TEST ID: 203

ACE Engineering Academy

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ESE- 2020 (Prelims) - Offline Test Series Test-5

ELECTRICAL ENGINEERING

SUBJECT: CONTROL SYSTEMS & POWER ELECTRONICS SOLUTIONS

01. Ans: (b)

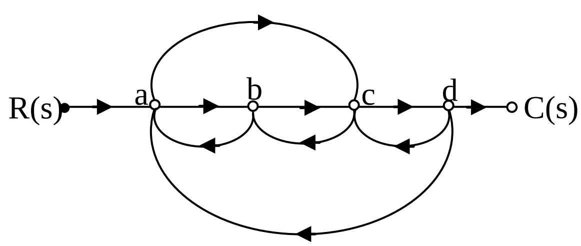
Sol: $C = aR - C\beta$

$C(1+\beta) = aR$

$$\frac{C}{R} = \frac{a}{1+\beta}$$

02. Ans: (b)

Sol:



Number of individual loops = 6

$\rightarrow$ aba, bcb, cdc, abcda, acda, acba

03. Ans: (a)

Sol: Human body system is a complex multi variable feedback system.

04. Ans: (d)

Sol: $\text{TF} = \frac{C(s)}{R(s)} = \frac{s+\omega}{s^2+\omega^2}$

$r(t) = \delta(t)$, $R(s) = 1$

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

Apply inverse Laplace transform

$$c(t) = \cos(\omega t) + \sin(\omega t)$$

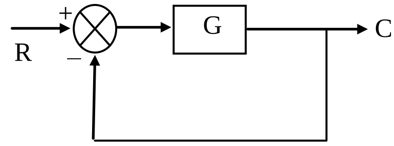
$$= \sqrt{2}\left[\frac{1}{\sqrt{2}}\cos(\omega t) + \frac{1}{\sqrt{2}}.\sin(\omega t)\right]$$

$$= \sqrt{2}\,[\sin 45^\circ \cos(\omega t) + \cos 45^\circ.\sin(\omega t)]$$

$$= \sqrt{2}\ \left(\sin(\omega t + 45^\circ)\right) = \sqrt{2}\sin\left(\omega t + \frac{\pi}{4}\right)$$

05. Ans: (b)

Sol:



$$\frac{C}{R} = \frac{s+4}{s^2+7s+13}$$

$$G(s) = \frac{s+4}{s^2+6s+9}$$

DC gain s = 0 ⇒ $G(0) = \dfrac{4}{9}$

06. Ans: (a)

Sol: dc gain = 1.5

$$TF = \frac{K(s+3)}{(s+2)(s+4)}$$

$$\underset{s\to 0}{Lt}\frac{K(s+3)}{(s+2)(s+4)} = 1.5$$

$\therefore$ K = 4

07. Ans: (b)

Sol: $\dot{X}_2 = -3X_2 + u$

$\dot{X}_1 = -2X_1 + 4x_2$

$$\begin{bmatrix}\dot{X}_1\\ \dot{X}_2\end{bmatrix} = \begin{bmatrix}-2 & 4\\ 0 & -3\end{bmatrix}[X] + \begin{bmatrix}0\\ 1\end{bmatrix}u$$

08. Ans: (d)

Sol: $TF = \dfrac{k}{(s^2+1^2)^2}$

$$IR = L^{-1}\left[\frac{k}{(s^2+1^2)^2}\right]$$

IR = kt sin t

09. Ans: (c)

Sol: ⇒ PI controller is equivalent to lag compensator

⇒ PD controller is equivalent to lead compensator

⇒ PID controller is equivalent to lead - lag compensator.

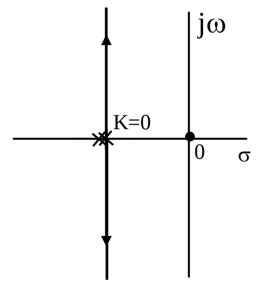
⇒ ON-OFF controller is also known as relay controller

10. Ans: (b)

Sol: CE = 1+G(s) = 0

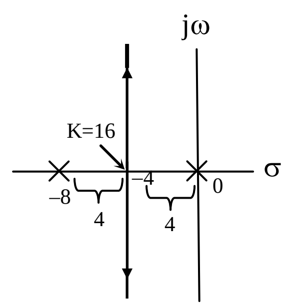
CE = s^2 + 2s + K + 1= 0

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



11. Ans: (c)

Sol: G(s)H(s) = $\dfrac{K}{s(s+8)}$



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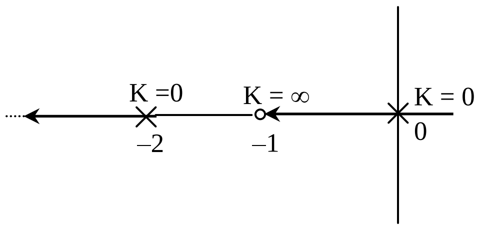
12. Ans: (c)



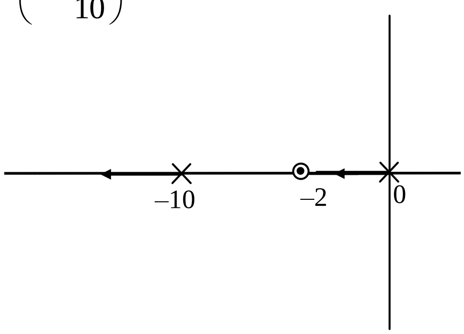
Break point does not exist

13. Ans: (c)

Sol: type 0 system: open loop pole at origin.

14. Ans: (b)

Sol: $$\text{TF} = \frac{K\left(1+\frac{s}{2}\right)}{s\left(1+\frac{s}{10}\right)} = \frac{5K(s+2)}{s(s+10)}$$



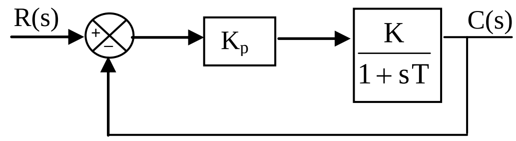
15. Ans: (c)

Sol: $$\frac{V_0(s)}{V_i(s)} = \frac{1M + \frac{1}{s1\mu}}{1M + 1M + \frac{1}{s1\mu}}$$

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

16. Ans: (b)

Sol:



$$\xrightarrow{e_{ss}} G(s) = \frac{KKp}{1+sT}, H(s) = 1$$

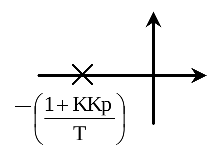
$$e_{ss} = \frac{A}{1+K_p} = \frac{1}{1+KK_p}$$

As K_p increases $\Rightarrow$ e_{ss} decreases

$$\text{CLTF} = \frac{KK_p}{sT+1+KK_p}$$

$$S = \frac{-(1+KK_p)}{T}$$

$$T_{CL} = \frac{T}{(1+KK_p)}$$



K_p increases $\rightarrow$ Time constant of closed loop system decreases

17. Ans: (a)

Sol: N = P–Z

N = 0, P =0

$\therefore$ Z = 0

18. Ans: (a)

Sol: 1. One pole at origin $\Rightarrow$ slope of bode plot $\frac{K}{s}$ is –20dB/dec

2. $G(s) = \dfrac{1-s}{1+s}$

$G(j\omega) = \dfrac{1-j\omega}{1+j\omega}$

$\omega = 0 \Rightarrow 1\angle 0°$

$\omega = \infty \Rightarrow -1\angle -180°$

$\therefore$ Nyquist plot not a straight line

3. $G(j\omega) = \dfrac{1}{1-j\omega}$

At $\omega = 0 \Rightarrow \phi = -\tan^{-1}\omega = -\tan^{-1}(0) = 0°$

19. Ans: (d)

Sol: Since the system is unstable, the steady state output is unbounded.

20. Ans: (a)

Sol: $\angle \dfrac{10}{j\omega(j\omega+4)(j\omega+6)} = -180°$

$\omega = \sqrt{24}$ rad/sec

$\left|\dfrac{10}{j\omega(j\omega+4)(j\omega+6)}\right| = \dfrac{10}{240}$

$GM = \dfrac{240}{10} = 24$

21. Ans: (b)

Sol: $TF = C[sI - A]^{-1}B$

$= \dfrac{10}{s^2+4s+3}$

22. Ans: (c)

Sol: $G(s) = \dfrac{k}{s\left(1+\frac{s}{2}\right)\left(1+\frac{s}{8}\right)}$

$= \dfrac{k}{s(1+sT_1)(1+sT_2)}$

20 log k = 26 dB

k = 20

Point of intersection = $\dfrac{kT_1T_2}{T_1+T_2} = 2$

23. Ans: (d)

Sol: $|G(j\omega)|$ at $\omega = 40 = 60 - 12 = 48$ dB

$|G(j\omega)|$ at $\omega = 160 = 48 - (6 \times 2) = 36$ dB

24. Ans: (d)

Sol: For system to be unstable

- One or more poles must lie in the right half of s – plane
- Repeated poles lie on the imaginary axis
- Repeated poles lie at the origin.

25. Ans: (a)

Sol: Characteristic Equation = $1+\dfrac{8k}{s(s+10)} = 0$

s^2	1	8k
s^1	10	
s^0	8k	

$s^2 + 10s + 8k = 0$

8 k > 0

$k > 0$

For any value of $k > 0$ system is stable

26. Ans: (b)

Sol:

$$\begin{array}{l|lll} +s^5 & 1 & 1 & 1 \\ +s^4 & 1 & 1 & 1 \\ +s^3 & 0(2) & 0(1) & 0 \\ +s^2 & \frac{1}{2} & 1 & 0 \\ -s^1 & -3 & 0 & \\ +s^0 & 1 & & \end{array}$$

$AE = s^4 + s^2 + 1 = 0$

$$\frac{dA}{ds} = 4s^3 + 2s$$

$$= 2s^3 + s$$

Two sign changes in the 1st column

$$\left.\begin{array}{r} \therefore \text{ Number of RHP} = 2 \\ j\omega P = 0 \\ \text{LHP} = 3 \end{array}\right\} \text{unstable}$$

27. Ans: (b)

Sol:

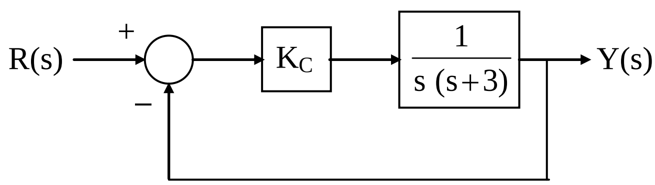
s^3	1	16
s^2	10	k
s^1	$\frac{160-k}{10}$	
s^0	k	

$160 - k = 0$

$k = 160$

28. Ans: (c)

Sol: Given block diagram is shown in below figure,



Characteristic equation is $s(s+3) + K_C = 0$

$s^2 + 3s + K_C = 0$

Poles to be on left of $s = -1$, put $s + 1 = z$

$(z-1)^2 + 3(z-1) + K_C = 0$ $\Rightarrow s = z - 1$

$z^2 + z + K_C - 2 = 0$

by applying Routh's criteria we get,

$$\begin{array}{l|ll} z^2 & 1 & K_C - 2 \\ z^1 & 1 & \\ z^0 & K_C - 2 & \end{array}$$

$K_C - 2 > 0$

$\Rightarrow K_C > 2$ for the poles to be on left of $s = -1$

29. Ans: (a)

Sol: Poles of the output are input and system poles i.e., -4, -1 and -10

$\therefore$ Time constants are $\frac{1}{4}$, 1 and $\frac{1}{10}$ sec

30. Ans: (c)

Sol: $M_p = \left(e^{\frac{-n\zeta\pi}{\sqrt{1-\zeta^2}}}\right) = e^{\left(-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}\right)^n}$

1^{st} under shoot = $\left(e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}\right)^2 = 0.25$

1^{st} over shoot = $e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} = 0.5$

2^{nd} over shoot $\left(e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}\right)^3 = (0.5)^3 = 0.125$

31. Ans: (d)

Sol: Let a = 2 , b = 6 $\frac{s+a}{s+b}$

aT=1/2, T=1/6, a=3, $\sin^{-1}\frac{a-1}{a+1}=30^0$

32. Ans: (d)

Sol: CLTF : $\frac{C(s)}{R(s)} = \frac{6}{s+11}$

The unit step response is given by

$$C(s) = \frac{6}{s(s+11)} = \frac{6/11}{s} - \frac{6/11}{s+11}$$

$$c(t) = \left(\frac{6}{11} - \frac{6}{11}e^{-11t}\right)u(t)$$

33. Ans: (d)

Sol:
- Root loci starts at poles and ends at zero of the loop transfer function G(s) H(s)
- At poles of G(s) H(s) the value of k = 0
- At zeros of G(s) H(s) the value of k = ∞

34. Ans: (a)

Sol: $\phi^2(t) = \phi(2t)$ i.e., replace 't' by 2t

$$\phi^2(t) = \begin{bmatrix} e^{-4t} & 0 \\ 0 & e^{-6t} \end{bmatrix}$$

35. Ans: (c)

Sol: By applying Gilbert's test, X_1 is not controllable

X_3 is not observable

36. Ans: (a)

Sol: From given characteristic,

$$\upsilon_T = 0.8 + \frac{2-0.8}{100}i_a = 0.8 + 0.012\,i_a$$

When current of 80A is following

$$\upsilon_T = 0.8 + 0.012 \times 80 = 1.76V$$

∴ Average power loss

$$= \frac{1.76 \times 80 \times (T/2)}{T} = 70.4W$$

37. Ans: (a)

38. Ans: (a)

Sol: For switching the inductive load, t_d should not be considered. Here t_n is the conduction period of transistor.

Turn on energy loss is given by

$$E_{ON} = \frac{1}{2}V_{cc}I_L(t_n + t_{fv1}) = 32mJ$$

Turn off energy loss is given by

$$E_{off} = \frac{1}{2}V_{cc}I_L(t_n + t_{rv2}) = 32mJ$$

39. Ans: (a)

Sol: Surge currents are assumed to be sine waves with frequency of 50 or 60 Hz depending upon the supply frequency. This rating is specified in terms of the number of surge cycles with corresponding surge current peak. Surge current rating is inversely proportional to the duration of the surge. It is usual to measure the surge duration in terms of the number of cycles of normal frequency of 50 or 60 Hz.

$\int I^2 t$: This rating is employed in the choice of a fuse or other protection equipment for thyristors. This rating in terms of amp^2-sec specifies the energy that the device can absorb for a short time before the fault is cleared. It is usually specified for overloads lasting for less than, or equal to, one- half cycle of 50 or 60 Hz supply.

40. Ans: (b)

Sol: The size of the filter circuits in three phase rectifier circuits is less than single phase circuits as the ripple content in three phase circuits is less filter circuits size required is also small.

As the ripple content is less THD is also less.

41. Ans: (c)

Sol: For $\alpha = 60$, FD conducts for same time duration as each SCR.

Hence for $\alpha = 60$, each SCR conducts for 60 degrees out of 360 degrees and FD conducts for 180 degrees out of 360 degrees. Hence, option c is correct.

42. Ans: (c)

Sol: IPF = $\sqrt{\dfrac{2}{\pi(\pi-\alpha)}}[1+\cos\alpha]$

$$= \sqrt{\frac{2}{\pi\times\pi/2}}[1+0] = \frac{2}{\pi}$$

43. Ans: (a)

Sol: In one cycle free wheeling duration = 180^0

means F.D conductor for $\dfrac{180}{3} = 60^0$ each time. This is possible when SCR triggers at $\alpha = 120°$

44. Ans: (b)

Sol: $I_0 = \dfrac{V_m}{2\omega L_s}[\cos\alpha - \cos(\alpha+\mu)]$

$\therefore$ For $\alpha_1 = 0^o$, $\mu_1 = 30^o$

$\alpha_2 = 45^o$, $\mu_2 = ?$

($\because I_0$ = constant)

$\Rightarrow \cos\alpha_1 - \cos(\alpha_1 + \mu_1) = \cos\alpha_2 - \cos(\alpha_2 + \mu_2)$

$\cos 0 - \cos 30 = \cos 45 - \cos(45+\mu_2)$

$\therefore \mu_2 = 10.03^o$

45. Ans: (c)

Sol: As the firing angle $\alpha \le 60°$, which is continuation conduction case. So both thyristor and diode conducts for 120°.

46. Ans: (b)

Sol: In boost converter input is current stiff type and output is voltage stiff type.

47. Ans: (c)

Sol: Type –A chopper is having 1^{st} quadrant characteristics. So regenerative braking is not possible. Remaining all given choppers has regenerating characteristics.

48. Ans: (b)

Sol: $$i(t) = \frac{V_{dc} - V_{co}}{\omega L}\sin\omega t + I_0\cos\omega t$$

$$V_c(t) = V_{dc} - \frac{Ldi}{dt}$$

$$v_c(t) = V_{dc} - (V_{dc} - V_{co})\cos\omega t + I_0\sqrt{\frac{L}{C}}\sin\omega t$$

If $V_{co} = V_{dc}$ then, $v_c(t) = V_{dc} + I_0\sqrt{\frac{L}{C}}\sin\omega t$

At turn OFF $\omega t = \frac{\pi}{2}$

$$\therefore V_c = V_{dc} + I_0\sqrt{\frac{L}{C}}$$

$$= 200 + 200\sqrt{\frac{4\mu}{20\mu}} = 289.4\text{V}$$

49. Ans: (d)

Sol: $V_0 = \frac{DV_s}{\beta - D} = \beta = 0.9$

$\beta T - DT = 6\mu$ sec

50. Ans: (d)

Sol: $\Delta I_{L_{MAX}} = \left[\frac{V_{DC}}{4Lf}\right]$ as the maximum value of peak to peak ripple is inversely proportional to switching frequency and the inductance. So maximum value of peak to peak ripple reduces if switching frequency and inductive effect increases.

51. Ans: (b)

Sol: $$V_0 = \frac{D}{1 + \frac{r_L}{R}}.V_{DC}$$

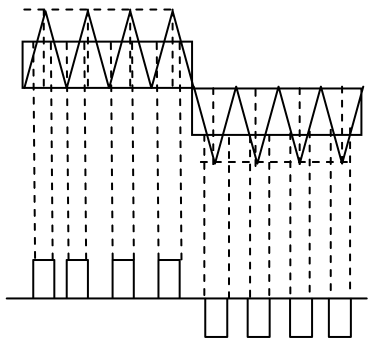
$$G = \frac{V_0}{V_{DC}} = \frac{D}{1 + \frac{r_L}{R}} = \frac{60}{151}$$

$$D = \frac{60}{151}\left(1 + \frac{1}{150}\right) = 0.4$$

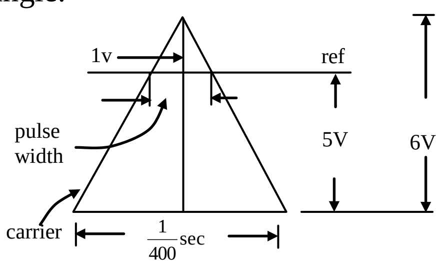
52. Ans: (c)

Sol: The voltage pulses are shown in figure. It is seen that there are

$$\left(\frac{f_c}{2f}\right) = \frac{400}{100} = 4 \text{ pulses per } \frac{1}{2}\text{ cycle.}$$



Pulse width: Drawing an enlarged figure of one triangle.

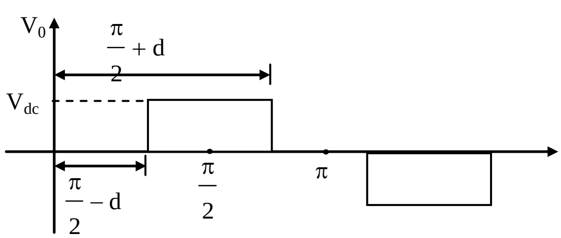


By similar triangles, $\dfrac{\text{Pulse width}(\text{sec})}{\left(\dfrac{1}{400}\right)} = \dfrac{1}{6}$

Pulse width $= \dfrac{1}{6}\dfrac{1}{400}\,\text{sec} = 0.4167\ \text{milli}-\text{sec.}$

53. Ans: (b)

Sol:



d = $\dfrac{\pi}{3}$

Pulse width = 2d = $\dfrac{2\pi}{3}$

RMS fundamental component of output voltage

$$= \frac{4 \times V_{dc}}{\pi \times \sqrt{2}} \times \sin d$$

$$= \frac{4 \times 1.414}{\pi \times \sqrt{2}} \times \sin\left(\frac{\pi}{3}\right)$$

= 1.102 V

54. Ans: (a)

Sol: Here, circuit allows current in both the half cycles, so current waveform is pure sinusoidal which has only fundamental frequency.

55. Ans: (c)

Sol: Harmonic factor for the lowest order harmonic, that is (third harmonic),

$$\rho_3 = \frac{V_{03}}{V_{01}} = \frac{2V_s}{3.\sqrt{2}.\pi} \times \frac{\sqrt{2}.\pi}{2V_s} = 0.333$$

56. Ans: (c)

Sol: Unipolar: $f_h = [j(2m_f) \pm k]f_1$

$\Rightarrow (2 \times 27 - 1) \times 53 = 2809$ Hz

Bipolar: $f_h = (jm_f \pm k)f_1$

m_f = odd, k must be even

$\Rightarrow (27 - 2) \times 53 = 1325$ Hz.

57. Ans: (c)

Sol: $\text{Power factor} = \dfrac{\text{power delivered to the load}}{\text{Input volt Ampere}}$

$$= \frac{V_{or} I_{or}}{V_s I_{sr}} \quad (\text{But } I_{or} = I_{sr})$$

$$\Rightarrow \frac{V_{or}}{V_s} = \frac{176.7}{229} = 0.77$$

58. Ans: (c)

59. Ans: (a)

Sol: If AC voltage controller feeding purely inductive load, then each thyristor conducts for 2α. The range of firing angle is 90 degrees to 180 degrees. If α = 90 degrees, then each SCR conducts for 180 degrees.

60. Ans: (b)

Sol: Average armature terminal voltage,

$V_t = (1-D)V_{dc}$

$= 0.6 \times 220 = 132V$

back emf, $E_b = V_t + I_aR_a$

$= 132 + 60 \times 0.15 = 141$ V

$\therefore$ Motor speed $= \dfrac{141}{0.05\times 60} = 47\text{rad/s}$.

61. Ans: (a)

Sol: $V_{sw} = V_{dc}\left[\dfrac{N_1}{N_3}+1\right] = 300\left[\dfrac{9}{12}+1\right]$

$= 300 \times 1.75 = 525$ V

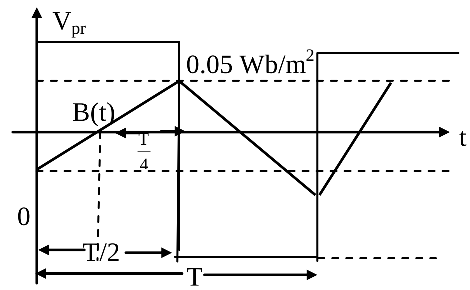
$V_D = V_{dc}\left[\dfrac{N_3}{N_1}+1\right]$

$= 300\left[\dfrac{12}{9}+1\right] = 700$ V

$\dfrac{N_2}{N_1} = \dfrac{9}{80} \approx \dfrac{1}{9}$

62. Ans: (c)

Sol:



$V_{pr} = N_{pr}.\dfrac{d\phi}{dt}$

$= N_{pr} \times A_c \times \dfrac{dB(t)}{dt}$

$100 = N_{pr} \times 0.55\times 10^{-4} \times \left(\dfrac{0.05}{T/4}\right)$

$T = 20\mu s$

$N_{pr} = 181.81$

$\Rightarrow N = 182$

63. Ans: (c)

Sol: Forward converter is also called Isolated buck converter

Hence, output voltage, $V_0 = D\times \dfrac{N_2}{N_1}\times V_{dc}$

64. Ans: (c)

65. Ans: (d)

Sol: The alternator leakage inductance will act as a low pass filter. So that the harmonics will be reduced.

66. Ans: (a)

67. Ans: (c)

Sol: SVC is not an active filter so statement II is false.

68 Ans: (d)

Sol: The Voltage/Current stress on the devices increases, which demands higher rating of devices compared to the hard switched converters.

69 Ans: (b)

Sol: (i) Let $V_0 = 150$ V & $V_s = 230$ V

For 1-ϕ full converter $V_0 = \frac{2V_m}{\pi}\cos\alpha$

$$\cos\alpha = \frac{V_0 \times \pi}{2V_m}$$

$$\alpha = \cos^{-1}\left[\frac{150\times\pi}{2\times\sqrt{2}\times 230}\right]$$

$\Rightarrow \alpha = 43.58°$

Power factor = 0.9 cos α

= 0.9 cos 43.58°= 0.651 lag

For semi converter $V_0 = \frac{V_m}{\pi}(1+\cos\alpha)$

$\alpha = 63.33°$

$$\text{Power factor} = \sqrt{\frac{2}{\pi(\pi-\alpha)}}(1+\cos\alpha)$$

$$= \sqrt{\frac{2}{\pi\left(\pi-63.33\times\frac{\pi}{180}\right)}}(1+\cos 63.33^{o})$$

= 0.81 lag

So for the same output voltage , the power factor of 1-ϕ semi converter is better than full converter.

70. Ans: (b)

Sol: Both the statements are individually true but statement II is not correct explanation of statement I

71. Ans: (c)

Sol: In phase lead compensator, compensating pole is located left of the compensating zero hence Statement (II) is wrong

72. Ans: (a)

Sol: For stability (–1, j0) should not be enclosed by the Nyquist plot

73. Ans: (b)

Sol: Block diagram techniques used for simplification of control system, but for complicated systems, the block diagram reduction is tedious and time consuming hence signal flow graphs are used.

Signal flow graph is a graphical representation for the variables representing the output of the various blocks of the control system.

74. Ans: (a)

Sol: For a minimum phase system to be stable, both PM and GM must be positive.

$$\left.\begin{array}{l} GM = 10\text{dB} \\ PM = 20^{o} \end{array}\right\}\text{both positive}$$

Thus, Statement (II) is correct explanation to Statement (I).

75. Ans: (b)

Sol: Steady state error of a type 1 system to a Ramp input is finite. Position error coefficient of type -1 system is infinite both Statements are correct but Statement (II) is not correct explanation for Statement (I).