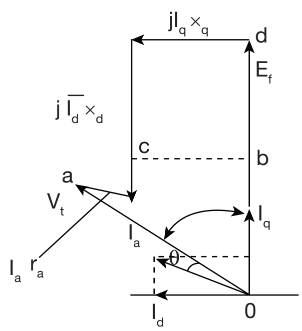
Electrical Machines Test I

Number of Questions: 35 **Section Marks: 90**

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. The phasor diagram representation of salient pole synchronous motor as shown in the figure. Then the synchronous motor operated is in ______ condition.



(A) Over excitation (B) Under excitation
(C) Normal excitation (D) No excitation

2. In which of the following methods is the regulation is more than the actual regulation value.
(A) EMF method
(B) Ampere – turn method
(C) ZPF method
(D) None of the above

3. The Buchholz relay is generally placed
(A) Inside the transformers tank
(B) Near to bushings of the transformer
(C) Between transformer tank and conservator
(D) None of the above

4. A 500V, 10 pole DC Shunt motor has rated armature current of 220 A with simplex wave winding. Find the current per path of the armature if the armature resistance is 5Ω.
(A) 20A (B) 100A
(C) 40A (D) 110A

5. A transformer has copper loss of 3% and reactance drop of 4% when tested at full load. The full – load regulation at U. P. F is
(A) 3% (B) 5%
(C) 4% (D) 8%

6. Which of the following torque has maximum value.
(A) Locked Rotor torque
(B) Break down torque
(C) Pull – up torque
(D) Full load torque

7. The conditions to be satisfied for proper synchronization of alternators with the bus bar are.
(1) The terminal voltages are same
(2) The frequencies are same
(3) Phase sequences are same
(A) 1 and 2 (B) 2 and 3
(C) 1 and 3 (D) 1, 2 and 3

8. The highest possible speed of 60 Hz alternator is
(A) 3600 rpm (B) 1500 rpm
(C) 3000 rpm (D) Insufficient data

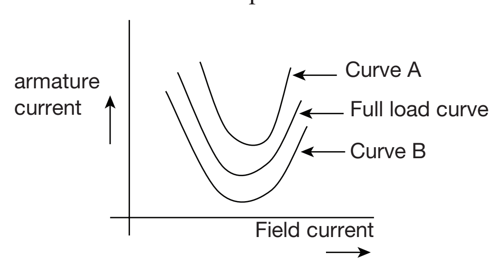
9. Which of the following methods are suitable for reversing the direction of rotation of a D. C. motor
(1) By reversing the current direction in the armature
(2) By reversing the field current direction
(3) By reversing Both armature and field current direction.
(A) 1 and 2 (B) 1 and 3
(C) 2 and 3 (D) 1, 2, and 3

10. A long shunt generator running at 1,000 rpm. Supplies 30 kW at a terminal voltage of 200 V. the resistance of armature, shunt field and series field are 0.06, 120 and 0.08 ohms respectively. The total copper loss of the machine is
(A) 3554 watts (B) 1380 watts
(C) 1714 watts (D) 2174 watts

11. The stepping angle for a 3 – stack; 18 – tooth variable reluctance motor is
(A) 7.56° (B) 6.67°
(C) 1.56° (D) 4.57°

12. A 230 V, 50 Hz, 6 – pole, 1 – phase, induction motor takes input current of 3 A and output power is 500 watts. calculate the efficiency of motor at 0.8 pf
(A) 85.42% (B) 88.96%
(C) 90.57% (D) Insufficient data

13. The V – Curves of synchronous motor as shown in the figure. In that curve – B Represents.



(A) Half load curve (B) $1\frac{1}{4}$ Full load curve
(C) $1\frac{1}{2}$ Full load curve (D) $1\frac{3}{2}$ Full load curve

14. A Δ/Y connected 3 – phase transformer has a voltage ratio of (Δ) 22 kV/330 kV(Y) a (line to line). The transformer is feeding 500 MW and 200 MVAR to the grid (330 kV) The VA rating of the transformer is

(A) 500 MVA (B) 700 MVA
(C) 200 MVA (D) 538 MVA

15. A 3 – ϕ 400 V, 50 Hz, 6 pole induction motor has a stator winding of 36 slots and rotates at a speed of 900 rpm. The fifth harmonic belt factor of a stator winding is
(A) 0.965 (B) 0.707
(C) 0.854 (D) 0.258

16. A five alternators are working in parallel with their terminal voltage equal to the rated value. In that one of the machine, which has a synchronous reactance of 40% and resistance 2% delivers a power output in kW equal to 60% of its rated KVA. If the emf of this unit equals 1.2 times the terminal voltage. The power factor of the machine is
(A) 0.5 lagging (B) 0.643 lagging
(C) 0.8 lagging (D) Unity

17. A dc series motor running a fan at 1500 rpm takes 25 A from 250 V. the armature plus field resistance is 0.8Ω if an additional resistance of 5Ω is inserted in series with the armature circuit. Then find the corresponding speed of the machine.
(A) 1000 rpm (B) 1160 rpm
(C) 1500 rpm (D) 1480 rpm

18. A 20 kW, 400 V, 3 – phase, 4 – pole, 50 Hz delta connected squirrel cage induction motor gave the following data. For blocked rotor test: 220 V, 25A, 10 kW Calculate the starting torque at a rated voltage and frequency for a 500 watts of stator core loss at rated voltage and frequency. [The d. c. resistance measured between any two stator terminals is 0.8Ω]
(A) 210 Nm (B) 200 Nm
(C) 150 Nm (D) 174.16 Nm

19. A 3–phase 11 kV, 20 MW, star connected synchronous generator has a synchronousimpedance of 0.6 + J8.ohms per phase, if the excitation is such that the open circuit voltage is 15 kV. Calculate the power factor at the maximum power output of the machine.
(A) 0.79 (B) 0.64
(C) 0.82 (D) 0.54

20. A single phase transformer with a ratio of 400/100 V takes a no load current of 5A at 0.3 power factor lagging. If the secondary supplies a current of 100 A at a p. f 0.6 lagging. The current taken by the primary is
(A) 25 A (B) 29.76 A
(C) 30.94 A (D) 27.84 A

21. A 3–phase, star connected, 50 Hz synchronous generator has direct – axis synchronous reactance of 0.8P.U and quadrature – axis synchronous reactance of 0.5P.U. the generator delivers rated KVA at rated voltage Calculate the voltage regulation at 0.8p. f. lagging when Resistive drop at full load is 0.02P.U
(A) 31% (B) 42%
(C) 38% (D) 61%

22. A 3–phase, 15 kV, 20 MW, Y – Connected synchronous generator has synchronous impedance of 0.6 + J5.0 ohm per phase. Find the maximum power output of generator for open circuit voltage of 18 KV
(A) 54 MW (B) 18 MW
(C) 21.6 MW (D) 64.8 MW

23. A 50 KVA, 1–phase transformer 2000 volts to 200 volts has primary resistance of 1.2Ω and a secondary resistance of 0.02Ω. Calculate the full load efficiency at 0.85 p.f if the iron loss of the transformer is 90% of the full load loss.
(A) 95.50% (B) 95.93%
(C) 97.32% (D) 91.79%

24. A 500 KVA transformer has an efficiency of 95% at full load if the maximum efficiency occurs at two third of full load. Calculate the efficiency at three quarters of full load and 0.8 p.f at all loads.
(A) 94.82% (B) 95.34%
(C) 96.72% (D) 97.82%

25. A 3 – phase 400 V, 1500 rpm slip ring induction motor is operating with 4% slip and taking a stator current of 50 A. speed of the motor is reduced at constant torque to 800 rpm. Using stator voltage control calculate the new value of stator current.
(A) 123.58A (B) 171.38A
(C) 173.54A (D) 23.5A

26. A 200 watts split phase motor draws its starting winding current of 5 A lagging the supply voltage by 20° electrical and its running winding current is 8 A lagging by 60° electrical. The power factor of the motor at steady state condition is
(A) 0.173 lagging (B) 0.70 lagging
(C) 0.766 lagging (D) 0.45 lagging

27. A 20 MVA, 10 kV, 4 – pole, 50 Hz alternator is connected to infinite bus – bars. The short circuit current is 3 times the normal full load current and the moment of inertia of the rotating system is 20,000 kg – m^2. The period of oscillation of alternator is
(A) 1.01 sec (B) 1.01 m sec
(C) 4.47 m sec (D) 1.01 μsec

28. The self and mutual inductance of a two winding transformer are
$L_1 = 5$ mH, $L_2 = 8$ mH, $M_{12} = M_{21} = 2$mH
The transformer is connected to 100 volts, 50 Hz supply. Calculate the primary winding current when the transformer secondary is connected to 0.4mH load.
(A) 70.37 A (B) 35.18 A
(C) 140.74 A (D) 17.59 A

29. In a Hopkinson's test on two 200 V, 200 kW generators, the circulating current is equal to the full load current and in addition 100 A are taken from the supply. The efficiency of the machine is
(A) 91.34% (B) 95.34%
(C) 98.35% (D) 90.12%

30. A 5 kW, 200 V, 50 Hz 4 – pole 3 – ϕ star connected induction motor has the following data
No load: Line voltage 200 V, line current 5A; total input 300 W
Blocked rotor: Line voltage 100 V, line current 25 A, total input 1800 W calculate the blocked rotor input when the normal voltage is applied.
(A) 1800 W (B) 5600 W
(C) 2100 W (D) 3600 W

31. A 300 W, single phase 50 Hz, 350 V universal motor runs at 1500 rpm and takes a current 2 A when connected to 350 V AC Supply. Calculate the back emf of the motor. Assume R_a = 25Ω and L_a = 0.5H
(A) 0 V (B) 104 V
(C) 110 V (D) 100 V

32 and 33 Common data Question:
A 50 kW, 3-phase slip – ring induction motor of negligible stator impedance runs at a speed of 0.95 times synchronous speed at rated torque. The slip at maximum torque is 5 times the full load value. [If the rotor resistance of the motor is increased by 6 times]

32. The rotor copper loss at rated torque
(A) 36.84 kW (B) 15.78 kW
(C) 18.42 kW (D) 11.052 kW

33. The speed corresponding to maximum torque
(A) $1.5N_s$ (B) $0.5N_s$
(C) $-1.5N_s$ (D) $-0.5N_s$

Linked answer questions 34 and 35:
A 250 V d. c series motor runs at 600 rpm. When taking a line current of 30 A. the resistance of the armature is 0.4Ω and that of the series field 0.3Ω if the motor develops, the same torque when armature divertor of 20Ω used [Assume a straight line magnetization curve]

34. The armature current of motor is
(A) 17.08 A (B) 5.94 A
(C) 8.04 A (D) 2.97 A

35. The speed of the motor is
(A) 600 rpm (B) 1200 rpm
(C) 1152 rpm (D) 1054 rpm

Answer Keys

1. A	**2.** B	**3.** C	**4.** D	**5.** A	**6.** B	**7.** D	**8.** A	**9.** A	**10.** A
11. B	**12.** C	**13.** A	**14.** D	**15.** D	**16.** B	**17.** B	**18.** D	**19.** A	**20.** B
21. D	**22.** A	**23.** D	**24.** B	**25.** B	**26.** B	**27.** A	**28.** A	**29.** B	**30.** B
31. B	**32.** B	**33.** D	**34.** B	**35.** C					

Hints and Explanations

1. Form the given phasor diagram the salient pole synchronous motor operated in leading power factor that means the motor operated in over excited condition.
Choice (A)

2. Choice (B)

3. The relay arranged in the pipe – line between the transformers tank and separate oil conservator.
Choice (C)

4. Rated armature current I_a = 220 A
Number of poles P = 10
With simplex wave winding
Number of parallel paths A = 2

Current per path = $I_C = \dfrac{I_a}{A} = \dfrac{220}{2} = 110$ A

Choice (D)

5. Given data
P. U. resistance = 0.03
P. U. reactance = 0.04
Voltage regulation at unity p. f full load = 3%
Choice (A)

6. By observing the Torque – speed characteristic of induction motor, Breakdown torque has maximum value. Choice (B)

7. Choice (D)

8. Speed = $\dfrac{120f}{P}$

$= \dfrac{120 \times 60}{2} = 3600$ rpm Choice (A)

9. The rotation of D. C. motor is reversed either By reversing the field current (or) armature current direction.
Choice (A)

10. Power output = 30,000 watts
Terminal voltage = 200 volts

Output current = $\dfrac{Power\ output}{V} = \dfrac{30000}{200} = 150$ A

Shunt field current $i_{sh} = \dfrac{V}{R_{sh}} = \dfrac{200}{120} = 1.67$ A

Armature current = 150 + 1.67 = 151.67A
Armature copper loss = $(151.67)^2 \times 0.06$ = – 1380.22 watts
Series field copper loss = $(151.67)^2 \times 0.08$= 1840.30 watts
Shunt field copper loss = 200 × 1.67 = 334watts
Total copper loss = 3554.52 watts
Choice (A)

11. Number of stacks (or) phases $n = 3$
Number of teeth (or) poles $P = 18$
Stepping angle $\alpha = \dfrac{360}{\eta p} = \dfrac{360}{3\times 18} = 6.67°$ Choice (B)

12. Power output = 500 watts
Power input $P_n = 230 \times 3 \times 0.8 = 552$ watts
Motor efficiency $= \dfrac{P_0}{P_{in}} = \dfrac{500}{552}\times 100 = 90.57\%$
Choice (C)

13. As observing the V – Curves of synchronous motor the curve B is below the full load curve. So. Only option (A) load is below the full load. Choice (A)

14. Load MVA $\bar{S} = 500 + J\,200$
$= 538$ MVA Choice (D)

15. Belt factor $K_{dn} = \dfrac{\sin\dfrac{nmr}{2}}{m\sin\dfrac{n\gamma}{2}}$

Fifth harmonic $n = 5$

Slots per pole per phase $= \dfrac{36}{3\times 6} = 2$

Slot angulers pitch $\gamma = \dfrac{P\times 180}{S} = \dfrac{6\times 180}{36} = 30$

$$K_{d5} = \frac{\sin\left(\dfrac{5\times 2\times 30}{2}\right)}{2\sin\left(\dfrac{5\times 30}{2}\right)} = \frac{\sin 150}{2\sin 75} = 0.258$$ Choice (D)

16. given $\dfrac{I_a\, r_a}{V_t} = 2\%$ & $\dfrac{I_a\, X_s}{V_t} = 40\%$

$E_f^2 = (V_t\cos\theta + I_a r_a)^2 + (V_t\sin\theta + I_a X_s)^2$

$$= V_t^2\left[\left(\cos\theta + \frac{I_a r_a}{V_t}\right)^2 + \left(\sin\theta + \frac{I_a\ X_s}{V_t}\right)^2\right]$$

$I_a = 0.6 I_{rated}$
$(1.2V_t)^2 = V_t^2\,[(\cos\theta + 0.02 \times 0.6)^2 + (\sin\theta + 0.4 \times 0.6)^2]$
$1.44 = 1.0577 + 0.024\cos\theta + 0.48\sin\theta$
$0.3823 = 0.024\cos\theta + 0.48\sin\theta$
$\times\ 0.48\sin(\theta + 2.862) = 0.3823$
$\times\ \sin(\theta + 2.862) = 0.7964$
$\theta + 2.862 = 52.79$
$\theta = 49.93$
Power factor = $\cos\theta = 0.643$ lagging Choice (B)

17. $E_{a1} = 250 - 25 - 0.8 = 230$V

$$E_{a2} = 250 - \frac{n_2}{60}(5 + 0.8)$$

$$= 250 - \frac{n_2}{60}\times 5.8$$

$$\frac{E_{a2}}{E_{a1}} = \frac{N_2\ \varphi_2}{N_1\ \varphi_1} \Rightarrow \frac{250 - 0.097n_2}{230} = \frac{n_2\cdot\dfrac{n_2}{60}}{(1500)(25)}$$

$\Rightarrow \dfrac{230}{60}n_2^2 - (250)(1500)(25) +$
$(0.097)(1500)(25)\ n_2 = 0$
$\Rightarrow\ 3.83n_2^2 + 3637.5n_2 + 9{,}37{,}5000 = 0$
$n_2 = 1160.14$ rpm Choice (B)

18. With the stator winding in delta, the resistance per phase R is obtained from the relation.

$$\frac{R\times 2R}{3R} = 0.8 \Rightarrow R = \frac{3}{2}\times 0.8 = 1.2\Omega$$

effective resistance per phase = 1.2 × 1.2 = 1.44
Power input at rated voltage during blocked rotor test

$$= 10\times\left(\frac{400}{220}\right)^2 = 33.05 \text{ KW}$$

Stator current at rated voltage during blocked rotor test

$$= 33.05\times\frac{400}{220} = 60.06 \text{ A}$$

Air gap power at rotated voltage and frequency

$$P_g = 33057 - 3\left(\frac{60.06}{\sqrt{3}}\right)^2\times 1.44 - 500 = 27{,}357.43 \text{ W}$$

Synchronous speed =

$$W_S = \frac{4\pi f}{P} = \frac{4\pi\times 50}{4} = 50\pi\text{rad/sec}$$

Starting torque $= \dfrac{27{,}357}{50\pi} = 174.16$N – m

Choice (D)

19. Current corresponding to maximum output

$$I_{\max} = \frac{\sqrt{V^2 + E^2 - 2VE\cos\theta}}{Z_s}$$

$$= \frac{\sqrt{\left(\dfrac{11000}{\sqrt{3}}\right)^2 + \left(\dfrac{15000}{\sqrt{3}}\right)^2 - 2\left(\dfrac{11000}{\sqrt{3}}\times\dfrac{15000}{\sqrt{3}}\right)\cos(85.71)}}{8.02}$$

< 1290.41 A

Power factor $= \dfrac{P_{\max}}{v\, I_{\max}}$

Maximum power output/phase $= \dfrac{EV}{Z_s} - \dfrac{V^2}{Z_s}\cos\theta$

$$= \frac{\dfrac{15000}{\sqrt{3}}\times\dfrac{11000}{\sqrt{3}}}{8.02} - \frac{\left(\dfrac{11000}{\sqrt{3}}\right)^2}{8.02}\cos 85.71$$

= 6.48 MW = 6,48,1655

$$\cos\phi = \frac{6{,}48{,}1655}{\dfrac{11000}{\sqrt{3}}\times 1290.41} = 0.79$$ Choice (A)

20. $\cos\phi_2 = 0.6 \Rightarrow \phi_2 = \cos^{-1}(0.6) = 53.13°$
$\cos\phi_0 = 0.3 \Rightarrow \phi_0 = \cos^{-1}(0.3) = 72.54°$

$$K = \frac{100}{400} = \frac{1}{4}$$

$$I^1{}_2 = KI_2 = 100 \times \frac{1}{4} = 25 \text{ A}$$

$I_0 = 5$ A
Angle between I_0 and $I_2^1 = 72.54 - 53.13 = 19.41°$

$$I_1 = \sqrt{5^2 + 25^2 + 2\times 25\times 5\times \cos 19.41°}$$
$= 29.76$ A Choice (B)

21. $I_a = 1$P.U, $V = 1$ $P.U$ $X_d = 0.8P.U$
$X_q = 0.5$P.U; $R_a = 0.02P.U$

$$\tan\Psi = \frac{V\sin\varphi + I_aX_q}{V\cos\varphi + I_aR_a} = \frac{1\times 0.6 + 1\times 0.5}{1\times 0.8 + 1\times 0.02} = 1.341$$

$\Psi = 53.29°$
$\delta = \Psi - \phi = 53.29 - 36.86° = 16.43°$
$I_d = I_a \sin\Psi = 1 \times \sin(53.29) = 0.80$ A
$I_q = I_a \cos\Psi = 1 \times \cos(53.29) = 0.59$ A
$E_0 = V\cos\delta + I_qR_a + I_dX_d = 1.61$V

$$\% \text{ regulation} = \frac{1.61 - 1}{1}\times 100 = 61\%$$ Choice (D)

22. P_{max} per phase $= \dfrac{EV}{X_s}$

Where V is the terminal voltage (or bus – bar. Voltage on general) and E is the emf of the machine

$$P_{max} = \frac{\left(\frac{15,000}{\sqrt{3}}\right)\left(\frac{18,000}{\sqrt{3}}\right)}{5} = 18,000 \text{ KW/phase}$$

$P_{max} = 3 \times 18,000 = 54,000$KW $= 54$ MW Choice (A)

23. $R_{02} = R_2 + KR_1$

$$= 0.02 + \frac{1.2}{100} = 0.032\Omega$$

$$\text{Full load current} = \frac{50,000}{200} = 250\text{A}$$

Full load copper loss $= I^2{}_2\, R_{02} = 250^2 \times 0.032$
$= 2000$ watts
Iron loss $= 0.9 \times 2000 = 1800$ watts
Total loss $= 1800 + 2000 = 3800$ watts
Full load output $= 50 \times 0.85 = 42.5$ kW $= 42,500$ watts

$$\text{Full load } \eta = \frac{42,500}{42500 + 3800} = 91.79\%$$ Choice (D)

24. Full load output at $0.8p.f = 500 \times 0.8 = 400$ kW
Full load efficiency $\eta = 95\%$ (or) 0.95

$$\text{Full load input} = \frac{Output}{\eta} = \frac{400}{0.95} = 421.05 \text{ kW}$$

Total losses on full load $= Pi + Pc =$ Input – Output
$= 421.05 - 400 = 21.05$kW ——(1)

Maximum efficiency occurs at two third of full load

$$\left(\frac{2}{3}\right)^2 P_C = P_i \Rightarrow \frac{4}{9}P_c = P_i \quad \text{——(2)}$$

From (1) and (2) $P_c + \dfrac{4}{9}P_c = 21.05$

$$\frac{13}{9}P_c = 21.05$$

Copper loss at Full load is $P_c = 14.57$ kW

$$\text{Iron loss } Pi = \frac{4}{9}\times 14.57 = 6.47 \text{ kW}$$

At three quarter of full load and 0.8p.f

$$\text{Output} = \frac{3}{4}\times 500 \times 0.8 = 300\text{kW}$$

$$\text{Total losses} = 6.47 + \left(\frac{3}{4}\right)^2 \times 14.57 = 14.66\text{kW}$$

$$\text{Efficiency } \eta = \frac{\text{Output}}{\text{Input}} = \frac{300}{300 + 14.66} = 0.9534$$
$= 95.34\%$ Choice (B)

25. Supply voltage $V = 400$ V
Slip $S = 0.04$
Stator current $I_1 = 50$ A
Synchronous speed = 1500rpm
Reduced speed $N = 800$ rpm

$$\text{Slip} = \frac{1500 - 800}{1500} = \frac{700}{1500} = 0.47$$

Torque developed $T \,\alpha\, SV^2$

$$V \alpha \sqrt{\frac{1}{S}} \Rightarrow V^1 = V\sqrt{\frac{S}{S^1}}$$

$$= 400\sqrt{\frac{0.04}{0.47}} = 116.69 \text{ V}$$

Stator current $I_1 \,\alpha$ SV

$$I_1{}^1 = I^1 \times \frac{S^1V^1}{SV} = \frac{50\times 0.47\times 116.69}{0.04\times 400}$$

$I_1{}^1 = 171.38$ A Choice (B)

26. Starting winding current $i_S = 5\angle -20$A
Running winding current $I_m = 8\angle -60$A
Total current $I_L = I_S + I_M$
$= 5\angle -20 + 8\angle -60$
$= 12.25\angle -44.80$
Power factor cos (–44.80) = 0.70 lagging Choice (B)

27. Moment of inertia of the rotating system $J = 20,000$ kg – m^2.

$$\text{Phase voltage } E = \frac{10,000}{\sqrt{3}} = 5773.50 \text{ volts}$$

$F = 50$ Hz

$$\text{Synchronous speed } N_s = \frac{2f}{P} = \frac{2\times 50}{4} = 25 \text{ rps}$$

Full load current $I = \dfrac{20,000 \times 1000}{\sqrt{3} \times 19,000} = \dfrac{2000}{\sqrt{3}}$ A

Short circuit current $I_{SC} = 3I = \dfrac{6000}{\sqrt{3}}$

Time period of oscillation $T = 9.1 n_s \sqrt{\dfrac{J}{EI_s f}}$

$= 9.1 \times 25 \sqrt{\dfrac{20,000}{\dfrac{10,000}{\sqrt{3}} \times \dfrac{6000}{\sqrt{3}} \times 50}} = 1.01\text{sec}$ Choice (A)

28. Consider all the given parameters are refered to primary
$a = 1$, $L_1 - aM = 5 - 2 = 3$mH
$aM = 2$mH
$a^2L_2 - aM = 8 - 2 = 6$mH
load inductance L referred to primary $a^2L = 0.4$mH
total inductance seen by the primary applied voltage

$$= (L_1 - aM) + \frac{(aM)(a^2L_2 - aM + a^2L)}{aM + a^2L_2 - aM + a^2L}$$

$$= 3\times10^{-3} + \frac{(2\times10^{-3})(6+0.4)\times10^{-3}}{(2+6+0.4)\times10^{-3}}$$

$$= 3\times10^{-3} + \frac{2\times6.4\times10^{-3}}{8.4}$$

$= 3 \times 10^{-3} + 1.52 \times 10^{-3} = 4.523 \times 10^{-3}$H
Total reactance at the primary terminals
$= 2\pi \times 50 \times 4.523 \times 10^{-3} = 1.420\Omega$

Current primary winding $= \dfrac{100}{1.420} = 70.37$A

Choice (A)

29. Output current of the generator

$I_1 = \dfrac{20000}{200} = 1000$A, $I_2 = 100$A

$\eta = \sqrt{\dfrac{I_1}{I_1 + I_2}} = \sqrt{\dfrac{1000}{1100}} = 95.34\%$ Choice (B)

30. Short circuit current with normal voltage

$= 25 \times \dfrac{200}{100} = 50$A

Blocked rotor input with normal voltage $= 1800 \times \left(\dfrac{50}{25}\right)^2$

$= 1800 \times 4 = 5600$ Choice (B)

31. $X_a = 2\pi fL = 2\pi \times 50 \times 0.5 = 157.07\Omega$
$V^2 = (E_{bac} + I_aR_a)^2 + (I_aX_a)^2$

$E_{bac} = -I_a R_a + \sqrt{V^2 - (I_a X_a)^2}$

$= -2\times25 + \sqrt{(350)^2 - (2\times157.07)^2}$

$= -50 + 154.32 = 104.32$ Choice (B)

32. Motor output $= P_{out} = 50$ kW
Speed at rated torque $N = 0.95\ N_s$

Full load slip $S_f = \dfrac{N_s - N}{N_s} = \dfrac{N_s - 0.95N_s}{N_s} = 0.05$

Slip corresponding to maximum torque $S_{max} = 5S_f$
$S_{max} = 0.05 \times 5 = 0.25$

$\Rightarrow \dfrac{\text{Full load torque}}{\text{maximum torque}} = \dfrac{T_f}{T_{max}} = \dfrac{2S_{max}\, S_f}{S^2_{max} + S^2_f}$

$= \dfrac{2\times0.05\times0.25}{(0.25)^2 + (0.05)^2} = 0.384$

When the rotor circuit resistance is increased 6 times, the magnitude of maximum torque will remain unchanged because it is independent of load but the slip. Corresponding to the maximum torque will change. Let the new slip corresponding to maximum torque be S'max

$\Rightarrow$ Since slip corresponding to maximum torque is proportional to rotor resistance provided its stand-still reactance is fixed so

$S^1_{max} = S_{max} \times \dfrac{R^1}{R} = S_{max} \times 6 = 1.5$

Now $\dfrac{T_f}{T_{max}} = \dfrac{2\times S_f^{\,1}\, S^1_{max}}{(S_f^{\,1})^2 + (S^1_{max})^2}$

Where S^1_f is the new fall load slip.

$0.384 = \dfrac{2\times S^1_f \times 1.5}{(S^1_f)^2 + (1.5)^2}$

$\Rightarrow S^{12}_f - 7.8125 S^1_f + 2.25 = 0$
$\Rightarrow S^1_f = 0.3, 7.51$
So new speed at full load
$N^1 = (1 - S^1_f)N_s = (1 - 0.3)N_s = 0.7N_s$

Gross torque at full load $= \dfrac{50\times1000}{2\pi\times\dfrac{N}{60}} = \dfrac{50\times1000}{2\pi\times\dfrac{0.7N_s}{60}}$

New power output at full load

$=$ Gross torque at full load $\times \dfrac{2\pi N^1}{60}$

$= \dfrac{50\times1000}{2\pi\times\dfrac{0.95N_s}{60}} \times \dfrac{2\pi N^1}{60}$

$= \dfrac{50,000\times0.7\text{Ns}}{0.95\text{Ns}} = 36,842.10 = 36.84$ kW

Rotor copper loss at rated torque

$= \dfrac{Power\ Output}{1-S} \times S = \dfrac{36.842}{0.7} \times 0.3$

$= 15.78$ kW` Choice (B)

33. Speed corresponding to maximum torque $= N_s(1 - S_{max})$
$= N_s(1 - 45) = -0.5N_s$ Choice (D)

34. Resistance of the motor = 0.4 + 0.8 = 1.2Ω
$E_{b1} = 250 - 30 = 1.2 = 214$V
Let the motor input current be I_2
Series field voltage drop $= 0.8I_2$
Potential difference at brushes $= 250 - 0.8I_2$

$\therefore$ Armature divertor current $= \left[\dfrac{250 - 0.8I_2}{20}\right]$A

$\therefore$ Armature current $I_{a2} = \left(\dfrac{20.8I_2 - 250}{20}\right)$

As torque in both cases same

$\therefore$ $\phi_1 I_{a1} = \phi_2 I_{a2}$

$$30 \times 30 = I_2 \times \left(\frac{20.8I_2 - 250}{20}\right)$$

$\Rightarrow$ $18000 = 20.8I_2^2 - 250I_2$
$\Rightarrow$ $20.8I_2^2 - 250I_2 - 1800 = 0$
$I_2 = 17.08$A
Potential difference at brushes
$= 250 - (17.08 \times 0.8) = 236.33$V

$I_{a2} = \dfrac{20.8 \times 17.08 - 236.33}{20} = 5.94$A Choice (B)

35. $E_{b2} = 236.33 - 5.94 \times 0.4 = 233.954$V

$\Rightarrow$ $N_2 = \dfrac{233.95}{214} \times \dfrac{30}{17.08} \times 600 = 1152.10$ rpm

Choice (C)