Q.1 A Transformer has its maximum efficiency of 99% at 10KVA at 0.9 pf. The Cu-losses at 5 kW and 0.8 pf are

(a) 91 W (b) 30.2 W (c) 35.6 W (d) 23.5 W

Ans. (c)

Exp. At a load $S_L = xS_0 = 10$ kVA, $S_0 \rightarrow$ Rated & pf cos ϕ = 0.9,

Maximum efficiency $\eta_{\max} = 0.99$

$$\eta = \frac{xS_0 Cos\phi}{xS_0 Cos\phi + P_i + x^2 P_{cF}}$$

P_i & P_{CF} are Iron loss & full load Cu losses.

for $\eta_{\max}$ $\quad P_i = x^2 P_{CF}$

$$\Rightarrow \quad 0.99 = \frac{10 \times 0.9}{10 \times 0.9 + P_i + P_i}$$

$$\Rightarrow \quad P_i = 0.091 \text{kW}$$

$$x = \frac{S_L}{S_0} = \frac{10}{S_0}$$

$$p_i = x^2 P_{CF}$$

$$\Rightarrow \quad 0.091 = \left(\frac{10}{S_o}\right)^2 \times P_{CF}$$

$$\Rightarrow \quad P_{CF} = 9.1 \times 10^{-4} S_o^2 \text{ kW}$$

At a load $P_L = 5$kW, $Cos\phi = 0.8$

$$S_L = \frac{P_L}{Cos\phi} = \frac{5}{0.8} = 6.25 \text{ kVA}$$

$$x = \frac{S_L}{S_0} = \frac{6.25}{S_0}$$

Cu losses = $x^2 P_{CF}$

$$= \left(\frac{6.25}{S_0}\right)^2 \times 9.1 \times 10^{-4} S_0^2$$

$$= 0.0356 \text{ kW}$$

$$= 35.6W$$

Common Data for Q.2, Q.3 & Q.4

A 10KVA, 1000V/100V Single phase transformer has

$R_1 = 2\Omega$, $X_1 = 5\Omega$, $R_2 = 0.03\Omega$ and $X_2 = 0.05\Omega$

Q.2 The secondary terminal voltage (approximately) at 0.707 lag pf when delivering full load current with primary voltage held fixed at 1 kV.

(a) 80.3 V (b) 90.4 V (c) 96.2 V (d) 98.5 V

Ans. (b)

Q.3 Determine the pf of rated load, supplied at 100V such that the terminal voltage observed on reducing the load to zero is still 100V.

(a) 0.89 lead (b) 0.707 lead (c) 0.92 lag (d) upf

Ans. (a)

Exp. Transformation rotio $K = \frac{N_2}{N_1} = \frac{1}{10}$

$$R_2' = \frac{R_2}{K^2} = \frac{0.03}{\left(1/10\right)^2} = 3\Omega$$

$$X_2' = \frac{X_2}{K^2} = 5\Omega$$

Total resistance referred to primary

$$R_{01} = R_1 + R_2' = 2 + 3 = 5\Omega$$

$$X_{01} = X_1 + X_2' = 5 + 5 = 10\Omega$$

Rated $S_0 = 10\text{ kVA}$

$$V_1 = 1\text{ kV},\ V_2 = 100\text{V}$$

$$S_0 = V_1 I_1 = V_2 I_2$$

$\Rightarrow$ $I_1 = 10A$ & $I_2 = 100A$

Base impedance referred to primary

$$Z_{1B} = \frac{V_1}{I_1} = \frac{1000}{10} = 100\Omega$$

per unit impedances.

$$R_{pu} = \frac{R_{o1}}{Z_{1B}} = \frac{5}{100} = 0.05$$

$$X_{pu} = \frac{X_{01}}{Z_{1B}} = \frac{10}{100} = 0.1$$

At rated current & $pf\ Cos\phi$ (lag), The voltage regulation,

$$VR = R_{pu} Cos\phi + X_{pu} S\text{in}\,\phi$$

At $Cos\phi = 0.707$ lag

$$\Rightarrow \phi = 45° \Rightarrow Sin\phi = 0.707$$

$$VR = 0.05 \times 0.707 + 0.1 \times 0.707$$

$$= 0.10605 = 10.605\%$$

Secondary voltage referred to primary

$$V_2' = \frac{V_2}{K} = 10V_2$$

$$V.R = \frac{V_1 - V_2'}{V_2'}$$

$$\Rightarrow 0.10605 = \frac{1000 - V_2'}{V_2'}$$

$$\Rightarrow V_2' = 904.12V$$

$$\Rightarrow V_2 = 90.412V$$

It no-load voltage is equal to full load voltage, i.e. $V_{nl} = V_{fl} \Rightarrow V.R = 0$

At leading pf $\cos\phi$

$$VR = R_{pu}Cos\phi - X_{pu}Sin\phi = 0$$

$$\Rightarrow \tan\phi = \frac{R_{pu}}{X_{pu}} = \frac{0.05}{0.1} = 0.5$$

$$\Rightarrow \phi = 26.57^o \Rightarrow pf = Cos\phi = 0.895\ lead$$

Q.4 Determine the maximum applied voltage on primary side if rated load is delivered at secondary at lag pf

(a) 1000 V (b) 988 V (c) 1231 V (d) 1112 V

Ans. (d)

Exp.

At lag pf & rated load

$$VR = R_{pu}Cos\phi + X_{pu}Sin\phi$$

$$VR_{\max} \quad if \quad \frac{d}{d\phi}(VR) = 0$$

$$\Rightarrow \tan\phi = \frac{X_{pu}}{R_{pu}} = \frac{0.1}{0.05} = 2$$

$$\Rightarrow \phi = 63.45^\circ$$

$$VR_{\max} = 0.05 \times \cos 63.45^\circ + 0.1 \times \sin 63.45^\circ$$

$$= 0.112 = 11.2\%$$

$$V_2 = 100V \text{ rated} \Rightarrow V_2' = \frac{V_2}{K} = 1000V$$

$$V.R. = \frac{V_1 - V_2'}{V_2'}$$

$$\Rightarrow VR_{\max} = \frac{V_{1\max} - V_2'}{V_2'}$$

$$\Rightarrow 0.112 = \frac{V_{1\max} - 1000}{1000}$$

$$\Rightarrow V_{1\max} = 1112V$$

Q.5 consider the following statements regarding Distribution Transformer.

1. It operates at rated load in general.
2. Its magnetising flux ϕ_m is smaller than the ordinary power transformer of the same rating.
3. Its Iron losses are large as compared to the ordinary power transformer of the same rating.
4. Its size is large as compared to the ordinary power trasformer of same rating.
5. It gives maximum efficiency at rated load

The currect statements are

(a) 1, 2 and 3 (b) 3 and 4 (c) only 3 (d) 3, 4 and 5

Ans. (c)

Exp.
Distribution transformer operates opproximately 70% of its rated load mostly

So $\eta_{\max}$ at $x = 0.7$

$$P_i = x^2 P_{CF} \Rightarrow P_i = 0.49 P_{CF}$$

while ordinary power transformer operates mostly at its rated load

So $\eta_{\max}$ at $x = 1$

$$P_i = x^2 P_{CF} \Rightarrow P_i = P_{CF}$$

So Iron loss in distribution transformer are comparatively smaller.

So peak flux density B_m in distrebution Transformer is designed to be small.

Magnetising flux $\phi_m \alpha \frac{V}{f}$ some for both.

If area of cross-section of core = A

$$\phi_m = B_m A$$

As B_m small so A is large in distribution transormer.

Common Data for Q.6 & Q.7

A 500 V/100 V, 10 kVA, T wo winding transformer is to be used as an autotransformer to supply a 100V load from 600V source.

Q.6 Its kVA rating as an auto transformer.

(a) 12 kVA (b) 8 kVA (c) 60 kVA (d) 48 kVA

Ans. (a)

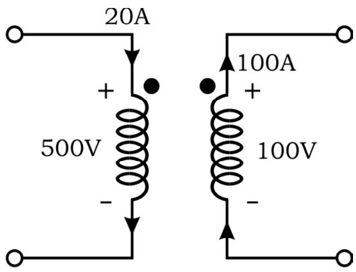
Q.7 Its efficiency at rated load and 0.9 pf(lag) is 98% as a 2-winding transformer. Then efficiency as an auto transformer

(a) 96.8 % (b) 99.6 % (c) 99.2 % (d) 98.3%

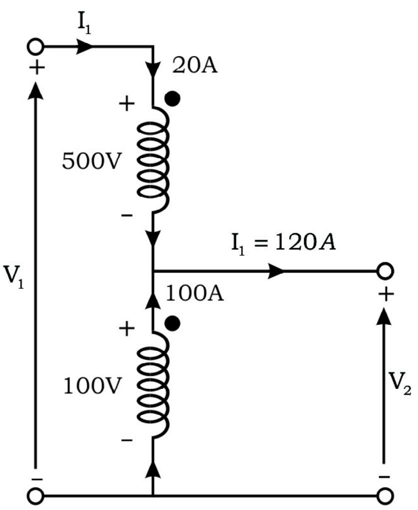
Ans. (d)

Exp.

	10 kVA
voltages	500/100 V
currents	20 A/100 A



Auto transformer as 600V/100V



$V_1 = 600V,\quad I_1 = 20A$

$V_2 = 100V,\quad I_2 = 120A$

$S_{auto} = V_1 I_1 = V_2 I_2 = 12$ kVA

At rated load $x = 1$

Efficiency of Tw transformer

$$\eta = \frac{Cos\phi}{SCos\phi + P_i + P_{CF}}$$

$$0.98 = \frac{10 \times 0.9}{10 \times 0.9 + P_i + P_{CF}}$$

$\Rightarrow \quad P_i + P_{CF} = 0.184$ kW

As current & voltages in each winding is same in both two-winding & auto trans

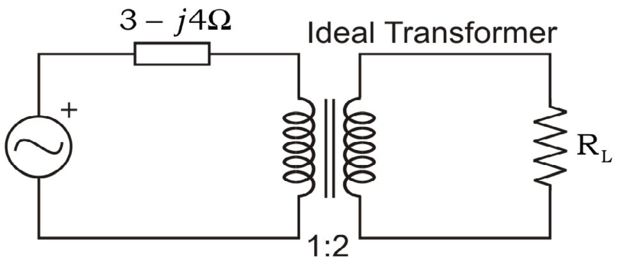
former configuration the losses $P_i + P_{CF}$ same

$$\eta_{auto} = \frac{S_{auto}\ Cos\varphi}{S_{auto}\ Cos\phi + P_i + P_{CF}}$$

$$= \frac{12 \times 0.9}{12 \times 0.9 + 0.184}$$

$= 98.32\%$

Q.8



The value of load resistance for maximum power delivered to R_L is

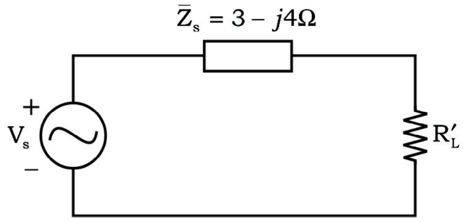
(a) 20 Ω (b) 5 Ω (c) 12 Ω (d) 1.25 Ω

Ans. (a)

Exp. Transformation Ratio $K = \frac{N_2}{N_1} = 2$

load resistance refarred to primary

$$R_L^1 = \frac{R_L}{K^2} = \frac{R_L}{4}$$

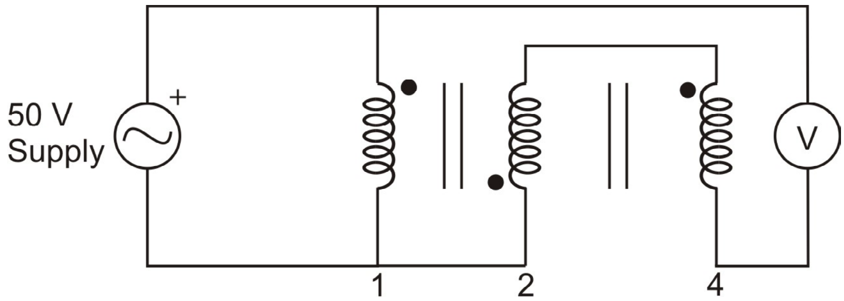


For maximum power delivered

$R_L^1 = |Z_s| = |3 - j4| = 5\Omega$

$\Rightarrow R_L = 20\Omega$

Q.9 A 1:2:4 three winding transformer is connected as shown in figure below

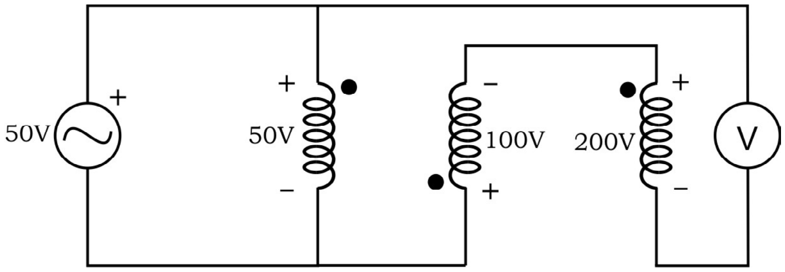


The reading of voltmeter

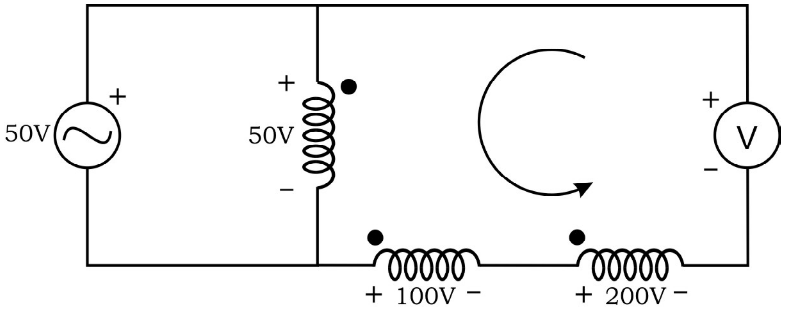
(a) 50 V (b) 250 V (c) 150 V (d) 350 V

Ans. **(d)**

Exp.



OR



Using KVL

$-V_0 + 50 + 100 + 200 = 0$

$\Rightarrow \quad V_0 = 350V$

Q.10 The efficiency of a 100 kVA transformer at upf is 98% at full as well as half load. The maximum efficiency is obtained at a load

(a) 70.7 kVA (b) 50 kVA (c) 90.6 kVA (d) 82.5 kVA

Ans. (a)

Exp.

$$\eta = \frac{xS_o Cos\phi}{xS_o Cos\phi + P_i + x^2 P_{CF}}$$

Rated $So = 100$ kVA

$\eta = 98\% = 0.98$

$pf\ \ Cos\phi = 1$

At full load $x = 1$

$$0.98 = \frac{1\times 100\times 1}{1\times 100\times 1 + P_i + 1^2 \times P_{CF}}$$

$\Rightarrow \quad P_i + P_{CF} = 2.04\text{kW}\ldots(1)$

At half full load $x = 0.5$

$$0.98 = \frac{0.5\times 100\times 1}{0.5\times 100\times 1 + P_i + (0.5)^2 \times P_{CF}}$$

$\Rightarrow \quad P_i + 0.25P_{CF} = 1.02\ldots(2)$

By solving (1) & (2)

$P_i = 0.68\text{kW}, \qquad P_{CF} = 1.36\text{kW}$

For $\eta_{\max} \quad P_i = x^2 P_{CF}$

$$\Rightarrow x = \sqrt{\frac{P_i}{P_{CF}}} = \sqrt{\frac{0.68}{1.36}} = 0.707$$

$S_L = xS_0 = 0.707\times 100$

$= 70.7$ kVA

Q.11 A 4-pole Alternator has 72 slots carrying a 6-phase distributed winding. Each coil has span from 1 to 10. The winding factor for 3rd harmonic is

(a) $\frac{\cot 15^0}{3}$ (b) $\frac{\cot 15^0}{6}$ (c) $\frac{1}{3\cos 15^0}$ (d) $\frac{1}{6\sin 15^0}$

Ans. (d)

Exp.

$S = 72,\ P = 4,\ m = 6$

SPP $q = \frac{S}{mp} = 3$

$$\gamma = \frac{\pi P}{S} = \frac{\pi\times 4}{72} = \frac{\pi}{18} = 10^\circ$$

$$K_{d_3} = \frac{Sin\,\frac{3q\gamma}{2}}{qSin\,\frac{3\gamma}{2}} = \frac{Sin\,\frac{3\times 3\times 10^\circ}{2}}{3Sin\,\frac{3\times 10^\circ}{2}}$$

$$= \frac{1}{3\sqrt{2}Sin15^{\circ}}$$

Coil span from 1 to 16

i.e. coil span $= 16 - 1 = 15$ slots

$$= 15\gamma = 150^{\circ}$$

Angle of chording $\rho = 180° - 150° = 30°$

Pitch factor $K_{P3} = Cos\frac{3\rho}{2} = Cos\frac{3 \times 30^{\circ}}{2}$

$$= \frac{1}{\sqrt{2}}$$

Winding factor

$$K_w = K_{d_3}K_{P_3} = \frac{1}{6\sin15^{\circ}}$$

Common Data for Q.12 & Q.13

A 220V, 10 kW, DC shunt motor is operating at a speed of 1000 rpm when taking 11A from supply. Its armature resistance is 2Ω and field resistance is 220Ω.

Q.12 The torque developed by motor

(a) 20 Nm (b) 23.2 Nm (c) 19.1 Nm (d) 18 Nm

Ans. (c)

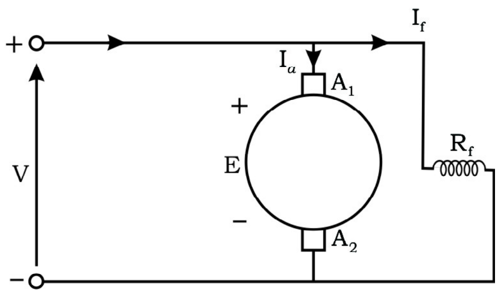
Q.13 If armature terminals are reversed suddenly and a resistance of 40Ω is connected in series with armature. The Braking Torque developed is

(a) 200 Nm (b) 23.2 Nm (c) 19.1 Nm (d) 230.2 Nm

Ans. (c)

Exp.

Shunt Motor



supply $V = 220V, I = 11A$

Field current $I_f = \frac{V}{R_f} = \frac{220}{220} = 1A$

arm current $I_a = I - I_f = 10A$

Back emf $E = V - I_aR_a = 220 - 10 \times 2 = 200V$

$$E = K_n\phi N \text{ Where } K_n = \frac{ZP}{60A}$$

As I_f = Constant $\Rightarrow \phi =$ Constant

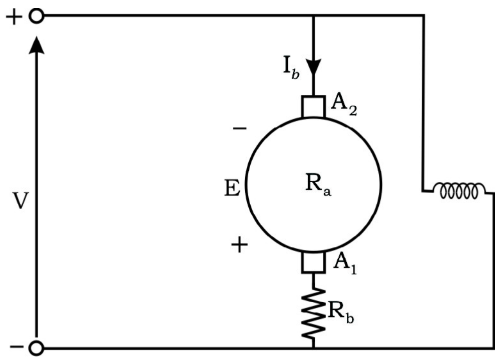
$$K_n\phi = \frac{E}{N} = \frac{200}{1000} = 0.2\ V/\text{rpm}$$

Toque developed $T = K_a\phi I_a$ Where $K_a = \frac{ZP}{2\pi A}$

$$T = \frac{30}{\pi}K_n\phi I_a = \frac{30}{\pi}\times 0.2\times 10$$

$$= 19.1 Nm$$

If arm. terminals are interchanged



Braking current

$$I_b = \frac{V+E}{R_a+R_b} = \frac{220+200}{2+40}$$

$$= 10A$$

Braking torque developed

$$T_b = K_a\varphi I_b = \frac{30}{\pi}K_n\varphi I_b$$

$$\frac{30}{\pi}\times 0.2\times 10$$

$$= 19.1 Nm$$

Q.14 An Isolated Induction Generator without Capacitor Bank can supply the power to

(a) $3-\phi$ Induction motor at no load

(b) DC motor through $3-\phi$ rectifier

(c) Overexcited synchronuous motor

(d) Under excited synchronuous motor

Ans. (c)

Exp.

Induction gen. can operate only at leading power factor. so load connected should be of leading pf i.e. overexcited syn. motor.

Q.15 If the voltage Regulation of a DC generator is –95% approximately. It is

(a) DC Shunt Generator (b) DC Series Generator

(c) Level Compound Generator (d) Differentially Compound Generator

Ans. (b)

Q.16 Match the lists

	List-I		List-II
A.	DC Shunt Generator	**1.**	–8%
B.	Level Compound Generator	**2.**	12%
C.	Cumulative Compound Generator	**3.**	0%
D.	Differential Compound Generator	**4.**	4%

	A	B	C	D
(a)	3	4	1	2
(b)	2	3	4	1
(c)	3	1	4	2
(d)	4	3	2	1

Ans. (b)

Q.17 A DC generator is supplying rated load at 230V. If the terminal voltage observed on reducing the load to zero is still 230V then it is a

(a) Under Compound Generator
(b) Differential Compound Generator
(c) Series Generator with large number of field turns
(d) Level Compound Generator

Ans. (d)

Q.18 A DC generator is operating at constant speed and constant field excitation. If it is supplying maximum power at a voltage of 220 it's generated emf is

(a) 110 V (b) 220 V
(c) 440 V (d) depends upon the armature resistance

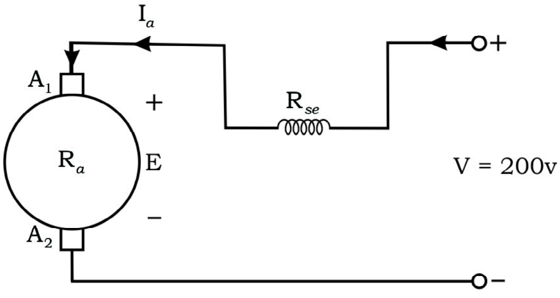
Ans. (c)

Q.19 A DC series motor is driving a load which is propotional to the cube of speed. The total resistance of motor is 2Ω and motor takes 5A and runs at 1000rpm, when operating from 200V supply. The resistance to be inserted in series with armature to reduce the operating speed to 600rpm, is (Neglect saturation).

(a) 10.23Ω (b) 61.4Ω (c) 5.2Ω (d) 2.5Ω

Ans. (b)

Exp. DC series motor



Total resistance $R = R_a + R_{se} = 2\Omega$

$V = 200V$ At $I_a = 5A$, $N = 1000$rpm

back emf $E = V - I_a R = 200 - 5 \times 2 = 190V$

Flux by series field $\phi_{se} \propto I_a$

$\Rightarrow \phi_{se} = K_{se} I_a$

$$E = K_n \phi_{se} N = K_n K_{se} I_a N$$

Constant $K_n K_{se} = \frac{E}{I_a N} = \frac{190}{5 \times 1000}$

$$= 0.038 \ \mathrm{V/A\text{-}rpm}$$

Torque $T \propto N^3$

$\Rightarrow \quad \frac{T'}{T} = \frac{N'^3}{N^3}$

Torque develope $T = K_a \varphi_{se} I_a = K_a K_{se} I_a^2$

or $\quad T \propto I_a^2$

$\Rightarrow \quad \left(\frac{I'_a}{I_a}\right)^2 = \left(\frac{N'}{N}\right)^3$

$\Rightarrow \quad \left(\frac{I'_a}{5}\right)^2 = \left(\frac{600}{1000}\right)^3 \Rightarrow I'_a = 2.32A$

At $\quad I'_a = 2.32A$

$$E' = K_n K_{se} I'_a N'$$

$$= 0.038 \times 2.32 \times 600$$

$$= 52.9V$$

Let $\quad R'_a = R_a + \mathrm{R}_{ext}$

$$E' = V - I'_a R'_a$$

$$52.9 = 200 - 2.33 \times R'_a$$

$\Rightarrow \quad R'_a = 63.4\Omega$

$\Rightarrow \quad \mathrm{R}_{ext} = 61.4\Omega$

Q.20 A 5 kW, 220 V, 4-pole, lap connected DC motor has 400 armature conductors. At full load, the flux per pole is 25 mWb and rotational losses are 200W. The armature resistance is $1\,\Omega$. The speed at full load is

(a) 1280 rpm (b) 1350 rpm (c) 1160 rpm (d) 1400 rpm

Ans. (c)

Exp.

At full load, Net mechanical output =5 kW

Gross power $o/p = 5000 + 200 = 5200W$

At full load current

$$E = V - I_a R_a = 220 - I_a \times 1$$

power output $P_0 = E I_a$

$$5200 = (220 - I_a) I_a$$

$$\Rightarrow I_a^2 - 220 I_a + 5200 = 0$$

$$I_a = 26.9A, 193.1A$$

So $I_a = 26.9A$, (193.1A large so it not considerable

$E = 220 - 26.9 = 193.1V$

$$E = \frac{\phi ZN}{60}\left(\frac{P}{A}\right)$$

Lap connected so number of paralled paths

$A = P = 4$

$$193.1 = \frac{0.025 \times 400 \times N}{60}\left(\frac{4}{4}\right)$$

$\Rightarrow$ $Speed\ N = 1158.6$rpm

Q.21 A DC shunt motor is driving constant power load at rated speed while drawing rated armature current. If the terminal voltage is halved but field current is kept constant, then (approximately).

(a) I_a gets doubled & N is halved

(b) Both I_a & N gets doubled

(c) I_a gets doubled but N remains same

(d) I_a gets halved & N gets doubled

Ans. (a)

Exp.

Power output $P_0 = EI_a$ constant

field current I_f = const $\Rightarrow \phi =$ constant

back emf $E = V - I_a R_a$

Let $R_a \simeq 0 \Rightarrow E \simeq V$

$P_o \simeq V\ I_a =$ constant

As $V' = \frac{V}{2}$ $P_o = V'I'_a = V\ I_a$

$\Rightarrow$ $I'_a = 2I_a$

Speed $N = \frac{E}{K_n \phi} \simeq \frac{V}{K_n \phi}$

$$N' = \frac{V'}{K_n \phi} = \frac{V}{2K_n \phi} = \frac{N}{2}$$

Common Data for Q.22 & Q.23

The stator of a $3-\phi$, 4-pole SRIM is connected to 50Hz supply. At the rotor terminals a frequency of 30Hz is required.

Q.22 The possible speed (s) of rotor is (are)

(a) 600 rpm (b) 2400 rpm

(c) 600 or 2400 rpm (d) 600 & 900 rpm

Ans. (c)

Q.23 For a frequency of 30Hz across rotor terminals

(a) Two emfs of equal magnitudes and opposite phase sequence can be obtained

(b) Two emfs of different magnitude and same sequence

(c) Only one possible emf
(d) The emf of any magnitude and sequence

Ans. (a)

Q.24 A 6-pole, 50Hz, $3-\phi$ I.M. has a rotor resistance of 0.2Ω per phase and maximum torque is obtained at a speed of 875rpm while full load speed is 960rpm. The resistance to be added in each rotor phase to obtain 80% of full load troque at starting is

(a) 0.16Ω (b) 0.05Ω (c) 0.22Ω (d) 0.192Ω

Ans. (d)

Exp.

$$N_s = \frac{120f}{P} = 1000rpm$$

speed for $T_{\max,}$ $N_m = 875rpm$

So slip $s_m = \frac{N_s - N_m}{N_s} = 0.125$

Full load speed $N_{fl} = 960$ rpm

$$s_{fl} = 0.04$$

if stator impedence is neglected

$$s_m = \frac{R_2}{X_2} = 0.125$$

$$\Rightarrow \frac{0.2}{X_2} = 0.125$$

$$\Rightarrow X_2 = 1.6\Omega$$

$$T = \frac{3}{\omega_s}\frac{E_2^2 R_2 / s}{\left(\frac{R_2}{s}\right)^2 + X_2^2}$$

At full load & $R_{20} = 0.2\Omega$

$$T_{fl} = \frac{3E_2^2}{\omega_s}\frac{0.2/0.04}{\left(\frac{0.2}{0.04}\right)^2 + (1.6)^2}$$

$$= 0.18 \times \left(\frac{3E_2^2}{\omega_s}\right)$$

At starting $s = 1$ & $R_2 = R_{20} + R_{ext}$

$$T_{st} = \frac{3E_2^2}{\omega_s}\frac{R_2}{R_2^2 + X_2^2} = 0.8T_{fl}$$

$$\Rightarrow \frac{3E_2^2}{\omega_s} \times \frac{R_2}{R_2^2 + (1.6)^2} = 0.8 \times 0.18\left(\frac{3E_2^2}{\omega_s}\right)$$

$$\Rightarrow \frac{R_2}{R_2^2+2.56}=0.145$$

$$\Rightarrow R_2^2-6.9R_2+2.56=0$$

$$R_2=0.39\Omega,\ 6.5\Omega$$

Higher value 6.5Ω creates excess power loss
So it is not acceptable

So $R_2=0.39\Omega$

$$\Rightarrow R_{ext}=0.19\Omega$$

Q.25 An alternator has a synchronuous reactance of 20% and neglegible resistance. The pf of rated load at which it gives zero voltage regulation is

(a) upf (b) 0.1 lead (c) 0.995 lead (d) 0.99 lag

Ans. (c)
Exp.

Resistance $R_a \simeq 0$, $X_s=20\%=0.2pu$

Rated current = I_a, Rated voltage = V

Base impedance $Z_B=\frac{V}{I_a}$

pu reactance $X_s=\frac{X_s}{Z_B}$

$$X_{s(pu)}=\frac{X_sI_a}{V}=0.2,\ R_{a(pu)}=\frac{I_aR_a}{V}$$

zero voltage regulation, i.e. E = V
At leading pf

$$E^2=(VCos\theta+I_aR_a)^2+(V\sin\theta-I_aX_s)^2$$

$$=V^2\left[\left(Cos\theta+\frac{I_aR_a}{V}\right)^2+\left(Sin\theta-\frac{I_aX_s}{V}\right)^2\right]$$

$$E^2=V^2\left[(Cos\theta+R_{pu})^2+(Sin\theta-X_{pu})^2\right]$$

$$\Rightarrow 1=(Cos\theta)^2+(Sin\theta-X_{pu})^2$$

$$=Cos^2\theta+Sin^2\theta-2X_{pu}Sin\theta+X_{pu}^2=1$$

$$\Rightarrow Sin\theta=\frac{X_{pu}}{2}=\frac{0.2}{2}=0.1$$

$$\Rightarrow Cos\theta=0.995 \text{ leading}$$

Q.26 An alternator has armature resistance of 2% and synchronuous reactance of 20%. The pf at which it gives voltage regulation of 10%.

(a) 0.956 lead (b) 0.944 lag (c) 0.823 lag (d) 0.853 lead

Ans. (b)
Exp.

$$V.R. = \frac{E - V}{V} \times 100 = 10$$

$$\Rightarrow E = 1.1V$$

As $E > V$, i.e. $pf\ Cos\theta$ lag

$$E^2 = (VCos\theta + I_a R_a)^2 + (VSin\theta + I_a X_s)^2$$

$$\Rightarrow E^2 = V^2\left[(Cos\theta + R_{pu})^2 + (Sin\theta + X_{spu})^2\right]$$

$$(1.1)^2 = (Cos\theta + 0.02)^2 + (Sin\theta + 0.2)^2$$

$\Rightarrow$ $1.21 = Cos^2\theta + Sin^2\theta + 0.04Cos\theta + 0.0004 + 0.4Sin\theta + 0.04$

$\Rightarrow$ $0.4Sin\theta + 0.04Cos\theta = 0.1696$

$\Rightarrow$ $Cos\theta + 10Sin\theta = 4.24$

$1 = RCos\alpha,\ 10 = RSin\alpha$

$\Rightarrow$ $R = 10.05$, $\alpha = 84.3^o$

$R\left[Cos\theta Cos\alpha + Sin\theta Sin\alpha\right] = 4.24$

$\Rightarrow$ $Cos(\theta - \alpha) = 0.422$

$$\Rightarrow \theta - \alpha = \pm 65^\circ$$

$$\Rightarrow \theta = 149.4^o, 19.3^o$$

pf angle $\theta < 90^\circ \Rightarrow \theta = 19.3^\circ \Rightarrow Cos\theta = 0.944$

Q.27 A lossless salient pole synchronuous motor has reluctance along q-axis twice that of along d-axis and operating in such a manner as excitation voltage is equal to the terminal voltage. The ratio of reluctance torque to the electro-magnetic torque developed when it is delivering maximum load is

(a) 0.5 (b) 0.75 (c) 0.25 (d) 1

Ans. (a)

Exp.

The power o/p developed

$$P = \frac{EV}{X_d} Sin\delta + \frac{V^2}{2}\left[\frac{1}{X_q} - \frac{1}{X_d}\right] Sin 2\delta$$

$$E = V,\ R_q = 2R_d$$

Reactances $X_q = \frac{\omega N^2}{R_q}, X_d = \frac{\omega N^2}{R_d}$

$$\Rightarrow X_q = \frac{X_d}{2}$$

$$P = \frac{V^2}{X_d} Sin\,\delta + \frac{V^2}{2X_d} Sin\,2\delta$$

Torque developed $T = \frac{P}{\omega_s}$

$$T = \frac{V^2}{\omega_s X_d} Sin\,\delta + \frac{V^2}{2\omega_s X_d} Sin\,2\delta$$

electromagnetic torque $T_{em} = \frac{V^2}{\omega_s X_d} Sin\delta$

Reluctance torque $T_{rel} = \frac{V^2}{2\omega_s X_d} Sin 2\delta$

Ratue $\frac{T_{rel}}{T_{em}} = \frac{Sin 2\delta}{2Sin\delta} = Cos\delta$

For maximum load $\frac{dP}{d\delta} = 0$ or $\frac{dT}{d\delta} = 0$

$$\frac{dP}{d\delta} = \frac{V^2}{X_d}\left[Cos\delta + Cos 2\delta\right] = 0$$

$$Cos 2\delta + Cos\delta = 0$$

$$\Rightarrow 2Cos^2\delta + Cos\delta - 1 = 0$$

$$Cos\delta = \frac{-1 \pm \sqrt{1+4}}{4}$$

$$= \frac{3-1}{4} = \frac{1}{2} \ (\text{As } \cos\delta \neq -ve)$$

$$\frac{T_{rel}}{T_{em}} = \frac{1}{2}$$

Q.28 A $3-\phi$ synchronuous motor, connected to $\infty -$ bus, is operating with normal excitation with increase in load

1. Armature current increases
2. pf becomes lagging
3. pf becomes leading
4. load angle increases
5. Reactive power flows from Bus to motor
6. Reactive power flows from motor to Bus

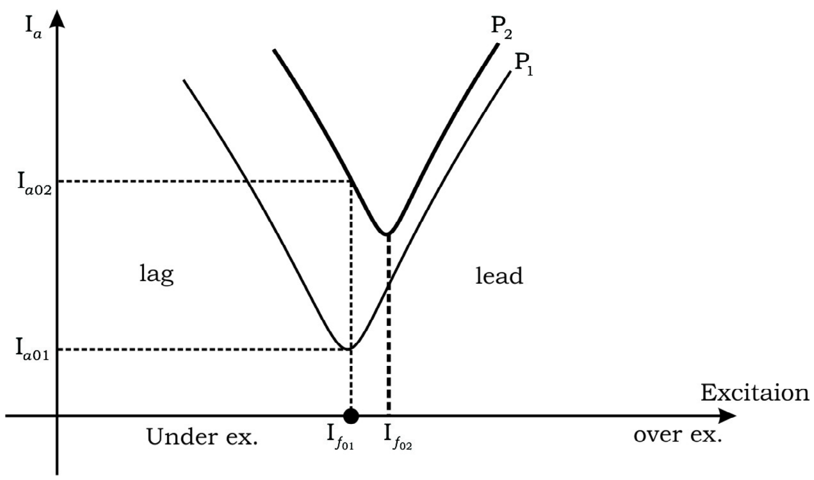
from these correct statements are

(a) 1, 3, 4 & 6 (b) 2, 4, & 5 (c) 1, 3, & 6 (d) 1, 2, 4 & 5

Ans. (d)

Exp.

The V curres of syn. motor

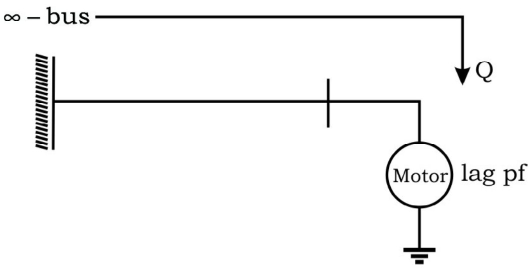


At load P_1, I_{f01} is nominal excitation (at upf) and current I_{a01}

If load is increased $P_2 > P_1$

Current increases $I_{a02} > I_{a01}$

For $P_{2,}$ I_{f02} is nominal. But I_f in constant at I_{f01} so for P_2, I_{f01} gives under excited syn. motor, i.e. at lag pf.

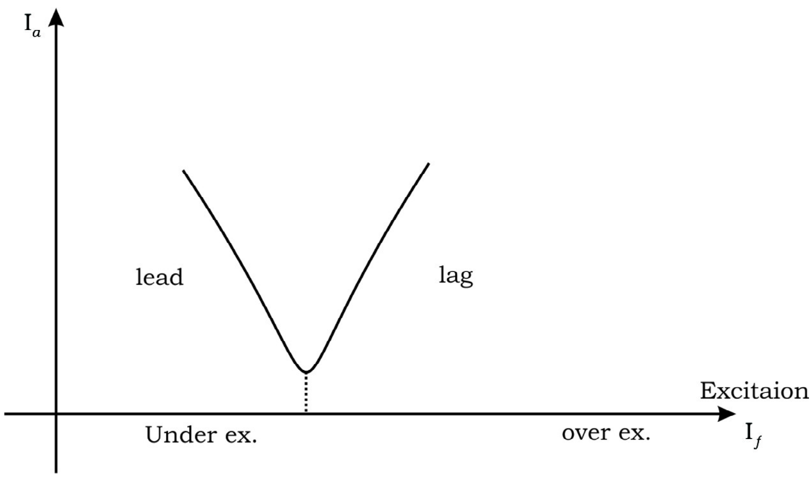


Syn. motor at lag pf consumes VAR from bus.

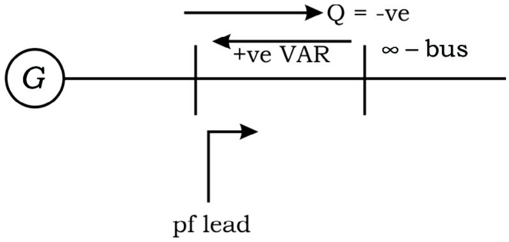
Q.29 A synchronuous generator fed from $\infty -$ bus is delivering half-full load. If an increase in its field current causes a reduction in its armature current, then generator is

(a) delivers active power to bus and absorbs reactive power from bus
(b) absorbs active power from bus and delivers reactive power to bus
(c) absorbs active and reactive power from bus
(d) delivers active and reactive power to bus

Ans. (a)
Exp.



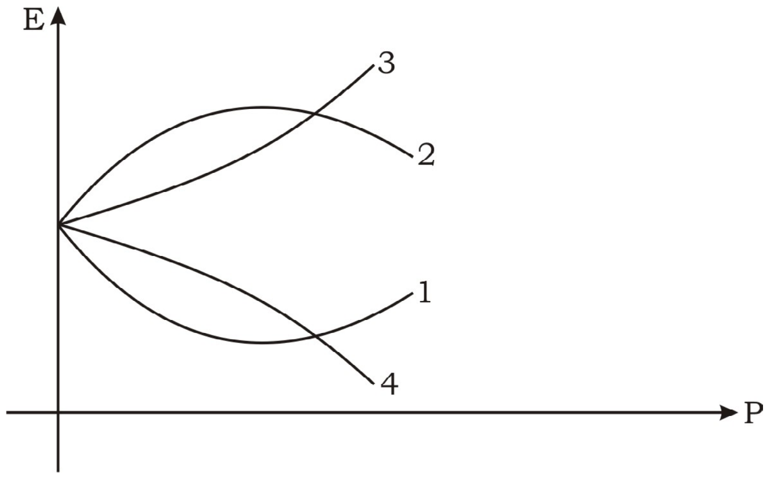
Increase in field current causes a reduction in armature current so syn. generator is operating in under excited condition, i.e. at leading pf .



Gen. delivering active power to the bus.

At lead pf , generator is supplying -ve VAR to bus hence it is consuming +ve VAR from the bus.

Q.30 A $3-\phi$ lossless cylindrical rotor synchronous motor is connected to $\infty-$bus, it is operating in under excited condition and at constant pf, if load on the motor is increased, the excitation voltage variation is represented by



(a) Curve-1 (b) Curve-2 (c) Curve-3 (d) Curve-4

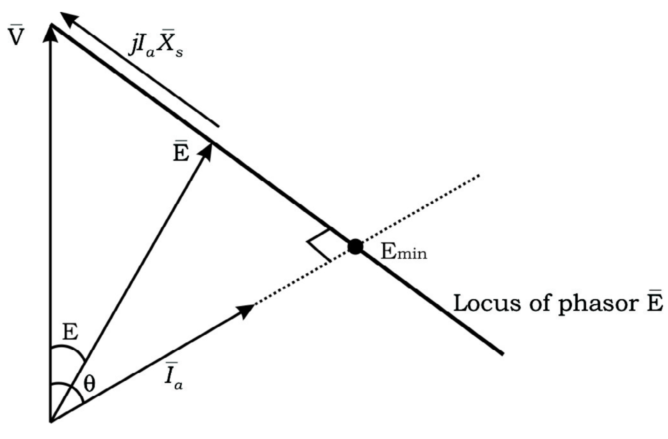
Ans. (a)

Exp.

For syn. motor

$$\overline{E} = \overline{V} - j\overline{I}_a X_s$$

At lag pf $cos\theta$ i.e $\overline{I}_a$ lags behind $\overline{V}$ by angle θ



Power $P = V\, I_a cos\theta$

V & $\cos\theta$ Cosnstant so if load P increases I_a increases and locus of phasor $\overline{E}$ is given by straight line as shown.

E is decreasing, reaches a minimum, i.e $E_{\min}$ and then increasing continuously.