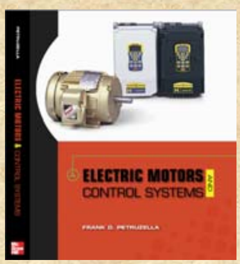
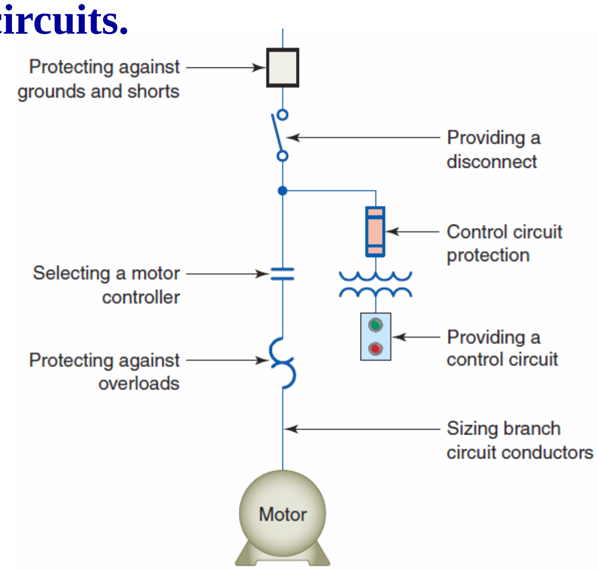


Chapter 8

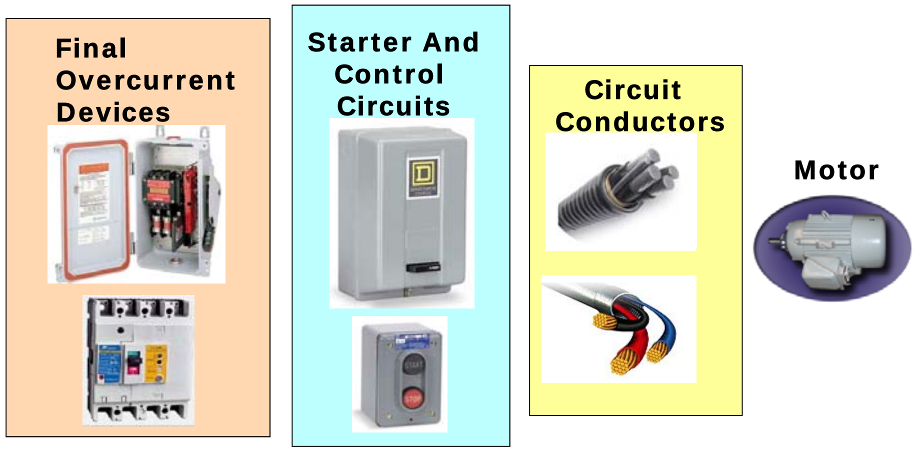
Motor Control Circuits

Understanding the rules detailed in the National Electrical Code is critical to the proper installation of motor control circuits.

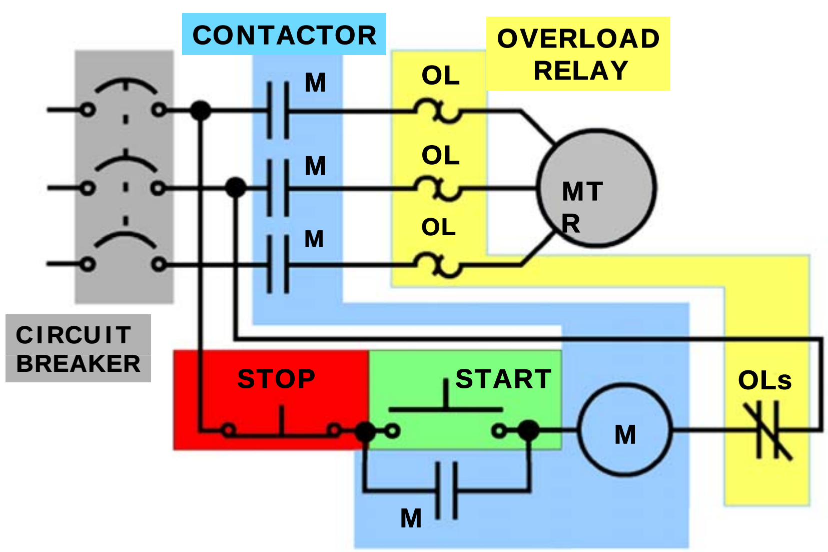


Article 430 of the NEC covers application and installation of motor circuits.

A motor branch-circuit includes the final overcurrent device, the motor starter and associated control circuits, circuit conductors and the motor.



Motor Branch Circuit Sections



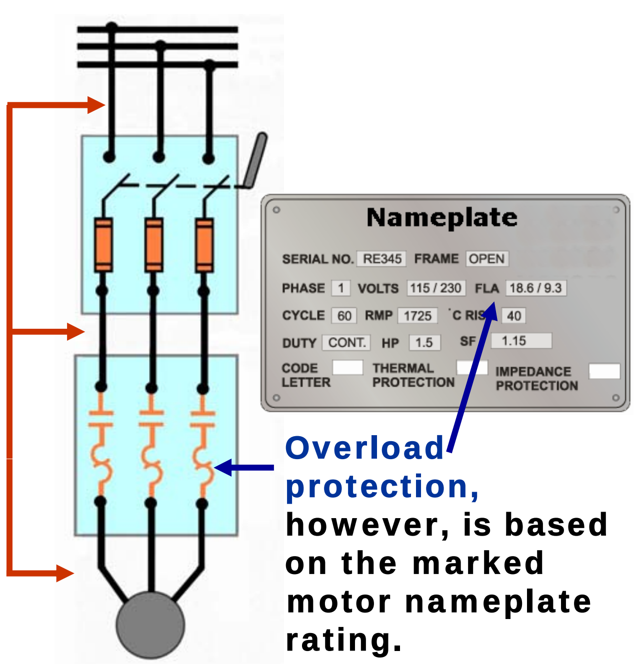
The full-load current rating shown on the motor nameplate *is not* permitted to be used to determine the ampacity of the

- **conductors**
- **switches**
- **motor branch-circuit short-circuit and ground-fault protection.**

The reasons are:

- The supply voltage normally varies from the voltage rating of the motor, and the current varies with the voltage applied.
- The actual full-load current rating for motors of the same horsepower may vary, and requiring the use of NEC tables ensures that if a motor must be replaced, this can be safely done without having to make changes to other component parts of the circuit.

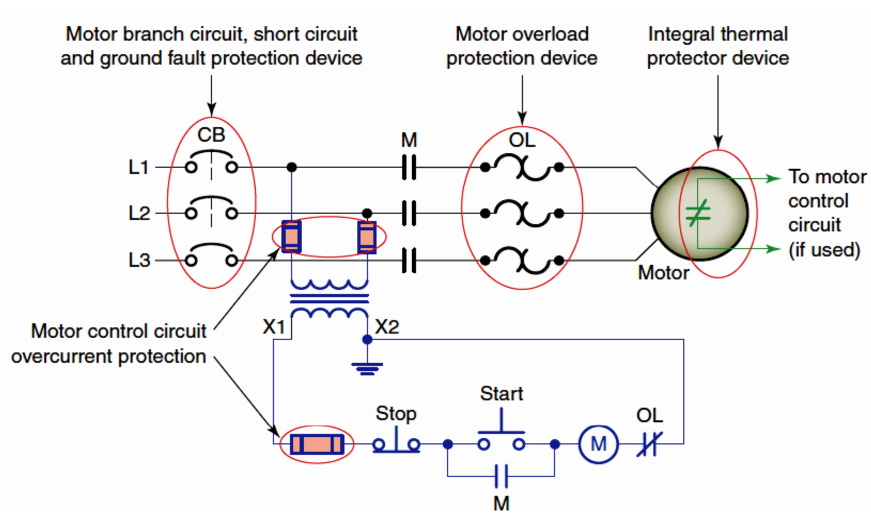
Conductor ampacity must be determined by ***NEC Tables 430-247 through 430-250*** and are based upon the motor nameplate horsepower rating and voltage.



Overload protection, however, is based on the marked motor nameplate rating.

BRANCH CIRCUIT MOTOR PROTECTION

Motor Branch Circuit Protection



This arrangement makes motor protection calculations different from those used for other types of loads.

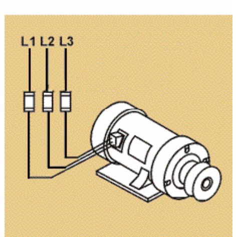
Time-delay fuses provide overload and short circuit protection usually allowing **five times** the rated current for up to **ten seconds** to allow motors to start.

Nontime-delay fuses provide short circuit protection usually allowing about **five times** of their rating for approximately **one-fourth second**, after which the current-carrying element melts.

The amount of time it takes for a fuse to open is known as the **clearing time**. Fuses have an **inverse time characteristic**. The greater the overcurrent, the less the clearing time.

A motor overload condition is caused by excessive load applied to the motor shaft.

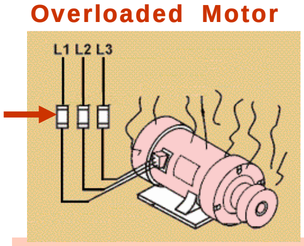
For example, when using a saw, if the board is damp or the cut is too deep, the motor may become overloaded and slow down. The current flow in the windings will increase and heat the motor beyond its design temperature.



Fuses are large enough to allow starting current

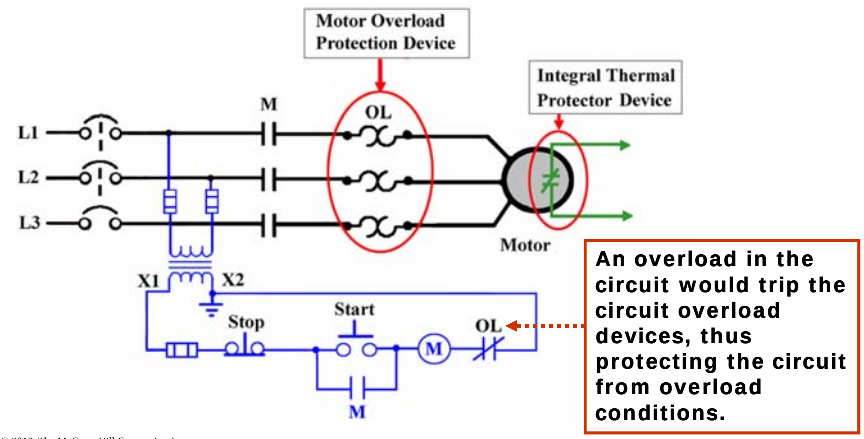
Overloaded Motor

Fuses do not blow

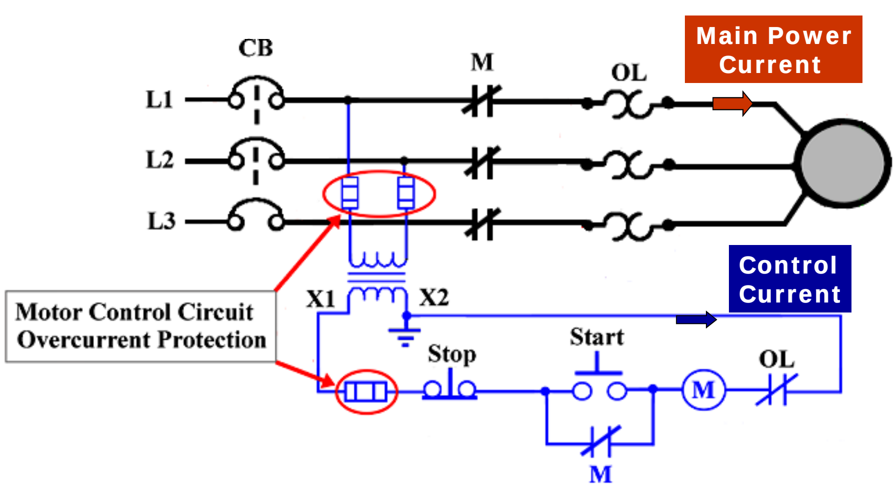


Additional overload protection required

Motors are required to have overload protection, either within the motor itself or somewhere in close proximity to the line side of the motor. This overload protection is actually protecting the motor, the conductors, and much of the circuit ahead of the overloads.

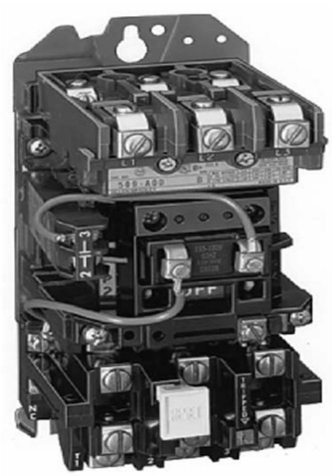


Motor control circuits carry the current that controls the operation of the controller, but do not carry the main power current to the motor.



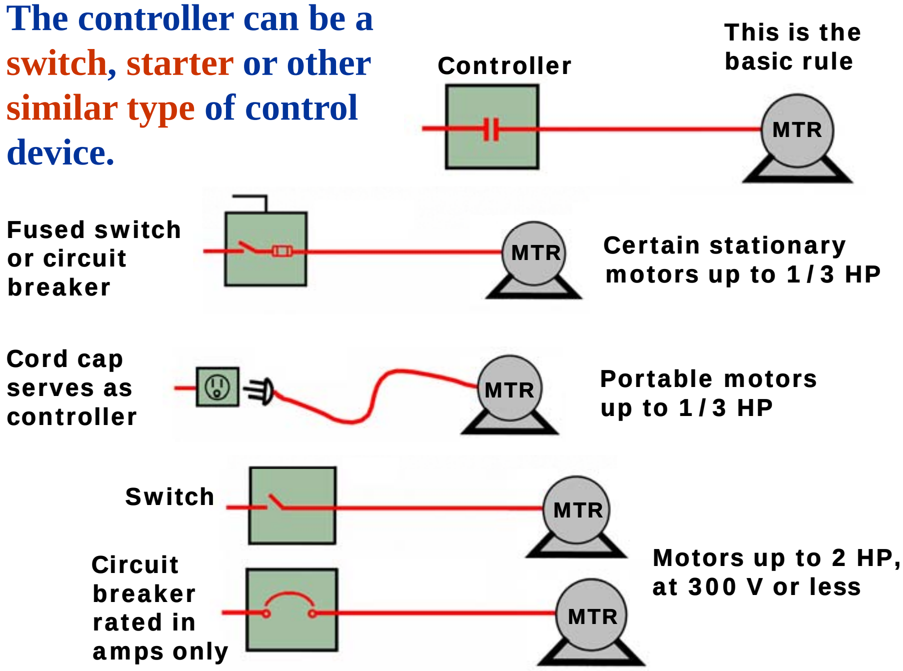
SELECTING A MOTOR CONTROLLER

A *motor controller* is any device that is used to directly start and stop an electric motor by closing and opening the main power current to the motor.



The magnetic starter consisting of a contactor and overload relay is considered to be a controller.

The controller can be a switch, starter or other similar type of control device.



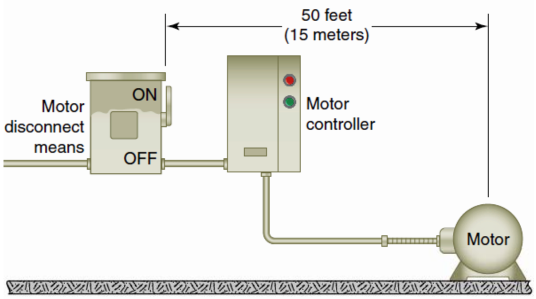
DISCONNECTING MEANS FOR MOTOR AND CONTROLLER

The ability to safely work on a motor, a motor controller or any motor-driven machinery starts with being able to turn the power off to the motor and its related equipment.

The Code requires that a means (a motor-circuit switch rated in HP or a circuit breaker) must be provided in each motor circuit to disconnect both the motor and its controller from all ungrounded supply conductors.

HP Rated Switch

The NEC requires that for motor circuits rated 600 volts or less, the disconnecting means must be located in sight from the controller, motor and the driven machinery location.

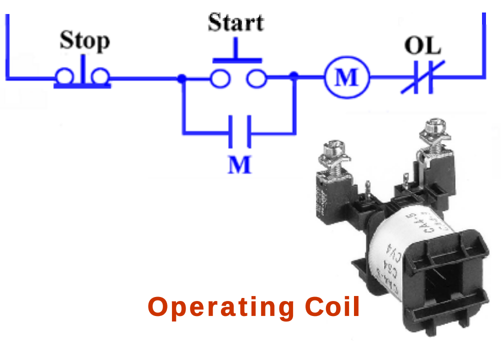


In sight from is defined as being visible and not more than 50 ft (15m)

One Exception to this basic requirement is that a disconnect does not have to be within sight if the required disconnect ahead of the motor controller is capable of being locked in the OPEN position.

PROVIDING A CONTROL CIRCUIT

A motor control circuit carries electrical signals directing the action of the controller but does not carry the main power circuit.



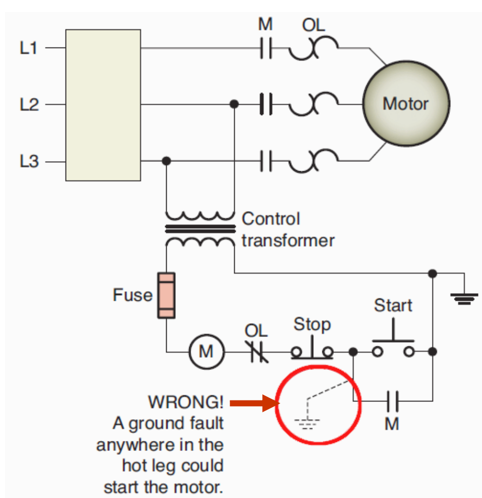
The control circuit commonly has as its load device the operating coil of a magnetic motor starter, a magnetic contactor, or a relay.

Control circuits associated with motor controls can be complex and vary greatly with application.

Elements of a control circuit include:

- Conductors and raceways
- Contactor operating coil
- Source of energy supply to the circuit
- Overcurrent protection devices
- All switching devices that govern energization of the operating coil.

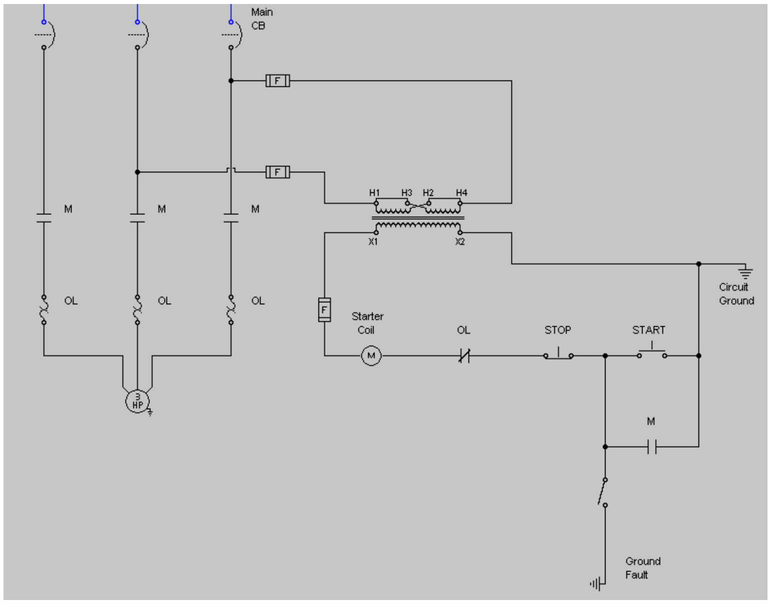
Where one side of the motor control circuit is grounded, the control circuit must prevent the motor from being started due to a ground fault in the control circuit wiring.



WRONGLY DESIGNED CONTROL CIRCUIT

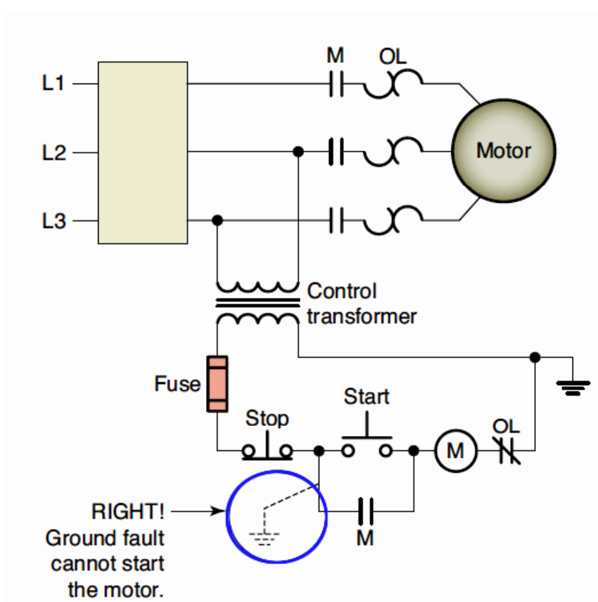
If one side of the start button is in the ground leg of the circuit, as shown, a ground fault on the coil side of the start button can short – circuit the start circuit and start the motor.

Simulated Wrongly Designed Control Circuit

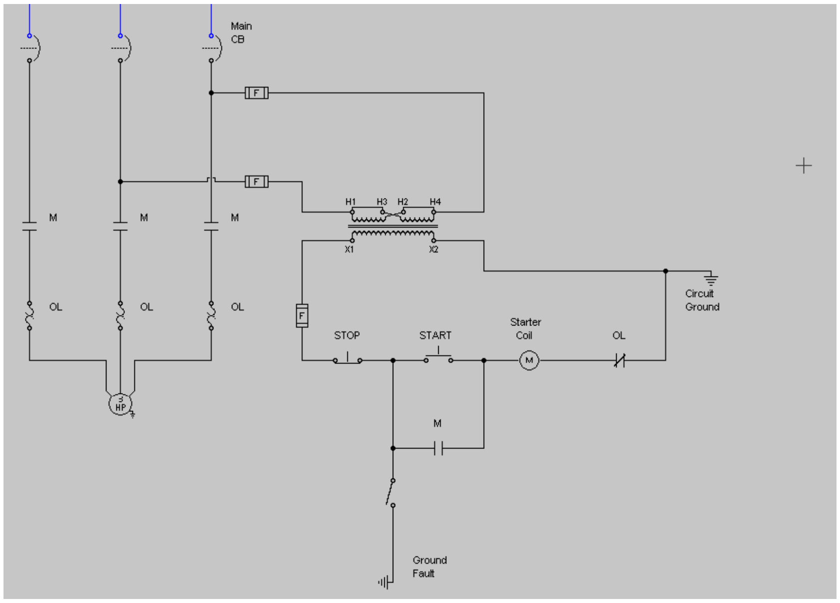


CORRECTLY DESIGNED CONTROL CIRCUIT

By switching the hot leg, as shown, the starting of the motor due to an accidental ground fault can be effectively eliminated.



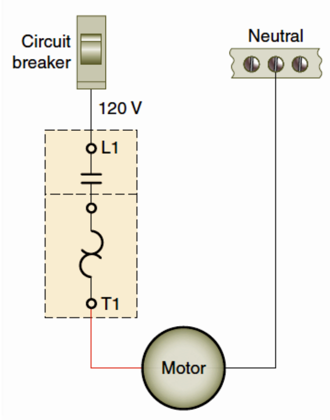
Simulated Correctly Designed Control Circuit



- **Where a transformer is used to obtain a reduced voltage for the motor control circuit and the transformer is located within the motor controller enclosure, the transformer must be connected to the load side of the motor control circuit disconnecting means. The control transformer must be protected in accordance with *NEC Article 430.72(C)***

FULL VOLTAGE STARTING OF AC INDUCTION MOTORS

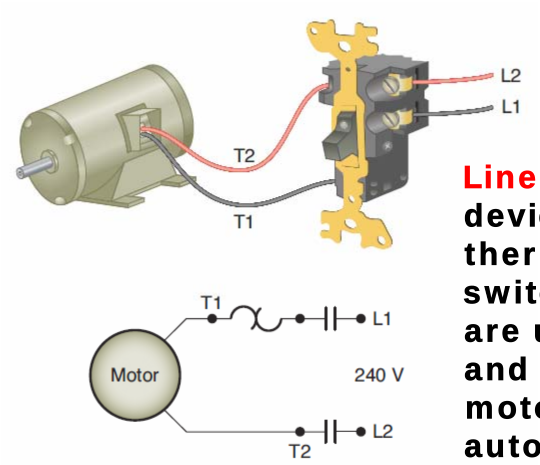
A full voltage, or across-the-line, starter is designed to apply full line voltage to the motor upon starting.



Fractional horsepower manual across-the-line starter

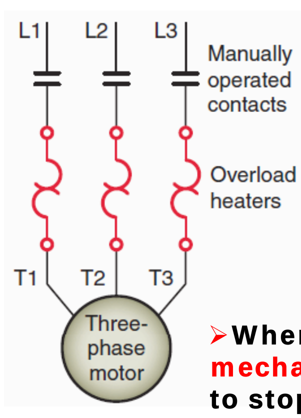
- Uses an ON/OFF snap-action switch with overload protection.
- When started the motor is connected directly across the line and in series with the starter contact and overload device.
- When an overload is sensed, the starter contacts open and cannot be reclosed until the overload relay is reset manually.

Double-pole manual motor starter with a single overload heater to protect the motor windings.



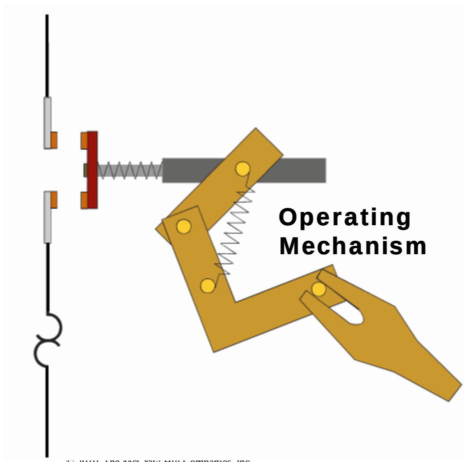
Line rated control devices such as thermostats, float switches and relays are used to connect and disconnect the motor when automatic operation is desired.

A three-pole manual starter provides three overload heaters to protect the motor windings.

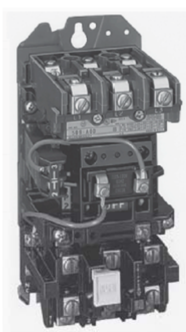


- This starter is operated by pushing a button on the starter enclosure cover that **mechanically** operates the starter.
- When an overload relay trips, the starter **mechanism unlatches**, opening the contacts to stop the motor.
- The contacts cannot be reclosed until the starter mechanism has been reset by pressing the STOP button; first, however, the thermal unit needs time to **cool**.

The power circuit contacts of manual motor starters are unaffected by the loss of voltage, so consequently will remain closed when the supply voltage fails.



- If the supply voltage fails, the motor will stop and restart automatically when the supply voltage is restored (no voltage release).
- Manual starters must be mounted near the motor that is being controlled. Remote control operation is not possible as it would be with a magnetic starter.

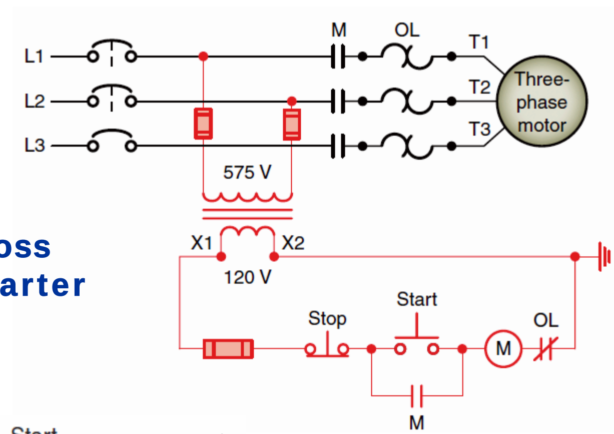


NEMA type

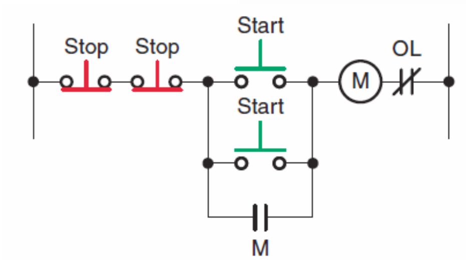
The magnetic starter contacts are closed by energizing a holding coil.

IEC type

- This enables the use of automatic and remote control of the motor.
- Pushbutton stations are mounted nearby, but automatic control pilot devices can be mounted almost anywhere on the machine.

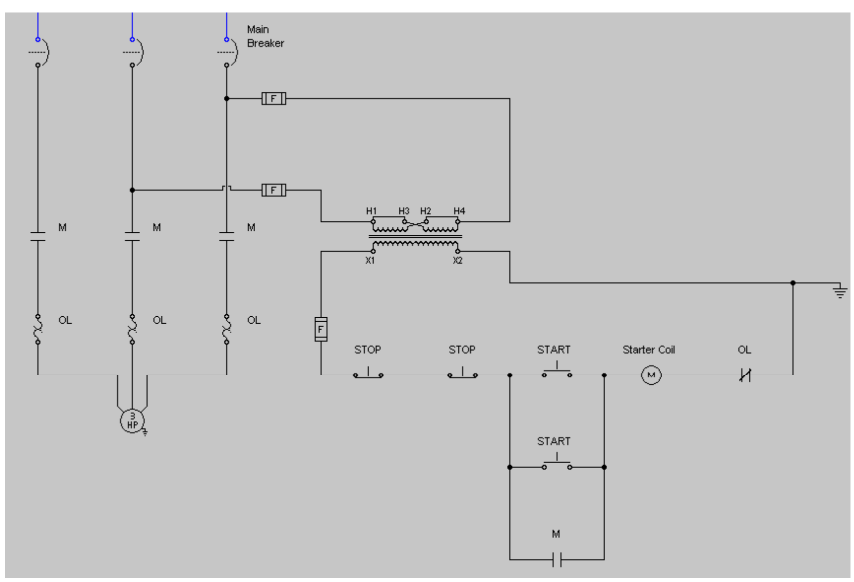


Three-phase magnetic across the line AC starter

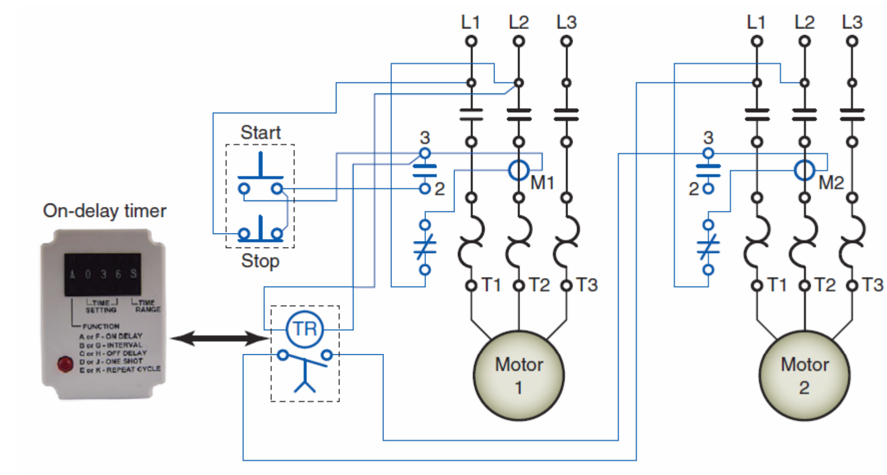


Additional stop and start connections

Simulated Two Start/Stop Magnetic Starter

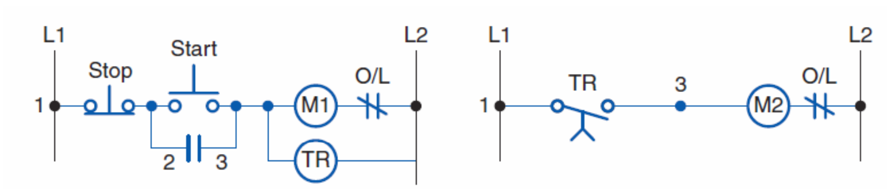


Circuit used to start two motors at full line voltage.



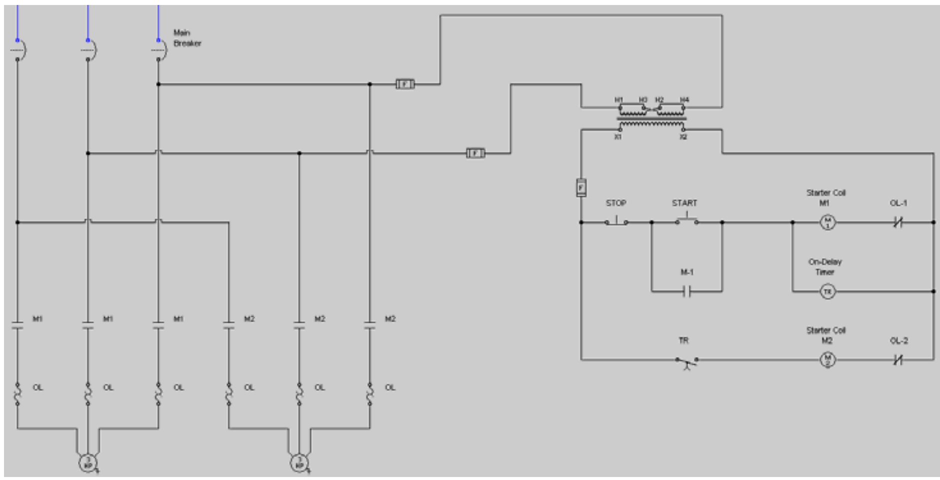
Power and control circuit wiring

Circuit used to start two motors at full line voltage.



- The first motor is started by pressing the start button connected in a three-wire control configuration to motor starter M1.
- Power is applied to both Motor 1 and on-delay timer coil TR.
- After the preset time, normally open timer contacts TR close to energize starter coil M2 and the second motor starts.
- Both motors will stop by pressing the stop button.

Simulated two motor starting circuit.

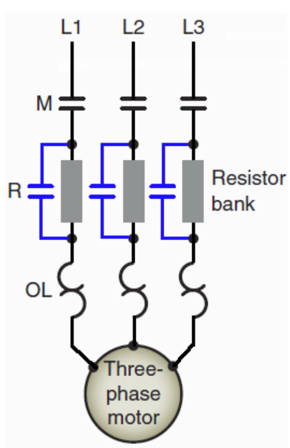


REDUCED VOLTAGE STARTING OF INDUCTION MOTORS

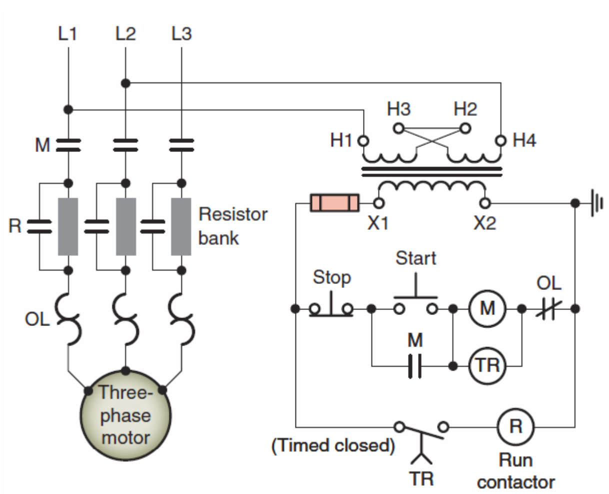
Reduced voltage starters limit line voltage disturbances and lower excessive starting torque

- The large starting in-rush current of a large size motor could cause line voltage dips and brownouts.
- In addition to high starting currents, the motor also produces starting torques that are higher than full-load torque. In many applications this starting torque can cause excessive mechanical, damage such as belt, chain, or coupling breakage.
- When a reduced voltage is applied to motor at rest, both the current drawn by the motor and the torque produced by the motor are reduced.

Reduced voltage is obtained in the primary resistance starter by means of resistances that are connected in series with each motor stator lead during the starting period.

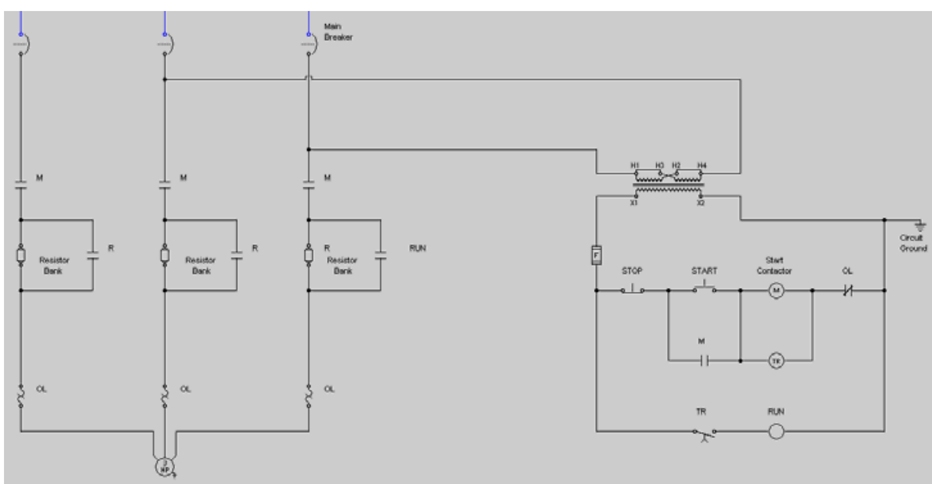


- The voltage drop in the resistors produces a reduced voltage at the motor terminals.
- After a preset time period the "R" contacts close to short circuit the starting resistors and apply full line voltage to the motor.



- Pressing the start button energizes motor starter coil M and timer coil TR.
- The motor is then started through a resistor in each of the three incoming lines.
- After the preset time has elapsed the timer contacts close to energize contactor C coil.
- This causes contacts C to close shorting out the starting resistor bank and applying full voltage to the motor.

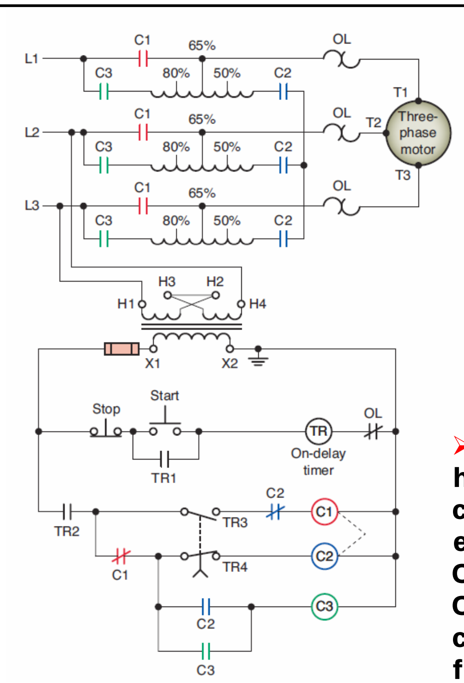
Simulated primary resistance starting circuit.



The autotransformer starter uses a step-down autotransformer to reduce the line voltage.

- Multiple taps on the transformer permit the voltage, current, and torque to be adjusted to satisfy many different starting conditions.

- In closed transition starting, the motor is never disconnected from the line source during acceleration.



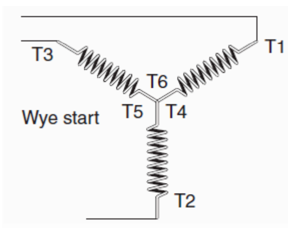
- On starting timer coil TR and contactor coils C2 and C3 are energized.

- Main contacts C2 and C3 close and the motor is connected through the transformers taps to the power line.

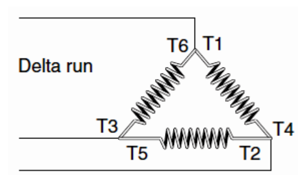
- After the starting period has elapsed TR timed contacts operate to de-energize contactors C2 and C3 and energize contactor C1, resulting in the connection of the motor to full line voltage.

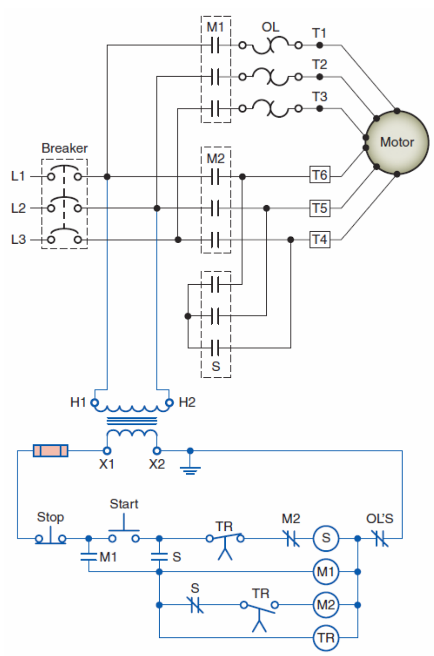
The Wye-Delta starter connects the motor windings first in Wye during the starting period and then in Delta after the motor has accelerated.

Wye-delta starters can only be used with three-phase AC motors where all six leads of the stator windings are available.



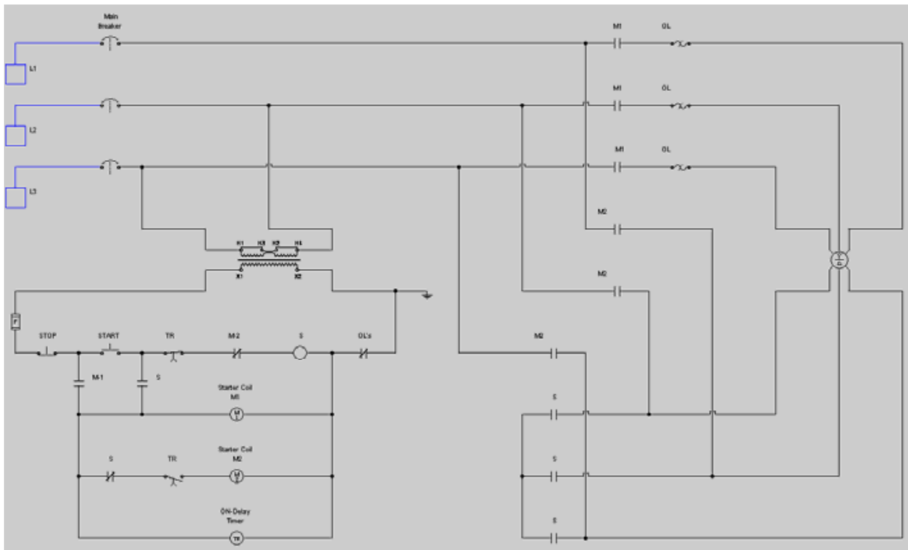
When wye connected the motor starts with a significantly lower current than when delta connected.



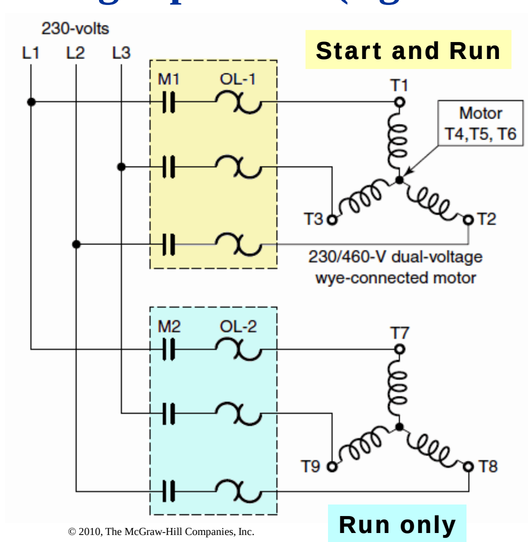


- **On starting coils S, M1 and TR are energized connecting the motor winding in a wye configuration**
- **After the time delay period has elapsed, the TR contacts change state to de-energize contactor coil S and energize contactor coil M2.**
- **The motor then continues to run with the motor connected in a delta arrangement.**

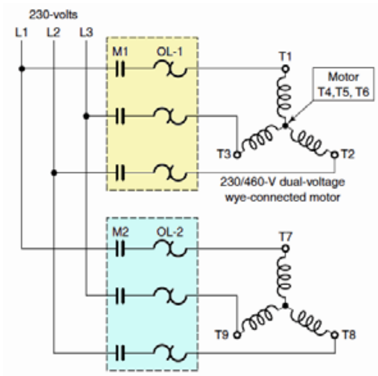
Simulated Wye-Delta Starter



Part-winding starters are used on induction motors wound for dual voltage operation (e.g. 230/460 V)

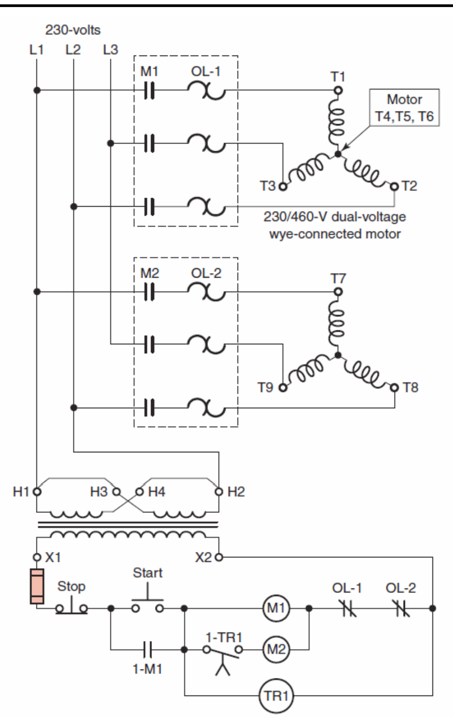


Power is applied to part of the motor windings on startup and then connects the remaining coils for normal speed.

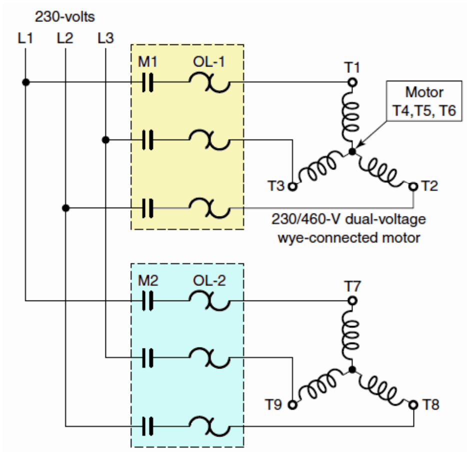


230/460 V motor operated @ 230 V

- These motors have two sets of windings connected in parallel for low-voltage operation and in series for high-voltage operation.
- When used on the *lower voltage*, they can be started by first energizing only one winding, limiting starting current and torque to approximately one-half of the full voltage values.
- The second winding is then connected in parallel, once the motor nears operating speed.
- Since one set of windings has higher impedance than the two connected in parallel, less inrush current flows to the motor on startup.



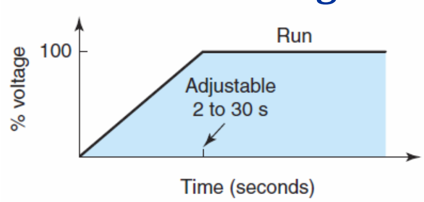
- On starting coils M1 and TR1 are energized.
- M1 contacts close immediately starting the motor at reduced current and torque through one-half of the wye windings.
- After the preset time has elapsed the timer contacts close to energize starter coil M2 applying voltage to the second set of wye windings.



- **It is of utmost importance to connect the motor terminals (T1, T2, T3, T7, T8 and T9) to the proper terminals on the motor starter.**
- **When motor winding T7- T8- T9 is connected, it must produce the same rotation.**

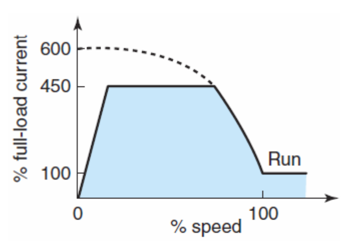
If by chance an error has been made, and T8 and T9 were interchanged, the second winding will attempt to change the rotation of the motor. Extremely high current will then flow, damaging the equipment.

Electronic soft-starters limit motor starting current and torque by ramping (gradually increasing) the voltage applied to the motor during the selected staring time.

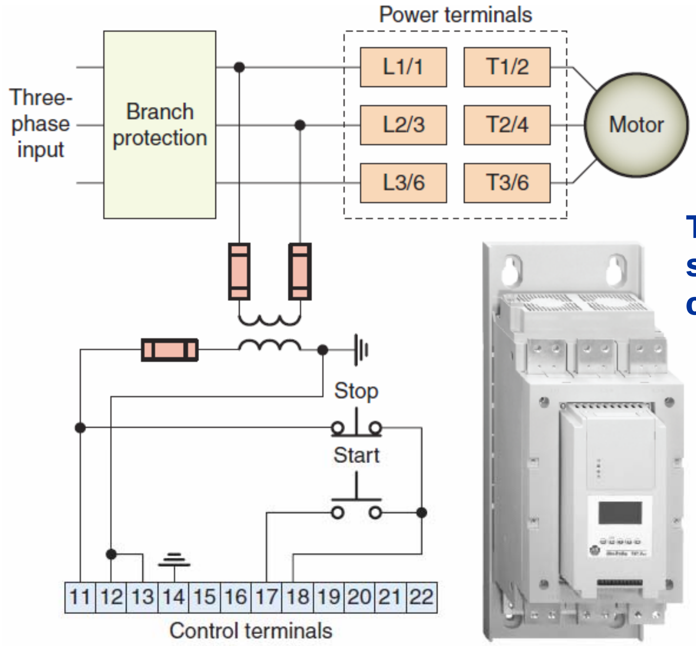


Ramped-up voltage

Current limit is used when it is necessary to limit the maximum starting current and is usually adjustable.



Current limiting

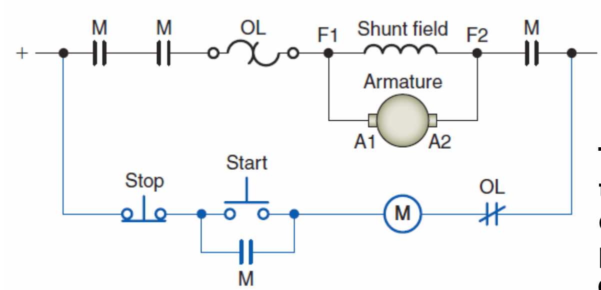


Typical soft starter connections.

DC MOTOR STARTING

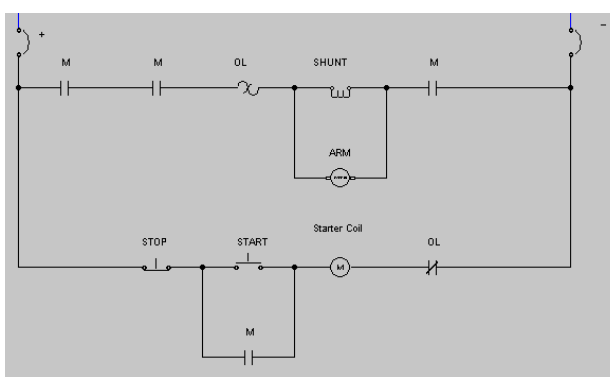
One major difference between AC and DC starters are the electrical and mechanical requirements necessary for suppressing the arcs created in opening and closing contacts under load.

To combat prolonged arcing in DC circuits, the contactor switching mechanism is constructed so that the contacts will separate rapidly and with enough air gap to extinguish the arc as soon as possible on opening.

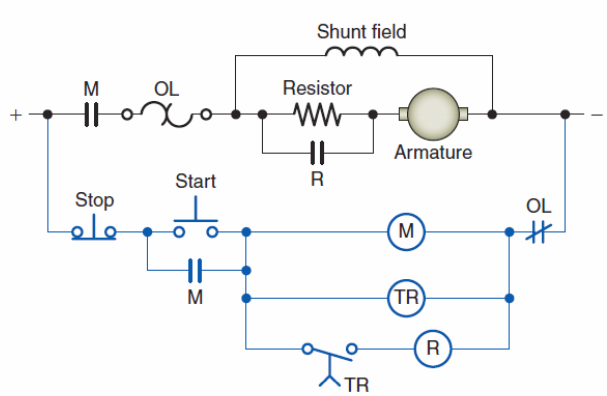


Across-the-line DC motor starter

To help extinguish the arc, the starter is equipped with three power contacts connected in series.

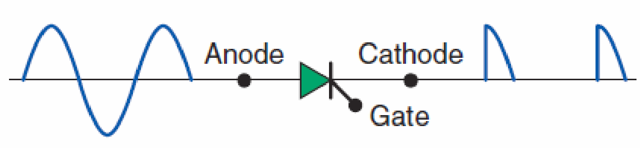


Definite-time reduced voltage DC motor starter.



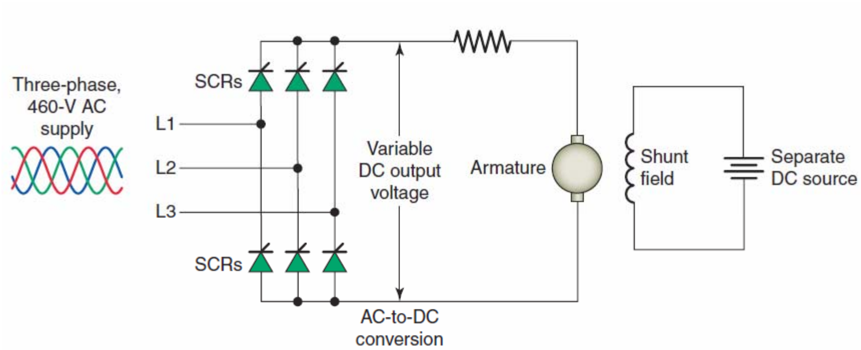
- When the M contact closes, full line voltage is applied to the shunt field while the resistor is connected in series with the armature.
- Following a preset time period, the contactor R closes, bypassing the resistor, allowing the motor to operate at base speed.
- This gives the motor smooth torque without creating a large surge of current.

Variable voltage acceleration of a DC shunt motor can be obtained by using an SCR (Silicon Controlled Rectifier) armature voltage controller.



An SCR is a semiconductor device that has three elements: anode, cathode, and gate.

The SCR provides a useful method of converting AC voltage to variable DC voltage.



- By applying a signal to the gate element at precisely the right time, you can control how much current the SCR will either pass or block during a cycle.
- This is known as phase control.
- The shorter the on time, the lower the DC voltage applied to the armature.

REVERSING OF AC INDUCTION MOTORS

REVERSING THREE-PHASE INDUCTION MOTOR STARTER

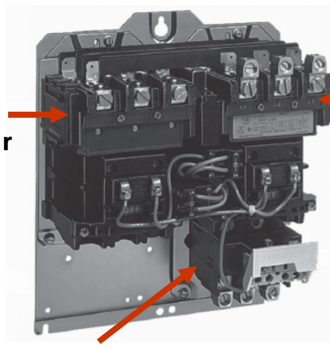
Interchanging any two leads to a three-phase induction motor will cause it to run in the reverse direction.

The industry standard is to interchange phase A (Line 1) and phase C (Line 3), while phase B (Line 2) remains the same.

Reversing starters are used to automatically accomplish phase reversal.

NEMA Type

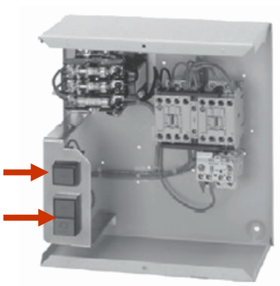
Forward Contactor



Reverse Contactor

OL Relay

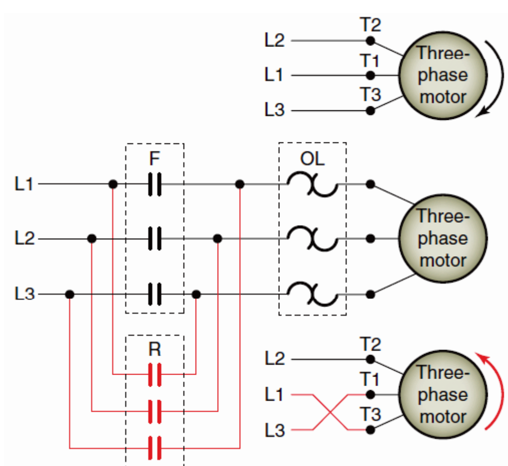
IEC Type



Stop

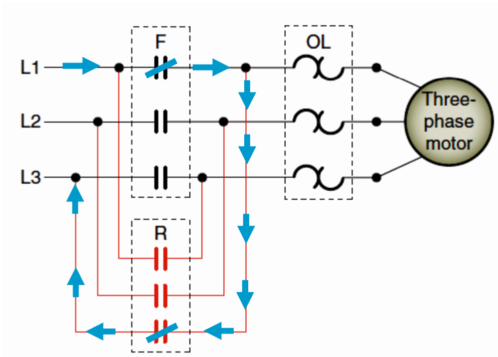
FWD/REV

Power circuit of a magnetic full voltage three-phase reversing motor starter



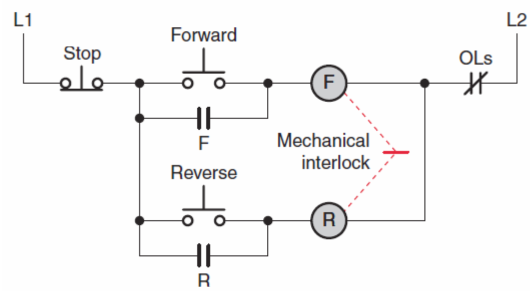
- Uses two three-pole contactors with a single overload relay assembly.
- The power circuits of the two contactors are interconnected.
- Contacts F connect L1, L2, and L3 to motor terminals T1, T2, and T3, respectively.
- Contacts R connect L1 to motor terminal T3 and connect L3 to motor terminal T1, causing the motor to reverse direction.

When reversing the motor, it is vital that the forward and reverse contactors *not* be energized at the same time.



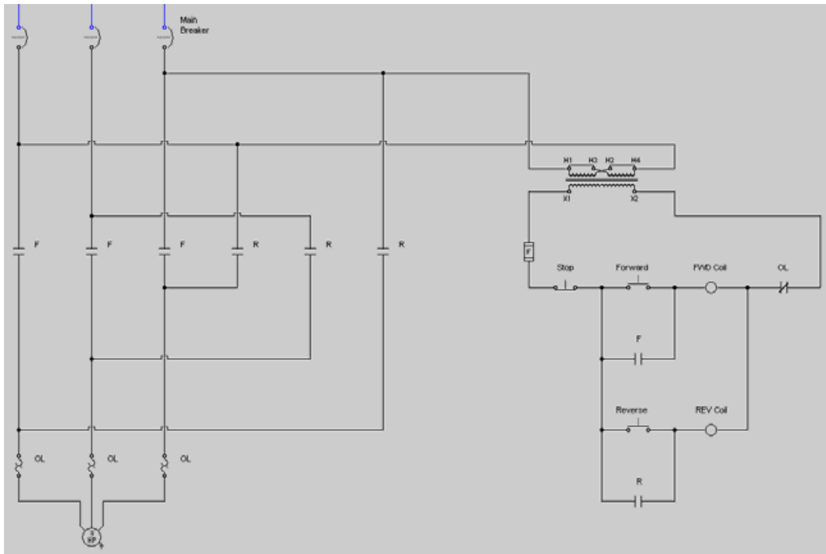
Activating both contactors would cause a short circuit since two of the line conductors are reversed on one contactor.

Both mechanical and electrical interlocks are used to prevent the forward and reverse contactors from being activated at the same time.

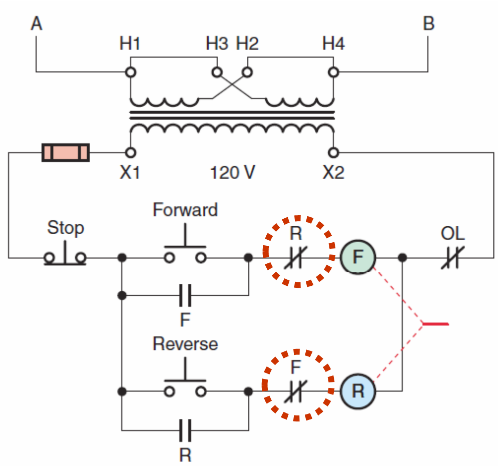


- **Mechanical interlocking uses a system of levers to prevent both contactors from being engaged at the same time.**
- **The broken line indicates that the coils F and R cannot close contacts simultaneously because of the mechanical interlocking action of the device.**

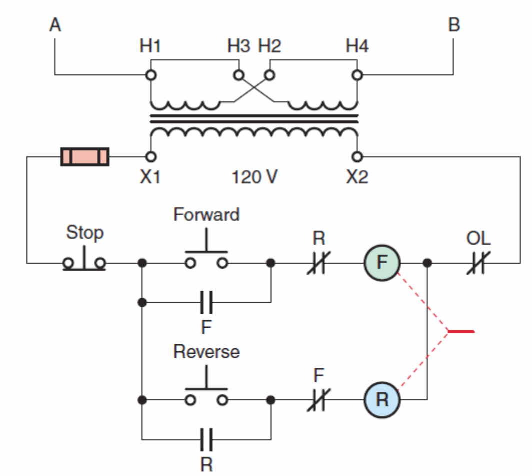
Simulated Reversing Starter With No Interlocking



Mechanical interlocks have been known to fail and for this reason additional electrical interlocking is used for added protection.

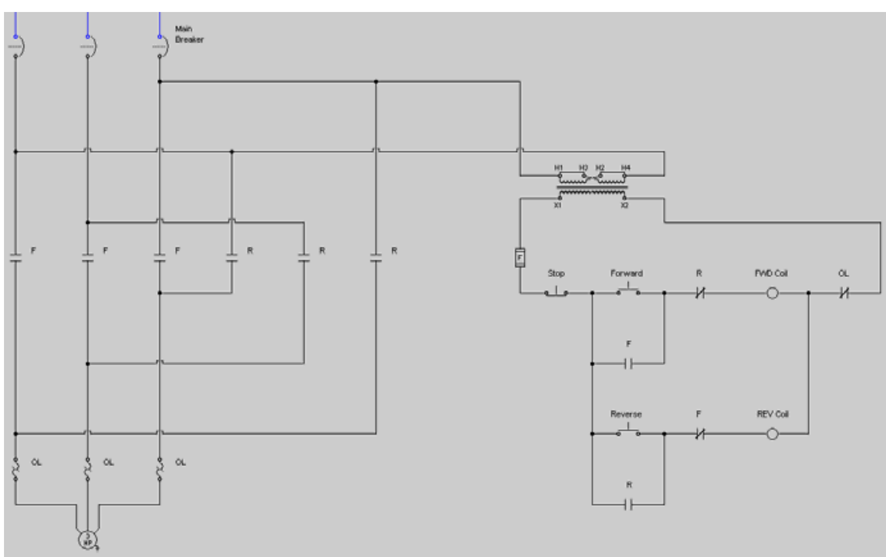


Most reversing starters utilize auxiliary contacts operated by the forward and reverse coils to provide electrical interlocking.

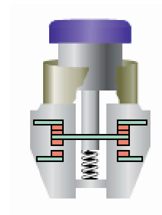


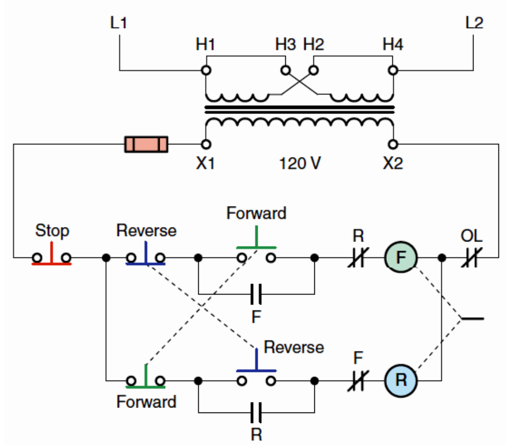
- The NC contact controlled by the forward coil is connected in series with the reverse coil.
- The NC contact controlled by the reverse coil is connected in series with the forward coil.
- When the F coil is energized, the NC contact in series with the R coil is opened to prevent the R coil from being energized
- When the R coil is energized, the NC contact in series with the F coil is opened to prevent the F coil from being energized.

Simulated Auxiliary Contact Interlocking

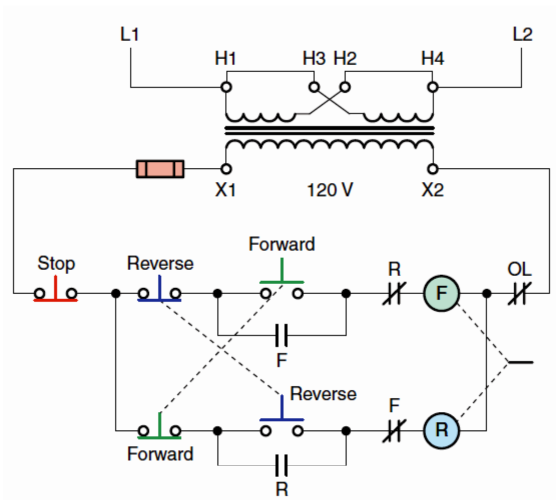


Electrical pushbutton interlocking utilizes break-make, normally closed and normally open switch contacts on the forward and reverse buttons.



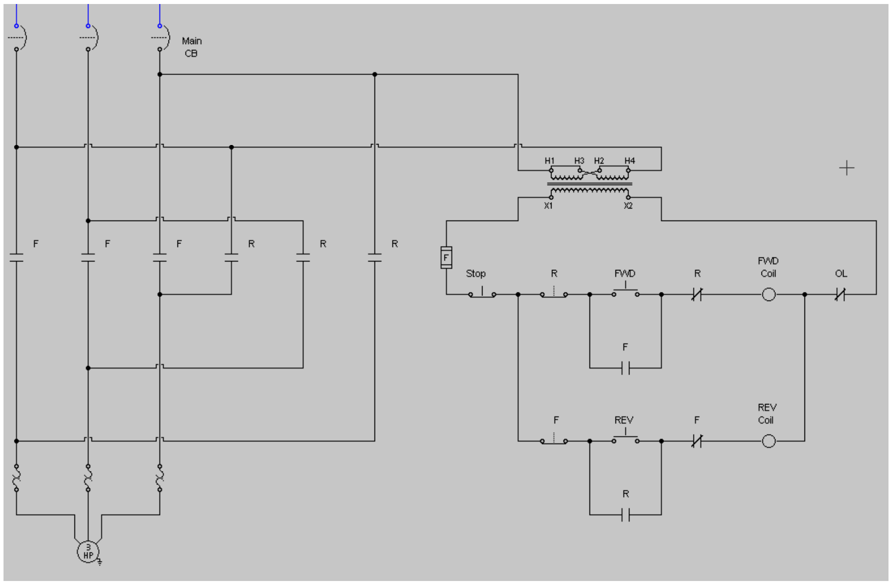


Interlocking is achieved by connecting the NC contact of the reverse button in series with the NO contact of the forward button and vise versa.

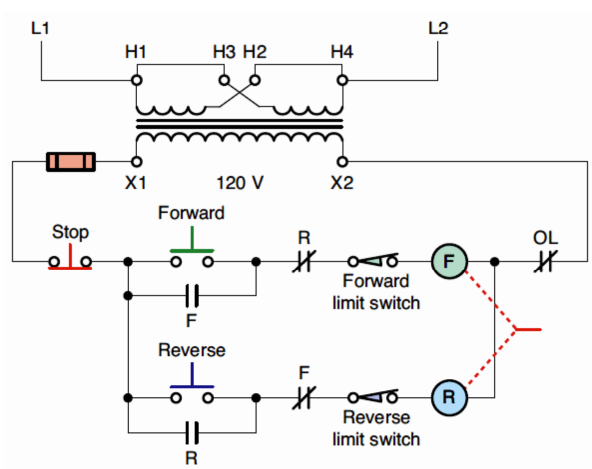


- **The NC contact of the reverse button acts like another stop button in the forward circuit.**
- **The NO contact on the reverse button is used as the start button for the reverse circuit.**
- **When the reverse button is pressed, its NC contact opens the circuit to the forward coil and at the same time its NC contact completes the circuit to the reverse coil.**
- **The motor reverses direction immediately without the stop button being pressed.**

Simulated Pushbutton Interlocking

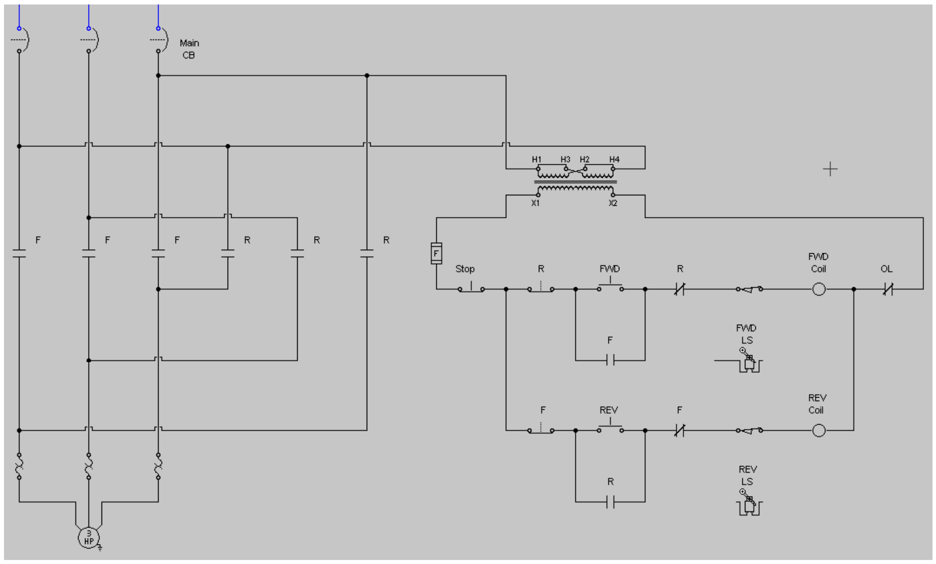


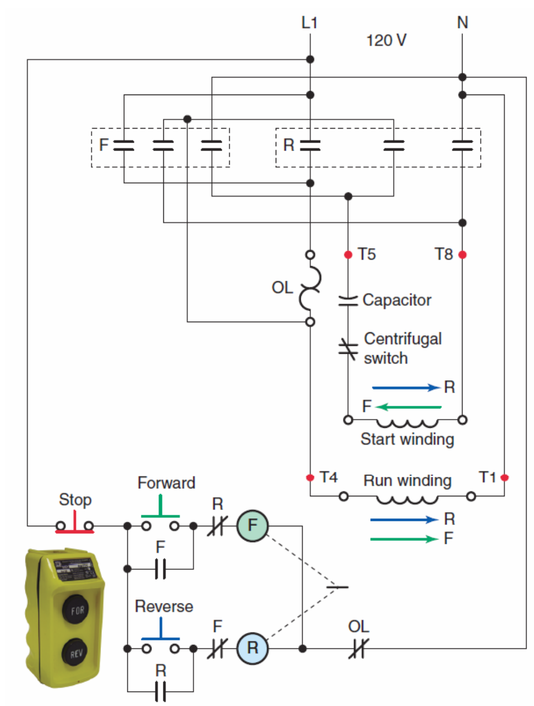
Limit switches can be incorporated into a reversing starter circuit to limit travel.



The location of the limit switches allows the direction of travel to be stopped if the motor is driving a device that has limits to its travel.

Simulated Travel Limit Switch Operation

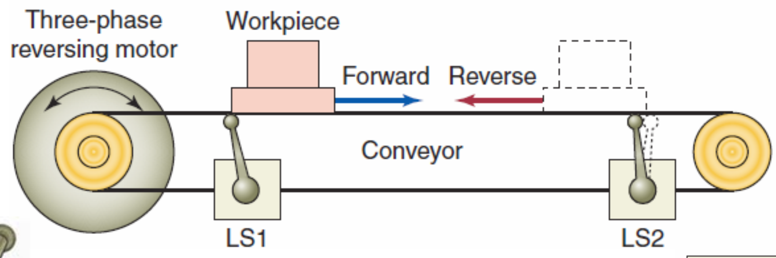




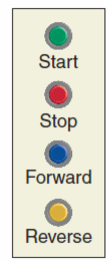
Single-Phase Motor Reversing

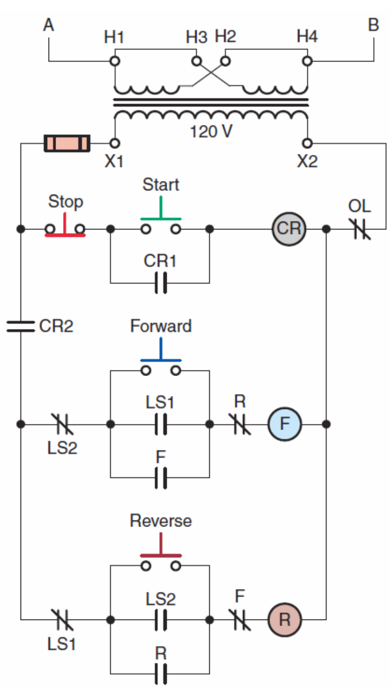
- Direction of rotation is changed by interchanging the start winding leads, while those of the run winding remain the same.
- The centrifugal switch must be allowed to reclose before any attempt to reverse the direction of rotation

Some reciprocating machine process use two limit switches to provide automatic control of the motor.



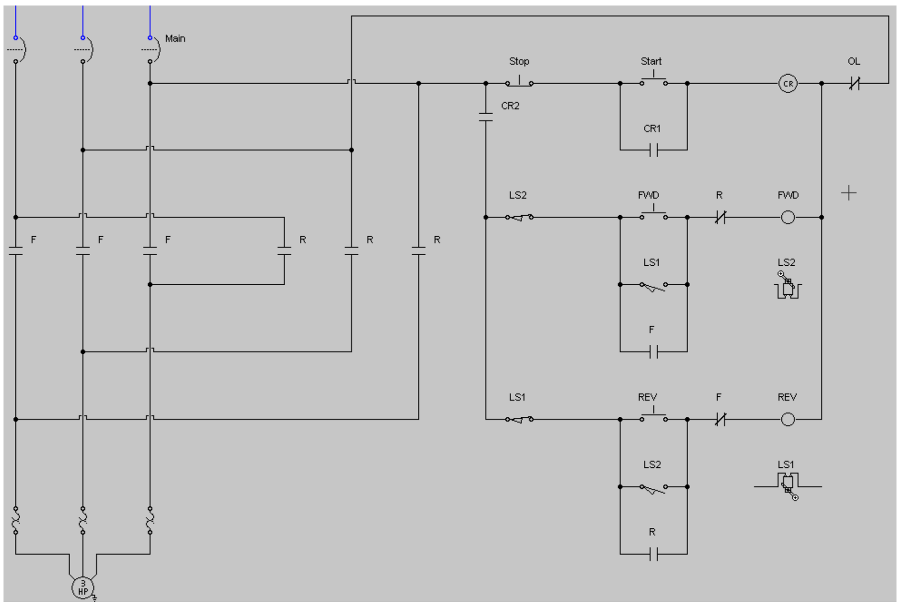
Each limit switch (LS1 and LS2) has two sets of contacts, one normally open and the other normally closed.





- **Start/Stop buttons are used to initiate and terminate the automatic control.**
- **The NC contact of LS2 acts as the stop for the FWD controller, and the NO contact of LS1 acts as the start contact for the FWD controller.**
- **The NC contact of LS1 is wired as a stop contact for the REV controller, and the NO contact of LS2 is wired as a start contact for the REV controller.**
- **FWD/REV buttons provide a means of starting the motor in order that the limit switches can take over automatic control.**

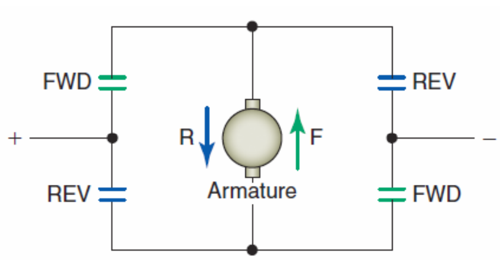
Simulated Reciprocating Machine Process



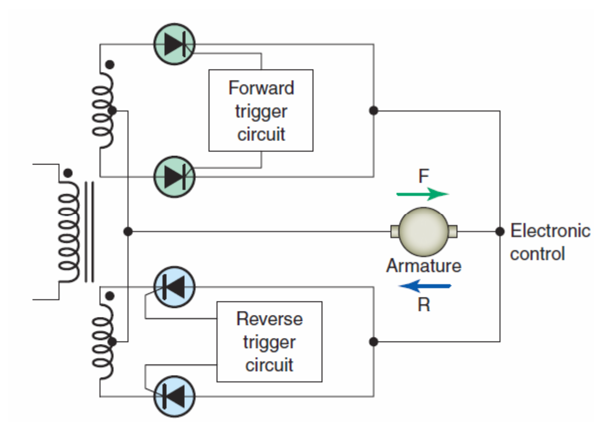
REVERSING OF DC MOTORS

A DC motor is reversed by:

- **Reversing** the direction of the **armature** current and leaving the field current the same.
- **Reversing** the direction of the **field** current and leaving the armature current the same.



- **Most are reversed by switching the direction of current flow through the armature.**
- **Since the armature has a much lower inductance than the field less arcing occurs at the contacts when reversed in this manner.**



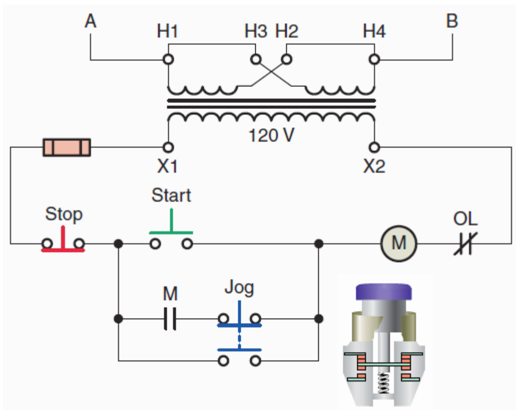
For electronic control, two sets of SCRs are provided. One set is used for current flow in one direction through the armature, and the second set is used for current flow in the opposite direction.

JOGGING

Jogging is the momentary operation of a motor for the purpose of accomplishing small movements of the driven machine.

- Jogging is used for frequent starting and stopping of a motor for short periods of time.

- It involves an operation in which the motor runs when the button is pressed and will stop when the button is released.

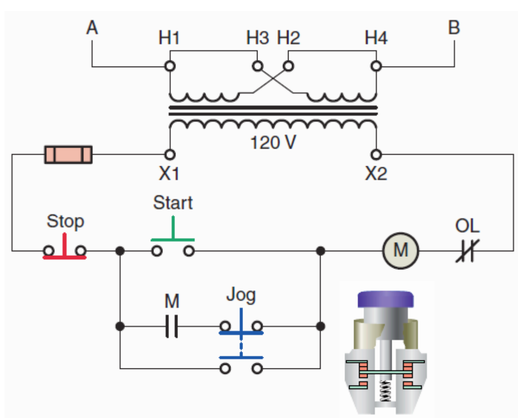


Pushbutton Jog Circuit

➢With the M coil deenergized and the jog button then pressed, a circuit is completed for the M coil around the M maintaining contact.

➢The M main contacts close to start the motor, but the maintaining circuit is incomplete as the NC jog contact is open.

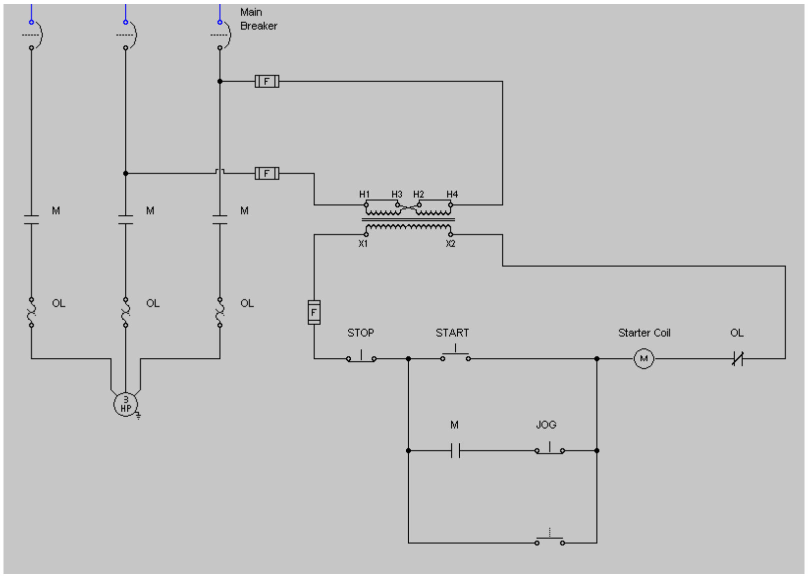
➢As a result, starter coil M will not seal in; instead, it can stay energized only as long as the jog button is fully depressed.



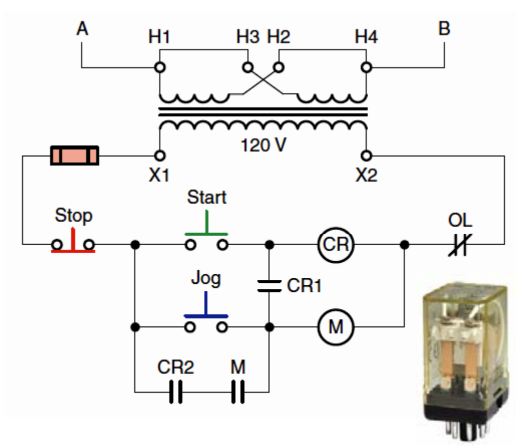
➢On quick release of the jog push button, should its NC contacts reclose before the starter maintaining contact M opens, the motor would continue to run.

➢In certain applications this could be hazardous to workers and machinery.

Simulated Pushbutton Jog Circuit

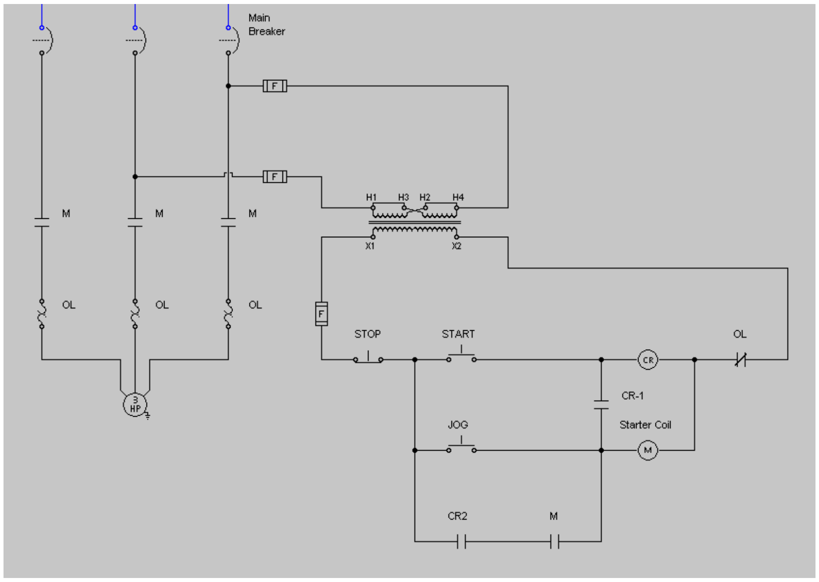


A control relay jogging circuit is much safer method of implementing jog control.

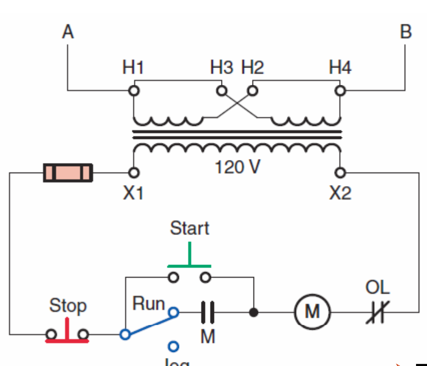


- Pressing the **start button** energizes coils CR and M to start and run the motor.
- Pressing the **jog button** energizes the M coil only, starting the motor. Both CR contacts remain open, and the CR coil is deenergized. The M coil will not remain energized when the jog push button is released.

Simulated Control Relay Jog Circuit

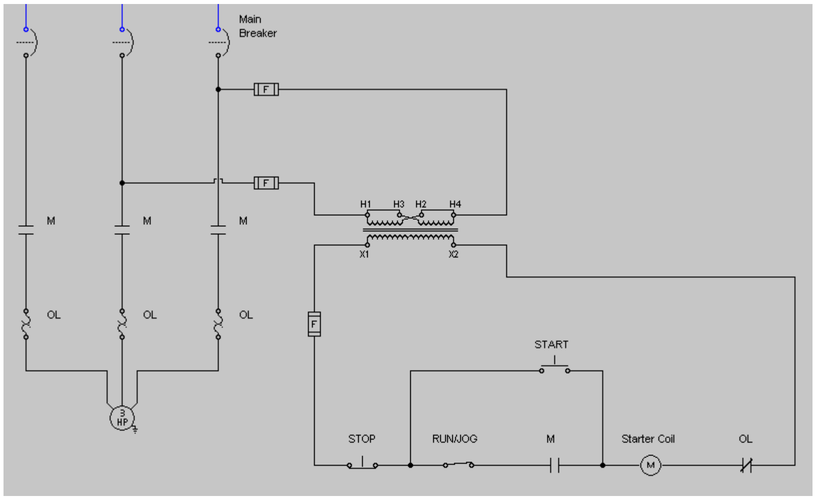


A selector switch connected in the control circuit can also be used to implement jogging.



- The start button doubles as a jog button.
- When the selector switch is placed in the run position, the maintaining circuit is not broken. If the start button is pressed, the M coil circuit is completed and maintained.
- Turning the selector switch to the jog position opens the maintaining circuit. Pressing the start button completes the circuit for the M coil, but the maintaining circuit is open.

Simulated Selector Switch Jog Circuit

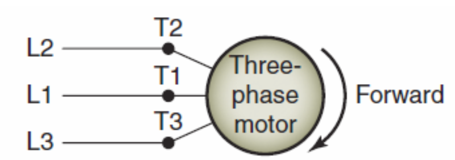


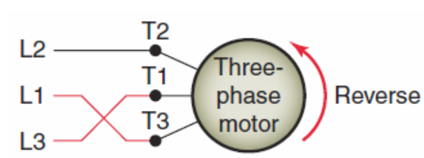
The most common method of stopping a motor is to remove the supply voltage and allow the motor and load to coast to a stop.

In some applications, however, the motor must be stopped more quickly or held in position by some sort of braking device.

PLUGGING AND ANTI-PLUGGING

Plugging stops a polyphase motor quickly, by momentarily connecting the motor for **reverse rotation** while the motor is still running in the forward direction.

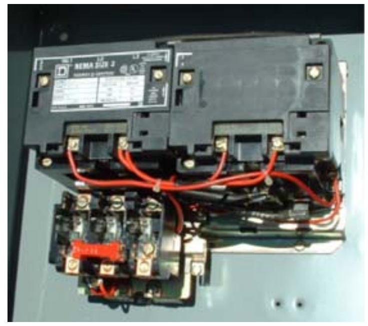




Plugging acts as a retarding force for rapid stop and quick reversal of motor rotation.

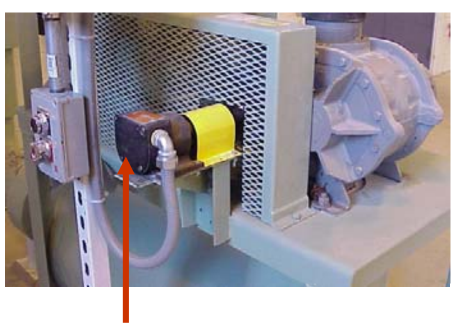
Plugging produces more heat than most normal-duty applications.

NEMA specifications call for reversing starters used for such applications to be **derated**.



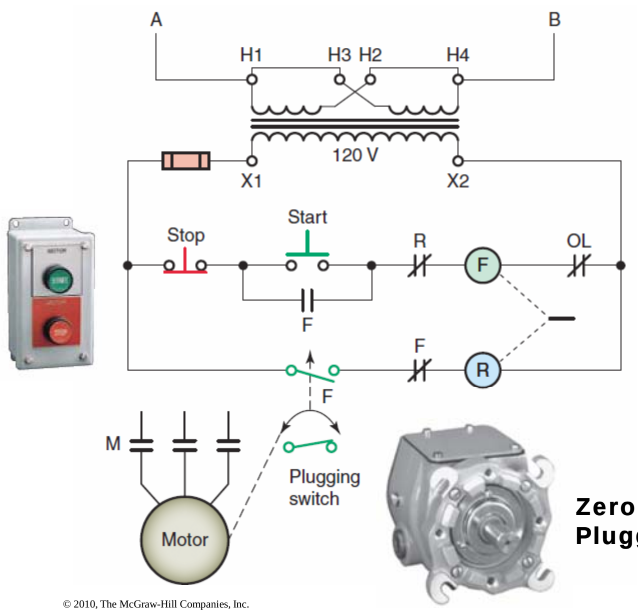
The next **size larger** reversing starter must be selected when it is used for plugging to stop or reverse at a rate of more than **five times per minute**.

A zero-speed or plugging switch wired into the control circuit of a standard reversing starter can be used for automatic plugging of a motor.



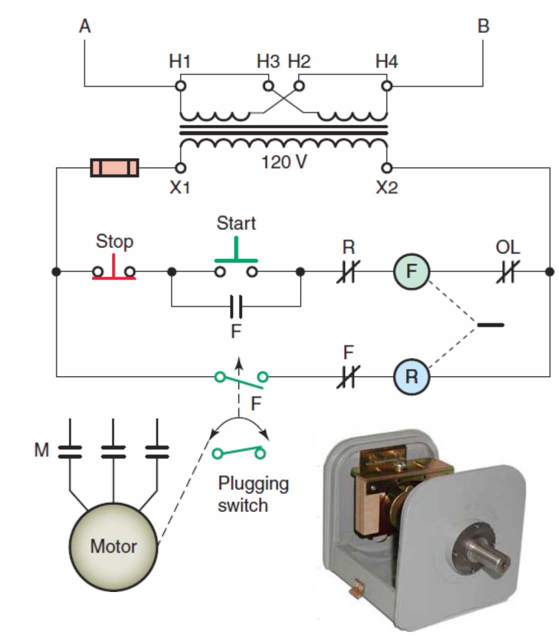
- The zero-speed switch is coupled to a moving shaft on the machinery whose motor is to be plugged.
- The switch prevents the motor from reversing after it has come to a stop.
- As the zero-speed switch rotates, centrifugal force or a magnetic clutch causes its contacts to open or close.

Forward direction plugging control circuit.



Reversing Starter

Zero-Speed or Plugging Switch

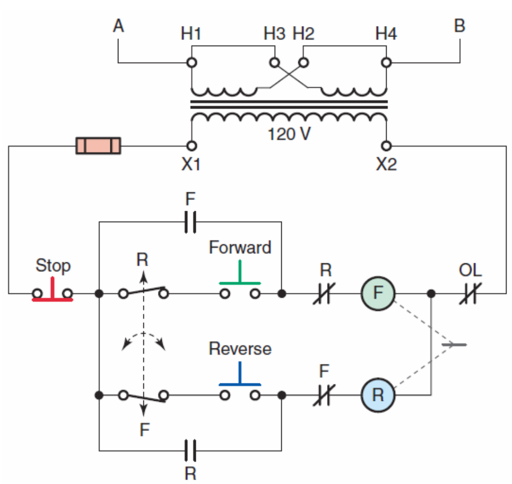


- **With the motor operating pressing the stop button deenergizes the forward contactor.**
- **The reverse contactor is energized, and the motor is plugged.**
- **The motor speed decreases at which point its forward contact opens and deenergizes the reverse contactor.**

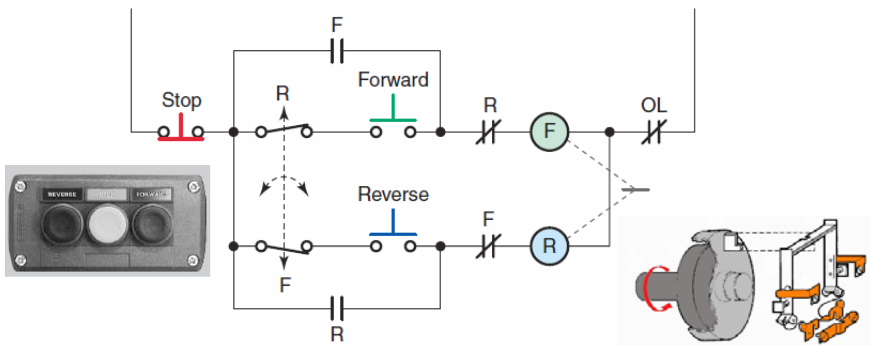
The sudden reversing torque applied when a large motor is reversed (without slowing the motor speed) could damage the driven machinery, and the extremely high current could affect the distribution system.

Antiplugging protection is obtained when a device prevents the application of a counter torque until the motor speed is reduced to an acceptable value.

Antiplugging circuit used to prevent reversing the motor before the motor has slowed to near zero speed.



- Pressing the forward button completes the circuit for the F coil, closing the F power contacts and causing the motor to run in the forward rotation.
- The F zero-speed switch contact opens because of the forward rotation of the motor.

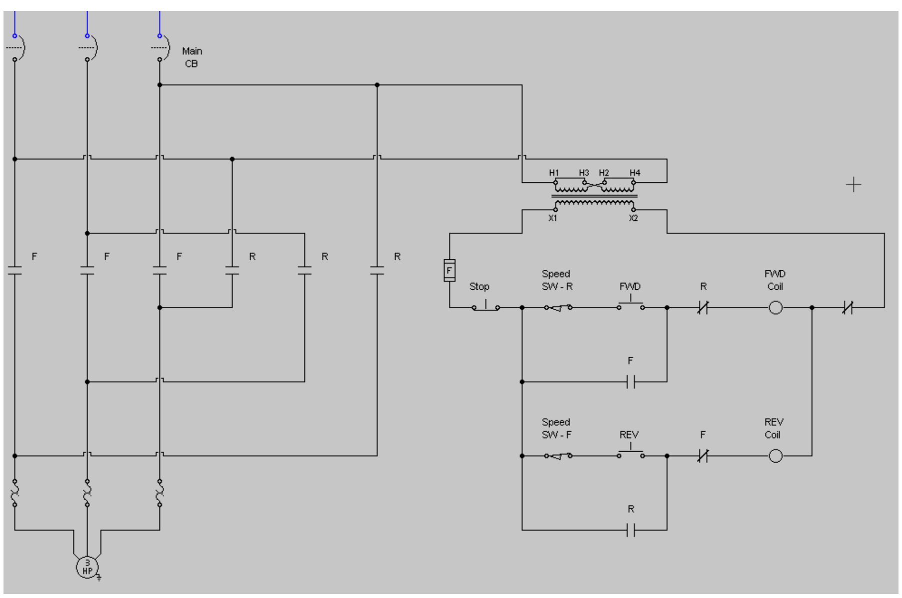


➢Pressing the stop button deenergizes the F coil, which opens the F power contacts, causing the motor to slow down.

➢Pressing the reverse button will not complete a circuit for the R coil until the F zero-speed switch contact recloses.

➢As a result, when the rotating equipment reaches near zero speed, the reverse circuit may be energized, and the motor will run in the reverse rotation.

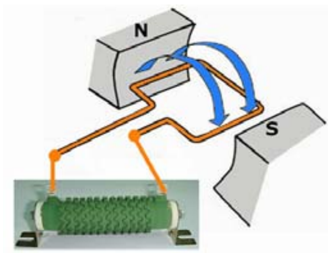
Simulated Anti-Plugging Protection Circuit



DYNAMIC BRAKING

Dynamic braking is achieved by reconnecting a running motor to act as a generator immediately after it is turned off, rapidly stopping the motor.

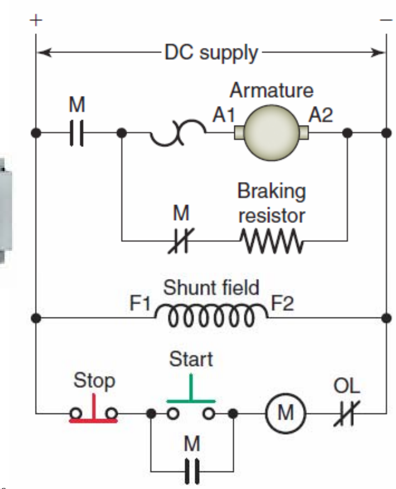
The generator action converts the mechanical energy of rotation to electrical energy that can be dissipated as heat in a resistor.



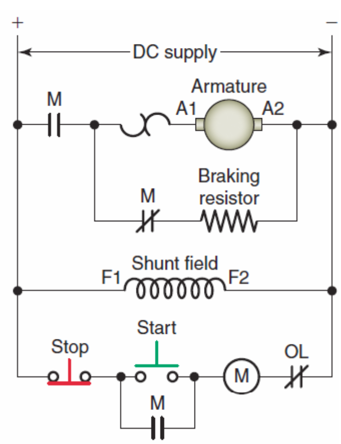
Dynamic Braking Resistor

The smaller the ohmic value of the braking resistor, the greater the rate at which energy is dissipated and the faster the motor comes to rest.

Dynamic braking of a DC motor may be needed because DC motors are often used for lifting and moving heavy loads that may be difficult to stop.

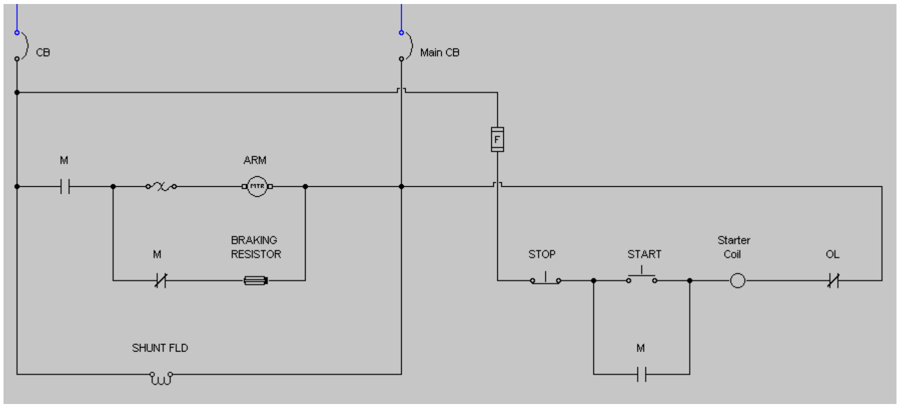


Braking resistor



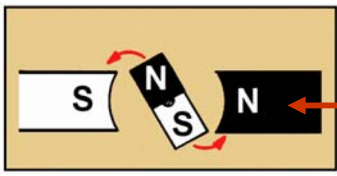
- Assume the motor is operating and the stop button is pressed.
- Starter coil M deenergizes to open the normally open M power contact to the motor armature.
- At the same time, the normally closed M power contact closes to complete a braking circuit around the armature through the braking resistor, which acts like a load.
- The shunt field winding of the DC motor remains connected to the power supply.
- The armature generates a counter emf voltage. This counter emf causes current to flow through the resistor and armature.

Simulated Dynamic Braking Circuit



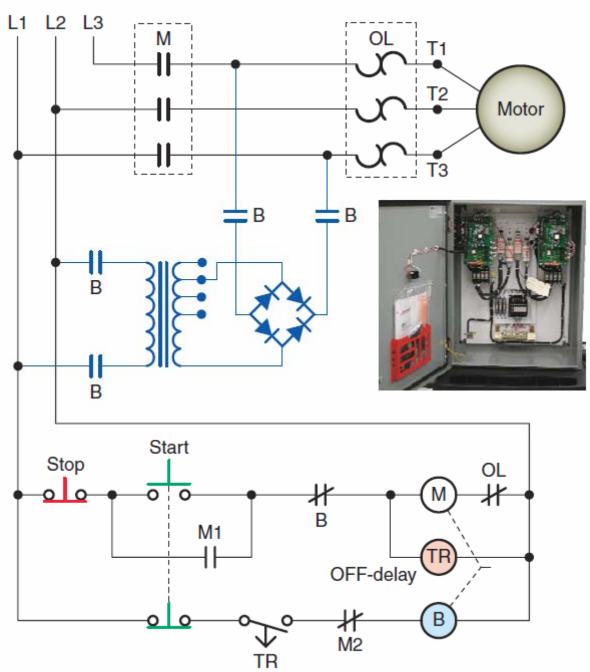
DC INJECTION BRAKING

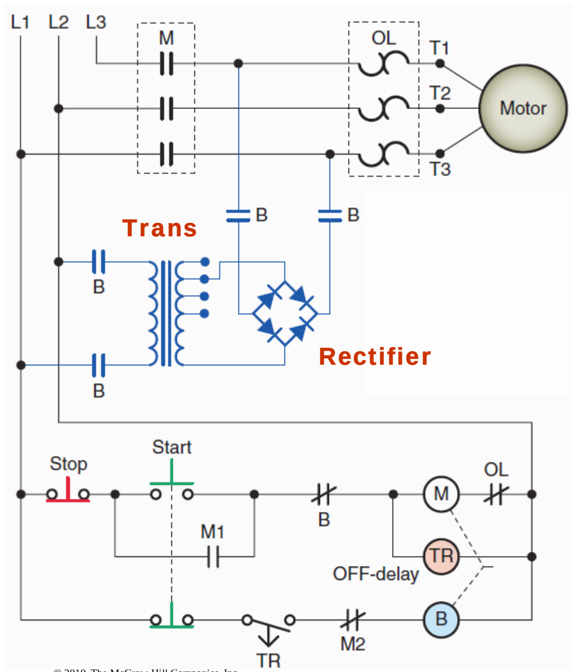
DC injection braking is a method of braking in which direct current is applied to the stationary windings of an AC motor after the applied AC voltage is removed.



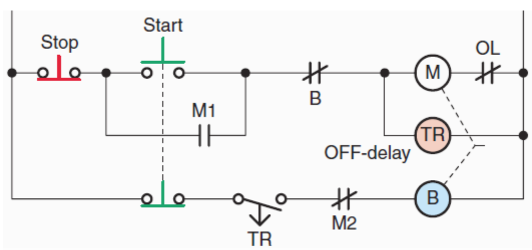
- The injected DC voltage creates a magnetic field in the motor stator winding that does not change in polarity.
- In turn, this constant magnetic field in the stator creates a magnetic field in the rotor.
- Because the magnetic field of the stator is not changing in polarity, it will attempt to stop the rotor when the magnetic fields are aligned (N to S and S to N).

DC injection braking applied to a three-phase AC induction motor.



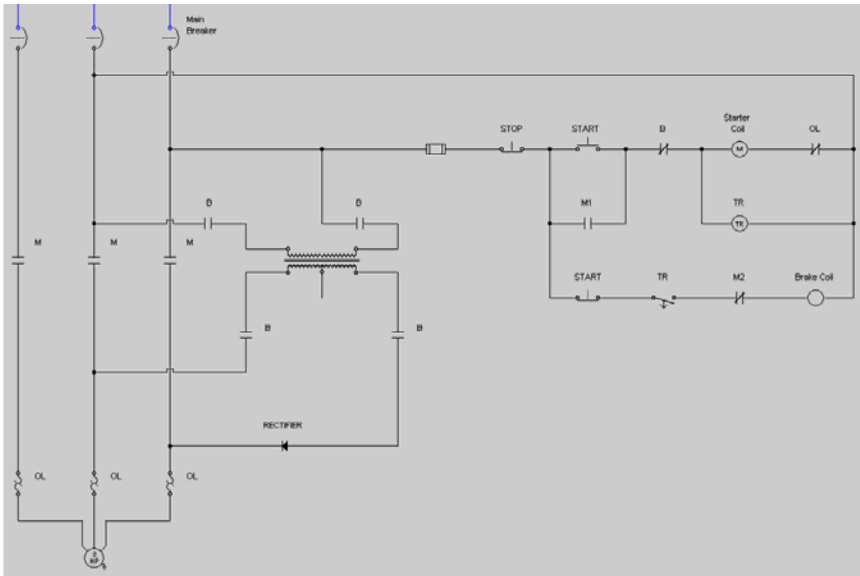


- A transformer with tapped windings is used to adjust the amount of braking torque applied to the motor.
- The DC injection voltage is obtained from the full-wave bridge rectifier circuit, which changes the line voltage from AC to DC.
- Coils M and B are interlocked so that the AC and DC supplies are not connected to the motor at the same time.



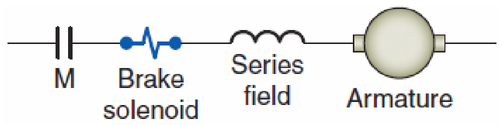
- Pressing the start button energizes starter coil M and off-delay timer coil TR.
- M1 contact closes to maintain current to the starter coil and M2 contact opens to open the current path to braking coil B.
- Off-delay timer contact TR remains closed at all times while the motor is operating.
- When the stop button is pressed, starter coil M and off-delay timer coil TR are deenergized.
- Braking coil B becomes energized through the closed TR contact.
- All B contacts close to apply DC braking power to the motor stator winding. Coil B is deenergized after the timer contact time out.

Simulated DC Injection Braking Circuit

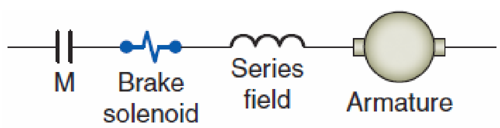


ELECTROMECHANICAL FRICTION BRAKES

Electromechanical **friction brakes** can hold the motor shaft stationary after the motor has stopped.

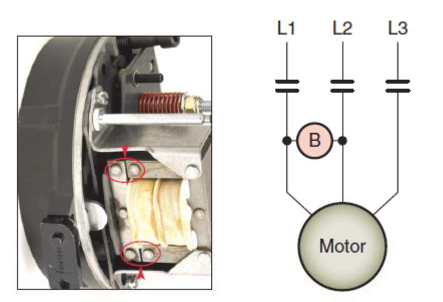


- Drum and shoe-type friction brake used on DC series motor drives.
- The brake drum is attached to the motor shaft and the brake shoes are used to hold the drum in place.
- The brake is set with a spring and released by a solenoid.
- When the motor is running, the solenoid is energized to overcome the tension of the spring, thus keeping the brake shoes clear of the drum.



- When the motor is turned off, the solenoid is deenergized and the brake shoes are applied to the drum through the spring tension.
- The brake operating coil is connected in series with the motor armature and release and sets in response to motor current.
- This type of braking is **fail-safe** in that the brake is applied in case of an electrical failure.

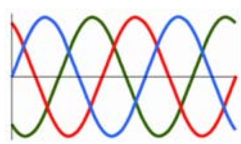
AC motor electromagnetic brakes are commonly used as parking brakes to hold a load in place or as stopping brakes to decelerate a load.



- These motors are directly coupled to an AC electromagnetic brake.
- When the power source is turned off, the motor stops instantaneously and holds the load.
- Most come equipped with an external manual release device, which allows the driven load to be moved without energizing the motor.

MULTISPEED MOTORS

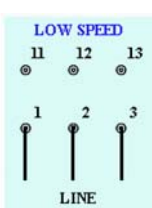
The speed of an induction motor depends on the number of poles built into the motor and the frequency of the electrical power supply.

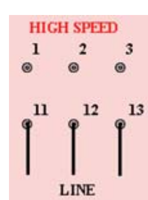


- A single-speed motor has one rated speed at which it runs when supplied with the nameplate voltage and frequency.
- A **multispeed motor** will run at more than one speed, depending on how you connect it to the supply.
- Multispeed motors typically have **two speeds** to choose from, but they may have more.

The different speeds of a multispeed motor are selected by connecting the external motor winding stator leads to a multispeed starter.

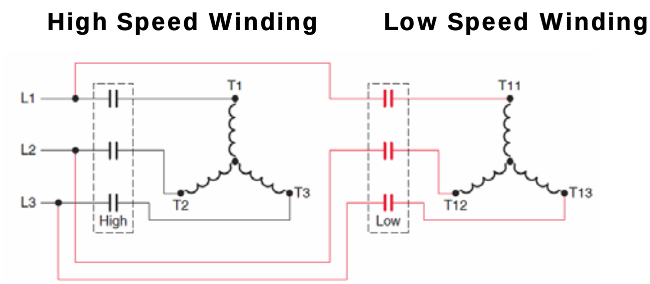
Multispeed magnetic starters automatically reconnect multispeed motor windings for the desired speed in response to a signal received from push button stations or other pilot devices.





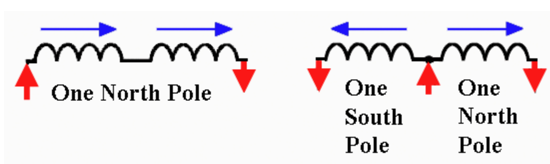
Multispeed motors are available in two basic versions: consequent pole and separate winding.

A **separate winding motor** has a winding for each speed.



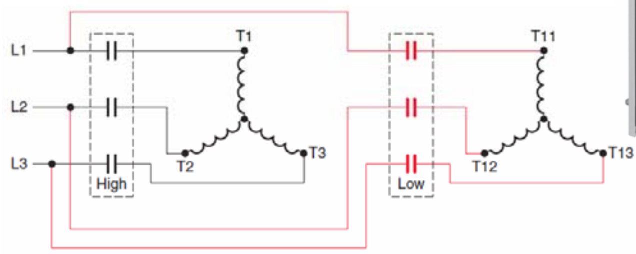
- The speed of each winding depends on the number of poles.
- The low-speed winding is wound for more poles than the high-speed winding.
- The motor cost is higher than consequent pole, but the control is simpler.

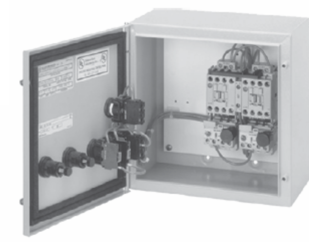
A **consequent pole motor** has a winding for every two speeds.



- Taps are brought from the winding for reconnection for a different number of poles.
- Two-speed, consequent-pole motors have one reconnectable winding.
- Low speed of a two speed, consequent-pole motor is one half the speed of high speed.
- Three-speed motors have one reconnectable winding and one fixed winding.

Two-speed separate winding starter.

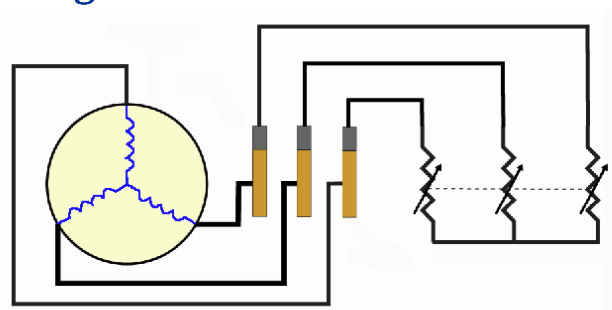




- Contains a high-speed and a low-speed starter, mechanically and electrically interlocked with each other.
- Requires two sets of overload relays, one for the high-speed circuit and one for the low-speed circuit.
- Control panel contains high-speed button, low-speed push , off / high / low selector switch, high-speed OL reset, and low-speed OL reset.

WOUND ROTOR MOTORS

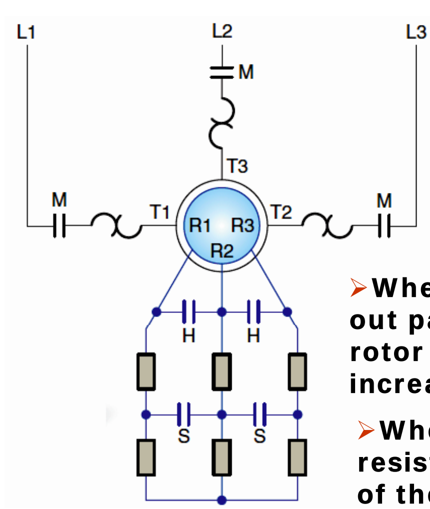
A **wound rotor motor** is constructed with rotor windings that are brought out of the motor through slip rings on the motor shaft.



- These windings are connected to a controller, which places variable resistors in series with the windings.

- By changing the amount of external resistance connected to the rotor circuit, the motor speed can be varied.

Power circuit for a wound-rotor magnetic motor controller.

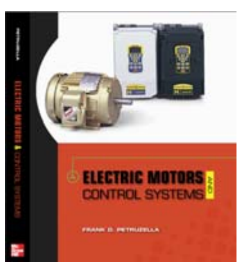


- A magnetic starter (M) connects the primary circuit to the line, and two secondary accelerating contactors (S and H), control the speed.
- When operating at low speed, contactors S and H are both open, and full resistance is inserted in the rotor's secondary circuit.
- When contactor S closes, it shunts out part of the total resistance in the rotor circuit; as a result, the speed increases.
- When contactor H closes, all resistance in the secondary circuit of the motor is bypassed; thus, the motor runs at maximum speed.

➢One disadvantage of using resistance to control the speed of a wound-rotor induction motor is that a lot of heat is dissipated in the resistors; the **efficiency**, therefore, is **low**.

➢**Speed regulation** is also **poor** when using resistance to control speed; for a given amount of resistance, the speed varies considerably if the mechanical load varies.

➢Modern wound-rotor controllers use **solid-state devices** to obtain stepless control. These may incorporate thyristors (semiconductors) that serve in the place of magnetic contactors.



Chapter 8

Motor Control Circuits