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Lockdown Period
Open Practice Test Series
(Also useful for ESE & Other Exams)

EE : ELECTRICAL ENGINEERING
TEST No. - 03 | ELECTRICAL MACHINES

Read the following instructions carefully

1. This question paper contains 33 MCQ's & NAQ's. Bifurcation of the questions are given below:

Subjectwise Test Pattern

Questions	Question Type	No. of Questions	Marks	Total Marks	Negative Marking
1 to 9	Multiple Choice Ques.	9	1	9	0.33
10 to 16	Numerical Answer Type Ques.	7	1	7	None
17 to 25	Multiple Choice Ques.	9	2	18	0.66
26 to 33	Numerical Answer Type Ques.	8	2	16	None
Total Questions : 33		**Total Marks : 50**		**Total Duration : 90 min**	

2. Choose the closest numerical answer among the choices given.

Multiple Choice Questions : Q.1 to Q.9 carry 1 mark each

Q.1 Current needed to set up the flux in ideal transformer will be
(a) 5-10% of rated current
(b) Approximately zero
(c) Rated current
(d) Very high current

1. (b)
Permeability of core in ideal transformer tend to infinite.

$$\text{Reluctance} = \frac{l}{\mu_0 \mu_r A} \text{ will tends to } 0$$

$$\text{mmf} = NI = \text{flux} \times \text{reluctance}$$

$$\Rightarrow \quad I = \text{flux} \times 0$$

$$\Rightarrow \quad I \approx 0$$

Q.2 The correct order of values of elements (in p.u.) in a transformer is (symbols represents their usual meaning)
(a) $R_c > X_m > X_{pu} > R_{pu}$
(b) $X_m > X_{pu} > R_c > R_{pu}$
(c) $X_m > R_c > X_{pu} > R_{pu}$
(d) $R_c > X_{pu} > X_m > R_{pu}$

2. (a)

Q.3 The reactance in a single phase 100 kVA, 2200/220 V transformer is 0.4 p.u. and full load copper loss is 10 kW, operates at 0.9 p.f. leading. The voltage regulation (in %) of the transformer at full load will be
(a) 26.40%
(b) –26.40%
(c) 8.4%
(d) –8.4%

3. (d)

$$V.R = r_{pu} \cos\theta \pm x_{pu} \sin\theta \qquad \text{('+' for lagging load, '–' for leading load)}$$

$$r_{pu} = \frac{10 \text{ kW}}{100 \text{ kVA}} = 0.1$$

$$x_{pu} = 0.4$$

$$\cos\theta = 0.9 \text{ leading}$$

$$\sin\theta = 0.435$$

$$V.R = [(0.1)(0.9) - 0.435 \times 0.4] \times 100$$

$$V.R = -8.4\%$$

Q.4 In a rotor fed induction motor, the speed of stator magnetic field with respect to rotor will be
(a) sN_s
(b) N_s
(c) N_r
(d) Stationary

4. (b)
The speed of stator magnetic field with respect to stator = sN_s
Rotor rotates in the opposite direction of stator magnetic field with a speed of N_r.

$$\therefore \quad \text{Relative speed} = sN_s - (-N_r)$$

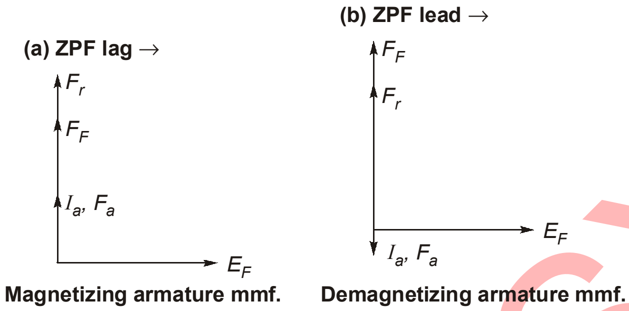
$$= sN_s + N_r$$

$$= N_s$$

Q.5 If the effect of armature reaction is purely demagnetizing, then type of load on a synchronous motor may be

(a) ZPF lag load
(b) ZPF lead load
(c) Lagging load
(d) Unity pf load

5. (b)



Q.6 A 4-pole, 50 Hz, 3-ϕ induction motor running on full load developes a useful torque of 200 N-m at a rotor frequency of 2 Hz, then the efficiency of the motor will be (considering no frictional losses)

(a) 96%
(b) 94%
(c) 95.8%
(d) 96.6%

6. (a)

$$N_s = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$s = \frac{2}{50} = 0.04 = 4\%$$

$$N_r = N_s(1 - s) = 1440 \text{ rpm}$$

$$P_0 = 200 \times \frac{2\pi}{60} \times 1440 = \text{Torque} \times \text{angular speed}$$

$$= 30159.28 \text{ W}$$

$$\text{Rotor copper loss} = \left(\frac{s}{1-s}\right)P_0$$

$$= \frac{0.04}{0.96} \times 30171.42 = 1256.64 \text{ W}$$

$$\text{Input} = 30159.28 + 1256.64 \text{ W} = 31415.92 \text{ W}$$

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100\% = 95.99 \approx 96\%$$

Q.7 A 3-ϕ induction motor has a starting torque of 100% and maximum torque of 400% of the full load torque. The value of slip when motor delivers maximum torque will be

(a) 0.25
(b) 0.127
(c) 0.284
(d) 0.204

7. **(b)**

The ratio of maximum torque to general torque is

$$\frac{T_m}{T} = \frac{\frac{s_m}{s} + \frac{s}{s_m}}{2}$$

$$\Rightarrow \quad \frac{400}{100} = \frac{s_m + \frac{1}{s_m}}{2} \qquad \text{(at starting, slip } s = 1)$$

$$\Rightarrow \quad s_m + \frac{1}{s_m} = 8$$

$$\Rightarrow \quad s_m^{\,2} - 8s_m + 1 = 0$$

$$s_m = 0.127$$

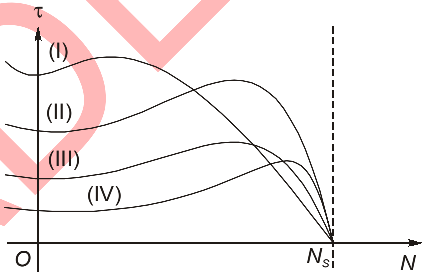
Q.8 In general view, the correct order relating the starting torque of below mention types of induction motor will be

Slip Ring, (I) Double cage, (II) Deep bar, (III) Normal Squirrel cage, (IV)

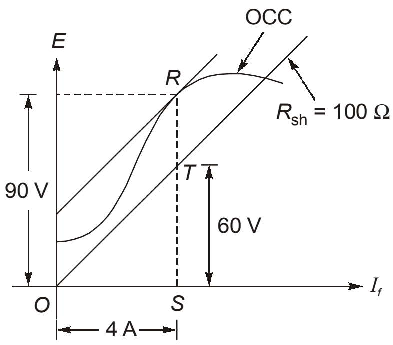
(a) I > II > III > IV
(b) I > III > IV > II
(c) I > III > II > IV
(d) II > I > III > IV

8. **(a)**

Torque speed characteristic of various rotors of induction motor is shown in figure below,
Where Slip Ring - (I), Double cage - (II), Deep bar - (III), Normal Squirrel cage - (IV)



Q.9 For given OC characteristic of dc shunt generator the value of critical speed for voltage buildup will be ______. For voltage buildup process to occur, the speed of generator should be ______ than critical speed. (Given rated speed = 1500 rpm)



(a) 1000 rpm, more
(b) 1000 rpm, less
(c) 2250 rpm, more
(d) 2250 rpm, less

9. (a)

Using OCC, $N_C = \frac{ST}{SR} \times N_{\text{Rated}}$

$$= \frac{60}{90} \times 1500 = 1000 \text{ rpm}$$

To build up the voltage in a generator, speed should be more than the critical speed.

Numerical Answer Type Questions : Q. 10 to Q. 16 carry 1 mark each

Q.10 In a 4 pole lap wound dc machine commutation technique, we have to reverse the armature current of magnitude 10 ampere in 5 milli second. The inductance of the coil is 1 mH in each 4 parallel paths, then the value of inductive kick (voltage occuring due to inductance of armature coil) will be _________ V.

10. 1 (0.50 to 1.50)

$$\text{Inductive kick} = \frac{L\frac{2I_a}{A}}{T_c}$$

$$= \frac{(1\times10^{-3}).\frac{2\times10}{4}}{5\times10^{-3}} = 1 \text{ V}$$

Q.11 A 4-pole dc motor is lap wound with 400 conductors. The pole shoe is 40 cm long and B_{avg} over one pole pitch is 0.2 T, the armature diameter being 30 cm. The torque developed when the motor is drawing 10 A and running at 1000 rpm is _________ Nm.

11. 12 (11.80 to 12.20)

$$\frac{\text{Flux}}{\text{Pole}} = \frac{\pi DL}{P} \times B_{avg}$$

$$= \left(\frac{\pi\times30\times10^{-2}\times40\times10^{-2}}{4}\right)\times0.2 = 188.50\times10^{-4} \text{ Wb/pole}$$

$$\text{Induced emf} = \frac{PN\phi Z}{60\ A} = \left(\frac{4}{4}\right)\times\frac{1000\times400\times188.50\times10^{-4}}{60\times1} = 125.66 \text{ V}$$

$$\text{Torque} = \frac{\text{Mechanical power}}{\omega} = \frac{E_bI_a}{\omega}$$

$$= \frac{125.66\times10}{\frac{2\pi}{60}\times1000} = 12 \text{ Nm}$$

Q.12 A 220 V dc generator supplies 11 kW at a terminal voltage of 220 V has armature resistance, $R_a = 1\ \Omega$. If the machine is now operated as a motor at the same terminal voltage and with same armature current, the ratio of generator speed to motor speed will be ________ . Assuming that flux/pole is made to increase by 50% as the operation is changed from generator to motor.

12. 2.38 (2.25 to 2.45)

We know,
$$E \propto N\phi$$
$$I_a = \frac{11\times 1000}{220} = 50\text{ A}$$
For generator action
$$E = V + I_a R_a$$
$$E_{ag} = 220 + (1)(50) = 270\text{ V}$$
For motor action
$$V = E + I_a R_a$$
$$E_{am} = 220 - (1)(50) = 170\text{ V}$$
$$\phi_m = 1.5\,\phi_g$$
$$\frac{N_g}{N_m} = \frac{E_g}{E_m}\times\frac{\phi_m}{\phi_g} = \frac{270}{170}\times 1.5 = 2.38$$

Q.13 The number of conductors on each pole piece required in a compensated winding which carries full armature current for a 6 pole lap wound dc armature containing 360 conductors will be ________ . (Assume ratio of pole arc to pole pitch = 0.8)

13. 8 (7.50 to 8.50)

$$AT_{cw}/\text{pole} = \frac{I_a Z}{2AP}\left(\frac{\text{Pole arc}}{\text{Pole pitch}}\right)$$
$$\text{Turns/pole} = \frac{Z}{2AP}\left(\frac{\text{Pole arc}}{\text{Pole pitch}}\right)$$
$$= \frac{360}{2\times 6\times 6}(0.8) = 4$$
$\therefore$ compensating conductor/pole
$$= 2\times 4 = 8$$

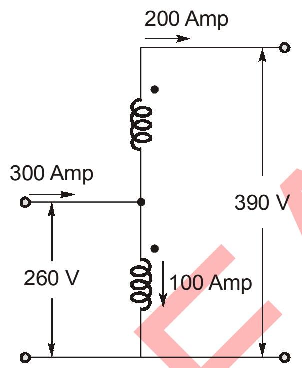
Q.14 A 260/130 V, 26 kVA single phase transformer has full load unity power factor efficiency of 94%. It is connected as an auto transformer to feed a load at 390 V with input voltage of 260 V. The full load efficiency of auto transformer at unity power-factor will be ________ %.

14. 97.91 (97.80 to 97.99)

$$\eta = \frac{P_0}{P_0 + P_L} = \frac{26}{26 + P_L} = 0.94$$

$$\Rightarrow \quad P_L = 1.659 \text{ kW}$$

$$\text{Rating of auto transformer} = 390 \times \frac{26 \times 10^3}{130} = 78 \text{ kVA}$$



$$\text{Efficiency of auto transformer} = \frac{P_0}{P_0 + P_L} = \frac{78}{78 + 1.659} \times 100\%$$

$$= 97.91\%$$

Q.15 The starting current of a delta-connected 3-phase induction motor at rated voltage is 5 times the full-load current and the slip at full load is 5%. The no-load current is negligible. If an autotransformer starter is used to limit the starting current from mains to 2 times the full-load current, ________ % be the starting torque obtained as a percentage of the full-load torque.

15. 50 (49.00 to 51.00)

Given, $s_{fl} = 0.05$,

$I_{sc} = 5 \times I_{fl}$ (Where I_{sc} = starting current without autotransformer)

This yields, $$\frac{I_{sc}}{I_{fl}} = 5 \quad \text{...(i)}$$

When auto transformer is used,

$$\frac{I_{st}}{I_{fl}} = 2 \quad \text{...(ii)}$$

(Where I_{st} = starting current with autotransformer)

To calculate starting torque in terms of full-load torque, applying the relation,

$$\frac{T_{st}}{T_{fl}} = \frac{I_{st} \times I_{sc}}{I_{fl}^2} \times s_{fl}$$

$$= \left(\frac{I_{st}}{I_{fl}}\right) \times \left(\frac{I_{sc}}{I_{fl}}\right) \times s_{fl}$$

$$= 2 \times 5 \times 0.05 = 0.5 = 50\%$$

$$T_{st} = 50\% \text{ of } T_{fl}$$

Q.16 A 3-ϕ, 400 V, synchronous motor takes 52.5 A, at a p.f. of 0.8 lead. The motor impedance per phase is (0.25 + j3.2) ohms. Induced emf (line) is ________ V. (Assume star connected motor)

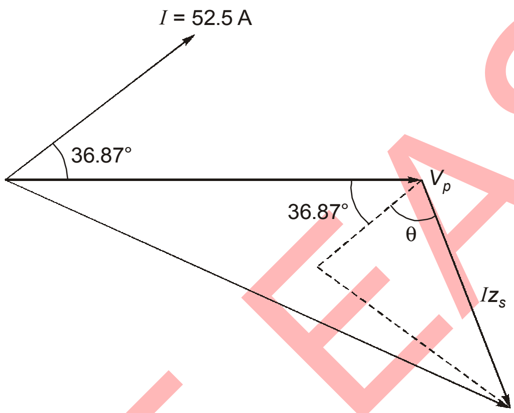
16. 608.47 (608.20 to 608.80)

$$z_S = (0.25 + j3.2) = 3.21\ \Omega,\ V_{ph} = \frac{400}{\sqrt{3}} = 231\text{ V}$$

$$\text{impedance angle } \theta = \tan^{-1}\frac{3.2}{0.25} = 85.53^\circ$$

$$\phi = \cos^{-1}(0.8) = 36.87^\circ$$

$$Iz_S = 3.21 \times 52.5 = 168.525\text{ V}$$



$$E_{\text{phase}} = \sqrt{V_p^2 + (Iz_S)^2 + 2V_p(Iz_S)\cos(122.40^\circ)}$$

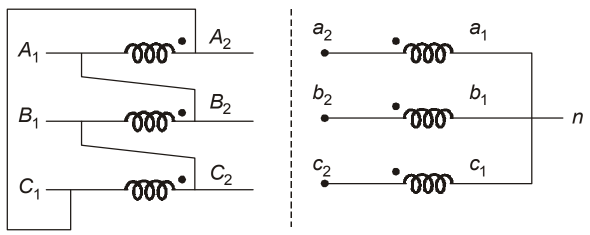
$$= \sqrt{(231)^2 + (168.525)^2 + 2 \times 231 \times 168.525 \times (0.535)}$$

$$= 351.3\text{ V}$$

$$E_{\text{Line}} = 608.47\text{ V}$$

Multiple Choice Questions : Q.17 to Q.25 carry 2 marks each

Q.17 Three single phase transformers are connected to form a 3 phase transformer bank. The transformers are connected in the following manner



The transformer connection will be represented by

(a) yd1
(b) Dy1
(c) Dy11
(d) Dy6

17. (c)

Q.18 3-ϕ induction motor is running at 810 rpm. Its rotor input is 2000 W and rotor gross output is 1800 W then the number of poles if the frequency of rotor is 6 Hz will be

(a) 4
(b) 6
(c) 8
(d) 10

18. (c)

$$\frac{\text{Rotor Gross Output}}{\text{Rotor Input}} = 1 - s = \frac{N}{N_s}$$

$$\frac{1800}{2000} = 1 - s \Rightarrow s = 0.1 \text{ or } 10\%$$

$$1 - 0.1 = \frac{810}{N_s} \Rightarrow N_s = 900 \text{ rpm}$$

$$f' = sf \Rightarrow 6 = 0.1 \times f \Rightarrow f = 60 \text{ Hz}$$

$$900 = \frac{120 \times (6/0.1)}{P}$$

$$P = \frac{120 \times 60}{900} = 8$$

Q.19 A 200/400 V, 20 kVA, 50 Hz transformer is connected as an auto-transformer to work as 600/200 V supply. With a load of 20 kVA 0.8 p.f. lagging connected to the 200 V terminals, the current in common winding and kVA rating of auto transformer respectively are

(a) 33.33 A, 20 kVA
(b) 33.33 A, 30 kVA
(c) 66.66 A, 30 kVA
(d) 66.66 A, 20 kVA

19. (c)

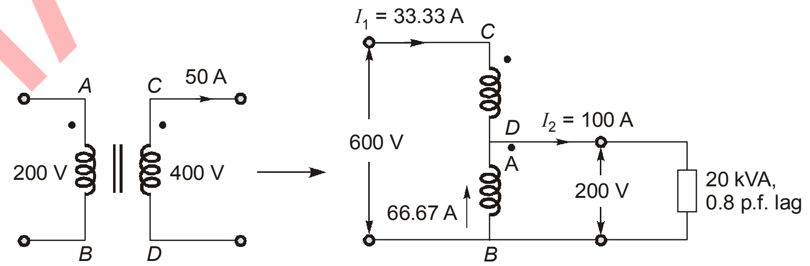
Two winding must be connected in series with the proper polarity so that 600 V can be applied across the total windings.

With 20 kVA load, load current

$$I_2 = \frac{20 \times 1000}{200} = 100 \text{ A}$$

$$I_1 = \frac{20 \times 1000}{600} = 33.33 \text{ A}$$

current in common winding $= (100 - 33.33)$ A $= 66.67$ A



For auto transformer rating,

$$S_{\text{auto}} = \frac{S_{TW}}{1 - x}$$

Where, $$x = \frac{200}{600}$$

then $$S_{\text{auto}} = \frac{20 \text{ kVA}}{1 - \frac{1}{3}} = 30 \text{ kVA}$$

Q.20 A 500 V shunt motor takes 2 A on no-load. The armature resistance including of brushes is 0.1 ohm, and field current is 1 A. If the line input current is 50 A then the efficiency will be

(a) 97.68% (b) 92.10%
(c) 94.32% (d) 95.04%

20. (d)

$$
\begin{aligned}
\text{Constant loss} &= \text{power input at no load} - \text{no load copper loss} \\
&= (500 \times 2) - (2-1)^2 \times 0.1 \\
&= 1000 - 0.1 \\
&= 999.9 \text{ W} \\
\text{Power input} &= 500 \times 50 = 25000 \text{ W} \\
\text{armature copper loss} &= (50-1)^2 \times 0.1 = 2401 \times 0.1 \\
&= 240.1 \text{ W} \\
\text{total losses} &= 999.9 + 240.1 = 1240 \text{ W} \\
\text{Efficiency} &= \frac{\text{Input} - \text{loss}}{\text{Input}} \times 100\% \\
&= \frac{25000 - 1240}{25000} \times 100 \\
&= 95.04\%
\end{aligned}
$$

Q.21 Two identical 2000 kVA alternators operate in parallel. The governer of first machine is such that the frequency drops uniformly from 50 Hz to 46 Hz from no load to full load and frequency drop of second machine is 50 Hz on no load to 47 Hz on full load. They have to share a load of 3000 kW. The frequency at which both will operate in parallel will be

(a) 47.42 Hz (b) 48.50 Hz
(c) 47.69 Hz (d) 46.94 Hz

21. (a)

$$\text{Slope of first alternator} = \frac{2000}{4} \text{ kVA/Hz}$$

$$\text{Slope of second alternator} = \frac{2000}{3} \text{ kVA/Hz}$$

Let they operate at frequency f

$$\therefore \quad \frac{2000}{4}(50-f) + \frac{2000}{3}(50-f) = 3000$$

$$\Rightarrow \quad \frac{1}{2}(50-f) + \frac{2}{3}(50-f) = 3$$

$$[50-f]\left[\frac{3+4}{6}\right] = 3$$

$$\Rightarrow \quad [50-f] = \frac{3 \times 6}{7}$$

$$\Rightarrow \quad f = 50 - \frac{18}{7} = 47.42 \text{ Hz}$$

Q.22 A 200 V dc series motor runs at 1000 rpm and takes 20 A. Combined resistance of armature and field is 0.4 Ω. Assuming torque is varying as square of the speed, the value of resistance to be inserted in series so as to reduce the speed to 600 rpm is

(a) 4 Ω (b) 10.5 Ω
(c) 6 Ω (d) 5.5 Ω

22. (b)

$$I_L = I_{a1} = 20 \text{ A}$$
$$N_1 = 1000 \text{ rpm} \qquad N_2 = 600 \text{ rpm}$$
$$E_1 = 200 - 20\,(0.4) = 192 \text{ V}$$
$$\frac{\tau_2}{\tau_1} = \frac{\phi_2 I_2}{\phi_1 I_1} = \left(\frac{I_2}{I_1}\right)^2 = \left(\frac{N_2}{N_1}\right)^2 \text{ ..... as given in question}$$
$$\frac{I_2}{I_1} = \frac{N_2}{N_1}$$
$$\Rightarrow \qquad I_2 = 20 \times \frac{600}{1000} = 12 \text{ A}$$
$$E_2 = V - I_2\,(0.4 + R) = 200 - 12\,(0.4 + R)$$
$$E_2 = (195.2 - 12\,R) \text{ V} \qquad \text{...(i)}$$
$$\frac{E_2}{E_1} = \frac{N_2\phi_2}{N_1\phi_1} = \frac{N_2 I_2}{N_1 I_1} = \frac{600 \times 12}{1000 \times 20} = 0.36$$
$$E_2 = 192 \times 0.36 = 69.12 \text{ V} \qquad \text{...(ii)}$$

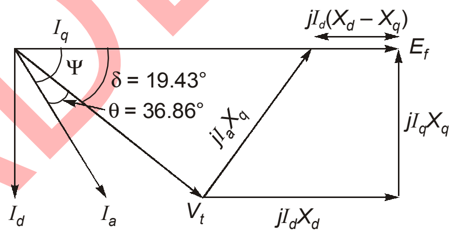
Using E_2 in equation (i) and solving for R

$$E_2 = 195.2 - 12\,R = 69.12 \text{ V}$$
$$R = \frac{195.2 - 69.12}{12} = 10.50\ \Omega$$

Q.23 A salient pole synchronous generator has $X_d = 0.8$ pu and $X_q = 0.6$ p.u. It is supplying full load at rated voltage at 0.8 pf lagging. The power angle and excitation emf in per unit will be respectively,

(a) 17.1°, 1.30 p.u.
(b) 17.1°, 1.60 p.u.
(c) 19.43°, 1.44 p.u.
(d) 19.43°, 1.60 p.u.

23. (d)



$$V_t = 1\angle 0° \text{ p.u.}$$
$$I_a = 1\angle{-36.86°} \text{ p.u.}$$
$$E_f'' = \vec{V_t} + j\vec{I_a}X_q$$
$$= 1\angle 0° + 1\angle{-36.86°} \times 0.6\angle 90°$$
$$= 1.44\angle 19.43° \text{ V}$$
$$\text{Excitation emf} = |E_f''| + I_d(X_d - X_q)$$
$$= 1.44 + (I_a \sin 56.29°)\,(0.2) = 1.44 + 0.166$$
$$= 1.60 \text{ p.u.}$$

Q.24 A 400 MVA, 22 kV synchronous generator is tested for O.C.C. and S.C.C. The following data are obtained from these characteristics extrapolated where needed.

$$I_f = 1120 \text{ A},\ V_{OC} = 22 \text{ kV},\ I_{SC} = 13.2 \text{ kA}$$

X_S (saturated) in per unit will be

(a) 0.962 (b) 0.795
(c) 0.21 (d) None of these

24. (b)

$$(\text{MVA})_{\text{base}} = 400, (\text{kV})_{\text{base}} = 22 \text{ (line) or } 12.7 \text{ (phase)}$$

$$(Z)_{\text{base}} = \frac{(22)^2}{400} = 1.21\ \Omega$$

$$I_f = 1120 \text{ A},$$

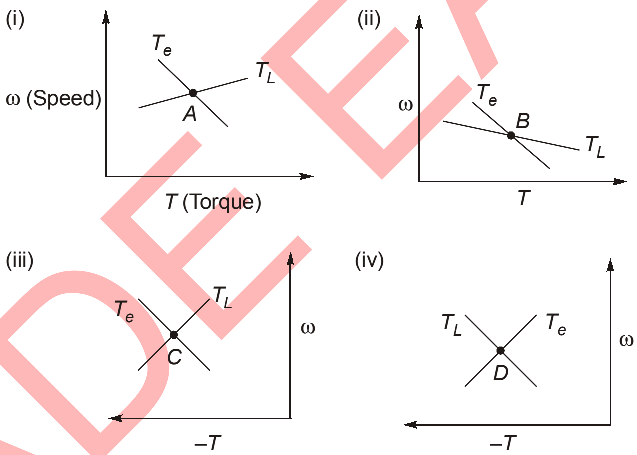
$$V_{OC} = V_{\text{rated}} = \frac{22}{\sqrt{3}} = 12.7 \text{ kV (phase)}$$

$$I_{sc} = 13.2 \text{ kA}$$

$$X_{S(\text{sat})} = \frac{12.7}{13.2} = 0.962\ \Omega$$

$$= \frac{0.962}{1.21} = 0.795 \text{ p.u.}$$

Q.25 Which one of the following points pair is stable if T_e is electromagnetic torque and T_L is load torque?



(a) A, D (b) A, C
(c) B, C (d) C, D

25. (b)

$$A = \text{stable}$$

$$T_e - T_L = J\frac{d\omega}{dt}$$

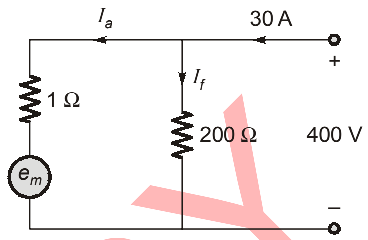
$$B = \text{unstable}$$
$$C = \text{stable}$$
$$D = \text{unstable}$$

Lower the speed of the machine and if it can accelerate to reach the original speed then it is stable, otherwise unstable. Similarly increase the speed of the machine and check whether it can decelerate to original speed.

Numerical Answer Type Questions : Q. 26 to Q. 33 carry 2 marks each

Q.26 A 400 V shunt motor supplies the rated load at a speed of 100 rad/sec and draws a current of 30 A. The armature resistance is 1 Ω and the field winding resistance is 200 Ω. If maximum armature current is limited to 1.4 times the rated armature current, then the plugging torque will be ________ N-m.

26. 145.82 (145.50 to 146.00)



$$I_f = \frac{400}{200} = 2\text{ A}$$

$$I_a = 30 - 2 = 28\text{ A}$$

$$E_m = 400 - 28 \times 1 = 372\text{ V}$$

$$372 = K_1 \phi \omega_m$$

$$K_1\phi = \frac{372}{100} = 3.72$$

Limited to 1.4 I_a.

$$I_{a\,\text{plugging}} = I_{a\,\text{max}} = 1.4 \times 28 = 39.2\text{ A}$$

$$T = K_1 \phi I_a = 3.72 \times 39.2 = 145.82\text{ N-m}$$

Q.27 A 3-ϕ, 50 Hz star connected alternator with 2 layer winding is running at 600 rpm. It has 12 turns/coil, 4 slots/pole/phase and a coil pitch of 10 slots. The winding factor at stator will be ________ .

27. 0.9253 (0.90 to 0.95)

$$P = \frac{120f}{N} = \frac{120 \times 50}{600} = 10$$

$$\text{Total slots} = 4 \times 3 \times 10 = 120$$

Conductor per phase, $N_{ph} = \frac{120 \times 12}{3} = 480$

$$q \times y = \frac{180}{\text{No. of phases}} = 60°$$

$$q = \text{Slots/pole/phase} = 4$$

∴ $y = 15°$

$$K_d = \frac{\sin\frac{qy}{2}}{q\sin\frac{y}{2}} = \frac{\sin 30°}{4\sin 7.5°} = 0.958$$

$$\text{pole pitch} = 12\text{ slots}$$

$$\text{coil pitch} = 10\text{ slot} = 15 \times 10 = 150° = (180° - 30°),\ \alpha = 30°$$

$$\text{coil factor} = \cos\frac{\alpha}{2} = \cos 15° = 0.966$$

Winding factor, $K_W = K_c . K_d = 0.9253$

Q.28 A 400 V, 50 Hz, 50 kVA synchronous motor is operating at 0.8 pf leading. The friction and windage losses are 2 kW and the core loss is 0.8 kW. The shaft is supplying 9 kW load at 0.8 pf leading then the line current is ________ A.

28. 21.29 (21.20 to 21.35)

$$\text{Input power} = 9\text{ kW} + 2\text{ kW} + 0.8\text{ kW}$$
$$= 11.8\text{ kW}$$
$$\therefore \quad 11800 = \sqrt{3}V_L I_L \cos\phi$$
$$\Rightarrow \quad \sqrt{3} \times 400 \times I_L \times 0.8 = 11800\text{ W}$$
$$\Rightarrow \quad I_L = 21.29\text{ A}$$

Q.29 A 400 V, 50 Hz, 4 pole, 1440 rpm star connected squirrel cage induction motor is controlled by V/f control and frequency is reduced to 30 Hz. The percentage slip at 30 Hz frequency is ________ %.

29. 6.67 (6.50 to 6.80)

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500\text{ rpm}$$
$$s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1440}{1500}$$
$$s = \frac{60}{1500} = 4\%$$
$$N_s = \frac{120f}{P} = 1500\text{ rpm}$$
$$sN_s = 60\text{ rpm}$$
$$N_s \text{ at 30 Hz} = \frac{120 \times 30}{4} = 900\text{ rpm}$$

The slip speed (sN_s) remains constant in (V/f) control.

$$\therefore \quad N_r = 900 - 60 = 840\text{ rpm}$$
$$\text{Slip} = \frac{60}{900} \times 100 = \frac{20}{3}$$
$$= 6.67\%$$

Q.30 A 3-phase, delta-connected, 4-pole, 50 Hz induction motor has a stator resistance of 0.4 Ω per phase at the operating temperature. For a line current of 20 A, the total stator input is 4000 watts. For negligible stator core losses, the internal torque will be ________ Nm.

30. 24.45 (24.00 to 25.00)

Given, $f = 50\text{ Hz}$, $P = 4$

$$\text{Power input } (P_{in}) = 4000\text{ W}$$
$$\text{Phase current} = \frac{I_L}{\sqrt{3}} = \frac{20}{\sqrt{3}} A$$
$$\text{Total stator } i^2 r \text{ loss} = 3 \times I_s^2 \times r_s = 3 \times \left(\frac{20}{\sqrt{3}}\right)^2 \times 0.4 = 160\text{ W}$$

Power across air gap,
$$P_G = P_{in} - \text{stator } i^2 r \text{ loss}$$
$$= 4000 - 160 = 3840\text{ W}$$

Synchronous speed,
$$n_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500\text{ rpm}$$

$\therefore \quad \omega_s = \dfrac{2\pi \times 1500}{60}$ rad/sec

Internal torque developed,

$$T_e = \frac{P_G}{\omega_s} = \frac{3840 \times 60}{2\pi \times 1500} = 24.45 \text{ Nm}$$

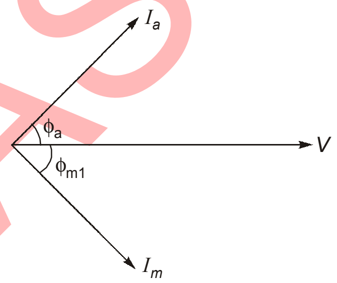
Q.31 A 1-ϕ induction motor has stator windings in space quadrature and is supplied with a 1-ϕ voltage of 200 V at 50 Hz. The stand still impedance of the main winding is $(5.2 + j10.1)\ \Omega$ and that of auxiliary winding is $(19.7 + j\,14.2)\ \Omega$. The value of capacitance to be inserted in the auxiliary winding for maximum starting torque is __________ μF.

31. 130.50 (130.00 to 131.00)

$$Z_{m1} = (5.2 + j\,10.1)\ \Omega$$
$$Z_a = (19.7 + j14.2)\ \Omega$$

For maximum starting torque

$$\phi_a + \phi_{m1} = 90^\circ \qquad \text{...(i)}$$
$$\phi_{m1} = 62.76^\circ$$



So using equation (i)

$$\phi_a = 27.24^\circ$$

$$\tan^{-1}\frac{X_c - 14.2}{19.7} = 27.24^\circ$$

$\Rightarrow \quad X_c = 24.34\ \Omega$

$$\omega C = 0.0410$$

$$C = \frac{0.041}{(2 \times \pi \times 50)} = 130.7\ \mu\text{F}$$

Q.32 A 500 kVA transformer has an efficiency of 95% at full load and half load also, both at upf. The value of $(2P_i - P_c)$ will be ________ kW. (Where P_i = total iron loss, P_c = full load copper loss)

32. 0 (0.00 to 0.05)

$$\eta = \frac{500 \times 1}{500 \times 1 + P_i + P_c} = 0.95 \qquad \text{(at full load)}$$

$\Rightarrow \quad P_i + P_c = 26.31$ kW ...(i)

$$\eta = \frac{500 \times 0.5}{500 \times 0.5 + P_i + (0.5)^2 P_c} = 0.95 \qquad \text{(at half load)}$$

$$\Rightarrow \quad \frac{250}{250 + P_i + 0.25 P_c} = 0.95$$

$\Rightarrow \quad P_i + 0.25\,P_c = 13.15$ kW ...(ii)

So, $\quad P_c = 17.54$ kW

$$P_i = 8.768 \text{ kW}$$
$$2\,P_i - P_c = 17.54 - 17.54$$
$$= 0 \text{ kW}$$

Q.33 A 220 V, 4 pole, 11 kW motor has lap connected armature winding with 1000 conductors. The mean flux density in the air gap under the interpoles is 0.2 Wb/m^2 on full load. If the radial gap length is 0.8 cm, the number of turns required on interpoles will be ________ .

33. **57 (55.00 to 58.00)**

$$I_a = \frac{11\times 10^3}{220} = 50 \text{ A}$$

$$AT_i = AT_a + \frac{B_i}{\mu_0} l_{gi} = \frac{I_a Z}{2AP} + \frac{B_i}{\mu_0} l_{gi}$$

$$= \frac{50\times 1000}{2\times 4\times 4} + \frac{0.2}{4\pi\times 10^{-7}} \times 0.8\times 10^{-2}$$

$$= 1562.5 + 1273.88$$

$$= 2836.38 \text{ AT}$$

$$N_i = \frac{AT_i}{I_a} = \frac{2836.38}{50} = 56.72 \approx 57 \text{ turns}$$

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