Conventional Practice Book

RPSC-AEn

Rajasthan Public Service Commission-Assistant Engineer

Mains Examination

ELECTRICAL MECHANICES

HIGHLIGHTS

- As per RPSC-AEn Mains Syllabus.
- Coverage of **2 Marks, 5 Marks and 20 Marks** Questions with Explanations.
- Previous Year Questions with Detailed Solutions.

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2 MARKS QUESTIONS

1. A DC machine induces an e.m.f. of 240 V at 1500 rpm. Find the developed torque for an armature current of 25 A.

Solution :

Given data, E= 240 V, N = 1500 rpm, I_a = 25 A, T = ?

$\therefore$ Power developed P $= EI_a = \omega T$

Where, ω = speed of rotor (rad./sec.)

T = torque (N-m)

I_a = armature current

E = back e.m.f.

$$T = \frac{EI_a}{\omega} \quad ; \quad \therefore \omega = \frac{2\pi N}{60}$$

$$T = \frac{EI_a \times 60}{2\pi N} = \frac{240 \times 25}{2\pi \times 1500} \times 60 = 38.22 \text{ N-m}$$

So the required answer is torque developed T = 38.22 N-m

2. A 3300/300 V single phase transformer gives 0.6 A and 60 W as ammeter and wattmeter readings when supply is given to the low voltage winding and high voltage winding is kept open. What is the power factor of no load current?

Solution :

This is a open circuit test so the wattmeter will give the reading of core loss

P_{OC} = 60 watt, I_0 = No load current = 0.6 A

$P_{OC} = V_{OC} I_0 \cos \phi_0$

Where, ϕ_0 = no-load power factor

As we know that the no load test is carried out on LV side hence value of V_{OC} = 300 V.

$$\cos \phi_0 = \frac{P_{OC}}{V_{OC} I_0} = \frac{60}{300 \times 0.6} = 0.333 \text{ (lag)}$$

So the required answer is cos ϕ_0 = 0.333 (lag)

3. What are the necessary conditions to operate two alternators in parallel to supply a common load?

Solution :

Necessary condition to operate two alternators in parallel to supply a common load.

(i) The terminal voltage of incoming alternator must be same as that of the existing system otherwise circulating current flows between the two systems. The terminal voltage can be adjusted with the field excitation.

(ii) The frequency of incoming alternator must be same or little higher than that of the existing system.

(iii) The phase sequence of incoming alternator must be same as that of the existing system otherwise large circulating currents exists because the voltage across the two system is equal to $\sqrt{3}$ times of their rated voltage.

(iv) Phase of voltage of incoming alternator must be same with phase of bus bar voltage w.r.t. external circuit.

4. Compare a bank of three single phase transformers with a single 3-ϕ unit for use in a power system.

Solution :

3 single phase transformers	Single 3-phase transformer
Costly, Larger, bulk installation space	Cheaper, smaller size and smaller installation space
Lower overall efficiency	Higher overall efficiency
In case of failure of one unit then this connection can operate in open delta connection	In case of failure of any unit transformer has to be changed. Open delta connection can't possible.

14. What precautions are taken during starting of DC shunt motors and why?

***Solution* :**

It is necessary to ensure before starting a DC motor, that the field circuit is closed, the rheostat in series with the shunt field winding is at zero resistance position and starting resistance in series with the armature circuit is at maximum value. It will restrict armature current to a safer value and develop higher torque at the starting instant.

15. A DC shunt motor is connected to a 3-point starter. What would happen if

(i) The starter handle is moved rapidly from 'off' to 'on' position

(ii) The field circuit becomes open circuited with the motor running at no load

***Solution* :**

(i) When the starter handle is moved rapidly from 'off' to 'on' position, the resistance connected in series with the armature is being cut at a faster rate and the speed of the motor is increased at a slow rate and because of the rates being different, the armature current will increase to a larger value and the ratio of upper and lower values of currents will no more remain constant.

(ii) With the opening of field circuit with motor running at no load, the field current will become zero. So flux will be negligibly small, that is due to residual magnetism motor speed will suddenly boost up and continue to increase if the supply is not cut off.

16. What are the requirements of good electric braking?

***Solution* :**

The requirements of good electric braking are:

(i) The braking should be quick and reliable in action.

(ii) The braking must be controllable.

(iii) Some suitable means must be provided for dissipation of kinetic energy of the moving parts of the motor and its driven machines.

(iv) Failure of any part of the braking system must result in application of brakes.

17. Why DC series motor is not suitable for belt driven loads?

***Solution* :**

Because the mishap to the belt would cause the DC motor to run on no load and on no load the series motor will attain dangerously high speed and the motor may get damaged due to heavy centrifugal forces set up in the rotating parts.

18. Why series motor is preferred for traction purposes?

***Solution* :**

DC series motor develops large starting torque and slows down with the increase in load and gets automatically relieved from heavy excessive load.

19. A DC shunt generator is developing rated terminal voltage at some speed. For this generator, answer the following and give a brief explanation in support of your answers:

(i) If only the direction of rotation is reversed, will the generator build up?

(ii) If the direction of rotation and also the residual magnetism are reversed, will the generator build up?

***Solution* :**

(i) The generator will not build up. With the direction of rotation reversed, the polarity of the generated emf will be reversed. The direction of field current will also reverse and hence the residual magnetism present in the poles will be wiped off and the generator will fail to build up.

(ii) When the direction of rotation and the residual magnetism both are reversed, then the small emf produced initially will strengthen the field further and hence the generator will build up voltage.

55. What is linear commutation?

Solution :

56. Elaborate on the statement "induction motor does not develop torque at synchronous speed, so it runs at subsynchronous speed".

Solution :

57. Why are starters used for starting of 3-ϕ induction motors?

Solution :

58. List out the methods of speed control of cage type 3-ϕ induction motors are :

Solution **:**

59. What is the advantage of using a capacitor-start motor over a resistance-start split-phase motor?

Solution **:**

60. Why the rating of transformer is express in kVA rather than in kW?

Solution **:**

61. Why DC series motor is never started on no load?

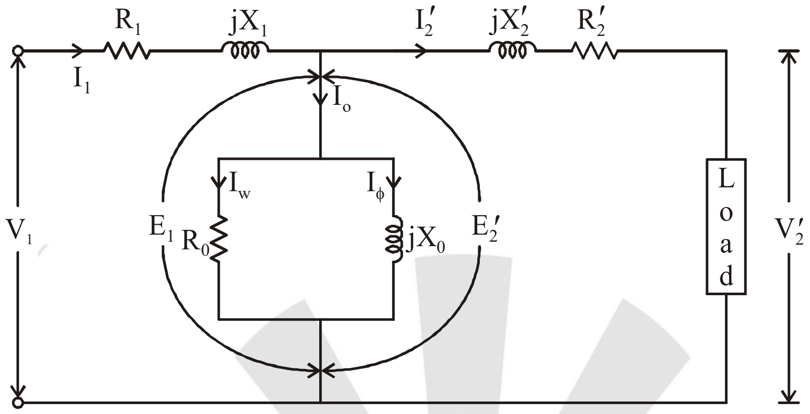
Solution **:**

5 MARKS QUESTIONS

67. Give the equivalent circuit of a transformer and define its various parameters.

Solution :

Equivalent circuit of a transformer :



R_1 = Primary resistance

X_1 = Primary leakage reactance

R_2 = Secondary winding resistance

X_2 = Secondary leakage resistance

R_0 = Core loss resistance

X_0 = Magnetizing reactance

V_1 = primary voltage

V_2' = Secondary terminal voltage referred to primary

I_1 = Primary current

I_2' = Secondary load current referred to primary

E_1 = Induced emf in primary winding

E_2' = Induced emf in secondary winding referred to primary

R_2' = Secondary resistance referred to primary

X_2' = Secondary leakage reactance referred to primary

I_0 = Exciting current

I_w = Core loss component of exciting current

I_ϕ = Magnetizing component of exciting current

68. A 11000/400 V, distribution transformer takes a no load primary current of 1 A at a power factor of 0.24 lagging. Find

(i) core loss current and magnetizing current

(ii) core loss in the transformer.

Solution :

Given data, $\frac{V_1}{V_2} = \frac{11000}{400}$

No load primary current $I_0 = 1A$

$\cos\phi_0 = 0.24$ lagging

(i) Core loss current $= I_0 \cos \phi_0$

$= 1 \times 0.24 = 0.24$ A

Magnetising current $= I_0 \sin \phi_0$

$$= I_0\sqrt{1-\cos^2\phi_0}$$

$$= 1\sqrt{1-(0.24)^2} = 0.97 \text{ A}$$

(ii) At no-load the transformer loss is core loss.

$\therefore$ core loss $= \sqrt{3}V_L I_L \cos\phi_0$ $[I_L = I_0]$

$$= \sqrt{3}V_L I_0 \cos\phi_0$$

$$= \sqrt{3} \times 11000 \times 1 \times 0.24$$

Core loss $= 4.5726$ kW

So the required answers are (i) $I_c = 0.24$ A and $I_\mu = 0.97$ A, (ii) Core loss = 166.27 W

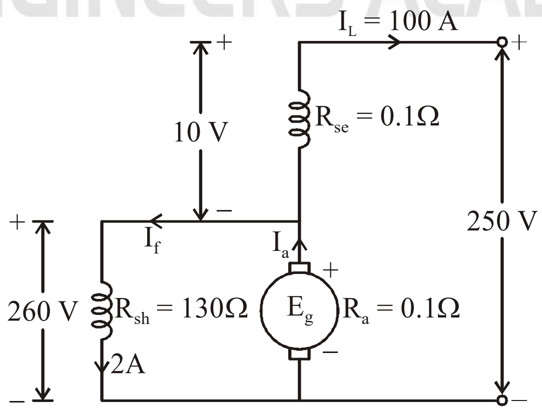
69. A short shunt compound dc generator delivers 100 A to a load at 250 V. The generator has shunt field series field and armature resistance of 130 Ω, 0.1 Ω and 0.1 Ω respectively. Calculate the voltage generated in armature winding. Assume 1V drop per brush.

Solution :

Given data, $I_L = 100$ A, $V_t = 250$ V, $R_{sh} = 130\ \Omega$

$R_{se} = 0.1\ \Omega$, $R_a = 0.1\ \Omega$, Brush voltage drop = 1V (each brush)

Short shunt DC generator



Series field drop $= 100 \times 0.1$

$= 10$ V

Voltage across armature $= 250 + 10 = 260$ V

Field current, $I_f = \frac{260}{130} = 2$ A

Armature current, $I_a = I_L + I_f$

$I_a = 100 + 2 = 102$ A

Armature voltage drop $= I_a R_a$

$= 102 \times 0.1 = 10.2$ V

Generated voltage= Voltage across armature + armature voltage drop + brush drop

$= 260 + 10.2 + 2$

$= 272.2$ V

So the required answer is $E_g = 272.2$ V.

70. What are the factors that control the speed of a DC motor ?

Solution :

Various factor that control the speed of DC motor.

In DC motor

$$E_b = K\phi\omega \quad \text{...(1)}$$

$$E_b = V - I_a R_a \quad \text{...(2)}$$

Speed of the DC motor

$$\omega = \frac{V - I_a R_a}{K\phi}, N \propto \frac{E_b}{\phi} \quad \text{...(3)}$$

The speed of a dc motor mainly depends on flux, armature resistance and supply voltage.

Therefore by these three, the speed of motor can be controlled and varied :

(1) Speed control by varying the field flux : From the above equation, if field flux is reduced then speed will increase.

In DC shunt motor, it is done by adding an external resistance (Rheostat) in series with the field winding and by increasing field circuit resistance, the field current and field flux are reduced. In case of series motor, it is done by connecting external variable resistance in parallel with field winding.

$$N \uparrow \propto \frac{E_b}{\phi \downarrow}$$

(2) Speed control by varying armature resistance : On increasing armature resistance (R_a), back emf reduces. As back emf is proportional to the speed so speed will also reduce.

$\because$ $E_b = V - I_a R_a$ and $E_b \propto \phi\ \omega$

As $R_a \uparrow$, $I_a R_a \uparrow$, $E_b \downarrow$, $\omega \downarrow$

(3) Speed control by Varying supply voltage : If armature terminal voltage V is varied, counter emf ($V_t - I_a R_a$) changes almost proportionally and for a constant flux motor (eg. DC shunt motor) the speed changes approximately in the same proportion as V.

83. Write critical notes on classification of magnetic materials depending on their behaviour and applications.

Solution **:**

These are following magnetic material :

A. Paramagnetic materials :

The materials which are not strongly attracted by a magnet such as aluminium, tin, platinum. Their relative permeability is small but positive.

In paramagnetic materials the individual atomic dipoles are oriented in a random fashion.

□ $\leftarrow$ □ □ $\rightarrow$ □

The resultant magnetic field is therefore is Negligible. When an external magnetic field is applied the permanent magnetic dipoles orient themselves parallel to the applied magnetic field and give rise to a positive magnetization.

B. Diamagnetic materials :

The materials which are repelled by a magnet such as zinc, mercury, lead, sulphur, copper, silver. They are slightly magnetized when placed in a strong magnetic field and act in the direction opposite to that of applied magnetic field.

C. Ferromagnetic materials :

The materials which are strongly attracted by a magnet such as iron, steel, Nickel, cobalt. Their-permeability is very high. Ferromagnetic materials are of two types. Those easily magnetized called soft magnetic material. Those retaining their magnetism with great tenacity, known as hard magnetic material.

D. Ferrites :

These occupy an intermediate position between ferromagnetic and non magnetic materials. They consist of extremely fine particles of a ferro-magnetic material possessing high-permeability.

84. Describe how the primary current adjust it self as the load on a transformer is increased with suitable phasor diagram.

Solution **:**

As the load on the transformer is increased the secondary current increases. Its Demagnetizing load tends ampere turns to reduce core flux and so the primary induced emf E_1. As per KVL round the source primary loop, the primary current increases to balance out the demagnetizing ATs. Load is thus reflected on the primary via the core. This current is over and above the magnetizing current, which being small enough and also 90° lagging can be ignored. Thus

$$N_1 I_1 = I_2 N_2$$

85. Briefly explain the concept of an ideal transformer stating the assumption made?

Solution **:**

An ideal transformer is based on the following assumption and their consequences:

(i) The core has infinite permeability i.e. it has zero reluctance.

(ii) There is no core loss.

(iii) As a result an ideal transformer does not draw any magnetizing current to establish core flux.

(iv) No flux can leak through such a core i.e. all the core flux links primary and secondary windings. As a consequence primary and secondary leakage reactances are zero.

(v) Primary secondary winding resistance are zero. As a consequence there is no copper loss.

For an ideal transformer

$$\frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

96. A synchronous motor is connected to an infinite bus and supplying constant torque and operates at unity power factor. If the field current is increased, explain what happens to the following:

(a) The magnitude of resultant flux wave.

(b) The magnitude of armature current and its power factor.

(c) Rotor current away from resultant mmf wave or towards it.

(d) Space angle between armature mmf and resultant air-gap mmf.

***Solution* :**

(a) The motor will become overexcited, the field mmf will increase but increase in field mmf will be neutralised by the increase in counter armature mmf and the magnitude of result flux wave will remain almost constant.

(b) The armature current will increase and power factor will drop.

(c) Rotor current will move towards the resultant mmf because the resultant flux wave will move towards the leading power factor side causing reduction in angle between rotor current and mmf wave.

(d) Space angle between armature mmf and resultant air gap mmf will also decrease because resultant flux wave will move towards the air-gap mmf.

97. An alternator supplying 500 kW at 0.7 power factor lagging has its power factor raised to unity by means of an overexcited synchronous motor at a constant armature current. How much input power is required for the synchronous motor? Find the power factor of the synchronous motor.

***Solution* :**

Load, P = 500 kW

$$\text{Load kVA, } S = \frac{P}{\cos\phi} = \frac{500}{0.7} = 714.3 \text{ kVA}$$

Power factor angle, $\phi = \cos^{-1}(0.7) = 45.57°$

Load kVAR $= S \times \sin\phi$

$= 714.3 \sin 45.57° = 714.3 \times 0.714 = 510$ kVAR

Thus a synchronous motor when connected to improve power factor under overexcited condition will operate as a synchronous condenser. The power required to be supplied by synchronous condenser, therefore, is 510 kVAR and the power factor of the synchronous motor will be zero (leading).

98. Explain the working principle and applications of brushless DC Motors

***Solution* :**

Brushless DC Motor Construction :

Just like any other motor, a BLDC motor also has a stator and a rotor. Permanent magnets are mounted on the rotor of a BLDC motor and stator is wound with specific number of poles, this is the basic constructional difference between a brushless motor and a typical DC motor. These are two types of BLDC motor on the basis of construction.

(i) Inner rotor Design

(ii) Outer rotor Design

Working principle :

Stator winding of a BLDC motor are connected to a control circuit (an integrated switch circuit). The control circuit energized proper winding at proper time in a pattern which rotates around the stator. The rotor magnet tries to align with the energized. Thus the rotor keeps running commutator helps in achieving unidirectional torque in a typical DC motor obviously commutator and brush arrangement is eliminated in a brushless DC motor and an integrated inverter switching circuit is used to achieve unidirectional torque. That is why these motors are sometimes also referred as electronically commuted motor.

Application :

(i) Used in small cooling fan, used in cordless power tools where the increased efficiency of the motor leads to longer periods.

(ii) Low speed, low power brushless motors are used in direct drive tunable for gramophone records.

118. Explain the working principle of three phase synchronous motor.

Solution **:**

119. Explain why a three-phase induction motor is self-starting and a single-phase induction motor is not.

Solution **:**

120. A 230V dc shunt motor takes 5A at no load and runs at 1000 rpm,. Calculate the speed when loaded an taking a current of 30A. The armature and field resistances are 0.2 Ω and 230 Ω Respectively.

Solution :

123. A 4-pole induction motor (main) & a 6 pole motor (auxiliary) are connected in cummulative cascade. Frequency in the secondary winding of the auxiliary motor is observes to be 1 Hz. For a supply frequency of 50 Hz the speed of the cascade set is

Solution :

124. **What is Hunting in Synchronous Machines and what are its effects? How is it reduced in salient pole Synchronous Generators?**

Solution :

125. Explain with the help of motor sketch diagram, how rotating magnetic field is produced in a single phase shaded pole motor.

***Solution* :**

126. Prove that the armature torque of a DC motor is given by

$$T = \frac{PZ}{2\pi A}\phi I_a$$

Where T, P, Z, A, ϕ, I_a have their usual meaning

***Solution* :**

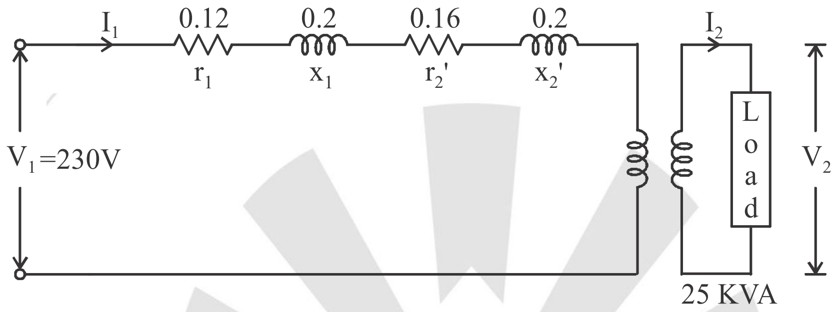
20 MARKS QUESTIONS

138. A 25 kVA, 230/115V, 50Hz transformer has the following data :

r_1 = 0.12Ω, r_2 = 0.04Ω, X_1 = 0.2Ω, X_2 = 0.05Ω

Find the transformer loading which will make the primary induced e.m.f. equal in magnitude to the primary terminal voltage when the transformer is carrying full load current. Neglect the magnetizing current.

Solution :



$V_1I_1 = V_2I_2 = 25000$

$$K = \frac{V_{H.V.}}{V_{L.V.}} = \frac{230}{115} = 2$$

Equivalent resistance referred to primary (hv) side,

$R_{01} = R_1 + R_2 \times K^2$

$= 0.12 + 0.04 \times 2^2 = 0.28\ \Omega$

Equivalent reactance referred to primary (hv) side,

$X_{01} = X_1 + X_2 \times K^2$

$= 0.2 + 0.05 \times 2^2 = 0.4\ \Omega$

Primary induced emf will be equal to primary terminal voltage i.e. voltage regulation is zero.

When, $I_1R_{o1}\cos\phi + I_1X_{o1}\sin\phi = 0$

or $\tan\phi = -\dfrac{R_{o1}}{X_{o1}} = -\dfrac{0.28}{0.4} = -0.7$

or $\phi = \tan^{-1}0.7 = 35^o$(lead)[$\because$ tan ϕ is negative]

And power factor $\cos\phi = \cos 35^o = 0.82$ (leading)

Load in kW on full load

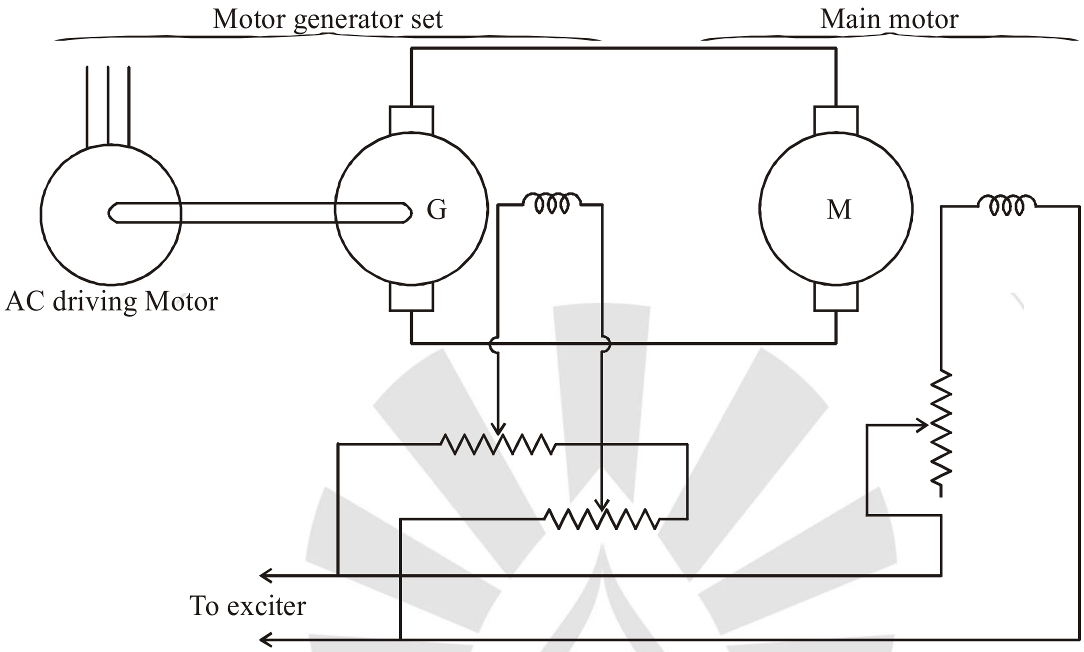
kVA × pf = 25 × 0.82 = 20.5 kW

So the required answer is transformer loading = 20.5 kW.

139. Explain in detail about the Ward-Leonard system of speed control of DC motors.

Solution :

Word-Leonard system : This system is used where an usually wide (upto 10:1) and very sensitive speed control is required.



M is the separately excited DC motor whose speed is to be controlled and G is separately excited DC generator driven by motor (usually an 3-ϕ induction motor). The combination of AC driving motor and the DC generator is called motor generator set and it converts AC power into DC, which is fed to the main motor M. If no supply is available, the three phase motor can be replaced by some prime mover.

Working :

- For starting motor M, its field circuit is first energized and then the generator output voltage is adjusted to a low value by decreasing its field excitation. This is done in order to limit the starting current to a safe value.

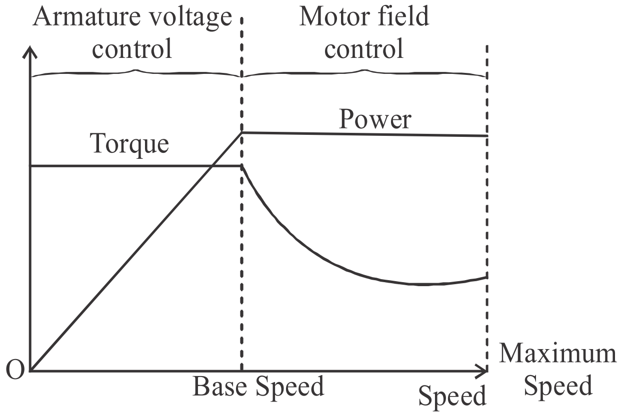
- A change in the generator field current varies the voltage applied to the motor armature, the motor speed is changed. Thus the motor speed control is obtained merely by changing the generator field current.

- In order to achieve higher speed control range, speeds below base speed are obtained by voltage control and above base speed, by flux control. For better utility of motor M, its current I_a is maintained equal its rated current during its speed control.

- Speeds from the lowest possible speed up to base speed, are obtained by increasing the generator output voltage, with constant motor field flux. Since the speed control is carried out with rated current I_a and with constant motor field flux ϕ, a constant torque ($\propto \phi I_a$) up to base speed is obtained. Power (= torque × speed) increases in proportion to speed. Thus constant torque and variable power drive is obtained upto base speed.

- Speeds above base speed are obtained by decreasing the motor field flux with constant generator voltage. As before the armature current I_a is kept equal to its rated value. Under these conditions V_tI_a or E_aI_a remains constant and the electromagnetic torque proportional to ϕI_a decreases as the field flux is decreased.

Thus weakening of the motor field flux results in constant power and variable torque drive above base speed.



Advantages :

(i) The main advantage of this system is its simplicity, wide range and smooth speed control.

(ii) Speed regulation is quite good.

(iii) The direction of main motor rotation can be changed merely by reversing generator field current.

Disadvantage :

(i) Higher initial cost because three machines having rating equal to the full load output.

140. A DC shunt motor is operated from 300 V mains. Its no-load speed is 1200 r.p.m. When fully loaded its speed drops to 1100 r.p.m. while it delivers a torque of 400 N-m. Find its speed and power when operated with an armature voltage of 600 V, when delivering the same torque. Excitation is assumed unchanged, i.e, the motor field is still excited at 300 V. State any assumption you are required to make.

Solution :

Given data,

Operating voltage = 300 V

No-load speed = 1200 r.p.m

Full load speed = 1100 r.p.m

Full load torque = 400 N-m

For DC shunt motor

$E_b = K\phi N$ (ϕ–constant for shunt motor)

At No load $(E_b)_{NL} = 300 = K\phi \times 1200$ ...(1)

At Full load $(E_b)_{FL} = K\phi \times 1100$

$\Rightarrow V_t - I_aR_a = K\phi \times 1100$ ...(2)

Equation (1) ÷ (2)

$$\Rightarrow \frac{300}{V_t - I_aR_a} = \frac{1200}{1100}$$

$$\frac{300}{300 - I_aR_a} = \frac{12}{11}$$

$\Rightarrow I_aR_a = 25$ Volt (at full load)

$\therefore T = K\phi I_a$ ...(3)

and $E_b = K\phi N$ ...(4)

$$(3) \div (4) \quad \frac{I_a}{N} = \frac{T}{E_b}$$

$$I_a = N \times \frac{T}{E_b} = \frac{2\pi \times 1100 \times 400}{60 \times 275}$$

$I_a = 167.55$ A (at full load)

Now operating voltage is changed to 600V.

$T \rightarrow$ constant (given)

$\phi \rightarrow$ constant (shunt motor)

So $I_aR_a = 25$ volt

$$V_{t_2} = E_{b_2} + I_aR_a$$

$$E_{b_2} = V_{t_2} - I_aR_a = 600 - 25$$

$$E_{b_2} = 575V$$

Let assume the speed is N. $\dfrac{N_2}{N_1} = \dfrac{E_{b_2}}{E_{b_1}}$

$$N = \left(\frac{575}{275}\right) \times 1100$$

$$N = 2300 \text{ r.p.m.}$$

Power $P = E_{b_2} \times I_a = 575 \times 167.55$

$$P = 96.341 \text{ kW}$$

So the required answer is P = 96.341 kW.

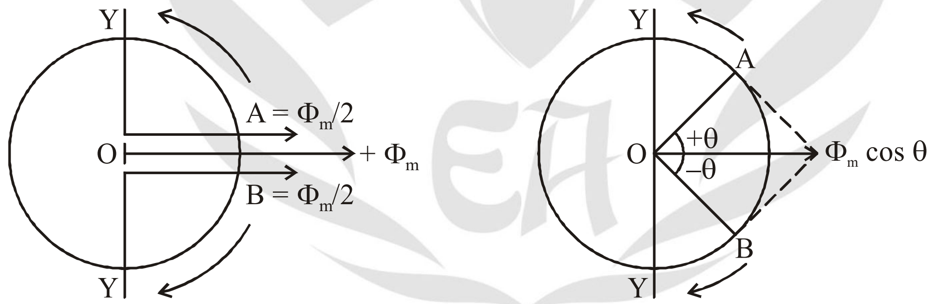
141. Explain the Double-field Revolving theory in connection with single-phase induction motor.

Solution :

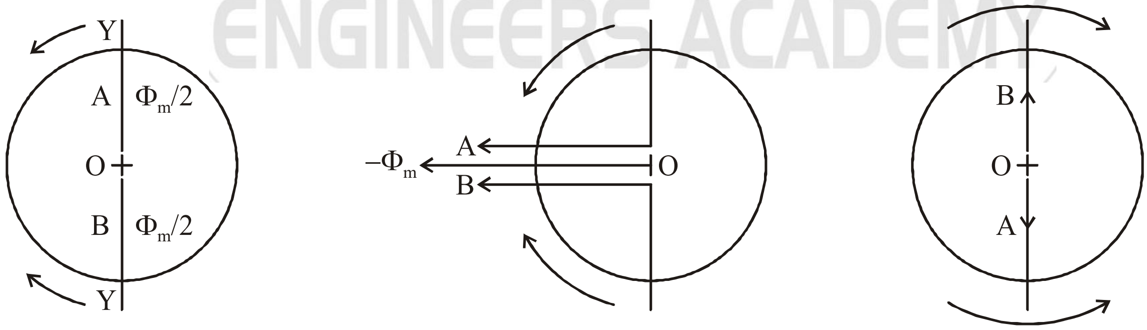
Double-field revolving theory

This theory makes use of the idea that an alternating uni-axial quantity can be represented by two oppositely-rotating vectors of half magnitude. Accordingly, an alternating sinusoidal flux can be represented by two revolving fluxes, each equal to half the value of the alternating flux and each rotating synchronously (N_s = 120f/P) in opposite direction.

As shown in figure (a), let the alternating flux have a maximum value of Φ_m. Its component fluxes A and B will each be equal to $\Phi_m/2$ revolving in anticlockwise and clockwise directions respectively.



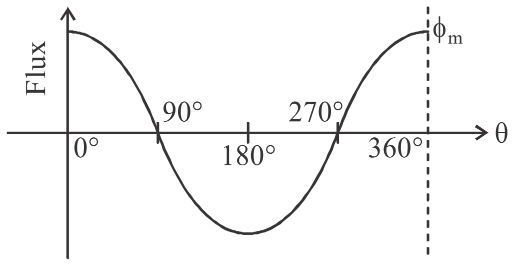
(a) (b)



(c) (d) (e)

After some time, when A and B would have rotated through angle + θ and – θ, as in figure (b), the resultant flux would be

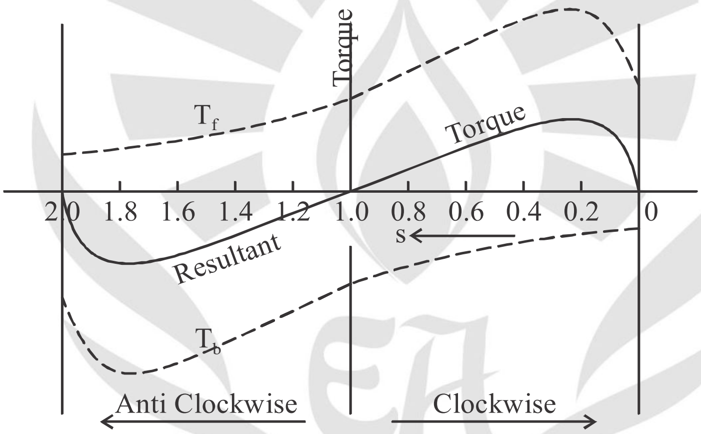
$$= 2 \times \frac{\Phi_m}{2} \cos \frac{2\theta}{2} = \Phi_m \cos\theta$$



After a quarter cycle of rotation, fluxes A and B will be oppositely-directed as shown in (c) so that the resultant flux would be zero.

After half a cycle, fluxes A and B will have a resultant of $-2 \times \Phi_m/2 = -\Phi_m$. After three-quarters of a cycle, again the resultant is zero, as shown in figure (e) and so on. If we plot the values of resultant flux against θ between limits θ = 0° to θ = 360°, then a curve similar to the one shown in figure is obtained. That is why an alternating flux can be looked upon as composed of two revolving fluxes, each of half the value and revolving synchronously in opposite directions.

Each of the two component fluxes, while revolving round the stator, cuts the rotor, induces an e.m.f. and this produces its own torque. Obviously, the two torques (called forward and backward torques) are oppositely-directed, so that the net or resultant torques is equal to their difference as shown in figure.



The forward torque is given by

$$T_f = \frac{kI_2^2 R_2'}{s}$$

and backward torque $T_b = \frac{kI_2^2 R_2'}{(2-s)}$

Total torque $T = T_f + T_b$

At standstill $s = 1, (2 - s) = 1$

Hence T_f and T_b are numerically equal but being oppositely directed, produce no resultant torque. That explains why there is no starting torque in a single-phase induction motor.

152. Describe with diagrams the working of the following induction motor starters

(i) Direct on-line starter

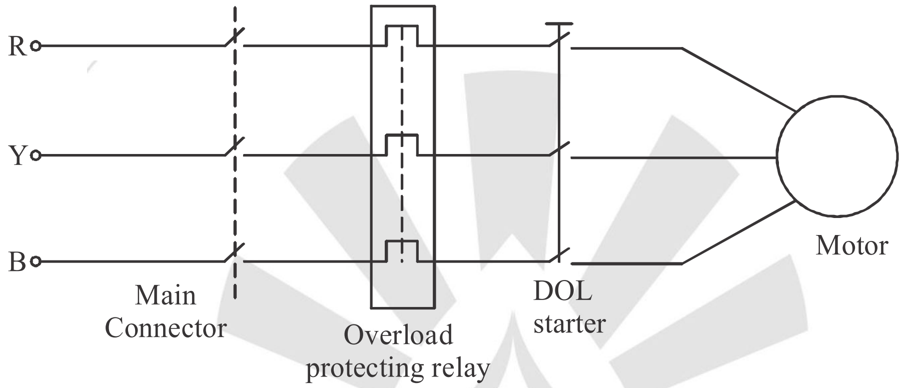
(ii) Autotransformer starter

(iii) Star-delta starter

Solution :

(i) Direct on-line starting : This method involves direct switching of polyphase stator on to the supply mains. The motor takes (low power factor) starting current of 5 to 7 times of full load current. The magnitude of current depends upon its motor size and design. Such large current is for short duration. It does not harm the motor but high currents may cause objectionable voltage drop in the power supply lines feeding induction motor.

If the supply system is of sufficient power capacity and the low power factor starting current surges don't cause objectionable voltage dips in the supply line voltage, then the direct on line starting can be preferred.

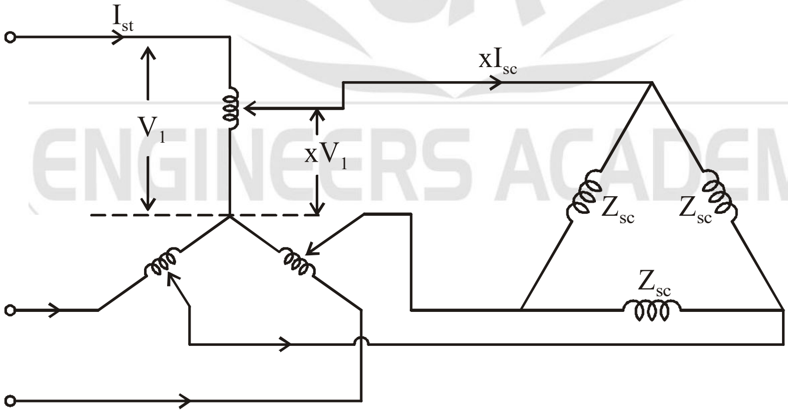


The torque developed in motor is given by

$$T = \frac{1}{\omega_s} I_2^2 \frac{r_2'}{s}$$

$$\frac{T_s}{T_{fl}} = \frac{I_s^2 \frac{r_2'}{1}}{I_{fl}^2 \frac{r_2'}{s_{fl}}} = \left(\frac{I_s}{I_{fl}}\right)^2 s_{fl}$$

(ii) Auto transformer starting :



A fraction xV_1 of the supply voltage V_1 is applied to the stator terminals at the time of starting, by means of an autotransformer. This reduces the motor current and also starting torque. After some time auto transformer is disconnected and full line voltage is applied to the induction motor by connecting it directly across the supply mains.

With auto transformer, per phase starting current in motor winding = $\dfrac{xV_1}{Z_{sc}}$ = xI_{sc}, x < 1.

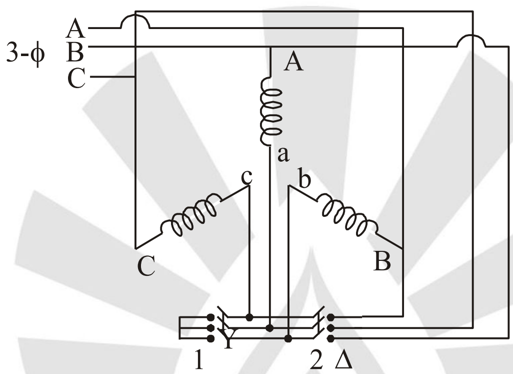
$$\frac{T_s}{T_{fl}} = \frac{(\text{per phase starting current in motor winding})^2}{(\text{Per phase motor full-load current})^2} s_{fl}$$

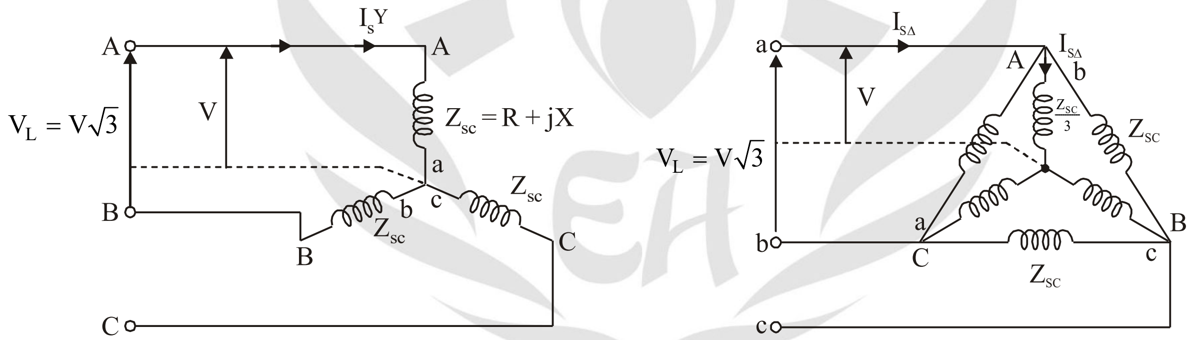
$$\frac{T_s}{T_{fl}} = \frac{(xI_{sc})^2}{I_{fl}^2} s_{fl} = x^2\left(\frac{I_{sc}}{I_{fl}}\right)^2 \times s_{fl}$$

$$T_{s(auto)} = x^2 T_{s(\Delta)}$$

$\because \quad I_{s(auto)} = x^2 I_{s(\Delta)}$

(iii) Star-delta starting : This method of starting is used for motors designed to operate normally in delta. The six terminals from the three phases of the stator must be available as shown in figure.





Three stator terminals are marked A, B, C and the other three stator terminals marked a, b, c are connected to the middle terminals of a triple pole double throw (TPDT) switch. The stator phases are first connected in star by throwing the triple pole double throw (TPDT) switch to position 1 and after state speed has reached, TPDT is thrown over to position 2, there by connecting in delta.

With star-delta starter, the starter current from mains is one-third of direct switching in delta. this method is used widely for starting purpose.

$$I_{s(Y)} = \frac{I_{sc}}{\sqrt{3}} = \frac{1}{\sqrt{3}} \times I_{s(\Delta)}$$

$$\frac{T_{s(Y)}}{T_{fl}} = \left(\frac{I_{sc}/\sqrt{3}}{I_{fl}}\right)^2 \times s_{fl}$$

$$T_{s(Y)} = \frac{1}{3} T_{s(\Delta)}$$

160. A shunt generator gives full load output of 30 kW at a terminal voltage of 200 V. The armature and shunt field resistances are 0.01 Ω and 100 Ω respectively. The iron and friction losses are 1000 W. Calculate the

(i) Emf generated

(ii) Copper losses

(iii) Efficiency

Solution :

Given

Full load output (P) = 30 KW

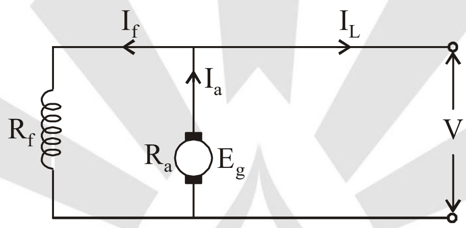
Terminal voltage (V) = 200 V

Armature resistance (R_a) = 0.01 Ω

Field resistance (R_f) = 100 Ω

Iron and friction losses = 1000 W

$$I_L = \frac{P}{V} = \frac{30 \times 10^3}{200} = 150 \text{ A}$$



(i) Emf generated $E_g = V + I_aR_a$ …(1)

$I_a = I_f + I_L$ …(2)

$$I_F = \frac{V}{R_f} = \frac{200}{100} = 2\text{A}$$

Put this value in equation (2)

$I_a = 2 + 150 = 152$ A

Now put all these values in equation (1)

$E_g = 200 + 152 \times 0.01 = 201.52$ V

(ii) Copper loss at armature (W_1) $= I_a^2 R_a$

$= (152)^2 \times 0.01 = 231.04$ W

Copper loss at field winding (W_2)$= I_f^2 R_f$

$= (2)^2 \times 100 = 400$ W

Total copper loss $= W_1 + W_2$

$= 231.04 + 400 = 631.04$ W

(ii) % efficiency (%η) $= \frac{\text{Output}}{\text{Input}} \times 100$

$$= \frac{30 \times 10^3}{30 \times 10^3 + 631.04 + 1000} \times 100 = 94.84\%$$

171. Explain in detail armature reaction in synchronous generators.

Solution **:**

172. 250 V DC shunt motor having an armature resistance of 0.25 Ω carries an armature current of 50 A runs at 750 r.p.m. If the flux is reduced by 10% find the speed. Assume that the load torque remains same.

Solution :

181. **Discuss the advantages and disadvantages of single phase AC motors. Derive an equivalent circuit of a capacitor run single phase motor on the basis of double revolving field theory.**

Solution :