UNIT 3
SPEED CONTROL AND STARTING

STARTING

Need for starter In case of DC Motor

When the DC motor is directly switched on to the supply it takes huge current. This current will damage the motor, if it is not reduced. The reason for huge current is explained below.

The voltage equation of DC motor is given by,

$$V = E_b + I_a R_a$$

From the voltage equation, the current drawn by a DC motor is given by

$$I_a = \frac{V - E_b}{R_a} \longrightarrow (1)$$

Where, V – supply Voltage
E_b - Back emf
R_a - Armature resistance

From the above equation it is clear that total voltage across armature is reduced because of back emf. The back emf is generated when the motor rotates. During starting the motor is at stand still and no back emf is developed in the armature (E_b = 0). If fully supply voltage is applied across stationary armature, it draws, it draws a very large current. Now the current taken by the motor is given by,

$$\text{Equation (1) becomes} \quad I_a = \frac{V}{R_a} \longrightarrow (2)$$

This is the starting current which is of very large value and capable of damaging the motor. This huge starting current is due to the absence of back emf (E_b). The value of starting current can be estimated from the following rough calculation. For a supply voltage of 440 V and armature resistance of 0.25 Ω the starting current according to equation 92) is I_a = 1760A which is nearly "35 times" of its full load current. This excessive current will below out the fuses and prior to that, it will damage the commentator and brushes in the motor. This initial high current should be restricted. The deice that is used to restrict initial high current (starting current) to a safe value is known as starters. Very small motors are started be connecting them directly to the supply lines, without starter because,

1. Small motor (upto 2 KW) have relatively higher armature resistance than the large motor hence their starting current is not so high.

2. Being small, they have low moment of inertia and hence they speeds up quickly. Here the back emf builds up quickly to restrict the initial inrush of current.

Disadvantages of high starting current

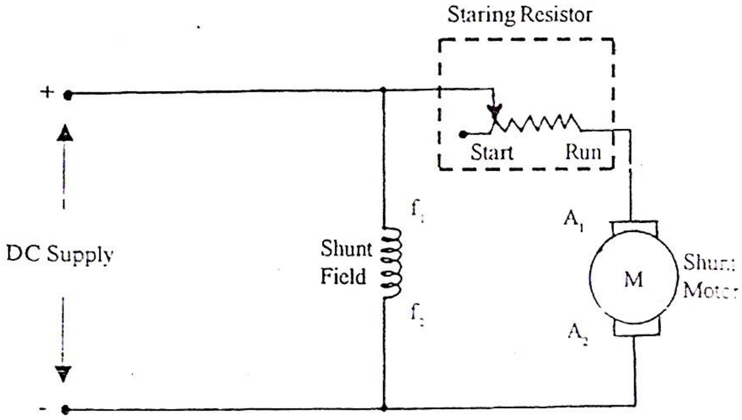
1. Due to high starting current, the supply lines are heavily loaded and huge voltage drop takes place. This affects other consumers connected to that supply lines.

2. Due to very high starting current, the motor generates huge torque and hence damages the load connected to it.

The principle of starter in DC motor

The principle of starter is based on inserting a variable resistor in the armature circuit during starting. This resistor is inserted during starting and removed during running and is known as starting resistor. The starting resistor restricts the initial high current i.e. starting current. The starting resistor causes voltage drop and as a result only part of the supply voltage is applied across the armature. Since the voltage across the armature is reduced the high current taken by the motor during starting is considerable reduced. If starting resistor is connected before the armature and field windings, it reduces both armature current and field current (Flux), as a result the starting torque is also reduced.

So the starting resistor should connected only in the armature circuit. If the motor develops speed, the back emf is increased. So the current taken from the supply main is reduced. Therefore the starting resistor is not required when the motor is running. Usually the starting resistor is gradually removed from the armature circuit, when the motor picks up speed. When the motor reaches rated no load speed, the starting resistor is completely removed from the armature circuit.



The connection diagram shows the method of connecting starting resistor in the armature circuit during starting. During starting, the movable arm of starting resistor is in the position . When the motor attains rated speed the movable arm is placed in the other end (Resistance, R = 0)

Types of DC motor starters

The starter for DC motor is classified into three types based on number of connection points available in it. They are,

1. Three – point Starter
2. Four – Point Starter
3. Two – Point Starter

The three – point starter is used for starting DC shunt and compound motor. The two-point starter is used for starting DC series motor.

Starter for DC shunt motor and Compound Motor

DC stunt motor and compound motor can be started with three-point starter as well as with four-point starter. The following section deals with Three-point starter and four point starter in detail.

(a) Three-point Starter

The three – point starter consist of the variable resistance, available with number of partitions. It has three connection points namely L,F and A. Hence it is known as three-point starter.

L - Line terminal - Connected with supply mains.
F - Field terminal - Connected with field circuit of DC motor
A - Armature terminal - Connected with armature circuit of DC motor

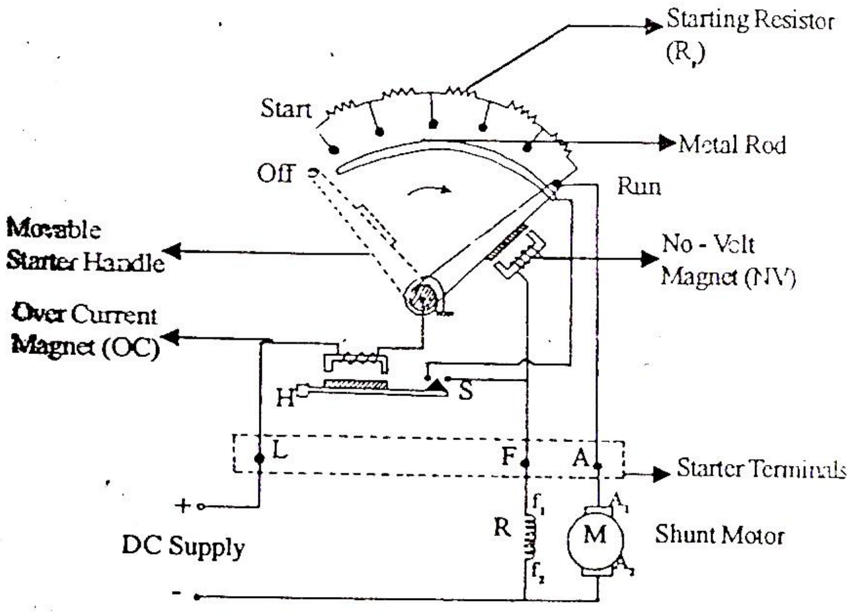
The supply main is connected to the connection point L. The connection point L is connected to Over Current magnet(OC). The OC is connected with conducting movable arm which makes contact with variable starting resistor. The other end of the starting resistor is connected to the connection point A. The connection point F is connected with the No volt magnet (NV)

Operation

The motor is connected with the starter as shown in the connection. Here the DC shunt motor is connected with the Three-point starter. The supply main is connected with point L. The shunt field (f_1 and f_2) of the motor is connected with point. The armature (A_1 and A_2) is connected with the control spring.

The start the motor, the handle is slowly moved against the control spring force, to make contact with first division (on position) of the variable starting resistance. At this point field winding gets supply through the metal rod and the No-Volt coil is energized. The metal rod forms parallel path with the starting resistance. The this point entire starting resistance is available in the armature circuit. As the handle moved further, it goes on making contact with divisions 2, 3, 4 etc. When starter handle is at division 3, the division to 1 and 2 are removed from the circuit.

If the starter handle reaches Run position, the entire starting resistance is removed from the armature circuit. Now the motor runs at rated speed. The starter is placed in the Run position with the help of No – Volt magnet.



Function of No-Volt magnet (NV)

1. The No-Volt magnet keeps starter handle at run position against the control spring. The No-Volt magnet attracts the soft iron bar place din the handle. The No-Volt magnet is energized by the current flowing through the field circuit. If there is no No-Volt magnet, the starter handle is pulled back to the Off position by the control spring and the motor is switched Off.

2. During the failure of DC supply the No-Volt magnet is de-energized so the magnetic power is lost. The handle comes backs to the Off position by the action of control spring, if the No-Volt magnet is not there.

Due to the presence of No-Volt magnet and control spring the starter handle comes backs back to the Off position whenever the supply fails. If there is no control spring then handle remains in the run position when the supply fails. When the supply returns the motor is directly connected to the supply main, developing high starting current.

3. During low voltage condition the No-Volt magnet releases the handle to the Off position and hence protect the motor form low voltage

Function of Over Current magnet (OC)

When the load on motor increases above the rated limit then the armature takes high current. When the motor is left unprotected from this high current, then it is damaged. The over current magnet is used for this protection. When there is high current due to over load or due to short circuit the over current magnet is energized and attracts soft iron rod H. As a result, the soft iron rod H closes the switch S. When the switch S is closed, it short circuits the No-Volt magnet. As a result No-Volt magnet is de-energized and release the starter handle to the Off position. So the motor is switched off and protected from the over current or high current.

Disadvantage of Three point starter

During the speed control of DC shunt motor, using flux control method, the field current is reduced to get speed above the rated speed. Now the No-Volt magnet is de-energized due to reduced field current. This is because No-Volt magnet is connected in the field circuit. Since the No-Volt magnet is de-energized, the handle reaches Off position and the motor is switches Off. This problem can be rectified if No-Volt coil and field circuit are separated. This is done four – point starter, which is described in the following section.

(b) Four Point Starter

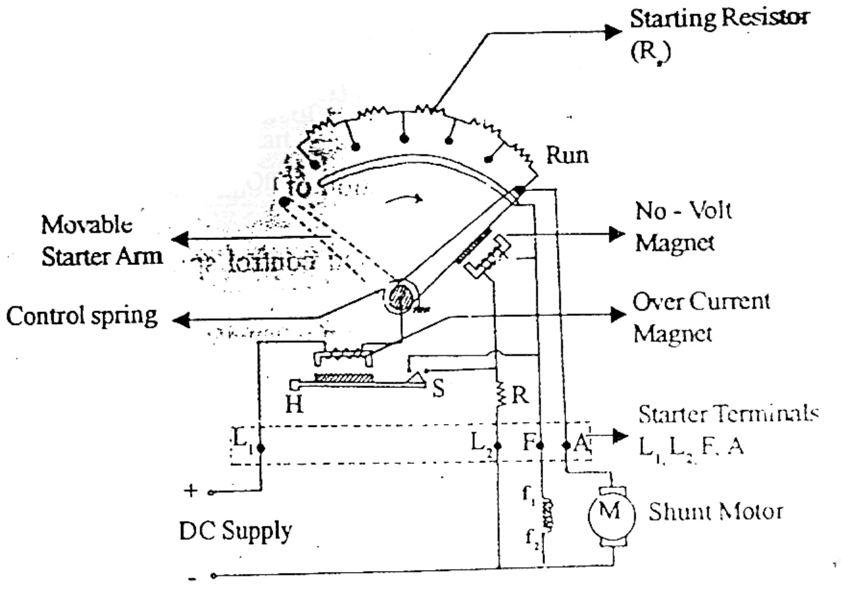
The Three-point starter control circuit cannot be used for speed control of DC shunt motor and compound motor. This is because in Three-Point starter, the No-Volt magnet and field windings are in the same circuit and connected to point F. The four – point starter is the modification of three point starter so that it is used for speed control of DC motor. Hence No-volt magnet and field winding is placed in the separate circuits. The four-point starter has four connection terminals namely L_1, L_2 F and A

L_1 - Terminal that is connected to the supply main
L_2 - Terminal that is connected to the No Volt magnet
F - Terminal that is connected to the field winding of the motor
A - Terminal that is connected to the armature of the motor

Operation

Initially the handle is at Off position. When the handle is placed is division 1 of the starting resistor, the three circuits are connected to the supply mains i.e. No-Volt magnet circuit, field circuit and armature circuit. Now full starting, resistance is in the armature circuit, so the starting current is reduced. When the handle is placed in the Run position, the No-Volt Magnet attracts the handle and the handle is placed in the Run Position against the action of spring control.

Here the No-Volt magnet which is connected to the L_2 to terminal is directly connected across the DC supply. So this circuit forms the shot circuit. To overcome this problem a resistor is included in the field circuit (F). The field current is reduced to get the speed above the rated speed. Here the No-Volt magnet circuit is not affected because it forms the separate circuit. So the problem of speed control that exist in three point starter is eliminated in the four – point starter. The Typical Control Circuit For starting Shunt Motor Using Four Point Starter.



Function of No-Volt magnet (NV)

1. The No-Volt magnet keeps starter handle at run position against the control spring. The No-Volt magnet attracts the soft iron bar placed in the handle. The No-Volt magnet is energized by the current flowing through the field circuit. If there is no No-Volt magnet the starter handle is pulled back to the Off position by the control spring and the motor is switched Off.

2. During the failure of DC supply, the No-Volt magnet is de-energized and the magnetic power is lost. So the handle comes back to the Off position by the action of control spring. Due to the presence of No-Volt magnet and control spring, the starter handle comes back to the Off

position whenever the supply fails. If there is no control spring, the handle remains in the run position when the supply fails. When the supply returns the motor is directly connected to the supply main, developing high starting current.

3. During low voltage condition the No-Volt magnet releases the handle to the Off position and hence protect the motor from low voltage.

Function of Over Current magnet (OC)

When the load on motor increases above the rated limit, then armature takes high current. When the motor is left unprotected from the high current, then it is damaged The Over Current magnet is used for this protection. When there is high current due to over load or due to short circuit, the over current magnet is energized and attracts soft iron rod H. Now the soft iron rod H closes the switch S. When the switch S is closed, it short circuit the No-Volt magnet is de-energized and release the starter handle to the Off position. So the motor is switched off and protected from the over current or high current.

Disadvantage of Four point Starter

The Four - point starter has only one disadvantage i.e. it does not provide high-speed protection. If the field circuit of the motor suddenly opens, the flux is zero. The speed is inversely proportional to Flux. Since the flux is zero speed becomes infinity theoretically, but practically speed rises to the dangerous limit. This problem is because of the fact that when the field circuit opens the No-Volt magnet is still energized and the motor is not switched Off. But this problem never takes place incase of three-point starter. If field circuit is opened the No-volt magnet present in the same circuit releases the starter handle, so the motor is switched off.

Starters for D.C. Series motor

The DC series motor has armature and field winding connected in series and hence forms the single circuit. So no extra terminal is required for the field circuit. Therefore DC series motor used special kind of starter known as Two-point starter.

Two-Point starter

All the series motor starters are based on same principle of inserting high resistance at starting in series with armature of motor and then gradually removing it when the speed increases.

The DC Series motor should be started with load. When DC series motor is started without load, the armature current is very low. In series motor, armature current is same as field current, so the flux is also very low. The speed of the motor is inversely proportional to the flux. If the flux is very low the speed becomes dangerously high. Hence the series motor should be started with load on it. The DC series motor hence needs the No Load protection besides No-Volt protection. So the two-point state for DC series motor is classified into two types. Namely

1. Two-point Starter with No-Load Protection
2. Starter with No-Volt Protection

(a) Two Point Starter (with No-Load Protection)

The Two-point starter has two terminals namely L and A. The DC series motor has only one circuit that contains armature connected in series with the field winding.

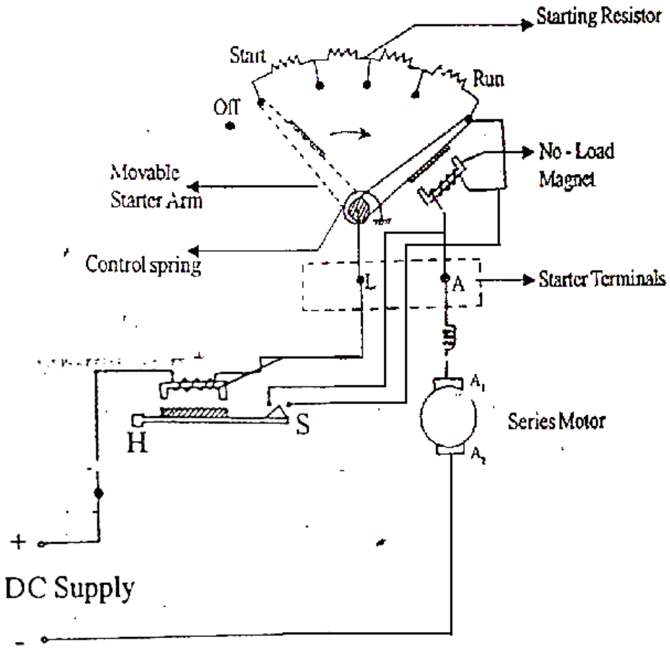
L - Line terminal - Connected with the supply main

A - Armature terminal - Connected with armature of the DC series motor

This starter provides No Load protection for DC series motor.

Operation

Initially the starter handle is in off position. To switch on the DC series motor, the handle is placed at division 1 (On) of starting resistance. Now the entire resistance is included in the series circuit containing armature and field winding. So the initial high starting current is reduced. Now the handle is gradually moved over the various divisions of starting resistance and finally reach the run position, where the entire starting resistance is removed from the series circuit. The handle is kept at Run position, due to the presence of No-Load magnet which is connected in series with the armature and field windings.



No-Load Protection

When the DC series motor is started without any load, the armature current is very low because of starter resistance. Since the starting current is very low due to the absence of load, the No-Load magnet is not sufficiently energized to attract the starting handle. So if the starter handle is placed at run position it returns back to the off position due to spring action. The DC series motor is now switched off and No Load protection is thus accomplished.

No-Volt Protection

When supply fails, the No-Volt magnet that is connected in parallel across the supply gets de-energized. As a result it releases the starter handle. So the starter handle reaches the off position, protecting the DC series motor from No-Volt. If No-Volt protection is not there, the starter handle remains at Run position. When supply returns the DC series motor is directly connected across the supply producing high starting current.

Disadvantage of Two point starter with No-Load Protection

The two-point starter seen above never provides the No-Volt protection. When the power fails and suddenly returns, the starter handle is at un position. This condition is equivalent to direct switch on of DC series motor. So there will be high starting current.

Need for starter in case of 3ϕ Inducting Motors

The 3ϕ inducting motor has two windings namely stator winding and rotor winding. Stator winding is supplied with 3ϕ supply. The rotor winding ahs conductors whose ends are short circuited. Now a 3ϕ induction motor is considered as transformer whose secondary (rotor) is short circuited. The stator winding is considered as primary or the transformer and the Rotor winding is considered as secondary of the transformer and the Rotor winding is considered as secondary of the transformer. The rotor conductors are short circuited, hence there is heavy rotor current which require corresponding heavy stator balancing current. Thus the stator of the 3ϕ induction motor draws heavy current during starting.

The heavy starting current has value equal to 5 to 7 times of full load current. The small induction motors upto 5 HP capacity may be directly switched on to the supply lines, using the starter called Direct – on-lines starter. But those of higher capacity must use some type of starting device or starters to restrict high starting current.

The principle behind all starting device is to reduce some amount of voltage applied to the starter winding during starting. The 3ϕ induction motor is of two types, namely squirrel cage induction motor and slip ring induction motor. In squirrel cage induction motor starter can be connected only in the stator side. But in the slip ring induction motor the starters can be connected both in stator side and rotor side.

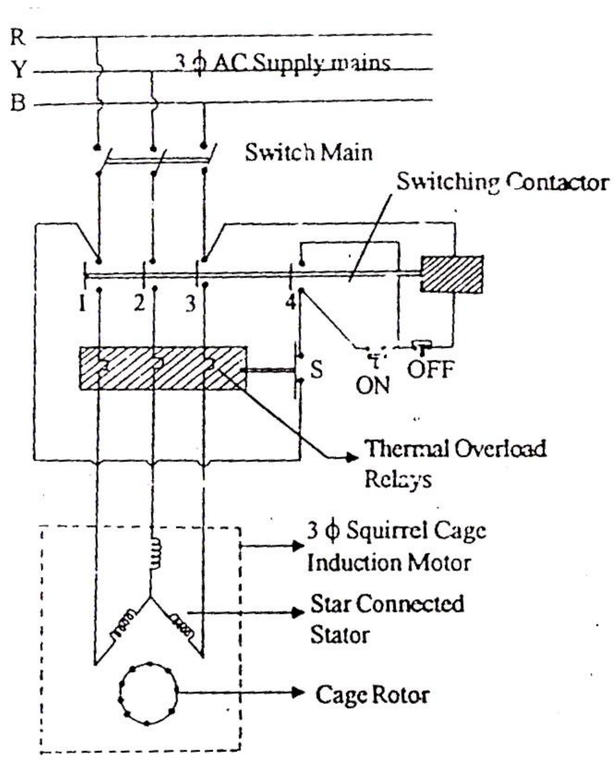
Starters for 3ϕ squirrel Cage Induction Motor

The 3ϕ induction motor has high starting current due to short circuited rotor conductors. The starters in case of squirrel cage induction motor can be connected only in the stator side, because rotor is short circuited. The small motors up to 5 HP can be directly switched on to the supply using Direct-on-line starter.

1. **Starter Up to 5 h.p**
   a) Direct-on-line starter
2. **Starter above 5 h.p**
   a) Stator rheostat starter
   b) Auto transformer Starter
   c) Star-delt Starter

(a) Direct-On-Line Starter (DOL Starter)

The 3ϕ induction motor below 5 HP can be directly switched on to the supply mains by means of DOL Starter. The motor below 5 HP has high armature resistance and hence has low starting current. Hence the motors up to 5 HP can be directly switched on using DOL Starter. The DOL starter provides protection against No-Voltage and Overload current.



Operation

The 3ϕ induction motor (upto 5HP) is started by means of DOL starter. Typical control circuit for starting 3ϕ induction motor by DOL starter. The induction motor is connected to supply mains through switching main and four normally open contacts. Initially the switching main is closed. The DOL starter consists of a Switching contacts are activated by plunger and No-volt coil arrangement. No-Volt coil is connected through two push buttons (ON and OFF) across any of the two phases of 3ϕ supply. The ON and OFF button are used to start and stop the motor. These are the manually operated control buttons available in DOL starter. There is a set of thermal relays which is connected in series with stator of induction motor provide overload protection.

To start the motor, the “ON” push button (normally open) is pressed which energize the ‘No-Volt Coil’ by connecting across two phase. The No-Volt, Coil pulls the plunger is such a direction that all the normally open (N.O) contacts are closed and now the motor is connected across the supply through three contacts. The fourth contact (4) serves as a 'hold on contact', which keeps the no volt coil circuit complete even after the ON Push button is released.

When the supply goes off or when 'OFF' switch (normally closed) is pressed, the No-Volt coil circuit is opened and hence is de-energized, as a result plunger is released. And all the contacts returns to open position thereby, disconnecting the motor from the supply mains. When the motor is overloaded, the thermal over load coil opens the switch S, hence the No-Volt coil circuit is open and plunger is sent back the contacts to normally open position. Thus disconnecting motor from the supply.

Expression for Starting Torque

We know that,

Rotor input = $2\pi N_s T = KT$

Also rotor cu loss = $31_2^2 R_2$ = S x rotor input

Therefore $3I_2^2 R_2 = RKT$

$$T \;\alpha\; \frac{I_2^2}{S} \text{ (if } R_2 \text{ is constant)}$$

Now $I_2 \;\alpha\; I_1$ [If $R_1 = R_2$]

$$T \;\alpha\; \frac{I_1^2}{S}$$

There fore $T = \frac{I_1^2}{S}$

At stating S = 1 ; $T = T_{st}$; $I_1 = I_{st}$

Therefore, $T_s = KI_{st}^2$

Let I_1 = normal full load current and S_f = full load slip

Then $T_f = \frac{KI_f^{\,2}}{S_f}$

$$\frac{T_{st}}{T_f} = \left(\frac{I_{st}}{I_f}\right)^2 x \; S_f$$

When the motor is directly switched on to voltage lines, then starting current is the short circuit current Isc

$$\frac{T_{st}}{T_f} = \left(\frac{I_{sc}}{I_f}\right)^2 x \; S_f$$

(b) Stator Rheostat (Resistance) Starter

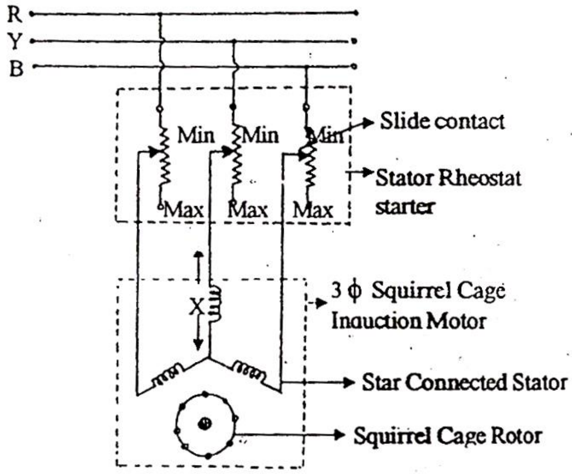
Principle

The basic principle behind the AC induction motor starters is reduction of applied voltage, thereby reducing high starting current. In stator Rheostat starter the voltage is reduced by, inserting the variable resistance in series with each of stator phase during starting

Operation

The variable resistance is connected in series with each stator phases, hence this kind starter is known as stator Rheostat Starter. The 3ϕ induction motor is connected with 3ϕ supply through the Stator Rheostat Starter. Typical control circuit for starting 3ϕ induction motor with stator Rheostat starter. During starting, the slide contact of stator rheostat is in maximum (Max) position. Now entire resistance is included in the stator circuit. So the voltage drop is more at this position of slide contact. The voltage applied to stator phases is reduced due to voltage drop in stator Rheostat. The reduction of stator voltage causes the starting current to decrease.

When the motor picks up speed, the sliding contact is moved from maximum (Max) position to the minimum (Min) position. When the sliding contact of stator rheostat is at the minimum (Min) position, the entire resistance is moved from the stator. Now 3ϕ induction motor is directly connected with 3ϕ AC supply mains. The stator rheostat starter is suitable only for small motors voltage is reduced during starting. This starter can be used for induction motor with both star connected stator and Delta-connected stator. In this starter huge power loss takes place in the stator Rheostat.



Disadvantage

1. Since the starting torque is proportional to square of the supply voltage, any reduction in the applied voltage will reduce the starting torque considerably.
2. Though this method of starting is cheapest, yet it is not commonly used because of more power wastage in the rheostat.

Expression for Starting Torque

If X = Fraction of voltage (v) reduced by stator resistors

Then $I_{st} = X\, I_{sc}$ $[I \propto V]$

$T_{st} = x^2\, T_{sc}$ $[T \propto V^2]$

$$\frac{T_{st}}{T_f} = \left(\frac{I_{st}}{I_f}\right)^2 \times S_f = \left(\frac{X I_{sc}}{I_f}\right)^2 \times S_f$$

$$\frac{T_{st}}{T_f} = X^2 \left(\frac{I_{sc}}{I_f}\right)^2 \times S_f$$

This method is suitable for starting only small motor. The torque is also reduced based on value of fraction X.

(c) Auto Transformer Starter

Principle

A 3ϕ Star-connected Autotransformer is used to reduce the voltage applied to the stator of the 3ϕ induction motr. Such starter is known as Autotransformer starter. The primary winding of Autotransformer is supplied with 3ϕ voltage from the supply mains. The secondary of Autotransformer produce reduced variable voltage.

Circuit connections

An Auto-transformer is connected between 3ϕ supply mains and 3ϕ squirrel cage induction motor. The primary (P) of the autotransformer is connected with the 3ϕ supply mains through a change over switch. The secondary (S) of the autotransformer is connected with the 3ϕ induction motor through change over switch.

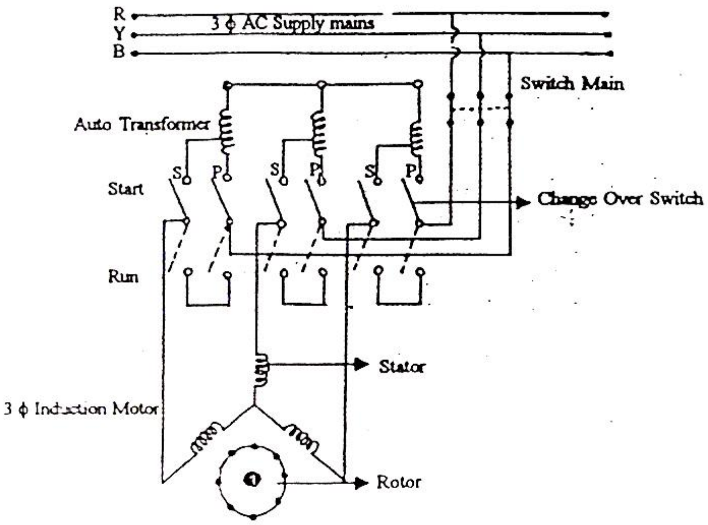
The change over switch has two positions namely, Start and Run. When the change over switch is in Start position, the 3ϕ induction motor is connected to 3ϕ supply mains through autotransformer. When the change over switch is in Run position, the 3ϕ induction motor is directly connected to the 3ϕ supply mains. i.e., Auto transformer is removed.

Operation

To start the 3ϕinduction motor the change over switch is kept is Start position. Now the 3ϕ induction motor is connected to 3ϕ supply mains through Autotransformer. The voltage is reduced in the

Auto-transformer and it depends upon on position of slide contact available in the transformer and this position decides transformation ratio (K). If the transformation ratio is 0.5, then half of the voltage applied to the primary appears across the secondary. This reduced voltage is now applied to the stator of 3 ϕ induction motor, through change over switch. Sincere reduced voltage is applied across the stator, the starting current is reduced to the safe limit.

Once the motor picks up 80% of rated speed, the change over switch can be switched to the Run position. Now the transformer is eliminated from the stator circuit. So 3ϕ induction motor is directly connected to supply mains. Due to this, rated voltage is applied to the stator winding. The motor starts rotating with rated speed. The changing of switch position can also be done automatically by the usage of relays. The power loss is very low in this type of starter. If can be used for both Star and Delta connected motors. This method is used for starting large motors.



Expression for Staring Torque

Let the motor be started by an Auto-transformer having transformation ratio (K). If I_{sc} is the starting current when normal voltage is applied and applied voltage during starting is KV, then motor input current $I_{st} = KI_{sc}$ (Secondary current)

Supply current = Current of auto transformer

$$KI_{st} = K(KI_{sc}) = K^2 I_{sc}$$

$$T_{st} \alpha K^2 I_{sc}^2$$

$$T_f \alpha \frac{I_f^2}{S_f}$$

$$\frac{T_{st}}{T_f} = K^2 \left(\frac{I_{sc}}{I_f} \right)^2 x \; S_f$$

If may be noted is similar o the expression obtained for stator rheostat starter except that x has been replaced by transformer ratio K.

(d) Star-Delta Starter

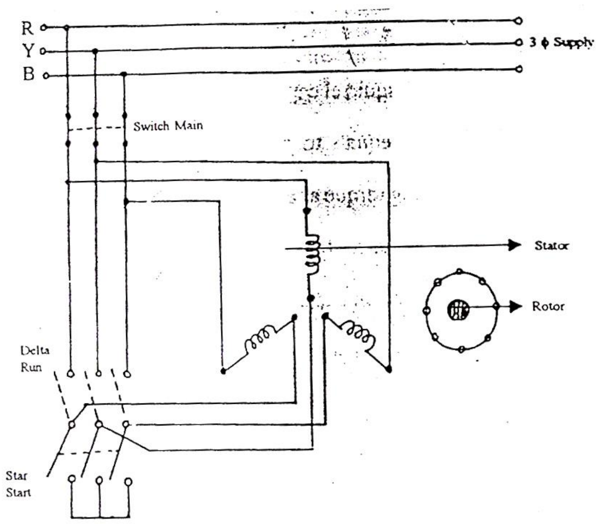
The 3ϕ stator winding of 3ϕ induction motor can be connected either in Star of Delta. If it is connected in Star the voltage per phase is reduced by the factor √3. If connected in Delta the voltage per phase is not reduced. During staring the stator windings can be connected in Star to get reduced voltage, hence the starting current is also reduced.

Operation

The Star-Delta starter uses triple pole double throw (TPDT) switch hat connects stator windings of 3ϕ induction motor either in Start or Delta. During starting the switch is in Start position. Now the switch connects stator windings in Star. The phase voltages of Star connected stator windings is reduced by the factor 1 /√3 when compared to the lien voltage. Since the voltage applied to the stator is reduced, the starting current is also reduced.

Once the motor picks up 80% of rated speed the changed over switch can be thrown over to the Run position. Now the switch connects stator windings in Delta. In Delta connection the phase voltage are not reduced and it is equal to the line voltage. So entire supply voltage is applied across the motor. The motor starts rotating with rated speed. The switch can also be operated automatically with the help of relays. This starter is the cheapest of all starters because no special device like rheostat or transformer is included in the circuit. The starter works by simply connecting the stator windings in Star and Delta.

This starter is normally used for 3ϕ induction motor with delta connected stator windings. This starter is used in places where the motor is not started with heavy load.



Expression for Starting Torque

$$I_{st} \text{ per phase} = \frac{1}{\sqrt{3}} I_{sc} \text{ per phase}$$

Now starting torque $T_{st} \propto I_{st}^2$

Full load torque

$$\frac{T_{st}}{T_f} = \left(\frac{I_{st}}{I_f}\right)^2 \times S_f = \left(\frac{I_{sc}}{\sqrt{3}I_f}\right)^2 \times S_f$$

Therefore

$$\frac{T_{st}}{T_f} = \frac{1}{3} \times \left(\frac{I_{sc}}{I_f}\right)^2 \times S_f$$

Starter For 3ϕ Slip Ring Induction Motor

The 3ϕ slip ring induction motor can be started by all the stator starters used for 3ϕ squirrel cage induction motor. In 3ϕ slip ring induction motor the rotor circuit can be accessed through the slip rings. In 3ϕ slip ring induction motor the rotor circuit has star connected windings. The ends of the three star connected windings are connected to three slip rings. The slip rings can be either short circuited or connected to external resistance. So starter for 3ϕ slip ring induction motor is connected in the rotor circuit. The best example for this type of starter is Rotor Rheostat starter. This is explained in the article given below

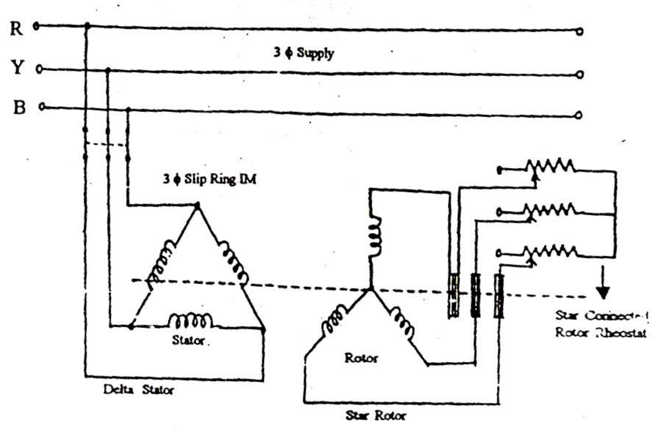
(a) Rotor Rheostat (resistances) starters

Principle

The 3ϕ induction motors has short circuited Rotor windings. So the rotor current during starting is very high. If this rotor current is reduced then stator current is also reduced. i.e, the starting current is reduced. The rotor current of squirrel cage induction motor cannot be directly reduced, because rotor current of the slip ring induction motor can be reduced by inserting rheostats through slip ring. As a result stator current, which is nothing but the staring current, is reduced.

Operation

The star connected rheostat is connected to the slip rings in the rotor circuit of 3ϕ slip ring induction motor during starting. As a result the rotor current is reduced. The stator current which depends on rotor current is also reduced i.e., starting current is reduced. The rotor resistance is gradually reduced as the motor picks up speed. When the motor picks up 80% of the rated speed, the slip rings are short circuited i.e, Star connected rotor rheostat is removed. So the motor runs at rated speed. He main advantage of this kind of starter is not only restricting the high starting current, but also increasing high starting torque. This is because starting torque is directly proportional to rotor resistance.



The addition of rotor resistance enables slip ring Induction motor to develop a high starting torque. Hence such motors can be started under heavy load.