Assignment # 01

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Electrical Machine II

Program:

EET

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Question # 1

Write Introduction, Advantages, disadvantages and Construction of three Phase Induction Motor.?

An electrical motor is an electromechanical device which converts electrical energy into mechanical energy. In case of three phase AC operation, the most widely used motor is a 3 phase Induction motor.

⇒ Introduction:

The Popularity of 3ϕ Induction motor on board Ships is because of their Simple, robust construction and high reliability facts in the Sea environment. A 3-ϕ induction motor can be used for different applications with various speed and load requirements. The 3-ϕ Induction motor are the most widely used electric motor 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. 3-ϕ Induction motors are simple, rugged,

Low-priced, easy to maintain and can be manufactured with characteristics to suit most industrial requirement. Like any electric motor, a 3-ϕ Induction motor has a stator and a rotor. The stator carries a 3-ϕ winding while the rotor carries a short-circuited winding. only the stator winding is fed from 3ϕ supply. The rotor winding derives its voltages and power from the externally energized stator winding through electromagnetic induction hence the name.

⇒ Advantage's:

There are many advantages of 3-ϕ Induction motor. In which:

i) It has simple and rugged construction.
ii) It is relatively cheap.
iii) It requires little maintenance.
iv) It has high efficiency and reasonably good power factor.
v) It has self starting torque.
vi) The operation of 3-ϕ Induction motor is quite reliable.

=> Disadvantage's:

There are few disadvantages of 3-phase induction motor:

i) The speed control of an induction motor is not possible without sacrificing its efficiency level.

ii) Also, the speed of the motor decreases with increasing mechanical load.

iii) Its starting torque is a little bit lower than that of a Dc shunt motor.

=> Construction:

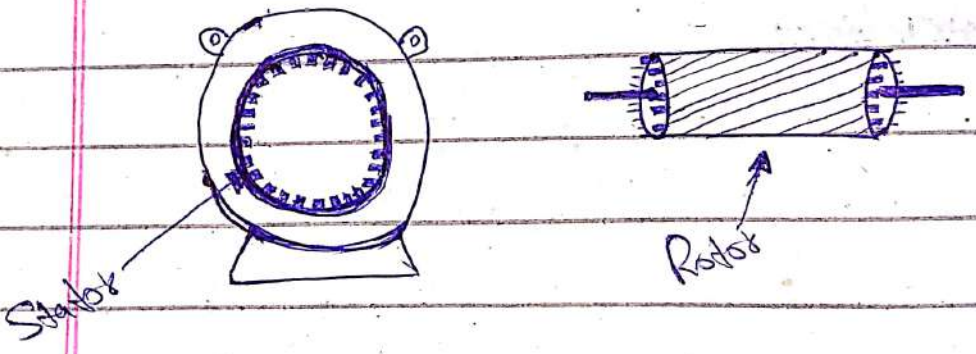
3ϕ induction motor is the most widely used electrical motor. Almost 80% of the mechanical power used by industries is provided by 3ϕ induction motor's because of its simple and rugged construction, low cost, good operating characteristics, absence of commutator and good speed regulation. In 3-ϕ induction motor the power is transferred from Stator to rotor winding through induction. The induction motor is also called asynchronous motor as it run at

a speed other than the synchronous speed. Like any other electrical motor induction motor also have two main parts namely rotor and stator.

A three phase induction motor has two main parts

i) Stator ii) Rotor

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



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

ii) Bearing for supporting the rotating shaft.

iii) One of the problems with electrical motors is the production of heat during its ~~heat~~ rotation. In order to overcome this problem we need for Fan Cooling.

iv) for receiving external electrical connection terminal box is needed.

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

i) Rotor:

The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft. Rotor is consists of cylindrical laminated core with parallel slots that carry conductor bars. Conductor's are ~~bar~~ heavy copper or aluminium bars which fit in each slots. These conductor's are brazed to the short circuting end ring's. The slots are not exactly made parallel to the axis of the shaft but are slotted a little skewed for the following reason.

There are two main types of a rotor

i) Squirrel cage rotor.

ii) Wound type rotor.

i) Squirrel Cage Rotor:

The rotor of the squirrel cage 3ϕ induction motor is cylindrical in shape and have slots on its periphery. The slots are not made parallel to each other but are bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and make the working of motor more smooth and quieter. The squirrel cage rotor consists of aluminum, brass or copper bars.

Advantage of Squirrel Cage I.R:

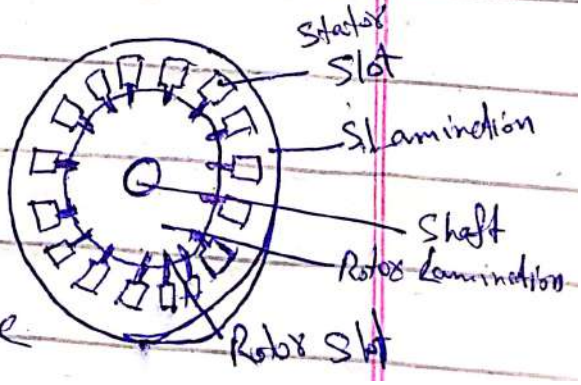
i) Its construction is very simple and rugged.
ii) As there are no brushes and slip rings, these motor requires less maintenance.

Application:

Squirrel cage induction motor is used in lathes, drilling machines, fan, blower, printing machines etc.

⇒ ii) Wound rotor:

Slip ring or wound three phase induction motor in this type of three phase induction motor the rotor is wound for same no. of poles as that of stator but it has less number of slots and has less turn per phase of a heavier conductor. The rotor also carries star or delta winding similar to that of stator winding. The rotor consists of no. of slots and rotor winding are placed into inside these slots. The three end terminals are connected together to form star connection. As its name induction 3ϕ slip ring induction motor consists of slip rings connected on same shaft as that of rotor. The three end of 3ϕ winding are permanently connected to these slip rings. The external resistance can be easily connected through the brushes and slip rings and hense used for speed control and improving the starting torque of 3ϕ induction motor. The external Resistance are used during starting period only. When the motor attains normal speed, 3 brushes are



Short-circuited so that the wound rotor runs like a squirrel cage rotor.

Advantages of slip ring:

i) It has high starting torque and low starting current.

ii) Possibility of adding additional resistance to control speed.

Application:

Slip ring induction motor are used where high starting torque is requried in hoists, cranes, elevator etc.

ii) Stator:

As it's name indicates Stator is a stationary part of induction motor. A Stator winding is placed in the Stator of induction motor and the 3ϕ supply is given to it. Stator is made up of no of stampings in which different slots are cut to receive 3ϕ winding circuit which is connected to 3ϕ AC Supply. The 3ϕ winding are arranged in such a manner in the slots that they produced a rotating magnetic field after A.C

is given to them.

It Consists of a steel frame which enclose a hollow, cylindrical core made up of thin lamination of Silicon steel to reduce hysteresis and eddy current losses. when 3Φ supply is given to the Stator winding, a rotating magnetic field of con constant magnitude is produced. This rotating field induces, current in the rotor by electromagnetic induction.

The Stator of three phase induction motor consists of three main parts:

i) Stator Frame:

It is the outer most part of the 3Φ induction motor. It main function is to support the stator core and the field winding. It acts as a covering and it provide protection and mechanical strength to all the inner parts of the induction motor. The frame is either made up of die cast or fabricated steel.

ii) Stator Core:

The main function of the stator core is to carry the alternating flux. In order to reduced the eddy current loss, the stator core is laminated. These laminated types of structure are made up of stamping which is about 0.4 to 0.5mm thick. All the stamping are stamped together to form stator core, which helps to reduced the hysteresis loss occuring in motor.

iii) Stator winding:

The slots on the periphery of stator core of the motor carries 3ϕ windings. This 3ϕ winding is supplied by 3ϕ A.C supply. The 3ϕ of the winding are connected either in star or delta depending upon which type of starting method is used. The squirrel cage motor is mostly started by star-delta starter and hence stator of squirrel cage motor is delta connected.

Question No. 2

write operation principal (working) of three Phase Induction Motor.

The Stator of the motor consists of overlapping winding offset by an electrical angle of 120° when we connected to primary winding or the Stator to a 3ϕ AC source, it establishes rotating magnetic field which rotates at the synchronous speed.

Secrets behind the rotation: According to Faraday's law an emf induced in any circuit is due to the rate of change of magnetic flux linkage through the circuit As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring. cut the Stator rotating magnetic field, an emf is include in the rotor copper bar and due to this emf a current flows through the rotor conductor.

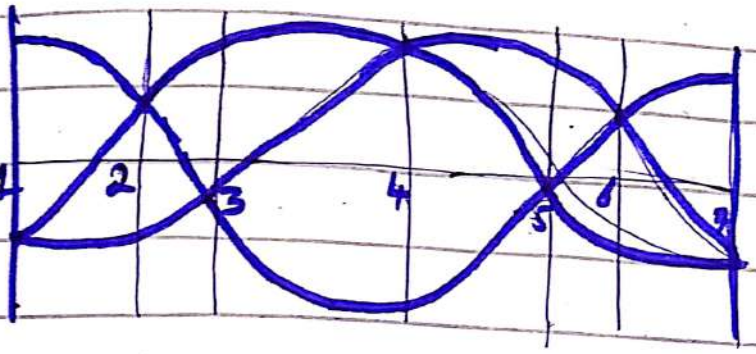
Thus from the working principle of 3ϕ induction motor, it may

be observed that the rotor speed should not reach the synchronous speed produced by the stator. if the speed become equal, there would be no such relative speed. So no emf induced in the rotor, and no current would be flowing, and therefore no torque would be generated. Consequently, the rotor cannot reached the synchronous speed. The difference between the stator and rotor speed is called the slip. The rotation of the magnetic field in an induction motor has the advantages that no electrical connections need to be made to the rotor.

⇒ Three phase Rotating field:

Three phase induction motor also operates on the principle of a rotating magnetic field. The following discussion shows how the stator windings can be connected to a 3φ ac input and have a resultant magnetic field that rotates.

The 3φ input voltage to the stator in the graph of Figure.



Use the Left hand rule for determing the electromagnetic Polarity of the poles at any given instant. In applying the rule to the coil in figure, Consider that current flows towards the terminal number for positive voltages and away from the terminal no. for negative voltage.

Genration of rotating magnetic field:

when a 3φ winding is energized from a 3-φ supply a rotating magnetic field is Produced This field is such that its poles do no remain in a fixed position on the Stator but go on shifting their position around the stator for this reason, it is called a rotating held. Considered a 3φ

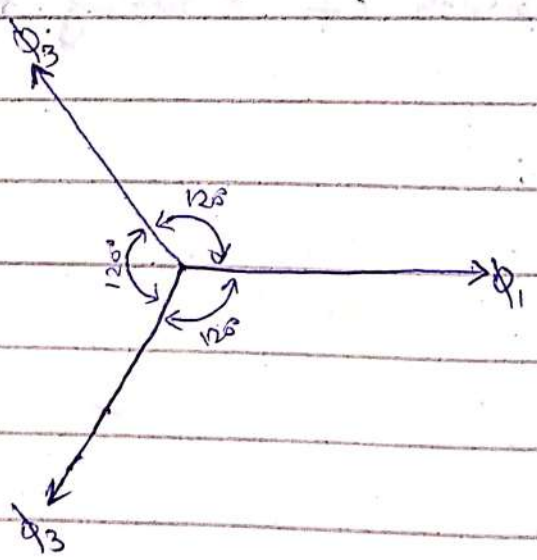
winding displaced in a space by 120°. supply by 3ϕ A.C supply. The 3ϕ current are also displaced from each other by 120°. the flux each phase current is also sinusidal in nature and all three flux are separated from each other by 120°. then the mathmatical equation for the instantanous value of the flux ϕ_1, ϕ_2, ϕ_3 can be given.

$\phi_1 = \phi_m \sin(\omega t) = \phi_m \sin(\theta - 0^\circ)$

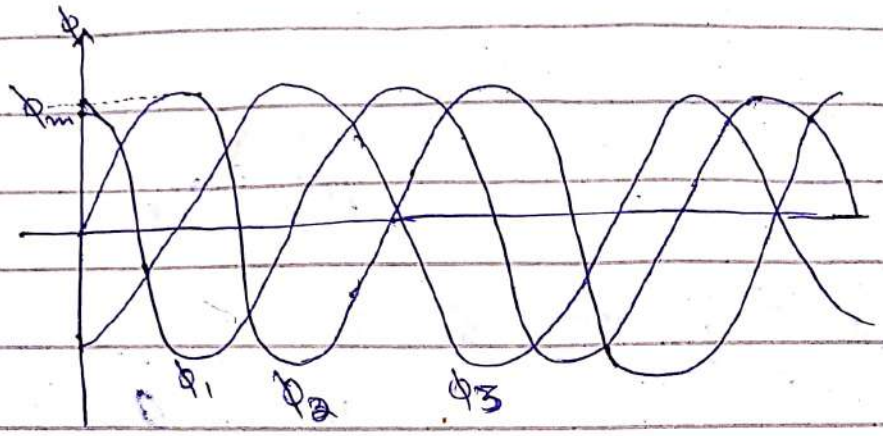
$\phi_2 = \phi_m \sin(\omega t - 120^\circ) = \phi_m \sin(\theta - 120^\circ)$

$\phi_3 = \phi_m \sin(\omega t - 240^\circ) = \phi_m \sin(\theta - 240^\circ)$

⇒ Assume positive direction



Wave From 3 Phase Flux



In Case #1 when $\theta = 0°$

$\phi_1 = \phi_m \sin(\omega t) = \phi_m \sin 0° = 0$

$\phi_2 = \phi_m \sin(\omega t - 120°) = \phi_m \sin(0° - 120°) = -0.866\phi_m$

$\phi_3 = \phi_m \sin(\omega t - 240°) = \phi_m \sin(0° - 240°) = 0.866\phi_m$

$\phi_T = \phi_1 + \phi_2 + \phi_3$

⇒According to diagram:-

Since $OD = DA = \phi_T/2$

Since $\triangle OBD$ the angle of $BOD = 30°$

So $\cos 30° = OD/OB = (\phi_T/2)/0.866\phi_m$.

$\phi_T = 2 \times 0.866\phi_m \times \cos 30° =$ **1.5ϕ_m**

In Case #2 when angle $\theta = 60°$

$\phi_1 = \phi_m \sin(\omega t) = \phi_m \sin 60° = 0.866\phi_m$

$\phi_2 = \phi_m \sin(\omega t - 120°) = \phi \sin(60° - 120°) = -0.866\phi_m$

$\phi_3 = \phi_m \sin(\omega t - 240) = \phi_m \sin(60° - 180°) = 0$

$\phi_T = \phi_1 + \phi_2 + \phi_3$

⇒ According to diagram

Since $OD = DA = \Phi_T/2$

Since ΔOBD, the angle of $BOD = 30°$

So $\cos 30° = OD/OB = (\Phi_T/2)/0.866\Phi_m$

$\Phi_T = 2 \times 0.866 \times \cos 30° = 1.5\Phi_m$

In Case of # 3 when $\theta = 120°$

$\Phi_1 = \Phi_m \sin(\omega t) = \Phi_m \sin 120° = 0.866\Phi_m$

$\Phi_2 = \Phi_m \sin(\omega t - 120°) = \Phi_m \sin(120° - 120°) = 0$

$\Phi_3 = \Phi_3 \sin(\omega t - 240°) = \Phi_m \sin(180 - 240) = -0.866$

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

⇒ According to diagram

Since $OD = DA = \Phi_T/2$

Since ΔOBD, the angle of $BOD = 30°$

So $\cos 30° = OD/OB = (\Phi_T/2)/0.866\Phi_m$

$\Phi_T = 2 \times 0.866\Phi_m \times \cos 30° = 1.5\Phi_m$

So the magnitude of resultant flux is 1.5Φ_m time the maximum value of flux

Case # 4 when $\theta = 180°$

$\Phi_1 = \Phi_m \sin(\omega t) = \Phi_m \sin 180° = 0$

$\Phi_2 = \Phi_m \sin(\omega t - 120°) = \Phi_m \sin(180 - 120) =$

$\Phi_2 = 0.866\Phi_m$

$\phi_3 = \phi_m \sin(\omega t - 240°) = \phi_m \sin(180° - 240°)$

$\phi_3 = -0.866 \phi_m$

$\phi_T = \phi_1 + \phi_2 + \phi_3$

⇒ According to diagram

Since $OD = DA = \phi_T/2$

Since ΔOBD, the angle of $BOD = 30°$

So $\cos 30° = OD/OB = (\phi_T/2)/0.866\phi_m$

$\phi_T = 2 \times 0.866 \phi_m \times \cos 30°$ **$= 1.5\phi_m$**

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

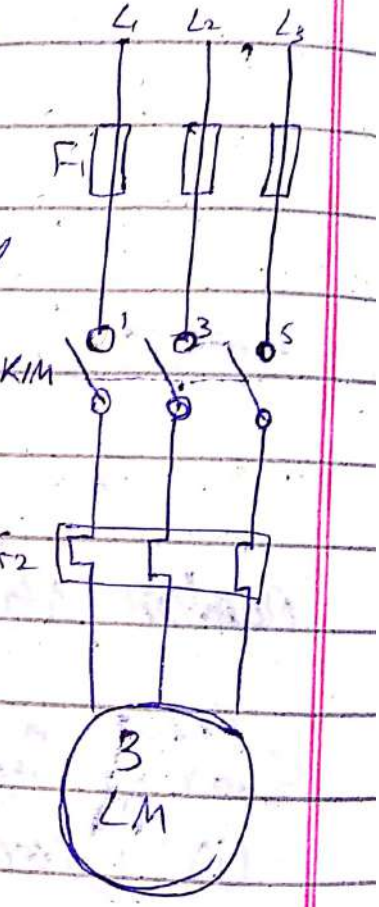
Question No. 3

Discuss different types of Starter for 3ϕ induction Motor.

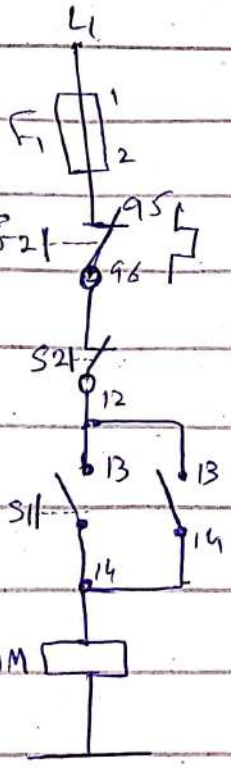
(i) Direct on-Line Starter (DOL)

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 motors. It directly connects the contacts of the motor to the full supply voltage. The starting current is very large, normally

6 to 8 times the rated currents. 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 for motors with a rating of less than 5Kw. There are safety mechanisms inside the DOL starter which provides protection to the motor as well as the operate of the motor. The power and control circuits of induction motor with DOL starter and the real picture of contactor are shown in figure →



The DOL starter consists of a power circuit coil operated contactor KM controlled by start and stop push button. On pressing the start push button S1, the contactor coil KM is energized from line L1. The 3 main contacts (1-2), (3-4) and (5-6) are closed. The motor is thus connected

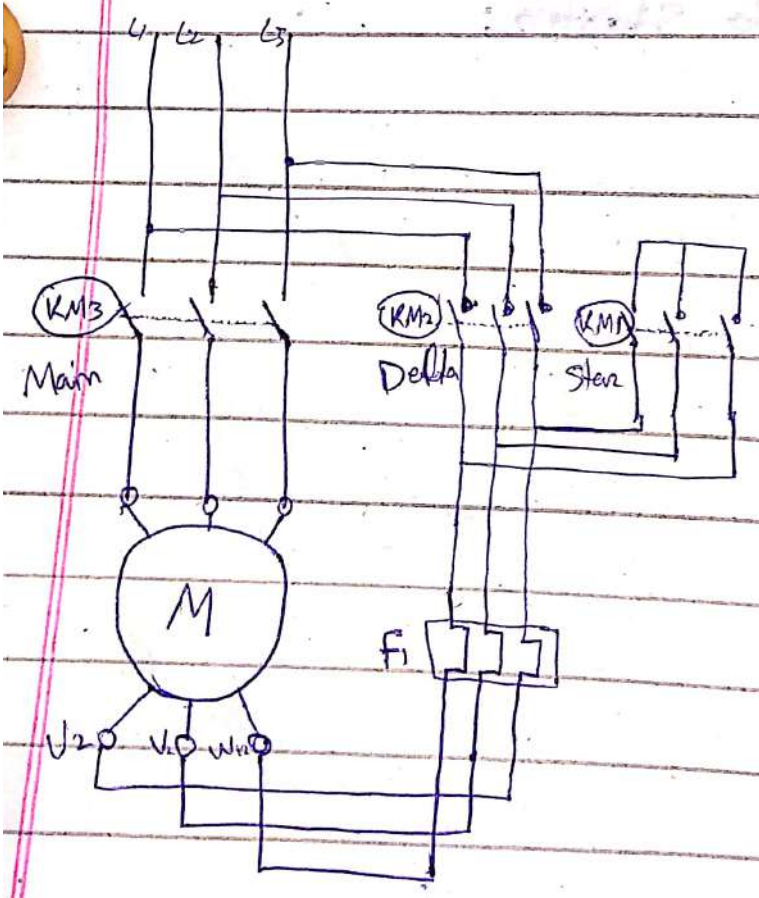


To the supply when the stop push button S2 is pressed, the supply through the contactor K1M is disconnected. Since the K1M is de-energized, the main contacts (1-2), (3-4) and (5-6) are opend. The supply to motor is disconnected and (Control Circuits) the motor stops.

ii) Star-Delta starter:

The star delta starter is a very simple common type of starter and extensively used, Compared to the other type of the starters. The method achived low starting current by first connecting the stator winding is star configuration, and then after the motor reaches a certain speed, throw switch changes the winding arrangments from star to delta configuration. By connecting the starter winding first in star and then in delta, the line current drawn by the

motor at Starting is reduced to one-third as Compared to starting Current with the winding Connected in delta. At the time of Starting when the Stator windings are start Connected, each stator phase gets voltage $V_L/\sqrt{3}$, where V_L is the Line voltage. Since the torque developed by an induction motor is proportional to the Square of the applied voltage, Star-delta Starting reduced the starting torque to one-third that obtained by direct delta starting.



iii) Auto Transformer Starter:

The operation principle of auto transformer method is similar to the star delta starter method. The starting current is limited by (using a 3ϕ auto transformer) reduced the initial starter applied voltage. The auto transformer starter is more expensive, more complicated in operation and bulkier in construction when compared with the star-delta ~~connected motors~~ methods. But an auto transformer starter is suitable for both star and delta connected motor's, and the starting current and torque can be adjusted to a desired value by taking the correct tapping from the auto transformer. when star delta method is connected voltage can be adjusted only by factor of $1/\sqrt{3}$.

➔ It can brief operation of auto transformer as:

i) Operated by a two position switch manually/automatically using a timer to change over from start run position.

ii) In starting position supply is connected

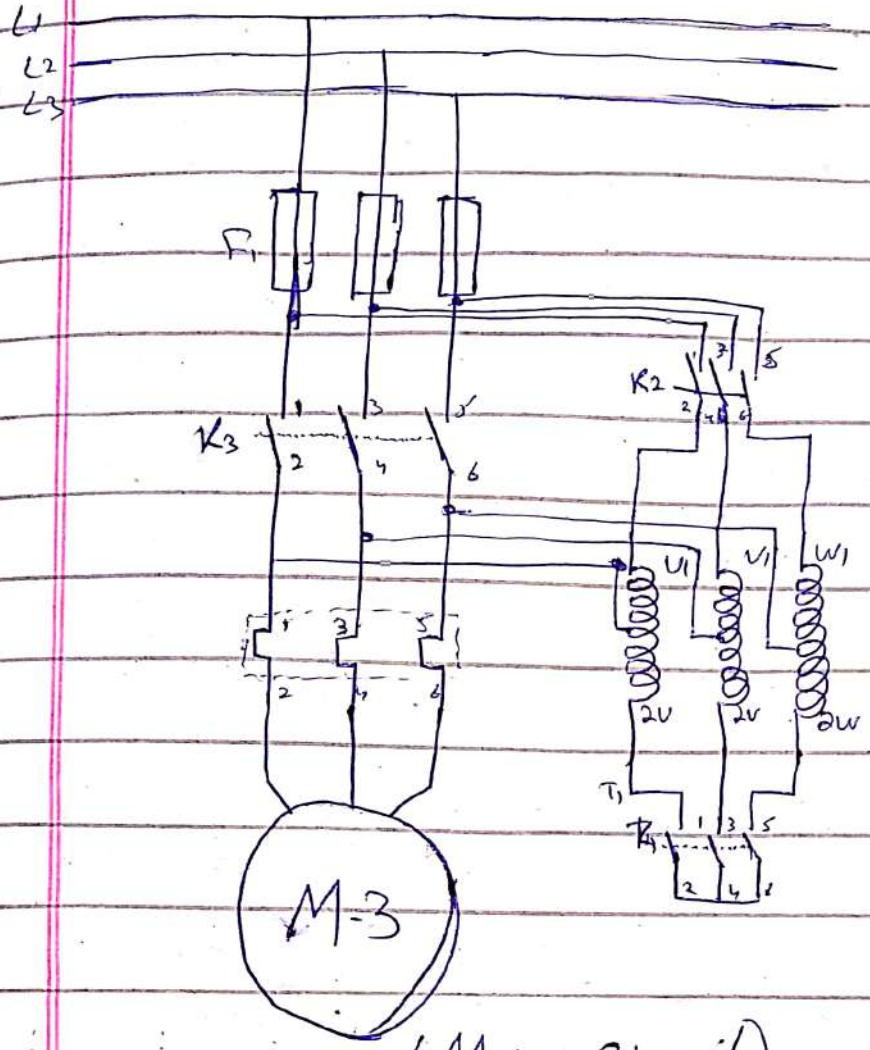
to Stator winding through an auto-transformer which reduces applied voltage to 50, 60, and 70% of normal value depending on tapping used.

iii) Reduced voltage reduces current in motor winding 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 be 25% of the taken by DOL Starter.

iv) 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.

v) Starter used in larger industries, it is larger in size and expensive.

vi) Switching from start to run position causing transient current which can be greater in value than those obtained by DOL Starting.



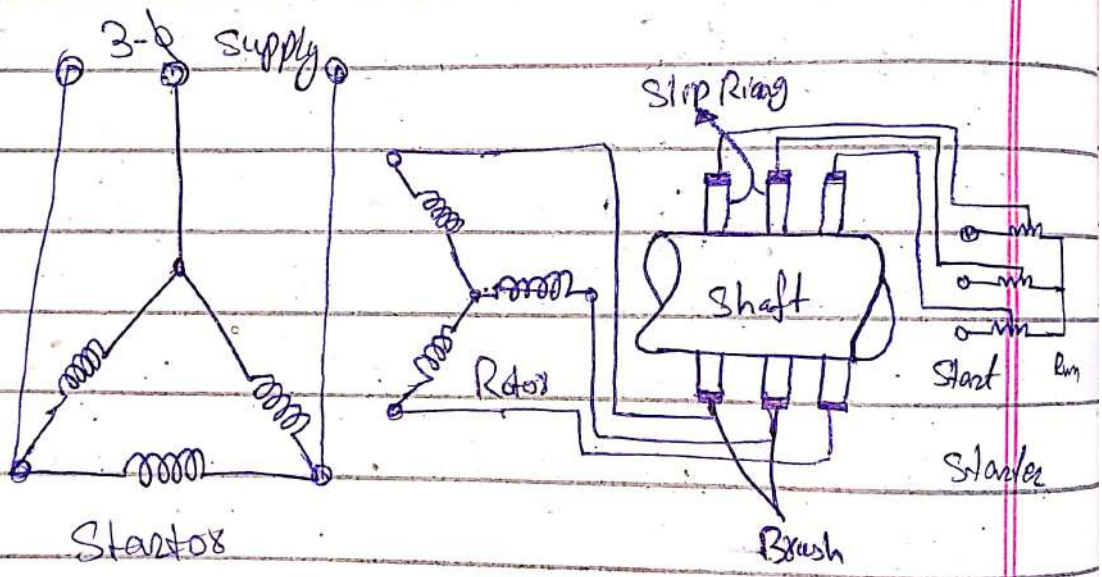
(Main Circuit)

(Power and control circuit of 3φ IM with auto-transformer Starter)

iv) Rotor impedance Starter:

This method allows external resistence connected to rotor through slip rings and brushes. Initially, the rotor resistance is set to maximum and is then gradully decrease as the motor speed increase until it become zero. The rotor impadance starting mechanism is

Usually very bulky and expensive when compared with other methods. It has very high maintinance costs. Also, a considerable amount of heat is greater through the resistence when current runs through them. The starting frequency is also limited in this method. However, the rotor impedance method allows the motor to be started while on load.



This will decrease the starting current, increase the starting torque and also improves the power factor. The circuit diagram is shown below. In the circuit diagram, the three slip rings shown are connected to the rotor terminals of the wound rotor motor. At the time

of starting of the motor, the entire external resistance is added in the rotor circuits. Then the external rotor resistance is decreased in steps as the rotor speeds up, however the motor torque remain maximum during the acceleration period of the motor. Under normal condition when the motor developed load the external resistance is removed.