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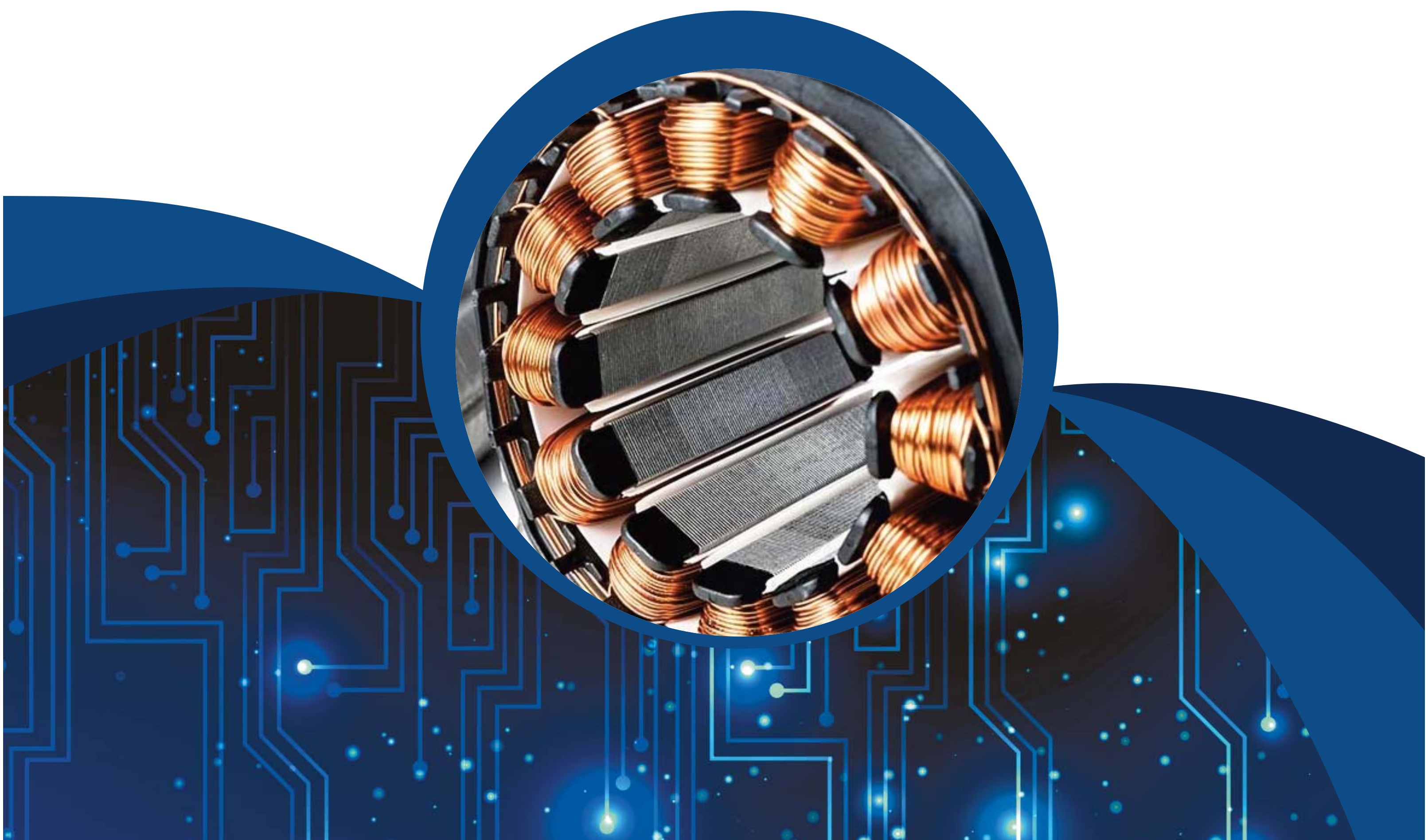
ELECTRONICS & TELECOMMUNICATION ENGINEERING

BASIC ELECTRICAL ENGINEERING

Volume - 1 : Study Material with Classroom Practice Questions



Chapter 1 Transformers
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (b)

Sol: $\uparrow B_{max} \propto \frac{V}{f\downarrow}$

Here V→ constant, f → decreased to half

$\Rightarrow$ B_{max} increased to double, which will drive the core in to deep saturation and also I_μ is very high to create double the rated flux.

02. Ans: (d)

Sol: As $\frac{V}{f}$ ratio is not equal

(i) $W_h \propto \frac{V_1^{1.6}}{f^{0.6}}$; as frequency increases, the hysteresis loss will decreases.

(ii) $W_e \propto V_1^2$ (Independent on frequency)

$\therefore$ Eddy current loss will be constant.

03. Ans: (a)

Sol: Lenz's Law:

The direction of statically induced emf is such that the current due to this emf will flow through a closed circuit in such a direction that it will in turn produce some flux according to **Electro Magnetic Theory** and this flux must opposes the changes in main field flux which is the cause for production of emf as well as current.

04. Ans: (a)

Sol: Specific weight = $\frac{\text{weight of transformer}}{\text{kVA rating}}$

If flux density is high, then required cross sectional area of core will be less. $\left(\because B \propto \frac{1}{A}\right)$

Therefore transformer weight will be decreased, the transformer should have less specific weight.

05. Ans: (b)

Sol: $\cos\phi_{sc} = \frac{R}{Z} = \frac{R_{02}}{\sqrt{5} \times R_{02}}$

$\cos\phi_{sc} = \frac{1}{\sqrt{5}}$

06. Ans: (d)

Sol: In ideal transformer, resistance of windings and magnetic leakage flux are zero.

07. Ans: (d)

Sol: As leakage flux is more, coefficient of coupling of transformer will decrease and also the inductive reactance drop will be increased.

08. Ans: (a)

Sol: V = constant and $f > f_{rated}$

$\Rightarrow \frac{V}{f}$ Ratio is not constant

$\therefore W_h \propto \frac{V_1^{1.6}}{f^{0.6}\uparrow} \Rightarrow W_h\downarrow$ & W_e= Const

But "W_h" is due to core loss component of current I_w

$\Rightarrow$ As f$\uparrow$, $W_h \downarrow \Rightarrow I_w \downarrow$.

Similarly $\downarrow I_\mu \propto \downarrow B_{max} \propto \dfrac{V}{f\uparrow}$

$\Rightarrow f\uparrow \Rightarrow B_{max}\downarrow \Rightarrow I_\mu \downarrow$

09. Ans: (b)

Sol: Deviation from first approximation is occurred by neglecting primary impedance drop, i.e I_0Z_1.

10. Ans: (d)

Sol: If the leakage impedance parameters for both primary and secondary are required separately, then it is usual to take $X_1 = X_2 = \frac{1}{2}X_e$ refer to the same side and $X_m >> X_1 (or) X_2$

11. Ans: (c)

Sol: Copper loss $\propto I^2$ i.e depends on load current called variable losses.

Iron loss $(W_h + W_e) \propto V^2$ (applied voltage), called constant losses.

12. Ans: (a)

Sol: W_i = 100 W at 40 Hz.

= 72 W at 30 Hz.

At 40 Hz, $W_i = Af + Bf^2$.

$100 = A\times40 + B\times40^2$ ……. (1)

At 30 Hz, $72 = A\times30 + B\times30^2$ ……. (2)

By solving above two equations,

B = 1/100 and A = 2.1

Hysteresis loss, $W_h = A\times f$

$= 2.1\times50 \Rightarrow 105$ W.

Eddy current loss $W_e = B\times f^2$

$= \dfrac{50\times50}{100}$

= 25 W.

13. Ans: (c)

Sol:
- For a given kVA rating of transformer, more the design frequency, lesser the cross sectional area of the core and lesser will be the size and weight of transformer.
- For a given kVA rating and designed frequency of transformer, superior the magnetic material used for transformer core, higher will be the flux density and lesser will be the size and weight of the transformer.
- Copper loss is directly proportional to square of the current and resistance.

14. Ans: (a)

Sol: **Distribution transformer:** Cu-losses take place based on load cycle of Consumer and Iron losses takes place throughout 24 hrs. Iron losses are kept minimum while designing

Power transformer: Cu-losses and Iron losses takes place steadily throughout 24 hrs. Copper losses are kept minimum while designing.

Both assertion and reason are correct, reason is correct explanation to assertion.

15. Ans: (a)

Sol: At 230 V, 50 Hz $\Rightarrow W_I$ = 1050 W

At 138 V, 30 Hz $\Rightarrow W_I$ = 500 W

V_{11} = 230 V $\qquad \dfrac{V_{11}}{f_1} = \dfrac{230}{50} = 4.6$

f_1 = 50 Hz $\qquad \dfrac{V_{12}}{f_2} = \dfrac{138}{30} = 4.6$

$V_{12} = 138$ V

$f_2 = 30$ Hz $\qquad \frac{V_1}{f} =$ constant

at $\frac{v_1}{f} = \text{constant}$

$W_I = Af + Bf^2$

at 50 Hz $\Rightarrow 1050 = A\,(50) + B\,(50)^2$ .... (i)

at 30 Hz $\Rightarrow 500 = A\,(30) + B\,(30)^2$ .... (ii)

by solving equation (1) & (2), we get

$A = 10.1667$

$B = 0.2167$

Then at 230V, 50 Hz

$W_h = Af = 10.1667 \times 50 = 508.33$ W

$W_e = Bf^2 = 0.2167 \times (50)^2 = 541.75$ W

16. Ans: (b)

Sol: **Open circuit test** is convenient to conduct on LV side by opening H.V winding due to the following reasons:

1. If the test is conducted on LV side, LV source sufficient to conduct the test to maintain rated flux.
2. If the test is conducted on LV side, low range meters are sufficient to conduct the test.
3. As magnitude of no-load current is more on LV side, this high no-load current can be accurately measured on LV side when compared to HV side.

Short circuit Test: As rated current is less on HV side, it is convenient to conduct this test on HV side by short circuiting LV terminals. By doing so low range of meters can be used for conducting this test.

17. Ans: (b)

Sol: $P = V\,I_w$

$\because$ Loss component $I_w = \frac{5\times10^3}{220} = 22.7$ A

18. Ans: (d)

Sol: Given that, no load loss components are equivally divided,

$W_h = W_e = 10$W

Initially test is conducted on LV side

Now $\frac{v}{f}$ ratio is $\frac{100}{50} = 2$

In HV side, applied voltage is 160V; this voltage on LV side is equal to 80V.

Now $\frac{V}{f}$ ratio is constant, $W_h \propto f$ and $W_e \propto f^2$.

$W_{h2} = W_{h1} \times \frac{f_2}{f_1}$

$= 10 \times \frac{40}{50} = 8$ W

$W_{e2} = W_{e1} \times \left(\frac{f_2}{f_1}\right)^2$

$= 10 \times \left(\frac{40}{50}\right)^2 = 6.4$W

Therefore,

$W_1 = W_{h2} + W_{e2}$

$\Rightarrow 8 + 6.4 = 14.4$W

In SC test,

I(HV side) = 5A

I(LV side) =10A

As the SC tests were conducted at rated current on both sides, the copper losses are same.

19. Ans: (a)

Sol: 1. O.C. Test ----------- Iron loss

2. S.C. Test ------------ Copper loss

3. Sumpner's test-- Copper loss and iron loss

4. Load Test ---------- Total losses

20. Ans: (a)

Sol: It is equivalent circuit of the Transformer under S.C condition when referred to primary side.

21. Ans: (b)

Sol: **Open circuit test** is convenient to conduct on LV side by opening H.V winding due to the following reasons:

1. If the test is conducted on LV side, LV source sufficient to conduct the test to maintain rated flux.
2. If the test is conducted on LV side, low range meters are sufficient to conduct the test.
3. As magnitude of no-load current is more on LV side, this high no-load current can be accurately measured on LV side when compared to HV side.

Short circuit Test: As rated current is less on HV side, it is convenient to conduct this test on HV side by short circuiting LV terminals. By doing so low range of meters can be used for conducting this test.

22. Ans: (d)

Sol: By keeping V_{sc} is constant, if supply frequency is increased.

X_{01} increases; Z_{01} increases

$$\downarrow I_{sc} = \frac{V_{sc} = \text{const}}{Z_{01}\uparrow}$$

$$\downarrow \cos\phi_{sc} = \frac{R_{01} = \text{const}}{Z_{01}\uparrow}$$

23. Ans: (c)

Sol: The Condition for maximum efficiency $= 2W_i$

$\therefore$ At maximum efficiency

$W_{total} = (150 + 150)$ W

$= 300$ W

24. Ans: (b)

Sol: kVA at $\eta_{max} = \text{F.L kVA} \times \sqrt{\frac{\text{Iron loss}}{\text{F.L cu loss}}}$

$$= \text{F.L kVA} \times \sqrt{\frac{P_C}{P_{SC}}}$$

25. Ans: (d)

Sol: **Methods to reduce Eddy current loss:**

The eddy current loss can be reduced by reducing conductivity of core. The conductivity of core can be reduced without affecting its magnetic properties by using following methods.

(i) By adding silica content up to an extent of 4 to 5 % to steel.

(ii) By using laminated core instead of solid core

Eddy current loss $w_e = KB_m^2 f^2 t^2$

Where, $K = \frac{\pi^2}{6\rho}$;

B_{max} = Maximum flux density.

f = frequency of eddy current (supply frequency).

t = Thickness of lamination

Observations:

$w_e \propto t^2$

The eddy current loss can be effectively reduced by reducing thickness of laminations.

Higher the design frequency of transformer, thinner will be the thickness of lamination required.

26. Ans: (c)

Sol: Core losses = 150 W (Constant)

Copper loss at full load = 220 W

$\therefore$ Copper loss at halt full load

$$= \left(\frac{1}{2}\right)^2 220\text{W} = 55 \text{ W}$$

$\therefore$ Total losses at half full load

= 150 + 55

= 205 W

Efficiency at half full load

$$= \frac{\frac{1}{2}\times 10^3 \times 1}{\frac{1}{2}\times 10\times 10^3 + 205}\times 100$$

= 96.06%

27. Ans: (c)

Sol: $$\%\eta = \frac{(x)(VI)\cos\phi}{x(VI)\cos\phi + W_C + W_{cu}}\times 100$$

x = 1 ($\because$ full load)

VI = 200 kVA; cosϕ = 0.9 lag; W_c = 1.8 kW

$$W_{cu} = \left(\frac{1.1}{100}\right)\times 200\times 10^3 = 2200 \text{ watts}$$

$$\%\eta = \frac{(1)(200\times 10^3)(0.9)}{(200\times 10^3\times 0.9)+(1.8\times 10^3)+2200}\times 100$$

= 97.82%

28. Ans: (a)

Sol: % Reg = (%R) cos ϕ_2 ± (%X) sin ϕ_2

For lagging power for

% V.R = (2) (0.8) + (4) (0.6)

= 4%

For leading power factor

% V.R = (2)(0.8) – (4) (0.6)

= – 0.8%

29. Ans: (a)

Sol: Given %R = 1%, %X = 5% and cosϕ = 0.8

% Reg = (%R)cosϕ + (%X)sinϕ ($\because$ lag pf)

= (1)(0.8) + (5)(0.6)

= 3.8%

30. Ans: (a)

Sol: V.R = (%R) cos ϕ_2 – (%X) sin ϕ_2 [at leading p.f]

At leading power factor, Resistive drop and reactive drop are opposing (cancelled out) each other

$\therefore$ Total drop = zero ⇒ V.R is zero.

31. Ans: (c)

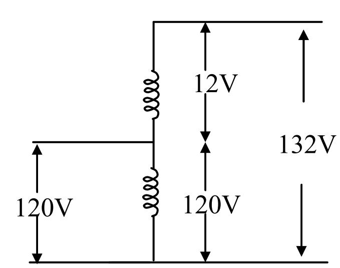
Sol: 3, 4, 5 condition's are necessary conditions 1 & 2 are desirable conditions for parallel operations.

32. Ans: (d)

Sol: If impedance decreases, current will increase and therefore sharing of load will increase.

33. Ans: (d)

Sol:



For series additive polarity of winding, voltage =132 V.

For series subtractive polarity of winding, voltage = 108 V.

34. Ans: (c)

Sol: 240/120 V, 12 kVA

$\eta = 96.2\%$

$$\eta = \frac{12000\times1}{12000\times1+\text{losses}} = 0.962$$

$\Rightarrow$ 12000 + losses = 12474

Losses = 474 W

When connected across 360V,

$$\text{The rating becomes} = \frac{12}{1-k} = \frac{12}{1-\frac{2}{3}} = 36\,\text{kVA}$$

$$\therefore \text{ Efficiency} = \frac{36000\times0.85}{36000\times0.85+\text{losses}}$$

$$= \frac{30{,}600}{30{,}600+474} = 98.5\%$$

35. Ans: (c)

Sol: In auto transformer, power is not only transferred by induction process but also by conduction process.

Chapter 2 DC Machines
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (c)
Sol: Current in armature conductor of dc machine is AC and commutator is used for converting AC to DC and vice-versa

02. Ans: (c)
Sol: For generator,

$E = V + I_aR_a$

$E = 200 + (50)(0.5) = 225V$

For motors,

$V = E_b + I_aR_a$

$200 = E_b + (50)(0.5)$

$E_b = 175$ V

03. Ans: (d)
Sol: For constant power output,

E_bI_a = constant

VI_a = constant (neglecting armature losses)

$V_1I_{a1} = V_2I_{a2}$

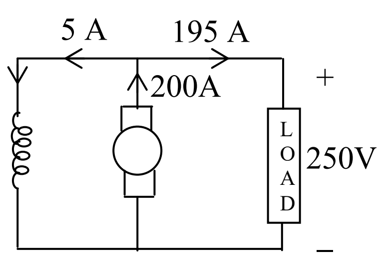
$V_2 = \frac{V_1}{2}$

$\therefore\ I_{a2} = I_{a1}(2)$

$I_{a2} = 100$ A

04. Ans: (d)
Sol: By short circuiting of series field winding the net flux developed by the generator decreases, then the emf generated also decreases.

05. Ans: (c)
Sol:



$I_{sh} = \frac{250}{50} = 5A$

$I_a = I_L + I_{sh} = 195 + 5 = 200A$

$E = V + I_aR_a$

$= 250 + (200)(0.05)$

$E = 260$ V

06. Ans: (b)
Sol: $E \propto \phi N$

$E_1 = K\phi_1N_1 = 136.8V$

$E_2 = K(2\phi_1)(0.75N_1) = 1.5\ E_1$

$\therefore\ E_2 = 1.5 \times 136.8 = 205.2V$

07. Ans: (d)
Sol: Under maximum power developed conditions $E_b = \frac{V}{2}$

At no load, speed (N_o) = 1200 rpm

No load voltage $V = E_b$

$\frac{N_2}{N_0} = \frac{E_{b2}}{E_{b0}}$

$\frac{N_2}{1200} = \frac{V/2}{V}$

$N_2 = 600$ rpm (speed under maximum power developed condition)

08. Ans: (b)
Sol: P = 4, N = 1500 rpm

f = ?

$N = \frac{120f}{P}$

$1500 = \frac{120 \times f}{4}$

f = 50 Hz

09. Ans: (c)
Sol: The armature MMF waveform of a dc machine is triangular

10. Ans: (b)

Sol: Compensating winding are connected in series with armature.

11. Ans: (d)

Sol: I = 20A, V = 200V

$E_{g1} \propto (\phi_{sn} + \phi_{se})\, N = 200V$

If $\phi_{se} = 0$

Then $E_{g2} \propto \phi_{sh}$, N < 200V

E_{g2} decreases; it will become less than 200V

12. Ans: (a)

Sol: Emf generated due to clockwise rotation is

$E_g \propto \phi N = 200V$

By reversing the direction of rotation, the emf generated also get reversed

$E_g \propto \phi(-N) = -200V$

So, net voltage becomes zero.

13. Ans: (d)

Sol: $I_L = 100\,A$, $I_{sh} = \frac{200}{100} = 2A$

$I_a = I_{sh} + I_L = 2 + 100 = 102\,A$

$E = V + I_aR_a = 200 + (102)(0.01)$

E = 201.02 V

14. Ans: (a)

Sol: Maximum efficiency will be obtained only when, Variable losses = Constant losses ……………… (1)

(i.e. copper loss)

From data;

Total losses = Input – Output

= 20 kW – 17 kW = 3000 W

But Total losses =

Copper losses+ Constant losses ……….. (2)

$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{50} = 4A$;

Input, $V.I_L$ = 20 kW = 20000W

200. $I_L = 20000 \Rightarrow I_L = 100A$

For shunt motor, $I_a = I_L - I_{sh}$

= 100 – 4 = 96A

In eq^n (2), Copper losses = $I_a^2R_a$

$= (96)^2 \times 0.04 = 368.64$

∴ Constant losses = total loss – copper loss

= 3000 – 368.68

= 2631.36W

∴ From eq^n (1), Total armature copper loss at max. Efficiency ≅ 2632 W

15. Ans: (d)

Sol: For series motor $\Rightarrow I_L = I_f = I_a$

but $\phi \propto I_f \propto I_a$

Developed torque in series motor,

$T \propto \phi.I_a \propto I_a^2$

∴ % increased torque, $\frac{T_2 - T_1}{T_1}$

$= \frac{I_{a2}^2 - I_{a1}^2}{I_{a1}^2} = \frac{144 - 100}{100} \times 100$

= 44%

16. Ans: (a)

Sol: In DC machine

Generate emf, $E_g = \left(\frac{\phi ZN}{60}\right)\left(\frac{P}{A}\right)$

$\Rightarrow E_g \propto (N\phi)$

Torque developed, $T = \left(\frac{Z\phi P}{2\pi}\right)\left(\frac{I_a}{A}\right)$

$\Rightarrow T \propto (\phi.I_a)$

Electrical power developed, $P = E_b.I_a$

Speed of the machine,

$N = 60.\left(\frac{E_b}{\phi}\right)\left(\frac{A}{ZP}\right) \Rightarrow N \propto \left(\frac{E_b}{\phi}\right)$

17. Ans: (c)

Sol: Due to reduction of armature reaction drop change in No load to Full load voltage is reduces so as the regulation also reduces

18. Ans: (d)

Sol: When shunt field winding is interchanged by series field winding. The operating flux of the motor will be very low that motor could not start.

19. Ans: (b)

Sol: If prime mover is failed then machine takes supply from lines, generator operates as motor. As changes in current direction in series field winding then cummulative compound generator becomes differentially compounded motor.

20. Ans: (c)

Sol: $T \propto I_a^2$

For series motor

21. Ans: (a)

Sol: Condition for maximum efficiency in any machine is Cu loss = iron loss

22. Ans: (c)

Sol: When terminal voltage is halved, voltage across field winding also get halved and hence flux also halved

23. Ans: (b)

Sol: From data $\Rightarrow I_a$ is constant

($\because I_a$ is supplied from constant current source)

From data $\Rightarrow$ as I_f is supplied from constant voltage source,

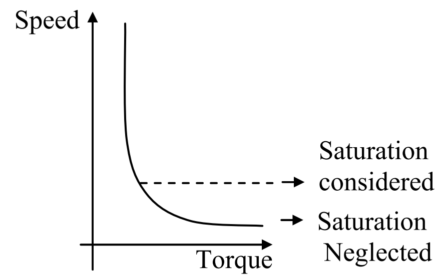
ϕ = constant ($\because \phi \propto I_f$)

$I_f = \dfrac{V}{R_{sh}}$ = constant

$\therefore T \propto (\phi.\ I_a)$ = constant irrespective of motor speed.

24. Ans: (b)

Sol:



We know that torque, $T \propto \phi.I_a$ but flux, $\phi \alpha I_{sh}$ (for series motor, $I_{sh} = I_a$)

$\therefore T \propto I_a^2 \Rightarrow \sqrt{T} \propto I_a$ ………. (1)

(when saturation and armature reaction are neglected)

Speed, $N \propto \dfrac{1}{\phi} \propto \dfrac{1}{I_a}$ ……….. (2)

$\therefore$ From (1) and (2)

$N \propto \dfrac{1}{\sqrt{T}} \Rightarrow$ Rectangular Hyperbola

Flux 'ϕ' is constant when saturation & armature reaction are considered $\Rightarrow T \alpha I_a$

$\therefore$ Speed, $N \propto \dfrac{1}{\varphi}$ = constant for any value of Torque i.e, N Vs T characteristics approaches to straight line.

25. Ans: (c)

Sol: For differential compound motor,

$\phi_r = \phi_{sh} - \phi_{se}$

As load $\uparrow \Rightarrow I_a \uparrow \Rightarrow \phi_{se} \uparrow \Rightarrow \phi_r \downarrow$

But $\uparrow N \alpha \dfrac{1}{\phi \downarrow} \Rightarrow$ as $\phi_r \downarrow \Rightarrow N \uparrow$

26. Ans: (d)

Sol: In DC series motor, Torque is directly proportional to square of current ($T \propto I_a^2$). Therefore if AC supply accidentally connected to DC motor; this AC current (either positive and negative of supply) through field and armature winding will always be in same direction (positive), hence torque will be unidirectional but due to AC nature of supply, torque will be pulsating nature.

27. Ans: (d)

Sol: In series motor

$$T \propto I_a^2 = \sqrt{T} \propto I_a$$

$$N \propto \frac{1}{\phi} \propto \frac{1}{I_a} \propto \frac{1}{\sqrt{T}}$$

$$N \propto \frac{1}{\sqrt{T}}$$

Rectangular hyperbola

28. Ans: (c)

Sol: $T \propto \phi I_a$

29. Ans: (c)

Sol: Here in 4-point starter unlike 3-point starter a separate path is being taken for holding coil.

30. Ans: (c)

Sol: $T \propto \phi.I_a$

For constant torque load,

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

Flux is constant as shunt field current is constant.

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

31. Ans: (b)

Sol: The speed control of dc shunt motor in both directions can be obtained by Ward Leonard method

Chapter **3**

Synchronous Machines
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (c)

Sol: The phase sequence of alternator can be reversed by changing the direction of rotor rotation (whether field may be rotating or armature rotating), but phase sequence is doesn't depends on polarities or direction of field current.

Whether the machine may be acting as generator or motor the phase sequence is related to rotor rotation only. Phase sequence is no way related with direction of field current (i.e., field polarities)

02. Ans: (c)

Sol: As the two alternators are mechanically coupled, both rotors should run with same speed. $\Rightarrow Ns_1 = Ns_2$

$$\Rightarrow \frac{120f_1}{p_1} = \frac{120f_2}{p_2}$$

$$\Rightarrow \frac{f_1}{f_2} = \frac{p_1}{p_2}$$

$$\Rightarrow \frac{p_1}{p_2} = \frac{50}{60} = \frac{5}{6} = \frac{10}{12}$$

$\Rightarrow p_1 : p_2 = 10 : 12$

Every individual magnet should contains two poles, such that number of poles of any magnet always even number.

G_1: p = 10, f = 50 Hz

$\Rightarrow N_s = 600$ rpm

(or)

G_2: p = 12, f = 60 Hz

$\Rightarrow N_s = 600$ rpm

03. Ans: (c)

Sol: As the ac supply given to the stator of synchronous motor, stator rotating magnetic poles are rotating at synchronous speed [say stator frequency = 50 Hz], means armature poles are interchanging their positions for every 10msec. But due to large inertia of rotor, it couldn't catch the quick reversal of stator poles. At standstill the rotor of a synchronous motor is subjected to alternate forces of repulsion and attraction, in other words there exist relative motion between stator field (poles) and rotor field (poles), means two field's are not stationary w.r. t each other.

$\therefore$ The average torque is zero, hence synchronous motor is not self starting.

04. Ans: (d)

Sol: These are the properties of cylindrical rotor synchronous machines.

05. Ans: (d)

Sol: For P – plate machine, $\frac{p}{2}$ cycles of e.m.f will be generated in one revolution thus for a p – pole machine

$$\theta_{elect} = \frac{p}{2}\theta_{mech}$$

06. Ans: (d)

Sol: Distribution winding eliminates "higher order harmonics" and short pitch winding processor eliminates "particular dominant harmonics" based on short pitch angle, hence resultant EMF wave closer to sine wave form.

07. Ans: (d)

Sol: Reason: When the rotor rotates at synchronous speed, there is no relative motion between armature flux and damper winding (since damper winding placed on rotor).Therefore EMF induced in the damper bars is zero means current through the damper bars equal to zero, hence damping torque production is zero.

08. Ans: (a)

Sol: Distribution: The distribution of the armature winding along the air-gap periphery tends to make the e.m.f. waveform sinusoidal.

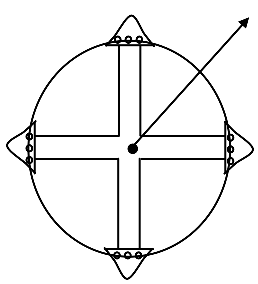
Chording: With coil-span less than pole pitch, the harmonics can be eliminated.

Skewing: By skewing the armature slots, only tooth harmonics or slot harmonics can be eliminated.

Fractional slot winding: With fractional slot winding slot harmonics can be eliminated.

09. Ans: (c)

Sol: Damper windings are provided on pole shoes with dampers in salient pole synchronous machine and these dampers on each pole are shorted by a "End ring".



Function of damper winding in Alternator:

(i) To suppress Negative sequence field

(ii) To eliminate Hunting

Function of Damper winding in synchronous motor:

(i) To eliminate hunting

(ii) For starting purpose

10. Ans: (b)

Sol: Distribution factor /belt factor/breadth factor/ spread factor (k_d):

$$k_d = \frac{\text{The e.m.f induced with Distributed winding}}{\text{The e.m.f induced with concentrated winding}}$$

$$k_d = \frac{\text{The vector sum of induced e.m.f}}{\text{The arithmatic sum of induced e.m.f}}$$

$$k_d = \frac{\sin m\frac{\gamma}{2}}{m\sin\frac{\gamma}{2}}$$

For n^{th} harmonic, $k_{dn} = \frac{\sin\frac{mn\gamma}{2}}{m\sin n\frac{\gamma}{2}}$

For concentrated winding, $k_d = 1$

$k_{d1} = k_{d2} = k_{d3}$ - - - - - = 1

For distributed winding, $k_d < 1$

Winding factor $K_w = K_p \times K_d$

11. Ans: (a)

Sol: The speed of n^{th} space harmonic is $= \frac{1}{n}F_1$

for 7^{th} space harmonic is $= \frac{1}{7}\times F_1$

$F_1 = \frac{120\times 50}{8} = 750 \quad = \frac{1}{7}\times 750 = 107.14$

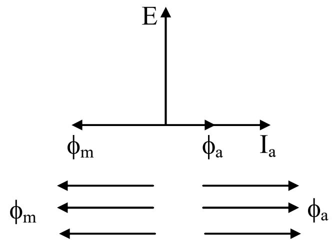
In forward direction

$(6K \pm 1)$ = '+' for forward

12. Ans: (b)

Sol: Alternator working under

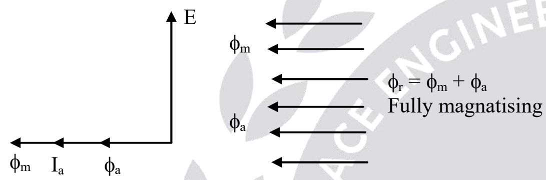
(i) ZPF lag pf



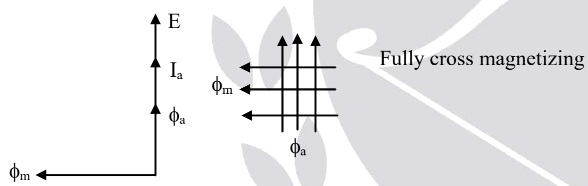
$\phi_r = \phi_m - \phi_a$

fully de-magnetising

(ii) ZPF Lead pf



(iii) UPFpf

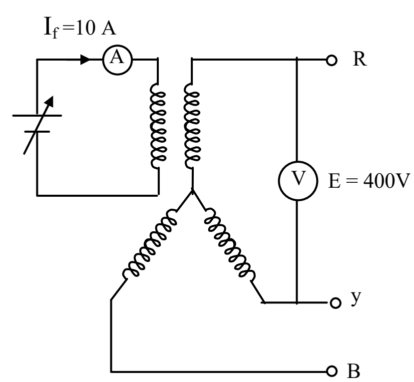


(iv) For intermediate lagging load, effect of armature reaction is partly cross-magnetizing and partly demagnetizing.

13. Ans: (a)

Sol: Open circuit characteristics (O.C.C)

$E\ V_s\ I_f\Big|_{N=\,constant}$



Fiigure 3.33: Circuit diagram for O.C.C

- To get O.C.C, the alternator has to be driven at constant rated speed and the open circuit terminal voltage is noted as field current is gradually increased from zero.

We know that, $E = 4.44\, k_p k_d\, \phi\, f\, T$

$E \propto \phi \propto I_f$

$E \propto I_f$

$\therefore$ E vs $I_f \Rightarrow$ linear $\Rightarrow$ Before saturation

$\Rightarrow$ Non-linear $\Rightarrow$ After saturation

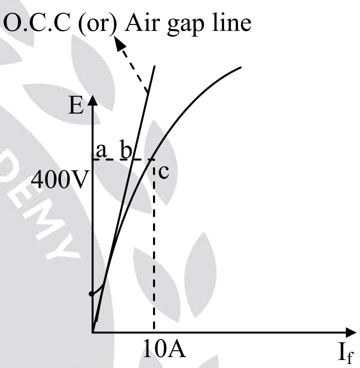


Figure 3.34: O.C.C of an alternator.

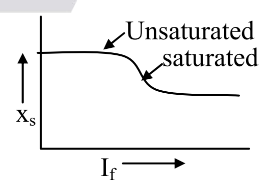
- When mmf (I_f) exceed a certain value the iron parts require a good amount of mmf and the saturation sets in.

ab = mmf (or I_f) for the air gap.

bc = mmf for the iron parts.

14. Ans: (b)

Sol:



$$Z_s \simeq X_s = \frac{E_{OC}}{I_{SC}}$$

I_f = constant

Up to knee point both OCC & SCC are linear.

$\therefore Z_s$ is constant for unsaturated position. But above knee OCC ic non linear & SCC is linear so Z_s decreases during saturated condition.

15. Ans: (a)

Sol: Y-axis indicates armature current (I_a) & X-axis indicates field current (I_f).

$\therefore$ V-curve Indicates the variation of 'I_a' w.r.t the changes in Excitation (I_f).

16. Ans: (d)

Sol: $S.C.R = \dfrac{1}{X_s\,(\text{adjusted saturation})\,P.U}$

17. Ans: (c)

Sol: $X_s = X_a + X_l$

Note: $X_s > X_a > X_l > R_a$

18. Ans: (a)

Sol: on d-axis

$$X_d = \frac{V_{max}}{I_{min}}$$
$$= \frac{108}{10} = 10.8\Omega$$

on q-axis

$$X_q = \frac{V_{min}}{I_{max}}$$
$$= \frac{96}{12} = 8\,\Omega$$

19. Ans: (a)

Sol: Power developed in synchronous machine

$\Rightarrow P = \dfrac{EV}{X_s}.\sin\delta$

$\Rightarrow P = P_{max}.\sin\delta$

$\therefore P_{max} = \dfrac{EV}{X_s}$

$\Rightarrow P_{max} \propto E, V$

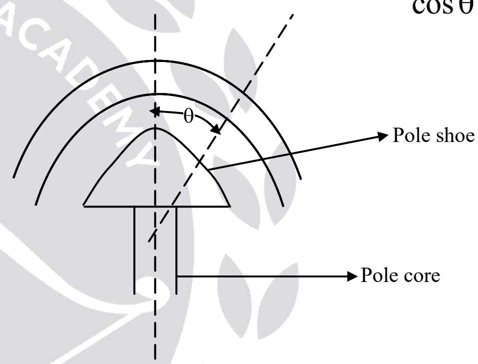
$\Rightarrow P_{max} \propto I_f$ and V $[\because E \propto I_f]$

20. Ans: (a)

Sol: The 'synchronous-impedance method' of finding the voltage regulation by a cylindrical rotor alternator is generally considered as a pessimistic method because saturation is not considered

21. Ans: (b)

Sol: Airgap length under pole shoe $\propto \dfrac{1}{\cos\theta}$



As $\theta\uparrow \Rightarrow \cos\theta\downarrow \Rightarrow$ airgaplength $\uparrow$

22. Ans: (d)

Sol: To run two alternators in parallel, the dark lamp test is preformed to ensure proper phase sequence matching

23. Ans: (c)

Sol: **Reason:** The prime mover speed of parallel connecting alternators can be anything which is depends on number of poles but frequency of an incoming alternator must be same to that of already existing alternator.

$f = \dfrac{P.N}{120}$; so, to get fixed frequency, if P $\uparrow$

$\Rightarrow$ N should be reduce.

Here P = number of poles of the machines and N = speed of rotor.

24. Ans: (d)

Sol: Salient pole synchronous machine:

$$P = \frac{EV}{X_d}\sin\delta + \frac{V^2}{2}\left(\frac{1}{X_q} - \frac{1}{X_d}\right)\sin 2\delta$$

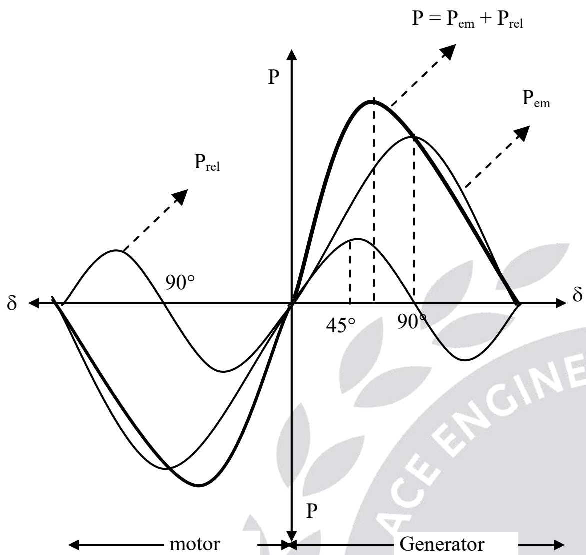
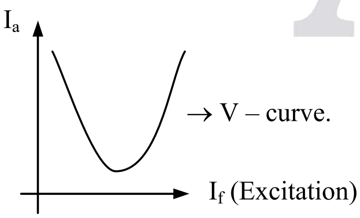


Figure : Power-Load angle Characteristic of a Salient pole synchronous machine

- P_{max} is obtained for load angle $\delta < 90^0$ (i.e in between 60^0 to 70^0)
- P v_s δ curve is Non sinusoidal.
- Steady state stability is more for salient pole synchronous machine due to extra reluctance power.

25. Ans: (a)

Sol:



26. Ans: (c)

Sol: As the load on the synchronous motor is suddenly increased, the motor becomes hunt i.e, rotor speed fluctuates around synchronous speed and finally reaches to synchronous speed.

27. Ans: (c)

Sol: **1**. Open-circuit Characteristic------E_g Vs. I_f

2. V curve ------------I_a Vs. I_f

3. Internal Characteristic------------ E_a Vs. I_a

4. Inverted V-curve ------------- p.f. Vs. I_f

28. Ans: (d)

Sol:
1. The terminal voltage of incoming alternator must be same as that of the existing system otherwise circulating current flows between the two systems. The terminal voltage can be adjusted with the field excitation.
2. The frequency of incoming alternator must be same as that of the existing system otherwise circulating current flows between the two systems. At a particular instant there may be dead short circuit when the two voltages are in adding polarity.
   The frequency can be adjusted by varying the prime mover speed.
3. The phase sequence of incoming alternator must be same as that of the existing system otherwise large circulating currents exist, because the voltage across the two systems is equal to $\sqrt{3}$ times of their rated voltage.
4. The phase displacement between existing system and alternator should be same.
5. Synchronization is possible with different kVA rating alternators. Rating is not a problem to synchronization.

29. Ans: (c)

Sol: Power factor of alternator mainly depends on reactive power, which is depends on field excitation.

30. Ans: (c)

Sol: $P = \frac{EV}{X_s}\sin\delta$, when δ = 90

$$P_m = \frac{EV}{X_s}$$

31. Ans: (b)

Sol: When excitation of sailent pole synchronous motor is removed. It will take reactive power from bus bar and acts as a reluctance motor.

32. Ans: (b)

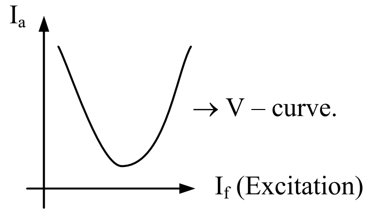
Sol: During starting, the field winding is short circuited with a low resistance to avoid damage of the field insulation and an induced voltage in the field winding will drive the current which will develop additional torque so that motor start with increased torque.

33. Ans: (a)

Sol: Synchronous motor maintains constant speed called synchronous speed irrespective of torque & it's load magnitude, so we can say torque will vary at constant speed.

34. Ans: (a)

Sol:



35. Ans: (d)

Sol: An over excited synchronous motor under no-load condition behaves as a capacitor which is used to improve the power factor. This is called synchronous condenser.

Chapter 4 Induction Machines
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (d)

Sol: In slip ring induction motor, if stator and rotor has different number of poles, the motor doesn't rotate.

02. Ans: (c)

Sol: Induction motor rotates at slightly less than the synchronous speed.

$$\therefore N_s = \frac{120\times 50}{6} = 1000\text{rpm}$$

N_r = less than 1000 rpm

03. Ans: (c)

Sol: In an induction motor, if the air gap is increased

1. Its power factor will reduce
2. Its magnetizing current increase

04. Ans: (b)

Sol: Skewing of a slot is shown in fig.1

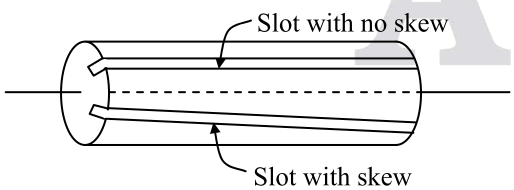


Fig. 1

Noise, vibrations, cogging, and crawling can be considerably reduced by skewing either the stator or the rotor. To eliminate the effects of any harmonic of the air-gap mmf, slots must be skewed by 2 pole-pitches corresponding to that harmonic. The usual practice is skew rotor slots by one stator slot-pitch.

A study of the torque–speed characteristics of an induction motor with skewing and without skewing shows that, with skewing,

1) Maximum or pull–out torque decreases.
2) Starting torque also decreases.

05. Ans: (a)

Sol: Open type slot:

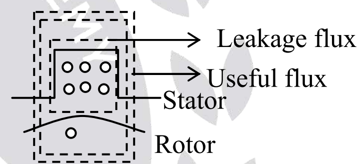


Figure: Open slots

Advantages:

(i) Windings can be placed into the slots very easily.
The winding which is formed before placed into the slots is called former winding.

(ii) Leakage reactance is less in open type slots. Therefore more amount of power will be transferred from stator to rotor and torque production is high.

06. Ans: (b)

Sol: Supply frequency, $f = \frac{1500\times 4}{120} = 50\text{Hz}$

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

$$\text{Slip, } \%S = \frac{N_s - N_r}{N_s} \times 100$$

$$\text{Slip, } \%S = \frac{1000 - 960}{1000} \times 100$$

$\%S = 4\%$

07. Ans: (a)

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

$$\text{Slip}, S = \frac{N_s - N_r}{N_s} = \frac{1500 - 1440}{1500} = 0.04$$

The frequency of emf induced in rotor,

$F_r = SF_s$

$F_r = 0.04 \times 50$

$F_r = 2\text{Hz}$

08. Ans: (c)

Sol: If an induction motor by some means is rotated at synchronous speed the slip is equal to zero, therefore the emf induced in the rotor is zero and the torque developed by the rotor is zero.

09. Ans: (d)

Sol: The induction motor is rotates at slightly less than the synchronous speed, therefore synchronous speed is 300 rpm.

$$300 = \frac{120 \times 50}{P}$$

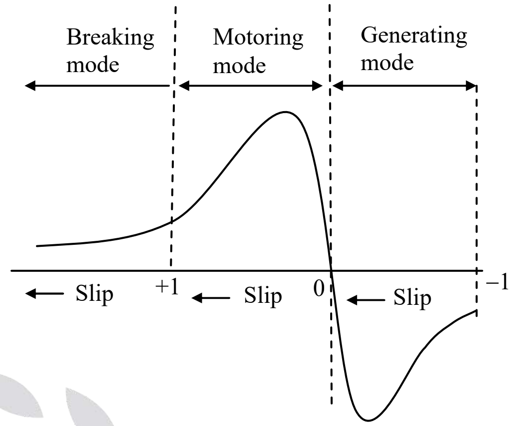
$\therefore P = 20$

10. Ans: (c)

Sol: If any two leads of stator are interchanged in a 3-phase induction motor, the motor will run in a direction opposite to previous one.

11. Ans: (a)

Sol:



Torque-slip characteristics of a 3-phase Induction machine

12. Ans: (b)

Sol: The no load current shown by the induction motor is usually more than that of transformer

13. Ans: (b)

Sol: $\frac{T_{st}}{T_{FL}} = \frac{2s_m}{1 + s_m^2}$

Where $s_m = \frac{N_s - N_r}{N_s}$

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

$N_r = 1200$ rpm

$$\therefore s_m = \frac{1500 - 1200}{1500} = 0.2 = 20\%$$

$$\text{Now, } \frac{T_{st}}{T_{FL}} = \frac{2(0.2)}{1 + (0.2)^2} = 0.384$$

14. Ans: (c)

Sol: $\text{Efficiency } (\eta) = \frac{\text{output shaft power}}{\text{input power}}$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

$N_r = 975$ rpm (Given)

$\therefore\ s = \dfrac{N_s - N_r}{N_s} = \dfrac{1000 - 975}{1000} = 0.025$

Airgap power = Stator input – Stator losses

= 40 – 1 = 39 kW

Gross mechanical power output

= (1 – s) × Air gap power

= (1 – 0.025) × 39 = 38.025 kW

Shaft power output

= Gross mechanical power output – Mechanical losses

= 38.025 – 2 = 36.025 kW

$\therefore\ \%\ \eta = \dfrac{36.025}{40} \times 100$

= 90.0625%

15. Ans: (c)

Sol: Slip s = 5% = 0.05

Rotor output/gross mechanical power developed P_{ro} = 20 kW

Rotor copper loss $= \dfrac{s}{1-s} \times P_{r0}$

$= \dfrac{0.05}{1-0.05} \times 20\,k$

= 1052 W

16. Ans: (c)

Sol: In an induction motor, if the air gap is increased

1. Its power factor will reduce
2. Its magnetizing current increase

17. Ans: (b)

Sol: $T_e = \dfrac{180}{2\pi N_s} \times \dfrac{SE_2^2 R_2}{R_2^2 + (SX_2)^2}$

$T_e \propto V^2$

$T_2 = \dfrac{T_1}{4} = \dfrac{500}{4} = 125$ Nm

18. Ans: (*)

Sol: Slip at maximum torque,

$S_{Tm} = \dfrac{r_2}{X_2} = \dfrac{0.21}{0.7} = 0.3$

The speed at maximum torque,

$N_{Tm} = N_s(1 - S_{Tm})$

$N_{Tm} = 1500\ (1 - 0.3)$

$N_{Tm} = 1050$ rpm

19. Ans: (d)

Sol: As load on an induction motor goes on increasing, its power factor goes on increasing up to full load and then it falls again.

20. Ans: (b)

Sol: The rotor bars of squirrel cage induction motor are short circuited at both ends by end-rings of the same material, hence we unable to connect external resistance into rotor, so Rotor resistance control not applicable to cage induction motor.

21. Ans: (a)

Sol: Rotor current's in an induction motor is due to relative speed between stator RMF and physical rotor.

If $N_r = N_s$ i.e. if rotor rotating with 'N_S' speed in the same direction of stator RMF (N_s speed), then the relative speed between them is zero.

⇒ EMF induced in the rotor winding is zero.

⇒ Current's in rotor winding is zero.
Hence torque production is zero

⇒ At N = N_S ; rotor won't rotate, hence called "Asynchronous machine".

22. Ans: (d)

Sol: The main function of a starter in a 3-ϕ induction motor is to limit high starting current to reasonable values.

23. Ans: (a)

Sol: The speed control of induction motor by pole changing is suitable for cage motors only because the cage rotor automatically develops numbers of poles equal to the poles of stator winding.

24. Ans: (a)

Sol: The rotor will start rotating in such a direction that it will oppose the cause, i.e., the relative speed between the rotating field and stationary rotor conductors should decrease.

25. Ans: (c)

Sol: A large capacity three-phase induction motor is started using a star delta starter instead of starting direct on line. The starting current is reduced to one third its value.

26. Ans: (c)

Sol: If the motor is started by an auto transformer with x% tapping, the starting line current will be reduced by x^2 times.

27. Ans: (a)

Sol: The star delta starting current of an induction motor is 50 A. Its DOL starting current is 150 A.

28. Ans: (a)

Sol: $$\frac{T_{st}}{T_{FL}} = X^2\left(\frac{I_{st}}{I_{FL}}\right)^2 \times S$$

$$\frac{1}{4} = X^2(4)^2 \times 0.03$$

$$\Rightarrow X = 72.2\%$$

29. Ans: (c)

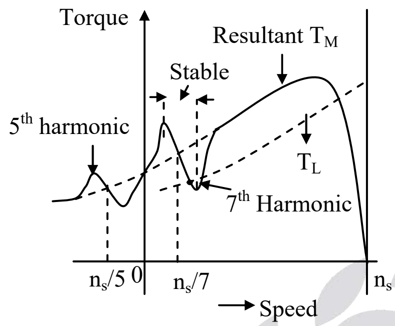
Sol: Magnitude of starting torque depends upon value of capacitor used at the time of starting. Practically permanent split capacitor start consist high value of capacitor and shaded pole type produces low starting torque.

30. Ans: (d)

Sol: In a single phase capacitor motor the direction of rotation will be in the opposite direction to the original when Capacitor is replaced by an inductor.

31. Ans: (d)

Sol: The tendency of squirrel cage induction motor to run at one seventh of the synchronous speed when connected to supply mains is called crawling. This is due to the space harmonics in the air gap flux wave. The dominant harmonics of the air gap flux wave are 5^{th} and 7^{th} harmonics. The 5^{th} harmonic flux rotates backwards with synchronous speed of $\frac{n_s}{5}$ and the seventh harmonic flux rotates forward at $\frac{n_s}{7}$. These harmonic fluxes produce their own harmonic torques of the same general torque-slip shape as that of the fundamental and will have stable operating regions around the rotor speeds of $-\frac{n_s}{5}$ and $\frac{n_s}{7}$ respectively. In the following figure, the superimposition of the fundamental, fifth and seventh harmonic torque- slip curves are shown.



In the motor operating mode of induction machine (i.e $0 < n < n_s$) there is a stable operating region around $\frac{n_s}{7}$th speed of the motor (see figure). If load torque curve intersects the motor torque curve in this stable region it results in stable operation of the induction motor around this low speed (i.e. $\frac{n_s}{7}$th speed). This phenomenon is known as crawling. This phenomenon is less prominent in slip ring induction machines as these possess higher starting torque than squirrel cage induction machines.

As the induction motor is working at low speeds, the slip will be high so rotor copper losses (s × Airgap power) will be more and efficiency will be poor. The crawling is also accompanied by much higher stator current and sometimes noise and vibration are also observed.

32. Ans: (b)

Sol: Functions of skewed rotor slots in induction motor

1. The skewed rotor slot increases the length of the copper bar thereby increases the resistance of the rotor bars and hence starting performance of the induction machine.
2. It makes the air gap flux distribution uniform thereby reduces harmonics torque produced by the machine.
3. As harmonic torque are reduced, the phenomenon due to harmonic torque can also be reduced.

Chapter 5 Power Systems
(Solutions for Vol-1_Classroom Practice Questions)

01. Ans: (d)

Sol: Water used = 60×10^6 cubic meter/year

$$\therefore Q = \frac{60\times10^6}{365\times24\times3600} = 1.9\,m^3\ /\sec$$

Head = 40 m

$$P = \frac{735.5}{75} QH\eta\ kW$$

$$= \frac{735.5}{75}\times1.9\times40\times1$$

$$= 745.3\ kW$$

02. Ans: (c)

Sol: Overall efficiency of the power station is

$$\eta_{overall} = \eta_{thermal}\times\eta_{elect} = 0.30\times0.92 = 0.276$$

Units generated / hour = $(100 \times 10^3) \times 1$

$= 10^5$ kWh

Heat produced / hour,

$$H = \frac{\text{Electrical output in heat units}}{\eta_{overall}}$$

$$\frac{10^5\times860}{0.276} = 311.6\times10^6\ kcal$$

($\therefore$ 1kWh = 860 kcal)

$$\therefore \text{Coal consumption/hour} = \frac{H}{\text{Calorific value}}$$

$$= \frac{311.6\times10^6}{6400}$$

$$= 48687 kg$$

03. Ans: (c)

Sol: 1 Hp = 735. 5 W

(or)

= 0.735 kW

Developed power,

$$P = \frac{735.5}{75}\times Q\times W\times H\times\eta\ \text{Watts}$$

Here, Density of water W = 1000kg/m^3

Discharge of water (Q) = $1m^3/s$,

efficiency (η) =100% and

Water head (H) = 1m

$$\therefore\ P = \frac{735.5}{75}\times1000\times1\times1 = 9.80kW$$

04. Ans: (d)

Sol: H = 102 m

Q = 30 m^3/sec

η = 80%

P = ηWQH × 1000

P = 0.8 × 30 × 102 × 9.81

P = 24,014.88

P = 24,014.88 × 1000

P = 24MW

05. Ans: (b)

Sol: H = 204m

Q = 8 m^3/sec

η = 0.8

$$P = \frac{0.736}{75}\times W\eta QH$$

$$P = \frac{0.8\times1000\times8\times204\times0.736}{75}$$

$= 12812.288kW \approx 12,800$ kW

06. Ans: (a)

Sol: Weight of water

= volume of water is stored×density

= $(10\times10^5)\times993$ kg

$= (10\times10^5)\times993\times9.81$ N

$= 9741.33\times10^6$ N

Energy produced by volume of water $= W\times H\times\eta_{overall}$

$= 9741.33\times10^6\times50\times1.00$ watt-sec

(losses are neglected, overall efficiency is 100%)

$$= \frac{9741.33\times10^6\times50}{3600}\text{ Whr}$$

= 135.3 MWhr

07. Ans: (d)

Sol: $N_s = 300$ rpm

f = 50 Hz

$$N_s = \frac{120f}{P} \Rightarrow P = \frac{120f}{N_s} = \frac{120\times50}{300} = 20$$

P = 20.

08. Ans: (c)

Sol: In the fully charged state, the negative plate consists of lead, and the positive plate lead dioxide, with the electrolyte of concentrated sulfuric acid. Overcharging with high charging voltages generates oxygen and hydrogen gas by electrolysis of water, which is lost to the cell. A lead acid battery cell is fully charged with a specific gravity of 1.265 at 80° F. For temperature adjustments, get a specific gravity reading and adjust to temperature by adding.

09. Ans: (b)

Sol: The state of discharge of a lead acid cell is determined by specific gravity of electrolyte

10. Ans: (a)

Sol: The storage battery, which is generally used in electric power station is lead acid cell.

11. Ans: (c)

Sol: In general terms, the capacity of a cell/battery is the amount of charge available expressed in ampere-hour(Ah).

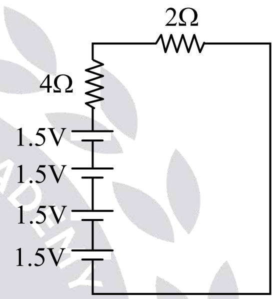
12. Ans: (c)

Sol: Given data

Four identical batteries is 1.5 V

Internal resistance 1Ω

Series feed load of 2Ω



The current in the circuit = $\frac{6}{6} = 1\text{ A}$

13. Ans: (c)

Sol: The capacity of the battery is usually expressed as a number of ampere-hour. One ampere-hour is the amount charge delivered when a current of one ampere is delivered for one hour. Ampere-hour efficiency always greater than watt-hour efficiency.

14. Ans: (c)

Sol: Storage cell in an auto mobile has lead for negative, PbO_4 for positive electrode and sulphuric acid for electrolyte

15. Ans: (c)

Sol: A commonly used primary cell is dry ice

16. Ans: (c)

Sol: In lead acid battery, the density of acid indicates charge of battery.

17. Ans: (a)

Sol: For the process of electrolysis, the supply required is dc supply

18. Ans: (c)

Sol: As each cell of voltage V of n are connected in series the total voltage becomes = nV and the capacity of each cell is same. So capacity of battery is nothing but capacity of each cell.

19. Ans: (c)

Sol: Cells (or) batteries connected in series have the positive terminals of one cell (or) battery connected in the negative terminals of another cell (or) battery. This has the effect of increasing the overall voltage but the overall capacity remains the same.

20. Ans: (b)

Sol: Sulphation in a lead-acid battery occurs due to incomplete charging.

21. Ans: (b)

Sol: Electrolyte of lead acid battery cell is a solution of sulfuric acid and distilled water. The specific gravity of pure sulfuric acid is about 1.84.

22. Ans: (b)

Sol: Trickle charging means charging a fully charged battery under no-load at a rate equal to its self-discharge rate, thus enabling the battery to remain at it's fully charged level.

23. Ans: (c)

Sol: Given data

A battery is charged at 5A for 8 hours,

Discharged at 4A in 9 hours,

Output = $9 \times 4 = 36$

Input = $5 \times 8 = 40$

$$\% \eta = \frac{\text{output}}{\text{input}} = \frac{36}{40} = 90\%$$