لێکۆڵینەوەیەک دەربارەی

بیرۆکەکانی کارپێکردنی مۆتۆر

Motor starting methods

ئامادەکاری لێکۆڵینەوە

ئەندازیاری کارەبایی ڕێپێدراو

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Motor starting methods

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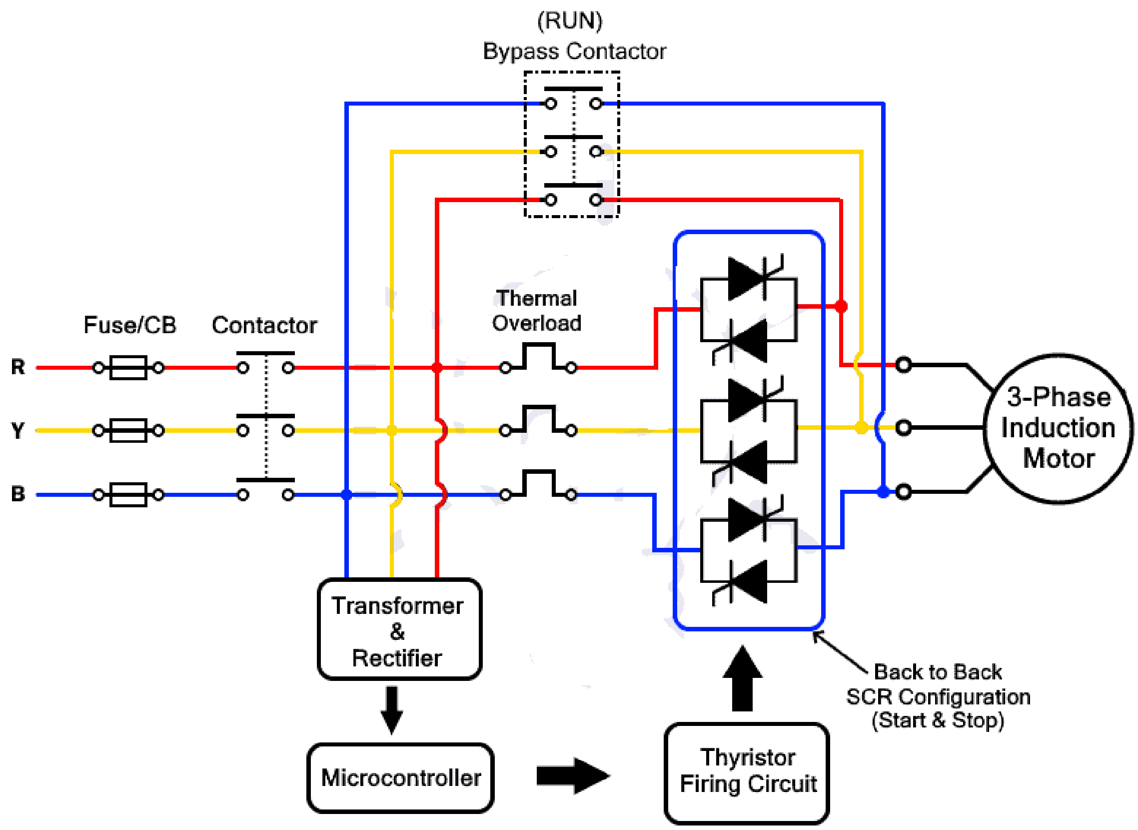


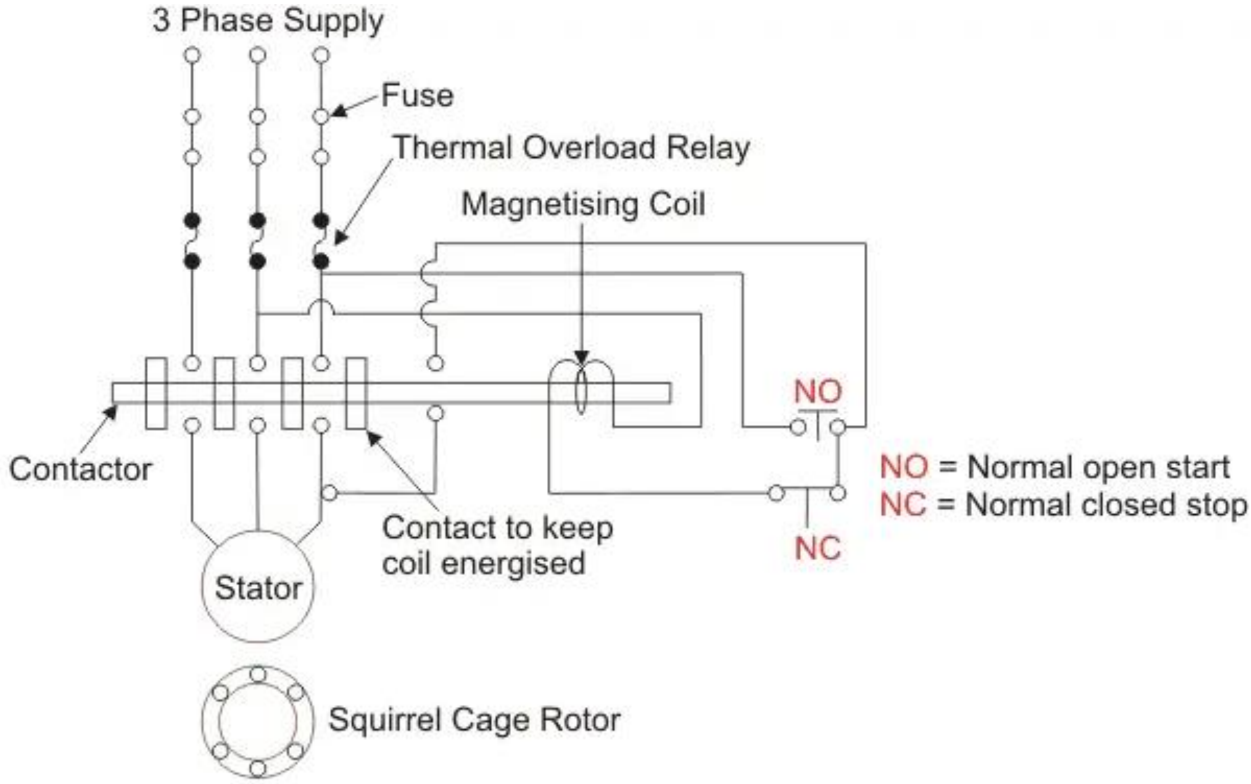
Soft Starter

A ٣-phase induction motor is theoretically self starting. The stator of an induction motor consists of ٣-phase windings, which when connected to a ٣-phase supply creates a rotating magnetic field. This will link and cut the rotor conductors which in turn will induce a current in the rotor conductors and create a rotor magnetic field. The magnetic field created by the rotor will interact with the rotating magnetic field in the stator and produce rotation. Therefore, ٣-phase induction motors employ a starting method not to provide a starting torque at the rotor, but because of the following reasons;

١) Reduce heavy starting currents and prevent motor from overheating. ٢) Provide overload and no-voltage protection. There are many methods in use to start
٢) ٣-phase induction motors.
٣) Some of the common methods are;
٤) Rotor Impedance Starter
٥) ¬ Power Electronics Starter

١- DOL Starter?

A **DOL starter** (also known as a **direct on line starter** or **across the line starter**) is a method of starting a ٣ phase induction motor. In a DOL Starter, an induction motor is connected directly across its ٣-phase supply, and the DOL starter applies the full line voltage to the motor terminals.
Despite this direct connection, no harm is done to the motor. A DOL motor starter contains protection devices, and in some cases, condition monitoring. A wiring diagram of a DOL starter is shown below:



Since the DOL starter connects the motor directly to the main supply line, the motor draws a very high inrush current compared to the full load current of the motor (up to ٥-٨ times higher). The value of this large current decreases as the motor reaches its rated speed.
A direct on line starter can only be used in circumstances when the high inrush current of the motor does not cause an excessive voltage drop in the supply circuit. If a high voltage drop needs to be avoided, a star delta starter should be used instead. Direct on line starters are commonly used to start small motors, especially ٣ phase squirrel cage induction motors.

As we know, the equation for armature current in the motor. The value of back emf (E) depends upon speed (N), i.e. E is directly proportional to N.

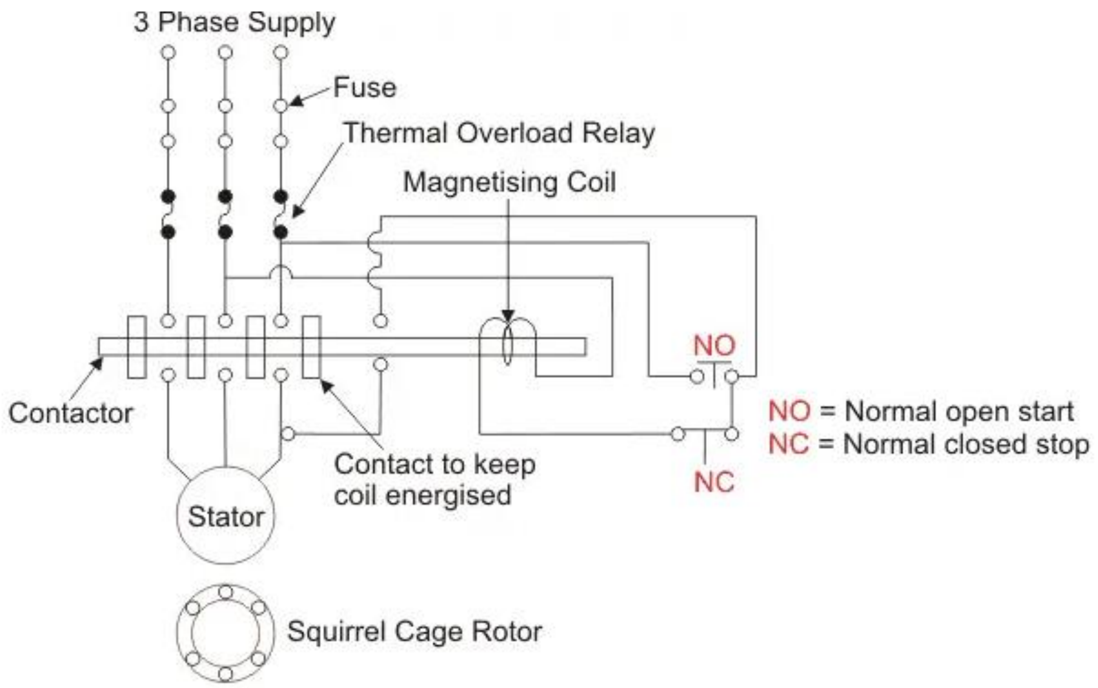
At starting, the value of E is zero. So starting current is very high. In a small rating motor, the rotor has a more considerable axial length and small diameter. So it gets accelerated fastly.

Hence, speed increases and thus the value of armature current decreases rapidly. Therefore, small rating motors smoothly run when it is connected directly to a ٣-phase supply.

If we connect a large motor directly across ٣-phase line, it would not run smoothly and will be damaged, because it does not get accelerated as fast as a smaller motor since it has short axial length and larger diameter more massive rotor. However, for large-rated motors, we can use an oil-immersed DOL starter.

DOL Starter Wiring Diagram

The wiring diagram for a DOL stater is shown below. A direct online starter consists of two buttons, a GREEN button for starting and a RED for stopping purpose of the motor. The **DOL starter** comprises an MCCB or circuit breaker, contactor and an overload relay for protection. These two buttons, i.e. Green and Red or start and stop buttons control the contacts.



To start the motor, we close the contact by pushing the Green Button, and the full line voltage appears to the motor. A contactor can be of ٣ poles or ٤-poles. Below given contactor is of ٤-pole type.
It contains three NO (normally open) contacts that connect the motor to supply lines, and the fourth contact is “hold on contact” (auxiliary contact) which energizes the contactor coil after the start button is released.

If any fault occurs, the auxiliary coil gets de-energized, and hence the starter disconnects the motor from supply mains.

٣ Phase Motor Starter with Overload Protection
When a motor draws excessive current to meet the load requirements such that this load requirement goes beyond the rated limit, this is known as overload.

Thermal overload protection is a type of security when the motor draws over current or excessive current and causes overheating of the equipment. Overload is also the type of over current. So overload relays are employed to limit the amount of current drawn.
But that does not mean that protects the short circuit. Fuse or MCB used in the system protects the over current. Overload protection opens a circuit at relatively low currents that are a little higher than the rating of the motor.

Overload currents are likely to damage if they persist for a long time, i.e. it will not trip if a high value of current flows for a short period such as starting of the motor.

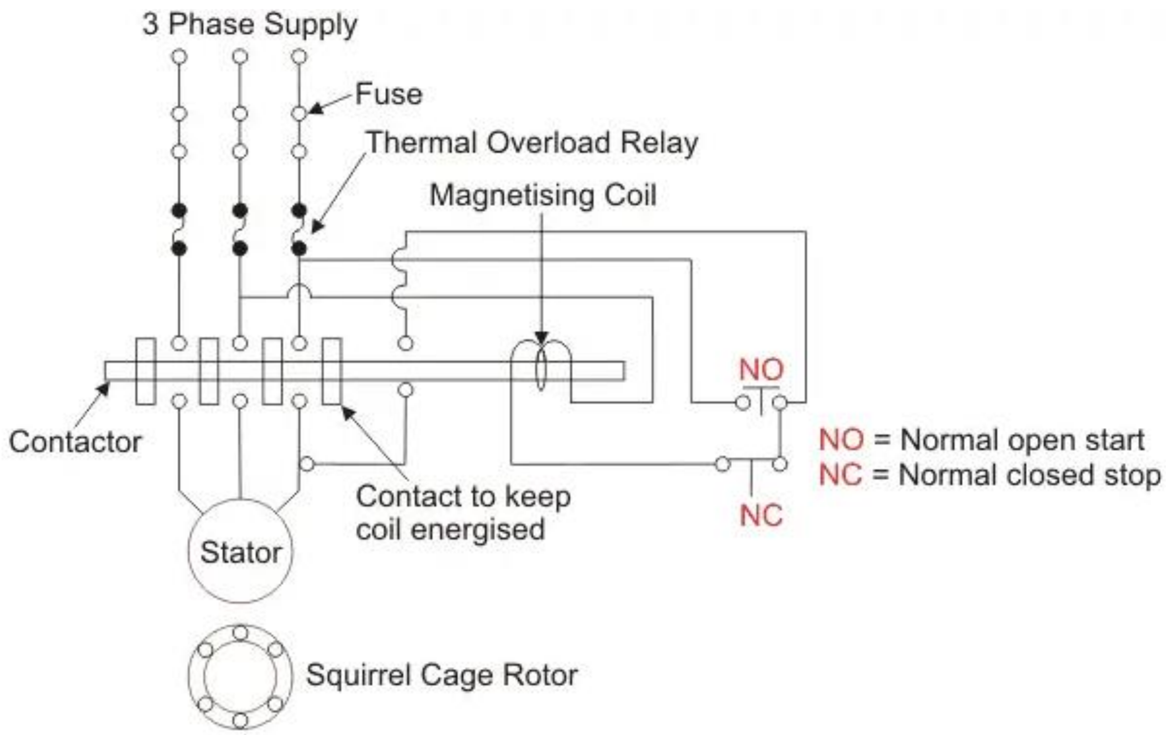
We often provide overload protection via an overload relay. Overload relays may be solid-state devices with adjustable trip setting also called as the electronic relay or by interacting with related temperature sensors called as a thermal relay or if only operates for excess current flow then called as a magnetic relay.

For most motors, the maximum rating of the overload protection device is ١٢٥٪ of the full load ampere rating.

DOL Starter Working Principle
The working principle of a **DOL starter** begins with the connection to the ٣-phase main with the motor. The control circuit is connected to any two phases and energized from them only.

When we press the start button, the current flows through the contactor coil (magnetizing coil) and control circuit also.

The current energises the contactor coil and leads to close the contacts, and hence ٣-phase supply becomes available to the motor. The control circuit for a DOL Starter is shown below.



If we press the stop button, the current through the contact becomes discontinued, hence supply to the motor will not be available, and the similar thing will happen when the overload relay operates. Since the supply of motor breaks, the machine will come to rest.

The contactor coil (Magnetizing Coil) gets supply even though we release start button because when we release start button, it will get supply from the primary contacts as illustrated in the diagram of the **Direct Online Starter**.

Advantages of DOL Starter

The advantages of a DOL starter include:

١. Simple and most economical starter.
٢. More comfortable to design, operate and control.
٣. Provides nearly full starting torque at starting.
٤. Easy to understand and troubleshoot.
٥. DOL starter connects the supply to the delta winding of the motor.

Disadvantages of DOL Starter

The disadvantages of a DOL starter include:

١. High starting current (٥-٨ times of full load current).
٢. DOL Starter causes a significant dip in voltage, hence suitable only for small motors.
٣. **DOL Starter** reduces the lifespan of the machine.
٤. Mechanically tough.
٥. Unnecessary high starting torque

DOL Starter Applications

The applications of DOL starters are primarily motors where a high inrush current does not cause excessive voltage drop in the supply circuit (or where this high voltage drop is acceptable).

Direct on line starters are commonly used to start small water pumps, conveyor belts, fans, and compressors. In the case of an asynchronous motor (such as the ٣-phase squirrel-cage motor) the motor will draw a high starting current until it has run up to full speed.

٢- Star delta starter:

Let us consider the case of starting of a ٣ phase inductor motor. Here, we apply a three-phase supply across the motor having three-phase stator winding. We arrange the stator winding in such a way that each phase is ١٢٠° separate from each other. This arrangement produces a revolving magnetic field in the stator due to applied three phase supply. The rotor remains stationary just after switching ON the supply. The change in flux linkage to the rotor is maximum therefore emf will be induced in rotor conductor causing large current to flow through it. This current is called starting current which is multiple times of full load current.

Hence now the rotor is acting like current carrying conductor placed in revolving magnetic field. Hence, the rotor conductors now experience mechanical force in the direction same as direction of the revolving magnetic field, and hence the rotor starts rotating and attends a speed given as Slip Speed = N_s – N

Where N_s is the synchronous speed that is the speed of revolving magnetic field present at stator winding and N is Rotor speed.

That is from the above equation the rotor always rotates with speed less than the speed of revolving magnetic field. If rotor rotates at a speed of revolving magnetic field then there will not be any flux cutting action by conductor and field, and hence there will not be emf induced phenomena in conductor, and hence motor will be decelerated rotate and that is why the induction motor never runs at synchronous speed. But here the important point is the large current flowing initially just after switching ON the supply causes large voltage drops across various elements of motor which greatly affects the functioning of motor.

To avoid this problem starters comes into the picture which helps to reduce that initial large current flowing just after switching supply ON and it ensures smooth switching of a motor. There are different types of starters for ٣ phase induction motor such as star delta starter, direct online starter, auto transformer etc.

Now, let us have a look at the contribution of starters in starting of an induction motor.

DOL Starter – It is a direct online starter consists of one-way switch simultaneously operates on each phase of the three-phase stator winding. The overload release of this switch protects the motor against overcurrent and No-volt release of this switch protects the motor from sudden three phase supply failure. DOL starters can be used to start motors up to ٥ H.P.

Star Delta Starter – The stator winding is connected in star fashion so that voltage at each phase is

Where, V_L is line voltage. Therefore voltage is reduced at each phase at starting and hence current is reduced. As soon as motor achieves certain speed, motor winding is connected in delta fashion such that line voltage is equal to phase voltage with the help of two way switch. The star delta starter is used for starting of induction motor above ٥ H.P.

Auto Transformer – The necessity of reduction of starting current to avoid failure of motor can be effectively done by auto transformer which consists of a single winding. The number of turns of the winding can be varied manually by moving the circular slider provided on it such that limited current will flow through the stator winding for an initial duration of time.

Star Delta Motor Starter by PLC Theory

Most three phase (٣-ph) induction motors are started directly on line, but when large motors (>٥ HP) are started that way, they cause a disturbance of voltage on the supply lines due to large starting current surges. To limit the starting current surge, large induction motors are started at reduced voltage and then have full supply voltage reconnected when they run up to near rotated speed. The high starting current will produce severe a voltage drop and will affect the operation of other equipment. It is not desirable to start large motors direct on line (giving full voltage to the stator). For reduction in the starting current, a lower voltage is applied to the stator, especially for the squirrel cage induction motors. Full voltage is only applied when the motor picks up speed. Supply reliability and reserve power generation dictates the use of reduced voltage or not to reduce the starting current of an induction motor, the voltage across the motor need to be reduced. This can be done by:

i) Auto transformer starter,
ii) ii) Star-delta starter or
iii) iii) Resistor starter. For this experiment we are concerned just about Star/Delta starter for ٣-ph induction motors. Simple motor starter needs to be reviewed before getting into the process of Star/Delta starter. Simple motor starter Motor starters are of many types however the scope of this experiment is confined to simple motor starter.
It should have the following provisions.

▪ Push button to start the motor: The motor should continue to rotate even when the push button is released.

▪ Stop Push button to halt the motor after it started.

▪ Over current protection: In case of over load, the motor should stop automatically by the signal coming from contactors of overload relay.

▪ Limit switch: It should prevent the motor from starting and can also stop the running motor.

▪ The motor starter should also have indicator (Lights) to show ON or OFF status of motor.

Figure ١ shows the physical layout of motor starter however this would be designed through ladder logic in this experiment.

The figure does not show limit switch because it depends on external interlock like say level switch, flow switch, pressure switch…etc depending on application. Figure ٢ shows the ladder diagram for motor starter. ٢ •

I١ normally open contact (Make contact) is used because the motor should only start when the button is pressed. Fig. ١ Motor Starter Fig.٢ Ladder diagram for Motor starter ٣ •

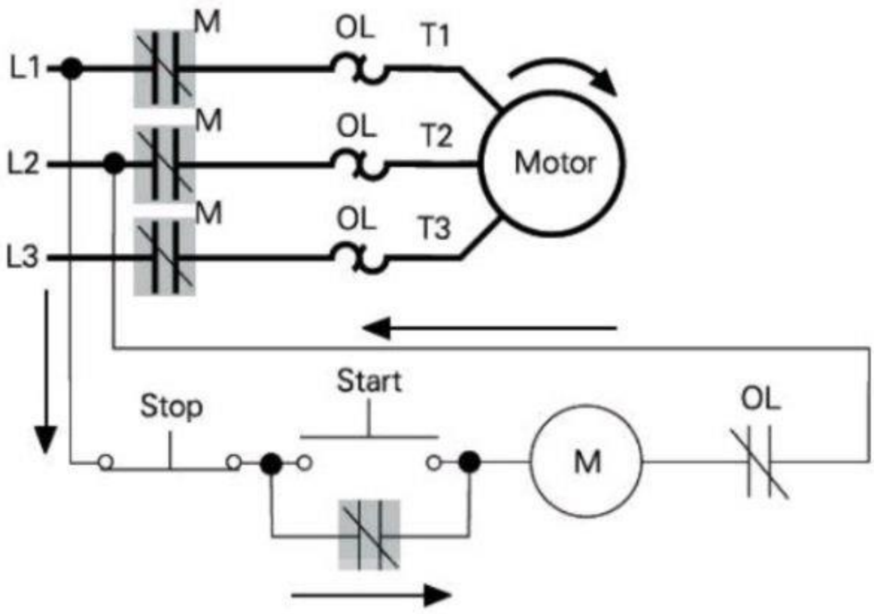


Fig. 1 Motor Starter

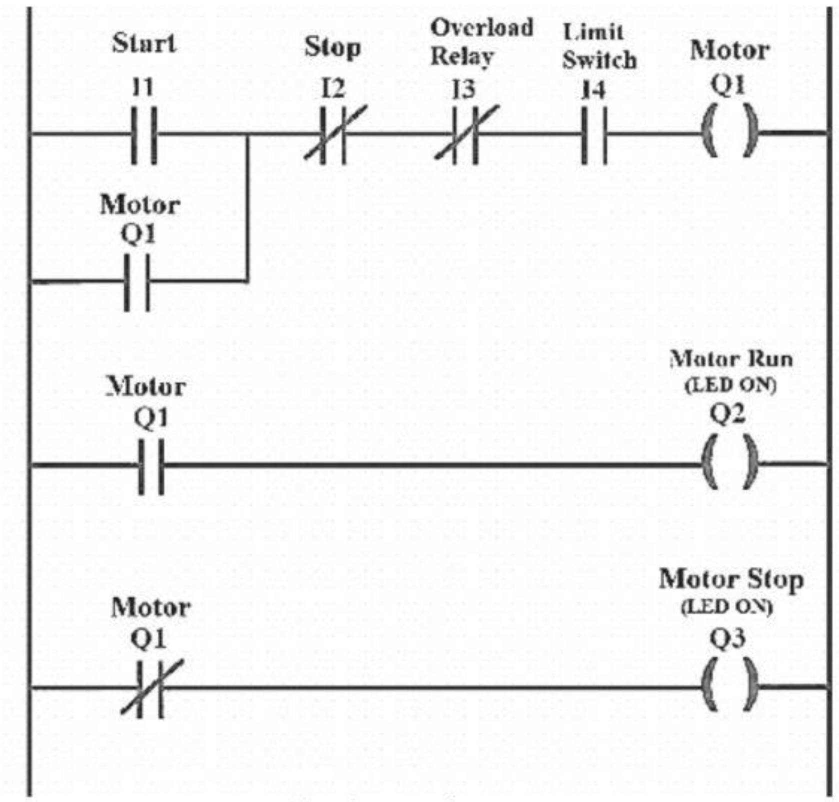


Fig.2 Ladder diagram for Motor starter

I٢ normally close (break contact) contact is used because the button should normally be closed or high so that the motor keeps on running. It should open when the button is pressed. It is opposite to start push button. •

I٣ in normal condition, this relay should allow the motor to rotate so normally close contact is selected for it. In case of overload it will stop the motor by opening its contact. •
I٤ the motor should only rotate when the limit switch is closed therefore normally open contact is used.
• Relay coil Q١, Q٢ and Q٣ represent motor output, motor indication ON and OFF respectively. ON indicator gets input from normally open input which depends upon output Q١. OFF indicator is fed by normally close input which depends upon output Q٢.

Since it is required that once push button is pressed, motor should run continuously even if the push button is released. To achieve this part, an input Q١ (normally open) is used and connected in parallel with I١. This input depends upon output Q١. When output is high, input Q١ is also high. Since input Q١ provides parallel path with I١, so if any of them is to be high, motor will run (if other conditions are also satisfied). Start button (Normally open), stop button (Normally close), overload relay (Normally close) and limit switch (Normally open) are connected in series. So, the motor will run if start button is pushed, stop button is not pressed, overload relay is not picked, and limit switch is closed.

Star/Delta starters

Star/Delta starters are probably the most common reduced voltage starters. They are used to reduce the start current applied to the motor during start as a means of reducing the disturbances and interference on the electrical supply.

Figure ٣ shows the winding connections in star and delta configuration one by one.

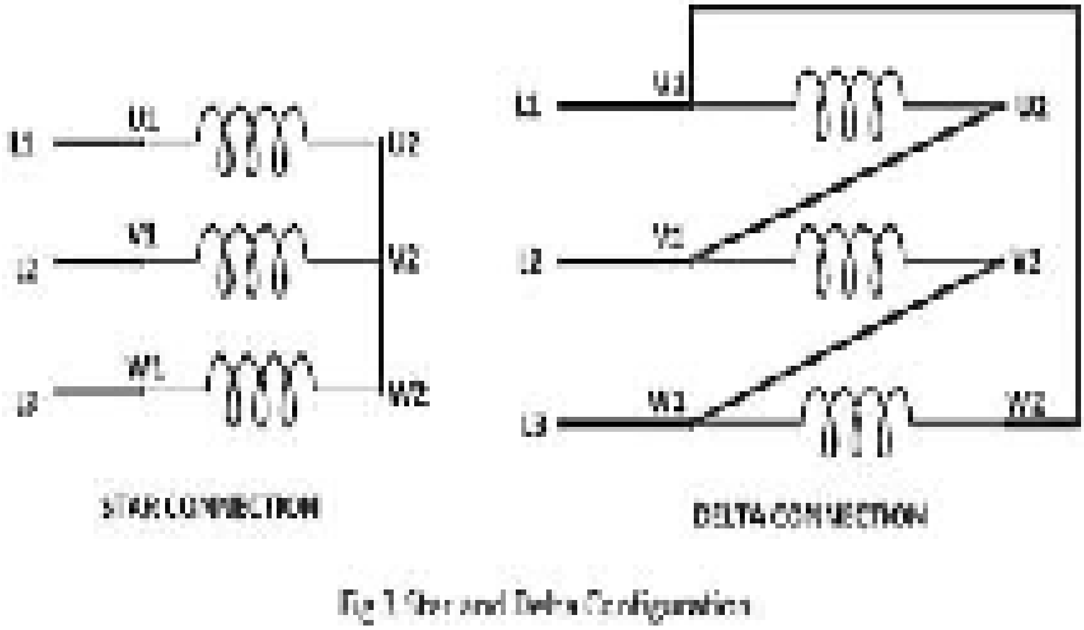


Fig.٣ Star and Delta Configuration

It can be seen that in star connection, one end of all three windings are shorted to make star point while other end of each winding is connected to power supply. In delta configuration, the windings are connected such that to make a close loop. The connection of each winding is shown in above figure. In actual motor the three phase connections are provided in the following order as shown in figure ٤.

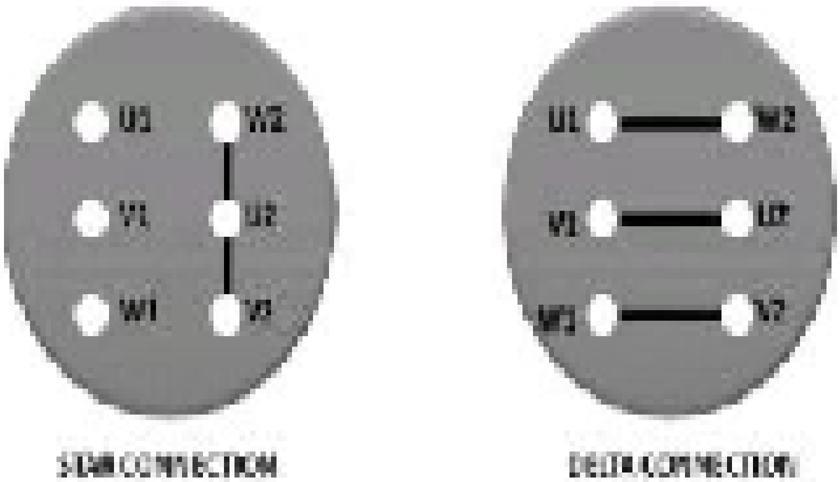


Figure ٥ shows the diagram of Star/Delta starter using contactors. Main contractor is used to supply power to the windings. It must be turned on all the time. Initially the star contactor is closed while delta contactor is open It makes the motor windings in star configuration.

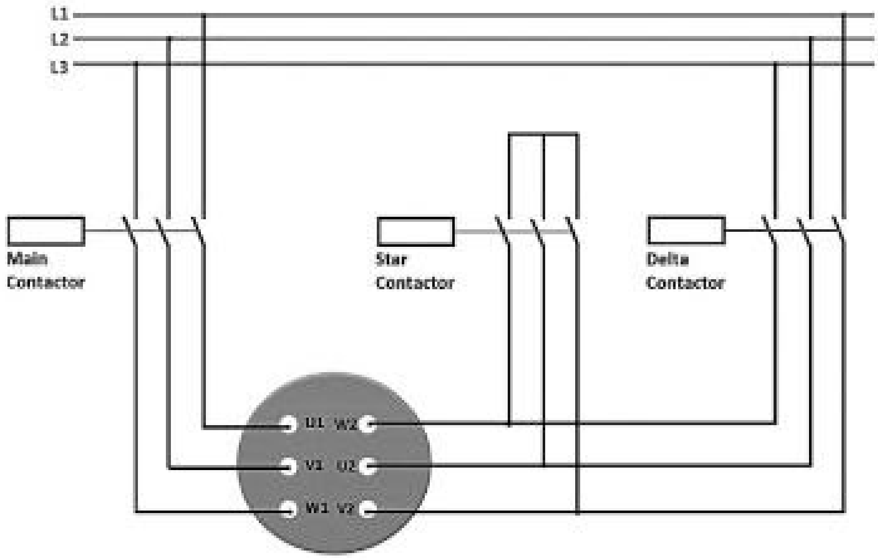


Fig.5 Star/Delta starter by Contactors

When the motor gains speed, the star contactor is opened while delta contactor is closed turning the motor windings into delta configuration. Fig.٤ Motor Terminals Connections in Star and Delta Configuration Fig.٥ Star/Delta starter by Contactors ٥ When the motor gains speed, the star contactor is opened while delta contactor is closed turning the motor windings into delta configuration. The contactors are controlled by using PLC as shown in figure ٦.

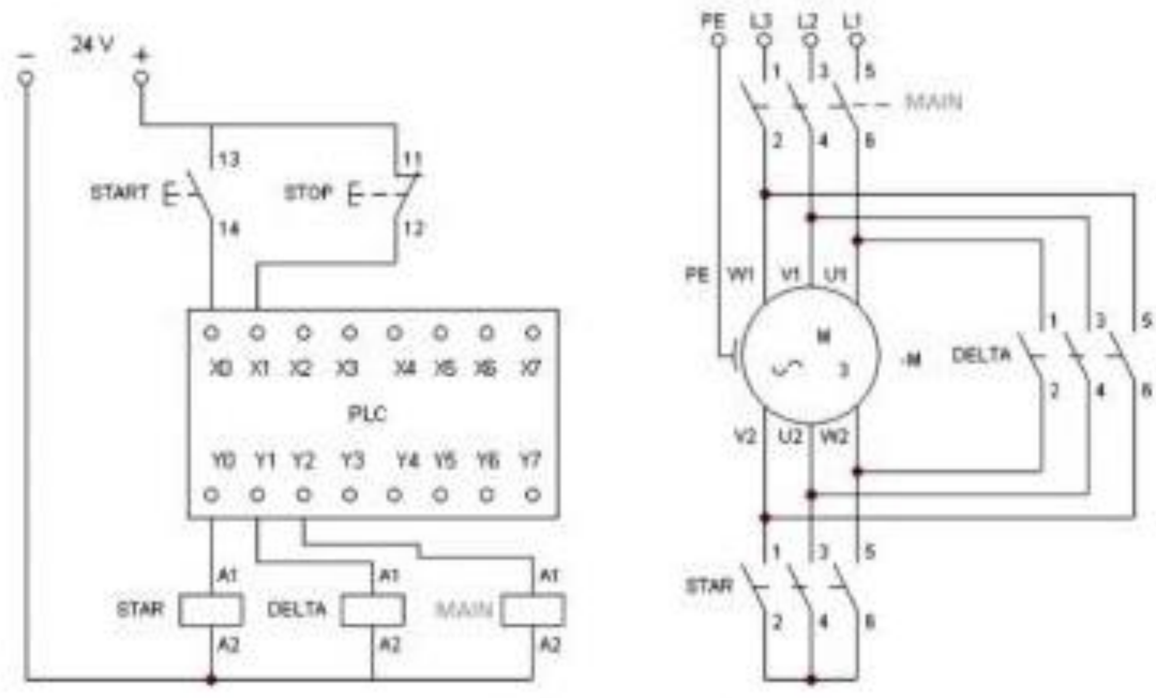


Fig.6 PLC Controlling the Contactors

Ladder Program

After wiring the PLC we need to program it by the suitable ladder logic as shown in figure ٧. Fig.٦ PLC Controlling the Contactors

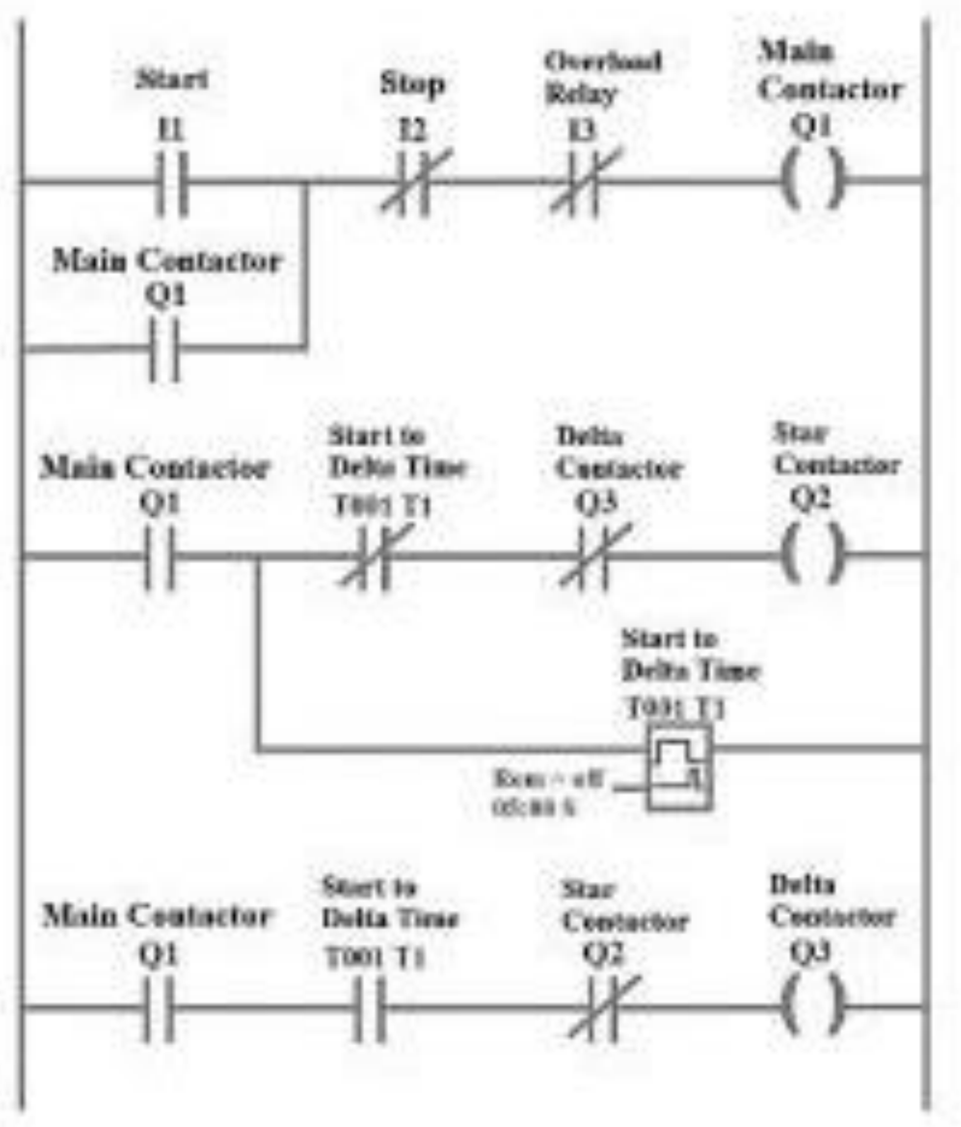


Fig.٦ Ladder diagram for star/delta starter

• The main contactor depends upon the normally open input start push button (I١), normally closed stop button (I٢) and normally closed overload relay. It means that main contactor will only be energized if start button is pressed, while stop is not pressed and overload relay is not activated. A normally open input named (Q١) is added in parallel to the start button I١. By doing so, a push button is created which means that once motor is started, it will be kept started even if start button is released.

• Star contactor depends upon main contactor, normally close contacts of timer (T١), and normally close contacts of output delta contactor (Q٣). So, star contactor will only be energized if main contactor is ON, time output is not activated and delta contactor is not energized.

• Timer T١ measures the time after which the winding connection of star delta starter is to be changed. It will start counting time after main contactor is energized.
• Delta contactor will be energized when main contactor (Q١) is energized, timer T١ is activated and star contactor (Q٣) is de-energized.

Procedure
١) Connect the circuit in figure ١ and wire the plc.
٢) Write the ladder for step ١, which is shown in figure ٢ and upload it to the plc. ٣) Run the system and observe the operation.
٤) Repeat step ١, ٢, ٣ & ٤ for the circuit in figure ٦ & ٧.

Soft Starter, Its Circuit Diagram, Operation, Advantages & Applications
What is Soft Starter?

The soft starter is a type of motor starter that uses the voltage reduction technique to reduce the voltage during the starting of the motor.

The soft starter offers a gradual increase in the voltage during the motor startup. This will allow the motor to slowly accelerate & gain speed in a smooth fashion. It prevents any mechanical tear & jerking due to sudden supplying of full voltage.

The torque of an induction motor is directly proportional to the square of current. & the current depends on the supply voltage. So the supply voltage can be used to control the starting torque. In a normal motor starter, applying full voltage to the motor generates maximum starting torque which possess mechanical hazard to the motor.

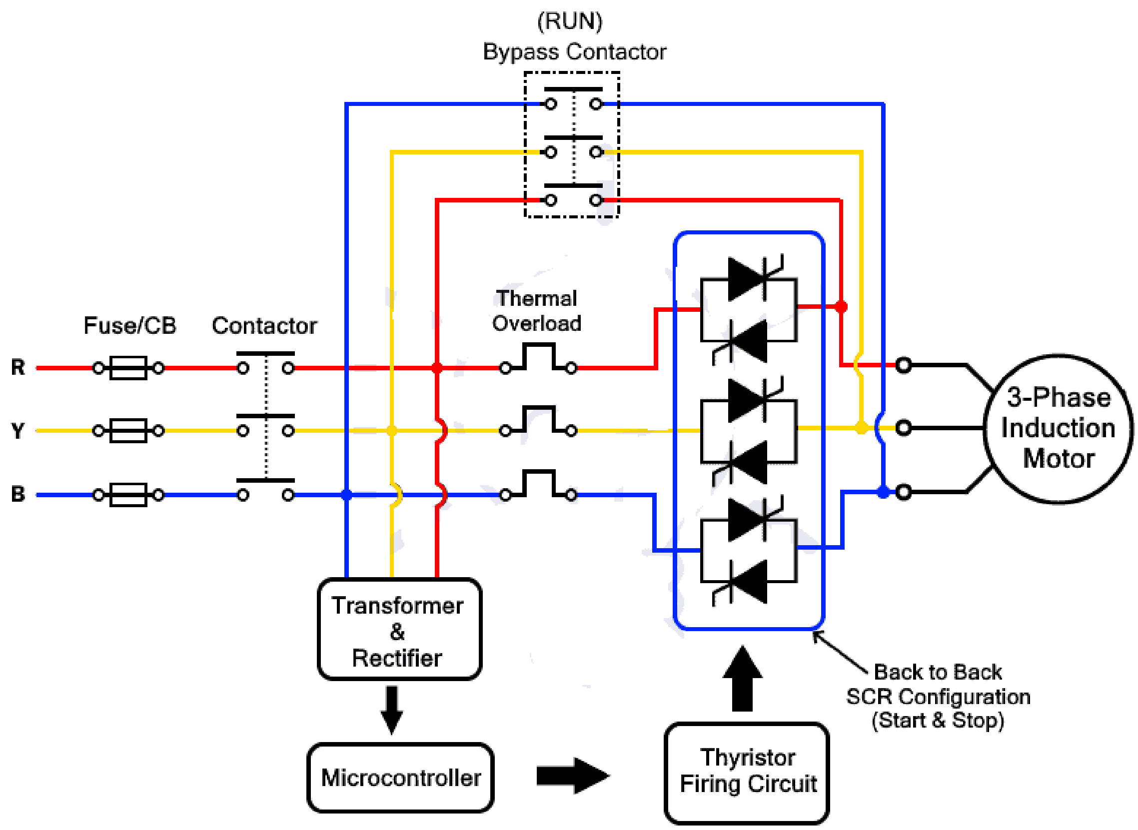
Therefore we can say that a soft starter is a device that reduces the starting torque & gradually increase it in a safely manner until it reaches it rated speed. One the motor attains its rated speed, the soft starter resumes the full voltage supply through it.

During motor stopping, the supply voltage is gradually reduced to smoothly decelerate the motor. Once the speed reaches zero, it breaks the input voltage supply to the motor.

The main component used for the regulation of voltage in a soft starter is a semiconductor switch such as a Thyristor (SCR). Adjusting the firing angel of the thyristor regulates the voltage supplying through it. Other components such as OLR (overload relay) used for overcurrent protection is also used.

Diagram of Soft Starter

In a three phase induction motor, two SCRs are connected in an anti-parallel configuration along each phase of the motor making it a total of ٦ SCRs. These SCRs are controlled using a separate logic circuitry that can be a PID controller or a microcontroller. The logic circuitry is powered from the mains using a rectifier circuit as shown in the figure.



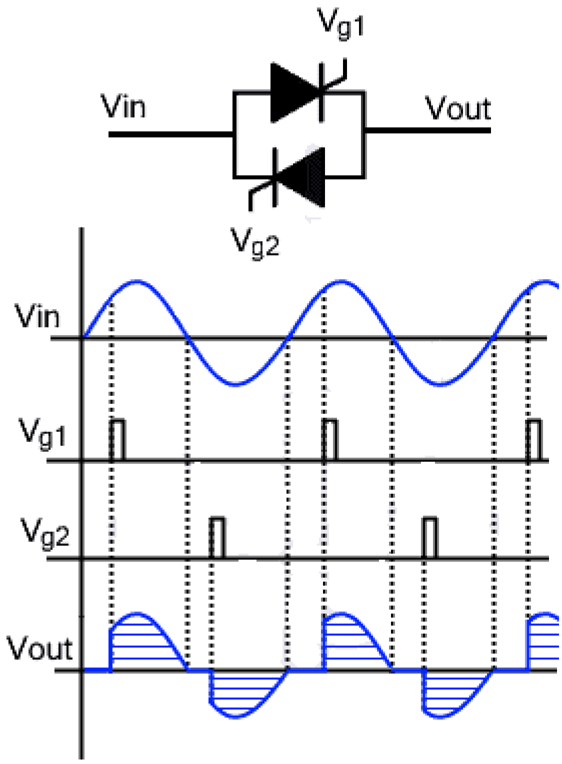
Soft Starter

Apart from the Power switches & logic circuitry, other protection components such as the circuit breaker or fuse, magnetic contactor for isolation & an OLR (Overload relay) for prevention of overcurrent is used.

A bypass switch is also used to resume the full voltage across the motor when it attains the full rated speed.

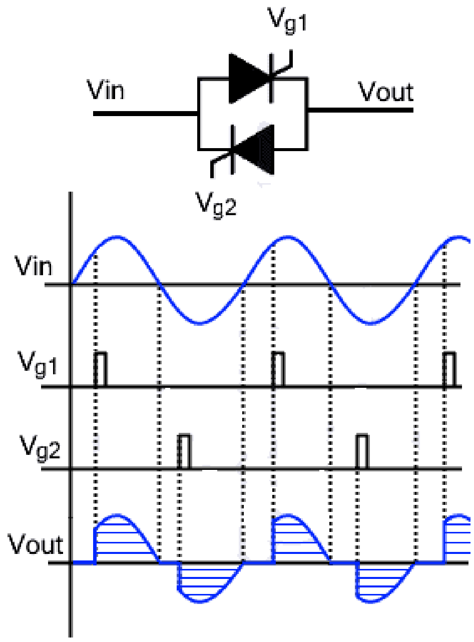
Working Principle of Soft Starter

The main component used for controlling the voltage in a soft starter is a thyristor. It is a controlled rectifier that starts conduction of the current flow in only one direction when a gate pulse is applied called the firing pulse.

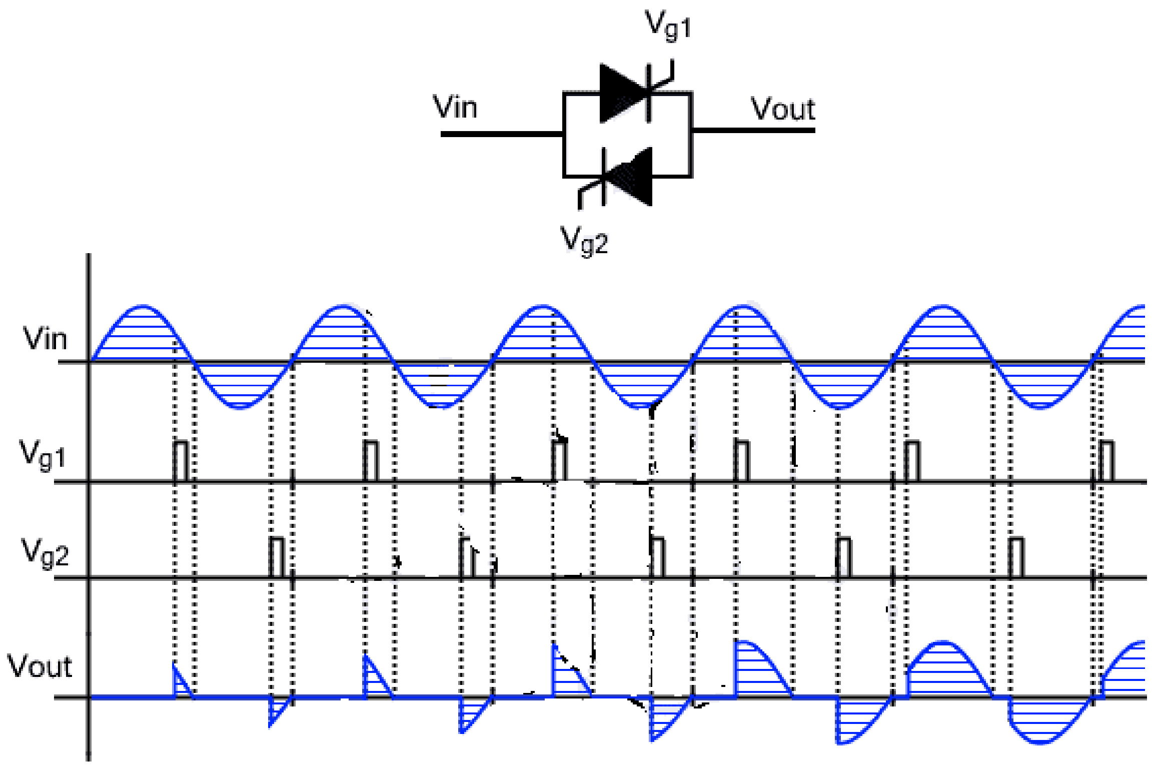


The angle of the firing pulse determine how much of the input voltage cycle should be allowed through it. Since AC swings between maximum & minimum peak forming a complete ٣٦٠° cycle, we can use the angle of firing pulse to switch on the thyristor for a specific duration and control the supplied voltage.

The firing pulses can vary between ٠° to ١٨٠°. The decrease in the angle of firing pulse increases the conduction period of thyristor, thus allowing high voltage through it.



Two such thyristors are connected in back-to-back formation for each phase. So it can control the current in both directions. Each half cycle, the firing angle



Thyristor-Pair Operation for each phase of Soft Starter

The three pairs of thyristors, each pair for individual phase are used for controlling the voltage to start & stop the motor. The thyristor conduction period depends on the firing angle controlled by the logic circuitry.

The logic circuitry contains PID controller or a simple microcontroller programmed to generate pulses. The controller is isolated from the supply mains using opto-isolator & a rectifier is used for supplying DC source. The pulses generated by microcontroller are fed to a thyristor firing circuit that amplifies it before triggering the SCR.

When the motor starts up, the controller generates pulses for each individual SCR. The pulse is generated based on the zero crossing that is detected using a zero crossing detector. The first firing pulse angle is approximately near ١٨٠° (very low conduction period) to allow minimum voltage.

Gradually after each zero crossing, the angle of firings pulses starts decreasing, increasing the conduction period of thyristor. The voltage through thyristor starts increasing. Hence the motor speed gradually increases.

Once the motor attains its full rated speed (at ٠° firing angle), the thyristors are completely bypassed using a bypass contactor under normal operation. It increases the efficiency of the soft starter since the SCR stops firing. During motor stopping, the SCR takes the control & starts firing in orderly fashion to reduce the supply voltage.

The bypass contactors can be internal or external. The internal bypass contactors are embedded inside the power switches. Each SCR have a bypass switch in parallel that supply the current under normal condition. Such contactors configuration takes small space & the starters are in compact design. While the external bypass contactors are connected externally in parallel with the soft starter. Such soft starter are bulky.

The bypass contactors are not meant to break or make the current supply to the circuit, thus it can be a low rated contactors.

Advantages of Soft Starter

Smooth Startup: Unlike conventional motor starter, it provides very gradual increase of voltage thus speed that results in a very smooth startup. There is no mechanical stress whatsoever or jerks that can damage the motor.

Acceleration & Deceleration Control: It offers a fully adjustable acceleration & deceleration of the motor. Varying the firing angle slowly or quickly can control the acceleration during startup & deceleration during stopping of motor. This is used in application where startup acceleration needs to be adjusted.

No Power Surges: Since the conventional motor starter allows full voltage across the motor, a huge inrush current start flowing into the motor that cause a power surge in the circuit. the soft starter limits such current thus preventing the power surges.

Multiple Startups: Some applications require the motor to start & stop multiple times in small period of time. such motor if used with a conventional starter will experience overheating due to high starting current. However, soft starters drastically increases the number of startups for a motor in a specific duration.

Reduction of Overheating: The motor overheating is a very serious problem. It occurs due to the high winding current during its startup. The soft starter allows a very small amount of starting current which prevents the overheating of motor.

Increased Life Span: The soft starter as compared to a conventional starter improves the life time of the motor. it is due to the smooth operation & absence of electrical & mechanical stress on the motor.

Less Maintenance: Due to its smooth operation, the induction motor is less likely to have any mechanical faults, which is why it require less maintenance as opposed to conventional motor starter.

Efficiency: A conventional motor starter supply full voltage (very high inrush current) to the motor that consumes too much energy. A soft starter significantly reduces it & allows a gradual increase in energy consumption. Also the power switches are controlled using very low voltage level. It improves the overall efficiency of the motor.

Compact & Small Size: The soft starter has a very compact design that takes up very small space. Unlike other motor starters, it has very small size.

Low Cost: compared to other starters such as VFD, this sure does cost cheaper.

Disadvantages of Soft Motor Starter

No Speed regulation: The soft starter only allows the control of input voltage supply i.e. from ٠ volts to line voltage with a fixed line frequency. Since the frequency is constant the motor speed is constant & only regulates by the load connected with it. The speed of induction motor is regulated by varying the supply frequency below or above the line frequency according to the need. Such feature is only available in **VFD** (variable frequency drive).

Heat dissipation: The semiconductor switches inside the soft starter dissipates some energy in the form of heat. Therefore, it also requires heat sinks for cooling the power switches.

Reduced starting Torque: Since it reduces the input voltage that corresponds to the input current which is directly proportional to the starting torque of the induction motor, it significantly reduces the starting torque. This is why **Soft starters are used for low or medium starting torque application.**

Applications of Soft Starter

The soft starter is used in industries & is more appropriate to be used for motors that run on a constant speed.

Fans: The huge fans used in industries runs at a constant speed. However, they do require the startup protection. A soft starter is a best option for such fans.

Conveyer belts: The conveyer belts in industries are used for moving objects & it needs extra care. The sudden jerks during starting or stopping using conventional starter may misalign the belts, damages the belt due to mechanical stress & damage the objects placed on it. It requires a smooth starting & stopping offered by a soft starter

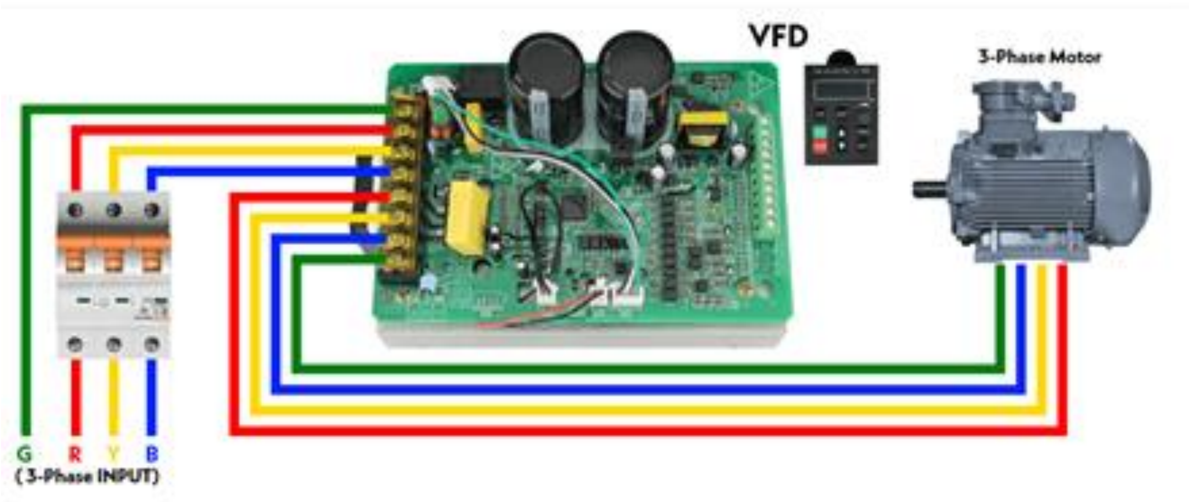
Motors using belt & pulleys: The motor that drives load through belts & pulleys cannot tolerate the sudden jerks. It wears the belt that couples it to the load. A soft starter offers a smooth starting for such motor applications.

Water or liquid Pump: Any type of pump connected with a motor requires a smooth starting & stopping due to the sudden pressure building inside the pipes. A conventional starter may generate enough pressure at startup to break the line. A soft starter offer gradual increase in the pressure to such liquid pumps. However, there is no speed control of the pump during normal operation. A VFD is a better choice for variable pump speed.

What is a VFD?

VFD stands for **Variable Frequency Drive**. As its name suggests it is an adjustable frequency drive that varies the frequency of the AC supply. Since the speed of an induction motor depends on the supply frequency, the VFD can be used to vary its speed.

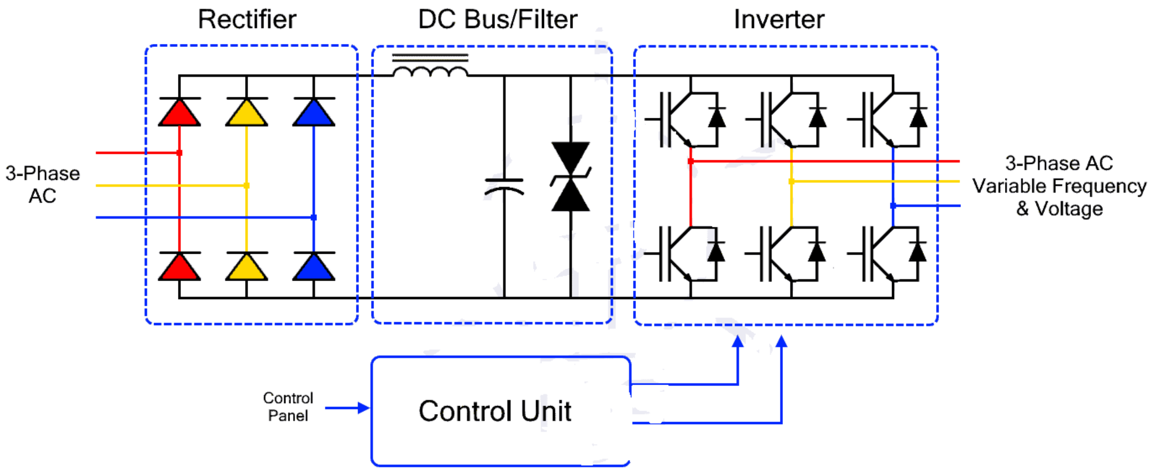
A VFD is a power converter that uses electronic circuits to convert a fixed frequency and fixed voltage into a variable frequency and variable voltage. It even enables a motor to run above its rated speed by increasing the frequency. Due to its programmable and easy to use UI (user interface), it can be easily used to monitor and maintain the speed of an electrical motor.



Circuit Diagram of VFD

Generally, a VFD is made of four blocks or sections where each section has its own function. The four blocks or sections of a VFD are **Rectifier**, **DC bus/filter**, **Inverter** and **Control Unit**. The block diagram of a VFD is also given below.

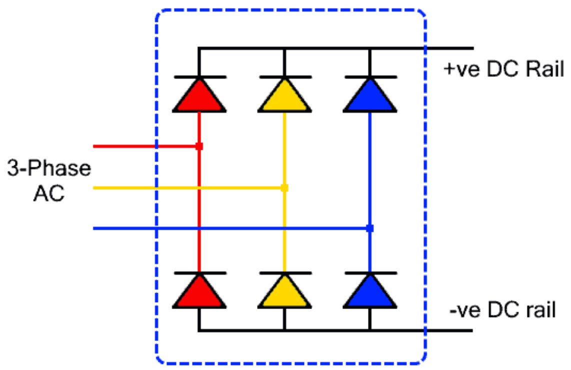
Each block is explained in detail down below.



Variable Frequency Drive

Working of VFD

The main function of a VFD is to vary the operating frequency of an AC supply. Simply put it converts the AC into DC and then into AC having adjustable frequency but the operation uses four blocks or sections of VFD. These sections are Rectifier Section, DC Bus / Filter Section, Inverter Section and Control Unit Section. Each one of the circuits is explained below.



Rectifier Section

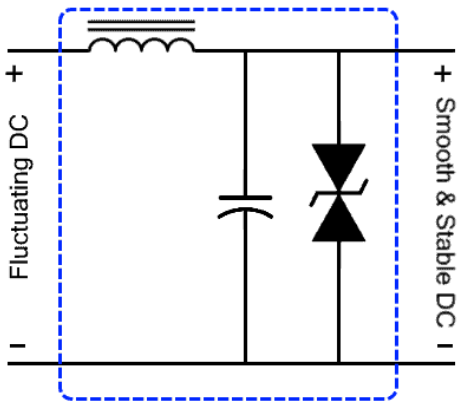
It is made of ٦ or ٤ diodes or thyristors. Six diodes are used for three-phase power conversion while ٤ diodes in bridge configuration are used for single-phase AC power conversion. Whereas the diode rectifier is used for uncontrolled conversion while the thyristor offers controlled switching that varies the output DC power.

The given circuit represents a three-phase diode rectifier. It consists of ٦ diodes where each phase is connected with a pair of diodes for rectification. Three of the six diodes are connected in forward bias with the positive DC output while the remaining three diodes are connected in reverse bias with the negative DC output.

The rectifier converts the sinusoidal input into a pulsating DC that swings between the maximum positive peak and zero volts. For a visual representation, the input and output waveforms are given with the circuit.

The DC Bus and Filter

This intermediate section is used for filtering and storing the DC power that is retrieved by the inverter. Its main function of filters is to remove the ripples from the pulsating DC output of the rectifier.

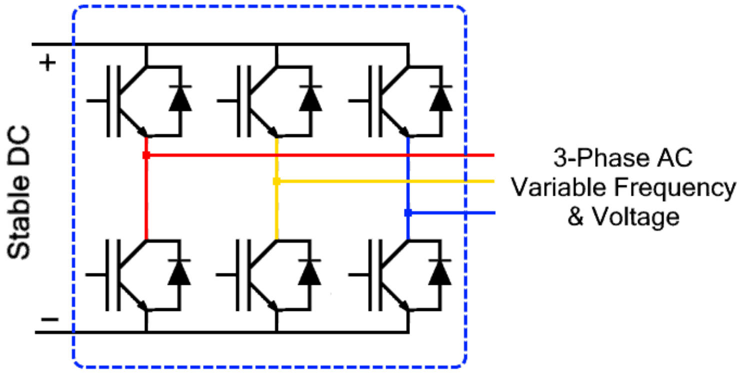


DC Bus & Filter Section

It is mainly made of capacitors to filter the ripples from the pulsating DC and also store it. It may include an inductor as well depending on the type of ripples.

The Inverter

This is the inverter or switching section that converts the steady DC into alternating AC with adjustable frequency.



Inverter Section

It is made of power transistors or IGBTs. They switch rapidly to provide alternating voltage at the output. Its switching frequency determines the output AC frequency. Whereas, the switching rate of IGBTs is controlled through the control unit.

There are ٤ IGBTs used for single-phase conversion while ٦ IGBTs are used for three-phase power conversion.

The Control Unit

This section is the controlling unit responsible for controlling the switching operation, output frequency, output power. It is integrated with the user interface and sensors to acquire the necessary data. It also monitors fault conditions.

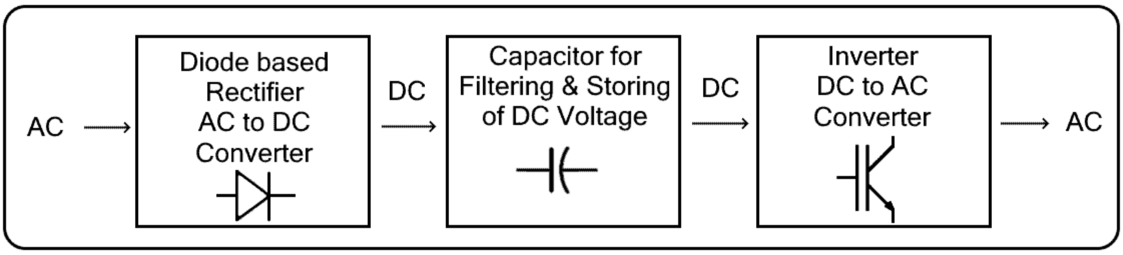
The control unit consists of an embedded microprocessor programmed for controlling the rectifier and inverter section. It can react in microseconds in case of any fault conditions. The feedback data from the speed sensor is used to monitor the speed as well as adjust it accordingly to the need.

Types of VFDs

There are three types of VFD classified based on the method of power conversion.

VSI type VFDs

The VSI or Voltage Source Inverter type VFD is the most common type. it provides a smooth voltage waveform that depends on the output frequency. It has a very simple design including a simple diode rectifier with a capacitor for filtering and storing DC energy. The DC voltage is then converted into AC using an inverter. They offer very good operating speed and control multiple motors.



VSI type VFD Block Diagram

The drawback of VSI is that they have poor power factors as well as they cause motor cogging at a low frequency below ٦ Hz. Apart from that, they are also non-regenerative i.e. they cannot store the energy flowing back from the motor.

Advantages

Here are some advantages of VSI based VFD

- It has a very simple design.
- It is very cheaper and cost-effective.
- It offers a very good operating speed range
- It can control multiple motors.

Disadvantages

Here are some disadvantages of VSI based VFD

- It has a very poor power factor, especially at low speed.
- It causes the motor to cog below ٦Hz frequency.
- The cogging causes the motor to jerk at starting and stopping.
- Different harmonics are generated at its output.
- They are non-regenerative.

Difference Between Soft Starter & VFD (Variable Frequency Drive)

What is the Difference Between VFD (Variable Frequency Drive) and Soft Starter?

Variable frequency drive or VFD and soft starter are both two different types of motor starter. Since both of these use semiconductor components to operate, people mostly confuse them with one another. Both of them can be used to safely start & stop an induction motor. Other than that they are quite different based on various other features. Some of these features are advantageous over the other.

Before going into the list of differences between VFD and soft starter, let's discuss what a motor starter is.

Table of Contents

- VFD (Variable Frequency Drive)
- Differences between Soft Starter & VFD

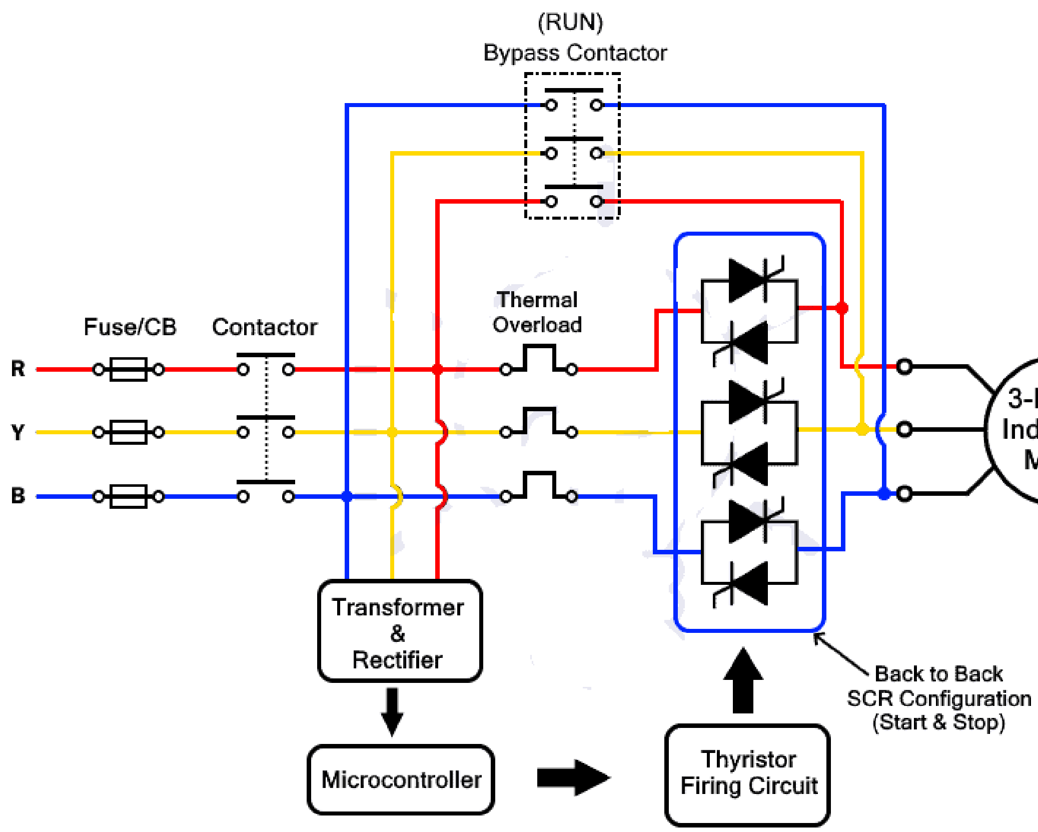
Motor Starter

A motor starter is a device that is used to safely start and stop an induction motor. An induction motor draws a huge amount of electric current (approximately ٨ time its rated current) during the startup due to its low winding resistance. This huge starting current is called inrush current which can damage the internal windings of the motor and reduces its life-time & in worst case causes burnout.

The motor starters are used to reduce the starting current so it can safely start without any damage to its windings or any other mechanical parts due to the sudden jerks. It also helps in stopping the motor once the power is turned off. They also offer protection against low voltage & overcurrent protection. That's why we need to use a motor starter.

Soft Starter

It is a type of motor starter that reduces the starting current or the high inrush current by reducing the voltage applied to the motor. it uses semiconductor thyristors to control the supplied voltage. A pair of thyristors in a back-to-back formation is used to control the current flow in both directions. So, a three-phase soft starter uses ٦ thyristors to offer voltage reduction on all three phases simultaneously. More info about its structure in article "soft starter"



Soft Starter

The thyristor has ٣ terminals i.e. anode, cathode & gate. The current cannot flow unless a voltage pulse is applied to the gate of the thyristor. Applying the gate signal triggers the thyristor & the current starts flowing through it. The amount of the current or voltage allowed by the thyristor is controlled by varying the angle of the gate signal called firing angle. Thus it reduces the starting inrush current supplied to the motor.

When the motor starts, the firing angle is controlled to supply low voltage which is gradually increased. The motor smoothly picks up its speed as the voltage reaches the line voltage & the motor starts running at its rated speed. Usually, a bypass contactor is used to supply line voltage directly to the motor in normal operation.

During the stopping of motor, the same operation occurs to reduces the voltage gradually to reduce the speed of the motor & eventually breaking the input voltage supply.

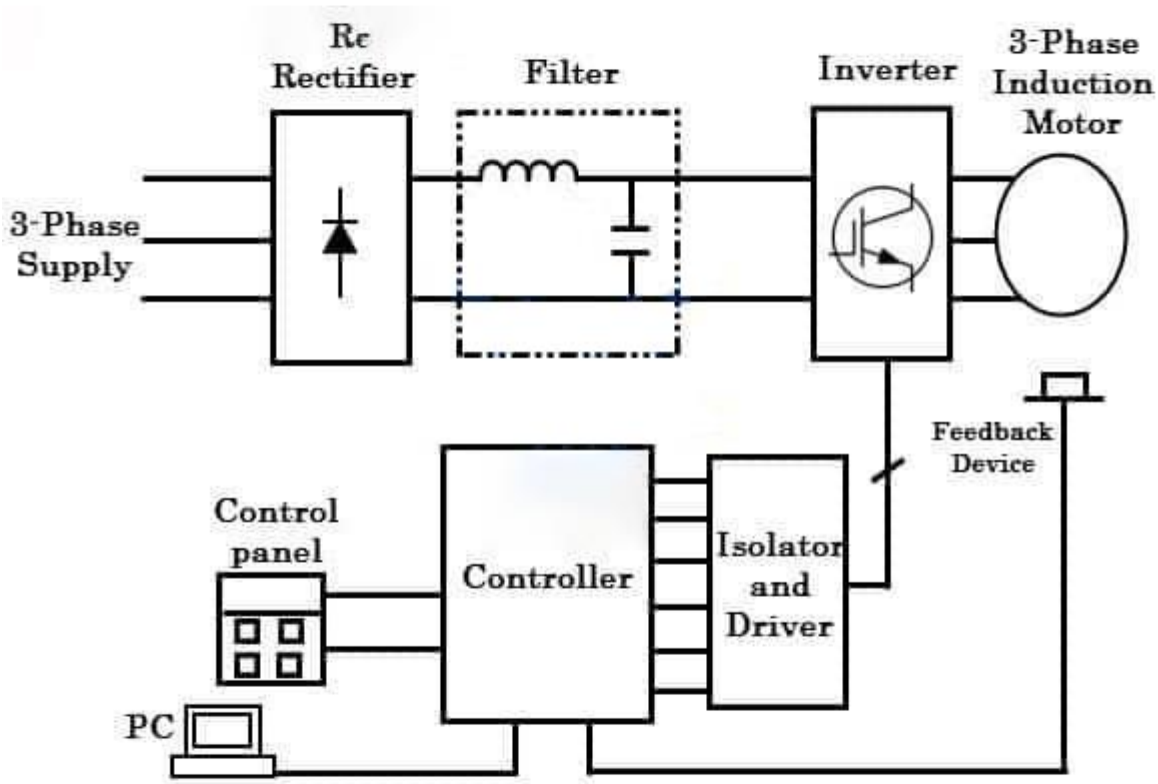
Since the soft starter only reduces the supply voltage during starting & stopping of the motor, it cannot vary the speed of the motor during normal operation. Therefore, they are used for constant speed application.

The soft starter does not generate any harmonics in the system. Therefore, it does not need any additional filters to remove the harmonics from the system.

It has a very compact design & its size is very smaller as compared to VFD since it requires fewer components for its operation. It also reduces the overall cost of the soft starter as compared to VFD.

VFD (Variable Frequency Drive)

A variable frequency drive "VFD" is a semiconductor based motor starter. It can safely start & stop electric motors as well as fully control the speed of the motor during its operation. It can control the supply voltage as well as its frequency. Since the speed of the induction motor depends on the supply frequency, VFD is mostly used for varying the speed of the motor during its operation.



BLOCK DIAGRAM OF TYPICAL VFD (AC DRIVE)

A VFD has three circuits i.e. Rectifier, DC Filter & Inverter. First, the AC line voltage is converted into DC using the rectifier circuit. It is then smoothen by passing through the DC filter. The steady DC voltage is then converted into AC using the inverter circuit. The inverter's logic control circuit allows to vary the voltage as well as the frequency of the output AC voltage. It can be used to smoothly increase the speed of the motor from ٠ RPM to its rated speed & sometimes above its rated speed by increasing the frequency. Therefore, it offers a complete control over the torque speed characteristics of the motor.

The VFD offer can vary the speed of the motor during its operating by varying the frequency of the supplied voltage. Therefore, it is used in applications where the speed of the motor needs to be varied. A better example would be a fan speed based on the temperature & a water pump speed based on the pressure of the incoming water.

The torque of the motor is directly proportional to the supply current & it is directly proportional to the supply voltage. We can fully control the voltage as well as the frequency to control the torque of the motor.

Traditional motor starters such as DOL starters and soft starter are cannot vary the speed of the motor. Therefore, it can either run the motor at full speed (full power) or stop the motor. While the VFD can minimize the power consumption by programming it to run the motor at a specific speed.

Unfortunately the VFD can generate harmonics in the line which is why additional filters must be connected with a VFD. Due to the use of so many circuits & components, the overall size of the VFD is larger than a soft starter. It also affects the cost of the VFD which is almost ٣ times greater than soft starter.

Overall, both soft starter & VFD are used for safe motor operation but the soft starter is used in application where the speed control is not necessary while the VFD is used for speed control. However, VFD should be used when high starting torque is required and high cost is not a problem.