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Subject:-

Electrical Machines – II

Submitted To:-

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EET-402

SP NOTES

Question # 01 :- Write Introduction, Advantages, disadvantages and construction of three phase (3-ϕ) induction motor.

Ans:-

Introduction:-

A 3-phase induction motor can be used for different applications with various speed and load requirements. Electric motors can be found in almost every production process today. Getting the most out of your application is becoming more and more important in order to ensure cost-effective operations. The three phase induction motors are the most widely used electric motors in industry. They run at essentially constant speed from no-load to full-load. However, the speed is frequency dependent and consequently these motors are not easily adapted to speed control. We usually prefer d.c motor when large speed variation are required. Nevertheless, the 3-ϕ induction motors are simple, rugged, low priced, easy to maintain and can be manufactured with characteristics to suit most industrial requirements. Like any electric motor, a 3-ϕ induction motor has a stator and rotor. The stator carries a 3-Φ winding (called stator winding) while the rotor carries a short-circuited winding (called rotor winding). Only the stator winding is fed from 3-Φ supply. The rotor winding derives its voltages and power from the externally energized stator winding through electromagnetic induction and hence the name. The induction motor may be considered to be transformer with a rotating secondary and it can, therefore be described as a "transformer type" a.c machine in which electrical energy is converted into mechanical energy.

Advantages

i) It has simple and rugged construction.
ii) It is relatively cheap.
iii) It requires little maintenance.
iv) It has high effeciency and reasonably good power factor.
v) It has self-starting torque.

Disadvantages:-

i) It is essentially a constant speed motor and its speed cannot be changed easily.
ii) Its starting torque is inferior to d.c shunt motor.

Construction :-

The 3-Φ induction motor is the most widely used electrical motor. Almost 80% of the mechanical power by used by industries is provided by three phase induction motors because of its simple and rugged construction.

A 3-Φ induction motor has two main parts (i) stator and (ii) Rotor.

The rotor is separated from the stator by a small air gap which ranges from 0.4 mm to 4mm, depending on the power of the motor.

i) Shaft for transmitting the torque to the load. This shaft is made up of steel.

ii) Bearings for supporting the rotating shaft.

iii) One of the problem with electrical motor is the production of heat during its rotation. In order to overcome this problem we need fan for cooling.

iv) For recieving external electrical connection Terminal box is needed.

v) There is a small distance between rotor and stator which usually varies from 0.4mm to 4mm. Such a distance is called air gap.

Stator :-

As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the 3-Φ supply is given to it. Stator is made up of numbers of stampings in which different slots are cut to recieve 3-phase winding circuit which is connected to 3-phase AC supply. Speed is inversaly proportional to the number of poles, given by the formula:

$$N_s = 120f/P$$

where N_s = synchronous speed
f = frequency , P = no. of poles

It consists of a steel frame which enclose a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysterssis and eddy current losses. The 3-phase stator winding is wound for a definite number of poles as per requirement of speed. Greater the no. of poles, lesser is the speed of the motor and vice, versa.

Stator of three phase Induction Motor

The stator of the three phase induction motor consists of main three parts.

i) Stator Frame :-

It is the outer most part of three phase induction motor.....

ii) Stator Core :-

The main function of the stator core is to carry the alternating flux. In order to reduce the eddy current loss, the stator core is leminated. These leminated types of structure are made up of stomping which is about 0.4 to 0.5mm thick.

iii) Stator winding or Field winding :-

The slot (of) on the periphery of stator core of the motor carries three phase windings. This 3-phase winding is supplied by 3-phase AC supply. The 3-phase of the winding are connected either in star or delta depending upon which type of starting method is used.....

Rotor:-

The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft. Rotor consists of cylindrical laminated core with parallel slots that carry conductor bars.

two types of Rotor:-

i) Squirrel cage
ii) wound type.

* A 3-Φ Squirrel cage induction motor is the type of three phase induction motor which functions based on the principle of electromagnetism---- The interaction of the magnetic fields produced by the stator and rotor windings produces a torque on the squirrel cage rotor.

⇒ A wound - rotor motor, also known as slip ring-rotor motor, is a type of induction motor where the rotor windings are connected through slip rings to external resistance. Adjusting the resistance allows control of the speed/torque characteristic of the motor.

Q#2:- Write Operation principal (working) of three phase induction motor.

Ans:-

Operation principal:-

The direction of rotation of the motor depends on the phase sequence of supply lines, and the order in which these lines are connected to the stator. thus interchanging the connection of any two primary terminals to the supply will reverse the direction of rotation. The number of poles and the frequency of the applied voltage determine the synchronous speed of rotation in the motor's stator. Motors are commonly configured to have 2,4,6 or 8 poles. The synchronous speed a term given to the speed at which the field produced by primary current will rotate, is determined by the following expression.

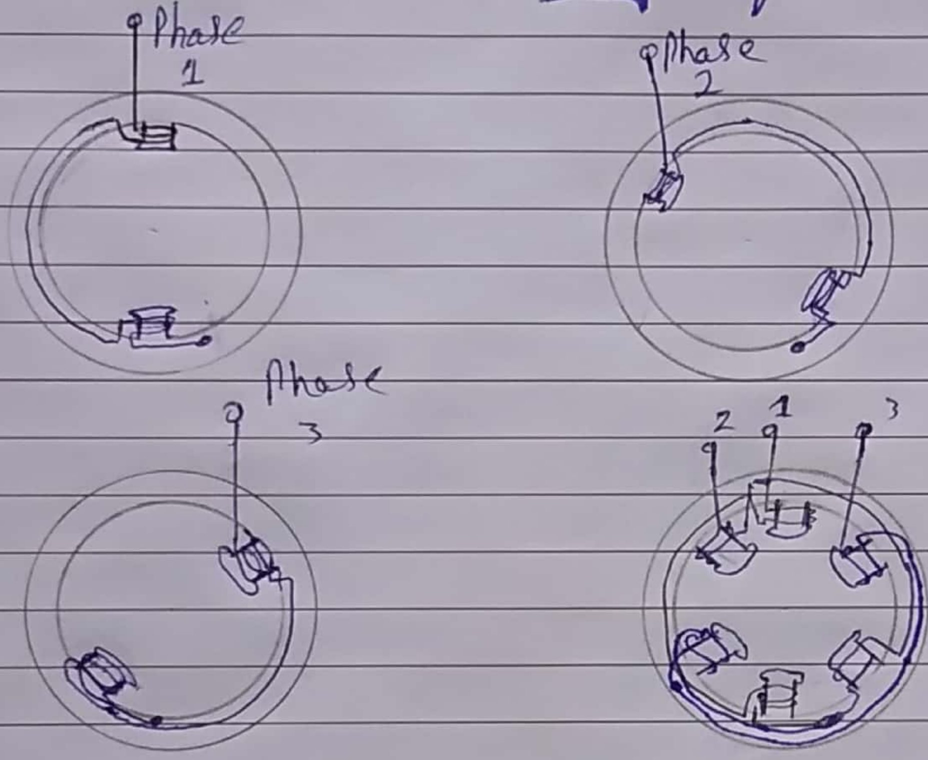
Synchronous speed of rotation = (120* supply frequency) / number of poles on the stator.

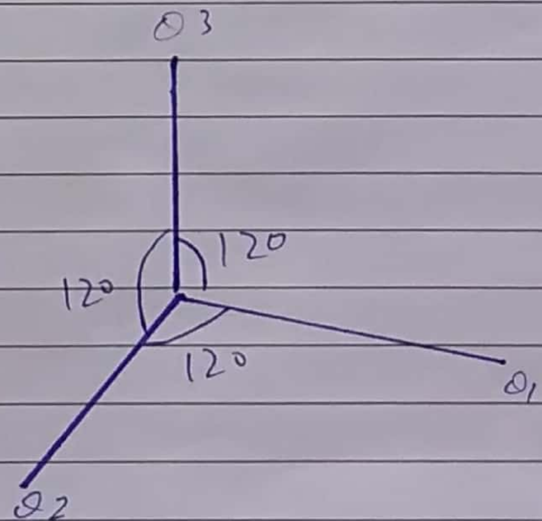
Thus the three phase induction motor is:

1) Self starting:-
2) robust in construction
3) easier to maintain.

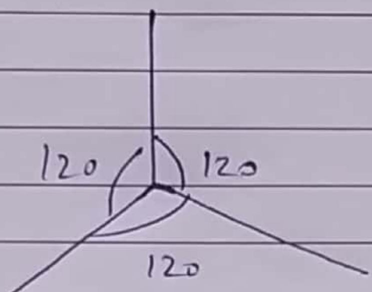
4) Less armature reaction and brush sparking because of the absence of commutators and brushes that may cause sparks.

Three - Phase rotating fields :-

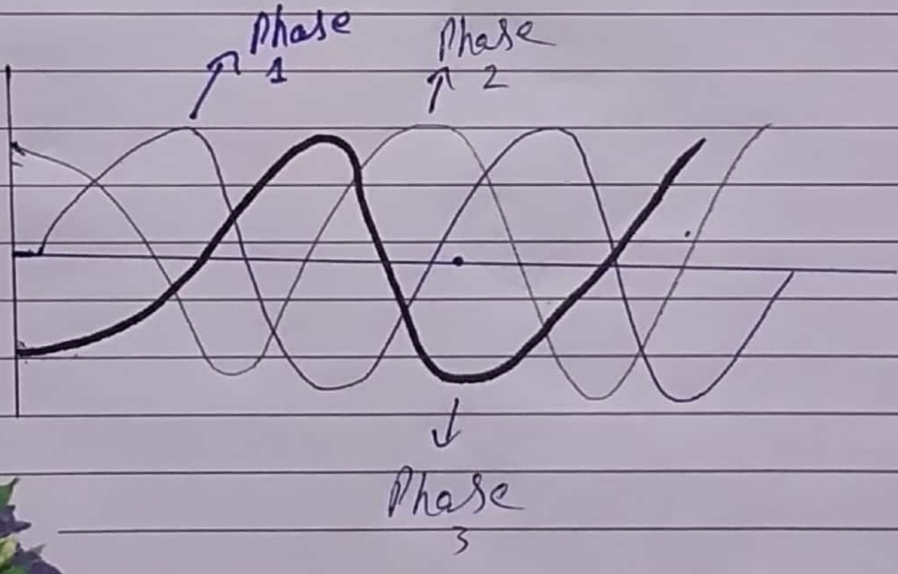




Generation of Rotating magnetic field (RMF)



$\phi_1 = \phi_m \sin(\omega t) = \phi_m \sin\theta$
$\phi_2 = \phi_m \sin(\omega t - 120^\circ) = \phi_m \sin(\phi - 120^\circ)$
$\phi_3 = \phi_m \sin(\omega t - 240^\circ) = \phi_m \sin(\omega - 240^\circ)$



Case 1 :- When $\phi = 0^\circ$

$\phi_1 = \phi_m \sin \omega t = 0$
$\phi_2 = \phi_m \sin(\omega t - 120^\circ) = -0.866\,\phi_m$
$\phi_3 = \phi_m \sin(\omega t - 240^\circ) = 0.866\,\phi_m$
$\phi_T = \phi_1 + \phi_2 + \phi_3$

$\Phi_T = 1.5\ \Phi_m$

So the magnitude of resultant flux is $1.5\ \Phi_m$ time the maximum value if flux.

Case #2 :- $\Phi = 60^\circ$

$\Phi_1 = \Phi_m \sin(\omega t) = \Phi_m \sin 60^\circ = 0.866\,\Phi_m$

$\Phi_2 = \Phi_m \sin(\omega t - 120^\circ) = -0.866\,\Phi_m$

$\Phi_3 = \Phi_m \sin(\omega t - 240^\circ) = 0$

$\Phi_T = 1.5\ \Phi_m$

So the magnitude of resultant flux is $1.5\ \Phi_m$ time the maximum value if flux.

Case #3 : $\Phi = 120^\circ$

$\Phi_1 = 0.866\,\Phi_m$

$\Phi_2 = 0$

$\Phi_3 = -0.866\,\Phi_m$

$\Phi_T = \Phi_1 + \Phi_2 + \Phi_3$

$\Phi_T = 1.5\ \Phi_m$

So the magnitude of the resultant flux is $1.5\ \Phi_m$ time the maximum value if flux

Case #4 : $\Phi = 180^\circ$

$\Phi_1 = 0$

$\Phi_2 = 0.866\ \Phi_m$, $\Phi_3 = -0.866\ \Phi_m$

$\Phi_T = 1.5\ \Phi_m$

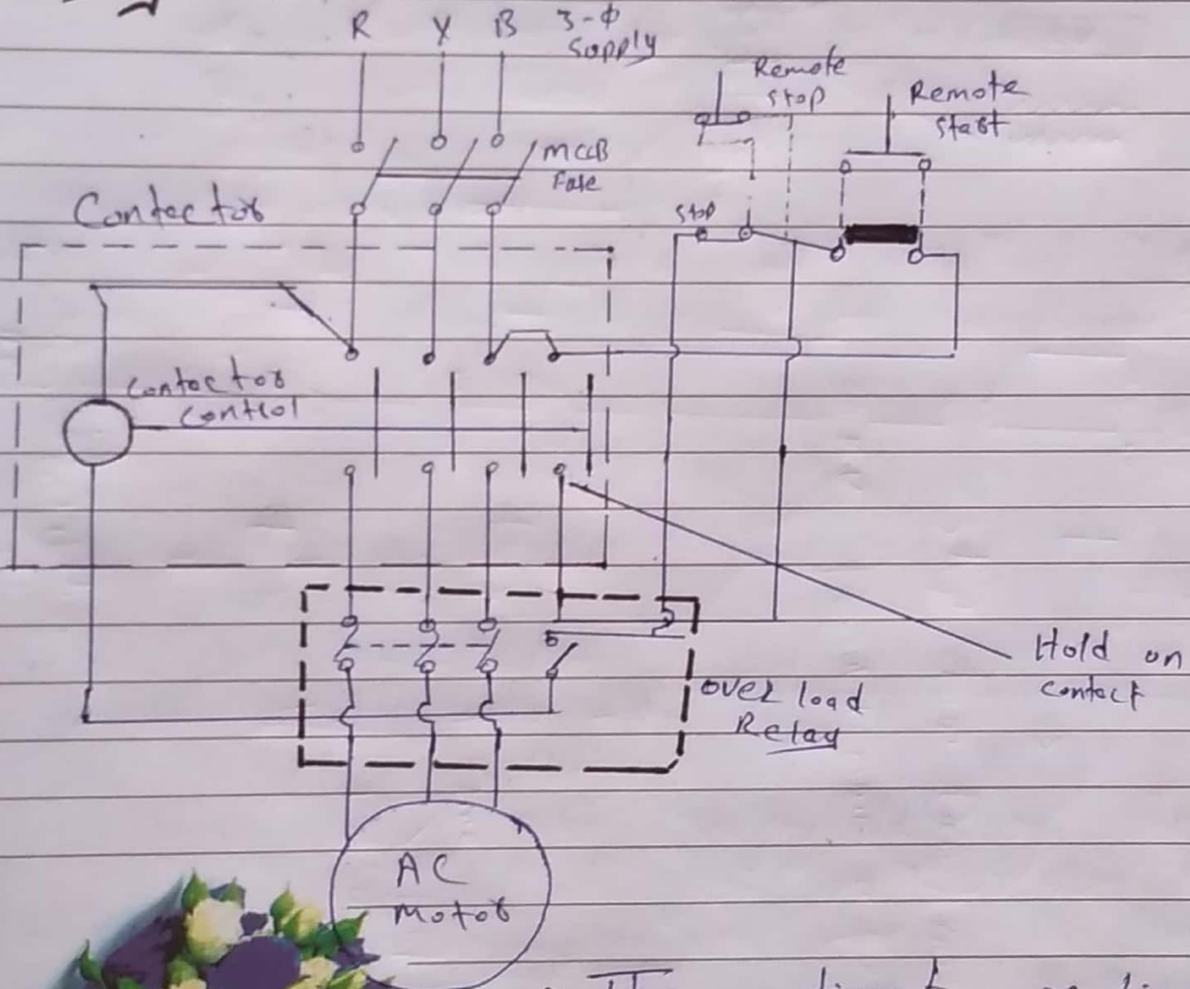
So the magnitude of resultant flux is $1.5\ \Phi_m$ time the maximum value if flux

Q#3: Discuss different types of starter for three phase induction motor.

Ans:-

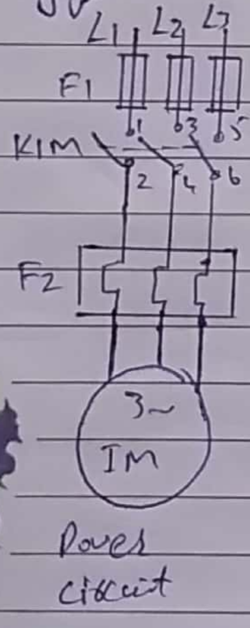
i) Direct on-Line starter (DOL)

Diagram:-

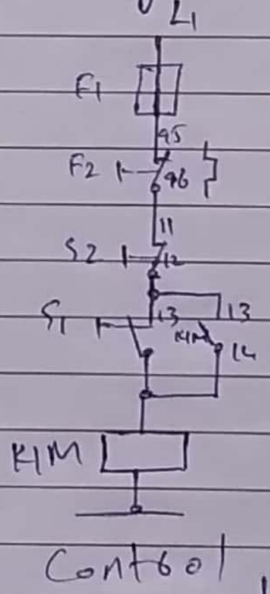


⇒ The direct on-Line (DOL) starter is the simplest and the most inexpensive of all starting methods and is usually used for squirrel cage induction motor.

It directly connects the contacts of the motor to the fully supply voltage. The starting current is very large normally 6 to 8 times the rated current. The starting torque is likely to be 0.75 to 2 times the full load torque. In order to avoid excessive voltage drops in the supply line due to high starting currents, the DOL starter is used only for motors with a rating of less than 5 KW. There are safety mechanisms inside the DOL starter which provides protection to the motor as well as the operator of the motor. The power and control circuit of induction motor with DOL starter and the real picture of contactor are shown in figures:-



Power circuit



Control circuit

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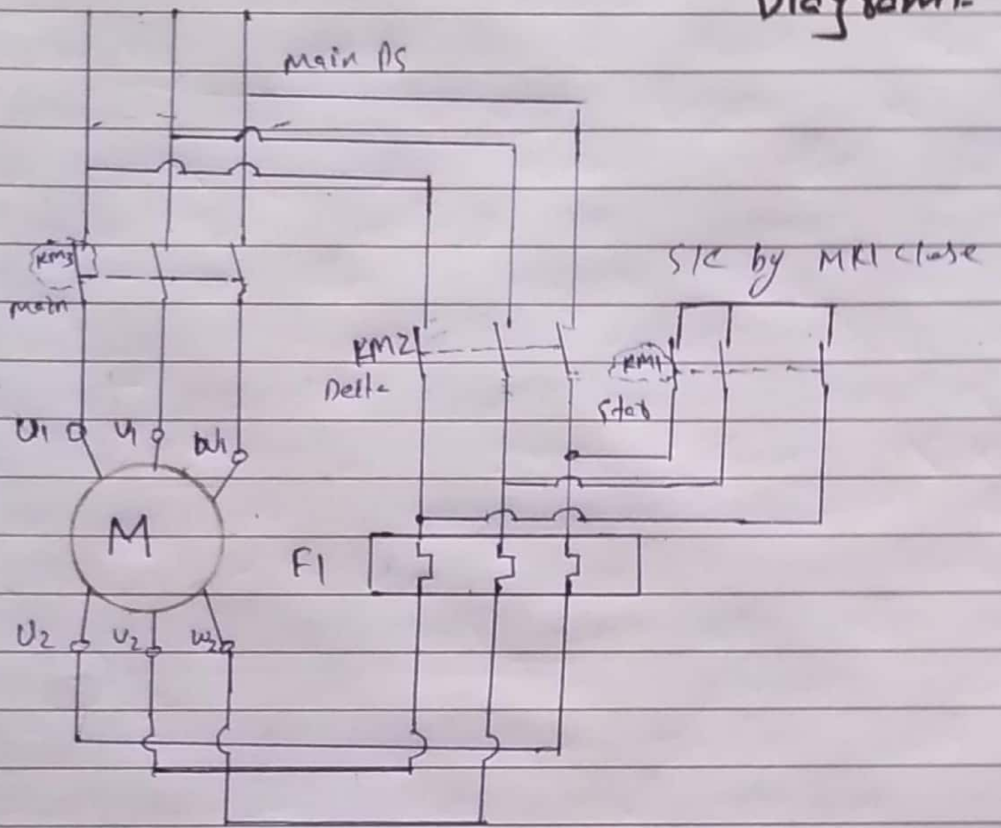
Star-Delta Starter:-

Diagram:-



1) KM3 = KM1 = Closed or main & Star contactor close
2) KM3 = KM1 = Open
3) Main & Delta closed and star is open

⇒ Theory:-

The Star delta Starting is a very common type of Starter and extensively used, Compared to the other types of the starters. This method used reduced supply voltage in Starting.

Figure shows the Connection of 3-ϕ induction motor with a Star-delta Starter. The method achieved low starting current by first connecting the stator winding in star configuration, and then after the motor reaches a certain speed, through switch changes the winding arrangements from star to delta configuration.

Auto Transformer Starter :-

The operation principle of auto transformer is similar to the star delta starter method. The starting current is limited by (using a three phase auto transformer) reduce the initial stator applied voltage. The Auto transformer starter is more expensive, more complicated in operation and bulker in construction when compared with star-delta starter method.

It can brief operation of auto transformer as.

1. Operation by a two position switch i.e. manually/automatically using a timer to change over from start to run position.
2. In starting position supply is connected to stator windings through an auto transformer which reduces applied

voltage to 50, 60 and 70% of normal value depending on tapping used.

3. Reduced voltage reduces current in motor windings with 50% tapping used motor current is halved and supply current will be half of the motor current. Thus starting current taken from supply will only be 25% of the taken by DOL.

4. For an induction motor, torque T is developed by V_2, thus on 50% tapping, torque at starting is only $(0.5V)^2$ of the obtained by DOL starting. Hence 25% torque is produced.

5. Starters used in larger industries, it is larger in size and expensive.

6. Switching from start to run positions causing transient current, which can be greater in value than those obtained by DOL starting.

Rotor Impedance Starter.

This method allows external resistance to be connected to the rotor through slip rings and brushes. Initially, the rotor resistance is set to maximum and is then gradually decreased as the motor speed increased, until it becomes zero. The rotor impedance starting mechanism is usually very bulky and expensive when

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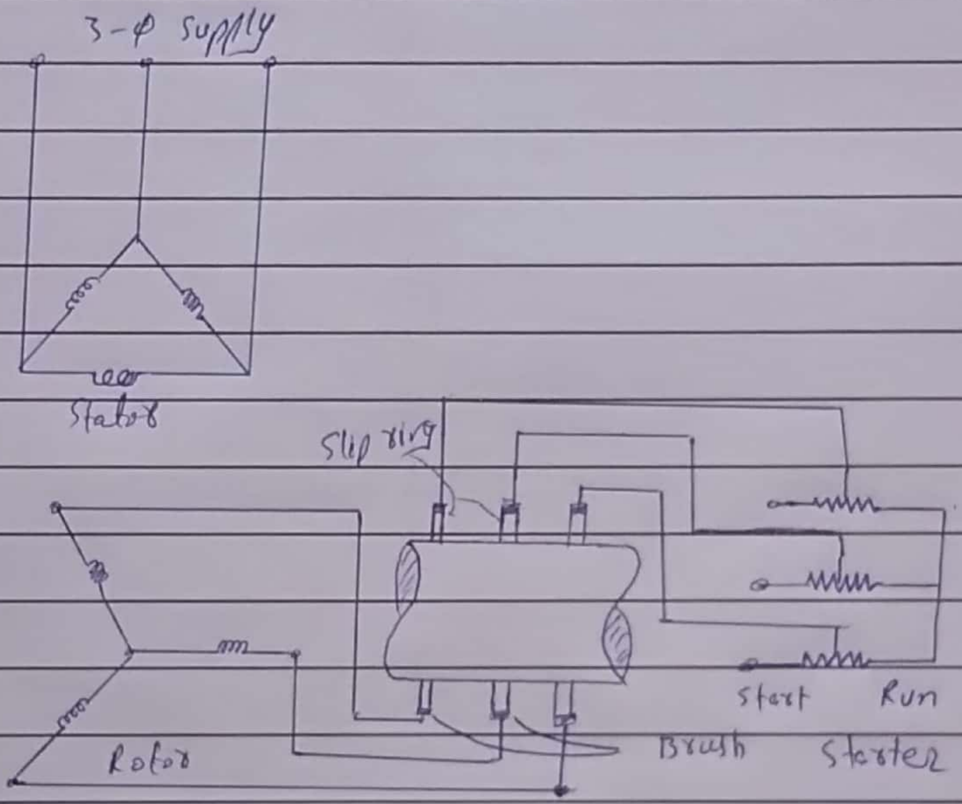
compared with other methods. It also has very high maintenance costs.

Diagram:-



This will decrease the starting current, increase the starting torque and also improves the power factor (P.F).