DETAILED SOLUTIONS

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ESE 2024 : 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.**	(d)	**46.**	(c)	**61.**	(b)
2.	(d)	**17.**	(a)	**32.**	(b)	**47.**	(d)	**62.**	(a)
3.	(a)	**18.**	(d)	**33.**	(c)	**48.**	(d)	**63.**	(c)
4.	(b)	**19.**	(b)	**34.**	(a)	**49.**	(a)	**64.**	(a)
5.	(c)	**20.**	(d)	**35.**	(c)	**50.**	(c)	**65.**	(b)
6.	(b)	**21.**	(b)	**36.**	(d)	**51.**	(b)	**66.**	(c)
7.	(d)	**22.**	(b)	**37.**	(c)	**52.**	(d)	**67.**	(d)
8.	(d)	**23.**	(b)	**38.**	(a)	**53.**	(a)	**68.**	(d)
9.	(b)	**24.**	(c)	**39.**	(c)	**54.**	(d)	**69.**	(d)
10.	(c)	**25.**	(b)	**40.**	(b)	**55.**	(d)	**70.**	(b)
11.	(c)	**26.**	(b)	**41.**	(c)	**56.**	(a)	**71.**	(c)
12.	(c)	**27.**	(c)	**42.**	(d)	**57.**	(a)	**72.**	(b)
13.	(d)	**28.**	(a)	**43.**	(c)	**58.**	(b)	**73.**	(b)
14.	(b)	**29.**	(a)	**44.**	(b)	**59.**	(c)	**74.**	(b)
15.	(d)	**30.**	(c)	**45.**	(c)	**60.**	(c)	**75.**	(b)

DETAILED EXPLANATIONS

Section A : Power Electronics and Drives

1. (b)

Class F commutation/Line commutation:

This type of commutation is also known as natural commutation. This can occur only when converter circuits are fed either from single phase source or from three phase source. The essential condition for natural commutation is that first anode current must decay to zero and then ac source must apply a negative voltage across SCR for bringing it to forward blocking capability.

3. (a)

The main purpose of feedback diodes in the d.c. to a.c. thyristor inverter freewheels the load current.

4. (b)

Average value of output voltage,

$$V_0 = \frac{2V_m}{\pi} = \frac{2\sqrt{2}}{\pi} \times 230 = 0.9003 \times 230$$

$$= 207.07 \text{ V}$$

Average value of output current,

$$I_0 = \frac{V_0}{R} = \frac{207.07}{10} = 20.704 \text{ A}$$

Average value of diode current,

$$I_{DA} = I_0\left(\frac{\pi}{2\pi}\right) = \frac{I_0}{2} = 10.352 \text{ A}$$

Rms value of diode current,

$$I_{Dr} = I_0\sqrt{\frac{\pi}{2\pi}} = \frac{I_0}{\sqrt{2}} = \frac{20.704}{\sqrt{2}} = 14.642 \text{ A}$$

5. (c)

$$V_g \cdot I_g = 1 \quad \text{...(i)}$$

$$\frac{V_g}{I_g} = 100 \quad \text{...(ii)}$$

Equation (ii) in (i),

$$100I_g^2 = 1$$

$$I_g = 0.1 \text{ A}$$

Gate voltage, $V_g = 100I_g = 100 \times 0.1 = 10 \text{ V}$

For the gate circuit, $E_s = I_g \cdot R_s + V_g$

$$R_s = \frac{E_s - V_g}{I_g} = \frac{15-10}{0.1} = 50\ \Omega$$

6. (b)

Output voltage waveform switches between $-\frac{1}{2}$ and $+\frac{1}{2}$.

7. (d)

Output voltage for flyback converter is similar to isolated Buck-boost converter,

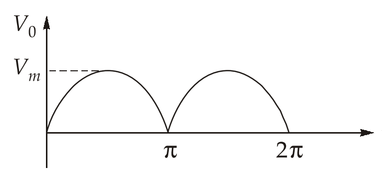
$$V_0 = \frac{N_2}{N_1} V_s \left(\frac{t_{ON}}{t_{OFF}}\right)$$

9. (b)

$$V_{0\,(rms)} = \frac{2\sqrt{2}}{\pi} V_s = 0.9 \times 230 = 207 \text{ V}$$

10. (c)

1-ϕ full wave rectifier



$$(V_0)_{avg} = \frac{2V_m}{\pi} = \frac{2 \times 40}{\pi} = \frac{80}{\pi} \text{V}$$

$$(V_0)_{rms} = \frac{V_m}{\sqrt{2}} = \frac{40}{\sqrt{2}} = 28.28 \text{ V}$$

11. (c)

In 120° conduction mode, during each step, only two thyristors conducts-one from the upper group and other from the lower group, whereas in 180° conduction mode, three thyristor conduct in each step.

12. (c)

In case of UJT, n-type base is lightly doped whereas p-type is heavily doped.

13. (d)

Power semiconductors in a current source inverter have to withstand reverse voltage, so devices such as GTOs, power transistors, power MOSFETs can not be used in a CSI.

14. (b)

Given, $\frac{V_{dc}}{2} = 96 \text{ V}$

$$V_{dc} = 192 \text{ V}$$

Output voltage of 1-ϕ, half bridge inverter

$$V_0(t) = \sum_{n=1,3,5}^{\infty} \frac{4 \cdot V_{dc}/2}{n\pi} \sin n\omega_0 t$$

$$= \sum_{n=1,3,5}^{\infty} \frac{2V_{dc}}{n\pi} \sin n\omega_0 t$$

Rms value of fundamental component of output voltage,

$$(V_{01})_{\text{rms}} = \frac{2V_{dc}}{\pi\sqrt{2}} = \frac{2 \times 192}{\sqrt{2} \times \pi} = 86.4 \text{ V}$$

15. (d)

$$V_r = 4 \text{ V}$$

$$V_c = 6 \text{ V}$$

Total pulse width = $2d$

$$\frac{2d}{N} = \left(1 - \frac{V_r}{V_c}\right)\frac{\pi}{N} \qquad \text{(Where } N \text{ is number of pulses per half cycle)}$$

$$2d = \left(1 - \frac{V_r}{V_C}\right)\pi$$

$$2d = \left(1 - \frac{4}{6}\right)180° = 60°$$

16. (b)

For single phase half wave diode rectifier, rms value of output current, is

$$I_{or} = \frac{V_m}{2R} = 50 \text{ A}$$

$$V_m = 100R \qquad \text{...(i)}$$

The charge is delivered by direct current I_0, which is given by

$$I_0 = \frac{V_m}{\pi R} = \frac{100R}{\pi R} = \frac{100}{\pi}\text{A} \qquad (V_m = 100R)$$

Also I_0 × time in hours = 200 Ah

Time required to deliver this charge

$$= \frac{200\pi}{100}\text{hrs} = 2\pi = 6.2832 \text{ hrs}$$

17. (a)

Let I and I_{sb} be the one cycle and sub-cycle surge current ratings of the SCR respectively. Then equating the energies involved in them, we get

$$I^2 T = I_{sb}^2 t$$

$$I^2 \times \frac{1}{100} = (3000)^2 \times \frac{1}{200}$$

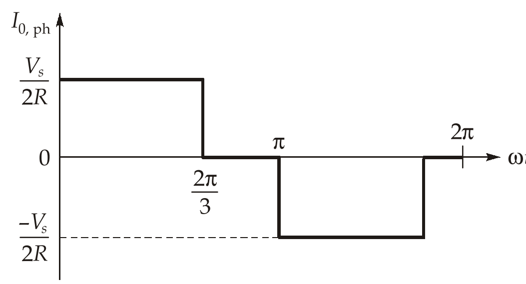
$$I = \frac{3000}{\sqrt{2}} \text{A}$$

$$I^2t \text{ rating} = I^2 \times \frac{1}{2f} = \left(\frac{3000}{\sqrt{2}}\right)^2 \times \frac{1}{2 \times 50}$$

$$= 45000 \text{ Amp}^2\text{-sec}$$

18. (d)

Wave form of load phase current in 120° conduction mode



Rms value of per phase load current $I_{0,\,rms}$ is

$$I_{ph\ rms} = \frac{V_s}{2R}\sqrt{\frac{\left(\frac{2\pi}{3}\right)}{\pi}} = \frac{450}{2 \times 10}\sqrt{\frac{2}{3}} = 18.37 \text{ A}$$

19. (b)

- On state voltage drop and the associated loss is more in a GTO.
- GTO has faster switching speed.

21. (b)

$$\text{String efficiency} = \frac{\text{String voltage}}{\text{No. of SCR's} \times \text{Voltage rating of each SCR}}$$

$$= \frac{3300}{6 \times 600} = \frac{3300}{3600} = 0.9166$$

$$\text{Derating factor (DRF)} = 1 - \text{String efficiency}$$

$$= 1 - 0.9166$$

$$= 0.083$$

22. (b)

Peak value of current through T_1

$$= \frac{V_S}{R_1} + \frac{2V_S}{R_2} = \frac{200}{10} + \frac{2 \times 200}{100} = 20 + 4 = 24 \text{ A}$$

Peak value of current through T_2

$$= \frac{V_S}{R_2} + \frac{2V_S}{R_1} = \frac{200}{100} + \frac{2 \times 200}{10} = 42 \text{ A}$$

23. (b)

Average power loss in power transistor

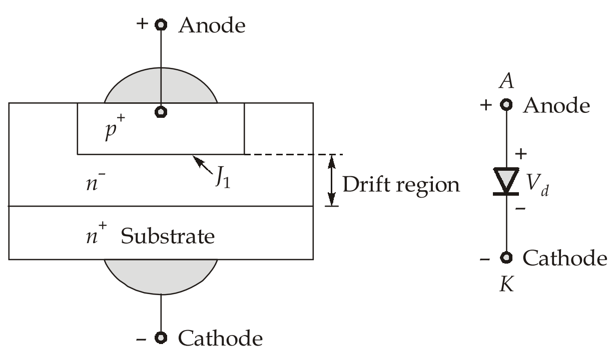
$$= \frac{V_{CC} \cdot I_{CS}}{6}(t_{ON} + t_{OFF}) \times f_{sw}$$

$$= \frac{220 \times 80}{6}(5.5 \times 10^{-6}) \times (2 \times 10^3)$$

$$= 32.267 \text{ W}$$

24. (c)

- **MOS-controlled thyristor :** An MCT is turned-on by negative voltage pulse at the gate with respect to the anode and is turned off by a positive voltage pulse.
- **Gate turnoff thyristor (GTO):** The GTO can be turned ON by a short pulse of gate current and can be turned OFF by a reverse gate pulse.
- **MOSFET:** MOSFET operation depends upon the flow of majority carries only, MOSFET is a unipolar device.
- **Power diode:** The practical realization and the resulting structure of power diode is shown in figure below. On this substrate, a lightly doped n^- layer is epitaxially grown. Now a heavily doped p^+ layer is diffused into n^- layer to form the anode of power diode.



25. (b)

$$\text{TUF} = \frac{P_{dc}}{\text{VA rating of transformer}}$$

$$= \frac{4}{\pi^2} V_m \cdot I_m \times \frac{2}{V_m \cdot I_m} = \frac{8}{\pi^2}$$

$$\text{TUF} = 0.8106$$

26. (b)

Ringing frequency ω_r in rad/sec, for series RLC circuit is

$$\omega_r = \sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2} = \text{damped frequency of oscillation } \omega_d$$

Load commutation is possible when load is underdamped

The condition for underdamping is that $\omega_d > 0$

$$\frac{1}{LC} - \left(\frac{R}{2L}\right)^2 > 0 \text{ and } R < \sqrt{\frac{4L}{C}}$$

$$R < \sqrt{\frac{4 \times 20 \times 10^{-6}}{40 \times 10^{-6}}}$$

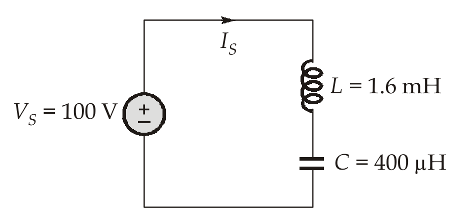
$$R < \sqrt{2}$$

$$R < 1.414\ \Omega$$

27. (c)

MOSFET is voltage controlled device and have higher input impedance.

28. (a)



Expression of current flowing through circuit

$$I_S = V_S\sqrt{\frac{C}{L}}\sin\omega_0 t$$

Maximum value of current,

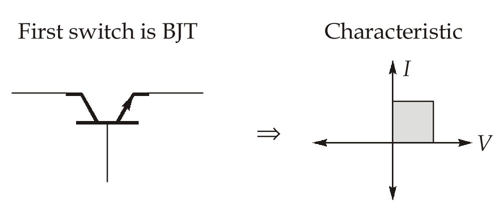
$$(I_S)_{max} = V_S\sqrt{\frac{C}{L}} = 100\sqrt{\frac{400 \times 10^{-6}}{1.6 \times 10^{-3}}}$$

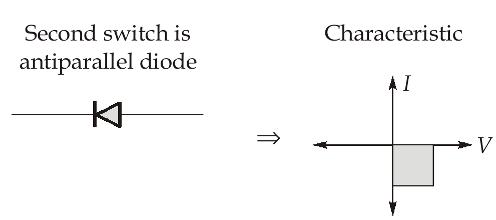
$$(I_S)_{max} = 50 \text{ A}$$

29. (a)

For the given configuration, the current flows in both direction (bidirectional). The switch has on state voltage drop. So option (a) is correct.

Alternate Solution:

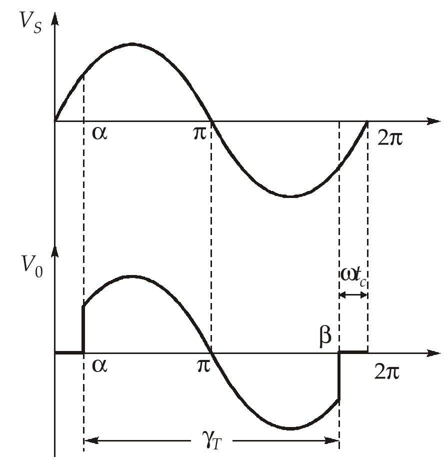




Both switches are parallely connected. So the parallel connection union of current characteristic is taken and intersection of voltage characteristics is taken.

30. (c)

Conduction angle of thyristor



$$\gamma_T = \beta - \alpha$$

and $\beta = 2\pi - \alpha$

$$\gamma_T = 2\pi - \alpha - \alpha$$
$$= 2(\pi - \alpha)$$
$$\gamma_T = 2(180° - 30°)$$
$$= 300°$$

and the value of ωt_c of thyristor

$$\omega t_c = 2\pi - \beta$$
$$= 2\pi - (2\pi - \alpha) \quad (\because \beta = 2\pi - \alpha)$$
$$= \alpha$$
$$\omega t_c = 30°$$

31. (d)

Value of input power factor for single phase full wave controlled rectifier when load current is constant

$$\cos\phi = \frac{2\sqrt{2}}{\pi}\cos\alpha$$
$$= 0.9 \times \cos 30°$$
$$\cos\phi = 0.78$$

32. (b)

Average value of switch current is Boost converter

$$(I_S)_{avg} = \alpha \cdot (I_L)_{avg} \qquad ...(i)$$

where $(I_L)_{avg}$: average value of inductor current

For boost converter

$$(I_L)_{avg} = \frac{I_0}{1-\alpha} = \frac{20}{1-0.75} = \frac{20}{0.25} = 80 \text{ Amp}$$

From equation (i),

$$(I_S)_{avg} = \alpha \cdot (I_L)_{avg} = 0.75 \times 80$$
$$(I_S)_{avg} = 60 \text{ Amp}$$

33. (c)

$$\text{Ripple factor} = \sqrt{(\text{Form factor})^2 - 1} \qquad ...(i)$$

$$\text{Form factor} = \frac{\text{Rms output voltage}}{\text{Average output voltage}}$$

$$= \frac{\sqrt{\alpha} \cdot V_S}{\alpha \cdot V_S} \qquad (V_S : \text{supply voltage})$$

$$= \frac{1}{\sqrt{\alpha}}$$

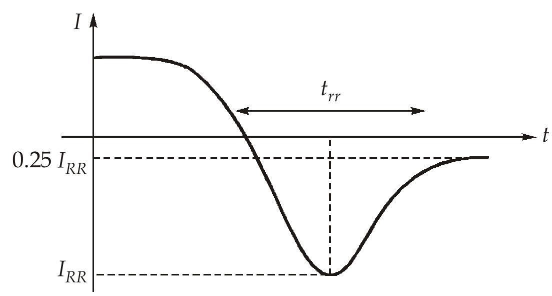
From equation (i),

$$\text{Ripple factor} = \sqrt{\left(\frac{1}{\sqrt{\alpha}}\right)^2 - 1} = \sqrt{\frac{1}{\alpha} - 1}$$

$$= \sqrt{\frac{1}{0.25} - 1} = \sqrt{4-1} = \sqrt{3}$$

Ripple factor = 1.732

34. (a)



Stored charged,

$$Q = \frac{1}{2} \times t_{rr} \times I_{RR} \qquad \text{...(i)}$$

$$\frac{di}{dt} = \frac{I_{RR}}{t_{rr}}$$

$$I_{RR} = t_{rr} \cdot \frac{di}{dt} \qquad \text{...(ii)}$$

Equation (ii) in (i),

$$Q = \frac{1}{2} t_{rr}^2 \times \frac{di}{dt}$$

$$135 \times 10^{-6} = \frac{1}{2} \times t_{rr}^2 \times \frac{30}{10^{-6}}$$

$$t_{rr} = 3 \ \mu\text{sec}$$

35. (c)

Frequency modulation ratio,

$$m_f = \frac{f_{\text{carrier}}}{f_{\text{reference}}}$$

Amplitude modulation ratio,

$$m_a = \frac{V_{m,\text{reference}}}{V_{m,\text{carrier}}}$$

36. (d)

All statements are correct.

37. (c)

UJT does not have the ability to amplify but it has the ability to control a large ac power with a small signal. It exihibits a negative resistance characteristics and so it can be employed as an oscillator.

39. (c)

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

Section B : Power Systems-1

41. (c)

For large nuclear power plants closed loop coolant system is used, which means the coolant passing through the reactor is recirculated and is not passed through the turbines and discharged with this, the discharge of the radioactive material into the atmosphere or rivers is avoided, thereby providing safety to the people residing in near by areas.

42. (d)

All statements are correct.

43. (c)

$$\text{Daily load factor} = \frac{\text{Energy produced daily}}{24\text{ hrs} \times \text{Max. demand}}$$

$$\text{Maximum demand} = \frac{360\text{ MWh}}{24 \times 0.6} = 25\text{ MW}$$

44. (b)

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega L}} = \sqrt{\frac{R}{G}\left(\frac{1 + j\omega L/R}{1 + j\omega C/G}\right)}$$

For distortion less line, $\frac{L}{R} = \frac{C}{G}$

$$Z_0 = \sqrt{\frac{R}{G}}$$

Since, $\frac{R}{G} = \frac{L}{C}$

$$Z_0 = \sqrt{\frac{L}{C}}$$

So, characteristics impedance of distortion less line

$$Z_0 = \sqrt{\frac{L}{C}} = 60\,\Omega = \sqrt{\frac{L}{0.1\times10^{-9}}} = 60$$

$$L = 3600 \times 0.1 \times 10^{-9}$$
$$= 0.36\ \mu\text{H/m}$$

45. (c)

For bundled conductors:

$$L_{ph} = 2\times10^{-7}\ln\left(\frac{D_m}{D_s}\right)$$

$$C_{ph} = \frac{2\pi\varepsilon_0\varepsilon_r}{\ln\left(\frac{D_m}{D_s}\right)}$$

By using bundled conductor D_s increased, so L_{ph} is decreased and C_{ph} is increased.

46. (c)

Series capacitor is not the method of voltage control in power system. In fact series capacitor is used to improve the steady state stability of the system.

47. (d)

Power loss occurs in the dielectric of a cable due to three main causes.

- conductivity of insulation.
- dielectric hysteresis or dielectric absorption.
- ionization or corona.

48. (d)

All statements are correct.

49. (a)

ABCD constants of transmission lines:

1. Short line,

$$A = 1, \qquad B = Z,$$
$$C = 0, \qquad D = A$$

2. Medium line (nominal *T* representation)

$$A = 1+\frac{ZY}{2}, \qquad B = Z\left(1+\frac{YZ}{4}\right),$$
$$C = Y, \qquad D = A$$

3. Medium line (nominal π representation),

$$A = 1 + \frac{ZY}{2}, \qquad B = Z,$$

$$C = Y\left(1 + \frac{ZY}{4}\right), \qquad D = A$$

50. (c)

Given, $V_S = 120$ kV, $V_r = 110$ kV

$A = 0.96$, $\alpha = 10°$

$B = 100$, $\beta = 70°$

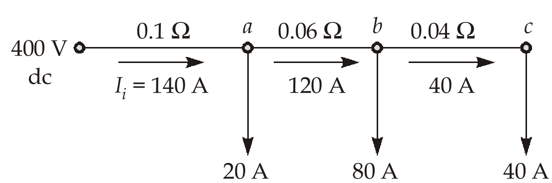
Maximum power transmitted is given by

$$P_{max} = \frac{V_s \cdot V_r}{B} - \frac{AV_r^2}{B}\cos(\beta - \alpha)$$

$$= \frac{110 \times 120}{100} - \frac{0.96 \times 110 \times 110}{100}\cos 60° = 73.92 \text{ MW}$$

51. (b)

For given dc system, SLD can redrawn,



Minimum potential will be at point C,

$$V_{min} = V_{dc} - I_1R_1 - I_2R_2 - I_3R_3$$

$$= 400 - (140 \times 0.1) - (120 \times 0.06) - (0.04 \times 40)$$

$$= 400 - 14 - 7.2 - 1.6 = 377.2 \text{ V}$$

52. (d)

Because of converter control and commutation process, the reactive power requirement varies as sine of firing angle.

53. (a)

In π model, the shunt admittance at each end of the line is $\frac{Y}{2}$

$$\frac{Y}{2} = j\omega\frac{C}{2} = j(2\pi \times 50) \times \frac{0.03}{\pi} \times \frac{1}{2} \times 10^{-6} \times 100$$

$$= 150 \times 10^{-6}\angle 90° \ ℧$$

54. (d)

Zero regulation of a transmission line occurs at a leading power factor,

When, $\phi = 45°$

Hence $\cos\phi = 0.707$ leading.

55. (d)

For lossless transmission line,

$$R = 0$$

and $G = 0$

Section C : Electrical Machines-2

56. (a)

Load torque is constant,

$$T \propto \phi I_a = \text{constant}$$

Here, $\phi = \text{constant}$

So, $I_a = \text{constant}$

So, $E_{b1} = V_t - I_a R_a$ ...(i)

if R_{ext} is added

$$E_{b2} = V_t - I_a(R_a + R_{ext}) \quad \text{...(ii)}$$

Here, $E_{b2} < E_{b1}$ so speed will decrease (since $E_b \propto N$)

57. (a)

The back emf, $E_b = V_t - I_a R_a$

$$= 240 - 0.5 \times 25 = 227.5 \text{ Volt}$$

So, Load torque, $T = \dfrac{E_b I_a}{N \times \dfrac{2\pi}{60}} = \dfrac{227.5 \times 25}{1200 \times \dfrac{2\pi}{60}} = 45.26$ N-m

Load torque = 45.26 N-m

58. (b)

The torque for DC series motor,

$$T \propto I_a^2$$

The torque, $\dfrac{T_2}{T_1} = \left(\dfrac{I_{a2}}{I_{a1}}\right)^2$

$$\frac{T_2}{21} = \left(\frac{6}{5}\right)^2$$

$$T_2 = 21\left(\frac{6}{5}\right)^2 = 30.24 \text{ N-m}$$

59. (c)

The undesirable phenomenon of hunting, can be guarded against in three ways:

- by using a flywheel
- by designing the synchronous machine with suitable synchronizing power coefficient.
- by the employment of damper winding.

60. (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.

61. (b)

It can not reduce the field current below the rated value this means that the field flux can not be weakend enough to increase the speed of the motor above rated speed.

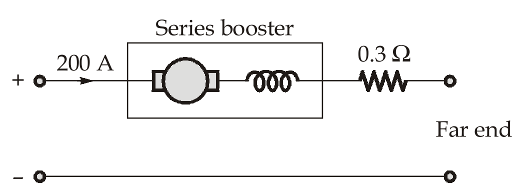
62. (a)

Pull in torque refers to the ability to pull into synchronism when changing from induction to synchronous motor operation. Pull out toque pertains to the ability of the motor to remain in synchronism under rated load conditions.

63. (c)

- Armature voltage control and field current control methods used very below base speed and above base speed respectively.
- Using Rheostatic control method, losses increases in the motor consequentely efficiency of motor reduced.
- Diverter resistor is used to control the speed of series motor.

64. (a)



$$\text{Load current} = 200 \text{ A}$$

$$\text{Voltage rise due to booster} = 50 \text{ V}$$

$$\text{Voltage drop in feeder} = I_L \times \text{feeder resistance}$$

$$= 200 \times 0.3 = 60 \text{ V}$$

Voltage difference between station bus bar and far end of the feeder

$$= 60 - 50 = 10 \text{ V}$$

65. (b)

For an over compounded dc generator,

percentage of compounding = voltage regulation

$$\% \ E_R = \left(\frac{E_a - V}{V}\right) \times 100 = \frac{I_a R_a}{V} \times 100$$

$$= \frac{800 \times 0.01}{600} \times 100 = 1.33\%$$

66. (c)

Compensating windings are embedded in slots in the pole faces and nullifies the effect of armature reaction and avoid distortion of flux distribution under the pole faces which may lead to poor commutation and flashover otherwise.

67. (d)

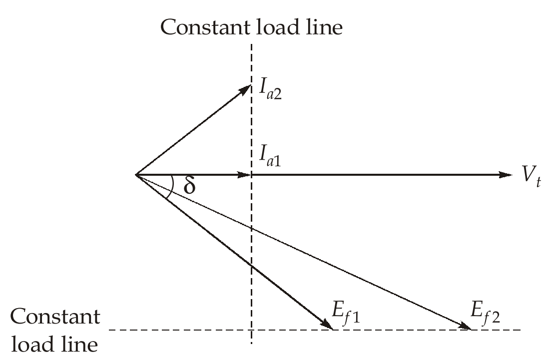
All statements are correct.

68. (d)

At starting of dc shunt motor, back emf is zero so to reduce armature current R_a should be maximum and flux be high so keep R_f minimum.

69. (d)

The power factor will decrease if excitation will be increased.



70. (b)

$$E_1 = V - I_{a1} R_{a1} = 220 - 20 \times 0.1 = 218 \text{ V}$$

$$E_2 = \frac{N_2 \phi_2}{N_1 \phi_1} E_1 \qquad [\because V = \text{constant}, \phi = \text{constant}]$$

Since,
$$I_{sh} = \frac{V}{R_{sh}}$$

the shunt field current I_{sh} remains constant and therefore,

$$\phi_2 = \phi_1$$

$$E_2 = \frac{N_2}{N_1} E_1 = \frac{520}{800} \times 218 = 141.7 \text{ V}$$

If R_A is the additional resistance inserted in the armature circuit,

$$E_2 = V - I_{a2}(R_{a1} + R_A)$$
$$141.7 = 220 - 20(0.1 + R_A)$$
$$R_A = 3.815\ \Omega$$

71. (c)

Equalizer rings in a lap wound DC machine is used to prevent the flow of circulating current through brushes, armature winding and brushes. Also equalizer rings connect points behind lap windings which are 360° (electrical) apart.

72. (b)

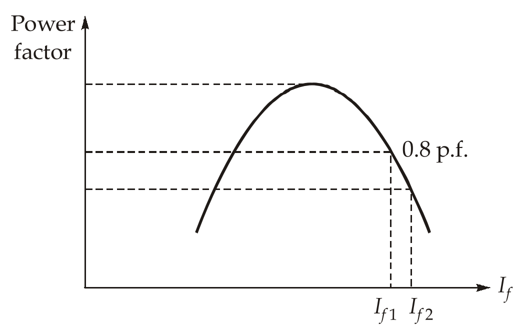
In order to reduce the saturation in the interpoles in dc machines have a tapering shape.

73. (b)

When the generator supplies a load of leading power the armature reaction is partly magnetizing and partly cross magnetizing.

74. (b)

$\because$ Inverted V curve is the curve between power factor and field current,



$\therefore$ Power factor reduces. Thus if power factor angle will increase.

75. (b)

Both statements are correct but statement-II is not correct explanation of statement-I.

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