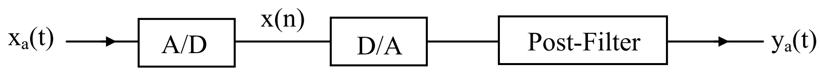
$$= 160 \text{ bits/sec}$$

$$\text{Maximum frequency in resulted digital signal} = \frac{\text{sampling rate}}{2}$$

$$= \frac{20}{2} = 10 \text{ Hz}$$

6(b) (ii) In a signal processing system shown below, sampling periods of the analog to Digital and Digital to Analog converters are T =5 m sec and T′ = 1 m sec respectively. Find the output y_a (t) of the system if the input is [14M]

$x_a(t) = 3\cos(100\pi t) + 2\sin(250\pi t)$

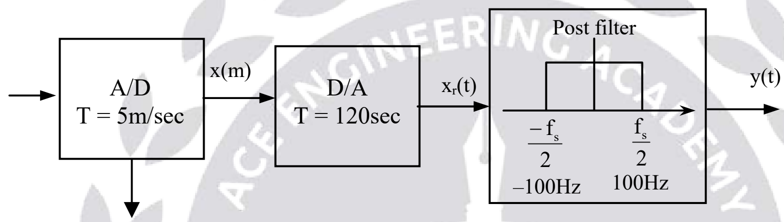


T = 5m sec T′ = 1m sec

(Post-filter removes frequency components that are above $\frac{F_s}{2}$).

Solution:

$x(t) = 3\cos(100\pi t)+2\sin(250\pi t)$



$$f_S = \frac{1}{T} = \frac{1}{5\times10^{-3}} = 200\text{Hz}$$

$$\text{O/p of A/D} \to x(nTs) = x\left[\frac{n}{200}\right] = 3\cos\left(\frac{100\pi n}{200}\right) + 2\sin\left(\frac{250\pi n}{200}\right)$$

$$= 3\cos\left(\frac{\pi n}{2}\right) + 2\sin\left(\frac{5\pi n}{2\pi + \frac{5\pi}{4}}\right) + 2\sin\left(\frac{-3\pi n}{4}\right)$$

$$= 3\cos\left(\frac{\pi n}{2}\right) - 2\sin\left(\frac{3\pi n}{4}\right)$$

For D/A Converter reconstruction frequency = $f_r = \frac{1}{10^{-3}} = 1000\text{Hz}$

Analog freq of the recovered signal at D/A O/P is $= \frac{\pi}{2}(1000) = 500\pi\,\text{rad}$ (or) 250 Hz

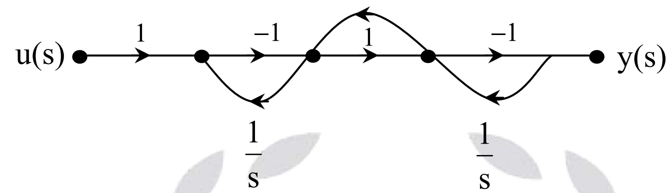
And $\frac{3\pi}{4}(1000)$ =750π rad (or) 375 Hz

As Per filter cut off frequency is 100 Hz

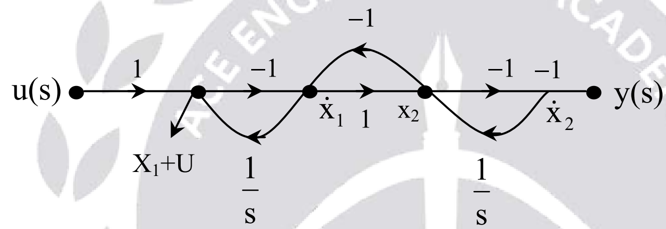
O/P of filter is zero.

6(c) The signal flow graph of a system relating output y(t) to input u(t) is shown in the figure. Represent the state variable model of the system. Determine its transfer function $\frac{y(s)}{u(s)}$ from the state model. **[20M]**

Derive corresponding state transition matrix.



Solution:



$\dot{x}_1 = -x_1 - U - \dot{x}_1 - x_2$

$2\dot{x}_1 = -x_1 - x_2 - U$

$\dot{x}_1 = -0.5x_1 - 0.5x_2 - 0.5U$ ……….. (1)

$\dot{x}_2 = \ \ -\dot{x}_1 - x_2$

$\dot{x}_2 = -(-0.5x_1 - 0.5x_2 - 0.5U) - x_2$

$\dot{x}_2 = 0.5x_1 + 0.5x_2 + 0.5U - x_2$ ……….. (2)

$y = \dot{x}_2 = 0.5x_1 - 0.5x_2 + 0.5U$

From equation (1), (2) and (3) state model is written as

$$\dot{X} = \begin{bmatrix} -0.5 & -0.5 \\ 0.5 & -0.5 \end{bmatrix} X + \begin{bmatrix} -0.5 \\ 0.5 \end{bmatrix} U$$

$Y = [0.5 \quad -0.5]X + [0.5]U$

$TF = C[sI - A]^{-1}B + D$

$$sI - A = \begin{bmatrix} s+0.5 & 0.5 \\ -0.5 & s+0.5 \end{bmatrix}$$

$$(sI - A)^{-1} = \frac{\begin{bmatrix} s+0.5 & -0.5 \\ 0.5 & s+0.5 \end{bmatrix}}{s^2 + s + 0.5}$$

$$TF = \frac{[0.5 - 0.5]\begin{bmatrix} s+0.5 & -0.5 \\ 0.5 & s+0.5 \end{bmatrix}\begin{bmatrix} -0.5 \\ 0.5 \end{bmatrix}}{s^2 + s + 0.5} + 0.5$$

$$= \left[\frac{(0.5s + 0.25 - 0.25 - 0.25 - 0.5s - 0.25)\begin{pmatrix} -0.5 \\ 0.5 \end{pmatrix}}{s^2 + s + 0.5}\right] + (0.5)$$

$$= \frac{-0.25s - 0.25s - 0.25}{s^2 + s + 0.5} + 0.5$$

$$= \frac{0.5s^2 + 0.5s + 0.25 - 0.5s - 0.25}{s^2 + s + 0.5}$$

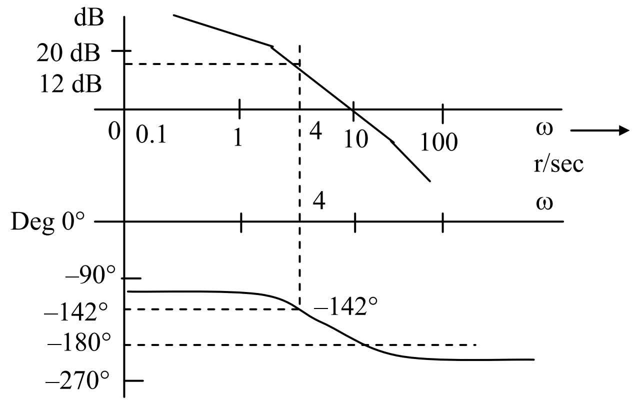
$$TF = \frac{0.5s^2}{s^2 + s + 0.5}$$

State transition matrix $e^{At} = L^{-1}[sI - A]^{-1}$

$$e^{At} = L^{-1}\begin{bmatrix} \dfrac{s+0.5}{(s+0.5)^2 + 0.5^2} & \dfrac{-0.5}{(s+0.5)^2 + 0.5^2} \\ \dfrac{0.5}{(s+0.5)^2 + 0.5^2} & \dfrac{s+0.5}{(s+0.5)^2 + 0.5^2} \end{bmatrix}$$

$$= \begin{bmatrix} e^{-0.5t}\cos 0.5t & -e^{-0.5t}\sin 0.5t \\ e^{-0.5t}\sin 0.5t & e^{-0.5t}\cos 0.5t \end{bmatrix}$$

7(a) (i) The frequency response of a steady state gain already adjusted open loop transfer function is shown in figure. Appropriately using the parameters highlighted in the figure. Design a Lag compensator to achieve a desired phase margin of +30° with a tolerance considered as 8°. Illustrate the design procedure clearly. [12M]



Solution:

Let $G_1(s) = \frac{1+aTS}{1+TS}$, (a < 1) is the desired lag compensator

From the given figure it is clear that lag compensator must provide an attenuation of 12dB at 4 rad/sec to obtain a phase margin of 38°

$$20 \log a = -12 \text{ dB}$$

$$a = 0.25$$

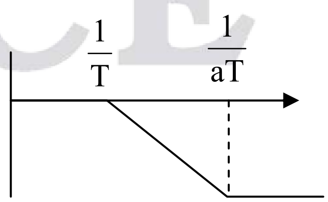
upper corner frequency of a lag compensator, must be taken as one decade below 4 rad/sec

$$\therefore \frac{1}{aT} = \frac{4}{10} = 0.4$$

$$\frac{1}{T} = 0.4 a = 0.4 (0.25)$$

$$\frac{1}{T} = 0.1$$

$\therefore$ Desired lag compensator



$$G_1(s) = \frac{(1+aTS)}{(1+TS)}$$

$$= \frac{a\left(s+\frac{1}{aT}\right)}{s+\frac{1}{T}} = \frac{0.25(s+0.4)}{(s+0.1)}$$

7(a) (ii) Consider a system described by the state model

$$X = \begin{bmatrix} -3 & 1 \\ -2 & 0 \end{bmatrix} X + \begin{bmatrix} 0 \\ 1 \end{bmatrix} \mathbf{u;}$$

Y = [1 0]X.

Design a control law u = –KX so that the closed loop poles of the system occupy in s-plane at –2± j2. [8M]

Solution:

Desired pole location $-2 \pm j2$

$\therefore$ Desired characteristic equation $= (s+2)^2 + 2^2$

$$= s^2 + 4s + 8 = 0 \quad \ldots\ldots(1)$$

Characteristic equation is obtained by doing $|SI - (A - BK)| = 0$

Where $k = [K_1\ K_2]$

$$(A - BK) = \begin{bmatrix} -3 & 1 \\ -2 & 0 \end{bmatrix} - \begin{bmatrix} 0 \\ 1 \end{bmatrix} [K_1\ K_2]$$

$$= \begin{bmatrix} -3 & 1 \\ -2 & 0 \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ K_1 & K_2 \end{bmatrix}$$

$$= \begin{bmatrix} -3 & 1 \\ -(K_1+2) & -K_2 \end{bmatrix}$$

$$sI - (A - BK) = \begin{bmatrix} s+3 & -1 \\ K_1+2 & s+K_2 \end{bmatrix}$$

$$|sI - (A - BK)| = s^2 + (K_2 + 3)\,s + 3k_2 + k_1 + 2 = 0 \quad \ldots\ldots..(2)$$

Comparing equation (1) and (2)

(1) = (2)

$K_2 + 3 = 4, \qquad K_2 = 1$

$3\,K_2 + K_1 + 2 = 8$

$3(1)\,K_1 + 2 = 8$

$K_1 = 3$

$\therefore\ K = [K_1\ K_2]$

$\therefore\ K = [3 \quad 1]$

7(b) A 415 V, 4-pole, 3-phase, 50Hz, 1440 rpm induction motor has per phase standstill rotor resistance and reactance of 0.4 Ω and 1.3 Ω respectively at rated frequency. Find torque at rated speed and the ratios of starting torque to maximum torque and rated torque to maximum torque.

Now, the motor is supplied from a source of 40 Hz at 20% reduced voltage. Find the operating slip at rated torque and the new ratios of rated torque to maximum torque and starting torque to maximum torque. [20M]

(Assume no saturation and negligible stator impedances)

Solution:

Motor poles (P) = 4

Supply voltage (V_L) = 415 V

Supply frequency = 50 Hz

Rated speed N_r = 1440 rpm

Rotor resistance/ph

$R_2 = 0.4\ \Omega/\text{Ph}$

Rotor stand still reactance

$X_{20} = 1.3\ \Omega$

Torque at rated speed rated speed/full load speed

$N_{rfl} = 1440$ rpm

$$N_s = \frac{120f}{P} = 1500 \text{ rpm}$$

$$S_{fl} = \frac{N_s - N_{rf1}}{N_s}$$

$$= \frac{1500 - 1440}{1500}$$

$$= 0.04$$

Since stator impedance is not given, stator voltage will appear across rotor. since, turns ratio also not given, we will consider it as 1

$$T = \frac{3}{\omega s}.\frac{E_2^2}{\left(\frac{r_2}{s}\right)^2 + x_2^2} \times \frac{r_2}{s}$$

$$= \frac{3\times 60}{2\pi\times 1500} \times \frac{\left(\frac{415}{\sqrt{3}}\right)^2}{\left(\frac{0.4}{0.04}\right)^2 + (1.3)^2} \times \frac{0.4}{0.04}$$

$$= 0.0191\times \frac{57411.70}{100+1.69}\times 10$$

$$= 0.0191 \times 564.575 \times 10$$

$T = 107.83$ Nm

Slip at maximum torque

$$S_{Mt} = \frac{R_2}{X_{20}} = \frac{0.4}{1.3} = 0.3076$$

$$\frac{T_{st}}{T_{max}} = \frac{2s_m T}{s_{mT}^2 + 1}$$

$$= \frac{2\times 0.3076}{0.3076^2 + 1}$$

$$= 0.5619$$

$$\frac{T_{f1}}{T_{max}} = \frac{2s_{f1}s_{mT}^2}{s_{f1}^2 + s_{mT}^2}$$

$$= \frac{2\times 0.04\times 0.3076}{0.04^2 + 0.3076^2} = 0.255$$

$f_2 = 40$Hz ; $V_2 = 0.8 \times 415$ V

$T \propto \frac{SV^2}{f}$ Assumes 415 as phase voltage

$$\frac{SV^2}{f} = \text{constant}$$

$$\frac{0.04\times 415^2}{50} = \frac{s_2\times (0.8\times 415)^2}{40}$$

$S_2 = 0.05$

New slip

X_{20} (new) = 0.8×1.3

$= 1.042$

$$S_{mT}(\text{new}) = \frac{0.4}{1.04} 0.3846$$

$$\frac{T_{f1}(\text{new})}{T_{max}} = \frac{2 \times 0.05 \times 0.3846}{0.05^2 + 0.3846^2}$$

$$= 0.255$$

$$\frac{T_{st}}{T_{max(new)}} = \frac{2s_{mT(new)}}{S_{mT(new)^2} + 1} = 0.67$$

7(c) A 100 MVA, 20 kV, 50 Hz three-phase generator is connected to a 100 MVA 20/400 kV three-phase transformer. The machine has the following per unit reactance and time constants:

X_d''=0.15 pu τ_d'' = 0.035 sec

X_d' = 0.25 pu τ_d' = 0.5 sec

X_d = 1.25 pu τ_d = 0.3 sec

The transformer reactance is 0.25 per unit. The generator is operating at the rated voltage and no-load when a three phase short-circuit occurs at the secondary terminals of the transformer. Find the sub transient, transient and the steady state short circuit currents in per unit and actual amperes on both sides of the transformer. [20M]

Solution:

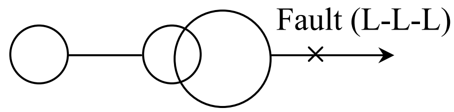
Generator rating

20 kV, 100 MVA

Transformer rating: 100 MVA, 20/400 kV

$$\left.\begin{aligned} X_d'' &= 0.15 \\ X_d' &= 0.25 \\ X_d &= 1.25 \end{aligned}\right\} \text{Generator reactances}$$

Transformer reactance: 0.25 pu



Fault at secondary side of transformer

Sub-transient current is

$$I_F = \frac{E_{R1}}{Z_{1eq}} = \frac{1.0}{X''_d + X_{T/F}} = \frac{1.0}{0.15+0.25} = \frac{1.0}{0.4}$$

$I_F = 2.25$ pu

$$\text{Actual fault current} = 2.5\times\frac{100}{\sqrt{3}\times 400}$$

$$= 2.5\times\frac{1}{\sqrt{3}\times 4} = 0.36 \text{ kA}$$

Sub-transient current on LV side of transformer also 2.5 pu

Actual sub-transient current on LV side is

$$2.5\times\frac{100}{\sqrt{3}\times 20} = \frac{12.5}{1.732} = 7.21 \text{ kA}$$

Transient current on HV side

$$I_F = \frac{E_{R1}}{Z_{1eq}} = \frac{1.0}{X'_d + X_{T/F}} = \frac{1.0}{0.25+0.25}$$

$$I_F = \frac{1.0}{0.5} = 2.0 \text{ pu}$$

$$I_{F(actual)} = 2.0\times\frac{100}{\sqrt{3}\times 400} = \frac{0.5}{1.732}$$

$I_{F\,(actual)} = 0.288$ kA

Transient current on LV side of transformer is 2.0 pu

Actual transient current is

$$2.0\times\frac{100}{\sqrt{3}\times 20} = \frac{2.0\times 5}{1.732} = \frac{10}{1.732} = 5.77 \text{ kA}$$

Steady state fault current:

$$I_F = \frac{E_{R1}}{Z_{1eq}} = \frac{E_{R1}}{X_d + X_{T/F}} = \frac{1.0}{1.25 + 0.25} = \frac{1.0}{1.5}$$

$I_F = 0.66$ pu

$$I_{F\,(actual)} = 0.66 \times \frac{100}{\sqrt{3} \times 400} = 0.095 \text{ kA}$$

Steady state current on LV side is also 0.66 pu

Actual current on LV side is

$$0.66 \times \frac{100}{\sqrt{3} \times 20} = \frac{0.66 \times 5}{1.732} = 1.9 \text{ kA}$$

8(a) Determine the unilateral Laplace transform of the signals given below.

Specify the property used, if any, in each step. **[20M]**

(i) $x(t) = u(t-1) * e^{-2t}\, u(t-1)$

(ii) $x(t) = t.\frac{d}{dt}[e^{-t}.\cos(t)\, u(t)]$

Solution:

U.L.T. of signals

Time shifting $x(t-t_0) \xleftrightarrow{LT-Sto} e \times (s)$

(i) $x(t) = u(t-1) + e^{-2t}u(t-1)$

we know

L.T. $= u\,(t-1) + e^{-2(t-1+1)}u(t-1)$

$e\text{–}atu(t) \xleftrightarrow{L.T.} \frac{1}{s+a}; \sigma < -a$

$$X(s) = \frac{e^{-S}}{S} + \frac{e^{-2}.e^{-S}}{S+2}$$

$u(+) \leftrightarrow \frac{1}{S}; \sigma > 0$

(ii) $x(t) = \frac{-d}{ds}\left[\frac{S(S+1)}{(S+1)^2 + (1)^2}\right]$

Time $dx(t) \xleftrightarrow{L.T.} SX(s)$

Diff in S-Domain $tx(t) \leftrightarrow \frac{-d}{ds}X(s)$

$$\left[\frac{(S+1)^2 + (1)^2[2S+1] - (S^2+S)(2S+2)}{(S+1)^2 + (1)^2}\right]$$

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8(b) A 10kVA, 50Hz single-phase transformer has maximum efficiency of 97% at rated frequency and rated voltage while delivering 90% at rated load at 0.8 pf lag. The same transformer shows maximum efficiency of 96% at same load when supplied from a 35 Hz source at rated voltage. Find

(i) The hysteresis and core losses of the transformer under rated condition and

(ii) Efficiency of the transformer at rated voltage and rated load at 0.8 pf lag. [20M]

(Assume no stray losses and a steinmetz constant of 2.0 for the core)

Solution:

Given data:

10 kVA, 50 Hz, 1-ϕ transformer

η_{max} = 97% at 90% rated load, 0.8 pf lag at rated voltage and frequency 50 Hz

η_{max} = 96% at 90% rated load, 0.8 pf lag at rated voltage and frequency 35 Hz

$$\eta_{max(at\ 90\%\ load)} = \frac{9000\times0.8}{9000\times0.8+2W_i} = 0.97$$

$$= \frac{7200}{7200+2W_i} = 0.97$$

By solving W_i = 111 W

$$\eta_{max(at\ 90\%\ load)} = \frac{9000\times0.8}{9000\times0.8+2W_i} = 0.96$$

$$= \frac{7200}{7200+2W_i} = 0.96$$

By solving W_i = 150 W

Iron loss at rated voltage, 50 Hz is W_i = 111 W

Iron loss at rated voltage, 35 Hz is W_i = 150 W

V_1 constant, f is varying

$$\frac{V_1}{f} \neq \text{constant}$$

$W_h \propto V_1^x f^{1-x}$ and $W_e \propto V_1^2$

As V_1 constant, x = 2

$W_h \propto \frac{1}{f}$ and W_e = constant

$W_i = W_h + W_e$

$\Rightarrow A V_1^2 f^{-1} + B V_1^2 = 111$

As V_1 is constant

$\Rightarrow \frac{A}{f} + B = 111$ ………… (1)

$\frac{A}{f} + B = 150$ ………… (2)

By solving A = 4550 and B = 20

(i) W_h at rated voltage, rated frequency 50 Hz

$$= \frac{A}{f} = \frac{4550}{50} = 91 \text{ W}$$

W_h at rated voltage, rated frequency 35 Hz

$$= \frac{A}{f} = \frac{4550}{35} = 130 \text{ W}$$

Iron loss at rated voltage, 50 Hz is W_i = 111 W

Iron loss at rated voltage, 35 Hz is W_i = 150 W

(ii) As efficiency is maximum at 90% load,

Copper loss at 90% load = Iron loss = 111 W

$\therefore$ Full loa copper loss $= \frac{111}{0.9^2} = 137$ W

Efficiency at full laod $= \frac{10000 \times 0.8}{10000 \times 0.8 + 137 + 111}$

$= 96.99\%$


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AIR 6th ME ABHISHEK MEWAR
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AIR 6th IN HARSHIT GUPTA
AIR 6th IN RAJU SHARMA
AIR 6th CE TANMAY MAHAJAN
AIR 6th XE MANISH YADAV
AIR 7th ME VATSAL PANCHAL
AIR 7th PI SACHIN DUBOLIYA
AIR 7th PI ATULYA JYOTHI
AIR 8th ME RAJAT GUPTA
AIR 8th ME ROHIT S PATIL
AIR 8th EC ANKUR LAL MEENA
AIR 8th IN KUNAL SAURAV
AIR 8th CE PRANSHU JANGID
AIR 8th CE RAHUL PATI
AIR 8th EE UJJWAL KUMAR
AIR 8th EE HEMANT JINDAL
AIR 9th EC ABHISHEK SINGH
AIR 9th EC ALEESHA ROSE
AIR 9th EC SAI VAMSI DOSAPATI
AIR 9th IN RAMESH KUMAR
AIR 9th CS NIRANJAN NITIN DHOOT
AIR 9th XE RACHIT KUMAR
AIR 10th ME DEEPESH AGARWAL
AIR 10th PI VYOM SHARMA
AIR 10th IN PRAGYA KAUSHIK
AIR 10th CE GOVIND PRASAD B
AIR 10th XE D KUMAR PATIL
AIR 10th XE R SHIVAJI NALE
and many more...
Total 57 Ranks in Top 10
ME : 10
PI : 09
CE : 08
EE : 4
EC : 09
CS : 03
IN : 08
XE : 06

8(c) A 10 kW, 220V, 1750 rpm dc separately excited motor is controlled by three-phase fully controlled converter. The connecting cable between motor and converter has a resistance of 1.0 Ω. The input side of the converter is supplied from a 3-phase 300V, 50Hz ac source. The dc motor has armature resistance r_a = 0.5 Ω. The armature current is flat and ripple free. Determine

(i) The triggering angle of the converter when the motor delivers rated power at rated voltage and speed.

(ii) The converter input rms current and power factor under the above condition of (i).

(iii) No load speed of the motor when the triggering angle is same as (i) and the motor takes 10% of rated current. [20M]

(Assume constant field current at rated value for the entire operation)

Solution:

3-ϕ fully controlled converter

$R = 1\Omega$; $V_5 = 300V$; $f = 50Hz$

$r_a = 0.5\Omega$; $i_0 = I_0$

(i) $\alpha = ?$

At rated power; rated voltage and speed.

(ii) $i_{srms} = ?$; Power factor = ?

(iii)No load speed = ? (N_{NL} =?)

(i) $P_0 = V_0 \times I_0$

$$\therefore I_0 = \frac{P_0}{V_0} = \frac{10\times10^3}{220} = 45.45 \text{ A}$$

Converter output = V_0 + Voltage drop across 1 Ω resistance

$$\frac{3V_{ml}}{\pi}\times\cos(\alpha) = 220 + I_0 \times 1$$

$$\frac{3\times300\times\sqrt{2}}{\pi}\cos(\alpha) = 220 + 45.45 \times 1$$

$$\therefore \alpha = 49.06°$$

(ii) $i_{srms} = I_0 \times \sqrt{2/3} = 45.45 \times \sqrt{2/3}$

$I_{srms} = 37.109$ A

Power factor $= \frac{3}{\pi} \times \cos(\alpha)$

$= \frac{3}{\pi} \times \cos(49.06°)$

Power factor = 0.626 (lag)

(iii) At no load

$I_a = I_{a2} = \frac{10}{100} \times I_0 = 0.1 \times 45.45$

$I_{a2} = 4.545$ A

No load speed $= N_2 = ?$

At rated condition

$I_a = I_{a1} = I_0 = 45.45$ A

$E_{b1} = V_0 - i_{a1} \times r_a$

$= 220 - 45.45 \times 0.5$

$E_{b1} = 197.275$ V

No load emf

$E_{b2} = \frac{3V_{ml}}{\pi} \times \cos(\alpha) - i_{a2} \times (1+0.5)$

$= \frac{3 \times 300 \times \sqrt{2}}{\pi} \times \cos(49.06) - 4.545 \times 1.5$

$E_{b2} = 258.66$

$\therefore \frac{E_{b2}}{E_{b1}} = \frac{N_2}{N_1}$

$\therefore N_2 = \frac{E_{b2}}{E_{b1}} \times N_1$

$= \frac{258.66}{197.275} \times 1750$

$N_2 = 2294.5$ rpm


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AIR 9 ARPIT JAIN CE
AIR 10 HEMABH TRIVEDI ME
AIR 10 RAJAT DIXIT EE
AIR 10 L KUMARI JAISWAL E&T
AIR 10 AMIT SHARMA CE
and many more...
TOTAL 36 RANKS IN TOP 10
ME 10
EE 09
E&T 10
CE 07