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Important Questions *for* GATE 2022

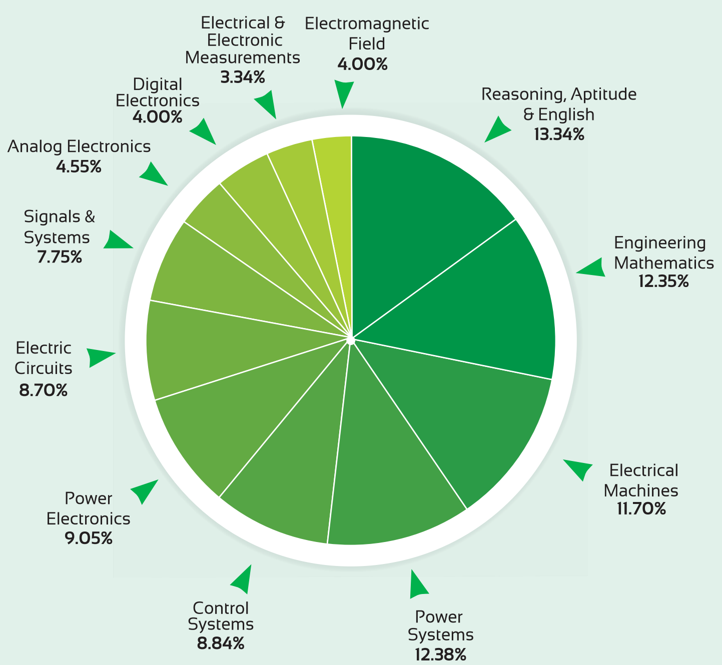
ELECTRICAL ENGINEERING

Day 5 of 8

Q.101 - Q.125 (Out of 200 Questions)

Electrical Machines

SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Reasoning, Aptitude & English	13.34%
Engineering Mathematics	12.35%
Electrical Machines	11.70%
Power Systems	12.38%
Control Systems	8.84%
Power Electronics	9.05%
Electric Circuits	8.70%
Signals & Systems	7.75%
Analog Electronics	4.55%
Digital Electronics	4.00%
Electrical & Electronic Measurements	3.34%
Electromagnetic Fields	4.00%
Total	**100%**

Electrical Machines

Q.101 Two shunt generators are in parallel with no load voltage 60 V and 50 V and full load power delivered 400 W and 500 W respectively at 20 V terminal voltage. The common voltage while delivering 700 W to load is

(a) 30.5 V (b) 22.6 V
(c) 20 V (d) 27.5 V

Q.102 A compensated dc machine has 20000 AT/Pole. The ratio of pole arc to pole pitch is 0.8. The interpolar airgap length and flux density arc 1.2 cm and 0.3 T. For rated armature current I_a = 1000 A, the number of turns on each interpole are,

(a) 7 (b) 8
(c) 5 (d) 9

Q.103 A 3-phase, 440 V, 50 Hz, six pole salient pole synchronous motor is drawing a 10 A current at 0.8 power factor leading. It has X_d = 10 Ω and X_q = 7 Ω. The torque angle (δ) is

(a) 9.4° (b) 12.1°
(c) 10.7° (d) 13.5°

Q.104 Two similar 400 V, 3-phase alternators share equal kW power delivered to a balanced three phase, 50 kW, 0.8 p.f. lagging load. If the power factor of one machine is 0.9 lag, then the current supplied by other machine is _______ A.

Q.105 At 400 V and 50 Hz the total core loss of a transformer was found to be 3200 W. When the transformer is supplied at 200 V and 25 Hz, the total core loss is 1000 W. The hysteresis and eddy current loss at 400 V and 50 Hz will be respectively

(a) 1600 W, 1600 W (b) 800 W, 2400 W
(c) 2400 W, 800 W (d) 1200 W, 2000 W

Q.106 A 220, 8 pole, 50 Hz, 3-ϕ star connected, wound rotor induction motor has a rotor impedance of (0.02 + *j*0.08) Ω/phase at standstill and has negligible stator impedance. The maximum torque developed by the motor is _________ N-m.

Q.107 A 100 MVA, 220 kV/110 kV, Δ–Δ, 3-ϕ power transformer has a resistance of 0.02 per unit and a reactance of 0.05 per unit. The transformer supplies a load of 80 MVA at 0.8 pf lagging. The percentage voltage regulation of the transformer is ________ %.

Q.108 A 20 kW, 6-pole, 50-Hz, 3-phase slip-ring induction motor runs at 960 revolutions per minute on full load with a rotor current per phase of 40 A. Allowing 300 W for the copper loss in the short-circuiting gear, and 1100 W for mechanical losses, the resistance per phase of the three-phase rotor winding will be ________ Ω. (upto three decimal places)

Q.109 A three phase induction motor operates at 50 Hz and 400 V. Maximum torque occurs at slip 0.4. The ratio of starting currents when operating at 25 Hz and 50 Hz is

(a) 0.595 (b) 1.68
(c) 0.94 (d) 1.92

Q.110 A 4-pole, 50 Hz alternator has double layer winding with 10 turns per coil and number of slots are 60. If each coil is short pitched by an angle to 36° electrical. The fundamental flux per pole is 0.015 Wb. The line to line induced emf for a 3-ϕ star connection is approximately

(a) 1050.2 V
(b) 606.33 V
(c) 350.14 V
(d) 1818.9 V

Q.111 A 20 kW, 300 V dc shunt motor is driving a constant torque load with line current of 100 A at a speed of 1600 rpm. Motor has armature and field winding resistance as 0.02 Ω and 100 Ω respectively. If 50 Ω external resistance is added in field circuit, then motor is running at (Assume linear magnetization curve)

(a) 1594.8 rpm
(b) 1812.9 rpm
(c) 2392.18 rpm
(d) 2100 rpm

Q.112 A 3-ϕ , 50 kVA, 400 V star connected synchronous motor is operating at 75% load with 0.8 leading power factor. Now excitation is decreased by 5% keeping prime mover power constant. Synchronous reactance of motor is 7.5 Ω. New input power factor is

(a) 0.8407 leading
(b) 0.952 lagging
(c) 0.952 leading
(d) 0.8407 lagging

Q.113 A dc series motor is driving a fan load where the load torque is proportional to square of speed. The resistance of armature and field are 0.03 Ω and 0.05 Ω respectively. If the motor takes 15 A and runs at 1500 rpm with supply voltage of 200 V. The value of resistance to be added in series with the armature to reduce the speed to 750 rpm, is ______ .

(a) 20.04 Ω
(b) 19.96 Ω
(c) 20.12 Ω
(d) 19.88 Ω

Q.114 A 10 kVA, 1000/230 V, transformer is to be reconnected as autotransformer. The ratio of conductive transfer to total transfer for best connection is ________ .

Q.115 An alternator with a synchronous impedance of $(0 + j1.25)$ p.u. delivers rated current to infinite bus bar at pf 0.8 lagging. For the same excitation power factor just before falling out of step would be

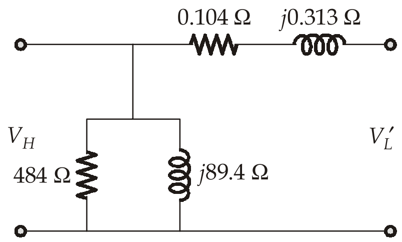
(a) 0.785 lagging
(b) 0.895 lagging
(c) 0.895 leading
(d) 0.785 leading

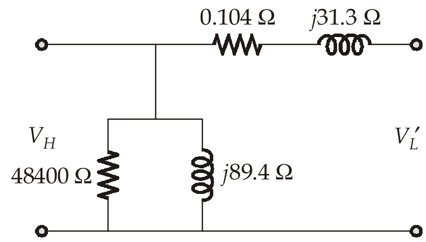
Q.116 A 230 V, 1800 rpm, long shunt, cumulative compound motor has a shunt field resistance of 460 Ω, series field resistance of 0.2 Ω and armature circuit resistance of 1.3 Ω. The full-load line current is 10.5 A. The rotational loss is 5% of the power developed. The efficiency (in percentage) of the motor at full load is _______ .

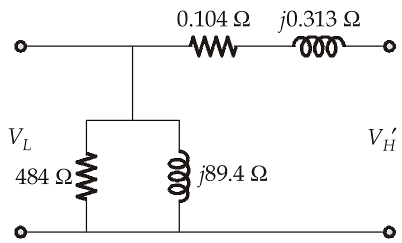
Q.117 Tests are performed on a 1-ϕ , 10 kVA, 2200/220 V, 60 Hz transformer and the following results are obtained.

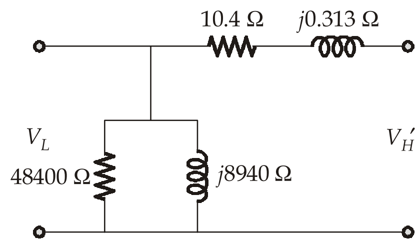
	Open circuit test (HV side open)	Short circuit test (LV side shorted)
Voltmeter	220V	150V
Ammeter	2.5A	4.55A
Wattmeter	100W	215W

The approximate equivalent circuit is,

(a) 

(b) 

(c) 

(d) 

Q.118 A 1-ϕ, 3 kVA, 240/120 V, 60 Hz transformer has the following parameters:

R_{HV} = 0.25 Ω, R_{LV} = 0.05 Ω

X_{HV} = 0.75 Ω, X_{LV} = 0.18 Ω

If the transformer is supplying full load on *LV* side at 110 V and 0.9 leading power factor, then the voltage regulation is

(a) –1.21% (b) 0.95%
(c) –0.95% (d) 1.21%

Q.119 A 6 pole, 50 Hz induction motor has an equivalent rotor resistance of 0.01 Ω/phase. If its stalling speed is 900 rpm, the resistance that must be inserted in rotor windings per phase to obtain maximum torque at starting is

(a) 0.1 Ω/phase (b) 0.09 Ω/phase
(c) 0.33 Ω/phase (d) 0.03 Ω/phase

Q.120 Two identical 250 kVA, 230/460 V transformers are connected in open delta to supply a balanced 3-ϕ load at 460 V and a power factor of 0.8 lagging. The real power delivered to the load is ________ kW.

(Assume maximum secondary line current without overloading the transformers)

Q.121 In a simple two pole generator the peak flux density of the rotor magnetic field is 0.2 T, and the mechanical rate of rotation of the shaft is 3600 rev/min. The stator diameter of the machine is 0.5 m, its coil length is 0.3 m, and there are 15 turns per coil. If the machine is Y-connected, then the rms terminal voltage of this generator is

(a) 280 V (b) 180 V
(c) 262 V (d) 208 V

Q.122 A 200 kVA, 480 V, 50 Hz, Y-connected synchronous generator with a rated field current of 5 A was tested, and the following data were taken:

1. $V_{T,\,O.C.}$ at rated I_f was measured to be 540 V.
2. $I_{L,\,S.C.}$ at rated I_f was found to be 300 A.

3. When a dc voltage of 10 V was applied to two of the terminals, a current of 25 A was measured.

The armature resistance and the approximate synchronous reactance in ohms respectively at the rated condition is

(a) 1.04 Ω and 0.5 Ω
(b) 0.2 Ω and 1.02 Ω
(c) 1.02 Ω and 0.2 Ω
(d) 0.5 Ω and 1.04 Ω

Q.123 A slip ring induction motor drives a constant torque load. If the supply voltage reduces to half times its previous stator voltage, then slip and rotor current gets modified by factors of: (Assume voltage control method).

(a) 4 and 2 respectively
(b) $\sqrt{2}$ and 2 respectively
(c) 2 and $\frac{1}{\sqrt{2}}$ respectively
(d) 4 and $\frac{1}{2}$ respectively

Q.124 A 3-phase induction motor has an efficiency of 0.9 when the load is 37 kW. At this load the stator copper and rotor copper loss each equals the iron loss. The mechanical losses are one-third of the no load loss, then the slip is _______ .

Multiple Select Questions (MSQ)

Q.125 The parameters of approximate equivalents circuit of 100 kVA 2000/200 V single-phase transformer are as follows:

R_1 = 0.2 Ω ; R_2 = 2 mΩ;
X_1 = 0.45 Ω , X_2 = 4.5 mΩ
R_C = 10 kΩ ; X_m = 1.55 kΩ

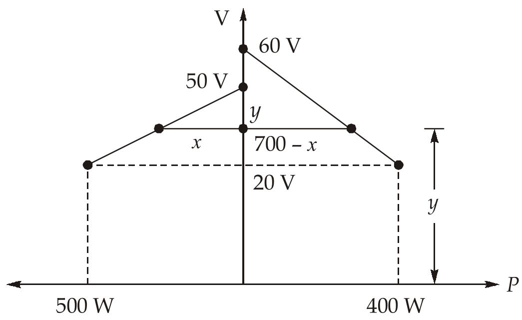
Choose the correct statement.

(a) Full load copper loss and iron losses are 400 W and 1000 W respectively.
(b) Efficiency of transformer at full load and 0.8 pf lag is 98.28%.
(c) Equivalent impedance referred to primary is 0.90 Ω.
(d) Equivalent resistance referred to primary is 0.4 Ω.

■■■■

Detailed Explanations

101. (d)



From similarity of triangles for generator 1,

$$\frac{50-y}{x} = \frac{50-20}{500}$$

$$50 - y = 0.06\,x$$

$$0.06\,x + y = 50 \qquad \text{...(i)}$$

For second triangle,

$$\frac{60-y}{700-x} = \frac{60-20}{400}$$

$$60 - y = 70 - 0.1\,x$$

$$0.1\,x - y = 10 \qquad \text{...(ii)}$$

Solving the equations (i) and (ii), we get

$$y = 27.5 \text{ V}$$

$$\text{Voltage} = 27.5 \text{ V}$$

102. (a)

$$AT_{CW}/\text{Pole} = AT_a(\text{peak}) \times \frac{\text{Pole arc}}{\text{Pole pitch}}$$

$$= 20000 \times 0.8 = 16000$$

$$AT_a(\text{peak}) \text{ interpolar region} = 20000 - 16000 = 4000$$

$$AT_i = AT_a(\text{peak}) + \frac{B_i}{\mu_0} l_{gl}$$

$$= 4000 + \left[\frac{0.3}{4\pi \times 10^{-7}} \times 1.2 \times 10^{-2}\right] = 6865 \text{ AT/P}$$

$$N_i = \frac{6865}{1000} \approx 7 \text{ turns}$$

103. (c)

$$\vec{E}' = \vec{V_t} - j\vec{I_a}X_q$$

$$X_q = 7\ \Omega$$

$$\text{p.u. value of } X_q = \frac{\text{ohmic value}}{\text{base value}}$$

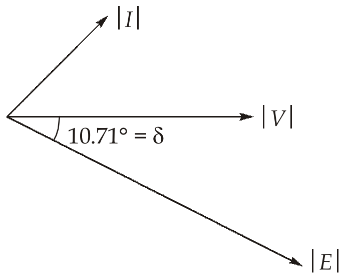
$$\text{Base ohms} = \frac{\left(\frac{440}{\sqrt{3}}\right)}{10} = 25.4\ \Omega$$

$$\text{p.u. value of } X_q = \frac{7}{25.4} = 0.2756 \text{ p.u.}$$

$$\vec{E} = 1 - ((j0.2756) \times 1\angle\cos^{-1}(0.8))$$

$$= 1.18\angle{-10.71°} \text{ p.u.}$$

$\therefore$ Torque angle, $\delta = 10.71°$



Alternative method:

$$\text{Torque angle, } \delta = \tan^{-1}\left[\frac{IX_q\cos\theta}{V + IX_q\sin\theta}\right]$$

$$= \tan^{-1}\left[\frac{10\times 7\times\cos(36.87°)}{254 + (10\times 7\sin(36.87°))}\right]$$

$$\delta = 10.71°$$

104. 51.47 (51.00 to 52.00)

Active power supplied to load is = 50 kW

Reactive power supplied to load,

$$Q = P\tan\phi$$

$$= 50\tan(\cos^{-1}0.8)$$

$$= 37.5 \text{ kVAR}$$

Active power supplied by one generator

$$= \frac{50}{2} = 25 \text{ kW}$$

Power factor of generator 1 = $\cos\phi_1 = 0.9$ lag

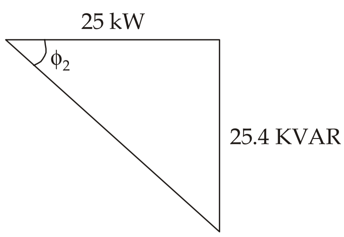
Reactive power supplied by generator 1

$$= 25 \times \tan(\cos^{-1}0.9) = 12.10 \text{ kVAR}$$

Reactive power supplid by generator 2

$$= 37.5 - 12.10$$

$$= 25.4 \text{ kVAR}$$



$$\phi_2 = \tan^{-1}\left(\frac{25.4}{25}\right) = 45.45°$$

$$\cos\phi_2 = 0.701 \text{ lagging}$$

Current supplied by machine 2 is,

$$I_2 = \frac{P_2}{\sqrt{3}V_L \cos\phi_2} = \frac{25\times10^3}{\sqrt{3}\times400\times0.701} = 51.47 \text{ A}$$

105. (b)

For first case; $\frac{V_1}{f_1} = \frac{400}{50} = 8$

For second case; $\frac{V_2}{f_2} = \frac{200}{25} = 8$

Since, $\frac{V_1}{f_1} = \frac{V_2}{f_2} = 8$; the flux density B_m remains constant

Now, Hysteresis loss, $P_h = K_1 f$

and Eddy current loss, $P_e = K_2 f^2$

Then, Iron loss, $P_i = K_1 f + K_2 f^2$

or, $$\frac{P_i}{f} = K_1 + K_2 f \quad ...(i)$$

Now, from Ist case:

$$\frac{3200}{50} = K_1 + K_2 \times 50 \quad ...(ii)$$

From IInd case:

$$\frac{1000}{25} = K_1 + 25\, K_2 \quad ...(iii)$$

From (ii) and (iii), we get

$$K_1 = 16$$

and $$K_2 = \frac{24}{25}$$

Hysteresis loss, $P_h = 16 \times 50 = 800$ W

and, eddy current loss, $P_e = \frac{24}{25}\times 2500 = 2400$ W

106. 3850.51 (3845.00 to 3855.00)

The slip at maximum torque is,

$$S_{\max,T} = \frac{R_2}{X_2} = \frac{0.02}{0.08} = 0.25$$

Synchronous speed, $N_s = \frac{120\times50}{8} = 750$ rpm

$$\omega_s = \frac{2\pi}{60}\times N_s = \frac{2\pi}{60}\times750 = 78.54 \text{ rad/sec}$$

Stator voltage, $V_1 = \frac{220}{\sqrt{3}} = 127$ V

Maximum torque developed by the motor,

$$T_{max} = \frac{3V_1^2}{2\omega_s \times X_2} = \frac{3\times(127)^2}{2\times78.54\times0.08} = 3850.51 \text{ N-m}$$

107. 3.70 (3.50 to 4.00)

Base current in secondary side,

$$I_{2\,(base)} = \frac{100\times10^6}{\sqrt{3}\times110\times10^3} = 524.86 \text{ A}$$

Since the transformer supplies a load of 80 MVA at 0.8 pf lagging, so secondary line current of the transformer is

$$I_S = \frac{80\times10^6}{\sqrt{3}\times110\times10^3} \approx 420 \text{ A}$$

$$(I_S)_{pu} = \frac{420}{525}\angle\cos^{-1}(0.8)$$

$$= 0.8\angle{-36.87°} \text{ p.u.}$$

Per unit no load voltage of this transformer is

$$E_{NL} = V_S + Iz$$

$$= 1\angle0° + (0.8\angle{-36.87°})\,(0.02 + j0.05)$$

$$= 1.037\angle1.24° \text{ p.u.}$$

According to definition of V.R. $= \dfrac{\text{No load voltage} - \text{Full load voltage}}{\text{Full load voltage}}\times100$

$$\text{V.R.} = \frac{1.037-1}{1}\times100\% = 3.7\ \%$$

108. 0.121 (0.100 to 0.150)

Given, Pole, $P = 6$

$f = 50$ Hz

Synchronous speed, $N_s = \dfrac{120f}{P} = \dfrac{120\times50}{6} = 1000$ rpm

Slip, $s = \dfrac{1000-960}{1000} = 0.04$

Mechanical power developed

$$P_{mech} = 20000 + 1100$$

$$= 21100 \text{ W}$$

Rotor copper loss $= \dfrac{s}{1-s} \times$ mechanical power developed

$$= \frac{0.04}{(1-0.04)}\times21100 \qquad \text{...(i)}$$

Also rotor copper loss $= 3I_2^2\times R_2 + 300$

$$= 3\times(40)^2\times R_2 + 300 \qquad \text{...(ii)}$$

From equation (i) and (ii), we get

$$4800 \times R_2 + 300 = \frac{0.04}{(1-0.04)} \times 21100$$

$$4800\ R_2 = 579.17$$

$$R_2 = 0.121\ \Omega$$

109. **(b)**

At starting slip, $s = 1$

$$I = \frac{V}{\sqrt{R_2^2 + X_2^2}}$$

$$(X_2)_{50\text{ Hz}} = X_2$$

and $(X_2)_{25\text{ Hz}} = 0.5\ X_2$

$$\text{Current, } (I)_{50\text{ Hz}} = \frac{V}{X_2\sqrt{\left(\frac{R_2}{X_2}\right)^2 + 1}}$$

and $$\text{Current, } (I)_{25\text{ Hz}} = \frac{V}{X_2\sqrt{\left(\frac{R_2}{X_2}\right)^2 + 0.25}}$$

$$\frac{(I)_{25\text{ Hz}}}{(I)_{50\text{Hz}}} = \frac{\sqrt{s_m^2+1}}{\sqrt{s_m^2+0.25}} \qquad \left(\text{Given}, s_m = \frac{R_2}{X_2} = 0.4\right)$$

$$\frac{(I)_{25\text{ Hz}}}{(I)_{50\text{Hz}}} = \frac{\sqrt{0.4^2+1}}{\sqrt{0.4^2+0.25}} = 1.68$$

110. **(a)**

For double layer winding,

No. of slots = No. of coils

Total number of turns = 60 × 10 = 600

$$\text{Turns per phase} = \frac{600}{3} = 200$$

$$\text{Pitch factor } (K_c) = \cos 18° = 0.951$$

$$\text{Distribution factor } (K_d) = \frac{\sin\frac{m\beta}{2}}{m\sin\frac{\beta}{2}}$$

$$m = \frac{60}{4} \times \frac{1}{3} = 5$$

$$\beta = \frac{180}{60/4} = 12°$$

$$K_d = \frac{\sin\frac{5\times 12}{2}}{5\sin\frac{12}{2}} = 0.9567$$

$$\text{Induced emf, } E_{ph} = \sqrt{2}\pi K_w \phi f T_{ph}$$

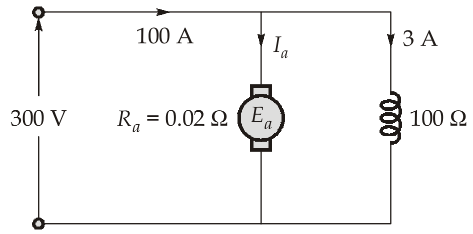
$$E_{ph} = \sqrt{2}\pi \times 0.9567 \times 0.95 \times 0.015 \times 50 \times 200$$

$$E_{ph} = 606.33 \text{ V}$$

$$E_{L\text{-}L} = 1.05 \text{ kV}$$

111. (c)

Case-I:



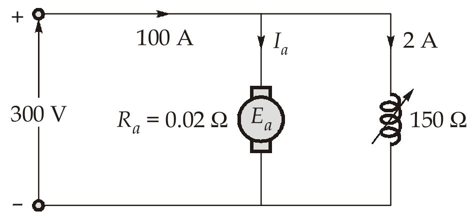
Armature current, $I_{a1} = 100 - 3 = 97$ A

Back emf, $E_{a1} = 300 - 97 \times 0.02$

$$E_{a1} = 298.06 \text{ V}$$

Case-II:

When 50 Ω external resistance added in field circuit,



Load torque is constant

$$T \propto \phi I_a$$

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

$$\phi \propto I_f$$

$$I_{a2} = I_{a1}\frac{\phi_1}{\phi_2} = 97 \times \frac{3}{2} = 145.5 \text{ A}$$

$$E_{a2} = 300 - 145.5 \times 0.02$$

$$E_{a2} = 297.09 \text{ V}$$

We know that, $E_a \propto \phi\omega_m$

$$\frac{E_{a2}}{E_{a1}} = \frac{\phi_2}{\phi_1} \times \frac{N_2}{N_1}$$

$$\frac{297.09}{298.06} = \frac{2}{3} \times \frac{N_2}{1600}$$

$$N_2 = 2392.18 \text{ rpm}$$

112. (d)

$$\text{Base impedance } (Z_B) = \frac{V_B^2}{S_B} = \frac{400^2}{50000} = 3.2\ \Omega$$

Synchrnous reactance,

$$(X_s)_{pu} = \frac{7.5}{3.2} = 2.34375 \text{ p.u.}$$

When motor is operating at 75% load with 0.8 p.f. leading

$$\vec{E}_{f1} = \vec{V} - j\vec{I}_{a1}X$$
$$= 1\angle 0° - j(0.75\angle\cos^{-1}(0.8)) \times (2.34375)$$
$$= 2.49\angle -34.4° \text{ p.u.}$$

Now excitation emf is decreased by 5%

$$E_f \sin\delta = \text{constant}$$
$$E_{f1}\sin\delta_1 = E_{f2}\sin\delta_2$$
$$E_{f2} = 0.95 \times 2.49 = 2.37$$
$$\delta_2 = \sin^{-1}\left(\frac{E_{f1}}{E_{f2}} \times \sin\delta_1\right)$$
$$\delta_2 = \sin^{-1}(0.594)$$
$$\delta_2 = 36.44°$$

$$\text{Current, } \vec{I}_{a2} = \frac{\vec{V} - \vec{E}_{f2}}{jX_s} = \frac{1 - 2.37\angle -36.44°}{j2.34375}$$
$$\vec{I}_a = 0.7144\angle 32.78°$$
$$\text{Power factor} = \cos 32.78° = 0.8407 \text{ lagging}$$

113. (b)

Load characteristic is

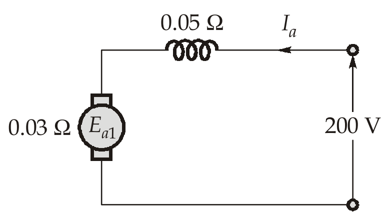
$$T_L \propto N^2$$

For dc series motor, torque-current relation is given by

$$T_d \propto I_a^2$$

$$\therefore \quad \frac{I_{a2}}{I_{a1}} = \frac{N_2}{N_1}$$
$$\frac{I_{a2}}{15} = \frac{750}{1500}$$
$$I_{a2} = 7.5 \text{ A}$$

Case-I:



$$E_{a1} = 200 - 15 \times (0.03 + 0.05)$$
$$E_{a1} = 198.8 \text{ V}$$

Case-II:

When additional resistance added in series with the armature circuit,

$$I_{a2} = 7.5 \text{ A},$$
$$N_2 = 750 \text{ rpm}$$

Now, $E_a \propto \phi\omega_m$

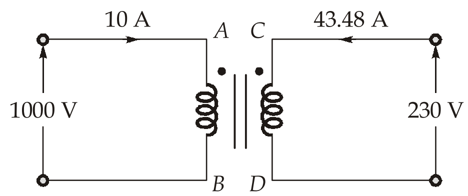
$$\frac{E_{a2}}{E_{a1}} = \frac{N_2}{N_1}\frac{I_{a2}}{I_{a1}} \quad \text{(In dc series motor } \phi \propto I_a\text{)}$$

$$\frac{E_{a2}}{198.8} = \frac{750 \times 7.5}{1500 \times 15}$$

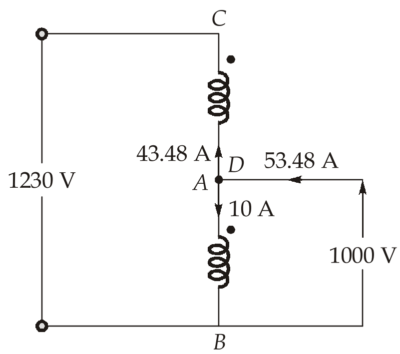
$$E_{a2} = 49.7 \text{ V}$$
$$E_{a2} = 200 - 7.5(0.08 + R_{ext}) = 49.7$$
$$0.08 + R_{ext} = \frac{200 - 49.7}{7.5}$$
$$R_{ext} = 20.04 - 0.08$$
$$= 19.96 \ \Omega$$

114. 0.813 (0.729 to 0.872)

Two winding transformer:



Best connection for autotransformer is additive polarity



$$\text{kVA rating} = \text{series winding current} \times \text{voltage}$$
$$= 43.48 \times 1230 = 53.48 \text{ kVA}$$
$$\text{Conductive transfer} = \text{Total kVA} - \text{Inductive transfer}$$
$$= 53.48 - 10 = 43.48 \text{ kVA}$$
$$\frac{\text{Conductive transfer}}{\text{Total transfer}} = \frac{43.48}{53.48} = 0.813$$

115. (c)

Take, $V_t = 1\angle 0°$ p.u.

So, $I_a = 1\angle -\cos^{-1}(0.8)$ p.u.

Alternator excitation emf,

$$\vec{E}_f = \vec{V}_t + \vec{I}_a \vec{Z}_s$$

$$\vec{E}_f = 1\angle 0° + [1\angle -\cos^{-1}(0.8)] \times 1.25\angle 90°$$

$$\vec{E}_f = 1 + 1.25\angle 53.13°$$

$$|\vec{E}_f| = \sqrt{(1 + 1.25\cos 53.13°)^2 + (1.25\sin 53.13°)^2} = 2.01 \text{ p.u.}$$

When motor just fall out of step,

$$\delta \approx 90$$

Now for same excitation,

$$2.01\angle 90° = 1\angle 0° + I_a \times 1.25\angle 90°$$

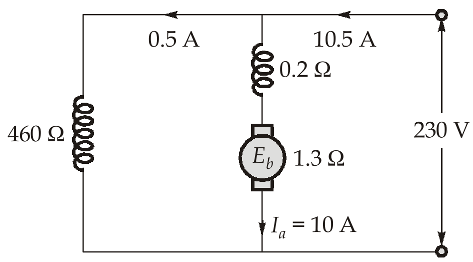
$$\vec{I}_a = \frac{j2.01 - 1}{j1.25} = 1.608 + j0.8$$

$$\vec{I}_a = 1.8\angle 26.45° \text{ p.u.}$$

$$\text{Power factor} = \cos(26.45°) = 0.895 \text{ leading}$$

116. 84.57 (84.00 to 85.00)

At full load:



At full load,

$$\text{Armature current, } I_a = 10.5 - \frac{230}{460} = 10 \text{ A}$$

$$\text{Back emf, } E_b = V - I_a(R_a + R_{se})$$

$$= 230 - 10(1.3 + 0.2)$$

$$E_b = 215 \text{ Volt}$$

$\therefore$ Power developed in armature = $E_b \cdot I_a$

$$= 215 \times 10 = 2150 \text{ Watt}$$

Given that, rotational losses is 5% of power developed

$$P_{output} = 0.95 \times P_{developed}$$

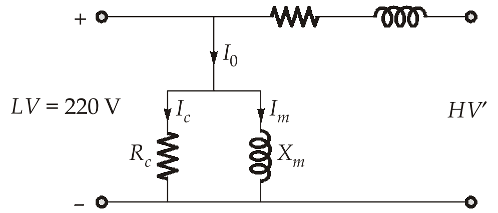
$$= 0.95 \times 2150$$

$$= 2042.5 \text{ Watt}$$

$$\therefore \quad \text{Efficiency, } \eta = \frac{P_{output}}{P_{input}} = \frac{2042.5}{230 \times 10.5} = 0.8457 \text{ (or) } 84.57\%$$

117. (c)

Lets take circuit referred to low voltage side,



$$\text{Watt meter reading} = VI\cos\phi$$

$$\cos\phi = \frac{100}{220 \times 2.5} = 0.1818$$

$$\sin\phi = \sin(\cos^{-1}(0.1818)) = 0.9833$$

$$I_c = I_0\cos\phi = 2.5 \times 0.1818 = 0.4545\text{ A}$$

$$I_m = I_0\sin\phi = 2.5 \times 0.9833 = 2.46\text{ A}$$

$$\therefore \quad R_c = \frac{V}{I_c} = \frac{220}{0.4545} = 484\ \Omega$$

$$X_m = \frac{V}{I_m} = \frac{220}{2.46} = 89.43\ \Omega$$

∴ Option (c) is the only equivalent circuit matching.

118. (c)

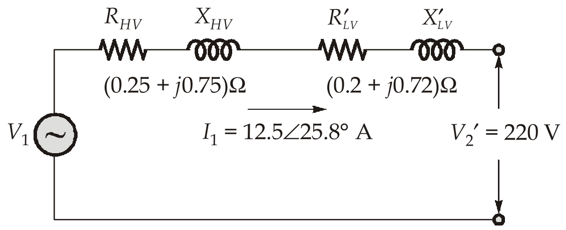
$$I_{1\text{ rated}} = \frac{3000}{240} = 12.5\text{ A}$$

I_2 rated is obtained by,

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

$$I_2 = I_1 \times \frac{N_1}{N_2} = 12.5 \times \frac{240}{120} = 25\text{ A (rated current)}$$

Since given load voltage, $V_2 = 110$ V so, $V_2' = 220$ V



$$Z'_{LV} = Z_{LV} \times \left(\frac{N_1}{N_2}\right)^2$$

$$= (0.05 + j0.18) \times \left(\frac{240}{120}\right)^2$$

$$Z'_{LV} = (0.2 + j0.72)\ \Omega$$

$$I_1 = 12.5\angle\cos^{-1}(0.9) = 12.5\angle 25.8^\circ \text{ A}$$

$$V_1 = \left[(12.5\angle 25.8^\circ)(0.45 + j1.47)\right] + (220\angle 0^\circ)$$

$$V_1 = 217.9\angle 5^\circ \text{ V}$$

$$\text{Percentage voltage regulation} = \frac{217.9 - 220}{220} \times 100 = -0.95\%$$

119. **(b)**

$$\text{Synchronous speed, } N_s = \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

$$\text{Stalling speed} = 900 \text{ rpm}$$

$$\text{Slip at stalling torque, } s = \frac{1000 - 900}{1000} = 0.1$$

$$\text{Slip at maximum torque; } S_{mT} = \frac{R_2}{X_2} = \frac{0.01}{X_2}$$

$$\because \quad 0.1 = \frac{0.01}{X_2}$$

$$X_2 = 0.1\ \Omega$$

To obtain maximum torque at starting,

$$\text{Let rotor resistance} = R_2'$$

$$\text{at starting, } s = 1$$

$$S_{mT} = \frac{R_2'}{X_2}$$

$$\Rightarrow \quad 1 = \frac{R_2'}{0.1}$$

$$\Rightarrow \quad R_2' = 0.1\ \Omega/\text{phase}$$

The external resistance to be added,

$$R_{ext} = 0.1 - 0.01 = 0.09\ \Omega/\text{phase}$$

120. **346.41 (345.00 to 347.00)**

The maximum secondary line current without over loading the transformers is,

$$I_L = \frac{\text{KVA}}{\text{V}} = \frac{250 \times 10^3}{460} = 543.48 \text{ A}$$

In open delta connection,

$$P_1 = VI\cos(30^\circ + \phi)$$

$$P_2 = VI\cos(30^\circ - \phi)$$

$$P_{\text{delivered}} = P_1 + P_2 = VI[\cos(30^\circ + \phi) + \cos(30^\circ - \phi)]$$

$$= 2\,VI\cos 30^\circ \cos\phi$$

$$= \sqrt{3}V_L I_L \cos\phi$$

$$= \sqrt{3} \times 460 \times 543.48 \times 0.8$$

$$P = 346.41 \text{ kW}$$

121. (d)

The flux in this machine is given by,

$$\phi = dlB \quad \text{[where } d \text{ is diameter and } l \text{ is length of the coil]}$$

$$\phi = (0.5)\ (0.3)\ (0.2)$$
$$= 0.03 \text{ Wb}$$

speed of the rotor is given by,

$$\omega = 3600 \times \frac{2\pi}{60} = 377 \text{ rad/sec}$$

The magnitude of peak phase voltage,

$$E_{max} = N_c\, \phi\, \omega$$
$$= 15 \times 0.03 \times 377$$
$$= 169.65 \text{ V}$$

Rms phase voltage, $E_{rms} = \dfrac{E_{max}}{\sqrt{2}} = \dfrac{169.65}{\sqrt{2}} = 120 \text{ V}$

Since generator is Y-connected,

$$V_{terminal} = \sqrt{3}(120) = 208 \text{ V}$$

122. (b)

The generator described above is Y-connected, so the direct current in the resistance test flows through two windings

$$2R_A = \frac{V_{DC}}{I_{DC}}$$

$$R_A = \frac{10}{2 \times 25} = 0.2\ \Omega$$

Internal generated voltage,

$$E_A = V_{ph\ O.C.} = \frac{V_T}{\sqrt{3}}$$

$$E_A = \frac{540}{\sqrt{3}} = 311.77 \text{ V}$$

The short circuit is equal to line current, since generator is Y-connected,

$$I_{A,\ SC} = I_L = 300 \text{ A}$$

$$\frac{E_A}{I_A} = \sqrt{R^2 + X_S^2}$$

$$X_S = \sqrt{\left(\frac{311.77}{300}\right)^2 - (0.2)^2}$$

$$X_S = 1.02\ \Omega$$

123. (a)

We know that,

$$\text{Torque, } T = \frac{3}{\omega_{sm}} \times \frac{V^2}{R_2'} s \text{ (for low slip)}$$

Now, T = constant $\quad T \propto V^2 s$

(or) $$V_2^2 s_2 = V_1^2 s_1$$

(or) $$s_2 = \left(\frac{V_1}{V_2}\right)^2 s_1$$

(or) $$s_2 = 4s_1,$$

hence slip increases 4 times,

Also, $$T = \frac{3I_2'^2}{\omega_{sm}} \times \frac{R_2'}{s} = \text{const.}$$

(or) $$I_2'^2 \propto s$$

$$\frac{I_2'}{I_1'} = \sqrt{\frac{s_2}{s_1}} = \sqrt{\frac{4}{1}} = 2$$

Hence, current increases by 2 times.

124. 0.03 (0.01 to 0.10)

Given, $\eta = 0.9$

Let, P = Stator copper loss

= Rotor copper loss = Iron loss

No load losses = P_{NL}

Mechanical loss = P_{mL}

No load losses = Iron loss + Mechanical losses

$$P_{NL} = P + P_{mL}$$

$$3\,P_{mL} = P + P_{mL}$$

$$P_{mL} = \frac{P}{2}$$

$$\text{Efficiency, } \eta = \frac{\text{Output Power}}{\text{Output power} + \text{losses}} = \frac{37}{37 + P + P + P + \frac{P}{2}}$$

$$0.90 = \frac{37}{37 + 3.5P}$$

$$P = 1.1746 \approx 1.175 \text{ kW}$$

Airgap power = P_{output} + Mechanical losses + Rotor copper losses

$$\text{Now slip, } s = \frac{\text{Rotor copper losses}}{\text{Air gap power}}$$

$$= \frac{1.175}{37 + \frac{1.175}{2} + 1.175} = 0.03$$

125. (b, d)

$$K = \frac{200}{2000} = 0.1$$

$$R_{01} = R_1 + R_2' = R_1 + \frac{R_2}{K^2} = 0.2 + \frac{0.002}{0.1^2} = 0.4\ \Omega$$

$$X_{0I} = X_1 + X_2' = X_1 + \frac{X_2}{K^2} = 0.45 + \frac{0.0045}{0.1^2} = 0.9\ \Omega$$

$$Z_{01} = \sqrt{R_{01}^2 + X_{01}^2} = 0.984\ \Omega$$

$$\text{Iron loss, } P_i = \frac{V^2}{R} = \frac{2000^2}{10000} = 400 \text{ Watts}$$

Copper loss at full load,

$$P_c = I_1^2 R_{01} = \left(\frac{100 \times 1000}{2000}\right)^2 \times 0.4 = 1000 \text{ W}$$

$$\%\eta = \frac{100 \times 1000 \times 0.8}{100 \times 1000 \times 0.8 + 1000 + 400} \times 100 = 98.28\%$$

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