Dt-15-12-2021

Commutator Motor (Chapter-05)

AC Series motor or Universal Motor

→ A dc series motor will rotate in the same direction regardless of the polarity of the supply.

→ One can expect that a dc series motor would also operate on a single-phase ac supply. It is then called as a.c series motor.

→ ~~It is the~~ However, some changes must be made in a d.c motor that is to operate satisfactorily on a a.c supply.

→ The changes effected are :→

(i) The entire magnetic circuit is laminated in order to reduce the eddy current loss.

→ A.c series motor requires a more expensive construction that a d.c series motor.

(ii) The series field winding uses as few turns as possible to reduce the reactance of the field winding to a minimum.

→ This reduces the voltage drop across the field winding.

(iii) A high field flux is obtained by using a low-reluctance magnetic circuit.

(iv) There is considerable sparking between the brushes and commutator when the motor used on A.c supply.

→ It is because the alternating flux establishes high currents in the coils short-circuited by the brushes.

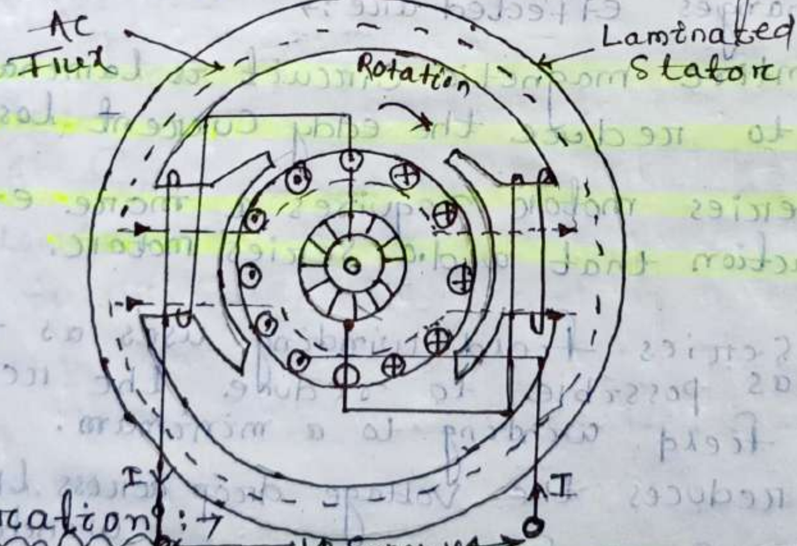
→ When the short-circuited coil break contact from the commutator, excessive sparking is produced.

→ This can be eliminated by using high resistance segments.

Constructions :→

→ The constructions of an a.c series motor is very similar to a d.c series motor except that above modifications are in-corporated.

→ Such a motor can be operated either on a.c or d.c supply and the resulting torque-speed curve is about the same in each case. for this reason, it is sometimes called a universal motor.



Operation :→

→ When the motor is connected to an a.c supply, the same alternating current flows through the field and armature windings.

→ The field winding produces an alternating flux φ that reacts with the current flowing in the armature to produce a torque.

→ Since both armature current and flux reverse simultaneously, the torque always acts in the same direction.

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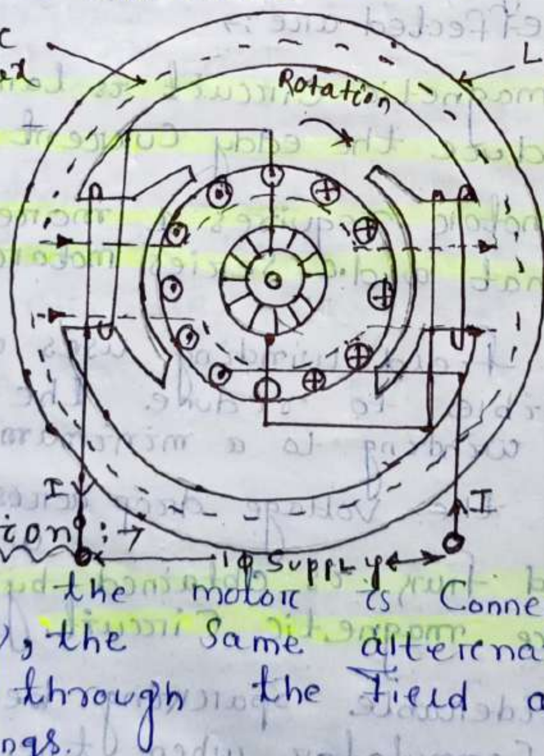

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It may be noted that no rotating flux is produced in this type of machines.

→ The principle of operation is the same as that of a d.c series motor.

Characteristics :→

The operating characteristics of an a.c series motor are similar to those of d.c series motor.

(i) The speed increases to a high value with a decrease in load.

→ In very small series motors, the losses are usually large enough at no load that limit the speed to a "definite value (1500 – 15000 rpm)

(ii) The motor torque is high for large armature current, thus giving a high starting torque

(iii) At full-load, the power factor is about 90%. However at starting or when carrying an overload the power factor is lower.

Applications :→

The fractional horsepower a.c series motors have high speed and large starting torque they can, therefore, be used to drive.

(a) High-speed vacuum cleaners

(b) Sewing machines

(c) electric shavers

(d) drills

(e) Machine tools, etc.

Repulsion Motor :→

A Repulsion motor is Similar to an a.c Series motor.

(i) Brushes are not Connected to Supply but are Short-Circuited., Consequently Currents are induced in the armature Conductors by transformer action.

(ii) The Field Structure has non-salient pole construction.

By adjusting the position of short-circuited brushes on the Commutator, the Starting torque can be developed in the motor.

Principle of Operation :→

→ The principle involved in the starting of the motor is illustracted by 2-pole motor.

→ The alternating flux produced by stator or field winding will induce, during one half cycle, voltages in the respective armature conductors as shown in fig

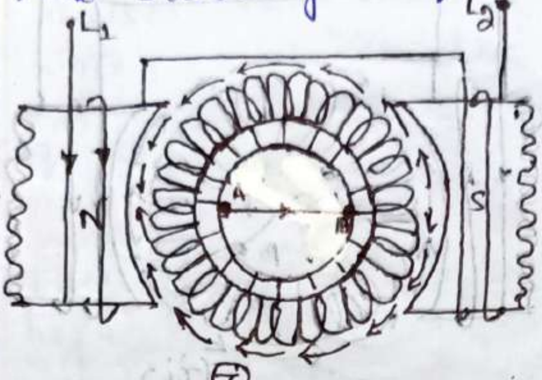
(i) In the brush axis is set in line with the stator-field axis

→ The induced voltage in the armature Conductors are additive on each side of the brushes.

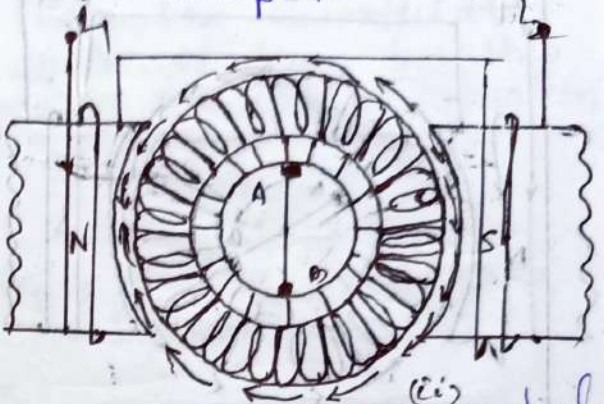
→ Consequently, the net voltage between the brushes is maximum and so is the current through the short circuited armature.

→ The Same is true under the s pole. therefore, as much torque is developed in one direction as in the other and

the armature remain stationary.
→ No starting torque is developed.



(i)



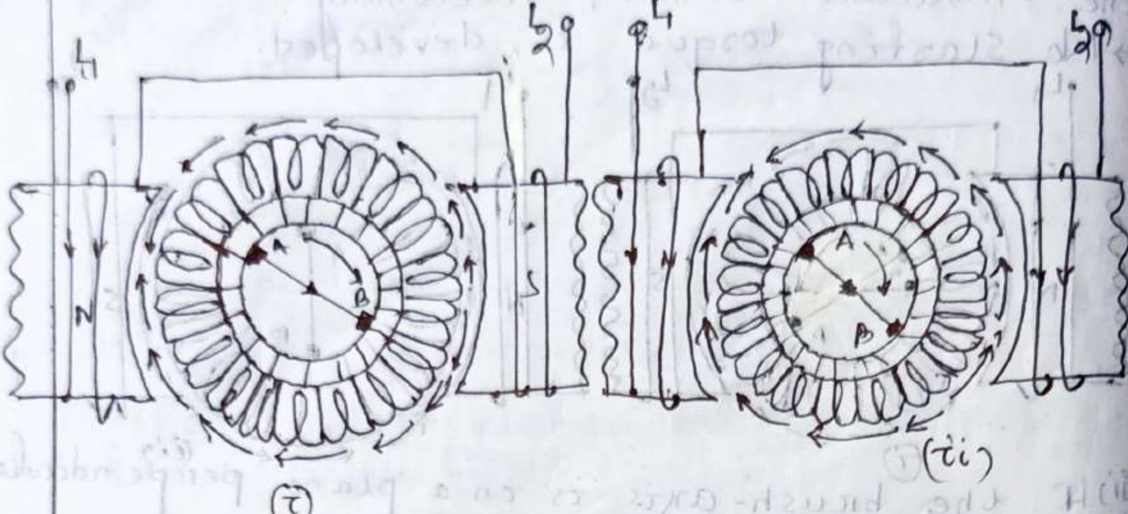
(ii)

(ii) If the brush-axis is in a plane perpendicular to the stator-field axis.

→ The voltage in each path will be neutralised
→ As a result, the net voltage between the brushes is zero.
→ Therefore, no current flows in the armature circuit and no torque is produced

(iii) If the plane of the brush-axis is other than 0° or 90° to the plane of the stator-field.

→ The direction of rotation would depend upon the direction in which the brushes are shifted from the plane parallel to the field.
→ The brushes are shifted clockwise, and the net torque acts in a clockwise direction.
→ If the brushes are shifted in the anticlockwise direction. The currents in the armature conductors under the poles are reversed and the torque is developed in anticlockwise direction.



(iv) after a repulsion motor has been Started in either direction, it will Continue to develop torque in that direction and give Series-motor type performance Characteristics.

Repulsion Start Induction-Run motor :-

→ The Repulsion Start Induction-run motor has the Same general Construction of a repulsion motor,

→ The Only defference is that in addition to the basic repulsion-motor Construction

→ It is equipped with a Centrifugal device field on the armature shaft.

→ When the motor reaches 75% of its full running Speed, the Centrifugal device forces a Short-circuiting ring to come in Contact with the inner Surface of the Commutator.

→ This Short-Circuits. all the Commutator bars the rotor then resembles Squirrel Cage type and the motor runs as a Single phase induction motor.

→ At the Same time, the centrifugal device raises the brushes from the Commutator which reduces the wear of the brushes and Commutator as well as makes the operation quiet.

Repulsion Induction Motor :→

→ The repulsion-induction motor produces a high Starting torque entirely due to repulsion motor action.

→ It functions through a Combination of induction-motor and repulsion motor.

Constructions :→

fig Shows the connections of a 4-pole repulsion-induction motor for 230-V Operation

(i) It Consists of a stator and a rotor.

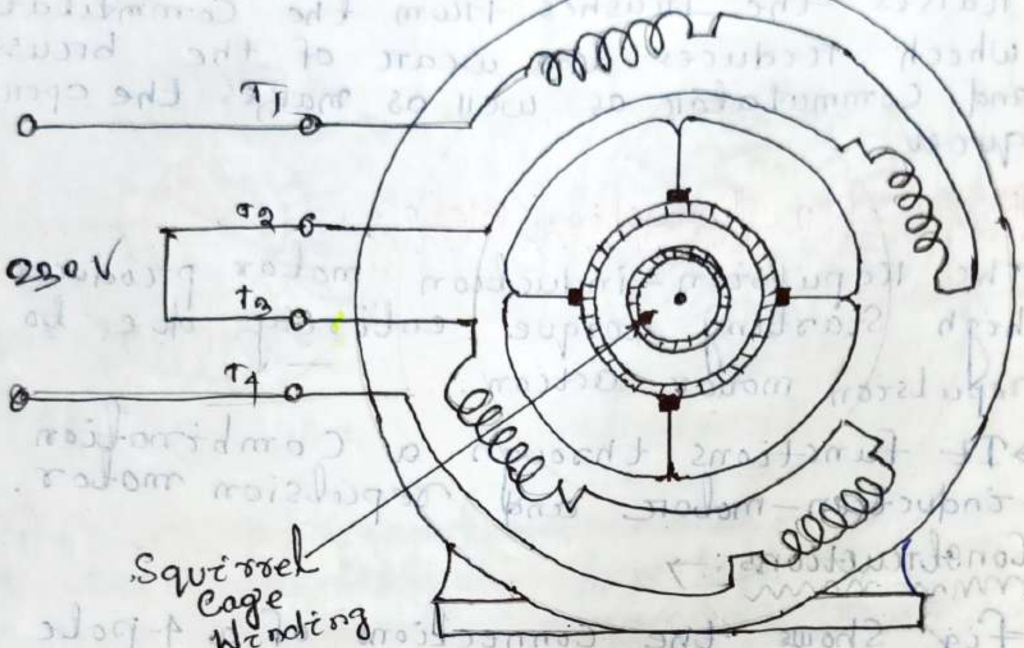
(ii) The stator Carries a Single distributed winding fed from single-phase Supply

(iii) The rotor is provided with two independent winding placed one inside the other.

→ The inner ~~cage~~ winding is a Squirrel cage winding with rotor bars permanently short-Circuited.

→ placed over the Squirrel cage winding is a repulsion Commutator armature winding

→ The repulsion winding is ~~placed~~ connected to a Commutator on which ride Short-Circuited brushes. There is no centrifugal device and the repulsion winding functions at all times.



Operation :→

(i) When Single-phase supply is given to the stator winding, the repulsion winding is active, consequently, the motor starts as a repulsion motor with a corresponding high starting torque.

(ii) As the motor speed increase, the current shifts from the outer to inner winding due to the decreasing impedance of the inner winding with increasing speed.

(iii) Consequenly, at running speed, the squirrel cage winding caries the greater part of rotor current.

(iv) This shifting of repulsion motor action to induction-motor action is thus achieved without any switching arrangement.

(v) It may be seen that the motor starts as a repulsion motor. when running it functions through a combination of principle of induction and repulsion.

Single Phase Synchronous Motors :→

→ Very small single-phase motor have been developed which run at true synchronous speed.

→ They do not require d.c excitation for the ~~moto~~ rotor. Because of these characteristics they are called unexcited single-phase synchronous motors.

→ The most commonly used types are-

(i) Reluctance Motors.

(ii) Hysteresis Motors.

The efficiency and torque-developing ability of these motors is low.

→ The output of most of the commercial motors is only a few watts.

Three Phase Induction Motor :→

Three Phase Induction Motor :→

→ A 3-phase Induction motor has a Stator and rotor..

→ The Stator carries a 3-phase winding is called Starter Winding while the rotor carries a short circuited winding is called rotor winding.

→ Only the Starter winding is fed from 3-phase Supply.

→ The rotor winding drives it voltage and power from the externally energised Stator winding through electromagnetic Induction.

→ As a transformer a.c machine in which electrical energy is converted into Mechanical energy.

→ Construction of 3-phase Induction Motor

→ A 3-phase Induction motor has two main Parts (i) Startor (ii) Rotor

→ The rotor is Separated from the stator by a Small air gap which ranges from 0-4 mm to 4 mm depending on the Power of the motor.

STARTOR :→

→ It Consists of a steel frame which enclose a hollow cylindrical Core made up of thin laminations of Silicon steel to reduce hysteresis and eddy Current loss.

→ A number of evenly Speced slots are provided on the inner periphery of the lamination.

→ The insulated conductors are placed in the stator slots and are suitably connected. to form a balanced 3-phase star or delta connected circuit.

→ The three phase stator winding is wound for a definite number of poles as per requirement of speed.

→ Greater the number of poles, lesser is the speed of the motor and vice-versa.

→ When 3-phase supply is given to the stator winding, a rotating magnetic field of constant magnitude is produced.

→ This rotating field induces currents is the rotor by electromagnetic induction.

Rotor :→

the rotor, mounted on a shaft, is a hollow laminated core having slots on its periphery.

→ The winding placed in these slots (called rotor. winding),

→ Its two type 1 - Squirrel cage type.
2 - Wound type.

Squirrel cage rotor :→

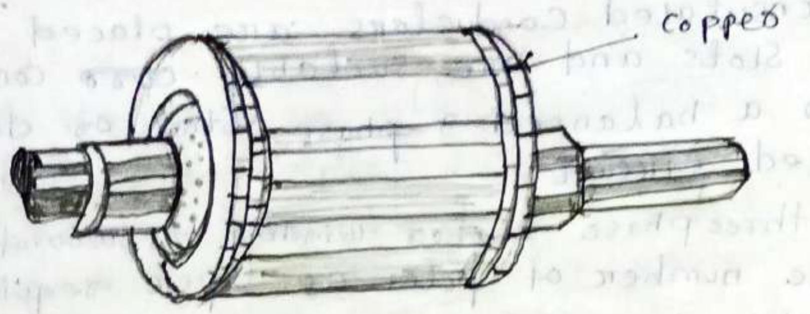
→ It consists of a laminated cylindrical core having parallel slots on its periphery.

→ One copper or aluminium bar is placed in each slot.

→ All these bars are joined at each and by metal rings called end rings.

→ This forms a permanently short-circuited winding which is indestructible.

→ The entire construction resembles a squirrel cage and hence the name.



→ Those induction motors which employ squirrel cage rotor called squirrel cage induction motors.

→ Most of 3-phase induction motors use squirrel cage rotor as it has a remarkably simple and rebust construction, enabling it to operate in the most adverse circumstances.

→ It suffers from the disadvantages of a low starting torque.

→ It is because the rotor bars are permanently short-circuited and it is not possible to add any external resistance to the rotor circuit to have a large starting torque.

Wound type :-

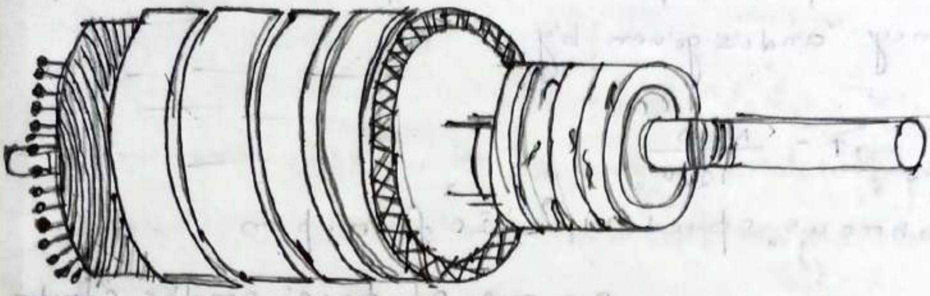
→ It is consists of a laminated cylindrical core and carries a 3-phase winding similar to the one the stator.

→ The rotor winding is uniformly distributed in the slots and is usually star connected.

→ The open ends of the rotor winding are brought out and joined to three insulated slip rings mounted on the rotor shaft with one brush resting on each slip ring.

→ The three brushes are connected to a 3-phase star connected reheostat.

→ At starting the external resistances are include in the rotor circuit to give a large starting torque



→ These resistances are gradually reduced to zero as the motor runs up to speed.

→ The external resistances are used during starting period only.

→ When the motor attains normal speed, the three brushes are short-circuited so that wound rotor runs like a squirrel cage rotor.

Rotating Magnetic Field :—

→ When a 3-phase winding is energised from a 3 phase supply a rotating magnetic field is produced this field is such that it's poles donot remain in a fixed position on the stator but go on shifting their position around the stator.

→ For this reason it is called rotating field.

→ It can be shown that magnitude of this rotating field is constant and is equal to 1.5 ϕ_m where ϕ_m is the maximum flux due to any phase.

Synchronous speed :—

→ The speed at which the revolving flux rotates is called synchronous speed.

→ its value depend upon the no. poles and the supply Frequency and is given by

$$F = \frac{N_1 P}{120}$$

Synchronous speed $N_1 = 120 f / P$ r.p.m

P = no. of poles on the Strator

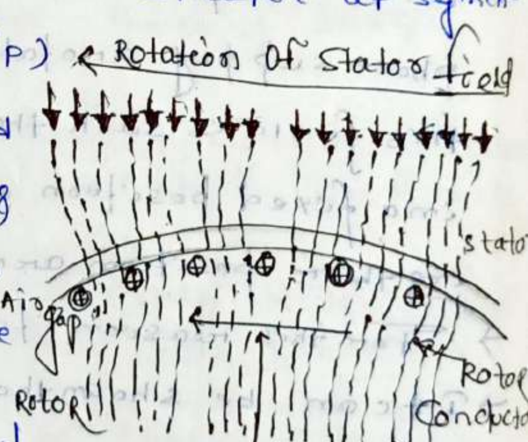
Where F = supply Frequency in Hz

→ Thus for 6-pole, 50 Hz motor, $N_S = 120 \times 50 / 6$ = 1000 r.p.m. it means that the flux rotates around the strator at a speed of 1000 r.p.m.

Operation of 3-phase induction Motor :-

→ When 3 phase strator winding is energised from a 3-phase supply a rotating magnetic fields set up which rotates round the strator at synchronous speed $N_S (= 120 f/P)$

→ Due to the relative speed between the rotating flux & the stationary rotator, emf are induced in the rotor conductors.



→ Since the rotor circuit is Short circuit current start following in the rotor conductors.

→ The current carrying rotor conductors are placed in the magnetic field produced by a strator

→ consequently mechanical force act on the rotor magnetic field conductor.

→ The sum of the mechanical forces on all the rotor conductor produces a torque which tends to move the rotor in the same direction as the rotating field.

→ **Lenz Law :-**

→ According to this law the direction of rotor current will be such that they tend to oppose the cause producing them.

→ Now the cause producing the rotor currents is the relatives speed betn the rotating field and the stationary rotor conductors.

→ Hence to reduce this relative speed, the rotor to slow down.

→ Hense the rotor speed the rotor starts running in the same direction as that of Stator field and tries to catch it.

Slip :-

→ We have seen above that rotator rapidly accelerates in the direction of rotating field.

→ In practice the rotor can never reach the speed of stator flux.

→ If it did there would be no relative speed between the stator field and rotor conductors no induced rotor current and there force no torque to drive the rotor.

→ The friction and windage would immediately cause the rotor to slow down.

→ Hense the rotor speed (N) is always less than the strator field speed (Ns). This difference in speed depend upon load on the motor.

→ The difference bet'n the synchronous speed Ns of the rotating stator field and the actual rotor speed N is called slip.

→ It is usually expressed as a percentage of synchronous speed i.e

$$\%\text{age slip} \quad S = \frac{N_S - N}{N_S} \times 100$$

→ The quantity $N_S - N$ is sometimes called slip speed.

→ When the rotor is stationary (i.e N=0) slip, s = 1 or 100%.

→ In an Induction motor the change in slip from no-load to full load is hardly 0.1% to 3%. So that it is essentially a constant speed motor.

Effect of slip on Rotor circuit:-

→ When the rotor is stationary s=1

→ Under these conditions the per phase rotor emf E_2 has a frequency equal to that supply frequency.

→ At any slip the relative speed bet'n strator field and is rotor is decreased.

→ consequently the rotor e.m.f and frequency are reduced proportionally to sE_2 and sf respectively.

→ At the same time per phase rotor reactance X_2, being frequency dependent is reduced to sX_2.

→ When the rotor is standstill position (i.e. stator winding energised from 3-phase supply) the voltage induced in the stator conductor's is maximum (s=1)

→ If the rotor revolves at synchronous speed the voltage induced in the rotor conductor is zero ($\because$ s=0)

→ The above treatment also applies to rotor reactance i.e.

→ The rotor resistance is independent of rotor frequency and hence the slip.

Rotor current:-

→ 3 phase induction motor at any slip s.

→ The rotor is assumed to be of round type & star connected.

→ Note that rotor e.m.f / phase and rotor reactance/phase are sE_2 and sX_2 respectively. The rotor resistance/phase is R_2 and independent of frequency and therefore depend upon slip.

→ Since the motor represents a balanced 3-phase load we need consider one phase only, the conditions on the other two phase being similar.

At standstill :-

Rotor current / phase $= I_2 = \frac{E_2}{Z_2} = \frac{E_2}{\sqrt{R_2^2 + X_2^2}}$

Rotor p.f $\cos\phi_2 = \frac{R_2}{Z_2} = \frac{R_2}{\sqrt{R_2^2 + X_2^2}}$

Rotor current frequency :-

→ The frequency of a voltage or current induced due to the relative speed bet'n a winding & a magnetic field is given by the general formula.

$$\text{Frequency} = \frac{NP}{120}$$

Where,

N - Relative speed bet'n magnetic field and the winding

P = No. of poles.

→ For a rotor speed N, the relative speed bet'n the rotating flux and the rotor is $N_S - N$ consequently the rotor current frequency.

$$f = \frac{(N_S - N)P}{120}$$

$$= \frac{s N_S P}{120} \quad \left(\because s = \frac{N_S - N}{N_S}\right)$$

$$= sf \quad (\because f = N_S P/120)$$

<u>Rotor current frequency =</u>

(i) When the rotor is at stand still or stationary (i.e $s=1$) the frequency of rotor current is the same as that of supply frequency ($f' = sf = 1 \times f = f$)

(ii) As the rotor picks up speed the relative speed bet'n the rotating flux and the rotor decreases. Consequently the slip s and hense rotor current frequency decreases.

ALTERNATOR (Synchronous Generator)

Introduction :→

→ The machine which produce 3-phase power form Mechanical Power is called alternator or Synchronous generator.

→ These machines are the largest energy converter found in the world. They convert mechanical energy into a.c energy.

→ An alternator operates on the same fundamental principle electromagnetic induction as a d.c generator. i.e. when a flux linking a conductor change an e.m.f is induced in the conductor.

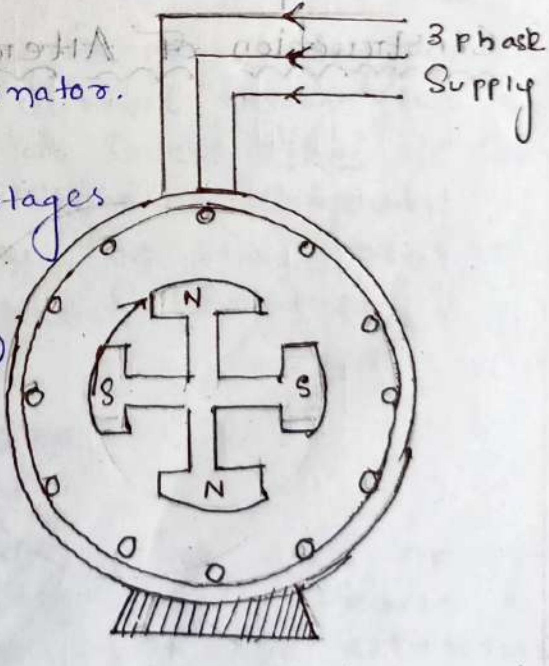
→ Like d.c generator an alternator also has an armature winding and a field winding.

→ The field poles are placed on the starting part of a machine.

→ No commutator is required in an alternator.

→ It is usually more convenient and advantages to place the field winding on the rotating part (i.e rotor)

→ Armature winding on the stationary part (i.e stator)



Advantages of Stationary armature :→

The field winding of an alternator is placed the rotor and his Connected to d.c Supply through two slip ring.

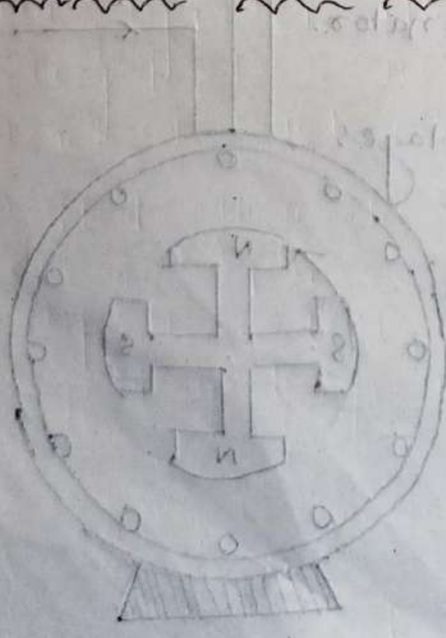
→ The 3 phase armature winding is placed on the stator. This arrangement has the following advantages.

(i) The stationary 3 phase armature can be directly Connected to load without going through large, unreliable slip ring and brushes.

→(ii) It is easier to insulated stationary winding for high voltage for which the alternator are usually design.

(iii) Due to simple and robust Construction of the rotor, higher speed of a rotate dc field is possible.

Construction of Alternator :→



As alternator has 3-phase winding on the stator and d.c field winding on the rotor.

Stator

It is the stationary part of the machine and is built up of sheet-steel laminations having slots on its inner periphery. A 3 phase winding in placed in this slot and serves as the armature winding of alternator.

Rotor

The rotor carries a field winding which is supplied with direct current through two slip ring by a separate dc source. This dc source generally a small dc shunt or compound generator mounted on the shaft of the alternator. Rotor, construct two types:

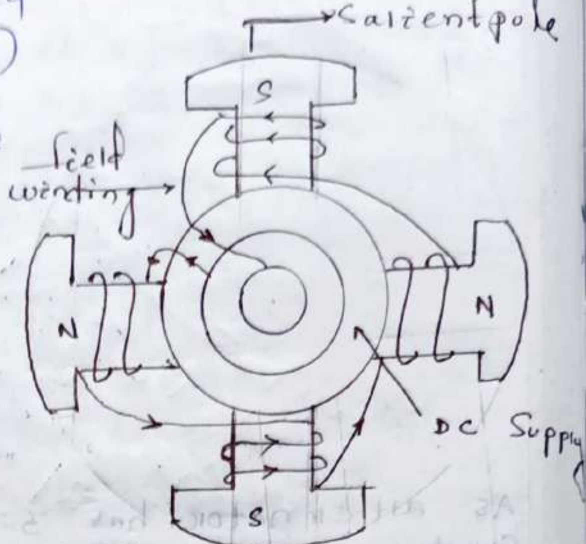
(1) Salient pole type.
(2) Non-Salient pole type.

Salient pole type :→

→ In this type salient poles are mounted on a large circular steel frame which is fixed to the shaft of the alternator as shown in fig.(a)

→ Adjacent poles have opposite polarities.

→ Slow and medium-speed alternator (120-400 rpm) such as diesel engines or water turbine have Salient pole type rotors.



→ The salient field poles would cause an excessive windage loss if driven at high speed and would lead to produce noise.

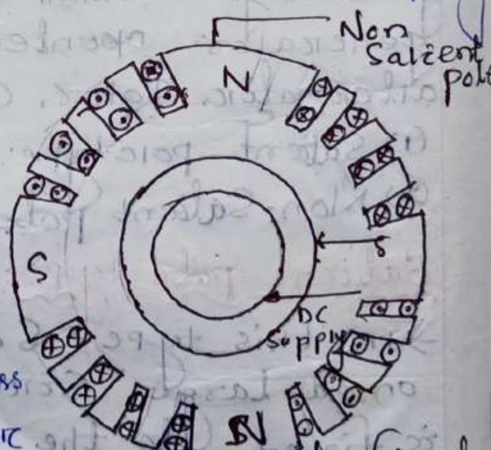
→ The salient pole construction cannot be made strong enough to withstand the mechanical stresses to which they may be subjected at higher speed.

⇒ Salient pole type rotors have large diameters and short axial lengths.

(ii) Non-salient Pole type :→

→ In this type of the rotor is made of smooth solid forged-steel radial cylinder having a number of slots along the outer periphery.

→ High speed alternators (1500 or 3000 r.p.m) are driven by steam turbines and use non-salient type rotors due reasons.



1. This type of construction has mechanical robustness and gives noiseless operation at high speed.

2. The flux distribution around the periphery is nearly sinewave and hence a better e.m.f. waveform is obtained than in the

Case of Salient pole type.

→ Steam turbine run at high speed & a frequency of 50HZ required.

→ Turboalternators process 2 or 4 poles and have Small diameters and very long axial lengths.

Alternator operation :→

→ The Rotor Winding is energised from the d.c exciter and alternate N & S poles are developed on the rotor.

→ When the rotor is anticlockwise direction a primemover, the stator or armature Conductors are cut by the magnetic flux of rotor poles.

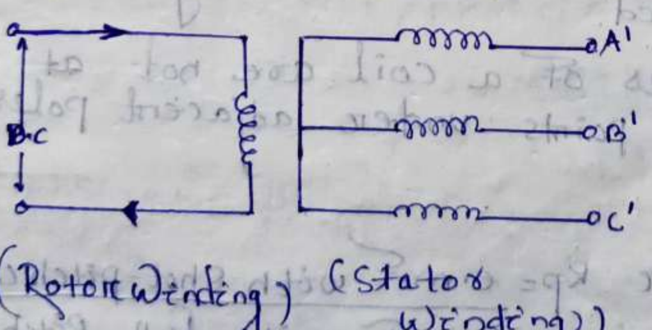
→ Consequently, e.m.F is induced in the armature Conductors due to electromagnetic induction.

→ The direction of induced e.m.F can be found by fleming's Right hand rule & frequency is given by

$$f = \frac{NP}{120}$$

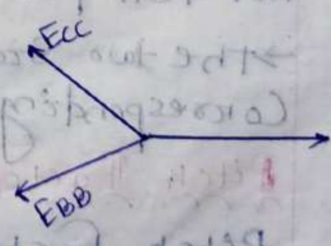
N = Speed of rotor in r.p.m.

P = Number of rotor poles.



(Rotor Winding) (Stator Winding)

(i)



(ii)

Frequency

The frequency of induced e.m.f in the armature conductors depend upon speed and the number of poles.

N – Rotor Speed
P – Number of Rotor poles.
F = frequency of e.m.f in Hz

No of cycle / revolution = No of pairs of poles $= \frac{P}{2}$

No of revolutions / Second $= \frac{N}{60}$

No of cycles / Second $= \frac{P}{2} \times \frac{N}{60} = \frac{PN}{120}$

But number of cycles of emf per second is its frequency.

$$f = \frac{NP}{120}$$

N – is the synchronous motor

→ Alternator is sometimes called synchronous generator.

Pitch factor & distribution Factor.

The coils of armature-windings are not full pitched.

→ The two sides of a coil are not at corresponding points under adjacent poles

Pitch Factor :→

Pitch factor $k_p = \frac{\text{e.m.f with Shot-pitch coil}}{\text{e.m.f with full pitch coil}}$

→ pitch-factor is defind as the ratio of voltages generated by the short pitch winding to that which is generated on the full pitch winding.

Distribution Factor :→

Distribution factor (Kd) = $\frac{\text{E.m.f with distributed winding}}{\text{E.m.f with concentrated winding}}$

The conductor spread over the surface of the armature ~~spreear~~ in slots, their e.m.f differ in phase and the total e.m.f is the vector sum are not arithmatic sum.

E.M.F equation of an alternator :→

Z = No of conductors or coil sides in series

ϕ = Flux per pole in webers

P = Number of rotor poles

N = rotor speed in r.p.m.

In one revolution, each stator conductor is cut by Pϕ webers i.e.

$$d\phi = P\phi, \quad dt = \frac{60}{N}$$

Average e.m.f induced in one stator conductor.

$$\frac{d\phi}{dt} = \frac{P\phi}{60/N} = \frac{P\phi N}{60} \text{ volts}$$

There are Z conductors in series per phase

$$\text{Average e.m.f / phase} = \frac{P\phi N}{60} \times Z$$

$$= \frac{P\phi Z}{60} \times \frac{120f}{P}$$

$$= 2f\phi Z \text{ Volts}$$

R.M.S value of emf / phase

= Average value / phase × Form factor

= $2f\phi Z \times 1.11 = 2.22 f\phi Z$ volts.

E.r.m.s/phase

$$= 2.22 f\phi Z \text{ volts.}$$

∴ If K_p and K_d are the pitch factor and distribution factor of the armature winding, then,

$$E_{rms}/\text{Phase} = 2.22 K_p K_d Z f \phi \text{ volts}$$

Alternator on load:→

→ If there is no current in the armature of the alternator, the only internal voltage in the armature ckt will be generated voltage E.

and the terminal voltage V

Machine will be E

However,

When the alternator is loaded the terminal voltage 'V' changes due to the three effect.

(i) Voltage drop in armature resistance.
(ii) Voltage drop in armature leakage reactance x_L
(iii) Voltage drop due to armature reaction.

→ The voltage drop due to armature reaction is accounted for by assuming a fictious reactance x_a in the armature winding.

→ The phasor sum of x_L and x_a given synchronous reactance x_s

$$x_s = \sqrt{x_L^2 + x_a}$$

→ Synchronous impedance/phase $Z_s = \sqrt{R_a^2 + x_s^2}$

If V is the terminal voltage/phase and E is generated e.m.f/phase than

$$E = V + I_a(R_a + jx_s) = V + I_a Z_s$$

Phasor diagram of Loaded Alternator :→

E = No-load e.m.f / phase

V = terminal voltage/phase

I_a = armature Current/phase

Z_s = Synchronous impedance/phase

ϕ = Load p.f angle.

(i) Unit power Factor load :→

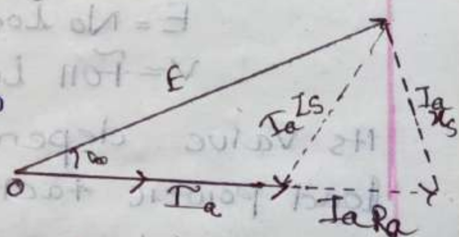
→ phasor diagram of an alternator for unity p.f load. here V is taken the reference phasor.

→ The current phasor I_a in phase with V.

→ The Voltage I_aR_a is in phase with V. the voltage drop I_aR_a in phase with I_a.

→ While the Voltage drop I_aX_s leads I_a by 90°.

→ The phasor Sum of the two giving I_aZ_s, the phasor sum of V & I_aZ_s gives E.



$$E = \vec{V} + \vec{I_aZ_s}$$

$$= I_aR_a + I_aX_s = I_aZ_s$$

$$E = \sqrt{(V + I_aR_a)^2 + (I_aX_s)^2}$$

(ii) Lagging Power Factor Load :→

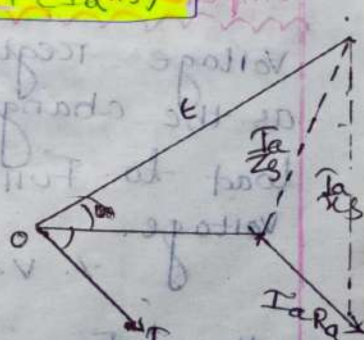
→ Again 'V' is taken as the reference phasor.

→ The ckt phasor 'I_a' Lags 'V' by ϕ.

→ The I_aR_a drop is phase with 'I_a' while the drop I_aX_s Leads 'I_a' by 90°

→ The phasor Sum of the two giving I_aZ_s,

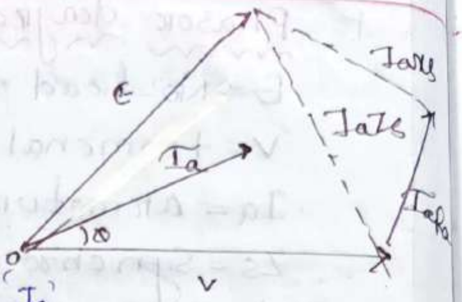
→ The Phasor Sum of V & I_aZ_s gives E.



$$E = \sqrt{(V\cos\phi + I_aR_a)^2 + (V\sin\phi + I_aX_s)^2}$$

(iii) Leading P.F Load :→

V is taken as the reference phasor the current phasor I_a leads V by ϕ. The I_aR_a drop is in phase with I_a.



→ While the drop I_aX_s lead I_a by 90°

→ The phasor sum of V & I_aZ_s gives E.

→ The phasor sum of the two giving I_aZ_s.

$$E = \sqrt{(V\cos\phi + I_aR_a)^2 + (V\sin\phi - I_aX_s)^2}$$

Voltage Regulation

The Voltage regulation of an alternator is defind as the percentage rise in terminal voltage when full load is removed.

$$\%\text{age regulation} = \frac{E - V}{V} \times 100$$

E = No load voltage per phase

V = Full Load voltage per phase.

Its value depends upon load current and load power factor.

Voltage Regulation of alternator by Synchronous impedance method.

Voltage regulation of an alternator is defind as the change in terminal voltage from no load to Full load divided by full load voltage.

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

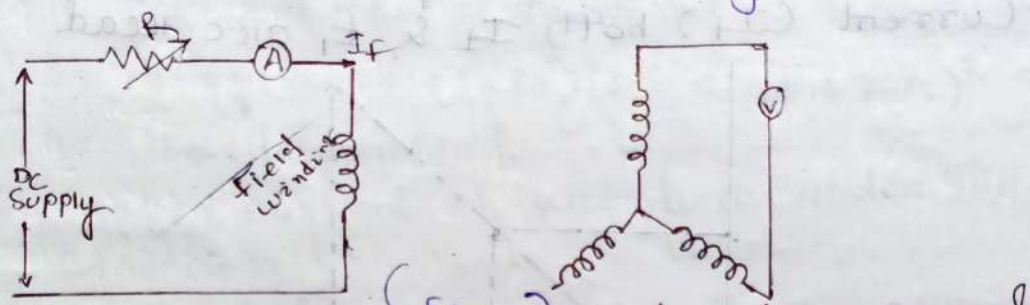
Where E_0 and V are the no-load and Full load terminal voltage.

In this method both o.c test and s.c test of alternator is to be performed and armature resistance is to be determine.

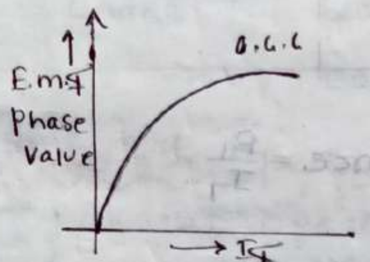
O.C Test

→ In this alternator is run with rated Speed no-load, a voltmeter (V) is connected in between two phase which reads the line voltage, the phase voltage (E_0) will be now determined by dividing $\sqrt{3}$ with the voltage reading.

→ This Voltage (E_0) will very according to the field Current (I_f) which is degin in Fig 2.



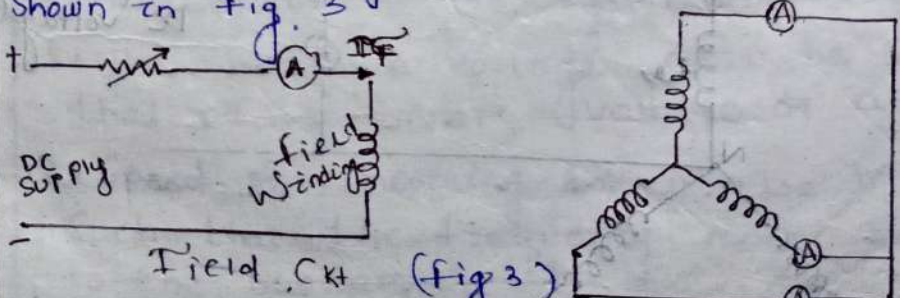
Field Circuit (fig 1) Armature circuit



(fig.2)

S.C Test

→ In this State the alternator is run at rated Speed & the armature terminals are Short Circuited through identical ammeters as Shown in Fig. 3



Field Ckt (fig 3) Armature Ckt

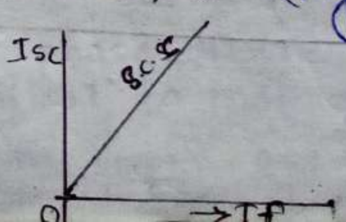
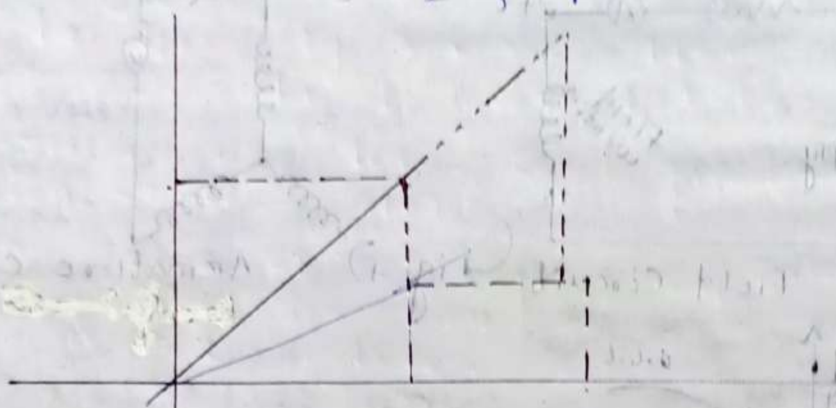


fig 4

The armature reading will give rise to I_{sc} and this I_{sc} is now varied by the Field current (I_f)

The Synchronous impedance Z_s will be determined by taking the plots of O.C.C & S.C jointly as shown in Fig 5.

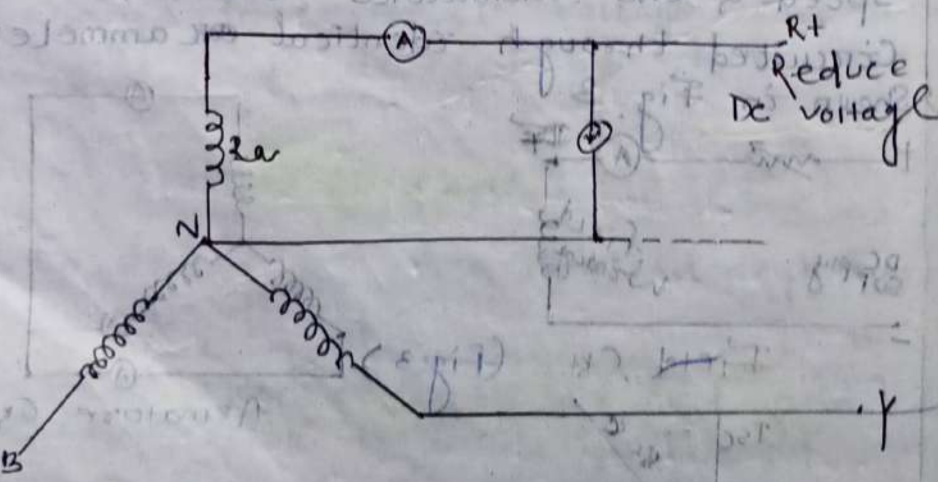
→ From the plot at a particular Field Current (I_f) both I_1 & E_1 are read.



$\therefore Z_S$ = Synchronous impedance $= \frac{E_1}{I_1}$

i.e $= Z_s = \frac{E_1 (O.C)}{I_1 (S.C)}$

R_a will be determined by using Voltmeter ammeter method.



→ A reduced voltage (d.c) is applied across the armature with alternator is at rest. The voltmeter and ammeter readings are noted

$\therefore R_a = \frac{V}{I}$ which is the d.c value.

$\therefore R_a(a.c) = 1.5\ R_a(d.c)$

1.5 is multiplied due to skin effect.

$\therefore X_s = \sqrt{Z_s^2 - R_a^2}$ is found out

$\therefore E_0 = \sqrt{(V\cos\phi + I_a R_a)^2 + (V\sin\phi + I_a X_s)^2}$

will be determined

I_a = rated current of armature under full-load condition

$\therefore$ V = rated terminal voltage of the alternator under full-load condition.

$\therefore V.R = \frac{E_0 - V}{V}$ will be found it.

Parallel operation of Alternator

→ parallel operation of Alternator is called synchronisation.

→ It is generally done in the generating stations because there are more alternators and they have to be synchronised.

→ The conditions for synchronisation are that

1. The bus bar voltage must be same to that of terminal voltage of alternator
2. Speed of incoming alternator must be such that the frequency must be equal to the bus bar.
3. The phase of the alternator voltage must be identical to that of bus bar voltage.

→ Synchro scopes are generally preferred for synchronisation results.

Dt - 18-11-2021

(CH-7) (Single Phase Induction Motor)

→ Single phase Induction motor is very Similar three phase Squirrel cage induction motor

→ It has a Identical Squirrel cage rotor & a single phase winding on the starter.

Working

→ The single phase starter winding produces a magnetic field that pulsates in Strength in Sinusoidal Manner.

→ The Field polarity reverses after each half Cycle but the Field does'nt rotate.

→ The alternating Fulse can't produce rotation in the rotor.

→ If the rotor of a Single phase rotor is rotated in one direction by sum mechanical Means, it will Continue to run in the direction of rotation.

→ Once the motor is running at Synchronous Speed it will Continue to rotate eventhough the single phase Current is flowing through the starter winding.

→ This method of starting is generally not applicable for the large motor.

Make Self Starting

→ To make a single phase Induction motor Self Starting we should produce a revolving stator Magnetic field.

→ This may be achieved by Converting a single phase Supply into two phase supply through the use of additional winding.

→ According to the method of to make the single phase induction.

Dt-18-11-2021

(CH-9) (Single Phase Induction Motor)

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Working

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→ The Fieldpolarity reverses after each half cycle but the Field does'nt rotate.

→ The alternating fulse can't produce rotation in the rotor.

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The Single phase Induction motor divided into 5 types

1. Split phase motor
2. Capacitor start, Motor.
3. Capacitor start, run motor
4. Permanent Capacitor type motor.
5. Shaded pole motor.

(1) Split phase motor :→

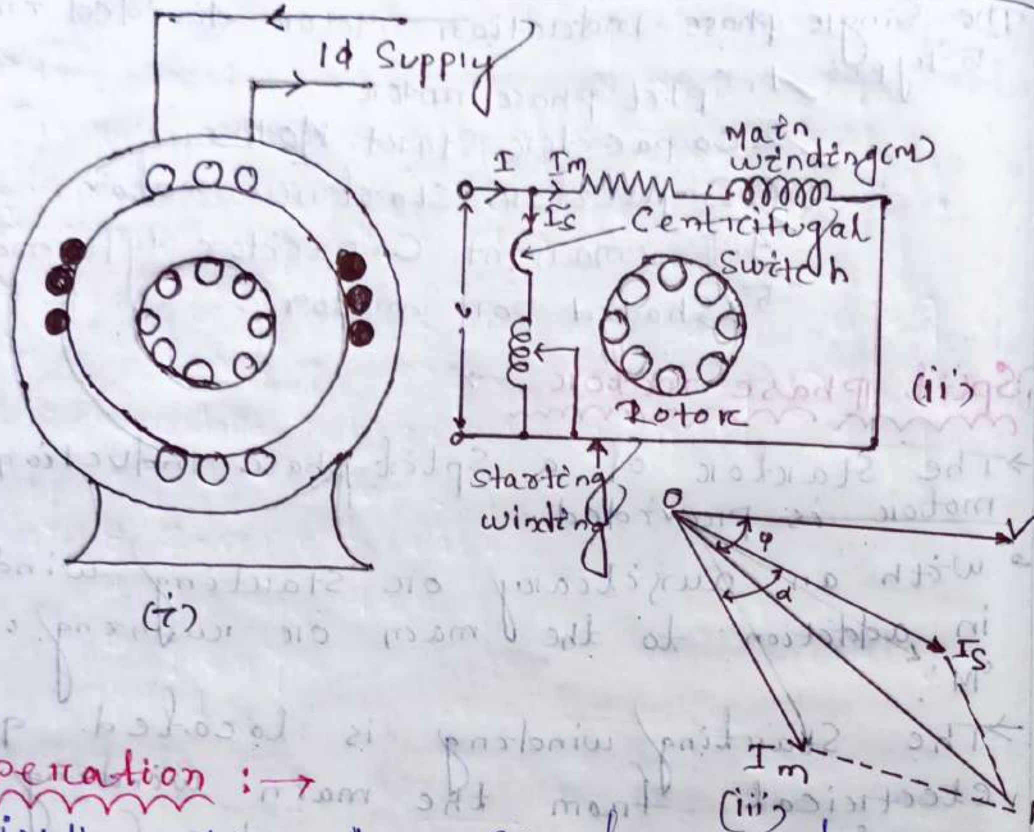
→ The Stator of a split-phase induction motor is provided.

- with an auxiliary or starting windings in addition to the main or running 'M'.

→ The Starting winding is located 90° electrical from the main winding and operates only during the brief period when the motor starts up.

→ The two windings are so designed that the starting winding (S) has a high resistance and relatively small reactance while the main winding 'M' has relatively low resistance and large reactance as shown in the schemetic connections in fig (ii)

→ Consequently the currents flowing in the two windings have reasonable phase difference α (25° to 30°) as shown in fig.



Operation :→

(i) When the two Starter windings are energised from a single-phase Supply, the main winding carries current I_m while the Starting winding carries current I_s.

(ii) Since main winding is made highly inductive while the starting winding highly resistive, the current I_m and I_s have a reasonable phase angle α (25^0 to 30°) between them as shown in fig (iii)

→ A weak revolving field approximating to that of a 2-phase machine is produced which starts the motor.

→ The starting torque is given by

$$T_s = K I_m I_s \sin\alpha .$$

Where K is a constant whose magnitude depends upon the design of the motor.

(iii) When the motor reaches about 75 % of synchronous speed, the centrifugal switch open the circuit of the starting winding.

→ The motor than operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed.

→ the normal speed of the motor is below the synchronous speed and depends upon the load on the motor.

(02) Capacitor Start Motor :→

→ the capacitor start motor is identical to a split-phase motor except that the starting winding has as many turns as the main winding.

→ a capacitor C is connected in series with the starting winding as shown in fig.

→ The value of capacitor is so chosen that I_s leads I_m by about 80° (i.e $\alpha \cong 80°$) which is considerably greater than 25° found in split-phase motor. (fig-ii)

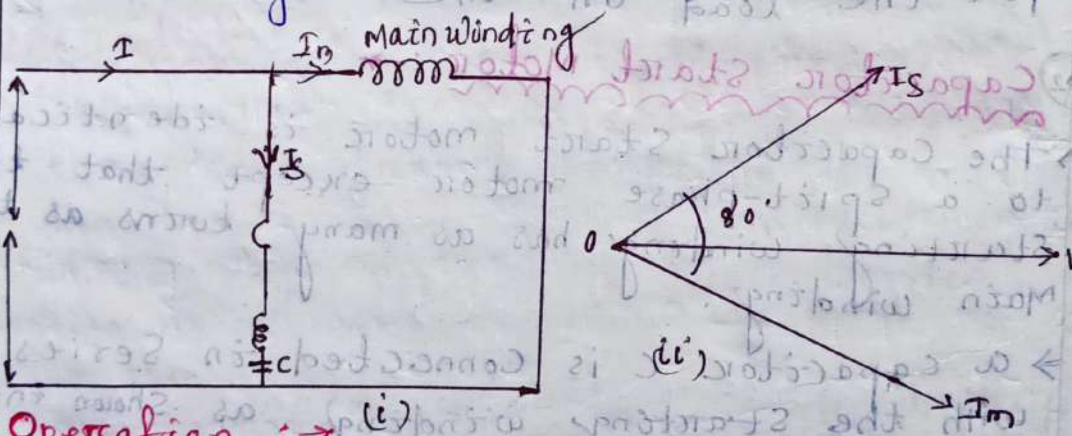
→ Consequently, starting torque ($T_s = K I_m I_s \sin \alpha$) is much more than that of a split-phase motor.

→ 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 continuous to accelerate till it reaches the normal speed.

→ Capacitor-start motors are used where high starting torque is required and where the starting period may be long, e.g to drive:

(i) compressors
(ii) large fans
(iii) pumps
(iv) High-inertia loads.



Operation :→

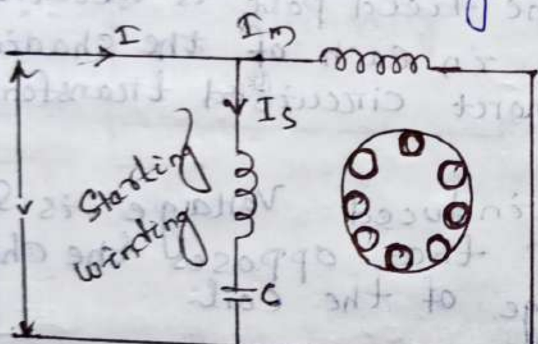
• When the two starter windings are energised from a single-phase supply the main winding carries current Im while the starting winding carries current Is.

• Since main winding is made highly inductive while the starting winding highly resistive, the current Im and Is have a reasonable phase angle is near about 80° between them as shown in fig (ii)

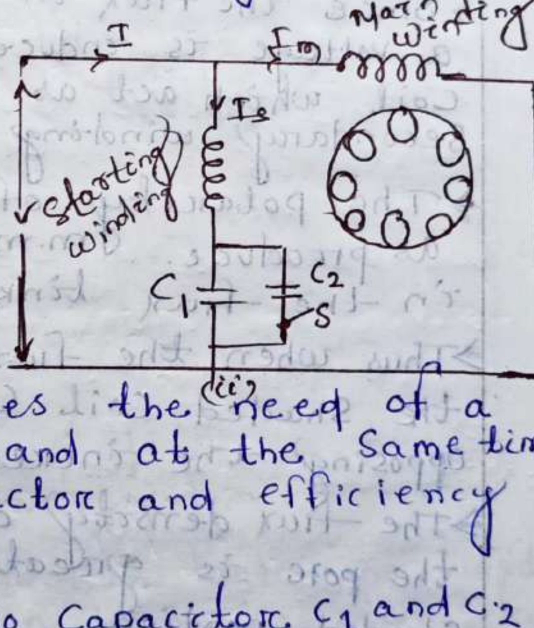
(3) Capacitor-Start Capacitor-Run Motor :→

★ This motor is identical to a capacitor-start motor except the starting winding is not opened after starting so that both the windings remain connected to the supply when running as well as at starting. Two designs are generally used.

(i) In one design, a single capacitor C is used for both starting and running as shown in fig.



(i)



(ii)

(i) This design eliminates the need of a centrifugal switch and at the same time improves the power factor and efficiency of the motor.

(ii) In the other design two capacitor C_1 and C_2 are used in the starting winding as shown in fig.

→ The smaller capacitor C_1 required for optimum running conditions is permanently connected in series with the starting winding.

→ The much larger capacitor C_2 is connected in parallel with C_1 for optimum starting and remains in the circuit during starting. The starting capacitor C_2 is disconnected when the motor approaches about 75 % of synchronous speed.

(4) Shaded-pole motor :→

→ The Shaded pole motor is very popular for starting below 0.05 HP (≃ 40w) because of its extremely simple construction. It has salient pole on the stator excited by single phase supply & a squirrel cage rotor.

→ A portion of each pole is surrounded by a short circuit turn of copper strip called shading coil.

Operation :→

→ Since the flux in the field pole is alternating a voltage is induced in each of the shading coil which act as short circuited transformer secondary winding.

→ The polarity of induced voltage is such as produce m.m.f that opposes the change in the flux linkage of the coil.

→ Thus when the flux in the pole is increasing the shaded coil current produce an m.m.f opposing the increase.

→ The flux density of the unshaded portion of the pole is greater than that of the shaded portion.

→ When the pole flux is decreasing the shading coil current flow to oppose the decrease.

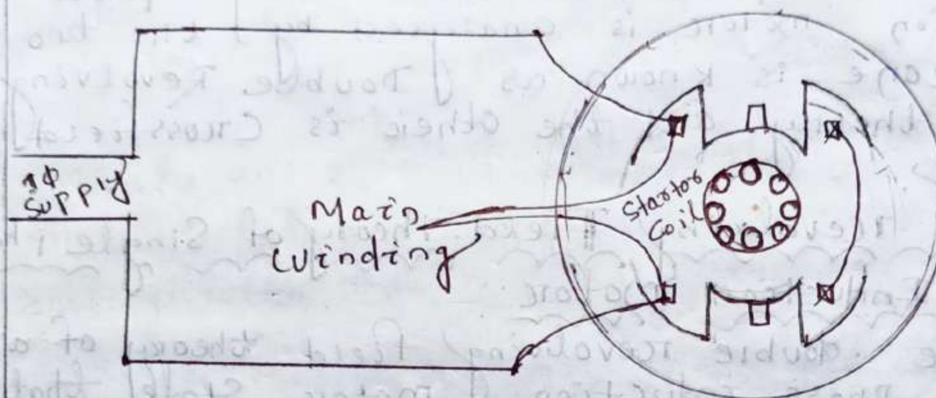
→ Thus the effect of the shading coil is to produce a shift in the flux from the unshaded portion.

→ This shift in flux may be considered to be a partiality rotating field and is sufficient to produce in the direction of the shift in the flux.

→ Because of Small Starting torque developed in the motor and relatively Large power Loss in the Shading Coil.

→ The Shaded pole motor is built in Smallsize.

→ The Most common application being to fan.



To change the direction of the rotation of Motor

- The Single phase Induction motor has wide range of use both in house and industry working.
- It has one Starting winding and one running winding.
- Generally the Starting winding has more number of turns. when it get ~~innerge~~ innergaised it create addictive polarity which cause the motor to rotate in ~~co~~ clock wise direction.

* When we connect the phase with the running winding, as the running winding has less number of turns and it creat less polarity. The motor achive anticlock wise direction of rotation.

* The perfomance of the single phase induction motor is analysed by the two theoriesone is known as Double Revolving field theory and the other is Crossfield theory.

Double Revolving Field Theory of Single phase Induction motor

The double revolving field theory of a single phase induction motor state that a pulsating magnetic field is resolved into two rotating magnetic field.

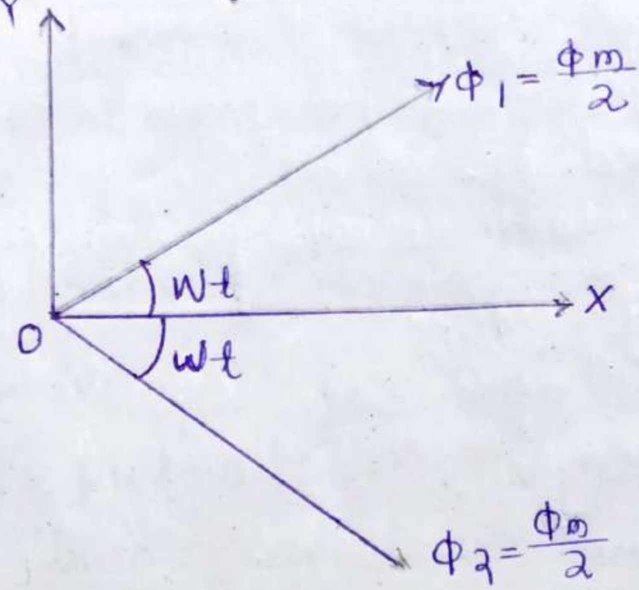
→ They are equal in magnitude but opposite in direction.

→ The Induction motor responds to each of the magnetic fields separately.

→ The net torque in the motor is equal to the sum of the torque due to each of the two magnetic field

→ The equation form on alternating magnetic field is given as the 1st term of the right-hand side of the equation (2) represent the revoving field moving in the +ve α direction it is known as forward rotating field.

→ The second term shows the revolving field moving in the -ve α direction and is known as the Backward rotating field.



> Consider two rotating magnetic fluxes ϕ_1 and ϕ_2 each of magnetude $\frac{\phi m}{2}$ and rotating in opposite directing with angular velocity "ω"

Totally x-component $= \frac{\phi m}{2} \cos \omega t + \frac{\phi m}{2} \cos \omega t = \phi m \cos \omega t$

Total y-component $= \frac{\phi m}{2} \sin \omega t - \frac{\phi m}{2} \sin \omega t = 0$

Resultant flux $(\phi) = \sqrt{\phi x^2 + \phi y^2}$

$= \phi m \cos \omega t$

Thus the resultant flux vector is $\phi = \phi m \cos \omega t$ acting along OX-axis.

→ The direction in which the Single phase motor is started initially known as the +ve direction

→ Both the revolving field rotate at the Synchronous speed $W_s = 2\pi f$ in the opposite direction.

→ The pulsating magnetic field is resolved into two rotating magnetic fields. Both are equal in magnitude and opposite in direction but at the same frequency.

Ferraries Principle :→

Ferraries devised a motor using electromagnet at right angle and power by alternating current that were 90 out of Phase.

• Thus producing a revolving magnetic field

→ The direction of motor could be reversed by reversing the polarity of one of the currents.

Cross field theory :→

→ Cross field revolving theory is the theory which discusses the cause of non Self starting of Single phase induction motor.

→ If the single-phase stator winding is excited and the rotor of the motor is rotated by an auxilary means and the starting device is then removed.

→ The motor continues the rotate in the direction in which it started.

Permanent Capacitor type motor:→

→It has a cage rotor and Stator.

→The stator has two windings - main and auxiliary winding.

→It has only one Capacitor in Series with Starting winding.

→It has no starting Switch.

Advantages of permanent split capacitor motor:→

→No Centrifugal Switch is needed.

→It has higher efficiency and pull-out torque.

Applications of permanent Split Capacitor motor:→

→ It finds applications in Fans and blowers in heaters and air Conditioners.

→It is also used to drive office machinery.