DETAILED SOLUTIONS

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ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

ELECTRICAL ENGINEERING

Test 10

Section A : Power Electronics and Drives [All Topics]
Section B : Power Systems-1 [Part Syllabus]
Section C : Electrical Machines-2 [Part Syllabus]

ANSWER KEY

1.	(b)	**16.**	(b)	**31.**	(b)	**46.**	(a)	**61.**	(a)
2.	(d)	**17.**	(c)	**32.**	(d)	**47.**	(c)	**62.**	(b)
3.	(a)	**18.**	(a)	**33.**	(c)	**48.**	(b)	**63.**	(d)
4.	(d)	**19.**	(b)	**34.**	(d)	**49.**	(b)	**64.**	(d)
5.	(c)	**20.**	(a)	**35.**	(d)	**50.**	(d)	**65.**	(c)
6.	(a)	**21.**	(b)	**36.**	(d)	**51.**	(c)	**66.**	(c)
7.	(c)	**22.**	(a)	**37.**	(a)	**52.**	(c)	**67.**	(d)
8.	(c)	**23.**	(d)	**38.**	(a)	**53.**	(a)	**68.**	(c)
9.	(d)	**24.**	(c)	**39.**	(c)	**54.**	(c)	**69.**	(b)
10.	(a)	**25.**	(b)	**40.**	(b)	**55.**	(d)	**70.**	(c)
11.	(b)	**26.**	(c)	**41.**	(c)	**56.**	(a)	**71.**	(d)
12.	(c)	**27.**	(b)	**42.**	(b)	**57.**	(b)	**72.**	(b)
13.	(b)	**28.**	(b)	**43.**	(c)	**58.**	(d)	**73.**	(c)
14.	(b)	**29.**	(b)	**44.**	(c)	**59.**	(c)	**74.**	(a)
15.	(b)	**30.**	(b)	**45.**	(d)	**60.**	(c)	**75.**	(b)

DETAILED EXPLANATIONS

Section A : Power Electronics and Drives

1. (b)

The distortion factor, $DF = \dfrac{I_{s1}}{I_s}$

$$I_{s1} = \frac{12}{\sqrt{2}}\text{Amp}$$

$$I_s = \sqrt{5^2 + \frac{1}{2}(12^2 + A^2)}$$

$$\Rightarrow \quad \text{D.F.} = \frac{6\sqrt{2}}{13} = \frac{12/\sqrt{2}}{I_s}$$

$$\Rightarrow \quad I_s = 13 \text{ A}$$

$$\Rightarrow \quad 13^2 = 5^2 + \frac{A^2 + 12^2}{2}$$

$$\Rightarrow \quad A = 12$$

2. (d)

The power factor, $\text{pf} = \dfrac{P}{S} = \dfrac{P}{V_{\text{rms}} I_{\text{rms}}}$

$$\text{pf} = \frac{V_{1,\text{rms}} I_{1,\text{rms}} \cos(\phi_1)}{V_{1,\text{rms}} I_{\text{rms}}} = \left(\frac{I_{1,\text{rms}}}{I_{\text{rms}}}\right)\cos\phi_1$$

$$I_{\text{rms}} = \sqrt{8^2 + \left(\frac{1}{\sqrt{2}}\right)^2 \left[15^2 + 6^2 + 2^2\right]} = \sqrt{8^2 + 0.5(265)} = \sqrt{196.5}$$

$$I_{\text{rms}} \approx 14 \text{ Amp}$$

So, $$\text{power factor} = \frac{\left(\frac{15}{\sqrt{2}}\right)\times \cos 30°}{14} = \frac{\frac{15}{\sqrt{2}} \times \frac{\sqrt{3}}{2}}{14} = \frac{15 \times 1.732}{28 \times 1.414} = 0.66$$

3. (a)

The current supplied to the gate should occur at a time when the main circuit conditions are favourable to conduction.

4. (d)

Given,

The ambient temperature,

$$T_A = 28° \text{ C}$$

The junction temperature,

$$T_j = 100° \text{ C}$$

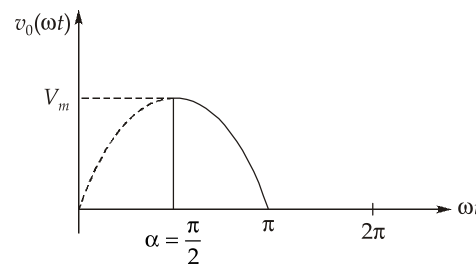
The thermal resistance, $\theta = 2.4° \text{ C/W}$

The internal power dissipation,

$$P_D = \frac{T_J - T_A}{\theta} = \frac{100-28}{2.4} = 30 \text{ W}$$

5. (c)

The load voltage waveform,



Here, $V_m = 230\sqrt{2}$ V

The rms voltage across load,

$$V_{0r} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi}(V_m \sin\omega t)^2 d(\omega t)} = \sqrt{\frac{V_m^2}{2\pi}\left[\int_{\alpha}^{\pi}\frac{1-\cos 2\omega t}{2}d(\omega t)\right]}$$

$$V_{0r} = \frac{V_m}{2\sqrt{\pi}}\left(\pi - \alpha + \frac{\sin 2\alpha}{2}\right)^{1/2} = \frac{230\sqrt{2}}{2\sqrt{\pi}}\left(\pi - \frac{\pi}{2} + \frac{\sin 2\times\frac{\pi}{2}}{2}\right)^{1/2}$$

$$V_{0r} = \frac{230\sqrt{2}}{2\sqrt{\pi}}\left[\frac{\pi}{2}\right]^{1/2} = \frac{230}{2} = 115 \text{ V}$$

So power loss or dissipated in load,

$$P_{\text{load}} = \frac{V_{0r}^2}{R} = \frac{115^2}{100} = 132.25 \text{ Watts}$$

6. (a)

For the given circuit,

$$\text{current, } i = \frac{1}{L}\int v_{dc} dt$$

$$i = \frac{1}{0.2}\int 500\, dt = 2500t$$

Latching current can be achieved by applying pulse for a minimum time i.e. t_{min}

$$10 \times 10^{-3} = 2500\ t_{min}$$

$$t_{min} = \frac{10 \times 10^{-3}}{2500} = \frac{10}{2.5} \times 10^{-6}$$

$$t_{min} = 4\ \mu sec$$

7. (c)

The harmonics present in output phase voltage is given by,

$$n = (6K \pm 1)$$

$$K = 1, 2, 3$$

So, lowest order harmonics is

$$n = 6 \times 1 - 1 = 5$$

So, frequency of lowest harmonics

$$f_5 = nf_s = 5 \times 60 = 300\ \text{Hz}$$

8. (c)

With the help of PWM switching scheme, the total harmonics distortion is reduced with modest filtering.

9. (d)

The fundamental peak voltage

$$\hat{V}_{01} = \frac{4V_{dc}}{\pi} = \frac{4 \times 130\pi}{\pi} = 520\ \text{V}$$

The impedance at 100 Hz

$$Z = \sqrt{R^2 + X^2} = \sqrt{5^2 + 12^2} = 13\ \text{ohm}$$

The fundamental peak current,

$$\hat{I}_{01} = \frac{\hat{V}_{01}}{z} = \frac{520}{13}$$

$$\hat{I}_{01} = 40\ \text{A}$$

10. (a)

The rms voltage of waveform,

$$V_{0\ rms} = \sqrt{\frac{\alpha}{\pi}} \times 1 = \sqrt{\frac{\alpha}{180°}}$$

$$V_{0\ rms} = \sqrt{\frac{120}{180}} = \sqrt{\frac{2}{3}}\ \text{V}$$

The fundamental rms voltage,

$$V_{01} = \frac{4V_{dc}}{\pi \times \sqrt{2}} \sin(d) = \frac{4 \times 1}{\pi \times \sqrt{2}} \sin(60) = 0.90 \times 0.866$$

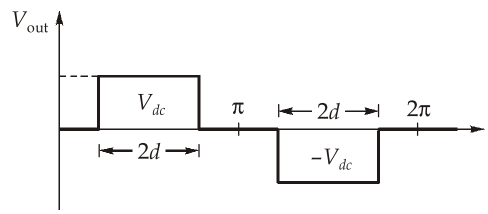
$$V_{01} = 0.78 \text{ V}$$

$$\text{THD} = \frac{V_{\text{harmonics}}}{V_{01}} \times 100 = \sqrt{\frac{V_{0\text{rms}}^2 - V_{01}^2}{V_{01}^2}} \times 100$$

$$= \sqrt{\frac{\frac{2}{3} - (0.78)^2}{(0.78)^2}} \times 100 = \sqrt{\frac{0.058}{0.78^2}} \times 100$$

$$= \sqrt{0.0957} \times 100 = 30.94\%$$

11. (b)



The n^{th} harmonics, $\hat{V}_{on} = \frac{4V_{dc}}{n\pi}\sin(nd)$

5^{th} order harmonics, $\hat{V}_{o5} = \frac{4V_{dc}}{5\pi}\sin(5d)$

Given, $\hat{V}_{o5} = 0 = \frac{4V_{dc}}{5\pi}\sin(5d)$

$$\sin(5d) = 0$$

$$5d = n\pi \qquad (n = 1, 2)$$

$$d = \frac{\pi}{5} \text{ or } \frac{2\pi}{5}$$

$$d = 36° \text{ or } 72°$$

So, pulse width, $2d = 36 \times 2 \text{ or } 72 \times 2$

$$2d = 72° \text{ or } 144°$$

12. (c)

The fundamental component of load voltage,

$$\hat{V}_{01} = \frac{4V_{dc}}{\pi}$$

The rms voltage, $V_{01\,(rms)} = \frac{2\sqrt{2}V_{dc}}{\pi} = 0.90 \times V_{dc}$

$$V_{01\,(rms)} = 0.90 \times 100 = 90 \text{ V}$$

The load rms current,

$$I_{0\,(rms)} = \frac{A}{\sqrt{2}}$$

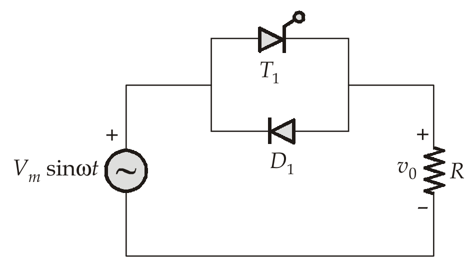
The power, $P = V_{01\,(rms)} I_{0\,(rms)} \cos 45°$

$\Rightarrow \quad 90 \times \frac{A}{\sqrt{2}} \times \cos 45° = 225$

$$\frac{90}{2} A = 225$$

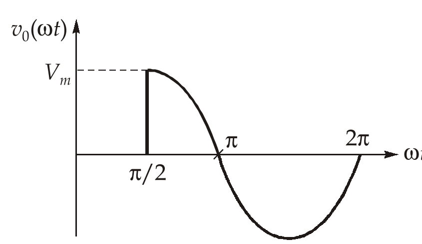
$$A = \frac{225}{45} = 5$$

13. (b)



Here, $V_m = 240\sqrt{3} \times \sqrt{2} = 240\sqrt{6}$ V

The waveform



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

$$\alpha = \frac{\pi}{2} \text{rad}$$

$$V_{or} = \frac{240\sqrt{6}}{2\sqrt{\pi}}\left[\left(2\pi - \frac{\pi}{2}\right) + \frac{1}{2}\sin\left(2 \times \frac{\pi}{2}\right)\right]^{1/2}$$

$$V_{or} = \frac{240\sqrt{6}}{2\sqrt{\pi}}\left[\frac{3\pi}{2}\right]^{1/2}$$

$$= 120\sqrt{6}\left(\frac{3}{2}\right)^{1/2} = 360 \text{ V}$$

The power dissipated, $P = \frac{V_{or}^2}{R} = \frac{360^2}{360} = 360$ W

14. (b)

The average output voltage of a single-phase full wave rectifier with highly inductive load is given by

$$V_0 = \frac{2V_m}{\pi}\cos\alpha = \frac{2\times 230\times\sqrt{2}}{\pi}\times\cos 60°$$

$$= 103.54 \text{ V}$$

15. (b)

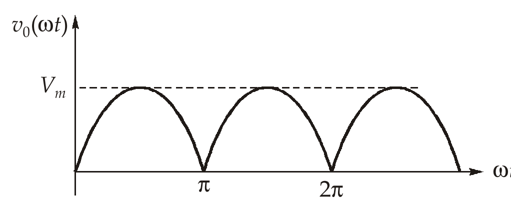
Power IGBT is a minority carrier device.

16. (b)

As compared to power BJT, a power MOSFET has lower switching losses but higher conduction losses.

17. (c)

The output of the 1-ϕ , full bridge converter is shown



The frequency of output ripple = $2f_s$ = 120

$$f_s = \frac{120}{2} = 60 \text{ Hz}$$

18. (a)

The output power for constant current load,

$$P_0 = V_0 I_0$$

For single phase fully controlled converter source current,

$$I_{sr} = I_0$$

So, input power factor, IPF = $\dfrac{P_0}{V_{sr}I_{sr}}$

$$\text{IPF} = \frac{V_0 I_0}{V_{sr} I_0}$$

$$0.85 = \frac{V_0}{V_{sr}}$$

$$V_0 = 0.85 \times 230 = 195.5 \text{ V}$$

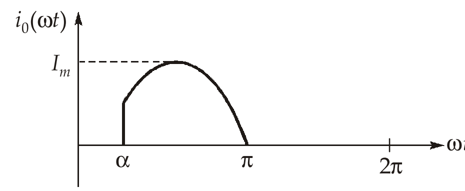
19. (b)

The input power factor,

$$IPF = \frac{3}{\pi}\cos\alpha$$

$$IPF = \frac{3}{\pi}\cos 30° = 0.95 \times 0.87 = 0.8265 \approx 0.83$$

20. (a)



The average current, $$I_0 = \frac{1}{2\pi}\int_{\alpha}^{\pi} I_m \sin\omega t(\omega t)$$

$$I_0 = \frac{1}{2\pi} I_m[-\cos\omega t]_{\alpha}^{\pi} = \frac{I_m}{2\pi}[1+\cos\alpha]$$

Given, $$I_0 = \frac{I_m}{4} = \frac{I_m}{2\pi}[1+\cos\alpha]$$

$$1 + \cos\alpha = \frac{\pi}{2}$$

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

21. (b)

When an UJT is used for triggering an SCR, the wave shape of the voltage obtained from the UJT circuit is a saw-tooth wave.

22. (a)

For boost-regulator, $$V_0 = \frac{V_{DC}}{1-D}$$

⇒ $$20 = \frac{10}{1-D}$$

So, duty cycle (D) = 0.5

and average inductor current,

$$I_{L\,avg} = \frac{I_0}{1-D} = 20\text{ A}$$

23. (d)

$$V_{L\text{ avg}} = 0$$

$$\Rightarrow \quad V_{\text{ON}} \cdot T_{\text{ON}} + V_{\text{OFF}} \cdot T_{\text{OFF}} = 0$$

$$\Rightarrow (20)(DT) + (-10)(1 - D)T = 0$$

$$\Rightarrow \quad 20D - 10 + 10D = 0$$

$$\Rightarrow \quad D = \frac{1}{3}$$

24. (c)

$$\eta = \frac{R(1-D)^2}{r_L + R(1-D)^2}$$

Where r_L is inductor resistance and R is load resistance,

As the duty ratio increases, efficiency of the boost converter decreases.

25. (b)

Buck-boost regulator provides output voltage polarity reversal without a transformer.

26. (c)

$$\text{Duty cycle} = \frac{T_{\text{ON}}}{T}$$

$$\Rightarrow \quad D = \frac{4\,\text{ms}}{10\,\text{ms}} = 0.4$$

$$V_{0\text{ rms}} = \sqrt{D} \cdot V_{\text{in}} = \left(\sqrt{0.4}\right)100 = 63.25\text{ V}$$

27. (b)

$$\frac{V_0}{V_i} = \frac{I_i}{I_0} = \frac{D}{1-D}$$

$$\Rightarrow \quad \frac{3}{2} = \frac{D}{1-D}$$

$$\Rightarrow \quad D = \frac{3}{5}$$

$$\Rightarrow \quad I_{sr} = \sqrt{D}\, I_{L\text{avg}} = \sqrt{\frac{3}{5}} \times \left(\frac{2}{1-3/5}\right) = 3.87\text{ A}$$

28. (b)

$$\text{Ripple factor} = \sqrt{\frac{1}{D} - 1} = \sqrt{\frac{1}{1/4} - 1} = \sqrt{3}$$

29. (b)

$AB \rightarrow$ Maximum limit for DC and continuous current.

$BC \rightarrow$ Limit of junction temperature to safe value.

$CD \rightarrow$ Secondary breakdown limit.

$DE \rightarrow$ Maximum voltage capability.

30. (b)

Switching speed of GTO is more than that of SCR.

31. (b)

The power delivered,

$$P_{\text{battery}} = V_B I_0 = 200$$

$$I_0 = \frac{200}{100} = 2 \text{ Amp}$$

So average load voltage, $V_0 = V_B + I_0 R$

$$= 100 + 2 \times 20$$

$$V_0 = 140 \text{ V}$$

32. (d)

The fundamental component of the source current,

$$\hat{I}_{s1} = 15\sqrt{2} \text{ Amp}$$

rms current, $I_{s1} = 15$ Amp

The fundamental power factor angle,

$$\phi_{s1} = \frac{\alpha}{2}$$

So, real power, $P = V_S I_{s1} \cos \phi_{s1}$

$$P = 230 \times 15 \times \cos(30) \approx 3 \text{ kW}$$

33. (c)

Given, $V_{LL} = 400$ V

The average output voltage,

$$V_0 = \frac{3V_{mL}}{2\pi} = \frac{3 \times 400 \times \sqrt{2}}{2\pi} = 270 \text{ V}$$

So, average current, $I_0 = \frac{V_0}{R} = \frac{270}{10} = 27$ Amp

34. (d)

The PIV of diode $(\text{PID})_D = 2 \times (50\sqrt{2})$

$$= 100\sqrt{2} \text{ V}$$

35. (d)

For 1-phase, semi-converter,

$$I_{s1r} = \frac{2\sqrt{2}}{\pi} I_0 \cos\frac{\alpha}{2},$$

$$I_{sr} = \sqrt{\frac{\pi-\alpha}{\pi}} I_0$$

$$\text{Input power factor} = g \times \text{FDF}$$

$$= \frac{I_{s1r}}{I_{sr}} \cdot \cos\frac{d}{2}$$

$$= \frac{\frac{2\sqrt{2}}{\pi}\left(\cos\frac{\alpha}{2}\right)^2}{\sqrt{\frac{\pi-\alpha}{\pi}}} = \frac{3\sqrt{3}}{2\pi}$$

36. (d)

The source inductance always reduces the average load voltage.

37. (a)

The lower the switching losses, higher will be the frequency of operation of the device.

39. (c)

Every SCR in 3-ϕ full converter conducts for 120°.

40. (b)

Both are true but not related to each other.

Section B : Power Systems-1

41. (c)

Electrostatic precipitator is installed between induced fan and air preheater.

42. (b)

$$\text{Output power} = WQh\,\eta \times 9.81 \times 10^{-3}\ \text{kW}$$

Where, W = density ; h = head ; Q = Reservoir capacity ; η = efficiency

$$P_0 = 1000 \times 50 \times 100 \times 0.7 \times 9.81 \times 10^{-3}\ \text{kW}$$

$$= 34.33\ \text{MW}$$

43. (c)

$$\text{Diversity factor} = \frac{\text{Sum of individual maximum demand}}{\text{Maximum demand on power station}}$$

$$\text{Coincidence factor} = \frac{1}{\text{Diversity factor}}$$

44. (c)

Classification of transmission lines based on $f\,l$:

$$f\,l < 4000 \quad \text{short } TL$$
$$4000 < f\,l < 10000 \quad \text{medium } TL$$
$$f\,l > 10000 \quad \text{long } TL$$

Given : $f = 200$ Hz, $l = 75$ km

$$f\,l = 200 \times 75 = 15000$$

As $f\,l > 10000$, so given power line is long transmission line.

45. (d)

Given, $A = D = 0.9\angle 10°$, $B = 100\angle 70°$

$V_S = 120$ kV, $V_R = 100$ kV

$$P_{max} = \frac{V_S V_R}{B} - \frac{A V_R^2}{B}\cos(\beta - \alpha)$$

$$= \frac{120 \times 100}{100} - \frac{0.9 \times (100)^2}{100}\cos(70° - 10°)$$

$$= 120 - 0.9 \times \frac{100}{2} = 75 \text{ MW}$$

46. (a)

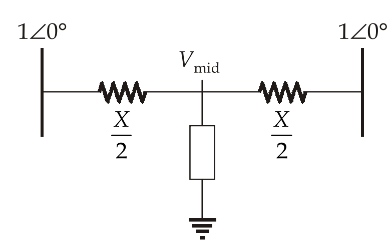
Corona loss (P_C) α (f + 25)

$$\frac{0.6}{P_C} = \frac{50 + 25}{75 + 25}$$

$$\frac{0.6}{P_C} = \frac{75}{100} = \frac{3}{4}$$

$$P_C = 4 \times 0.2 = 0.8 \text{ kW/ph/km}$$

47. (c)



$$\text{Steady state power limit} = \frac{1 \cdot V_{mid}}{X/2}$$

$$\frac{1 \times V_{mid}}{0.5/2} = 3.2$$

$$V_{mid} = 0.8 \text{ p.u.}$$

48. (b)

New surge impedance,

$$Z_{S1} = Z_S\sqrt{\frac{1 - K_{se}}{1 - K_{sh}}} = 400\sqrt{\frac{1 - 0.5}{1 - 0.75}}$$

$$= 400\sqrt{\frac{0.5}{0.25}} = 400\sqrt{2} = 565.68\ \Omega$$

49. (b)

Given, $P = 100$ kW, p.f. = 0.6 lag

Reactive power supply to make,

p.f. = 0.8 lag is

$$Q_C = P(\tan\cos^{-1} 0.6 - \tan\cos^{-1} 0.8)$$

$$= 100\left(\frac{8}{6} - \frac{6}{8}\right) = 100 \times \frac{7}{12} = 58.33 \text{ kVAR}$$

$$Q_C = 3\,V^2\,\omega C = 58.33 \text{ kVAR}$$

$$\Rightarrow \quad C = \frac{58.33 \times 10^3}{3 \times (10 \times 10^3)^2 \times 314} = \frac{58.33}{942} \times 10^{-5}$$

$$= 0.619\ \mu\text{F}$$

50. (d)

Length of distributor, $l = 50$ m

current loading, $i = 2$ A/m

resistance per meter run of both of the conductors,

$$(r) = \frac{2 \times 2}{1000}\ \Omega/\text{m} = 0.004\ \Omega/\text{m}$$

$$\text{Maximum voltage drop} = \frac{irl^2}{8} = \frac{2 \times 0.004 \times (50)^2}{8} = 2.5 \text{ V}$$

51. (c)

$$R_1 = \frac{\rho_1 l_1}{A_1} = 10\ \Omega$$

$$R_2 = \frac{\rho_2 l_2}{A_2}$$

$\rho_1 = \rho_2$ (resistivity)

$$r_2 = \frac{r_1}{4}$$

As volume in both the case is same

$$V_2 = V_1$$

$$l_2 \cdot \pi\left(\frac{r_1}{4}\right)^2 = l_1 \cdot \pi\, r_1^2$$

$$\frac{l_2}{16} = l_1$$

$$\Rightarrow \quad l_2 = 16\, l_1$$

$$\frac{R_1}{R_2} = \frac{l_1}{A_1} \cdot \frac{A_2}{l_2} = \frac{l_1}{16 l_1} \cdot \frac{\pi \left(\frac{r_1}{4}\right)^2}{\pi r_1^2}$$

$$\frac{10}{R_2} = \frac{1}{16 \times 16}$$

$\Rightarrow$ $R_2 = 2560\ \Omega$

52. (c)

For minimum cost of generation,

$$I_{C1} = I_{C2}$$

$$0.2P_1 + 300 = 0.4P_2 + 250$$

$$0.2P_1 + 300 = 0.4(400 - P_1) + 250 \qquad (\text{As } P_1 + P_2 = 400)$$

$$0.2P_1 + 0.4P_1 = 160 + 250 - 300$$

$$0.6P_1 = 110$$

$$P_1 = 183.33 \text{ MW}$$

$$P_2 = 216.66 \text{ MW} > 200 \text{ MW (maximum limit)}$$

Thus unit-2 will be share 200 MW i.e., P_2 = 200 MW

then $P_1 = 400 - 200 = 200$ MW

53. (a)

HVDC systems can use ground/sea return.

54. (c)

In HVDC transmission the rectifier consumes reactive power and inverter supplies reactive power from/to the respective connected ac system.

55. (d)

Radius of receiving-end power

$$\text{circle diagram} = \frac{V_S V_R}{B} = \frac{510 \times 500}{150} \text{MVA} = 1700 \text{ MVA}$$

56. (a)

$$Z_S = \sqrt{\frac{L}{C}}$$

If we use bundled conductors, inductors L is decreased. So Z_S is also decreased.

If Z_S is decreased, SIL will increase $\left(\because SIL = \frac{V^2}{Z_S}\right)$.

57. (b)

Both statement are individually correct.

58. (d)

For lossless transmission line,

$$R = 0$$

and $$G = 0$$

Section C : Electrical Machines-2

59. (c)

$$\text{Synchronous coefficient} = \frac{EV}{X_s}\cdot\cos\delta \qquad \alpha \text{ stability, } \alpha \text{ excitation}$$

At B excitation is more as compare to at A, hence alternator is more stable at B.

60. (c)

$$Z_S = (0.6 + j0.8)\ \Omega$$

$$|Z_S| = 1\ \Omega$$

Maximum output power in case of synchronous motor is,

$$P_{\text{output}} = \frac{E_f\cdot V_t}{Z_S} - \frac{E_f^2}{Z_S}\cdot\left(\frac{R_a}{Z_S}\right)$$

$$= (4000)^2\left(\frac{1}{1} - \frac{0.6}{1^2}\right) = 6.4\text{ MW}$$

61. (a)

Number of slots per pole per phase

$$\Rightarrow \quad m = \frac{36}{4\times 3} = 3$$

$$\Rightarrow \quad \beta = \frac{180°}{(36/4)} = 20°$$

$$\Rightarrow \quad \text{Breadth factor} = \frac{\sin\left(\frac{m\beta}{2}\right)}{m\sin\left(\frac{\beta}{2}\right)} = \frac{\sin\left(\frac{3\times 20°}{2}\right)}{3\sin\left(\frac{20°}{2}\right)} = 0.9598$$

62. (b)

- In overexcited condition, synchronous generator will deliver inductive VARs or accept capacitive VARs, hence it acts as a source.
- Synchronous motor in underexcited condition is absorbing inductive VARs so it is acting as a sink.
- Induction motor absorbs active power and reactive power, so it is acting as a sink.

63. (d)

$$V = 3300 \text{ V}, \quad \text{pf} = 0.707$$

$$I_{aL} = \frac{800 \times 10^3}{\sqrt{3} \times 3300 \times 0.707} \approx 198 \text{ A},$$

$$I_{aph} = 114.3 \text{ A}$$

$$|E_f| = \sqrt{(3300 \times 0.707 - 0^2) + (3300 \times 0.707 + 114.3 \times 5)^2}$$

$$= 3726.09 \text{ V}$$

64. (d)

Since after connecting the stator to the supply, flux per pole is increased to 25 mWb from the initial value of 20 mWb, hence effect of armature reaction is magnetizing i.e $F_f < F_r$, due to which motor is under excited and runs at lagging power factor.

65. (c)

The difference between electromagnetic torque and prime mover torque is due to losses in iron core, friction and windage.

66. (c)

$$I_f \text{ (field current)} = \frac{400}{200} = 2 \text{ A}$$

$$I_{a \text{ no-load}} = 5.6 - 2 = 3.6 \text{ A}$$

$$I_{a \text{ full-load}} = 68.3 - 2 = 66.3 \text{ A}$$

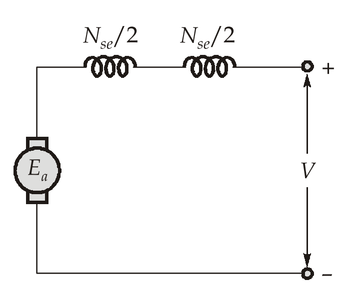
$$E_{a \text{ no-load}} = 400 - (3.6 \times 0.18) - 2 = 397.352 \text{ V}$$

$$E_{a \text{ full-load}} = 400 - (66.3 \times 0.18) - 2 = 386.066 \text{ V}$$

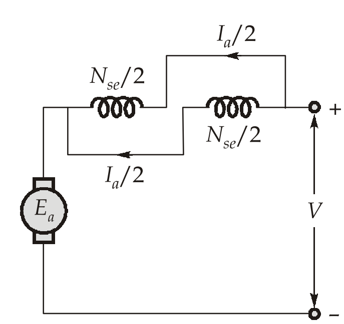
$$\frac{N_{\text{full-load}}}{N_{\text{no-load}}} = \frac{E_{a\text{full-load}}}{E_{a\text{no-load}}} \times \frac{\phi_1}{0.97\phi_1} = \frac{386.066}{397.352 \times 0.97} \approx 1$$

67. (d)

The field windings are divided into two halves and then connected in series or parallel to control the field ampere-turns. In dc series motor,



(a) series



(b) parallel

$$\phi_{(\text{flux})} \propto I_a$$

$$\therefore \qquad \phi_{series} \propto I_a$$

$$\phi_{parallel} \propto \frac{I_a}{2}$$

$$N \propto \frac{1}{\phi}$$

$$\therefore \qquad \frac{N_{parallel}}{N_{series}} = 2$$

Hence parallel connection gives higher speed.

69. (b)

- physically the brush is along the direct-axis in dc machine.
- schematically the brush is along the quadrature axis, in dc machine.
- armature mmf is directed along the brush axis.

70. (c)

$$I_f = \frac{250}{250} = 1\text{ A}$$

$$I_a = 21 - 1 = 20\text{ A}$$

Torque is constant,

Hence $I_{a2} = I_{a1}$

$$E_{b1} = 250 - (20 \times 0.5) = 240\text{ V}$$

$$E_{b2} = 250 - 20(0.5 + 0.5) = 230\text{ V}$$

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

$$\Rightarrow \qquad N_2 = 600 \times \frac{230}{240} = 575\text{ rpm}$$

71. (d)

Compensating winding ampere turns per pole,

$$AT_C = 0.7 \times 15000 = 10500\text{ ATs}$$

mmf required for the air-gap under the interpole

$$= \frac{B}{\mu_0} \times l_g = \frac{0.25}{4\pi \times 10^{-7}} \times 1 \times 10^{-2}$$

$$= 1989.43 \approx 1989\text{ ATs}$$

$\therefore$ Ampere turns furnished by each interpole are

$$= (15000 - 10500) + 1989 = 6489\text{ ATs}$$

72. (b)

Given, $l = 0.3$ m, $r = 0.2$ m,

$Z = 500$, $I_a = 20$ A

$B_{avg} = 0.5$ T, $P = 4$

$$\text{Flux per pole, } \phi_{pp} = 0.5 \times \frac{2\pi \times 0.2 \times 0.3}{4} = 0.04712 \text{ Wb}$$

$$\text{Torque} = P\phi \cdot \frac{I_a}{2\pi} \cdot \frac{Z}{A} = 4 \times (0.04712) \times \frac{20}{2\pi} \times \frac{500}{4} = 0.04712 \times 0.159 \times 10000$$

$$= 74.996 \text{ Nm} \approx 75 \text{ Nm}$$

74. (a)

The poor commutation in dc machine is caused by some mechanical conditions which includes uneven commutator surface, non-uniform brush pressure, vibration of the brushes in the holders etc. The electrical conditions include an increase in the voltage between commutator segments, an increase in the current density at the trailing edge of the brush etc.

75. (b)

Isolated generated is not connected to the bus-bar, so its frequency can be altered. But, when generator is connected to an infinite bus then its frequency is governed by bus-bar frequency.

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