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PART - A

2 Marks Questions

1

Sol. This law states that electromagnetically induced current always flows in such direction that the action of the magnetic field set up by it tends to oppose the very cause which produces it.

2

Sol. Here $B = 1.5\,Wb/m^2, l = 1\,m, \upsilon = 50\,m/s;\ e = ?$

Now In the first case $\theta = 90^o$

$$\sin 90^o = 1$$

$$e = Bl\upsilon\sin(\theta) = 1.5\times1\times50\times1 = 75\,V$$

In the second case $\theta = 30^o$

$\therefore \quad \sin 30^o = 0.5$

$$e = Bl\upsilon\sin(\theta) = 1.5\times1\times50\times0.5 = 37.5\,V$$

3

Sol. When a ferromagnetic material is made to undergo a cycle of magnetisation, the intensity of magnetisation (I) and the magnetic flux density (B) lags behind the applied magnetic field (H), and this process is known as Hysteresis.

4

Sol. Flux linkages, $\psi = N\ \phi = 1000\times2\times10^{-3} = 2\,Wb\,turns$

Energy stored in the magnetic field $= \frac{1}{2}\psi i \equiv \frac{1}{2}\times2\times1 = 1\,Joule.$

5

Sol. **Retentivity (or) remanence:**
When the external magnetic field applied to a magnetic material is removed, the magnetic material will not loss magnetic property immediately. There exits some residual intensity of magnetisation in the specimen even when the magnetic field is cut off. This is called residual magnetism or retentivity.
Coercivity:
The residual magnetism can be completely removed from the material, by applying a reverse magnetic field. Hence coercivity of the magnetic material is the strength of reverse magnetic field ($-H_c$) which is used to completely demagnetize the material.

6.

Sol. When the output voltage is lower than the input voltage, it is called a step-down transformer. when the output voltage is higher than the input voltage, it is known as a step-up transformer.

7.

Sol. The function of a transformer can be any one of the following:
(i) To decrease or increase the voltage and current levels from one circuit to another circuit.
(ii) To match the load inpedance with thesource impedance for maximum power transfer to the load.
(iii) To isolate one circuit from another or to stop the flow of dc while ac is permitted to flow to the load.

8.

Sol. The iron loss in a transformer is made up of hystersis loss and edy-current loss. Hystersis loss is reduced by using cold-rolled-grain-oriented electrical steel for the transformer core. Eddy current loss is minimised by using thin sheets (0.35 mm) of laminations for preparing the transformer core.

9.

Sol. For maximum transformer efficiency, variable ohmic loss = constant iron loss i.e. $n^2 P_0 = P_i$

$\therefore$ Fractional load at which maximum efficiency occurs, $n = \sqrt{\frac{P_i}{P_0}}$

10.

Sol. Inductively transferred VA $= \left(1 - \frac{V_2}{V_1}\right) \times$ Total input VA

$\therefore \frac{\text{Power transferred inductively}}{\text{Total input power}} = \left[\frac{V_1 - V_2}{V_1}\right] = \left[1 - \frac{V_2}{V_1}\right] = [1 - k]$ where $k = \frac{V_2}{V_1}$ and $k < 1$

11.

Sol. Current from source, $I_1 = \frac{1000}{50} = 20\,A$

Load current, $I_2 = \frac{1000}{40} = 25\,A$

$\therefore$ Current in common section of the winding

$= I_2 - I_1 = 25 - 20 = 5A$

12.

Sol.

Transformer works on the principle of mutual induction.

13.

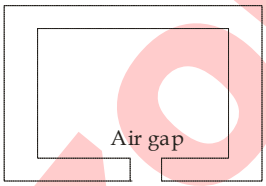
Sol.

It is a static device, Transfer electrical power from one electrical circuit to another electrical circuit There is no change in frequency, It step-up or step-down the voltage and current level keeping the power same. Electrically isolated, magnetically coupled, Require less maintenance, Efficiency high because of no rotating part, For matching the impedance of a source and its load for maximum power transfer in electronics circuit.

14.

Sol.

In the transformer core if their is a small air gap then the I_M (magnetizing current)will increase for the same flux requirement



$\phi = \frac{MMF}{R_l}$ $\phi = \frac{NI_m \uparrow}{R_l \uparrow}$ {Relucatance of air is high}

15.

Sol.

Transformer :- $\phi = \frac{MMf}{R_l(\text{core})} = \frac{NI_m \downarrow}{R_l \downarrow}$ [3 to 5% of I_{FL}(full load current)]

Induction motor :- $\phi = \frac{NI_m \uparrow}{R_l \uparrow}$ [30 to 50% of I_{FL}]

16.

Sol.

Copper Losses/ Variable Losses/ Ohmic Losses

When X-mer is loaded these losses take place otherwise negligible small these are resistance losses in the primary and secondary winding. So these are called I^2R or ohmic losses.

17.

Sol.

It is define as the change in secondary terminal voltage expressed as a percentage of the secondary rated voltage. When load at a given power factor is reduced to zero with primary applied voltage held constant. The change in secondary terminal voltage depends on the load power factor, load current, equivalent resistance and equivalent leakage reactance of the X-mer.

Ideal voltage regulation = 0

18.

Sol.

$V.R = R_{PU}\cos\theta + X_{PU}\sin\theta$

For maximum V.R $\quad \tan\theta = \dfrac{X_{PU}}{R_{PU}}$

Maximum V.R is possible in lagging power factor load

$$\text{Maximum V.R} = R_{PU}\left(\frac{R_{PU}}{Z_{PU}}\right) + X_{PU}\left(\frac{X_{PU}}{Z_{PU}}\right)$$

$$\boxed{(V.R)_{max} = Z_{PU}}$$

19.

Sol.

$V.R = R_{PU}\cos\theta - X_{PU}\sin\theta$

$V.R = 0$

$$\tan\theta = \frac{R_{PU}}{X_{PU}}$$

zero voltage regulation will take place at leading power factor load.

20.

Sol.

At maximum efficiency

Cu losses = iron losses

$$\boxed{P_{cuFL} = P_i}$$

Other than full load

$$\left[P_{cuFL} = I_2^2 R_{O2}\right]; \left[P_{cu\,x\,load} = x\,P_{cuFL}\right]$$

For maximum efficiency

$$x = \sqrt{\frac{P_i}{P_{cuFL}}}$$

x = loading load at which maximum efficiency occur.

21.

Sol.

The transformers used in distribution purpose are connected to the supply for 24 hrs but the load is not connected for 24 hrs. So the iron losses will occur for 24 hrs but the cu-losses will occur only when the transformer is delivering load.Thus For same rating the transformer size in distribution is more than the transformer size in transmission. Distribution transformer is designed for low iron losses.

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22.

Sol.

A transformer in which winding is common to both the primary and secondary circuit is known as auto transformer.In auto transformer the primary and secondary circuits are connected as conductively (electrically) as well as inductively (magnetically).

$(VA)_{auto} = (VA)_{Ind.} + (VA)_{cond}$

$(VA)_{Ind} = (1 - k)\ (VA)_{auto}$ $\qquad$ $(VA)_{cond} = k(VA)_{auto}$

23.

Sol.

1. It is used in labs for testing.
2. It is used as an auto starter
3. It is used as a regulating X-mer

24.

Sol.

1. For same rating, Cu require is less. Cu saving $(G_{T.W} - G_{auto}) = k(G)_{T.W}$
2. The size and cost is less
3. Cu losses are less.
4. Better voltage regulationis and is equal to (1 – k).

$$\frac{(V.R)_{auto}}{(V.R)_{T.W}} = 1 - k$$

5. Higher efficiency. $\eta_{auto} > \eta_{T.W}$
6. Resistance and Reactance are less
7. For same turn (VA) rating is higher.

$$(VA)_{auto} = \frac{(VA)_{T.W}}{1-k}$$

25.

Sol.

1. Due to low impedance , the value of S.C current is high.
2. Their is no electrical separation between primary and secondary circuit.
3. If the connection point between primary and secondary common winding is open accidentally then full primary voltage appears across the secondary (load)

26.

Sol. **Area:-** Increase by K^2 times.

Flux:- Increase by K^2 times.

$\phi = BA$

$\phi' = k^2\phi$

Voltage:- Increase by K^2 times.

$V = 4.44\ \phi f N$

$V' = K^2V$

Current

$I = JA$

$I' = K^2I \rightarrow$ increase by K^2 times.

Power rating (VA)

$VA \rightarrow$ increase by K^4 times.

27.

Sol. **Losses α volume.**

losses increase by K^3 times.

28.

Sol. **Area:-** Increase by K^2 times.

Flux:- Increase by K^2 times.

$\phi = BA$

$\phi' = k^2\phi$

29.

Sol.

Due to variations in load and climatic conditions, the oil in transformers expands or contracts. In the absence of a conservator tank, high pressures are developed which may burst the tank.

30.

Sol.

To provide proper insulation to the output leads to be taken from the transformer tank.
Porcelain type bushings are used up to 33 kV.
Condenser type and oil-filled type bushings are used beyond 33 kV.

31.

Sol.

Absorption of moisture and dust by oil must be prevented. To prevent moisture and dust from entering the conservator tank oil, breather is provided.

32.

Sol.

The nature of magnetic field is rotating which rotates with constant magnitude of 1.5 times of single phase flux ($3/2f_M$) at 'N_S' speed.

33.

Sol.

When 3 - ϕ AC supply connected to 3 - ϕ stator winding, a rotating magnetic field is produced which rotates at synchronous speed. At starting when $N_r = 0$ so the stationary rotor conductor get cuts by the rotating flux so according To faraday's law of electro - magnetic induction their is induced EMF in rotor conductors. Since the rotor winding is short circuited so their is induced current in the rotor.
Acc. to the Lenz law, this current opposes the causes of production i.e. opposes the relative motion ($N_s - N_r$) so to minimize the relative motion the rotor will rotate in the direction of rotating magnetic field.
So a 3 - ϕ induction motor is a self starting motor.

34.

Sol.

If $N_r = N_s$ then relative speed will be zero. So their is no induced EMF and Hence motor will not start. due to this 3 - ϕ induction motor is also known as asynchronous motor as it never runs at synchronous speed.

35.

Sol.

$$f_s = \frac{N_s P}{120}$$

$$f_r = \frac{(N_s - N_r)P}{120}$$

$$= s\frac{N_s P}{120}$$

$f_r = s\, f_s$ (slip frequency)

At stand still

$$s = \frac{N_s - 0}{Ns} = 1$$

$f_r = f_s$ = stator frequency

In running condition due to vey low frequency on rotor, the rotor iron losses (frequency depend) are

generally neglected.

36.

Sol.

Air gap power(P_{ag})
copper losses(P_{cu})
output mechanical power(P_0)
slip (s)

$P_{ag} : P_{cu} : P_0 = 1 : s : (1 - s)$

$$\frac{P_0}{P_{cu}} = \frac{1-s}{s}, \quad \frac{P_g}{P_0} = \frac{1}{1-s}$$

$$P_{cu} = sP_g$$

$$P_0 = (1-s)P_g$$

37.

Sol.

$$T = \frac{P_0}{W_r} = \frac{(1-s)}{(1-s)}\frac{P_g}{W_s}$$

$$T = \frac{P_g}{W_s}$$

$$P_g = 3I_2'^2R_2'/s$$

$$T = \frac{3}{W_s}\left[\frac{V^2R_2'/s}{\left(R_1 + R_2'/s\right)^2 + \left(X_1 + X_2'\right)^2}\right]$$

If stator losses = 0

$[R_1 = 0, x_1 = 0]$

$$T = \frac{3}{W_s}\left[\frac{V^2R_2'/s}{\left(R_2'/s\right)^2 + \left(X_2'\right)^2}\right] \qquad T = \left[\frac{V^2sR_2'}{\left(R_2'\right)^2 + \left(sX_2'\right)^2}\right]$$

Starting torque depends on rotor resistance but max. torque does not depend on rotor resistance.

38.

Sol.

Slip at maximum torque

$$s_m = \frac{R_2'}{\sqrt{R_1^2 + \left(x_1 + x_2'\right)^2}}$$

If $R_1 = 0$, $x_1 = 0$ than

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

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$$T_{max} = \frac{3}{W_s}\left[\frac{0.5V^2}{R_1 + \sqrt{R_1^2 + \left(X_1 + X_2^{'}\right)^2}}\right]$$

(with stator losses.)

$$T_{max} = \frac{3}{W_s}\left[\frac{0.5V^2}{X_2^{'}}\right]$$

(without stator losses.)

It is also clear that the maximum torque of 3 - ϕ I.M not depends on rotor circuit resistance (R'_2). While the slip at maximum torque will depends on rotor circuit resistance.

39.

Sol.

$$\frac{T_{FL}}{T_{max}} = \frac{2s_{FL}s_m}{s_{FL}^2 + s_m^2}$$

S_{fl} = full load slip

S_m = slip at maximum Torque

40.

Sol.

$$\frac{T_{st}}{T_{max}} = \frac{2s_m}{1 + s_m^2}$$

S_m = slip at maximum Torque

41.

Sol.

It is Performed at Rated Voltage to measure No load losses (iron + Friction and Windage losses)
At No load

$$N_r \simeq N_S$$

$$s = 0$$

At no load rotor current is minimum, so rotor Cu losses are neglected. Also rotor iron losses are neglected. Mainly the power consists of stator iron losses and friction & windage losses which are constant, so they are called fixed losses of motor.

42.

Sol.

Performed at Rated current
Blocked rotor

$$N_r = 0$$

$$s = \frac{N_s - 0}{N_s} = 1$$

Measure Copper losses (stator + rotor)

43.

Sol.

At starting $N_r = 0$ and slip is equal to one then magnitude of induced EMF in rotor is very large. So large induced current will flow in the short circuited rotor. This current is an order of 5 - 8 times of full load

current. So starter is used to limit high starting current by suppling reduced voltage to the motor. Such a reduced voltage applied only for short period of time. Once the rotor gets accelerated full normal voltage applied to the motor.

44.

Sol.

In case of small capacity motor having rating less than 5HP the starting current is not very high. So such motors can withstand such starting current the starter winding is directly connected to the supply without any reduction in supply voltage. Hence this starter is known as DOL starter.

Under over load condition the current drawn by the motor is high. So their is excessive heat produced which ↑es the temp. so a thermal over load relay is used with this starter to protect this from over loading condition.

45.

Sol.

$$N_r = (1 - s)N_s$$

$$N_r = (1 - s)\left(\frac{120f}{P}\right)$$

1. **Frequency control** $\left(\frac{V}{f} = \text{constant}\right)$
2. **Supply voltage control**
3. **Controlling Number of Poles**
4. **Adding external resistance in rotor circuit**

46.

Sol.

In squirrel cage I.M during starting for certain combination of stator and rotor slot (equal or integral multiple) due to the variation of reluctance as a function of space producing strong magnetic forces then the starting accelerating torque. Due to this the motor fails to start. This phenomenon is called cogging. Such combination of stator and rotor slots should be avoided while designing the motor. This can also be minimize by skewing of stator and rotor slots.

47.

Sol. The difference between the synchronous speed N_s and the actual speed N of the rotor is known as slip. Though it may be expressed in so many revolutions/second, yet it is usual to express it as a percentage of the synchronous speed. Actually, the term 'slip' is descriptive of the way in which the rotor 'slips back' from synchronism.

$$\%\text{slip } s = \frac{N_s - N}{N_s} \times 100$$

Sometimes, $N_s - N$ is called the slip speed.

Obviously, rotor (or motor) speed is $N = N_s(1 - s)$.

It may be kept in mind that revolving flux is rotating synchronous, relative to the stator (i.e. stationary space) but at slip-speed relative to the rotor.

48.

Sol.
- Single phase motor have low power factor
- The starting torque is low in single phase motors
- Single phase motor have lower efficiency
- Single phase motor are costly than 3-phase motor of the same rating

49.

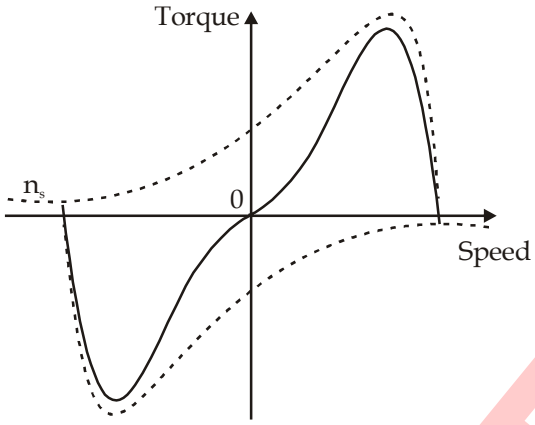
Sol.

Forward slip

$$s_f = \frac{N_s - N_r}{N_s} = s$$

Backward slip

$$s_b = \frac{N_s - (-N_r)}{N_s} = 2 - s$$



50.

Sol. Synchronous speed is the speed of rotationg magnetic field produced when polyphase currents are applied to a polyphase winding. Synchronous speed N_s is given by.

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

This shows that synchronous speed depends on the frequency of supply given to polyphase windings and the number of poles for which polyphase winding is designed.

51.

Sol.

In the coil span of a coil is equals to 180° electrical (pole pitch) then this type of coil is called full pitch coil.

52.

Sol.

If the coil span of a coil is less than the pole pitch (180° electrical) then this type of winding or coil is called short pitch or fractional pitch winding or coil.

Generally the coils are short pitch by 1 or 2 slots because

1. Less copper required , Hence economical
2. Short pitching eliminates high frequency harmonics. Which distortes the sinusoidal nature of EMF.
3. As the high frequency gets eliminated so the eddy current and hystresis losses also get minimized.

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53.

Sol.

Pitch factor or coil span factor:- The factor by which the induced EMF get reduced due to short pitching of the coil is known as pitch factor or coil span factor.

$$\text{Pitch factor/Coil span factor} = \frac{E_R\,(\text{short pitch})}{E_R\,(\text{full pitch})}$$

$$(K_P) < 1$$

$$= \cos\frac{\alpha}{2}$$

α = short pitch angle.

54.

Sol.

$$K_d = \frac{\sin m\beta/2}{m\sin\beta/2}$$

Distribution factor (K_d):- It is define as the ratio of resultant induced EMF when coils are distributed to the resultant induced EMF when the coil are concentrated, it is always less than 1.

55.

Sol.

Cylindrical Type Alternator

$$\uparrow Ns = \frac{120f}{P\downarrow}$$

56.

Sol.

Salient pole/Projected pole type alternator
Speed $\downarrow$ and no. of poles increases

57.

Sol.

The alternator works on the principle of electromagnetic induction Acc. to it when their is relative motion between the armature conductor and the magnetic flux, emf will induced in the conductor. D.C generator also works on the same principle the only difference is that in alternator stationary armature and rotating field type construction is used.

58.

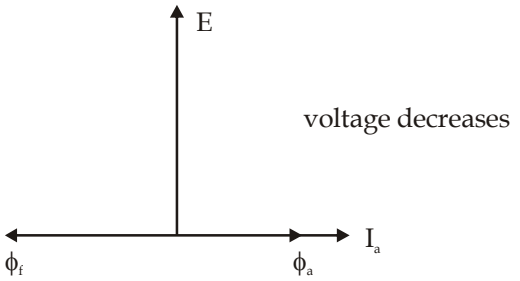
Sol.

At loaded condition the armature flux opposes the main flux. This effect of armature flux is known as armature reaction effect.

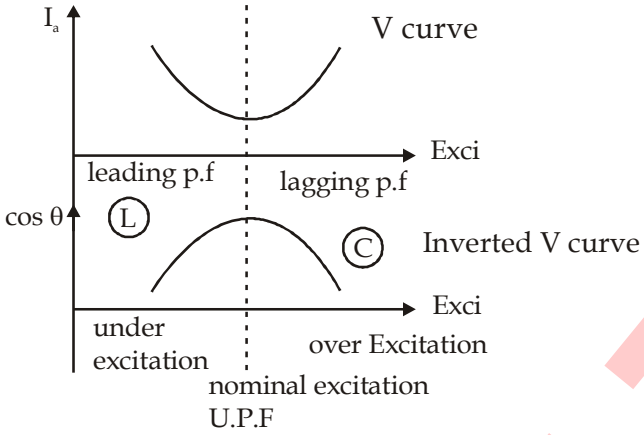
Zero power factor lagging(pure inductive load)

Demagnetizing A.R effect

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59.
Sol.



60.
Sol. For a uniformly distributed winding, distribution factor is given by

$$k_d = \frac{\sin(m\sigma/2)}{m\sigma/2} \quad \text{where } m\sigma = \text{ phase spread angle}$$

(a) For $\sigma = 60^o$, $\quad k_d = \dfrac{\sin 30}{30 \times \frac{\pi}{180}} = 0.955$

61.
Sol. In Lap winding No of parallel path is equal to No of poles(A = P)
It is used for low voltage application
Where A = Number of parallel path
P = Number of poles

62.
Ans In wave winding Number of parallel path is equal to 2 (A = 2)
It is used for high voltage application
Where A = Number of parallel path

63.
Sol.
It is a form of a rotating switch placed between the rotating armature and the stationary external circuit. And it is so arranged that it will reverse the connection that with the external circuit at the instant of each reversal of current in armature.

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It provide electrical connection between rotating armature and stationary external circuit.

For DC Motor:- It converts D.C to A.C work as mechanical inverter.

For DC Generator:- It converts A.C to D.C work as mechanical rectifier.

In D.C machine commutator work as both mechanical inverter as well as mechanical rectifier.

64.

Sol.

At no load, DC series motor has very high dangerous speed.So that the machine may get damged due to heavy centrifugal forces set up in the rotating part. This is the region that the D.C series motor are never started without any load. Due to high starting torque, this type of motor used in traction, electric vehciles, left games etc. For very high armature current, speed is constant.

65.

Sol.

D.C generator convert mechanical power into electrical power when it is connected to a mechanical source or prime force, its armature conductor cuts the stationary magnetic flux and acc. to the faraday's law of electro magnetic induction EMF get induced. In D.C generator the magnetic field is stationary and the armature conductor's are rotating.

66.

Sol.

If series winding turn are so adjusted that with increase in load current the terminal voltage increase. It is called over-compound generator.

67.

Sol.

If series winding turns are so adjusted that with increase in load current the terminal voltage remians same. it is called flat compound generator.

68.

Sol.

In D.C machine the main flux is due to the main poles, however when armature current flows in armature conductor, it also creates a magnetic flux called armature flux (ϕ_A), that distort or weak the flux coming out from the main poles. So this effect of armature flux on main field flux is called armature reaction.

69.

Sol.

When the armature coil passes through the brush the current in the coil will reverse, this reversal of current is called commutation process .

70.

Sol.

When commutation take place the coil under-going commutation is short-circuited by the brush.
The time period during which the coil remains short-circuits is known as commutation time (T_C). If the reversal of current is completed by the end of commutation time, it is called ideal commutation under ideal condition no sparking will take place between brush and commutator segment. But if the reversal of current is not completed by that time than sparking will occur between brush and commutator segment which results in progressive damage to brush.

71.

Sol.

The ideal commutation can not be attained due to armature coil inductance (L_a) which opposes the reversal of current. So a EMF is induced in the coil which is called reactance voltage. This reactance voltage opposes the reversal of current in coil. This result in sparking and over-heating between the brush and commutator.

72.

Sol.

The MMF of interpoles neutralize the cross- magnetizing effect (sparking) of armature reaction. the reactance voltage is neutralize by interpoles and hence improve commutation.

73.

Sol. The interpolar mmf does two tasks, (i) it neutralises the armature cross flux in the commutating zone and (ii) in addition, it provides extra interpolar flux in the commutating zone so as to induce rotational emf in the commutated coil in such a direction as to nullify the reactance voltage.

74.

Sol. A commutator in a dc motor performs the following two functions:

(i) DC supplied at the armature terminals is converted to ac in the armature winding by means of commutator.

(ii) It renders the armature mmf stationary in space along the q-axis even though the armature rotates.

75.

Sol. Armature control is superior to field control scheme, due to following reasons:

(i) It provides a constant-torque drive. In the shunt motor case by keeping the field current at maximum value full motor torque can be obtained at full-load armature current at all speeds.

(ii) Since the main field ampere-turns are maintained at a large value, flux density distortion caused by armature reaction is limited.

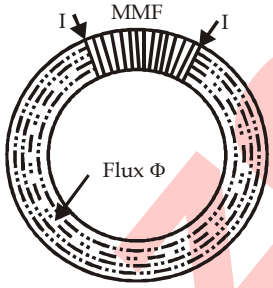
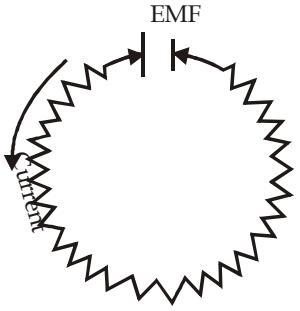
(iii) Unlike field control scheme, speed reversal can be easily implemented here.

PART - B

5 Marks Questions

76.

Sol.

	Magnetic circuit	**Electric circuit**
		
1.	$\text{Flux} = \frac{\text{m.m.f.}}{\text{reluctance}}$	$\text{Current} = \frac{\text{e.m.f.}}{\text{resistance}}$
2.	M.M.F. (Ampere-trun)	E.M.F. (volt)
3.	Flux Φ (weber)	Current I (ampere)
4.	Flux density B (Wb/m^2)	Current density (A/m^2)
5.	Reluctance $S=\frac{l}{\mu A}=\frac{l}{\mu_0\mu_r A}$	Resistance $R=\rho\frac{l}{A}$
6.	Permeance(= 1/reluctance)	Conductance(= 1/resistance)
7.	Reluctivity	Resistivity

8.	Permeability (= 1/reluctivity)	Conductivity (= 1/resistivity)
9.	Total m.m.f. $= \Phi S_1 + \Phi S_2 + \Phi S_3 + ...$	Total e.m.f. $= IR_1 + IR_2 + IR_3 + ...$

77.

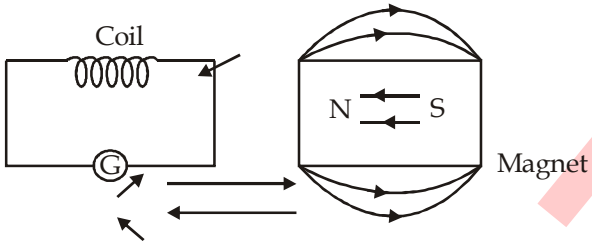
Sol.

	Soft	**Hard**
1.	They can be easily magnetised and demagnetised.	They cannot be easily magnetised (or) demagnetised.
2.	Loop area is less and hence the hystersis loss is minimum.	The loop area is large and hence the Hystersis loss is maximum.
3.	Susceptibility and permeability is high.	Susceptibility and permeability is low.
4.	Retentivity and coercivity are small	Retentivity and coercivity are large.
5.	They have low eddy current loss.	They have high eddy current loss.

78.

Sol.

1. **1st Law of Faraday:-** According to this law whenever their is change in magnetic flux linkage with respect to a coil/ conductor, an EMF will induced in the coil or conductor.



2. **Faraday's 2nd Law:-** According to this law the mangitude of this induced EMF is directly proportional to the rate of change of flux linkage

$$e \propto \frac{d\lambda}{dt}$$

$$e = \frac{Nd\phi}{dt}$$

79.

Sol. Induced emf in the circuit

$$e(t) = \frac{d\phi(t)}{dt}$$

$$e(t) = \frac{d}{dt}\left[6t^2 - 5t + 1\right]$$

$$e(t) = 12t - 5$$

At t - 0.25 sec.

$$e(0.25) = 12(0.25) - 5 = 3 - 5$$

$$e(0.25) = -2\,\text{Volt}$$

$\therefore$ Current $I = e/R$

$$= -\frac{2}{10}$$

But magnitude

$$|I| = 0.2\ \text{Amp.}$$

80.

Sol. given data $\phi = 0.5$ **mWb**
Number of turns(N) = 600
current(I)= 3A

(i) Inductance of the first coil $L = \frac{N\phi}{I} = \frac{600 \times 0.5 \times 10^{-3}}{3} = 0.10$ H

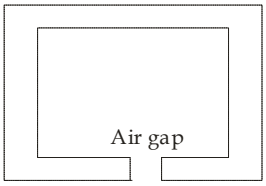
(ii) e.m.f. induced $e_1 = L\frac{di}{dt} = 0.10 \times \frac{(4-0)}{2 \times 10^{-3}} = 200$ V

(iii) $M = \frac{N_2 \phi_1}{I_1} = \frac{600 \times 0.5 \times 10^{-3}}{3} = 0.1$ H

81.

Sol.

In the transformer core if their is a small air gap then the I_M (magnetizing current)will increase for the same flux requirement



$\phi = \frac{MMF}{R_l}$ $\phi = \frac{NI_m \uparrow}{R_l \uparrow}$ {Relucatance of air is high}

82.

Sol.

Transformer :- $\phi = \frac{MMf}{R_l(core)} = \frac{NI_m \downarrow}{R_l \downarrow}$ [3 to 5% of I_{FL}(full load current)]

Induction motor :- $\phi = \frac{NI_m \uparrow}{R_l \uparrow}$ [30 to 50% of I_{FL}]

83.

Sol.

2. Copper Losses/ Variable Losses/ Ohmic Losses

When X-mer is loaded these losses take place otherwise negligible small these are resistance losses in the primary and secondary winding. So these are called I^2R or ohmic losses.

84.

Sol.

It is define as the change in secondary terminal voltage expressed as a percentage of the secondary rated voltage. When load at a given power factor is reduced to zero with primary applied voltage held constant. The change in secondary terminal voltage depends on the load power factor, load current, equivalent resistance and equivalent leakage reactance of the X-mer.
Ideal voltage regulation = 0

85.

Sol.

$V.R = R_{PU}\cos\theta + X_{PU}\sin\theta$

For maximum V.R $\tan\theta = \dfrac{X_{PU}}{R_{PU}}$

Maximum V.R is possible in lagging power factor load

Maximum V.R = $R_{PU}\left(\dfrac{R_{PU}}{Z_{PU}}\right) + X_{PU}\left(\dfrac{X_{PU}}{Z_{PU}}\right)$

$$\boxed{(V.R)_{max} = Z_{PU}}$$

86.

Sol.

$V.R = R_{PU}\cos\theta - X_{PU}\sin\theta$

$V.R = 0$

$\tan\theta = \dfrac{R_{PU}}{X_{PU}}$

zero voltage regulation will take place at leading power factor load.

87.

Sol.

At maximum efficiency

Cu losses = iron losses

$$\boxed{P_{cuFL} = P_i}$$

Other than full load

$$\left[P_{cuFL} = I_2^2 R_{O2}\right];\ \left[P_{cu\,x\,load} = x\ P_{cuFL}\right]$$

For maximum efficiency

$$x = \sqrt{\frac{P_i}{P_{cuFL}}}$$

x = loading load at which maximum efficiency occur.

88.

Sol.

The transformers used in distribution purpose are connected to the supply for 24 hrs but the load is not connected for 24 hrs. So the iron losses will occur for 24 hrs but the cu-losses will occur only when the transformer is delivering load.Thus For same rating the transformer size in distribution is more than the transformer size in transmission. Distribution transformer is designed for low iron losses.

89.

Sol.

A transformer in which winding is common to both the primary and secondary circuit is known as auto transformer.In auto transformer the primary and secondary circuits are connected as conductively (electrically) as well as inductively (magnetically).

$(VA)_{auto} = (VA)_{Ind.} + (VA)_{cond}$

$(VA)_{Ind} = (1 - k)\ (VA)_{auto}$ $\qquad$ $(VA)_{cond} = k(VA)_{auto}$

90.

Sol.

1. It is used in labs for testing.

2. It is used as an auto starter
3. It is used as a regulating X-mer

91.

Sol.

1. For same rating, Cu require is less. Cu saving $(G_{T.W} - G_{auto}) = k(G)_{T.W}$
2. The size and cost is less
3. Cu losses are less.
4. Better voltage regulationis and is equal to (1 – k).

$$\frac{(V.R)_{auto}}{(V.R)_{T.W}} = 1 - k$$

5. Higher efficiency. $\eta_{auto} > \eta_{T.W}$
6. Resistance and Reactance are less
7. For same turn (VA) rating is higher.

$$(VA)_{auto} = \frac{(VA)_{T.W}}{1-k}$$

92.

Sol.

1. Due to low impedance , the value of S.C current is high.
2. Their is no electrical separation between primary and secondary circuit.
3. If the connection point between primary and secondary common winding is open accidentally then full primary voltage appears across the secondary (load)

93.

Sol. **Area:-** Increase by K^2 times.

Flux:- Increase by K^2 times.

$\phi = BA$

$\phi' = k^2\phi$

Voltage:- Increase by K^2 times.

$V = 4.44\ \phi f N$

$V' = K^2V$

Current

$I = JA$

$I' = K^2I \rightarrow$ increase by K^2 times.

Power rating (VA)

$VA \rightarrow$ increase by K^4 times.

94.

Sol. Losses α volume.

losses increase by K^3 times.

95.

Sol. **Area:-** Increase by K^2 times.

Flux:- Increase by K^2 times.

$\phi = BA$

$\phi' = k^2\phi$

96.

Sol.

Due to variations in load and climatic conditions, the oil in transformers expands or contracts. In the absence of a conservator tank, high pressures are developed which may burst the tank.

97.

Sol.

To provide proper insulation to the output leads to be taken from the transformer tank.
Porcelain type bushings are used up to 33 kV.
Condenser type and oil-filled type bushings are used beyond 33 kV.

98.

Sol.

Absorption of moisture and dust by oil must be prevented. To prevent moisture and dust from entering the conservator tank oil, breather is provided.

99.

Sol. **Core Type Transformer :**

- In core type transformer winding surround the steel core.
- This type of transformer requires less iron but more conductor material
- The vertical portion of the core are usually called limbs or leg and the top and bottom portion are called the yoke. This means that for single-phase transformer, core type has two legged core.
- The L.V. winding is placed adjacent to the steel core and H.V. winding out side, in order to minimise the amount of insulation required.

Shell Type Transformer :

- In shell type transformer steel core surround a major part of the winding.
- Shell type transformer has three legged core.
- In shell type transformer, the L.V. and H.V. winding are wound over the center limb and are interleaved or sandwitch.
- Shell type transformer are preferred for low voltage low-power levels.

100.

Sol. hysteresis loss $P_h = k_h f B_m^{\ x}$

Eddy current loss, $P_c = k_e f^2 B_m^{\ 2}$

$$\frac{P_{h1}}{P_{h2}} = \frac{k_h f_1 B_{m_1}^2}{k_h f_2 B_{m_2}^2}$$

Given, x = 2

$$= \left(\frac{f_1}{f_2}\right)\left(\frac{V_1}{V_2}.\frac{f_2}{f_1}\right)^2 = \left(\frac{50}{60}\right)\left(\frac{100}{110}\times\frac{60}{50}\right)^2$$

or $$\frac{P_{h1}}{P_{h2}} = 0.991$$

$$\frac{P_{e1}}{P_{e2}} = \frac{k_e f_1^2 B_{m_1}^2}{k_e f_2^2 B_{m_2}^2} = \left(\frac{50}{60}\right)^2\left(\frac{100}{110}\times\frac{60}{50}\right)^2$$

or $$\frac{P_{e1}}{P_{e2}} = 0.826$$

101.

Sol.

Since $V \propto B_{mf}$ and hysteresis loss is $P_h = k_n f B_m^x$
then % decrease in hysteresis loss

$$= \frac{P_{h_2} - P_{h_1}}{P_{h_1}} \times 100 = \frac{f_2 . B_{m_2}^x - f_1 B_{m_1}^x}{f_1 B_{m_1}^x} \times 100$$

$$= \left[\frac{f_2}{f_1} \left(\frac{V_2}{V_1} . \frac{f_1}{f_2} \right)^x - 1 \right] \times 100 = \left[\frac{40}{50} \left(\frac{160}{200} . \frac{50}{40} \right)^x - 1 \right] \times 100 = -20\%$$

Eddy current loss $= k_e f^2 B_m^{\ 2}$

% decrease in eddy current loss

$$= \frac{P_{e_2} - P_{e_1}}{P_{e_1}} \times 100 = \left[\left(\frac{f_2}{f_1} \right)^2 . \left(\frac{V_2}{V_1} . \frac{f_1}{f_2} \right)^2 - 1 \right] \times 100$$

$$= \left[\left(\frac{40}{50} \right)^2 . \left(\frac{160}{200} \times \frac{50}{40} \right)^2 - 1 \right] \times 100 = -36\%$$

102.

Sol.

A transformer has a silicon steel core (soft-iron) and the 2 winding are placed on it. These windings are insulated from both the core by each other. Core is built up with thin soft iron or silicon steel laminations to provide low reluctance path to the magnetic flux.

Sheets are laminated to reduce eddy current loss, Thickness of lamination is 0.35mm for 50 Hz operation The winding connected to the supply mains is called primary winding and the winding connected with the load side is called secondary winding. Windings are made of high grade copper.

103.

Sol.

When the primary winding is connected to alternating supply an alternating current will flow in the primary winding turns (N_1) this current produces flux (ϕ_M) which induces EMF (E_2) in the secondary winding and also in the primary winding. Due to E_2 load current (I_2) flow in the secondary circuit which also produces its own flux ϕ_2 in opp. direction to ϕ_M. Due to this ϕ_2 an additional current draw from the primary (I_2^1) which produces the flux $(\phi_2)'$ opp. to the ϕ_2. So it is clear that the total core flux remains ϕ_M as the ϕ_2 cancel out the flux ϕ_2^1 .So the transformer is called constant mutual flux device as its core flux does not depend on load, it remain same. And it is the reason that iron losses/core losses does not depend on load it remains constant.

104.

Sol.

1. Iron Losses become zero.
2. Copper Losses zero
3. Leakage Flux (X_1, X_2) = 0 $\rightarrow$ $X_1 = 0$, $X_2 = 0$
4. Core should have infinite permeability so that zero magnetizing current is needed to establish the requisite amount of flux in the core
5. There is no stray capacitance

105.

Sol.

Iron Losses are the constant lasses and it is of 2 type

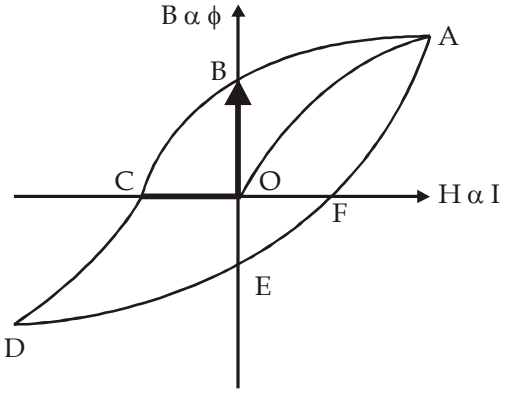
(a) Eddy Current Losses:- These are the losses occured in the X-mer core due to eddy current produce by the alternating flux. Which results the core become heat up and to minimize these losses.

1. Laminated core is used.
2. Add silica (2 to 4%)

$P_e = Kef^2 B_m^{\ 2} t^2$

(b) Hysteresis Loss:- These are the Losses occured in X-mer core when it magnetize or De-magnetize due to alternating flux. So the mangetic grains required energy, this required energy is known as Hysteresis losses. This losses can be represented by the area under the B – H curve or (ϕ – I) curve

$$P_M = K_M B_M^{1.6} fV$$



OB = Retaintivity (Residual magnetic field)
OC = Coercive field/Coercive force/Coercivity
To minimize, these losses CRGO (cold rolled grain Oriented) steel is used

106.
Sol.

Case - I

Voltage $\rightarrow$ Constant,
Frequency $\rightarrow$ Variable

$V = 4.44 \phi_m f N$

$V = 4.44 B_m A f N \qquad [\phi_M = B_M A]$

$$B_m \propto \frac{1}{f}$$

Eddy current losses

$$P_e = K_e f^2 B_m^2 t^2$$

$$P_e \propto f^2 \left(\frac{1}{f}\right)^2$$

P_e = constant

Hysteresis Losses

$$P_h = K_n f B_m^{1.6}$$

$$P_h \alpha f\left(\frac{1}{f}\right)^{1.6} \qquad P_n \alpha \frac{1}{f^{0.6}}$$

Total Iron Losses

$P_i = P_e + P_h$

V, f $\uparrow$, $B_m \downarrow$, $\phi_m \downarrow$, $I_h \downarrow$, P_e, $P_h \downarrow$, $P_i \downarrow$,

107.
Sol.

Voltage $\rightarrow$ Variable,
Frequency $\rightarrow$ Variable.

$\because \frac{V}{f} = \text{constant}$

$\left(\frac{V}{f}\right) = 4.44\ B_m\ AN \quad B_m = \text{Constant}$

Eddy Current Losses

$P_e = K_e f^2 B_m^2 t^2$

$P_e \alpha f^2$

Hysteresis losses

$P_h = K_m f\ B_m^{1.6}$

$P_h \alpha f$

Total Iron Losses

$P_i = P_e + P_h$

Effect if $f \uparrow V \uparrow \frac{V}{f} = \text{constant}$

$B_M \rightarrow$ Const.

$\phi_M \rightarrow$ Const.

$I_M \rightarrow$ Const.

$P_e \uparrow, P_h \uparrow, P_i \uparrow$

108.

Sol.

It is used to determine Iron Losses and shunt parameter of transformer.

Test Performed on L.V side and H.V side Open circuited.

Rated Voltage applied on L.V. side

The input power taken from the supply is equal to the transformer no load losses or iron losses.

109.

Ans: It is used to determine full load Cu losses/Ohmic losses and series parameter of transformer

Rated current applied at H.V. side

In this test it is performed on H.V side and L.V is kept short circuited so to flow rated short circuit current, only 5-12% of the rated H.V side voltage is applied at rated frequency.

110.

Sol.

This test can be performed when 2 identical X-mers are available and these 2 X-mers are connected such that primaries of the 2 X-mers are connected in parallel across the supply and secondaries are connected in series such that EMF of them are opposite to each other (voltage opposition), another low voltage supply is connected in series with secondaries to get the readings.

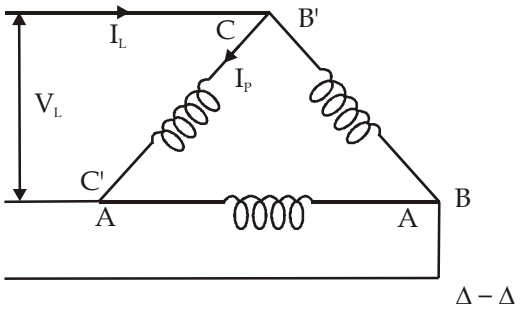
Since the secondaries are connected in voltage oppsition, so in this case no current will flow in the secondary and thus no load test is simulated. So the i/p power measured by wattmeter is equal to the iron losses of both the X-mers.

Now a small voltage is injected in the secondary with the help of a low voltage transformer and this voltage is adjusted so that the rated current will flow through the secondaries. In this case S.C test is simulated and the wattmeter measured the total full - load Cu losses of both the X-mer

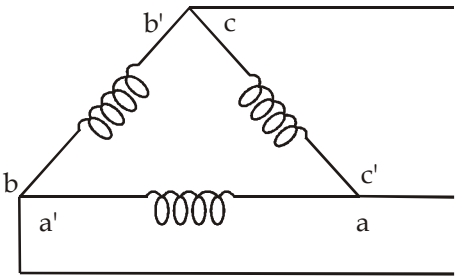
ZONE TECH

111.

Sol.

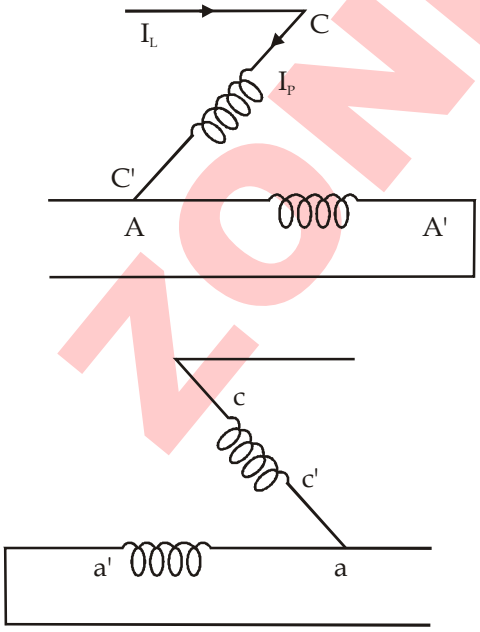


$\Delta - \Delta$



$V_L = V_{PH}$ $I_L = \sqrt{3} I_{ph}$

$S_{\Delta\Delta} = \sqrt{3} V_L I_L$ $S_{\Delta\Delta} = 3 V_p I_p$



V – V connection

ZONE TECH

$$S_{VV} = \sqrt{3}V_L I_L$$

$$= \sqrt{3}\left(V_p\left(I_p\right)\right) \qquad [I_L = I_P]$$

$$= \sqrt{3}\, V_p I_p$$

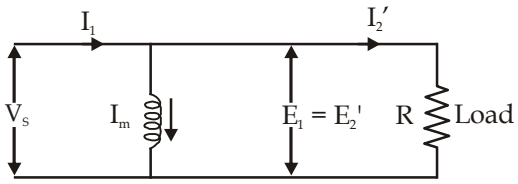
Ratio

$$\frac{S_{VV}}{S_{\Delta\Delta}} = \frac{\sqrt{3}V_p I_p}{3V_p I_p} = \frac{1}{\sqrt{3}} = 0.57$$

$$\boxed{S_{VV} = 57\% \text{ of } S_{\Delta\Delta}}$$

112.

Sol.



$$I_1 = \vec{I}_m + \vec{I}_2' \quad ...(1)$$

$$I_2' = kI_2 \angle 0^0 \quad k = 2$$

$$I_2' = 2\angle 0^0 \text{ Amp}$$

$[\because I_2 = 1 \text{ Amp}]$

$$I_m = 1\angle -90^0$$

Put I_2' & I_m in equation (1)

$$I_1 = 1\angle -90^0 + 2\angle 0^0$$

$$I_1 = 1\cos 90^0 - j\sin 90^0 + 2$$

$$I_1 = 2 - j1$$

$$|I_1| = \sqrt{4+1} = \sqrt{5}$$

$$|I_1| = 2.24 \text{ Amp.}$$

113.

Sol.

A transformer may have a third winding in addition to the normal primary and secondary windings. It is called a tertiary winding.

A tertiary winding is used,

1. To supply an additional load at a voltage different from that of the primary and secondary.
2. To supply phase compensating devices (for example, condenser) operated at a voltage different from both the primary and the secondary voltages.
2. In star-star connected transformers to suppress harmonic voltages, to allow sufficient earth fault current to flow for the operation of protective devices and to enable them to supply single-phase loads.
4. As a voltage coil in a cascaded testing transformer.

   Tertiary windings are normally delta-connected to provide a path for zero-sequence currents in the case of single line or double line to ground faults. The unbalanced produced by these unbalance ground faults is reduced.

ZONE TECH

114.

Sol.

If the air gap flux is not purely sinusoidal as it contains $(6n \pm 1)$th odd harmonics (5^{th}, 7^{th}). Hence at low speed the torque slip characteristic are not smooth. The most important and predominent harmonics which effect must be analysis are 5^{th} and 7^{th} harmonics.

As the 5^{th} harmonics field rotates opposite to the rotor rotation. Torque due to 5^{th} harmonic field opposes fundamental torque. The 7^{th} harmonics field rotates in the direction of rotor rotation. so the torque due to 7^{th} harmonics supports the fundamenal torque.

SO the resultant torque which is addition of fundamental torque 5^{th} harmonics torque and 7^{th} harmonics torque. The stable operation of the motor is achieved at $\left(\frac{N_s}{7}\right)$ speed (sub- syn speed)This is called crawling, due to this their is much higher stator current cause noise and vibration.

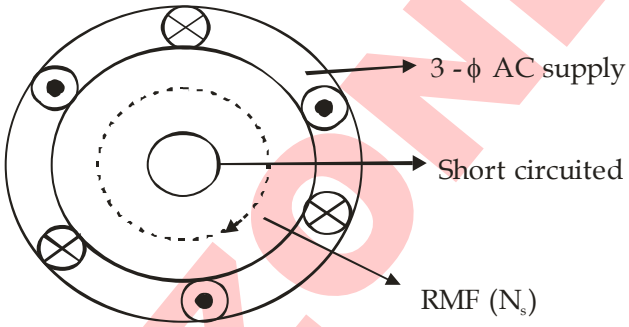
The crawling effect can be reduced by using chorded(short pitched) winding, still if the crawling observed it can be overcome by applying a sudden external torque in direction of rotor rotation.

115.

Sol. When 3 - ϕ AC supply connected to 3 - ϕ stator winding , a rotating magnetic field is produced which rotates at synchronous speed. At starting when $N_r = 0$ so the stationary rotor conductor get cuts by the rotating flux so according To faraday's law of electro - magnetic induction their is induced EMF in rotor conductors. Since the rotor winding is short circuited so their is induced current in the rotor.

Acc. to the Lenz law, this current opposes the causes of production i.e. opposes the relative motion $(N_s - N_r)$ so to minimize the relative motion the rotor will rotate in the direction of rotating magnetic field. So a 3 - ϕ induction motor is a self starting motor.

If $N_r = N_s$ then relative speed will be zero. So their is no induced EMF and Hence motor will not start. due to this 3 - ϕ induction motor is alsoknown as asynchronous motor as it never runs at synchronous speed.



116.

Sol. Given that :

Full load speed of motor,

$$N_r = 1440 \text{ rpm}$$

Synchronous speed of motor,

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

$$\therefore \quad N_s > N_r$$

Let, $N_s = 1500$ rpm (Nearest standard synchronous speed for even number of poles).

(i) Number poles $1500 = \frac{120 \times 50}{P}$

$P = 4$

(ii) Full load slip $s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1440}{1500} = 0.04$

(iii) Rotor frequency, $f' = s.f. = (0.04 \times 50 = 2\ Hz)$

(iv) Speed of stator field w.r.t. rotor field

$= N_s - N_s = 1500 - 1500 = 0$

(As two MMFs are stationary w.r.t. each other)

(v) Speed of stator field w.r.t. rotor structure

$= N_s - N_r = sN_s$

$= 1500 - 1440 = 60$ rpm

117.

Sol. Given that :

Full load slip of motor, s= 4%

Number of poles, p=4

(i) Synchronous speed of motor,

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

$\therefore$ =1500rpm

Let, $N_s = 1500$ rpm (Nearest standard synchronous speed for even number of poles).

(ii) Full load speed $N_r = N_s(1 - s) = 1500(1 - 0.04) = 1440$

(iii) Speed of rotor field w.r.t. stator.

$N_s - 0 = 1500$rpm

118.

Sol.: Given that :

Number poles $P = 4$

speed at maximum torque $N_r = 1440$ rpm

Synchronous speed of motor, $N_s = \frac{120f}{P}$

$N_s = 1500$ rpm

slip at maximum torque $s = \frac{N_s - N_r}{N_s} = \frac{1500 - 1440}{1500} = 0.04$

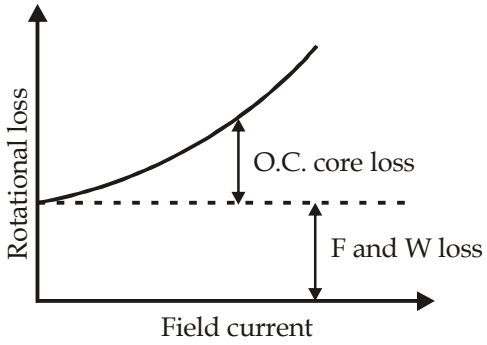
at maximum torque, $s_m = \frac{R_2'}{X_2'}$

where rotor resistance, $R'_2 = 0.1$ ohm

now, rotor reactance at standstill, $X'_2 = 2.5$ ohm

119.

Sol. The mechanical loss and open circuit core loss combined together are caused by rotor rotation. their sum is called as no-load rotational losses.



Mechanical Loss: This loss consists of bearing friction, brush friction and windage losses. The windage or wind friction loss includes the power required to circulate air through the machine and ventilating ducts and is approximately proportional to square of the speed.

Open Circuit Core Loss: Consists of hystersis and eddy current losses. These occurs in case of stator and rotor carrying an alternating flux.

$$\text{Hystersis loss } P_n = K_h f B_m^x$$

$$\text{Eddy current loss } P_e' = K_e f^2 B_m^2$$

No load rotational losses can be determined by running the electrical machine as an unloaded motor at the rotor speed and with armature voltage equal to the normal generator emf. The total power input to the unloaded motor minus the no load armature ohmic loss gives the magnitude of no-load rotational loss.

120.

Sol. **Air gap power (P_g):** The power that is transferred from the stator to the rotor via the air-gap magnetic field, is known as the air-gap power (P_g)

$$P_g = \frac{3I_2'^2 . R_2'}{s}$$

Subtracting the rotor copper loss from Air-gap power (P_g) gives the internal mechanical power developed (P_m)

$$P_m = P_g - 3I_2'^2 . R_2 = \frac{3I_2'^2 R_2'}{s} - 3I_2'^2 . R_2$$

$$= 3I_2'^2 . R_2 \left(\frac{1}{s} - 1\right) = (1-s)P_g$$

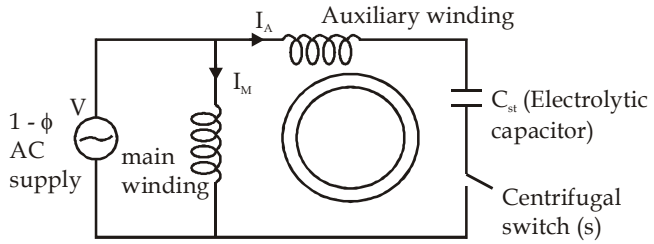
The internal mechanical power developed (P_m) is three times the electrical power absorbed in resistance $R_2'\left(\frac{1}{s} - 1\right)$.

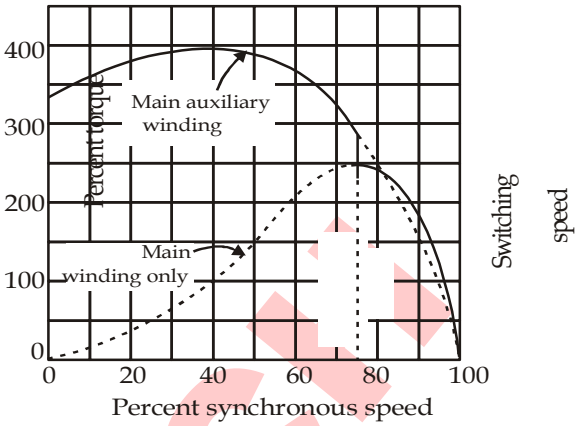
Shaft power (P_{sh}) is the power available at shaft after subtracting mechanical losses from P_m.

$$P_{sh} = P_m - \text{mechanical losses}$$

121.

Sol.



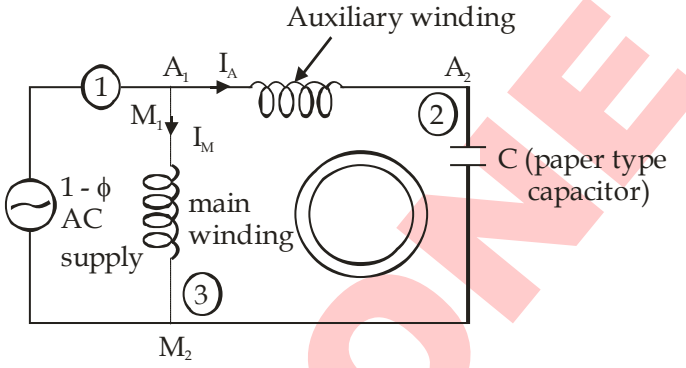


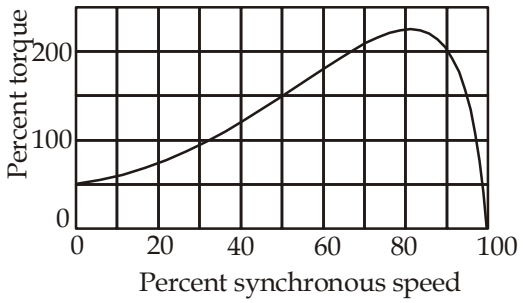
1. Highest starting torque.
2. C is electrolytic capacitor(due to high VAR rating) and it is short time rated
3. Rating 120 watt to 7.5 K watt.
4. Used in hard starting such as compressor, large fan, pump and high inertia load application.

122.

Sol.

Permanent capacitor or capacitor- run 1 – ϕ Induction Motor



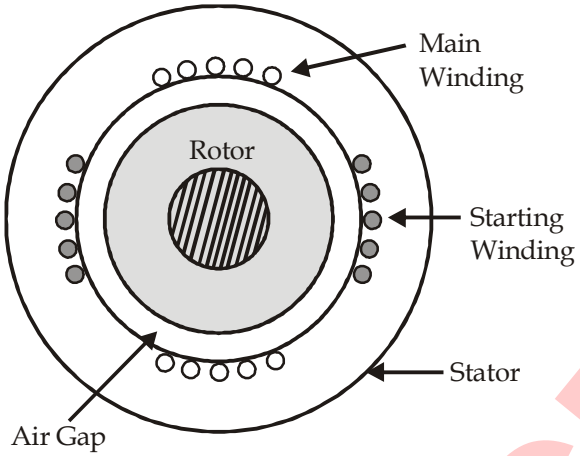


1. Because of constant torque this motor is vibration and noise free. So this motor used in application where silence is required.
2. Used in ceiling fans, air circulater, blower etc.
3. The capacitor used is a paper type capacitor which creates starting torque at starting and improve power factor in running condition.
4. No centrifugal switch is used.

123.

Sol. A single-phase induction motor is not self-starting. To overcome this drawback and make the motor self-starting. It is temporarily converted into a two-phase motor during starting period. For this purpose, the stator of a single-phase motor is provided with an extra winding, known as starting (or auxiliary) winding, in addition to the main or running winding. The two windings are spaced 90° electrically apart and are connected in parallel across the single phase supply as shown in figure.

ZONE TECH



It is so arranged that the phase difference between the currents in the two stator windings is very large (ideal value being 90°). Hence, the motor behaves like a two phase motor. These two currents produce a revolving flux and hence make the motor self-starting.

124.
Sol.

The construction of Universal motor is very similar to a D.C series motor (with some modification). Such motors can be operated either on A.C or D.C supply and resulting torque speed characteristic is about the same. So it is called universal motor.
When 1 – ϕ A.C supply is connected to series motor same alternating current will flow through the field ad armature windings. So the field winding flux reacts with the armature current to produces a torque. Since both armature and field flux reverse simultaneous so the torque always act in the same direction.
Application:- This motor is used in high speed vaccum motors, cleaners, drill M/C, mixer and grinder m/c tool application, swing M/C etc.

125.
Sol.

In this type of motor, the rotor is a smooth solid cylinder made up of ferro-magnetic material which have hysteresis loss property. They are generally made up of chromium, cobalt, steel or alnico.
Stator is wound with main and auxiliary windings with a permanently connected capacitor is fed from 1 - ϕ A.C supply so their is rotating magnetic field is produced. This RMF indues eddy current in the rotor and the rotor start to move initially with slip 's' and after stator pulls the rotor into synchronism. So it runs at synchronous speed. This type of motor is used in record player, (tape recorders) clock applications, CD player etc.

126.
Sol.

In this type of motor the rotor is squirrel cage, motor with some teeth removed to provide the desired no. of salient poles. Due to this an additional reluctance power is generated which align the rotor with the magnetic field of the stator.
The starting of this motor is just like a 1 - ϕ I.M and due to reluctance torque is start to rotate after 75% speed of synchronous speed. it runs at synchronous speed.
This motor is used in application where constant speed is required such as clock timmers, recording equipments.

ZONE TECH

127.

Sol.

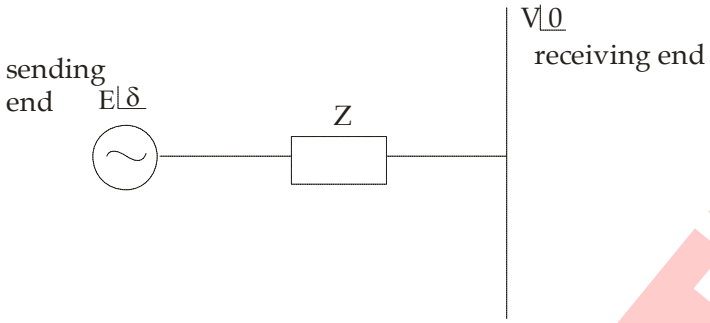
In alternators rotating field, stationary armature type construction is used due to following advantages. (In D.C generator, stationary field, rotating armature construction is used).

1. Required less insulation.
2. Less slip rings are required.
3. Less cooling required.
4. Less sparking
5. Centrifugal forces are less.

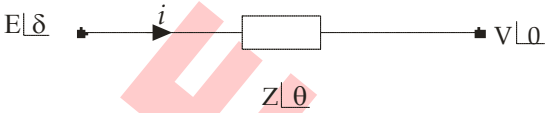
128.

Ans

.



$$P + j\theta = S = VI^*$$



$$I = \frac{E\angle\delta - V\angle 0}{Z\angle\theta}$$

⇒ Sending end voltage receiving end volage

$$I^* = \frac{E\angle -\delta - V\angle 0}{Z\angle -\theta}$$

$$P + j\theta = S_R = \frac{EV\angle\theta - \delta}{Z} - \frac{V^2\angle\theta}{Z}$$

$$P = \frac{EV}{Z}\cos(\theta - \delta) - \frac{V^2}{Z}\cos\theta$$

if $Z = X, \theta = 90° \ \theta = \tan^{-1}(X/R)$

$$P = \frac{EV}{X}\sin\delta$$

$$Q = \frac{EV}{Z}\sin(\theta - \delta) - \frac{V^2}{Z}\sin\theta$$

if $Z = X, \theta = 90°$

$$Q = \frac{EV}{X}\cos\delta - \frac{V^2}{X}$$

ZONE TECH

$$Q = \frac{V}{X}[E\cos\delta - V]$$

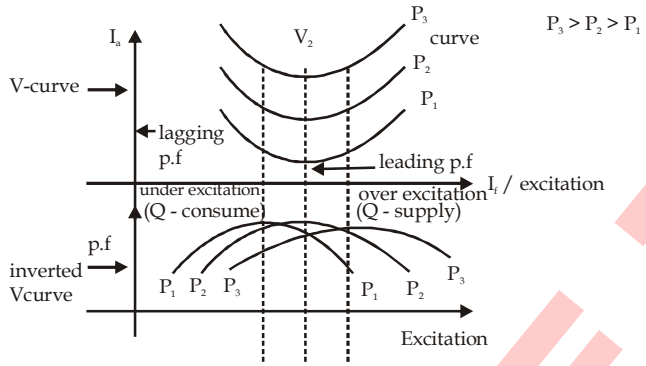
Active power $\Rightarrow P \alpha \delta$ (load angle)
Reactive power $\Rightarrow Q \alpha \Delta V$ (voltage differance)

129.
Sol.

V- Curve shows the Effect of excitation on armature current for constant power output.
Inverted V- Curve shows the Effect of excitation on power factor for constant power output.
P = constant V = constant

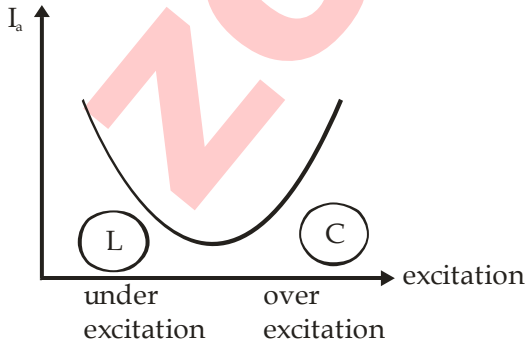
$$\frac{EV}{X}\sin\delta = \text{const}$$

$E \sin \delta = \text{const}$
$VI_a \cos\theta = \text{constant}$
$I_a \cos\theta = \text{constant}$



130.
Sol.

Synchronous motor without any shaft power or mechanical load work as a synchronous phase modifier which in under excitation condition works as a pure inductor consume reactive power called synchronous reactor.
In over - excitation condition it works as a pure capacitor, supply reactive power called synchronous condensor.



131.
Sol.

At the time of starting the rotor is stationary so rotor MMF is stationary and the stator field when connected

to 3 - ϕ A. C supply rotating at synchronous speed. So due to the interaction of stator and rotor poles the torque is developed in a particular direction. 'S' interact with 'n' and 'N' interact with 's'. Hence the torque develop in a particular direction but after half cycle (0.02 sec/rotation) the 'N' interact with 'n' and 'S' interact with 's' so the torrque will develop in opp. direction. So due to its inertia the rotor can not respond to this fast reversal of torque. So motor remains stationary and Hence the synchronous motor is not self started.

132.

Sol.

1. **External Prime Mover starting**
   By using some external prime mover source the rotor is made to rotate at a speed close to synchronous speed due to this their is magnetic locking between opp. poles of stator and rotor. And the rotor will rotate at synchronous speed then the prime mover (P.M) is disconnected from motor.
2. **Damper winding starting (only in salient pole synchronous motor)**
   In this the rotor is made like a squirrel cage rotor by using short circuited damper bars called damper winding. So the motor will start like a squirrel cage I.M and often D.C excitation connected to rotor and their is magnetic locking and then rotor will rotate at synchronous speed.
   At synchronous speed their is no role of damper winding because their is no relative speed.

$$N_s - N_r = 0$$

133.

Sol.

The phenomenon of oscillation of the rotor around its final equilibrium condition is called hunting.

Reduction in Hunting

The hunting can be minimized by using damper winding because in damper winding EMF will induced only If $(N_r \neq N_s)$ and in this condition this opposes the causes of production and pulls the rotor into synchronism.

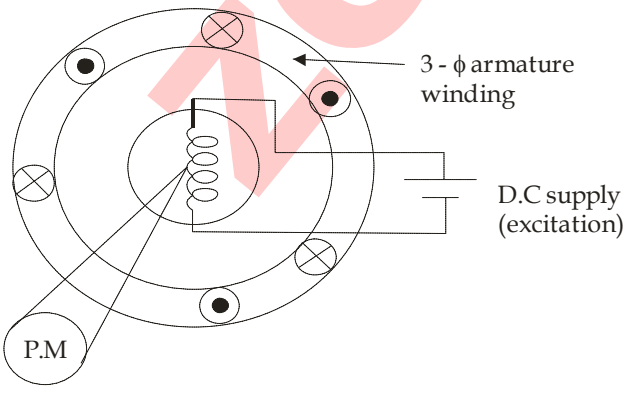
Use of flywheels which helps in maintaining the rotor speed constant.

By using suitable synchronizing power coefficient

In alternator the value of damper winding resistance should be low for minimizing hunting.

134.

Sol. The alternator works on the principle of electromagnetic induction Acc. to it when their is relative motion between the armature conductor and the magnetic flux, emf will induced in the conductor. D.C generator also works on the same principle the only difference is that in alternator stationary armature and rotating field type construction is used.



Using prime mover, rotor is made to rotate at synchronous speed, field flux is rotating in space at N_s at no load Induced emf (per phase)

$$E_f = \sqrt{2}\pi f N_{Ph} \phi_f K_W$$

f= frequency of generated emf
N_{ph}= series turns per phase
K_w= winding factor
ϕ_f= flux per pole produced by dc current in the field winding

135.

Sol. **Voltage Regulation:**

The voltage regulation of an alternator is defined as "the rise in the terminal voltage when full-load is removed (Field excitation and speed remaining the same) Divided by the rated terminal voltage".

$$\% \text{ V.R.} = \frac{E_0 - V}{V} \times 100$$

Method of Determination of voltage regulation.

1. Synchronous Impedance or E.M.F. method.
2. The ampere-turn or m.m.f. method.
3. Zero power factor or potier method
4. American standarad association method.

136.

Sol. The two alternator operate in parallel should to necessary following conditions:

1. They must have the same output voltage rating.
2. The rated speed of machines should be such as to give same frequency $\left(f = \frac{PN}{120}\right)$
3. The prime-mover of the alternators should have same speed-load characteristics which of course must be drooping ones, so as to load the alternator in proportion to their output ratings.
4. The alternator phase sequence should be same.
5. The alternator should have reactance in their armature.
6. The alternators should generate voltages of the same waveform.

137.

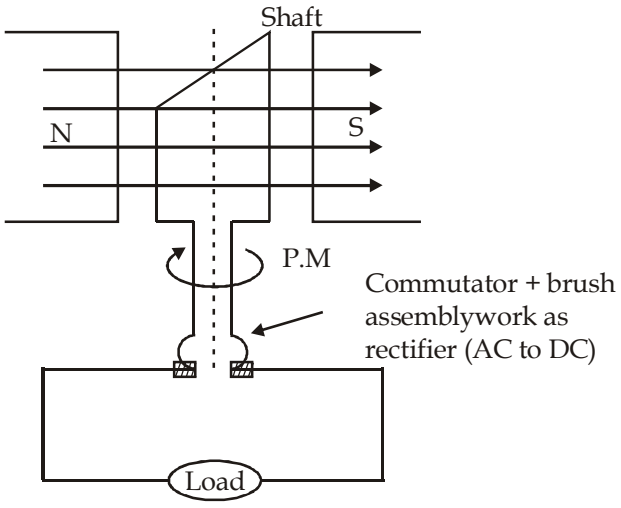
Sol.

The synchronous machine oscillates about the operating point, due to:
(i) a sudden change in load.
(ii) a fault in the supply system.
(iii) a load containing harmonic torques.
(iv) a sudden change in field current.
This oscillatory behaviour of the synchronous machines is known as hunting.
The effects of hunting are as follows.
(i) It produces severe mechanical stress and fatigue in the shaft.
(ii) It causes great surges in current and power flow
(iii) It increases machine losses and thus the temperature rise of the machine.

ZONE TECH

138.

Sol.



If a current carrying conductor placed in a magnetic field expirenced a mechanical force, which is called Laurentz force (f = BIL sin θ), the direction of this force is given by flemings left hand rule. In D.C motor force on 2 conductors of a armature coil are opposite so due to this torque is produces in a particular direction and the motor is rotated.

139.

Sol.

When the motor armature continue to rotate due to motor action the armature conductor cuts the magnetic flux therefore EMF is induced in armature conductor. This induced EMF is called back EMF (E_b) as it is opposite to the supply voltage.

$$E_b = \frac{\phi PZN}{60A} \text{ volt}$$

Z = No of armature conductor N = Speed in RPM

A = No of parallel path

P = No of poles

ϕ = flux

$$I_a = \frac{V - E_b}{R_a}$$

R_a = armature resistance

I_a = armature current

E_b = Back EMF

V = supply voltage

At the time of starting speed is zerodue to this back EMF is zero, Current is more.When E_b is there Current is less.This induced EMF (E_b) depends on the armature speed (N), if the armature speed is high the back EMF (E_b) will be large and therefore the armature current will be less and if the back EMF is low (speed is low) the large armature current will flow. So it is clear that the presence of back EMF makes the D.C motor a self regulating machine (By limiting the armature current).

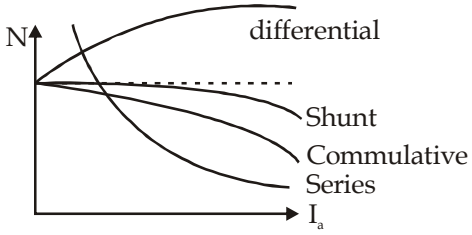
the mechanical power (P_M) developed depends on the back EMF (E_b)

$P_m = E_b I_a$

140.

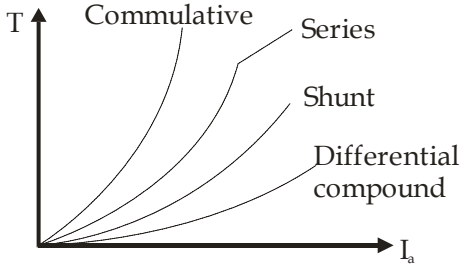
Sol.

(a) Speed V/S Armature Current (N V/S I_a)

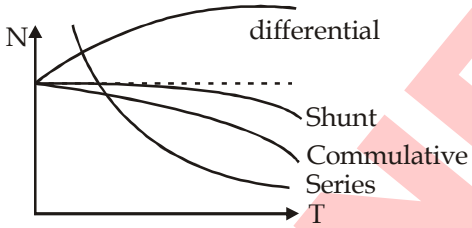


(b) Torque V/S Armature Current (T V/S I_a

$T = K_a \phi I_a$



(c) Speed V/S Torque (N V/S T)

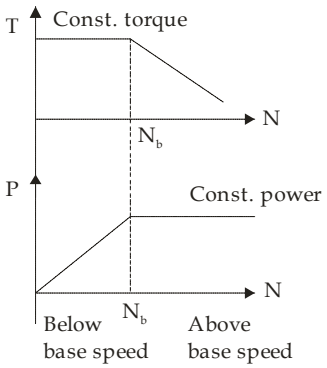


141.

Sol.

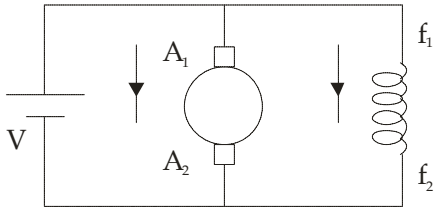
Base Speed:- The speed at which no external resistance in the armature

Below base speed	Above base speed
→ Armature resistance control	→ Field flux control
→ $T = K_a \phi I_a$ = constant	→ $T = K_a \phi I_a$ $T \propto \frac{1}{N}$
→ $P = TW$ $P \propto N$	→ $P = TW$ P = constant

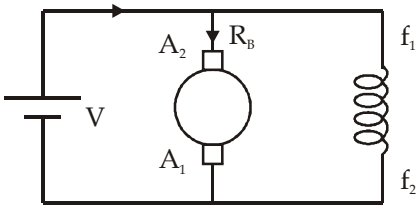


ZONE TECH

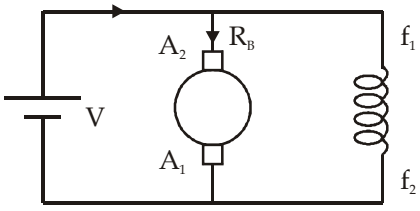
142.
Sol.



$$T = K_a \phi I_a$$



If armature terminal reverse



$$T = K_a (\phi) (-I_a)$$
$$T = - K_a \phi I_a$$
$$T = - ve$$

Reverse Torque

$$E_b = V - I_a R_a$$

$$I_a = \frac{V - E_b}{R_a}$$

During plugging

$$I_a = \frac{V + E_b}{R_a + R_b}$$

To limit high armature current.
In this method by changing the armature on field terminals the torque can be produced in reverse direction but if the supply terminal change the torque will produce in same direction.
So in plugging generally armature terminals are reverse because of high inductance of field circuit. So their is more opposition of change in current in field circuit.
During plugging their is large armature current will flow to limit this a braking resistance R_B is inserted in the armature circuit but due to energy losses in this braking resistance this method is wasteful of energy. Although it is a efficient method of braking which is commonly used in controlling rolling mills elevator, printing press, machine tools applications etc.

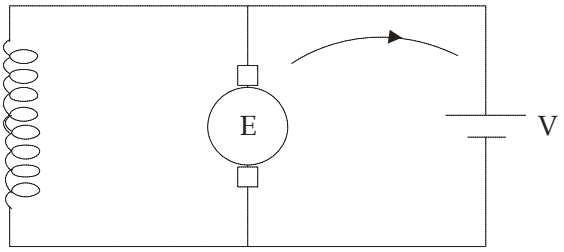
143.
Sol.

In regenerative braking their is no change of connections required in particular cases where the speed of motor is high then the EMF induced in armature (E) will be greater than the supply voltage (V) and in this condition the motor work as a generator and the power transfer will be take place from machine to supply.

ZONE TECH

So it is clear that in this method their is no any energy loss in braking resistance. So this is a regenrative braking method and hence economical method

E > V



Ex. Crane owing weight release, train during sloping region, In D.C series motor this braking can be used with some modification because the reversal of armature current would also reverse the field current.

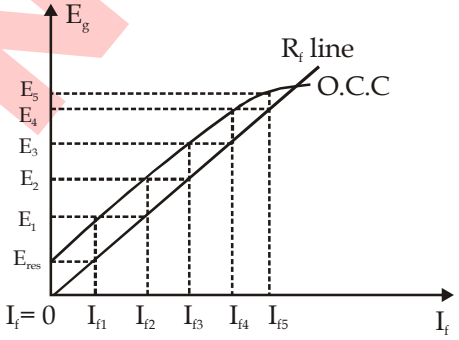
144.

Sol.

1. **Swinburn test**
   Example of indirect testing. It is a simple indirect test in which constant losses are measured separately and by using this, efficiency at any load can be calculated. However this test is applicable to those machines which has constant flux i.e shunt or compound machine. In this test it is advantage that the power i/p is required very less even if the machine to be tested is large.
2. **Hopkinson's / Regenerative test / back to back test**
   In this method full load that can be carried out on two shunt machines preferably identical without wasting their o/p. These 2 machines are mechanically coupled and are so adjusted that one of the machine remains as a motor which supply mechanical power to the another machine which runs as a generator. The electrical O/P of the generator is used to supply major part of the i/p to the motor. In this condition the power drawn from the supply is only equals to the losses of 2 machine

145.

Sol.

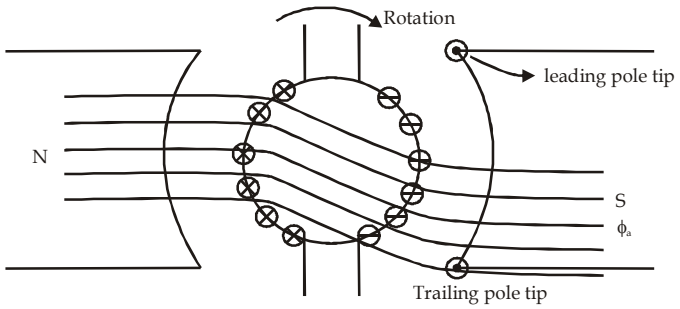


If a shunt generator running at constant speed. Some EMF will be generated due to residual flux in the main poles. This small EMF causes a field current (I_{f1}) Which produces additional flux (ϕ_{f1}) to reinforce the original residual flux ($\phi_{res} + \phi_{fl}$). This results in again. increase in induced EMF which causes the increase field current and this process continue and the generator built - up the normal generated voltage corresponding to the open-circuit characterstic. This process is called commulative process of voltage build-up in D.C shunt generator. So the voltage build-up of the generator can be given by the point of inter-section between the O.C.C and R_f line.

ZONE TECH

146.

Sol.



When the armature current flow by the resultant flux distribution, it is clear that the flux density at the trailing pole tip is increases while at leading pole tip it decreases. So this unequal flux distribution across the pole produce following two effects.

1. Main flux distortion.
2. Due to higher flux density at trailing pole tip it is saturated so the increases in flux at trailing pole tip is less than the decreases in flux at leading pole tip.

As the conductor rotate the pole tip they meet first is called leading pole tip and the another is called trailing pole tip.

147.

Sol.

GNA :- It is the axis that bisect the angle between the central line of adjacent pole or it is the axis perpendicular to the main field flux (ϕ_f) direction

MNA :- It is the axis perpendicular to the resultant flux, it passes through the centre of the armature clearly their is no EMF produced in the armature conductor along this axis because at this position they cuts no flux.

With no current in the armature the MNA coincide with GNA.

When current flow in the armature conductor due to the combined action of main flux and armature flux. The MNA shifts from GNA.

In Generator, the MNA shifts in the direction of rotation and while in case of motor, the MNA shifts in opposite direction of rotation.

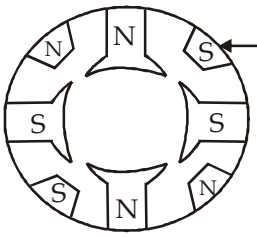
In order to achieve sparkless commutation the position of brushes have to be moved along the new MNA.

148.

Sol.

1. **Resistance Commutation:-** If the contact resistance between brush and commutator is made large than the current divided in the inverse ratio of contact resistance which improve commutation. This can be achieved by using carbon brushes which has high contact resistance. This method does not effect the reactance voltage (main cause of sparking) but it only help in improving commutaiton.
   Time constant= L/R
   If the resistance of coil increases then time taken in commutation decreases
2. **EMF Commutation :-** In EMF commutation the reactance voltage is neutralize by producing a reversal voltage or commutating voltage in the coil undergoing commutation. This can be achieved by using interpoles. These are the small pole fixed to the yoke and place between the main pole. The interpole winding is bound for few turn and connected in series with the armature. So that it carry the armature current.The polarity of interpole is same as the next main pole in the direction of rotation for the generator and visa-versa for motor.

ZONE TECH



Shape of interpole :- wider base narrow interpole

149.

Sol.

Compensating winding:- In order to neutralize the cross-magnetizing effect of armature reaction compensating winding is used, it is a auxiliary winding connected in series with armature in a manner so that the direction of current through the compensating winding will be just opposite to the direction of current in armature conductor. By this the armature flux get neutralize and the armature reaction is also neutralize.

The best way to achieve this compensation is by means of pole face winding embedded in the slots in the pole faces.

PART - C

20 Marks Questions

150.

Sol. E.M.F. equation of a Transformer

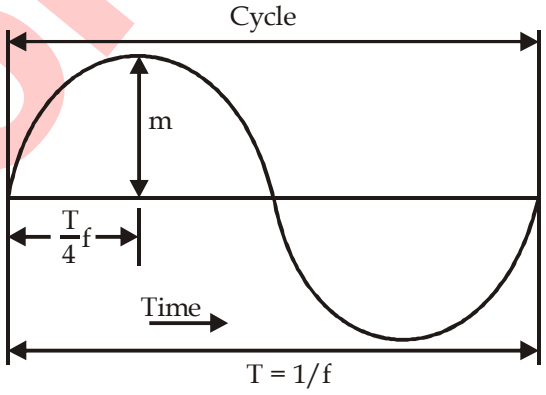
Let N_1 = No. of turns in primary

N_2 = No. of turns in secondary

Φ_m = Maximum flux in core in webers $= B_m \times A$

f = Frequency of a.c. input in Hz

As shown in figure flux increases from its zero value to maximum value Φ_m in one quarter of the cycle i.e. in 1/4 f second.



Average rate of change of flux $= \dfrac{\Phi_m}{1/4f}$

$= 4f\Phi_m$ W b / s

Now, rate of change of flux per turn means induced e.m.f. in volts.

Average e.m.f./turn $= 4f\Phi_m$ volt

If flux Φ varies sinusoidally, then r.m.s. value of induced e.m.f. is obtained by multiplying the average value with form factor.

$$\text{Form factor} = \frac{\text{r.m.s. value}}{\text{average value}} = 1.11$$

r.m.s. value of e.m.f./turn $= 1.11 \times 4 f \Phi_m = 4.44 f \Phi_m$ volt

Now, r.m.s. value of the induced e.m.f. in the whole of primary winding.

= (induced e.m.f/turn) × No. of primary turns

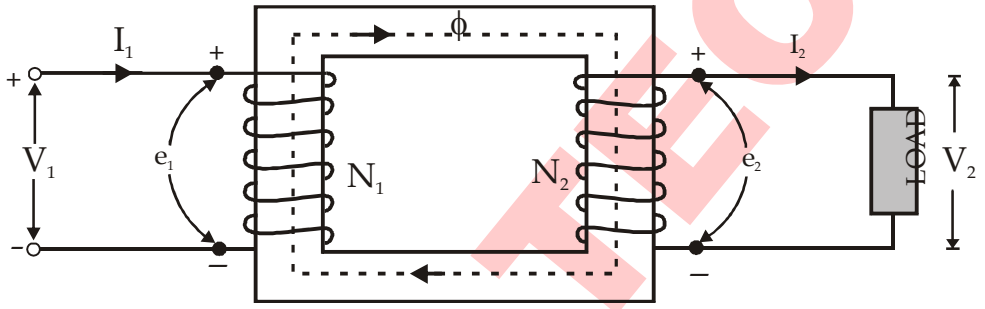
$E_1 = 4.44 f \Phi_m N_1 \qquad E_1 = 4.44 f N_1 B_m A$

Similarly, r.m.s. value of the e.m.f. induced in secondary is,

$E_2 = 4.44 f \Phi_m N_2 \qquad E_2 = 4.44 f N_2 B_m A$

151.

Sol.



Supply voltage $= V_1$
Emf induced in primary winding $= e_1$
Current in primary winding $= I_1$
Magnetic flux $= \phi$
Turns in primary winding $= N_1$
Turns in secondary winding $= N_2$
Emf induced in secondary winding $= e_2$
Current in secondary winding $= I_2$
Voltage across load $= V_2$

When sinusoidal voltage applied to primary winding, a sinusoidal flux is set up in the iron core which links both windings.

Sinusoidal flux variation, $\phi = \phi_{max} \sin \omega t$

where ϕ_{max} is the maximum value of the magnetic flux

The emf e_1 induced in the primary winding by the alternating flux.

$$e_1 = N_1 \frac{d\phi}{dt} (\text{magnitude})$$

The direction of induced emf can be determine by Lenz's law,

$$e_1 = N_1 \frac{d}{dt}(\phi_{max} \sin \omega t) = N_1 \omega \phi_{max} \cos \omega t$$

$$e_1 = E_{1(max)} \cos \omega t = E_{1(max)} \sin(\omega t + 90°)$$

where, $E_{1(max)}$ is the maximum value of induced emf

The emf induced in primary winding is 90° ahead by the core flux.

Rms value of emf e_1 induced in primary winding ,

$$E_1 = \frac{E_{1(max)}}{\sqrt{2}} = \frac{N_1 \omega \phi_{max}}{\sqrt{2}}$$

$$E_1 = \frac{N_1 (2\pi f)\phi_{max}}{\sqrt{2}} = \sqrt{2}\pi f N_1 \phi_{max}$$

$$= 4.44\ f N_1 \phi_{max} \quad ...(i)$$

Similary emf induced in secondary winding ,

$$e_2 = N_2 \frac{d\phi}{dt} = N_2 \omega \phi_{max} \cos \omega t$$

$$= N_2 \omega \phi_{max} \sin(\omega t + 90°)$$

$$e_2 = E_{2(max)} \sin(\omega t + 90°)$$

Rms value of emf e_2 induced in secondary winding

$$E_2 = \frac{E_{2max}}{\sqrt{2}} = \frac{N_2 \omega \phi_{max}}{\sqrt{2}} = \frac{N_2 (2\pi f)\phi_{max}}{\sqrt{2}}$$

$$E_2 = \sqrt{2}\pi f N_2 \phi_{max} = 4.44\, f N_2 \phi_{max} \quad ...(ii)$$

From equation (i) and (ii) we get

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \text{ or } \frac{E_1}{N_1} = \frac{E_2}{N_2} = \text{emf per turn}$$

i.e. emf per turn in primary winding is equal to emf per turn in secondary winding.

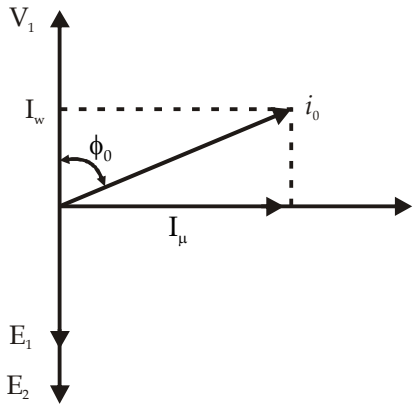
152.

Sol. Even when the transformer is on no-load, the primary input current is not wholly reactive. The primary input current under no-load conditions has to supply (*i*) iron losses in the core i.e. hysteresis loss and eddy current loss and (*ii*) a very small amount of copper loss in primary (there being no Cu loss in secondary as it is open). Hence, the no-load primary input current I_0 is not at 90° behind V_1 but lags it by an angle $\phi_0 < 90°$. No-load input power.

$$W_0 = V_1 I_0 \cos\phi_0$$

where $\cos\phi_0$ is primary power factor under no-load conditions. No-load condition of an actual transformer is shown vectorially in figure.

As seen from figure primary current I_0 has two components:



(*i*) One in phase with V_1. This is known as active or working or iron loss component I_w because it mainly supplies the iron loss plus small quantity of primary Cu loss.

$$I_w = I_0 \cos\phi_0$$

(*ii*) The other component is in quadrature with V_1 and is known as magnetising component I_μ because its function is to sustain the alternating flux in the core. It is wattless.

$$I_\mu = I_0 \sin\phi_0$$

Obviously, I_0 is the vector sum of I_w and I_μ, hence $I_0 = \left(I_\mu^2 + I_\omega^2\right)$.

153.

Sol. Open Circuit Test:

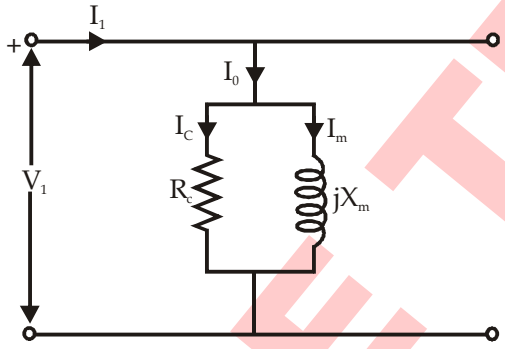
This test is to determine the core loss P_i and no-loaad current I_0 and thereby the shunt branch parameters R_C and X_m of the equivalent circuit.

A voltmeter, wattmeter and an ammeter are connected in the low voltage side of the transformer .

Readings are recorded when we apply rated voltage to low voltage side and keep high voltage side opencircuited

The armmature records the no-load current or exciting current I_0, since I_0 quite small (2 to 5%) of rated current, so primary leakage impedance drop is negligible.

The wattmeter records input power which consists of core loss.



(Open circuit equivalent circuit diagram)

Applied primary voltages $= V_1$ volts

No-load current $= I_0$ Amp

Iron loss, P_i = input power on no-load $= P_{OC}$ watt

Equivalent circuit parameters,

$$R_C = \frac{(V_{OC})^2}{P_{OC}} \text{ and } X_m = \frac{V_{OC}}{I_m}$$

No-load loss current component,

$$I_e = I_0 \cos\phi_0 = \frac{P_{OC}}{V_1}$$

No-load magnetizing component current.

$$I_m = \sqrt{I_0^2 - I_e^2}$$

Short-circuit test

This test is to determine full load copper loss and equivalent resistance and equivalent reactance and also voltage regulation of transformer.

* In short-circuit test, all the measuring intruments are connected on high voltage side and low voltage side of transformer is short–circuited.
* The applied voltage is adjusted by autotransformer to circulate rated current in the high voltage side.

This circulated rated current achieved by only 2 to 10% of its rated value of primary voltages.

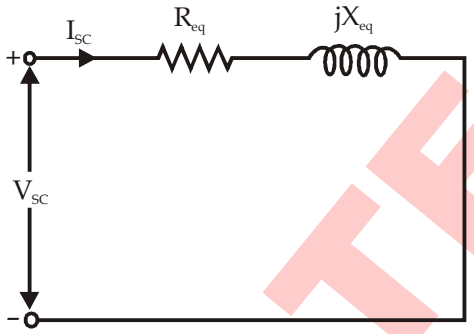
* In this test, the wattmeter records the core loss and ohmic loss in both the winding but core loss and short circuit branch parameter ignored because only 2 to 10% of rated voltage is applied.

Full load copper loss, $P_{sc} = I_{sc}^2 R_{eq}$

Equivalent resistance, $R_{eq} = \frac{P_{sc}}{I_{sc}^2}$

Equivalent impedance, $Z_{eq} = \frac{V_{sc}}{I_{sc}}$

Equivalent reactance, $X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$



(Short-circuit equivalent circuit diagram)

154.

Sol. A transformer has the following types of losses:

1. **Iron or Core Losses:** Iron loss is caused by the alternating flux in the core and consists of hysteresis and eddy current losses.

   (i) Hysteresis Loss: The core of a transformer is subjected to an alternating current magnetizing force and for each cycle of emf a hystersis loss is traced out. The hysteresis loss per second is given by the equation.

   Hysteresis loss, $P_h = \eta.(\beta_{max})^x .f.V$ Joules/sec. (or) Watts

   where, f is the supply frequency in Hz.
   V is the volume of core in cubic meters.
   η is the hysteresis coefficient.
   β_{max} is peak value of flux density in the core.
   x lies between 1.5-2.5 depending upon the material and is often taken as 1.6.

   (ii) Eddy Current Loss: If the flux linkage with a closed electric circuit changes, an emf is induced in the circuit and a current flows, the value of which depends on the emf around the circuit and the resistance of the circuit. If is not necessary that the circuit be a wire and that the flux passes entirely through it. If a solid block of metal is traversed by a varying flux, metallic circuits in the block itself which are linked by the flux will carry current. If the magnetic circuit is made up of iron and if the flux in the circuit is variable current will be induced by induction in the iron circuit itself. All such currents are known as eddy currents.
   Eddy currens result in a loss of power with consequent heating of the material.

   Eddy current loss, $P_e = k_e \times B_{max}^2 \times f^2 \times t^2 \times$ Volume of laminations

Eddy current loss per unit volume $= k_e \times B_{max}^2 \times f^2 \times t^2 \times$ Watts

i.e. eddy current loss varies:
(a) as the square of maximum flux density.s
(b) as the square of the frequency.
(c) as the square of thickness of laminations.

2. **Copper (or ohmic) Losses:** These losses occur due to ohmic resistance of the transformer windings. If I_1 and I_2 are the primary and secondary current respectively and R_1 and R_2 are respective resistances of primary and secondary windings then copper losses occuring in primary and secondary windings will be $I_1^2R_1$ and $I_2^2R_2$ respectively so total copper losses will be $\left(I_1^2R_1 + I_2^2R_2\right)$. These losses vary as the square of the load current or kVA.
3. **Stray Load Loss:** Leakage present in a transformer induce eddy currents in the conductors, tank walls, bolts etc. These eddy currents give rise to stray load loss.
4. **Dielectric Loss:** This loss occurs in the insulating materials particularly in oil and solid insulations. The stray and dielectric loss are vary small and therefore neglected.

155.

Sol. Cu loss $= I_1^2R_{01}$ or $I_2^2R_{02} = W_{cu}$

Iron loss = Hysteresis loss + Eddy current loss $= W_h + W_e = W_i$

Considering primary side,

Primary input $= V_1I_1\cos\phi_1$

$$\eta = \frac{V_1I_1\cos\phi_1 - \text{losses}}{V_1I_1\cos\phi_1} = \frac{V_1I_1\cos\phi - I_1^2R_{01} - W_i}{V_1I_1\cos\phi_1}$$

$$= 1 - \frac{I_1R_{01}}{V_1\cos\phi_1} - \frac{W_i}{V_1I_1\cos\phi_1}$$

Differentiating both sides with respect to I_1, we get

$$\frac{d\eta}{dI_1} = 0 - \frac{R_{01}}{V_1\cos\phi_1} + \frac{W_i}{V_1I_1^2\cos\phi_1}$$

For η to be maximum $\frac{d\eta}{dI_1} = 0$ Hence, the above equation becomes

$$\frac{R_{01}}{V_1\cos\phi_1} = \frac{W_i}{V_1I_1^2\cos\phi_1} \text{ or } W_i = I_1^2R_{01} \text{ or } I_2^2R_{02}$$

or Cu loss = Iron loss

156.

Sol.: Condition for maximum efficiency is variable loss = fixed loss

In case of transformer

Cu loss = Iron loss

or, $P_{cu} = P_i$

as given $\eta_{max} = \dfrac{x \times (kVA) \times \cos\phi}{x \times (kVA) \times \cos\phi + P_i + (P_{cu} = P_i)}$

ZONE TECH

$$0.974 = \frac{0.9\times 50\times 1}{0.9\times 50\times 1+2P_i}$$

$$2P_i = \frac{0.9\times 50}{0.974} - 0.9\times 50$$

$$P_i = 0.6 \text{ kW}$$

From equation (1), $P_{cu} = P_i = 0.6$ kW

at maximum efficiency

$$x^2 (P_{cu})_{\text{full load}} = p_i$$

so, $(P_{cu})_{\text{full load}} = \frac{0.6}{(0.9)^2} = 0.74kW$

$$(P_{cu})_{\text{full load}} = 0.74 \text{ kW}$$

(i) $$\eta_{full load} = \frac{50\times 1\times 0.8}{50\times 1\times 0.8+0.74+0.6} = 0.9675 \, or \, 96.75\%$$

(ii) $$\eta_{1/2\, full load} = \frac{\frac{1}{2}\times 50\times 0.9}{\frac{1}{2}\times 50\times 0.9+0.6+\left(\frac{1}{2}\right)^2\times 0.74} = 0.96628 = 96.62\%$$

157.

Sol.: Short-circuit test is conducted on hv side i.e.. delta side.

Hence

$$V_{phase} = V_{l-l} = 300 \text{ V}$$

$$I_{phase} = \frac{I_{l-l}}{\sqrt{3}} = \frac{131.21}{\sqrt{3}} = 75.75 Amp$$

Copper loss/phase $= \frac{30}{3} = 10kW$

Hence $I_{phase}^2 R_\Delta = 10 \times 10^3$

$$R_\Delta = \frac{10\times 10^3}{75.75^2} = 1.74\Omega$$

$$Z_\Delta = \frac{V_{phase}}{I_{phase}} = \frac{300}{75.75} = 3.96\Omega$$

$$X_\Delta = \sqrt{Z_\Delta^2 - R_\Delta^2} = \sqrt{3.96^2 - 1.74^2} = 3.55\Omega$$

Converting R_Δ, X_Δ into equiavalent star R_Y, X_y,

$$R_Y = \frac{R_\Delta}{3} = \frac{1.74}{3} = 0.58\Omega; \; X_y = \frac{3.58}{3} = 1.18$$

$$Z_{Base} = \left(\frac{(kV_B)^2}{MVA_B}\right) = \frac{6.6^2}{1.5} = 29.04\Omega$$

Percentage resistance drop $= \in_r$

$$= \frac{R_Y}{Z_{Base}} = \frac{0.58}{29.04} = 0.0199 pu$$

$$\in_r = 1.99\%$$

Percentage reactance drop $= \in_x$

$$= \frac{X_Y}{Z_{Base}} = \frac{1.18}{29.04} = 0.0406 pu$$

$$\in_x = 4.06\%$$

$$\cos\phi = 0.8 \text{ lagging}$$

$$\sin\phi = 0.6$$

Percentage voltage regulation

$$= (\in_r \cos\phi + \in_x \sin\phi) \times 100$$

$$= (0.0199 \times 0.8 + 0.0406 \times 0.6) \times 100$$

$$= 4.028\%$$

losses = copper loss + iron loss

$$= 30 + 25 = 55 \text{ kW}$$

$$\text{efficiency} = \frac{output}{output + losses} \times 100 = \frac{1500 \times 0.8}{1500 \times 0.8 + 55} \times 100 = 95.61\%$$

158.

Sol. H.V. side.

Base voltage $V_{BH} = 2000\,V$

Base current $I_{BH} = \frac{10,000}{2000} = 5\,A$

$\therefore$ Base impedance $Z_{BH} = \frac{2000}{5} = 400\,\Omega$

$$r_{1p.u.} = \frac{3.6}{400} = 0.009$$

$$x_{1p.u.} = \frac{5.2}{400} = 0.013$$

$$r_{e1} \text{ in ohms} = r_1 + r_2\left(\frac{N_1}{N_2}\right)^2 = (3.6) + 0.04(10)^2 = 7.6\,\Omega$$

$\therefore$

$$r_{e1p.u.} = \frac{7.6}{400} = 0.019$$

$$x_{e1p.u.} = \frac{1}{Z_{BH}}\left[x_1 + x_2\left(\frac{N_1}{N_2}\right)^2\right] = \frac{1}{400}\left[5.2 + 0.056(10)^2\right] = 0.027.$$

L.V. side, Base voltage $V_{BL} = 200\,V$

Base current $I_{BL} = \frac{10,000}{200} = 50\,A$

ZONE TECH

$\therefore$ Base impedance $Z_{BL} = \frac{200}{50} = 4\,\Omega$

$$r_{2p.u.} = \frac{0.04}{4} = 0.01$$

$$x_{2p.u.} = \frac{0.056}{4} = 0.014$$

$$r_{e2p.u.} = \frac{1}{Z_{BL}}\left[r_2 + r_1\left(\frac{N_2}{N_1}\right)^2\right]$$

$$= \frac{1}{4}\left[0.04 + 3.6\left(\frac{1}{10}\right)^2\right] = 0.019$$

Similarly, $x_{e2p.u.} = 0.027$

159.

Sol. Statically Induced Emf: If the emf develope due to time variant nature of flux then this developed emf is called statically induced emf.

e.g.: Transformer, in which thre is no rotating part but emf is developed due to time variant nature of flux.

Dynamically Induced Emf; If the emf developed with the time invariant nature of flux i.e. flux variation with respect to space, not with respect to time then this developed emf is called dynamically induced emf.

e.g.: Synchronous machines in which excitations is always dc.

An expression given the variation of flux passing through the coil can be written as $\phi\cos\omega t$.

Therefore flux linkage coil at any time will be

$$\psi = N\phi\cos\omega t$$

$$e = -\frac{d\psi}{dt} = -\frac{d(N\phi\cos\omega t)}{dt}$$

$$e = -\left[N\phi\omega(-\sin\omega t) + N\cos\omega t\frac{d\phi}{dt}\right]$$

$$e = N\phi\omega\sin\omega t - N\cos\omega t\frac{d\phi}{dt}$$

where, $N\phi\omega\sin\omega t$ is speed voltage or dynamically induced voltage because it contains speed 'ω' in its

and $N\cos\omega t\left(\frac{d\phi}{dt}\right)$ is transformer voltage or statically induced emf because it involves time derivative of flux ϕ.

If flux is not varying with time (i.e. time invariant) the transformer emf reduces to zero.

i.e.f., $\frac{d\phi}{dt} = 0$ (if flux $\phi \to$ constant)

$$N\cos\omega t\frac{d\phi}{dt} = 0$$

So, generated emf is equal to speed voltage alone.

Dynamically induced emf $= N\phi\omega\sin\omega t$

In case of statically induced emf,

$$\omega = 0$$

$$e = -N\cos\omega t\frac{d\phi}{dt} \qquad \text{(Statically induced emf)}$$

$$e = -N\frac{d\phi}{dt} \qquad (\text{if } \omega = 0, \text{ i.e., } \cos\omega t = 1)$$

160.

Sol.

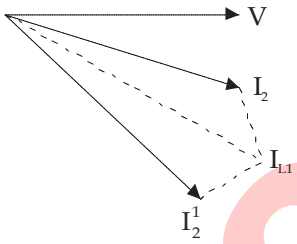
Conditions

1. Voltage rating (line – voltage ratio) should be same.
2. Polarity must be same.
   Different polarity :-large circulating current will flow
   Same polarity :- no circulating current will flow
3. Turn Ratio should be same or almost equal. The turn ratio of both the Transformers is equal $\left(\frac{N_2}{N_1} = \frac{N_4}{N_3}\right)$ then the circulating current will be zero.
4. Almost equal $\frac{X}{R}$ ratio

Case I

When $\frac{X_1}{R_1} \neq \frac{X_2}{R_2}$

$\theta_1 \neq \theta_2$

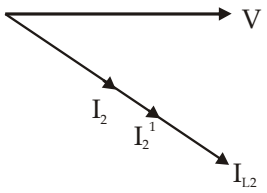


Case II

When $\frac{X_L}{R_1} = \frac{X_2}{R_2}$

$\theta_1 = \theta_2$

$\boxed{I_{L2} > I_{L1}}$



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It is clear that in case 2 when the X/R ratio of both the Transformer are same, then the load current will be high than the load current in case 1

5. $Z_{PU}\alpha\frac{1}{S}$

Load sharing (S_L) depends on per unit impedance (Z_{PU})

For 3 - ϕ two additional condition

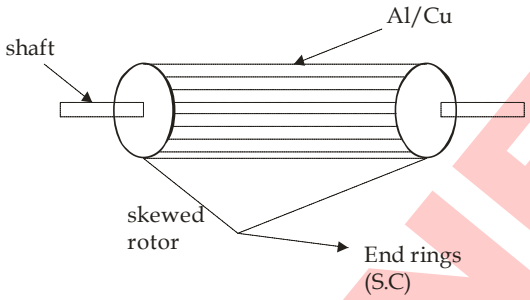
1. The relative phase different must be zero.
2. Phase sequence should be same.

161.

Sol. The two types of 3-phase induction motors are
(*i*) squirrel-cage induction motor (SCIM) and
(ii) slip-ring induction motor (SRIM).
Three-phase SCIM is generally preferred because it is rugged in construction, requires less maintenance and is economical as compared to 3-phase SRIM.

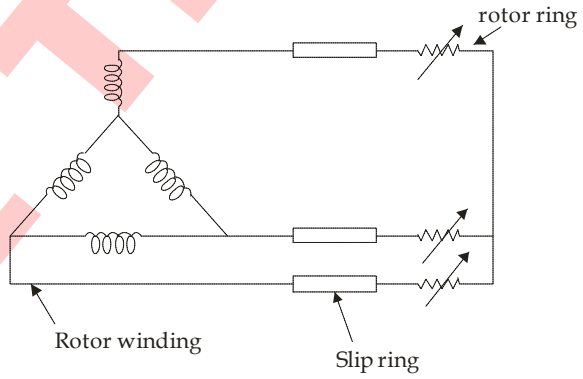
Comparison between SCIM and SRIM :-

SCIM



(1)The rotor core is cylindrical and slotted.
(2)The rotor consists of uninsulated Al or Cu bar called rotor conductors.
(3)These bars are permanently short circuited by end rings at each end.
(4)The entire structure looked like a cage forming a closed electrical circuit
(5)In this rotor, the slots are not parallel to the shaft excess but are skewed. Because to reduce magnetic hum and noise and it also reduces the locking tedency. This makes the rotor operation smooth.
(6)External rotor resistance can not be inserted
(7)Moderate starting torque.
(8)Efficiency higher than SRIM
(9)95% application uses this type of

SRIM



(1)The rotor winding is exactly similar to stator winding which is distributed winding and wound for same no of poles as stator.
(2)The rotor construction is laminated and slotted
(3)By using slip rings external rotor resistance can be inserted by this starting torque and speed can be control
(4)It is costly than SCIM.

(5)Only 5% application uses this type of rotor
(6)High starting torque can be achieved.

(7)Efficiency is low
(8)Loses are high as compare to SCIM
(9)This type of motor is used in application which require high starting torque such as compressors, lift, crannes, etc.

ZONE TECH

rotor.
(10)Used in lathe machine, drill machine fan, blowers, pumping instrument etc.

162.

Sol. **Three-phase Supply**

It will now be shown that when three-phase windings displaced in space by 120°, are fed by three-phase currents, displaced in time by 120°, they produce a resultant magnetic flux, which rotates in space as if actual magnetic poles were being rotated mechanically.

The principle of a 3-phase, two-pole stator having three identical windings placed 120 space degrees apart is shown in figure. The flux (assumed sinusoidal) due to three-phase windings is shown in figure. The assumed positive directions of the fluxes are shown in figure. Let the maximum value of flux due to any one of the three phases be Φ_m. The resultant flux Φ_r, at any instant, is given by the vector sum of the individual fluxes, Φ_1, Φ_2 and Φ_3 due to three phase.

(i) When $\theta = 0^o$

Here $\Phi_1 = 0,\ \Phi_2 = -\frac{\sqrt{3}}{2}\Phi_m,\ \Phi_3 = \frac{\sqrt{3}}{2}\Phi_m.$

The vector for Φ_2 in figure (i) is drawn in a direction opposite to the direction assumed positive in figure A.

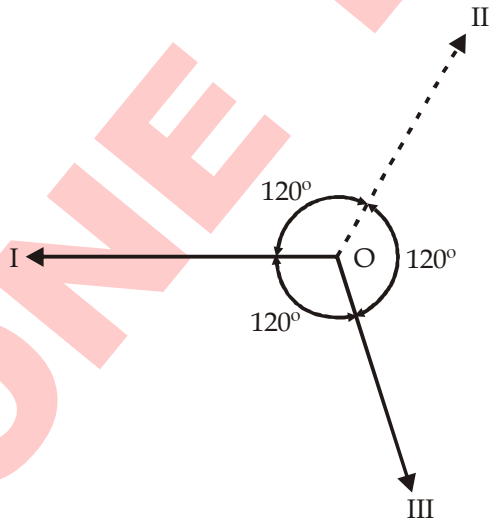


Figure – A

$\therefore \quad \Phi_r = 2 \times \frac{\sqrt{3}}{2}\Phi_m \cos\frac{60^o}{2} = \sqrt{3} \times \frac{\sqrt{3}}{2}\Phi_m = \frac{3}{2}\Phi_m$

(ii) when $\theta = 60^o$

Here $\Phi_1 = \frac{\sqrt{3}}{2}\Phi_m$

$\Phi_2 = -\frac{\sqrt{3}}{2}\Phi_m$

$\Phi_3 = 0$

$\therefore\ \Phi_r = 2\times\frac{\sqrt{3}}{2}\Phi_m\times\cos 30^o = \frac{3}{2}\Phi_m$ [figure (ii)]

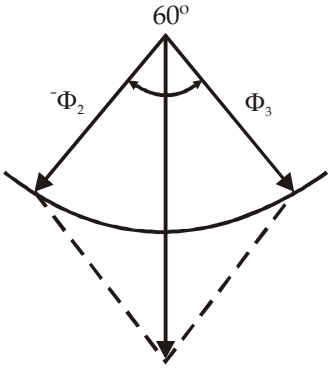
It is found that the resultant flux is again $\frac{3}{2}\Phi_m$ but has rotated clockwise through an angle of 60°.

(iii) When $\theta = 120^o$

Here, $\Phi_1 = \frac{\sqrt{3}}{2}\Phi_m,\ \Phi_2 = 0,\ \Phi_3 = -\frac{\sqrt{3}}{2}\Phi_m$

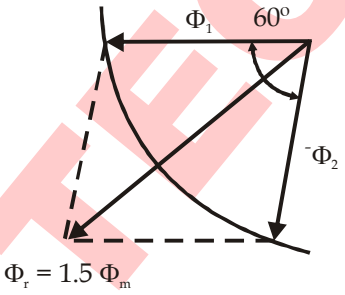
It can be again proved that $\Phi_r = \frac{3}{2}\Phi_m$.

So, the resultant is again of the same value, but has further rotated clockwise through an angle of 60° (figure (iii))



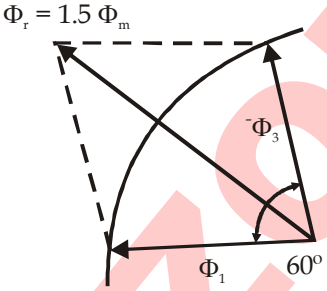
$\Phi_r = 1.5\ \Phi_m$

(*i*) $\theta = 0^o$

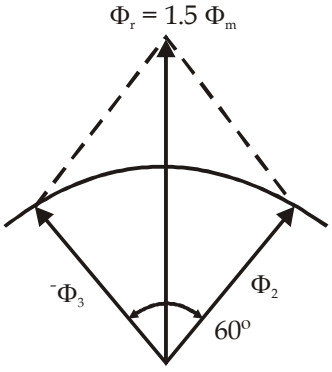


$\Phi_r = 1.5\ \Phi_m$

(*ii*) $\theta = 60^o$



(*iii*) $\theta = 120^o$



(iv) $\theta = 180^o$

(iv) when $\theta = 180^o$

$\Phi_1 = 0,\ \Phi_2 = \frac{\sqrt{3}}{2}\Phi_m,\ \Phi_3 = -\frac{\sqrt{3}}{2}\Phi_m$

The resultant is $\frac{3}{2}\Phi_m$ and has rotated clockwise through an additional angle 60° or through an angle of 180° from the start.

Hence, kwe conclude that

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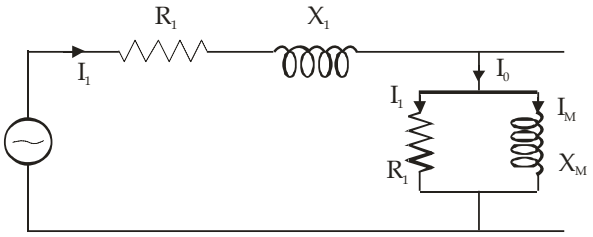
1. the resultant flux is of constant value $=\frac{3}{2}\Phi_m$ i.e. 1.5 times the maximum value of the flux due to any phase.
2. the resultant flux rotates around the stator at synchronous speed given by $N_s = 120\ f/P$.

figure (a) shows the graph of the rotating flux in a simple way. As before, the positive directions of the flux phasors have been shown separately in figure (b). Arrows on these flux phasors are reversed when each phase passes through zero and becomes negative.

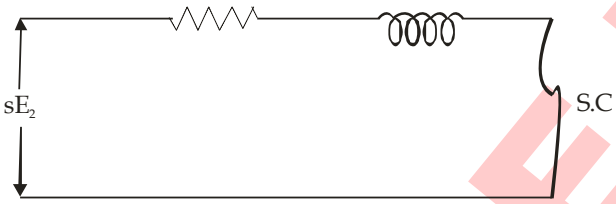
As seen, positions of the resultant flux phasor have been shown at intervals of 60^o only. The resultant flux produces a field rotating in the clockwise direction.

163.

Sol. Stator Equivalent Circuit :-



Rotor Equivalent Circuit :-



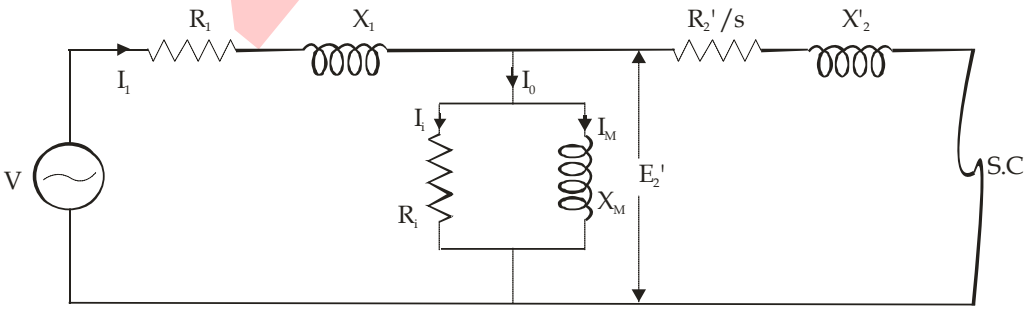
$sE_2 = I_2 (R_2 + jsX_2)$

$$E_2 = I_2 \left(\frac{R_2}{s} + jX_2\right)$$

$$\frac{E_2}{k} = KI_2\left(\frac{R_2/s}{K^2} + \frac{jX_2}{K^2}\right)$$

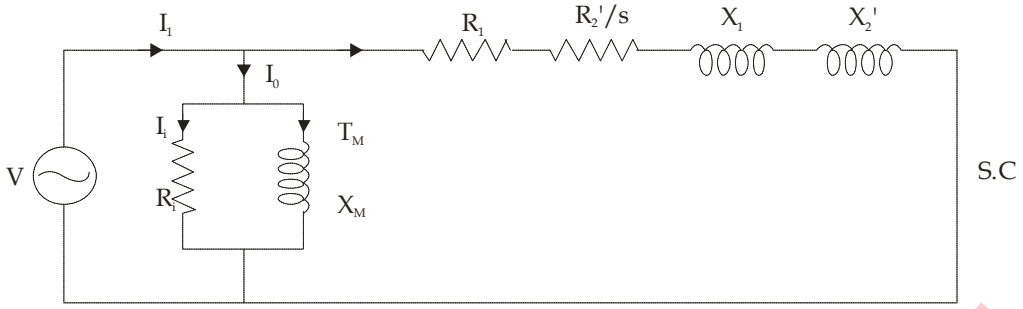
$$E_2' = I_2'\left[\frac{R_2'}{s} + jX_2'\right]$$ Referred to stator side.

Equivalent Circuit :-



Approximate Circuit :-

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164.

Sol. **Air gap power (P_g):** The power that is transferred from the stator to the rotor via the air-gap magnetic field, is known as the air-gap power (P_g)

$$P_g = \frac{3I_2'^2.R_2'}{s}$$

Subtracting the rotor copper loss from Air-gap power (P_g) gives the internal mechanical power developed (P_m)

$$P_m = P_g - 3I_2'^2.R_2 = \frac{3I_2'^2R_2'}{s} - 3I_2'^2.R_2$$

$$= 3I_2'^2.R_2\left(\frac{1}{s}-1\right) = (1-s)P_g$$

The internal mechanical power developed (P_m) is three times the electrical power absorbed in resistance $R_2'\left(\frac{1}{s}-1\right)$.

Shaft power (P_{sh}) is the power available at shaft after subtracting mechanical losses from P_m.

$P_{sh} = P_m$ – mechanical losses

165.

Sol.:

Input of motor $= \sqrt{3}V_l I_l \cos\phi$

$= \sqrt{3} \times 230 \times 60 \times 0.866$

$= 20700$ Watts

Stator output = input power – stator copper loss – core loss

$= 20700 - 850 - 450$

$= 19400$ Watts

(i) Airgap power = Stator output = Rotor input

$= 19400$ watts

(ii) slip, $S = \frac{Rotor\ copper\ loss}{Rotor\ inpit}$

$S = \frac{1050}{19400} = 0.054$

(iii) Mechanical power developed = (1 - s) Rotor input

$= (1 - 0.054)\ (19400)$

$= 18352.4$ watts

(iv) Output power = mechanical power developed - rotational losses

=18352.4 – 500
=17852.4

166.

Sol.

TORQUE IS GIVEN BY

$$T = \frac{3}{Ws}\left[\frac{V^2 R_2^{'}/s}{\left(R_1 + R_2^{'}/s\right)^2 + \left(X_1 + X_2^{'}\right)^2}\right]$$

For Low Value of Slip

$$T\alpha \frac{R_2^{'}/s}{\left(R_1 + R_2^{'}/s\right)^2}$$

$$T\alpha \frac{R_2^{'}/s}{\left(R_2^{'}/s\right)^2}$$

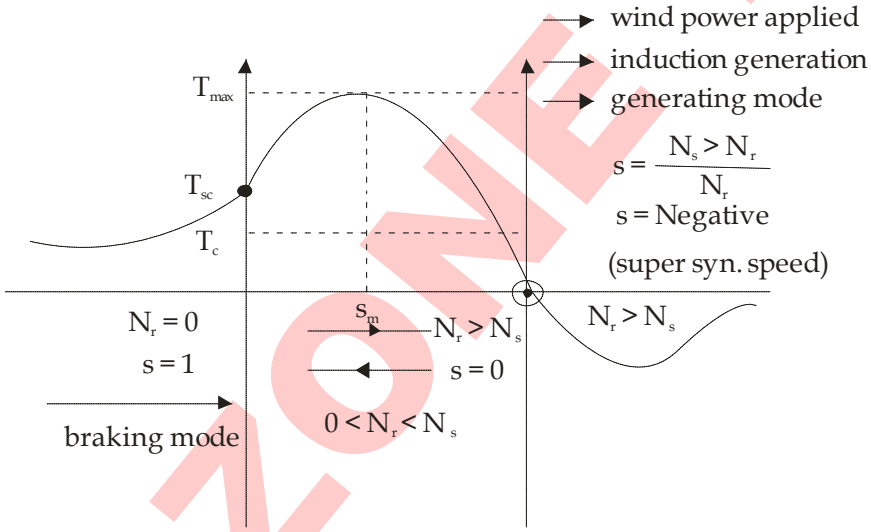
Torque is proportional to slip

High Value of Slip

$$T\alpha \frac{R_2^{'}/s}{\left(R_1 + R_2^{'}/s\right)^2}$$

$$T\alpha \frac{1}{s}$$

Torque is inversely proportional to slip



breaking slip

$$S_b = \frac{N_s - (-N_r)}{N_s} \qquad 0 < s < 1$$

$$= \frac{N_s + N_r}{N_s}$$

$$= 1 + \frac{N_r}{N_s} \qquad s = \frac{N_s - N_r}{N_s}$$

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$= 1 - (1 - s)$ $\quad\quad$ $\frac{N_r}{N_s} = 1 - s$

$s_b = 2 - s$ $\quad\quad$ $S_b > 1$

167.

Sol.:

Effect of frequency vaitation on torque-speed characteristics:

1. Below base speed by keeping V/f constant and frequency $f \leq f_{rated}$ i.e. $\frac{V}{f} = constant$

$$V \propto f$$

$$T_{max} = \frac{V_1^2}{2\omega_{sm} X_2'} \propto \frac{1}{f} \cdot \frac{(f)^2}{f} = constant$$

$$S_{T_{max}} = \frac{R_2'}{X_2'} \propto \frac{1}{f}$$

$$N_S - N = sN_s \propto sf$$

$$\tan\phi_2 = \frac{sX_2'}{R_2'} \propto sf$$

Region-I: (Normal operation region or low slip region) : $0 < s \leq s\ T_{max}$

(i) $\quad I_2' = \frac{sV_1}{R_2'} \propto sf$

(ii) Torque, $\quad T = \frac{1}{\omega_{sm}} \times \frac{sV_1^2}{R_2'} \propto \frac{1}{f} \times sf^2$

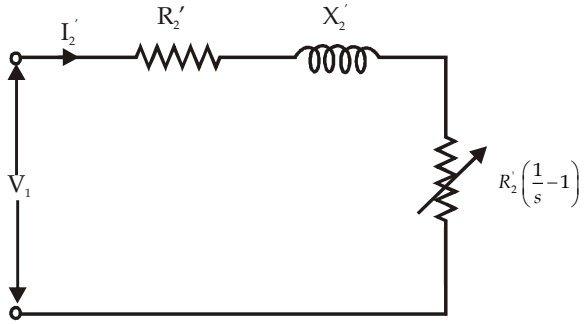
Region-II: (High slip region): $s > s_{Tmax}$

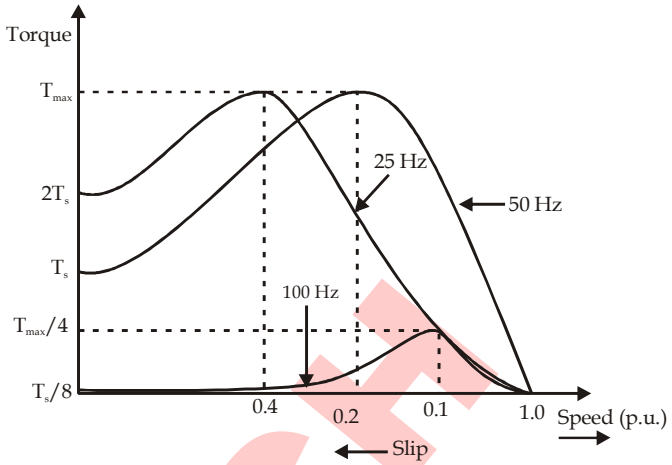
(i) $\quad I_2' = \frac{V_1}{X_2'} \propto \frac{f}{f} = constant$

(ii)Torque, $\quad T = \frac{1}{\omega_{sm}} \times \frac{V_1^2}{(X_2')^2} \times \frac{R_2'}{s} \propto \frac{1}{f} \times \frac{f^2}{f^2} \times \frac{1}{s}$

$T \propto \frac{1}{fs} \Rightarrow T_{st} \propto \frac{1}{f}$ $\quad\quad$ ($\because$ At starting time $s = 1$)

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168

Sol. **Speed Control of Induction Motors**: A 3-phase induction motor is practicqally a constant-speed machine, more or less like a d.c. shunt motor. The speed regulation of an induction motor (having low resistance) is usually less than 5% at full-load. However, there is one difference of practical importance between the two. Whereas d.c. shunt motors can be made to run at any speed within wide limits, with good efficiency and speed regulation, merely by manipulating a simple field rheostat, the same is not possible with induction motors. In their case, speed reduction is accompanied by a corresponding loss of efficiency and good speed regulation. That is why it is much easier to build a good adjustable-speed d.c. shunt motor than an adjustable speed induction motor.

Different methods by which speed control of induction motors is achieved, may be grouped under two main headings:

1. Control from stator side
   (a) by changing the applied voltage (b) by changing the applied frequency
   (c) by changing the number of stator poles
2. Control from rotor side
   (d) rotor rheostat control
   (e) by operating two motors in concatenation or cascade
   (f) by injecting an e.m.f. in the rotor circuit.

A brief description of these methods would be given below:

(a) Changing Applied Voltage

This method, though the cheapest and the easisest, is rarely used because

(i) a large change in voltage is required for a relatively small change in speed.

(ii) this large change in voltage will result in a large change in the flux density thereby seriously disturbing the magnetic conditions of the motor.

(b) Changing the Applied Frequency

This method is also used very rarely. We have seen that the synchronous speed of an induction motor is given by $N_s = 120 fl P$. Clearly, the synchronous speed (and hence the running speed) of an induction motor can be changed by changing the supply frequency *f*. However, this method could only be used in cases where the induction motor happens to be the only load on the generators, in which case, the supply frequency could be controlled by controlling the speed of the prime movers of the generators. But, here again the range over which the motor speed may be varied is limited by the economical speeds of the prime movers. This method has been used to some extent on electrically-driven ships.

(c) Changing the Number of Stator Poles:

This method is easily applicable to squirrel-cage motors because the squirrel-cage rotor adopts itself to any reasonable number of stator poles. This method has been used for elevator motors, traction motors and also for small motors driving machine tools.

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(d) Rotor Rheostat Control

In this method figure, which is applicable to slip-ring motors alone, the motor speed is reduced by introducing an external resistance in the rotor circuit. For this purpose, the rotor starter may be used, provided it is continuously rated. This method is, in fact, similar to the armature rheostant control method of d.c. shunt motors.

(e) Cascade or Concatenation or Tandem Operation

In this method, two motors are used and are ordinarily mounted on the same shaft, so that both run at the same speed (or else they may be geared together).

The stator winding of the main motor A is connected to the mains in the usual way, while that of the auxiliary motor B is fed from the rotor circuit of motor A. For satisfactory operation, the main motor A should be slip-ring type with stator to rotor winding ratio of 1 : 1, so that, in addition to concatenation, each motor may be run form the supply mains separately.

There are at least three ways (and some times four ways) in which the combination may be run.

1. Main motor A may be run separately from the supply. In that case, the synchronous speed is $N_{sa} = 120\ f/P_a$ where P_a = Number of stator poles of motor A.
2. Auxiliary motor B may be run separately from the mains (with motor A being disconnected). In that case, synchronous speed is $N_{sb} = 120 \times f / P_b$ where P_b = Number of stator poles of motor B.
3. The combination may be connected in cumulative cascade i.e. in such a way that the phase rotation of the stator fields of both motors is in the same direction. The synchronous speed of the cascaded set, in this case, is $N_{sc} = 120f / (P_a + P_b)$.

(f) Injecting an e.m.f. in the Rotor Circuit

In this method, the speed of an induction motor is controlled by injecting a voltage in the rotor circuit, it being of course, necessary for the injected voltage to have the same frequency as the slip frequency. There is, however, no restriction as to the phase of the injected e.m.f.

When we insert a voltage which is in phase opposition to the induced rotor e.m.f., it amounts to increasing the rotor resistance, whereas inserting a voltage which is in phase with the induced rotor e.m.f. is equivalent to decreasing its resistance. Hence, by changing the phase of the injected e.m.f and hence the rotor resistance, the speed can be controlled.

169.

Sol. Different induction motor starter are

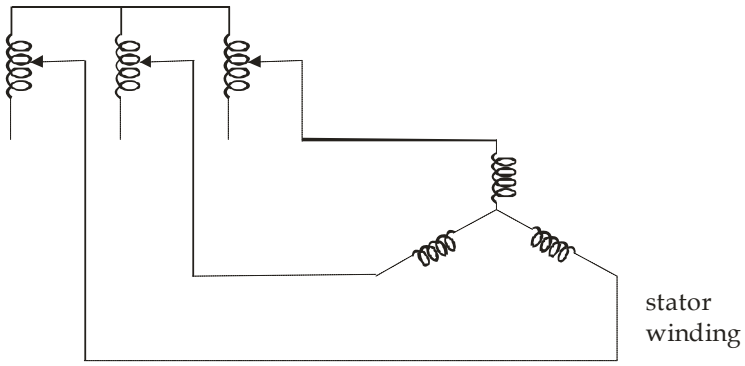
(a) Direct on line starter
(b) Auto-transformer starter
(c) Star – Delta starter
(d) Rotor - Resistance starter

(a) DOL - Direct Online Starter :-

In case of small capacity motor having rating less than 5HP the starting current is not very high. So such motors can withstand such starting current the starter winding is directly connected to the supply without any reduction in supply voltage. Hence this starter is known as DOL starter.

Under over load condition the current drawn by the motor is high. So their is excessive heat produced which ↑es the temp. so a thermal over load relay is used with this starter to protect this from over loading condition.

(b) Auto - Transformer starter :-



Suppose x = Auto x-mer ratio

$$x = \frac{I_{supply}}{I_{motor}}$$

$I_{supply} = x\, I_{motor}$

Due to x% tapping

$I_{motor} = x\, I_{st}$

I_{st} :- Starting current without starter (with full vol. V).

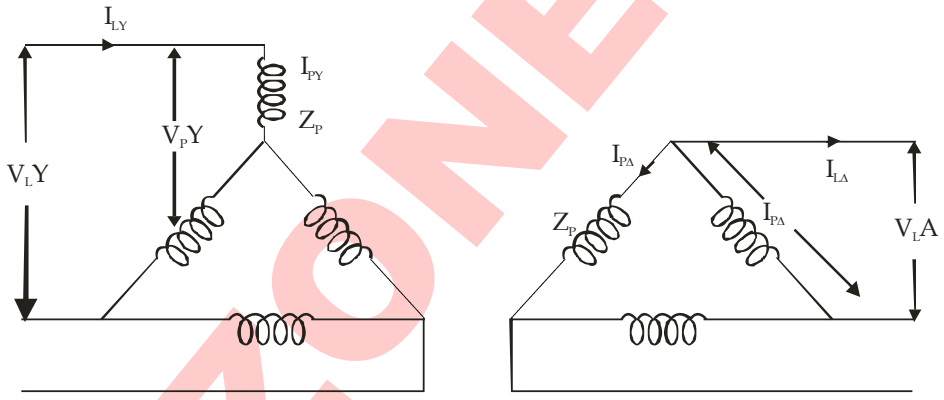
$I_{supply} = x\,(x\, I_{st})$

$I_{supply} = x^2\, I_{st}$

$T'_{st} = x^2 T_{st}$

With autotransformer starting both starting current and torque are reduced by same factor

(c) Star - Delta Starter :-



Star Connection

$V_{LY} = \sqrt{3} V_{PY}$

$I_{LY} = I_{PY}$

$$I_{PY} = \frac{V_{PY}}{Z_P} = \frac{V_{LY}}{\sqrt{3} Z_P}$$

$$\frac{I_{PY}}{I_{P\Delta}} = \frac{1}{\sqrt{3}}$$

Delta Connection

$V_{L\Delta} = V_{P\Delta}$

$I_{L\Delta} = \sqrt{3} I_{P\Delta}$

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$$\frac{I_{LY}}{\frac{(I_{L\Delta})}{\sqrt{3}}} = \frac{1}{\sqrt{3}} \qquad \frac{I_{LY}}{I_{L\Delta}} = \frac{1}{3}$$

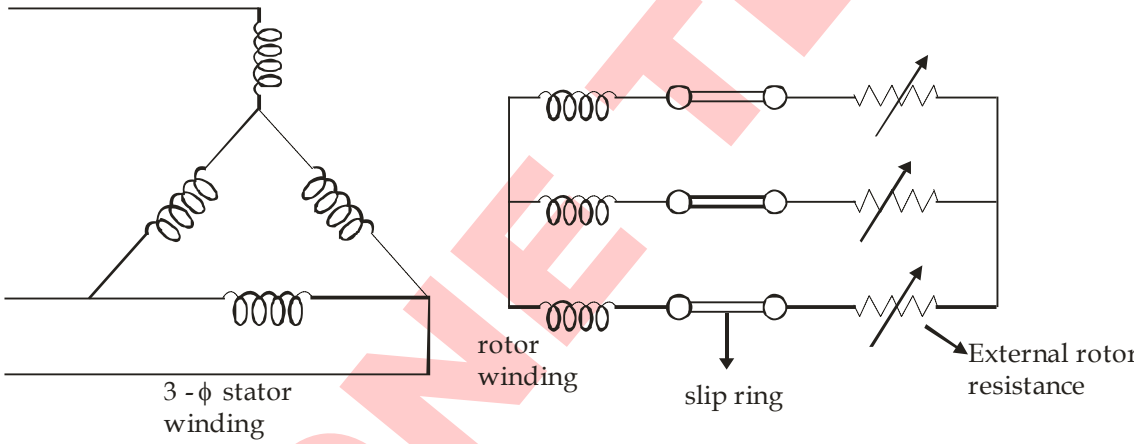
It is the cheapest method of starter. In this a TPDT (Triple pole double through) switch is used by this the per phase voltage get reduced by the factor $\frac{1}{\sqrt{3}}$ to limit the starting current

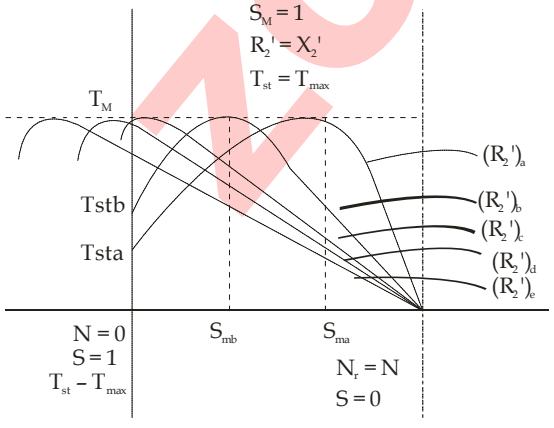
At starting the stator winding connection are kept in star connection $\left(V_{PY} = V_{LY} / \sqrt{3}\right)$ and in running condtion the stator winding is connected in Δ connection $\left(V_{P\Delta} = V_{L\Delta}\right)$. If the tappings in auto X-mer starter is kept at 55.7% then this starter work as star - delta starter

$$I = x I_{st} \qquad I = \frac{1}{\sqrt{3}} I_{st}$$

(d) Rotor - Resistance starter- It is used in SRIM(Slip ring induction motor) :-

$$\downarrow I_{st} = \frac{V}{\sqrt{\left(R_1 + R_2^{'}\right)^2 + \left(x_1 + x_2^{'}\right)^2}}$$





$$\left(R_2^{'}\right)_a < \left(R_2^{'}\right)_b < \left(R_2^{'}\right)_c < \left(R_2^{'}\right)_d < \left(R_2^{'}\right)_e$$

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170.

Sol.

Given,

$$I_{sc} = 6 \times I_{fl} \text{ at } s = 0.04$$

(a) I_{st} (line current) $= I_{sc} = 6I_{fl} = 6\,pu$

Starting torque in p.u. of full-load value

or $$\frac{T_{st}}{T_{fl}} = \left(\frac{I_s}{I_{fl}}\right)^2 \times 0.04 = 36 \times 0.04 = 1.44\,p.u.$$

$\Rightarrow$ $$T_{st} = 1.44\,pu$$

(b) I_{st} (motor) $= x.I_{sc} = 2I_{fl}$

and $$I_{sc} = 6.I_{fl}$$

then $$x = \frac{1}{3}$$

Line current, $$I_{st}\,(line) = x(x\,I_{sc}) = x^2\,I_{sc} = \frac{1}{9}.6.I_{fl}$$

$$I_s(line)_{p.u.} = \frac{I_s(line)}{I_{fl}} = \frac{2}{3} = 0.67\,pu$$

Starting torque in p.u. of full-load torque,

$$\frac{T_s}{T_{fl}} = x^2\left(\frac{I_{sc}}{I_{fl}}\right)^2 s_{fl}$$

$$= \frac{1}{9} \times 36 \times 0.04 = 0.16(p.u.)$$

$\Rightarrow$ $$T_{st} = 0.16\,p.u.$$

(c) Starting line current,

$$I_{st} = \sqrt{3}\,I_{sc} = \sqrt{3.6}\,I_{fl}\,(\text{direct-delta starting})$$

$$\frac{I_{st}(\Delta)}{I_{fl}} = 6\sqrt{3} = 10.392\,p.u.$$

In Y-starting line (phase current)

$$I_{st}(Y) = \frac{I_{sc}}{\sqrt{3}}$$

$$\frac{I_{st}(Y)}{I_{fl}} = \frac{6}{\sqrt{3}} = 3.45\,p.u.$$

$$\frac{T_s}{T_{fl}} = \frac{1}{3}\left(\frac{I_{sc}}{I_{fl}}\right)^2 .s_{fl} = \frac{1}{3}.(6)^2 \times 0.04$$

$$= 0.48\,p.u.$$

I_{st} = starting phase-current delta

171.

Sol. The braking is the process of reducing the speed of an induction motor. In braking, the motor works as a generator developing a negative torque which opposes the motion of a motor. The braking of an

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induction motor is mainly classified into three types. They are

1. Regenerative Braking
2. Plugging or reverse voltage braking
3. Dynamic Braking
AC dynamic braking
DC dynamic braking
Zero sequence braking

1. Regenerative Braking

The input power of the induction motor drive is given by

$$P_{IN} = 3VICOS(\Phi)$$

Where Φ is the phase angle between stator phase voltage and the stator phase current Is. For motoring operation, the phase angle is always less than the 90°. If the rotor speed becomes greater than synchronous speed, then the relative speed between the rotor conductor and air gap rotating field reverse. This reverse the rotor induces emf, rotor current and component of stator current which balances the rotor ampere turns. When the Φ is greater than the 90°, then the power flow to reverse and gives the regenerative braking. The magnetising current produced the air gap flux. When the supply frequency is fixed, the regenerative braking is possible only for speeds greater than synchronous speed. With a variable frequency speed, it cannot be obtained for speed below synchronous speed.

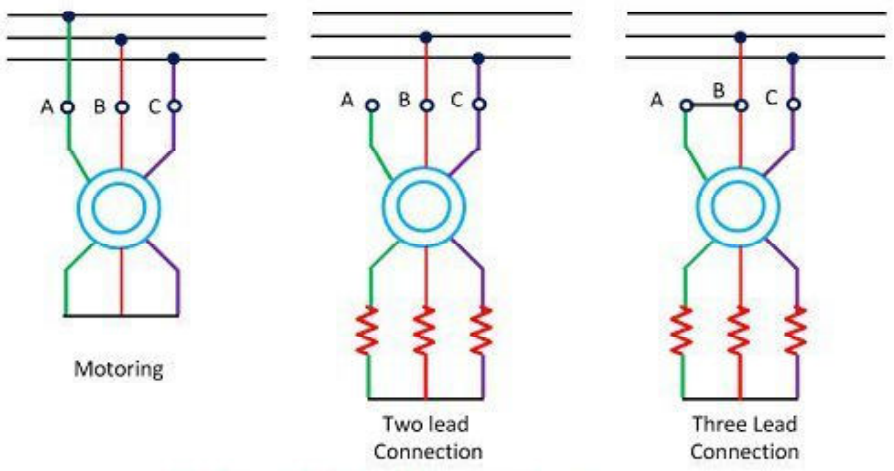
The main advantage of regenerative braking is that the generated power is fully used. And the main drawback is that when fed from a constant frequency source the motor can not employ below synchronous speed.

2. Plugging

When the phase sequence of supply of the motor running at speed is reversed by interchanging the connection of any two phases of the stator on the supply terminal, operation change from motoring to plugging. Plugging is the extension of motoring characteristic for a negative phase sequence from quadrant third to second. The reversal of phase sequence reverses the direction of a rotating field.

3. Dynamic Braking

AC Dynamic Braking – The dynamic braking is obtained when the motor is run on the single phase supply by disconnecting the one phase from the source and either leaving it open or connecting it with another phase. The two connections are respectively known as two and three lead connection.



When connected to a one phase supply the motor can be considered as to be fed by positive and

negative sequence three phase set of voltage. The total torque produced by the machine is **the** sum of torque due to positive and negative sequence voltage. When the rotor has high resistance, then the net torque is negative, and the braking operation is obtained.Assume the phase A of the star connected motor is open circuited. Then the current flow through the phase A becomes zero, i.e., Ia = 0 and current through the other two phases is IB = – IC.

DC Dynamic Braking – In this method, the stator of induction is connected across the DC supply. The method for getting DC supply with the help of a diode bridge. The direct current flow through the stator produces a stationary magnetic field, and the motion of the rotor in this field produces induces voltage in the stationary windings. The machine therefore works as a generator and the generated energy is dissipated in the rotor circuit resistance, thus giving the dynamic braking.

Zero Sequence Braking – In this braking, the three phases of the stator are connected in series across either a single AC or DC source. Such type of connection is known as zero sequence connection because the current in all the three phases is co-phase.
With the AC supply, the braking could be used only up to one-third of synchronous speed. The braking torque produces by this connection are considerable larger than motoring. With DC supply braking is available the entire speed range and the braking are essential a dynamic braking as all the generated energy is wasted into rotor resistance.

172.

Sol. Given $p_{sh} = 4.1$ kW

$p_{mech\ loss} = 750$ W

Mechanical power developed

$(p_m) = 4100 + 750$

$= 4850$ watt

$$I_2^2 R_2' \left(\frac{1}{s} - 1\right) = 4850$$

$$\text{Rotor cu loss } \left(\frac{1-s}{s}\right) = 4850$$

$$\text{Rotor cu loss} = \frac{4850\,s}{(1-s)} \quad \ldots(1)$$

$$N_S = \frac{120 \times 50}{6}$$

$$= 1000\,\text{rpm}$$

$N = 970$ rpm

$$\%\ S = \frac{N_s - N}{N_s} \times 100$$

$$= \frac{1000 - 970}{1000} \times 100$$

$S = 3\%$

Put the value is equation ...(1)

$$\text{Rotor cu loss} = \frac{4850 \times 0.03}{1 - 0.03}$$

$$= 150 \text{ watt}$$

173.

Sol.

For the rotor at blocked position, slip $S=1$

As magnetizing current is negligible, therefore

$$I_{BR}=\frac{V_{BR}}{\sqrt{R^2+X^2}}$$

where $R=r_1+r_2$

$X=X_1+X_2$

$$P_{BR}=3I_{BR}^2\times R$$

$I_{BR}=50,\ P_{BR}=15\ \text{kW}$

$$\Rightarrow \quad R=\frac{15\times10^3}{3\times50^2}=2\ \Omega$$

$$\text{Then}50=\frac{250/\sqrt{3}}{\sqrt{R^2+X^2}}$$

$$\Rightarrow \quad 50=\frac{250/\sqrt{3}}{\sqrt{2^2+X^2}}$$

$$\Rightarrow \quad X=2.08\ \text{W, at f}=50\ \text{Hz}$$

At $f=60$ Hz

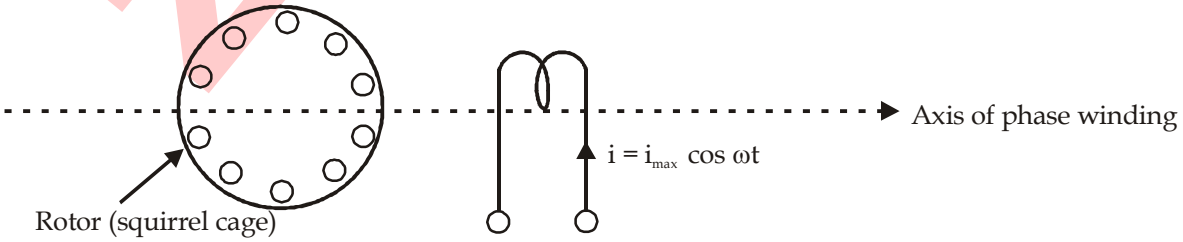
$$X=2.08\times\frac{60}{50}=2.5\ \text{W}$$

Hence at $f=60$ Hz, $V_{BR}=240$ V

$$I'=\frac{240/\sqrt{3}}{\sqrt{2^2+2.5^2}}=43\ \text{A}$$

174.

Sol. Figure gives the schematic diagram of a single-phase induction motor with one stator winding and a squirrel-cage rotor. The winding is distributed in space so that the space fundamental of mmf is the most dominant component of the actual mmf distribution. The sapce harmonics of mmf, as in the case of a 3-phase induction motor, would then be ignored. When the winding carries a sinusoidal current, it produces a sinusoidally space-distributed whose peak values pulstates with time.



As seen from the axis of the winding, the mmf at any time t is

$F=F_{peak}\cos\theta$ ...(i)

where θ is the angle measured from the winding axis, Now

$F_{peak}=F_{max}\cos\ \omega t$ ...(ii)

So that the mmf has both space and time distribution expressed as

$F = F_{max} \cos\theta \cos \omega t$ ...(iii)

This equation can be trignometrically manipulated into the form

$F = (1/2)F_{max} \cos(\theta - \omega t) + (1/2)F_{max} \cos(\theta + \omega t)$ ...(iv)

Equation (iv) shows, a pulsating single-phase field be considered as superposition of two rotationg fields rotating at synchronous speed is opposite direction.

$(1/2)F_{max} \cos(\theta - \omega t)$; forward rotating field, F_f,

$(1/2)F_{max} \cos(\theta + \omega t)$; backward rotating field, F_b.

The forward and backward rotating fields along with the rotor which is rotating at speed n in the direction of the forward field have slip (s) and (2 – s) respectively.

Under stationary rotor condition, the two rotating field slip past the rotor at the same slip s = 1, and inducing equal currents in the squirrel-cage rotor. The two rotating fields have the same strength and produce equal and opposite torques resulting is net starting torque of zero value.
If however, the rotor is made to run at speed n in the direction of the forward field, the two slips are now s and (2 - s) > > s and as a consequence the backward field induced rotor currents are much larger than at stand still and have lower power factor. The corresponding opposing rotor mmf, in presence of the stator impedance, causes the backward field to be greatly reduced in strength. On the other hand, the low-slip forward rotating field induces smaller currents of a higher power factor in the rotor than at stand still. This lead to great enhancement in the forward flux wave. This reduction in the backward field and strengthening of the forward field is slip-dependent and the difference increases as slip reduces or the rotor speed in the forward direction becomes close to the synchronous speed.

175.

Sol.

Capacitor Start Motor: Capacitors are used to improve the starting and running performance of the single phase induction motors. The capacitor-start motor is identical to a split-phase motor except that starting winding has an many turns as the main winding. More over a capacitor C is connected in series with the starting winding.

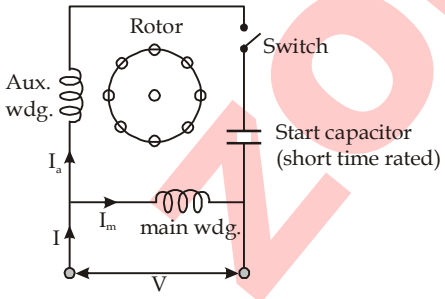


Fig. (a)
Schematic diagram

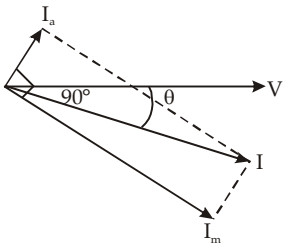


Fig. (b)
Phasor diagram

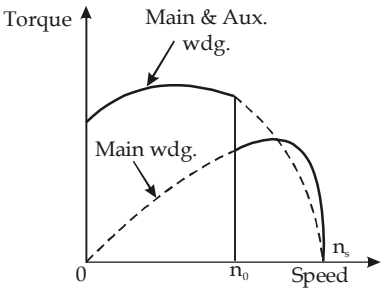


Fig. (c)
Torque-speed characteristic

The value of capacitor is so chose that I_a leads I_m by about 90° so that the starting torque is maximum for certain value of I_a and I_m. Again, the starting winding is opened by the centrifugal switch when the motor attains about 75% of synchronous speed. The motor then operates as a single phase induction motor and continues to accelerate till it reaches the normal speed.

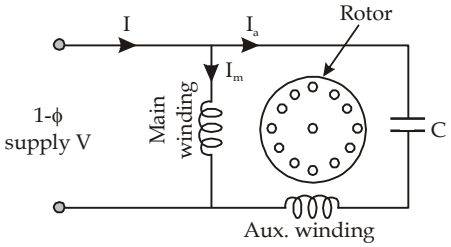
Characteristics

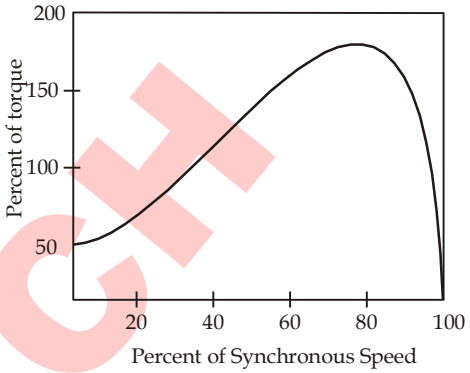
1. Although starting characteristics of a capacitor-start motor are better than those of a split-phase motor both machine possess the same running characteristics because the main winding are identical.
2. The phase angle between two currents is about 90° compared to about 25° in a split-phase motor

consequently, for the same starting torque, the current in the starting winding is only about half that in a split phase motor. Therefore, the starting winding of a capacitor start motor heats up less quickly and is well suited to application involving either frequent or prolonged starting periods.

3. Capacitor-start motors are used where high starting torque is required and where high starting period may be long. The power rating of such motor lies between 120 W and 0.75 kW.

Capacitor Run:





In this motor, the capacitor that connected in series with the auxiliary winding is not cut out after starting and is left in circuit all the time. This simplifies the construction and decreases the cost because the centrifugal and decreases the cost because the centrifugal switch is not needed. The power factor, torque pulsation and efficiency are also improved because the motor runs as a two-phase motor. The motor runs more quietly.

The capacitor value is of the order of 20-50 μF and because it operates continuously, it is an ac paper oil type. The capacitor is compromise between the best starting and running value and therefore starting torque is sacrificed.

Characteristics:

1. These motor are used where the required starting torque is low such as air-moving equipment i.e. fan, blower and voltage regulators and also oil burners where quite operation is particularly desirable.

Capacitor-Start-Capacitor Run:

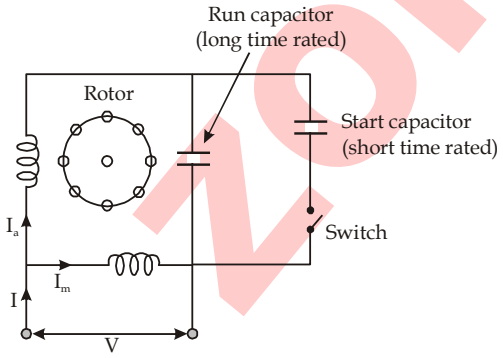


Fig. (a)
Schematic diagram

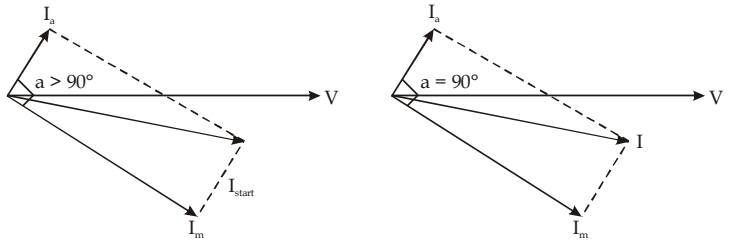


Fig. (b) Phasor diagram

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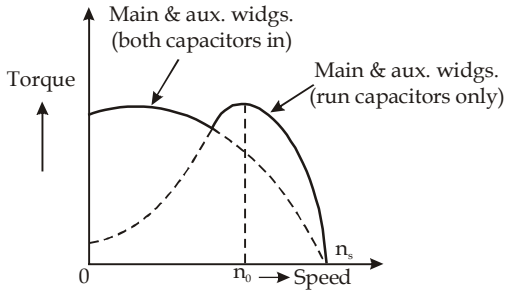


Fig. (c)
Torque-speed characteristic

Two capacitor one for starting and one for running theoretically, optimum starting and running performance can be achieved by having two capacitors.
The starting capacitor is larger in value and is of ac electrolytic type. The running capacitor permanently connected in series with the starting winding, is of smaller value and is of the paper oil type.

Characteristics:

1. Ability to start heavy loads.
2. Extremely quite operation
3. Higher efficiency and power factor.
4. Ability to develop 25% overload capacity. Hence such motors are ideally suited where load requirements are severe as in the case of compressors and conveyors etc.

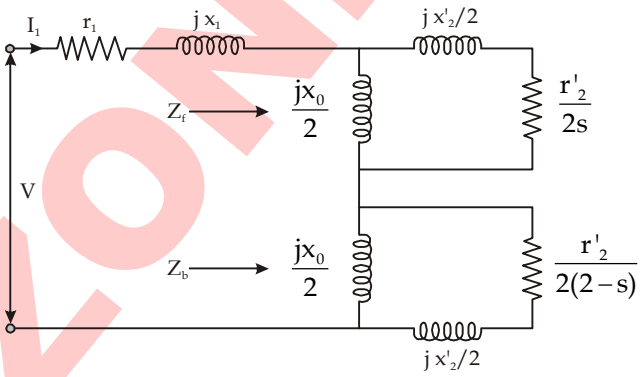
176.

Sol.

Given,

$r_1 = 11.4$ ohm $\quad x_1 = 14.3$ ohm $\quad x_0 = 275$ ohm

$r'_2 = 13.8$ ohm $\quad x'_2 = 14.3$ ohm $\quad S = 0.06$



$$Z_f = \left(\frac{jX_0}{2}\right)\left\|\left(\frac{r'_2}{2s} + j\frac{x'_2}{2}\right) = \left(j\frac{275}{2}\right)\right\|\left(\frac{13.8}{2\times 0.06} + j\frac{14.3}{2}\right)$$

$$\Rightarrow \quad Z_f = 85.75\angle 42.04\,\Omega$$

$$Z_b = \left(\frac{jX_0}{2}\right)\left\|\left(\frac{r'_2}{2(2-s)} + j\frac{x'_2}{2}\right) = \left(j\frac{275}{2}\right)\right\|\left(\frac{13.8}{2\times(2-0.06)} + j\frac{14.3}{2}\right)$$

$$\Rightarrow \quad Z_b = 7.58\angle 64.96\,\Omega$$

Taking supply voltage as the reference.

$$V = 230\angle 0$$

$$\text{Input current} = I = \frac{V}{(r_1 + jX_1) + Z_f + Z_b}$$

$$\Rightarrow \quad I = \frac{230\angle 0}{(11.4 + j14.3) + 85.75\angle 42.04 + 7.58\angle 64.96}$$

$$= 2.07\angle -45.10° \text{ Amp.}$$

Input power factor

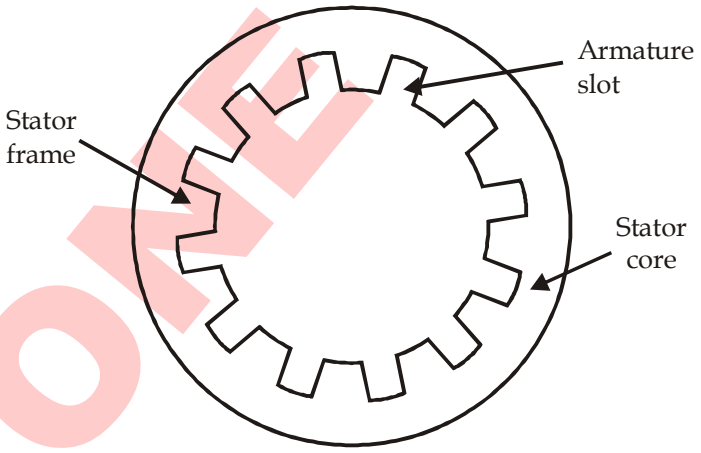
$$\Rightarrow \quad \cos\phi = \cos(45.10) = 0.7058 \text{ (lagging)}$$

$$\text{Input power} = VI\cos\phi = 230 \times 2.07 \times 0.7058$$

$$= 336.03 \text{ Watts}$$

177.

Sol. **Stator Construction:** The various parts of the stator include the frame, stator core, stator windings and cooling arrangement. The frame may be of cast iron for small-size machines and of welded steel type for large size machines. In order to reduce hysteresis and eddy-current losses, the stator core is assembled with high grade silicon steel laminations. A 3-phase winding is put in the slots cut on the inner periphery of the stator as shown in Figure. The winding is star connected. The winding of each phase is distributed over several slots. When current flows in a distributed winding it produces an essentially sinusoidal space distribution of emf.



Alternator Stator

Rotor Construction: There are two types of rotor constructions namely, the salient-pole type and the cylindrical rotor type.

Salient-Pole Rotor: The term salient means 'protruding' or 'projecting'. Thus, a salient pole rotor consists of poles projecting out from the surface of the rotor core.

Since the rotor is subjected to changing magnetic fields, it is made of silicon steel laminations to reduce eddy current losses. Salient-pole rotors have concentrated winding on the poles. Damper bars are usually inserted in the pole faces to damp out the rotor oscillations during sudden change in load conditions.

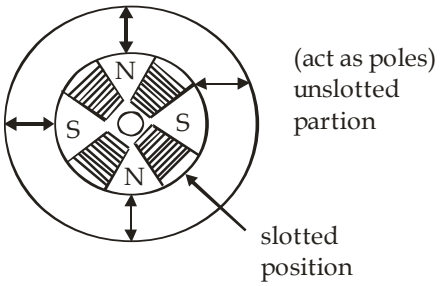
The slip rings are metal rings mounted on the shaft and insulated from it. They are used to carry current to or from the rotating part of the machine (usually a.c. machine) via carbon brushes.

Cylindrical Rotor: A cylindrical-rotor machine is also called a non-salient pole rotor machine. It has its

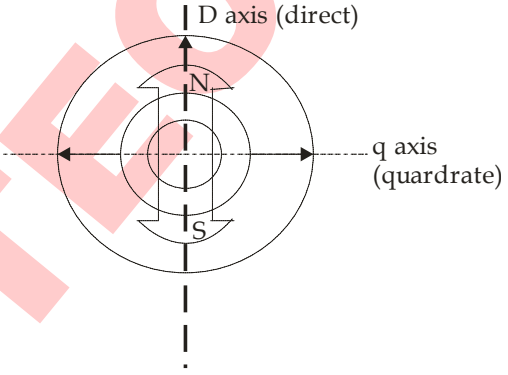
rotor so constructed that it forms a smooth cylinder. The construction is such that there are no physical poles to be seen as in the salient-pole construction. Cylindrical rotors are made from solid forgings of high grade nickel-chrome-molybdenum steel. In about two-third of the rotor periphery, slots are cut at regular intervals and parallet to the shaft. The d.c. field windings are accommodated in these slots. The winding is of distributed type. The unslotted portion of the rolor forms two (or four) pole faces. A cylindrical-rotor machine has a comparatively small diameter and long axial length. Such a construction limits the centrifugal forces. Thus, cylindrical rotors are particularly useful in high-speed machines. The cylindrical rotor type alternator has two or four poles on the rotor. Such a construction provides a greater mechanical strength and permits more accurate dynamic balancing. The smooth rotor of the machine makes less windage losses and the operation is less noisy because of uniform air gap.

Type of rotor :-

Cylindrical Type



Salient pole / Projected pole type



→ Uniform air gap
→ Diameter less, axial length high
→ No of poles less
→ $\uparrow Ns = \frac{120f}{P\downarrow}$
→ Mechanically strong
→ Thermal nuclear P.P (always mounted horizontally)
→ $P = \frac{EV}{X}\sin\delta$
100% excitation power
→ Stable less
→ Same size rating ↑es
→ Efficiency high

→ Non uniform air gap
→ Diameter more, axial length less
→ No of poles more
→ Speed ↓
→ Mechanically weak
→ Hydroelectric P.P (mounted vertically)
→ $P = \frac{EV\sin\delta}{X_d} + \frac{V^2}{2X_dX_q}\left(X_d - X_q\right)$
→ More stable
→ Same size rating ↓s

178.

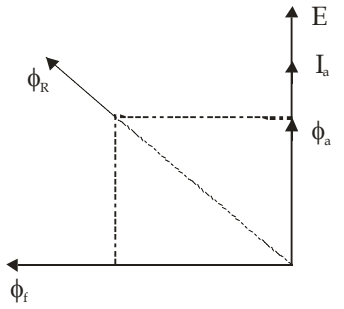
Sol.

Armature Reaction in Synchronous Generator:

The effect of armature (stator) flux wave on the field flux wave is called armature reaction. When the current flows through the stator winding of an alternator, a flux is produced by the resulting mmf. This armature flux reacts with the main pole flux, causing the resultant flux to become either less than or more than the original main field flux.

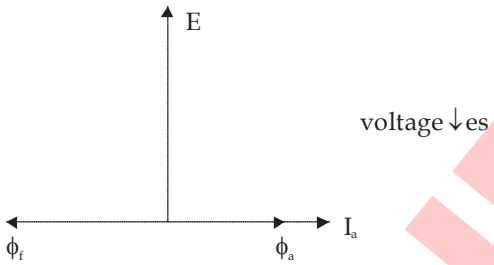
The armature reaction in synchronous generators are under following three conditions.

(*i*) Armature reaction at unity power factor load :
When Alternator is supplying current at unity power factor, The phase current I_A, I_B and I_C will be in phase with their respective generatred voltages i.e. E_A, E_B and E_C.hence flux is also in phase with their respective generatred voltages

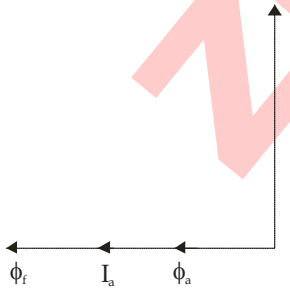


The armature reaction flux ϕ_{AR} lags behind the main field by 90°. This is called Cross magnetizing A. R effect

(*ii*) Armature reaction at zero power factor lagging load: If the alternator is loaded with an pure inductive loac or zero power factor lagging. The phase current I_A, I_B and I_C will be lagging with their respective phase voltage E_A, E_B and E_C by 90°.

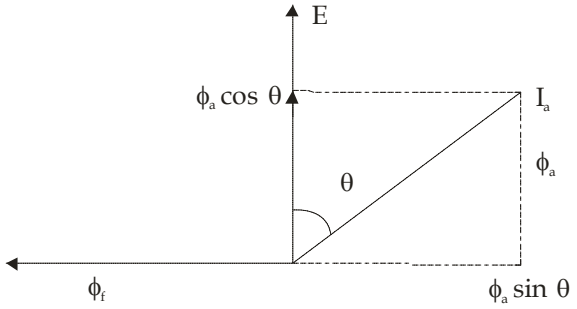


The direction of armature flux is opposite to the main field flux. Therefore it will oppose and weaken the main field flux. It is said to be demagnetized effect of armature reaction
(*iii*) Armature reaction at zero power factor leading load: If the alternator is loaded with a load of zero power factor leading. The phase current I_A, I_B and I_C will be leading their respective phase voltages E_A, E_B and E_C by 90°.



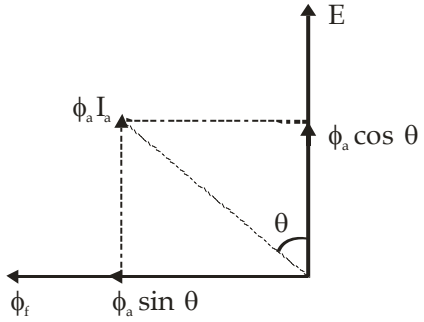
The direction of the armature reaction flux is in the direction of main field flux. It is known as magnetized effect of armature reaction.
(4) Lagging Load :- (R – L Load)

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armature reaction is Partially demagnetizing and partially cross-Magnetizing

(5) Leading Load :- (R – C load)



armature reaction is Partially magnetizing and partially cross-Magnetizing

At loaded condition the armature flux opposes the main flux. This effect of armature flux is known as armature reaction effect. This effect not only depends on the magnitude of armature current but also depend on the nature of power factor of the load.

Due to cross magnetizing and De-magnetizing causes a drop in terminal voltage while magnitizing effect of armature reaction causes greater EMF induce. Hence terminal voltage ↑es

179.

Sol. **Comparison between Synchronous and Induction Motors**:

1. For a given frequency, the synchronous motor runs at a constant average speed whatever the load, while the speed of an induction motor falls some what with increase in load.
2. The synchronous motor can be operated over a wide range of power factors, both lagging and leading, but induction motor always runs with a lagging p.f. which may become very low at light loads.
3. A synchronous motor is inherently not self-starting.
4. The changes in applied voltage do not affect synchronous motor torque as much as they affect the induction motor torque. The breakdown torque of a synchronous motor varies approximately as the first power of applied voltage whereas that of an induction motor depends on the square of this voltage.
5. A d.c. excitation is required by synchronous motor but not by induction motor.
6. Synchronous motors are usually more costly and complicated than induction motors, but they are particularly attractive for low-speed drives (below 300 r.p.m.) because their power factor can always be adjusted to 1.0 and their efficiency is high. However, induction motors are excellent for speeds above 600 r.p.m.
7. Synchronous motors can be run at ultra-low speeds by using high power electronic converters which generate very low frequencies. Such motors of 10 MW range are used for driving crushers, rotary kilns and variable-speed ball mills etc.

Synchronous Motor Applications:

Synchronous motors find extensive application for the following classes of service:

1. Power factor correction
2. Constant-speed, constant-load drives
3. Voltage regulation

(a) Power factor correction

Overexcited synchronous motors having leading power factor are widely used for improving power factor of those power systems which employ a large number of induction motors figure and other devices having lagging p.f. such as welders and flourescent lights etc.

(b) Constant-speed applications

Because of their high efficiency and high-speed, synchronous motors (above 600 r.p.m.) are well-suited for loads where constant speed is required such as centrifugal pumps, belt-driven reciprocating compressors, blowers, line shafts, rubber and paper mills etc.

Low-speed synchronous motors (below 600 r.p.m.) are used for driver such as centrifugal and screw-type pumps, ball and tube mills, vacuum pumps, clippers and metal rolling mills etc.

(c) Voltage regulation

The voltage at the end of a long transmission line varies greatly especially when large inductive loads are present. When an inductive load is disconnected suddenly, voltage tends to rise considerably above its normal value because of the line capacitance. By installing a synchronous motor with a field regulator (for varying its excitation), this voltage rise can be controlled.

When line voltage decreases due to inductive load, motor excitation is increased, thereby raising its p.f. which compensates for the line drop. If, on the other hand, line voltage rises due to line capacitive effect, motor excitation is decreased, thereby making its p.f. lagging which helps to maintain the line voltage at its normal value.

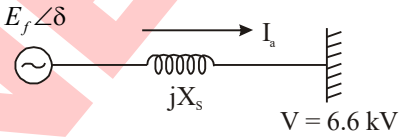
180.

sol. Given $S = 1000$ kVA

$V = 6.6$ kV

$X_S = j20\ \Omega$

p.f. $= 1$



From given data

$$I_a = \frac{P}{V}\underline{|0^\circ} \quad \text{... because p.f. unity}$$

$$I_a = \frac{1000\times10^3}{6.6\times10^3}\underline{|0^\circ}$$

$$I_a = 151.5151\,\text{Amp.} \qquad ...(2)$$

Now $E_f\angle\delta = V + I_a\times(j20)$

$$= 6.6 + 151.5151(j20)$$

$$E_f\angle\delta = 6.6 + j3.03030$$

$$E_f\angle\delta = 7.2kV\underline{|24.6^\circ} \quad \text{... polar form}$$

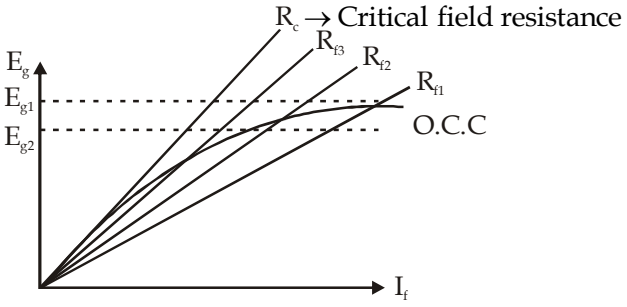
By comparing

$$E_f = 7.2\,\text{kV}$$

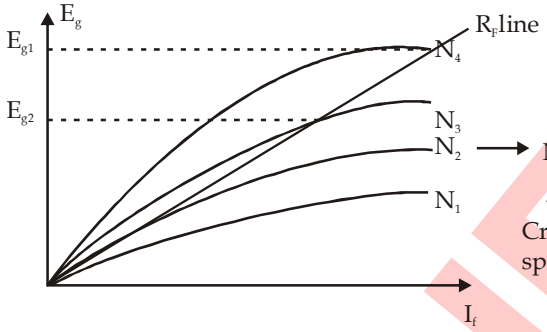
181.

Sol.

1. No residual flux ($\phi_{ris} = 0$).
2. Field winding connections are wrong ($\phi_{res} - \phi_{f1}) = 0$, (direction is opposite).
3. **Critical field resistance:-** The critical field resistance of shunt generator is define as the max. value of field resistance at given speed at which the generator would only Excite is known as critical field resistance. Above this critical field resistance their is no voltage build in the generator or the generator will not excite, so for proper voltage build-up the field circuit resistance should be always less than critical field resistance.



4. **Critical speed**



$E_{g1} > E_{g2}$

$N_1 < N_2 < N_3 < N_4$

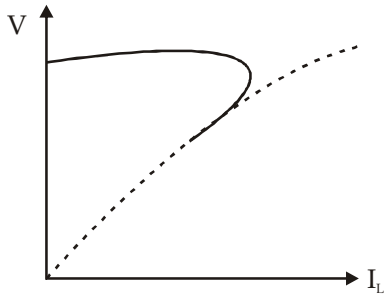
The critical speed is define as the minimum value of speed below which it fails to excite or speed at which the linear part of O.C.C coincids with R_f line. So it is clear that if the speed is less than critical speed the voltage build up will be fail.

Note:- If the value of field resistance ↓es, the critical speed of the generator will also ↓es.

5. **Critical external resistance for shunt generator**

If the load resistance of a shunt generator ↓es than the load current ↑es which results in ↑es in armature reaction and I_aR_a drop. So, this ↓es the field current and hence the field flux. So their is low induced EMF. If so critical external resistance is defined as the minimum value of load resistance which required to excite the generator on load. So if the external resistance is less than the critical external resistance the generator will not excite or will be excite while already running.

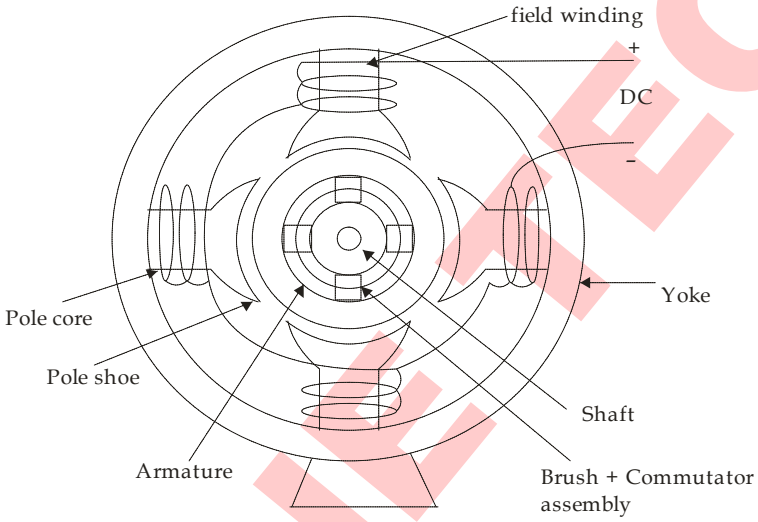
ZONE TECH



182.

Sol. Construction of DC machine :-

In dc machine armature winding is on the rotor field winding is on the stator



DC Motor :- Armature is connected to supply.
DC Generator :- Armature is connected to load.
It has mainly two parts
(1) Stator part
(2) Rotor part

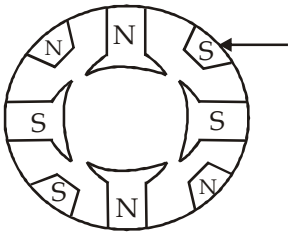
Stator part

(a)Yoke :- It act as outer frame of the machine and carry the magnetic flux produced by the poles.it is made by fabricated steel, and also provides mechanical strength to the whole machine.
(b)Pole core :- These are useally in circular section and are used to carry the field coils of insulated wires which carries the field current (exciting current). it is made from 1.5 mm thick cast steel.
(c)Pole shoe :- It act as a support to the field coil and it spread out the magnetic flux over the armature periphery more uniformly.
(d)Field coil :- The objective of the magnetizing or field coil is to provide the required magnetic flux when it is excited by field current or exciting current. It work as a electro-magnets.it is prepared from copper.The purpose of field system is to provide a uniform magnetic field. Electro magnets are generally preferred in

comparison with permanent magnets on account of the greater magnetic effect.

(e)Brushes :- The function of brushes is to collect the current from the commutator and supply it to the external circuit. It is placed in brush holder and it may classify as carbon brushes, carbon graphite brushes, metal graphite brushes and copper brushes. The current density range for carbon brushes vary from 5A/m^2 to 23 A/m^2 for the copper.These are housed in box type brush holder attached to the stator.

(f)Interpole:-The interpole winding is bound for few turn and connected in series with the armature. So that it carry the armature current.The polarity of interpole is same as the next main pole in the direction of rotation for the generator and visa-versa for motor.



Shape of interpole :- wider base narrow interpole

The MMF of interpoles neutralize the cross- magnetizing effect (sparking) of armature reaction.

(g)Compensating winding :- In order to neutralize the cross-magnetizing effect of armature reaction compensating winding is used, it is a auxiliary winding connected in series with armature in a manner so that the direction of current through the compensating winding will be just opposite to the direction of current in armature conductor. By this the armature flux get neutralize and the armature reaction is also neutralize.The best way to achieve this compensation is by means of pole face winding embedded in the slots in the pole faces.

(h)Bearings :- The bearings are used in D.C machine to provide smooth rotation and friction less rotation for small machine ball bearings are used and for large machine roller bearings are used.

Rotor part

(a)Armature core :- The armature core is made of .35 to .50 mm high permeability silicon steel stamping because to reduce the hysteresis and eddy current losses. it's purpose is to provide the low reluctance path to the magnetic flux .

(b)Armature winding:-The armature winding is made of copper. It is a group of rotating conductor which are rotating in magnetic field, It is a place where energy conversion will take place.

For Motor :- Electrical to Mechanical

For Generator :- Mechanical to Electrical.

Armature winding are of 2 type.

(i) Lap winding (A = P) (low voltage)

(ii)Wave winding (A = 2) (high voltage)

Where A = No of parallel path

P = No of poles

(c)Commutator :- It is of cylindrical structure build up of wedge shaped segments of high conductivity hard drawn copper. It is a form of a rotating switch placed between the rotating armature and the stationary external circuit. And it is so arranged that it will reverse the connection that with the external circuit at the instant of each reversal of current in armature. It provide electrical connection between rotating armature and stationary external circuit.

For DC Motor :- It converts D.C to A.C work as mechanical inverter.

For DC Generator :- It converts A.C to D.C work as mechanical rectifier.

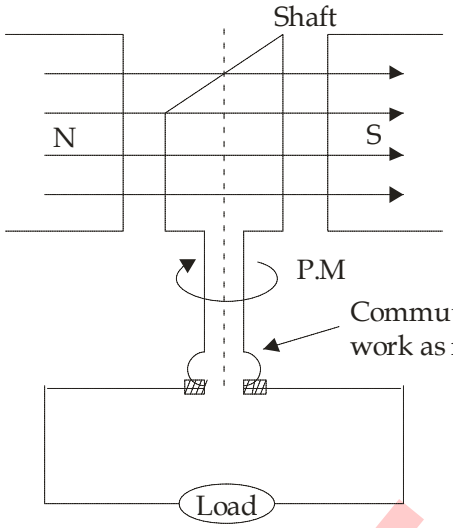
In D.C machine commutator work as both mechanical inverter as well as mechanical rectifier.

(d)Shaft :- The function of shaft is to transfer mechanical power from core to the machine. It is made of

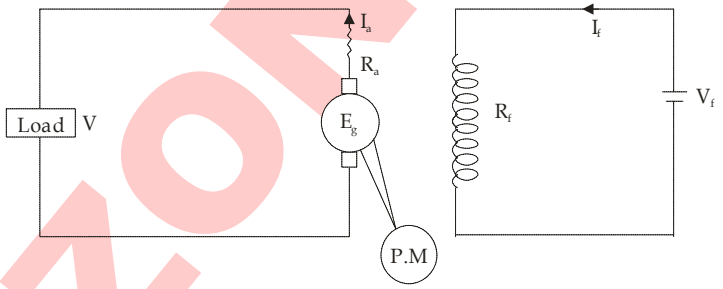
mild steel with a maximum breaking strength.

183.

Sol. D.C generator Working Principle :- D.C generator convert mechanical power into electrical power when it is connected to a mechanical source or prime mover, its armature conductor cuts the stationary magnetic flux and acc. to the faraday's law of electro magnetic induction EMF get induced. In D.C generator the magnetic field is stationary and the armature conductor's are rotating.



$$E_g = \frac{\phi PZN}{60A}$$

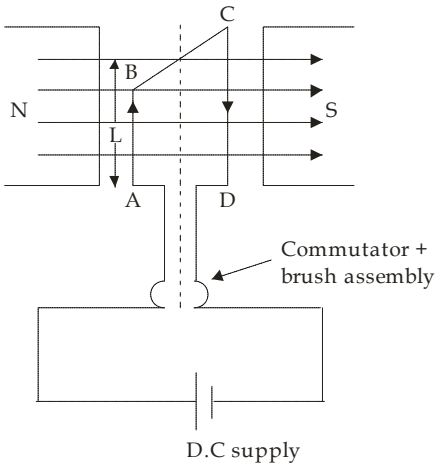


D.C Motor Working Principle

If a current carrying conductor placed in a magnetic field experienced a mechanical force by the conductor which is called Laurentz force (f = BIL sin θ), the direction of this force is given by flemings left hand rule.Acc to this rule, if the midle finger, index finger and thumb of left hand placed at 90° to each other and if index finger represent the direction of magnetic field and midle finger represent electric current. Then the mechanical force direction can be given by direction of thumb.

In D.C motor in 2 conductors of a armature coil, the direction of this force is opposite so due to this torque is produces in a particular direction and the motor is rotated.

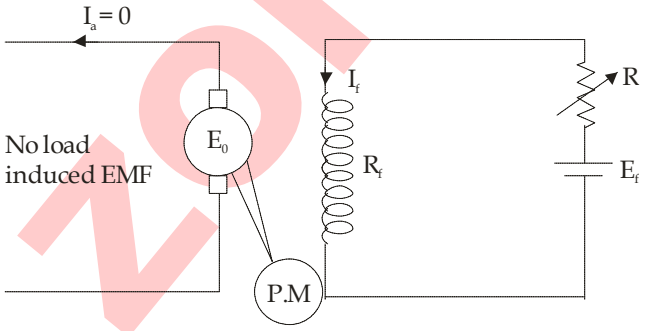
ZONE TECH



Laurentz force (F) :- BIL sin θ
B :- Magnetic field
I :- Current in conductor
L :- Length of conductor

184.

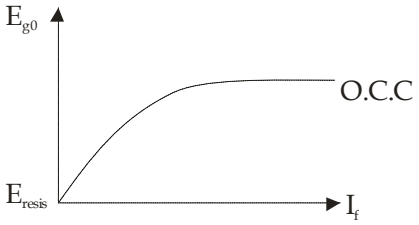
Sol. (A)Separately excited generator
(i)Open Circuit Characteristic / No load char. / Magnetisation curve (E_{g0} v/s I_f)
It gives the variation of armature generated voltage E_{g0} with field current I_f for zero armature current and constant speed



$\phi_f \alpha I_f$

$$\uparrow E_g = \uparrow \frac{\phi PZN}{60A}$$

ZONE TECH



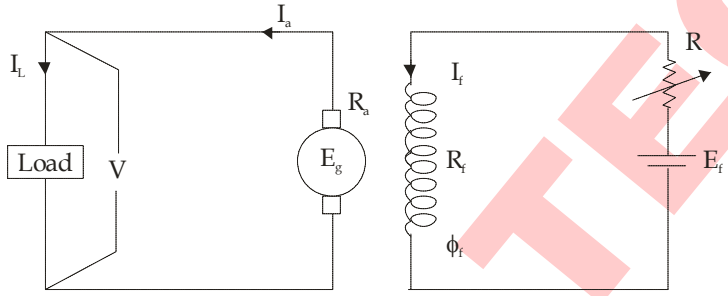
(ii)Internal Characteristic (E_g v/s I_a)

It gives the variation of armature generated voltage E_{g0} with armature current I_a for fixed field current and constant speed

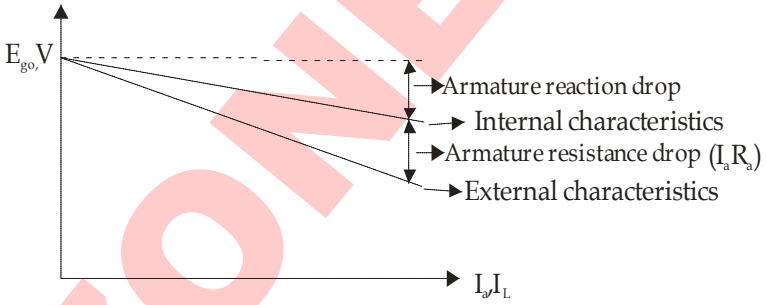
(iii) External Characteristic (V v/s I_L)

It gives the variation of terminal voltage V with load current I_L for fixed field current and constant speed. With the increased in load current, terminal voltage decrease slightly due to voltage drops cause by armature reaction and armature circuit resistance.

$V_t = E_g - I_aR$– Aramature reaction drop–Brush contact resistance drop



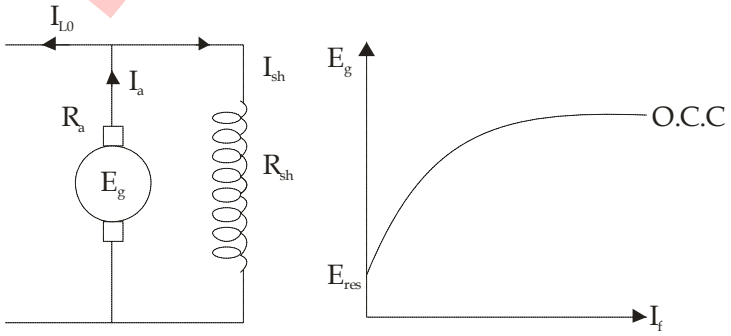
$\phi_a \alpha I_a$
(I_f = const.)



(B)DC Shunt Generator :-

(i)Open circuit / No load / Magnetisation curve :-

It gives the variation of armature generated voltage E_{g0} with field current I_f for constant speed



ZONE TECH

(ii)Internal and External Characteristic :-

The drop in terminal voltage is due to

(a) armature resistance drop I_aR_a

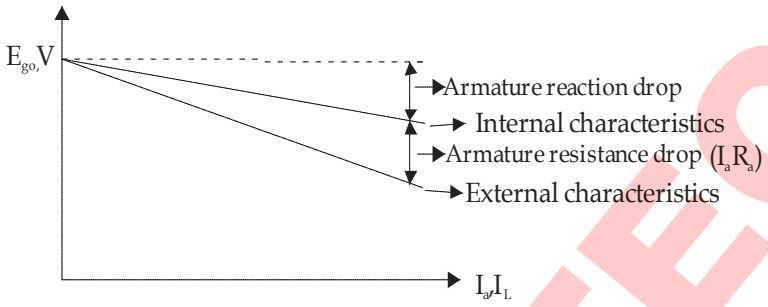
(b) reduction in main field flux due to armature reaction

(c) reduction in field current I_{sh}, since the terminal voltage has decreased because of the first two effects given in part (a) and (b).

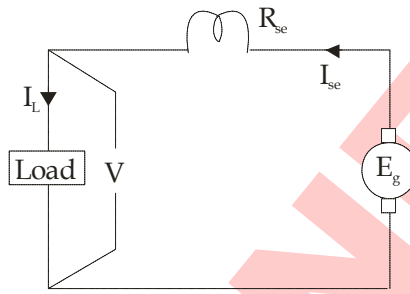
A reduction in field current (I_f) cause the flux and therefore the generated emf to decrease. Thus the terminal voltage of the generator for a given load will be lower than the separately excited, provided no-load voltage is same in both the cases. If we further increase the load current, after breakdown point, the terminal voltages fall back rapidly.

$\phi_a \alpha I_a$

$I_L \neq 0$

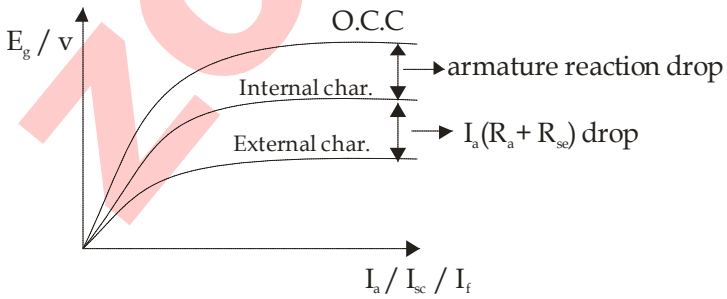


(C)D.C Series Generator :-



$I_a = I_{sc} = I_L$

$V = E_g - I_a (R_a + R_{sc})$



It has rising voltage characteristic in the operating region upto saturation. Series flux ϕ_{se} increase with load so terminal voltage V_t will increase as emf, E_g increase but $I_a(R_a + R_{se})$ drop will also increase. As increase armature current, armature reaction also increase i.e. $I_a \uparrow$, armature reaction $\uparrow$. Beyond saturation, it has shunt characteristics which is dropping in nature.

As load increase armature current I_a increase and $I_a (R_a + R_{se})$ drop also increase

i.e. Load $I_a \uparrow$ and $I_a (R_a + R_{se})$drop $\uparrow$

At saturation flux $(\phi) \rightarrow$ constant

So, Emf E_g remains constant

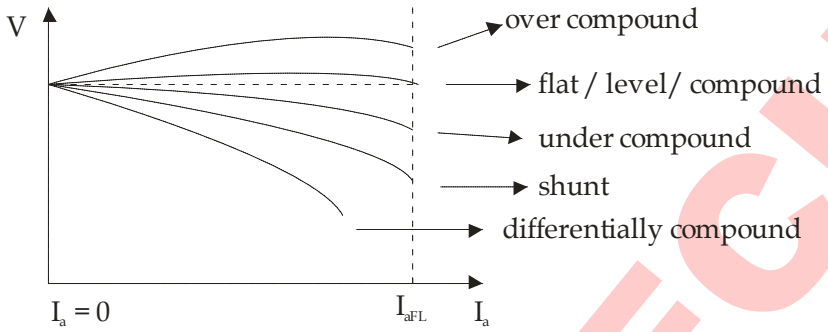
$$\downarrow V_t = E_g - I_a(R_a + R_{se}) \uparrow$$

Terminal voltage V_t will decrease

(D)Compound Generator Characterstic :-

Commulative $\uparrow\phi_T = \phi_{SH} + \phi_{se} \uparrow$

Differentially $\downarrow\phi_T = \phi_{SH} - \phi_{se} \uparrow$



The compound generator can be commulative compound or differentially compound generator. The differentially compound generator is rarely used in practice (Ex :- Welding application $\rightarrow$ voltage required low) as in this type of generator only increase in load current increase the series flux and thus $(\phi_{sh} - \phi_{sc})$ decrease. Which results in sharp decrease in terminal voltage.

In commulative compound generator with increase in load current total flux $(\phi_{sh} + \phi_{se})$ increase. Therefore their is increase in terminal voltage. In this 3 types of generators are possible.

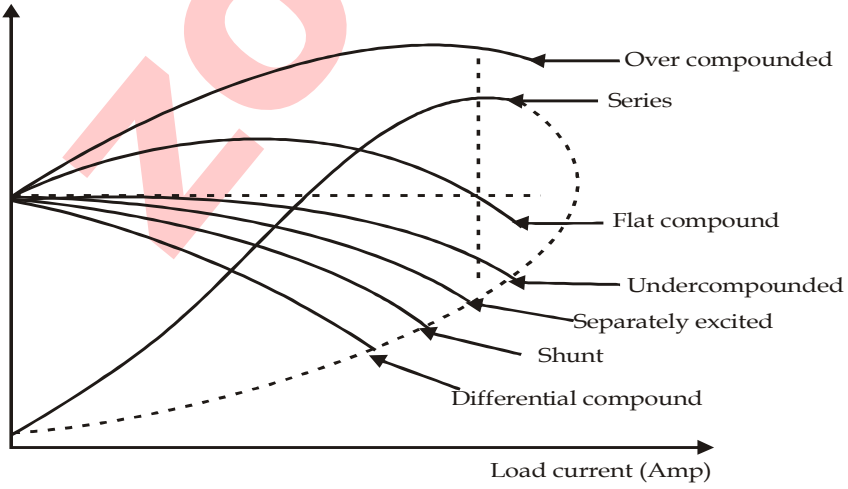
(i)Over compound generator :- If series winding turn as so adjusted that with increase in load current terminal voltage increase. It is called over-compound generator.

(ii)Flat or level compound generator :- If series winding turns are so adjusted that with increase in load current the terminal voltage remians same. it is called flat compound generator.

(iii)Under compound generator :- If series winding turns are so adjusted that with increase in load current, terminal voltage increase. it is called under-compound generator.

185.

Sol:-



External characteristic is drawn between terminal voltage with load current for constant speed and field current (or exciation)

(i) Separately excited dc generator: With te increased in load current, terminal voltage decrease slightly due to voltage drops cause by armature reaction and armature circuit resistance.

$V_t = E_g - I_aR$– Aramature reaction drop–Brush contact resistance drop

(ii) Shunt dc Generator:

The drop in terminal voltage is due to

(a) armature resistance drop I_aR_a

(b) reduction in main field flux due to armature reaction

(c) reduction in field current I_{sh}, since the terminal voltage has decreased because of the first two effectts given in part (a) and (b).

A reduction in field current (I_f) cause the flux and therefore the generated emf to decrease. Thus the terminal voltage of the generator for a given load will be lower shunt excited than when separately excited, provided no-load voltage is same in both the cases. If wed further increase the load current, after breakdown point, the terminal voltages fall back rapidly.

(iii) Series dc generator:-

It has rising voltage characteristic in the operating region upto saturation. Series flux ϕ_{se} increase with load so terminal voltage V_t will increase as emf, E_g increase but $I_a(R_a + R_{se})$ drop will also increase. As increase armature current, armature reaction also increase i.e. $I_a \uparrow$, armature reaction $\uparrow$. Beyond saturation, it has shunt characteristics which is dropping in nature.

As load increase armature current I_a increase and $I_a (R_a + R_{se})$ drop also increase

i.e. Load $I_a \uparrow$ and $I_a (R_a + R_{se})$drop $\uparrow$

At saturation flux $(\phi) \rightarrow$ constant

So, Emf E_g remains constant

$$\downarrow V_t = E_g - I_a(R_a + R_{se}) \uparrow$$

Terminal voltage V_t will decrease

(iv) Cumulatively Compound dc Generator

$$\text{Total flux} = \phi_{sh} + \phi_{se}$$

Sinc it has both flux ϕ_{sh} and ϕ_{se} so it has better characteristics than saparately excited and shunt dc generator. If the series excitastion is such that the terminal voltage (V_t) of the generator on full load is same as that of no-load, the generator is said to be level or flat compounded .

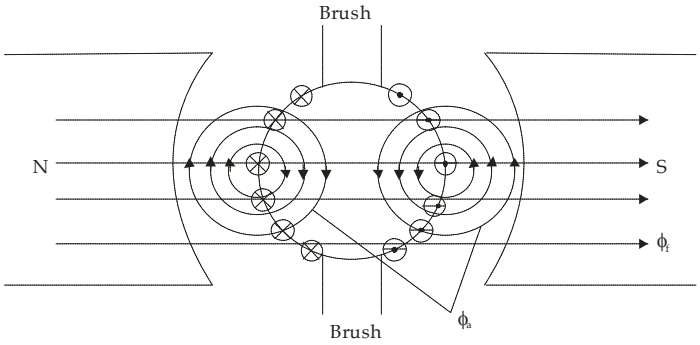
If the series excitation(I_{se}) become more prominent than that of the shunt field (I_{sh}) the terminal voltage rises with the increase in load and generator is said to be over compounded.

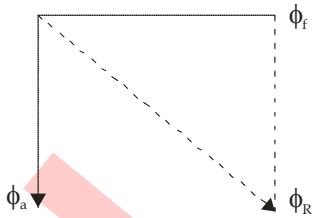
When the shunt field excitation (I_{sh}) becomes more prominent and terminal voltage is less than no-load terminal voltage, the generator is said to be under compunded.

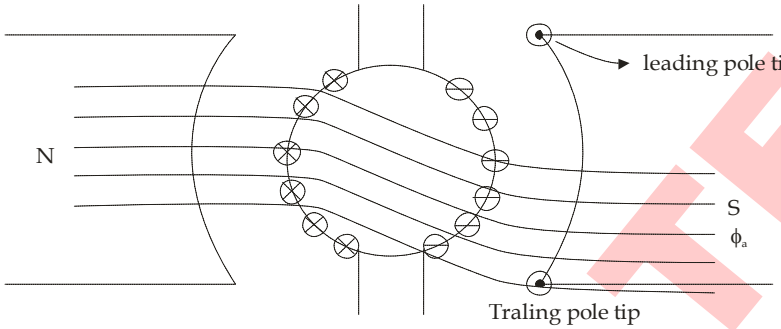
(v) Differential Compound dc Generator: In this case, with the increase in load, the series field flux opposes the shunt field flux and consequently the terminal voltage drop very rapidly.

186.

Sol. In D.C machine the main flux is due to the main poles, however when armature current flows in armature conductor, it also creates a magnetic flux called armature flux (ϕ_A), that distort or weak the flux coming out from the main poles. So this effect of armature flux on main field flux is called armature reaction.







When the armature current flow by the resultant flux distribution, it is clear that the flux density at the trailing pole tip is increases while at leading pole tip it decreases. So this unequal flux distribution across the pole produce following two effect.

(i) Main flux distortion.

(ii) Due to higher flux density at trailing pole tip it is saturated so the increases in flux at trailing pole tip is less than the decreases in flux at leading pole tip.

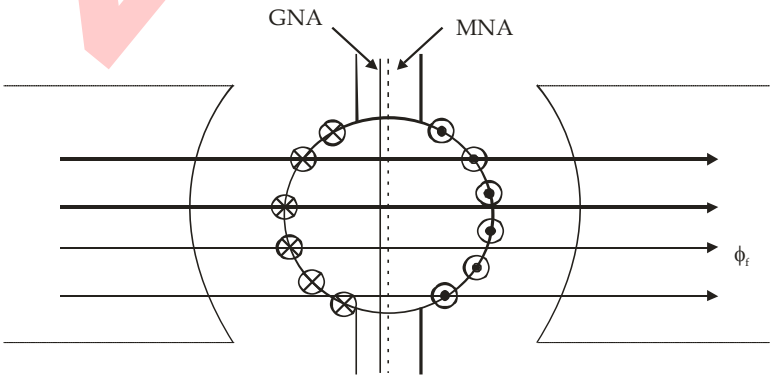
As the conductor rotate the pole tip they meet first is called leading pole tip and the another is called trailing pole tip.

→ With no current in the armature the MNA coincide with GNA.

→ When current flow in the armature conductor due to the combined action of main flux and armature flux. The MNA shifts from GNA.

In Generator, the MNA shifts in the direction of rotation and while in case of motor, the MNA shifts in opposite direction of rotation.

At No Load :-



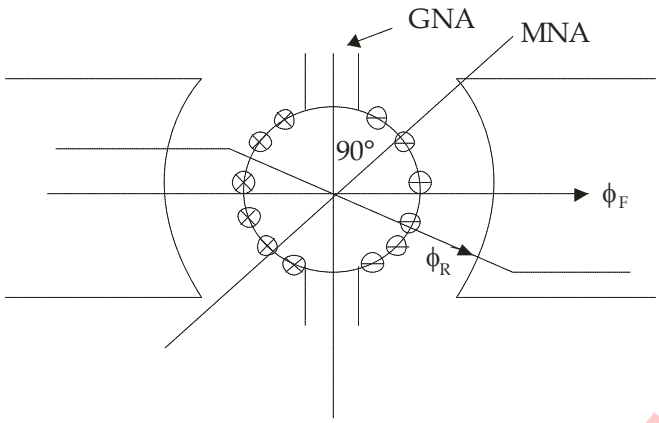
ZONE TECH

$I_a = 0, \phi_a = 0$

$\phi_R = \phi_f + \phi_a$

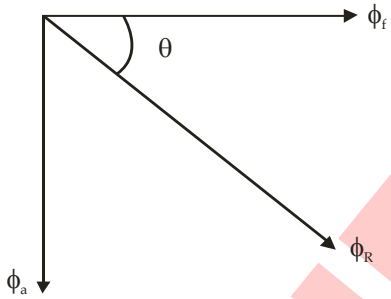
$\phi_R = \phi_f$

At loaded condition :-



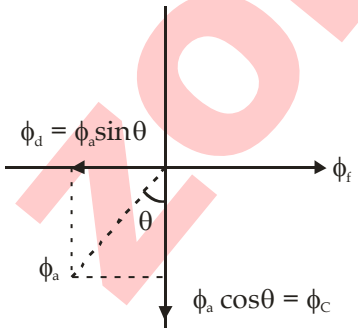
$I_a \uparrow \rightarrow \phi_a \uparrow$

$\phi_R = \phi_f + \phi_a$



(1)De - magnetizing

(2)Cross - Magnetizing



(i)De - Magnetizing Effect :- The component ϕ_d (ϕ_a sin θ) is in opposite direction to the main field flux (ϕ_f). So it De-magnetisation or weak the main field flux. So this weak the main field flux. So this effect of armature reaction is called De-magnetizing or weakes effect of armature reaction.
This effect leads to reduction in generated voltage.

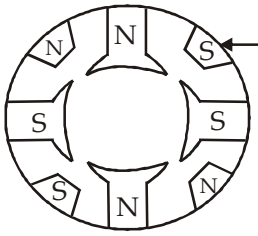
(ii)Cross - Magnetizing Effect :- The component ϕ_C (ϕ_a cos θ) is at right angle to the main field flux so it distort the main field flux. Hence this effect of armature reaction is called distorting effect or cross magnetizing effect of armature reaction.
This effect leads to sparking at the brushes and the commutator sagments.

ZONE TECH

Reduction of Armature Reaction :-

(i) Compensating winding :- In order to neutralize the cross-magnetizing effect of armature reaction compensating winding is used, it is a auxiliary winding connected in series with armature in a manner so that the direction of current through the compensating winding will be just opposite to the direction of current in armature conductor. By this the armature flux get neutralize and the armature reaction is also neutralize.The best way to achieve this compensation is by means of pole face winding embedded in the slots in the pole faces.

(ii)Interpole:-The interpole winding is bound for few turn and connected in series with the armature. So that it carry the armature current.The polarity of interpole is same as the next main pole in the direction of rotation for the generator and visa-versa for motor.



Shape of interpole :- wider base narrow interpole

The MMF of interpoles neutralize the cross- magnetizing effect (sparking) of armature reaction.

(iii) reducing armature flux by using laminated pole shoe , reluctance in the path of armature flux increased hence ϕ_a gets reduced and field flux remain same.

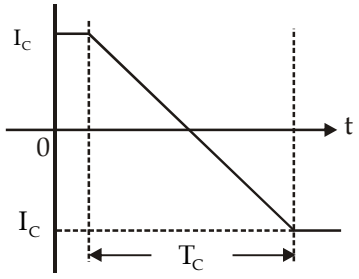
187.

Sol. Commutation :- When the armature coil passes through the brush the current in the coil will reverse, this reversal of current is called commutation.

When commutation take place the coil under-going commutation is short-circuited by the brush.

The time period during which the coil remains short-circuits is known as commutation time (T_C). If the reversal of current is completed by the end of commutation time, it is called ideal commutation under ideal condition no sparking will take place between brush and commutation segment. But if the reversal of current is not completed by that time than sparking will ocur between brush and commutator segment which results in progressive damage to brush.

The ideal commutation can not be attained due to armatures coil inductance (L_a) which opposes the reversal of current. So a EMF is induced in the coil which is called reactance voltage. This reactance voltage opposes the reversal of current in coil. This result in sparking and over-heating between the brush and commutator.



$$e = \frac{LdI}{dt}$$

$$e = L_a\left(\frac{I_C - (-I_C)}{T_C}\right)$$

I_C = armature current

T_C = commutation time

$e = L_a\left(\frac{2I_C}{T_C}\right)$ $\Rightarrow$ Reactance voltage

$T_C = \frac{\text{dist.}}{\text{speed}}$ $W_b \rightarrow$ brush width

$\downarrow T_C = \frac{W_b - W_M}{V\uparrow}$ $W_M \rightarrow$ Mica thickness $V \rightarrow$ Speed of rotor

Method Of Improving Commutation :-

Improved commutation means sparkless commutation.

(1) Resistance Commutation :- If the contact resistance between brush and commutator is made large than the current divided in the inverse ratio of contact resistance which improve commutation. This can be achieved by using carbon brushes which has high contact resistance.

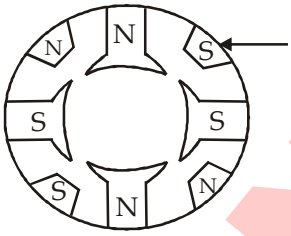
This method does not effect the reactance voltage (main cause of sparking) but it only help in improving commutaiton.

Time constant= L/R

If the resistance of coil increases then time taken in commutation decreases

(2) EMF Commutation :- In EMF commutation the reactance voltage is neutralize by producing a reversal voltage or commutating voltage in the coil undergoing commutation. This can be achieved by using interpoles or com-poles. These are the small pole fixed to the yoke and place between the main pole. The interpole winding is bound for few turn and connected in series with the armature. So that it carry the armature current.

The polarity of interpole is same as the next main pole in the direction of rotation for the generator and visa-versa for motor.



Shape of interpole :- wider base narrow interpole

The MMF of interpoles neutralize the cross- magnetizing effect (sparking) of armature reaction.

188.

Sol. Total number of turns, $N = 6 \times 500 = 3000$

Total initial flux $= 6 \times 0.02 = 0.12\,\text{Wb}$

Total residual flux $= 6 \times 0.002 = 0.012\,\text{Wb}$

Change in flux, $d\Phi = 0.12 - 0.012 = 0.108\,\text{Wb}$

Time of opening the circuit, $dt = 0.02\,\text{second}$

$\therefore$ Induced e.m.f. $= N\frac{d\Phi}{dt}\,\text{volt} = 3000 \times \frac{0.108}{0.02} = 16,200\,\text{V}$

The direction of this induced e.m.f. is the same as the initial direction of the exciting current.

189.

Sol. EMF Equation Of A DC Generator

Consider a DC generator with the following parameters,

P = number of field poles

ϕ = flux produced per pole in Wb (weber)
Z = total no. of armature conductors
A = no. of parallel paths in armature
N = rotational speed of armature in revolutions per min. (rpm)

Now,
Average emf generated per conductor is given by

$$d\phi/dt \text{ (Volts)} \quad \text{... 1}$$

Flux cut by one conductor per revolution

$$d\phi = P\phi \text{ ....(Weber),}$$

Number of revolutions per second (speed in RPS)

$$N/60$$

Therefore, time for one revolution

$$dt = 60/N \text{ (Seconds)}$$

From eq. 1, emf generated per conductor

$$d\phi/dt = P\phi N/60 \text{ (Volts)} \quad \text{.....2}$$

Above equation-2 gives the emf generated in one conductor of the generator. The conductors are connected in series per parallel path, and the emf across the generator terminals is equal to the generated emf across any parallel path.

Therefore, $E_g = P\phi NZ / 60A$

For simplex lap winding, number of parallel paths is equal to the number of poles (i.e. A=P),

For simplex wave winding, number of parallel paths is equal to 2 (i.e P=2),

Torque Equation Of A DC Motor
When armature conductors of a DC motor carry current in the presence of stator field flux, a mechanical torque is developed between the armature and the stator. Torque is given by the product of the force and the radius at which this force acts.
Torque T = F × r (N-m)
where, F = force and r = radius of the armature
Work done by this force in once revolution = Force × distance = F × 2πr (where, 2πr = circumference of the armature)
Net power developed in the armature = word done / time

$$= (\text{force} \times \text{circumference} \times \text{no. of revolutions}) / \text{time}$$
$$= (F \times 2\pi r \times N) / 60 \text{ (Joules per second)} \quad \text{..... 3}$$

But, F × r = T and
$\omega = 2\pi N/60$ = angular velocity in radians per second.
Putting these in the above equation 3
Net power developed in the armature = P = T × ω (Joules per second)

Armature Torque (T)
The power developed in the armature can be given as,

$$P = T \times \omega = T \times 2\pi N/60$$

The mechanical power developed in the armature is converted from the electrical power,
Therefore, mechanical power = electrical power
That means, $T \times 2\pi N/60 = E_b.I_a$
We know,

$$E_b = P\phi NZ / 60A$$

Therefore,

$$T \times 2\pi N/60 = (P\phi NZ / 60A) \times Ia$$

Rearranging the above equation,

$$T = (PZ / 2\pi A) \times \phi.I_a \text{ (N-m)}$$

The term (PZ / 2πA) is practically constant for a DC machine. Thus, armature torque is directly proportional to the product of the flux and the armature current i.e.

$$T = K \phi . Ia$$

Shaft Torque (T_{sh})

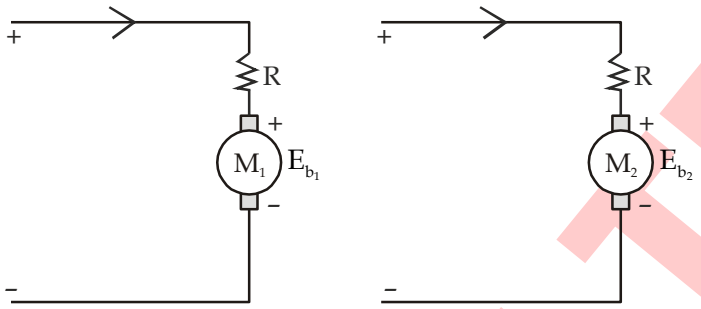
Due to iron and friction losses in a dc machine, the total developed armature torque is not available at the shaft of the machine. Some torque is lost, and therefore, shaft torque is always less than the armature torque.

Shaft torque of a DC motor is given as,

T_{sh} = output in watts / (2πN/60) ....(where, N is speed in RPM)

190.

Sol:



$$V = 500 \text{ V}, I_a = 50 \text{ A}, R = 0.36\ \Omega$$

$$E_{b_1} = E_{b_2} = V - R_a I_a$$

$$= 500 - (0.36)(50) = 482 \text{ V}$$

$$N_{m_1} = 700 \text{ rpm}$$

$$N_{m_2} = 750 \text{ rpm}$$

$\because$ $E_{b_1} = K\phi_1 N_{m_1}$

and $E_{b_2} = K\phi_2 N_{m_2}$

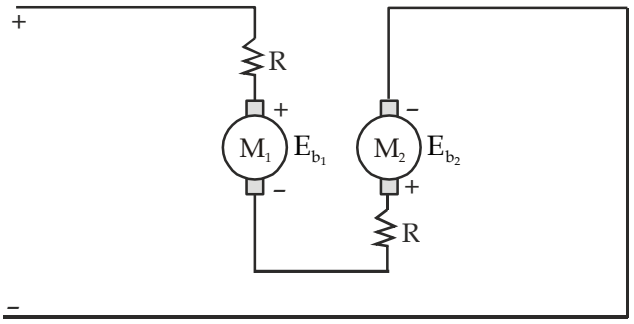
$\because$ $E_{b_1} = E_{b_2}$

then $$\frac{\phi_1}{\phi_2} = \frac{N_{m_2}}{N_{m_1}}$$

or $$\frac{\phi_1}{\phi_2} = \frac{750}{700} = \frac{15}{14}$$ .....(i)

When two motors are connected in series and mechanically coupled.

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$$E_{b_1} + E_{b_2} = 500 - 50\,(0.72)$$

$$E_{b_1} + E_{b_2} = 464 \text{ V} \qquad \text{.....(ii)}$$

Since, $N_{m_1} = N_{m_2} = N_m$ (For mechanical copupled motors)

then, $\dfrac{E_{b_2}}{E_{b_1}} = \dfrac{\phi_2}{\phi_1} = \dfrac{14}{15}$ [From equation (i)]

or $E_{b_2} = \dfrac{14}{15} E_{b_1}$

From equ. (ii) $E_{b_1} + \dfrac{14}{15} E_{b_1} = 464$

$\Rightarrow$ $E_{b_1} = 240$ V

$\Rightarrow$ $E_{b_2} = 224$ V

Comparing with data of seprate operation for machine (i),

$$E_{b_1} = K\phi N_{m_1}$$

or, $\dfrac{E'_{b_1}}{E''_{b_1}} = \dfrac{N'_{m_1}}{N''_{m_1}}$

$$\frac{240}{482} = \frac{N}{700}$$

$$N = 348.55 \text{ rpm}$$

Similar result can be obtained from machine 2.

if, $E'_{a_2} = 224$

or, $\dfrac{224}{482} = \dfrac{N}{750} = 348.55 rpm$

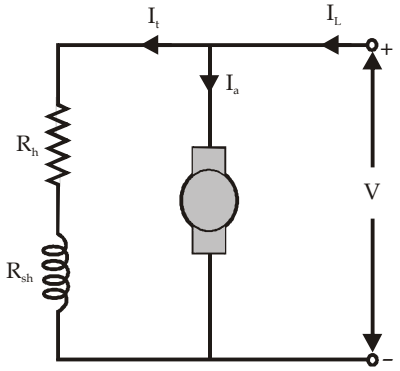
191.

Sol.: Various method of speed control of dc shunt motors are:

1. Field control method
2. Armature control method

1. **Field control Method:** In this method, weakening of field causes increase in the speed of a motor, and strengthening of field reduces the speed.

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(a) Field theostat control involving the variation of flux by means of a field rheostat. In this arrangement external resistance is inserted in series with the field winding and by increasing it from zero to maximum value, the field current and flux will reduce to increase speed of motor.
(b) Reluctance control involving the variation of reluctance of the magnetic circuit of the motor
(c) Field voltage control involving the variation of applied voltage to the field circuit which is separate from the main power supply to which the armature is connected.
* Field control method is used to control speed from base (or rated) speed to above the base speed
* In this method requires a four point starter.
* Also called as various torque constant power speed control method for a given load current.

2. Armature Control Method: In this method, speed variation of shunt motors by armature control requires that applied voltage to the armature terminals shall be changed, without altering the field current.
* This method is used to vary speed from rated speed to below.
* It is also called as various power constant torque speed control for a given load.

(a) Armature resistance control involving the varitaion of voltage applied to the armature terminal by mean of a variable resistance connected in series with armature as shown in figure.(a)
(b) Shunted armature control inolving the variations of applied voltage to the armature terminals by means of a combination of a variable resistance shunting the armature and variable resistance in series with the shunted armature as shown in figure(b)
(c) Armature terminal voltage control involving variation of voltage impressed upon the armature circuit.

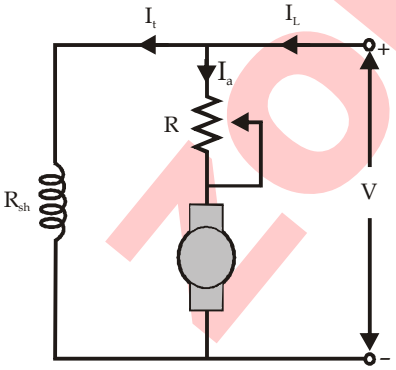


Fig. (a)

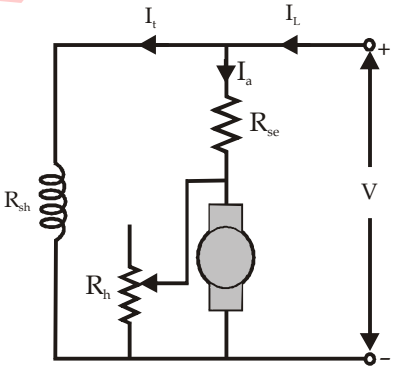
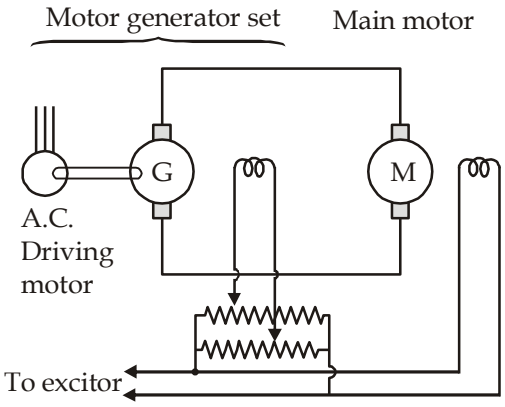


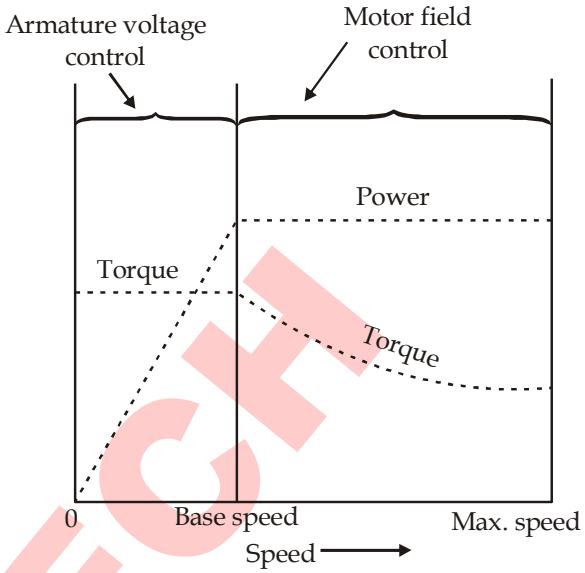
Fig. (b)

192.

Sol. **Ward-Leonard System:-** In this system M is the main d.c. motor whose speed is to be controlled and G is the separately excited d.c. generator driven by a three-phase driving motor (usually an induction motor). Motor speed control is obtained merely by changing the generator field current.
- In order to achieve wider speed control range speeds below base speed are obtained by armature voltage control and above base speed, by field flux control. For better utility of motor M, its armature

current I_a is maintained equal to its rated current during its speed control.





- Below base speed, constant torque drive, armature voltage control is applicable for suitable controlling and above base speed, constant power drive, motor field flux control is applicable for suitable controlling. When both types of speed controls are employed, the overall speed range is 40 : 1.

Advantage:

- The advantages of ward-leonard system of speed control are as follows:
  (i) Its simplicity, wide range and smooth speed control.
  (ii) Speed regulation is quite good.
- Control operations is not costly becasue its field circuits are low-power circuits.
- Efficiency at low speeds is higher.

Disadvantage:

- Higher initial cost, because three machines having rating equal to the full load output are required.

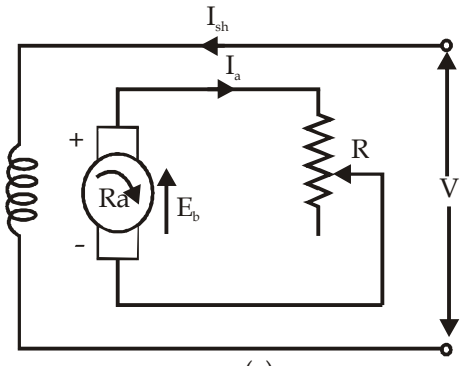
193.

Sol.:

Electrical Braking: There are three kinds of electrical braking
(i)Rheostatic or dynamic braking
(ii) Plugging and
(iii)Regenerative braking

(i)Rheostatic or Dynamic Braking (Shunt Motor): Figure (a) shows the rheostatic braking in which armature of the shunt motor is disconnected form the supply it is connected across a variable resistance R. The field winding is kept undisturbed and this braking is controlled by varying the series resisrtance R. This method uses the generator action in a motor to bring it to rest.

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(a)

Rheostatic Braking (Series Motor):

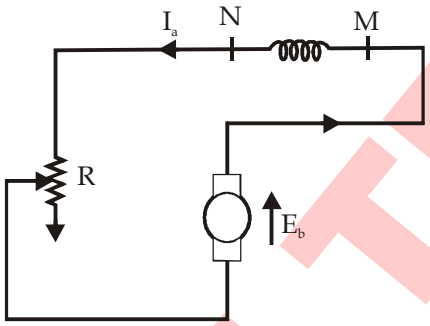


Figure shows the rhesotatic braking of DC series motor. In this method the motor is disconnected from supply. The fieldconnection is reversed and the motor is connected through a variable resistance R.

(ii) Plugging or Reverse Braking (Shunt Motor) :

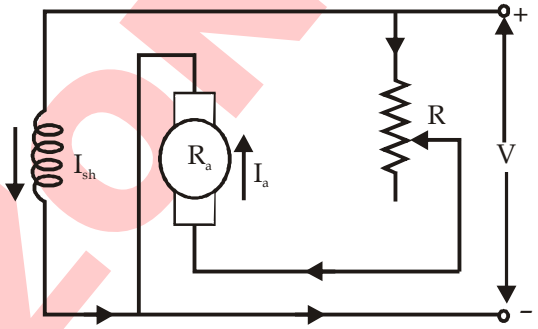
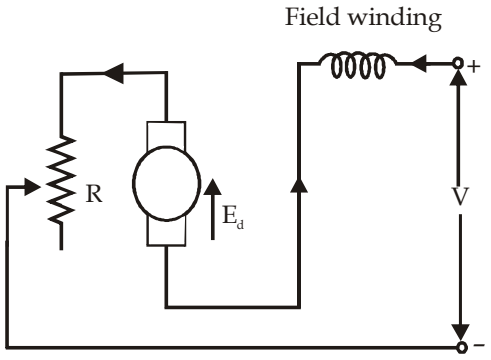


Figure shows plugging or reverse. In this method, the aramature terminals are reversed to rotate the motor in reverse direction and the applied voltage V and the back emf E_b start acting in the same direction. To limit the armature current a resistance is inserted in series with the armature during reversing the armature.

The kinetic energy of the system is dissipated in the armature and braking resistance .

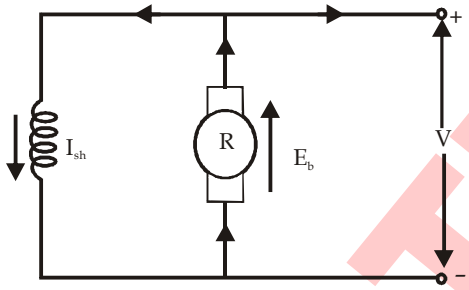
Plugging or Reverse Current Braking (Series Motor):

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It is similar to that of shunt motor

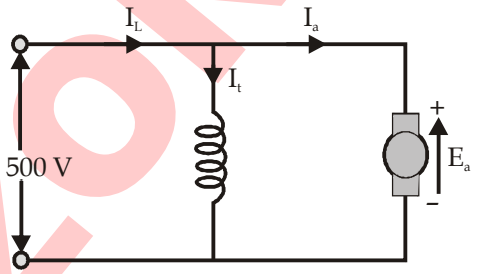
(iii)Regenerative Braking (Shunt Motor):



In regenerative braking, E_b is greater than V. Figure shows regenerative braking. The direction of I_a and the armature torque T_B are reversed. Most of the braking energy is returned to the supply. Regenerative braking is used for downgrade motion of an electric train. The kinetic energy of the system is dissipated in the armature and braking resistance.

194.

Sol.:



Given, 500V; 25 HP; r_j = 650 Ω ; r_a = 0.57 Ω

$$I_f = \frac{500}{650} = 0.77 \text{ amp}$$

At no load $I_{a0} = I_{L0} - I_t$

$= 2.4 - 0.77 = 1.63$ amp

Constant losses $= V_t . I_{L0} - I_{a0}^2 \times r_a - V_b . I_{a0}$

$= 500 \times 2.4 - (1.63)^2 \times 0.57 - 2 \times 1.63$

$= 1195.23$ Watt

Now at full-load, $E_b I_a = 25 \times 746$ (power output)

Power input = Power output + total losses

$$500(I_a + 0.77) = 25 \times 746 + V_b I_a + \text{constant losses} + I_a^2(0.57)$$

$$385 + 498\, I_a = 19845.23 + I_a^2(0.57)$$

or $$I_a^2 - 873\, I_a + 3410.75 = 0$$

$$I_a = \frac{873 \pm \sqrt{(873)^2 - 4 \times 34140.75}}{2}$$

$I_a = 831.96$A; 41.04 A

take I_a = 41.04 A

Input $= V_t\,(I_a + I_f) = 500\,(41.04 + 0.77) = 20905$ Watt

$$\text{Efficiency} = \frac{Output}{Input} \times 100 = \frac{25 \times 746}{20905} \times 100 = 89.21\%$$

195.

sol.

$V = E_1 + I_{a_1} R_a$

Given $V = 500$ V

$N = 750$ rpm

$I_a = 100$ A

$R_a = 0.5\,\Omega$

$\phi_1 = 100$ wb

$500 = E_1 + 100 \times 0.5$

$E_1 = 450$ V

Given Load torque constant

$$\phi_1 I_{a_1} = \phi_2 I_{a_2}$$

$$\phi_2 = \frac{\phi_1}{2}$$

$$\phi_1 .100 = I_{a_2} \times \frac{\phi_1}{2}$$

$I_{a_2} = 200$ A

$V = E_2 + I_{a_2} R_a$

$500 = E_2 + 200 \times 0.5$

$E_2 = 400$V

$$\frac{E_1}{E_2} = \frac{\phi_1 N_1}{\phi_2 N_2}$$

$$\frac{450}{400} = \frac{\phi_1 \times 750}{\frac{50\phi_1}{100} \times N_2}$$

$$\frac{45}{40} = \frac{750 \times 100}{50\, N_2}$$

$N_2 = 1333.3$ rpm

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196.

sol.

Given that torque

$T =$ constant

$T \propto I_a^2$

$I_{a1}^2 = I_{a2}^2 \Rightarrow I_{a1} = I_{a2} = 40A$

$E_{b1} = V - I_{a1} R_a$

$= 240 - 40 \times 0.3$

$E_{b1} = 228$ V

$\therefore E_b = K\phi \omega_m \quad \phi \propto I_a$

$E_b \propto I_a \omega_m$

$E_b \propto \omega_m \quad [I_{a1} = I_{a2}]$

$$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$$

$$E_{b2} = \frac{1000}{1500} \times 228$$

$E_{b2} = 152$ V

Now $E_{b2} = 240 - 40(0.3 + R_{ext}) = 152$

$R_{ext} = 1.9\ \Omega$

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