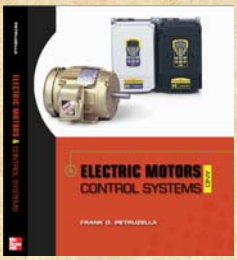


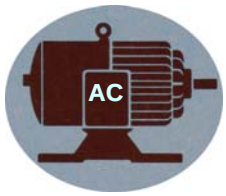
Chapter 2

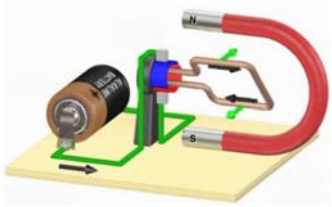
Understanding Electrical Drawings

PART 3 Motor Terminal Connections

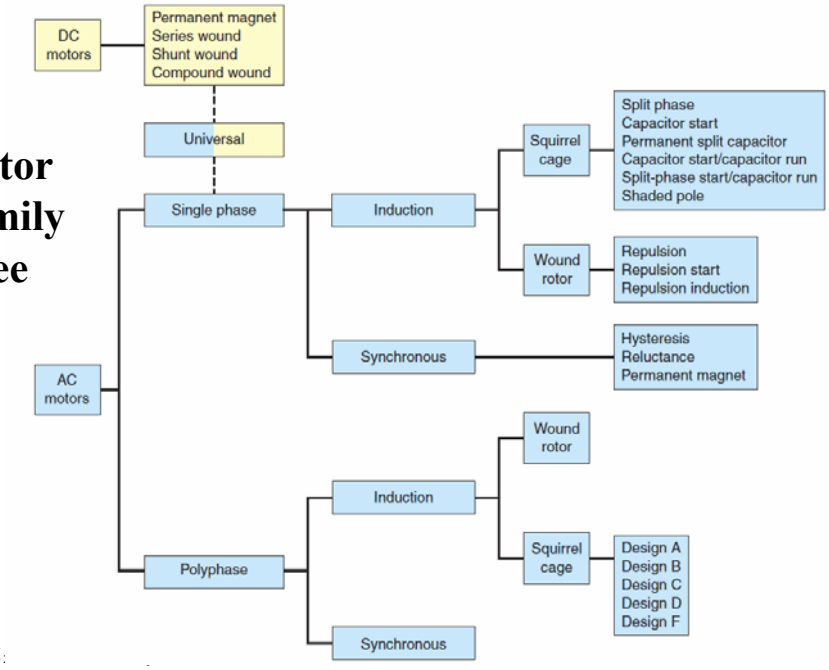
MOTOR CLASSIFICATION

In general, motors are classified according to the type of power used (AC or DC) and the motor's principle of operation.





Motor Family Tree

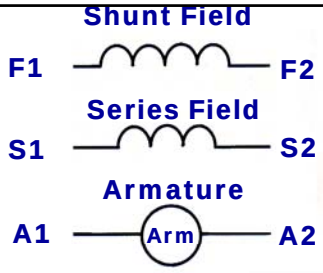


DC MOTOR CONNECTIONS

Industrial applications use DC motors because the speed-torque relationship can be easily varied. DC motor features include:

- **Smooth speed acceleration and deceleration control**
- **Dynamic braking or regenerative braking**
- **In emergency situations, DC motors can supply over five times rated torque without stalling.**

Direct Current (DC) compound motor



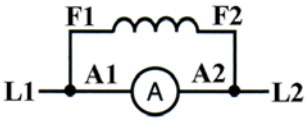
The rotating part is referred to as the *armature.*

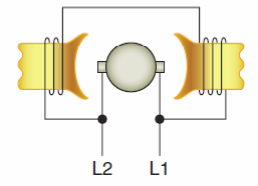
The stationary part of the motor is referred to as the *stator*.

A1 and A2 indicate the armature leads
S1 and S2 indicate the series field leads
Fl and F2 indicate the shunt field leads.

The kind of field excitation distinguishes one type of DC motor from another.

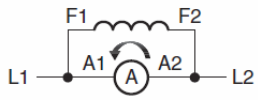
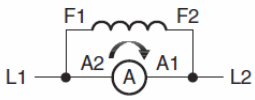
DC SHUNT MOTOR



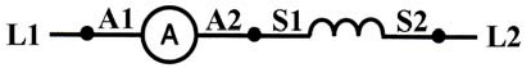


Connections

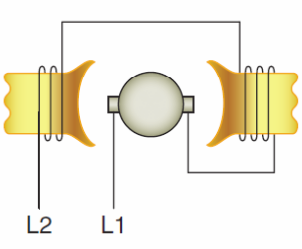
Shunt motors use a high resistance shunt field winding connected in parallel with the armature.

Counterclockwise		Clockwise	
Line 1 F1-A1	Line 2 F2-A2	Line 1 F1-A2	Line 2 F2-A1
			

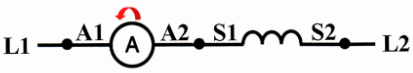
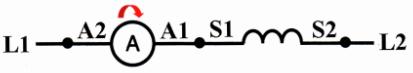
DC SERIES MOTOR



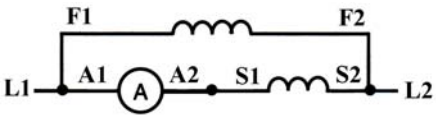
Series motors uses a very low resistance series field winding, made up of very few turns of heavy wire, connected in series with the armature.



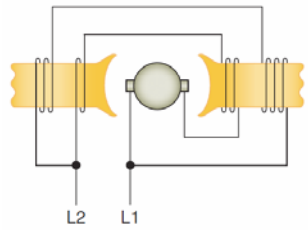
Connections

Counterclockwise			Clockwise		
Line 1 A1	Tie A2-S1	Line 2 S2	Line 1 A2	Tie A1-S1	Line 2 S2
					

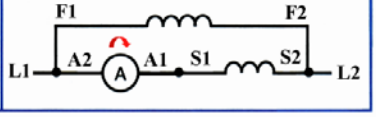
DC COMPOUND MOTOR



Compound motors use a combination of a shunt field in parallel with the armature, and series field in series with the armature.

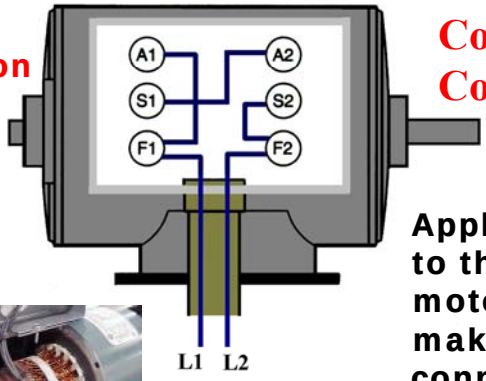


Connections

Counterclockwise			Clockwise		
Line 1 F1-A1	Tie A2-S1	Line 2 F2-S2	Line 1 F1-A2	Tie A1-S1	Line 2 S2-F2
					

Motor connections are shown for counterclockwise and clockwise rotation facing the end opposite the drive (commutator end).

CCW Rotation



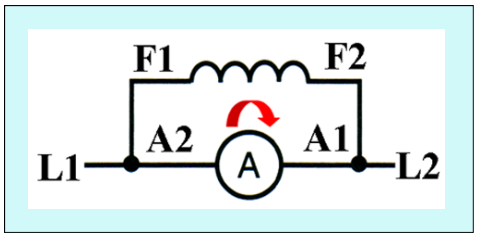
Compound Motor Connection

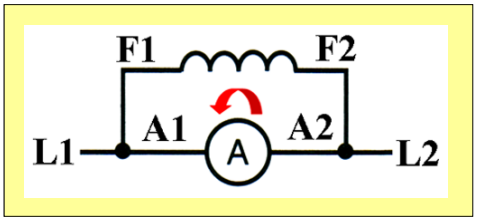
Commutator End

Applying markings to the terminals of motors aids in making connections when a when a predictable rotation direction is required.

The direction of rotation of a DC motor depends on the direction of the magnetic field and the direction of current flow in the armature.

If either the direction of the field or the direction of current flow through the armature is reversed, the rotation of the motor will reverse. However, if both are reversed at the same time the motor will continue rotating in the same direction.





AC MOTOR CONNECTIONS

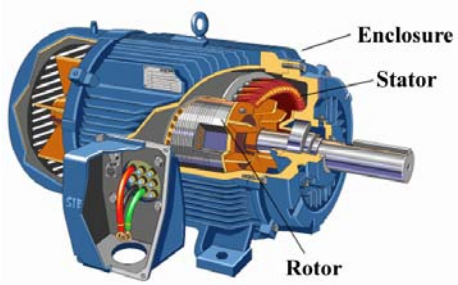
The AC induction motor is the dominant motor technology in use today, representing more than 90 percent of installed motor capacity.

Induction motors are available in *single-phase* and *three-phase* configurations.

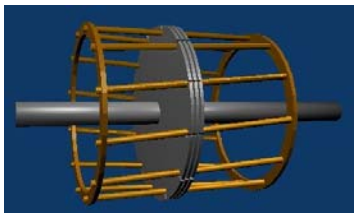
They may run at fixed speeds--most commonly 900, 1200, 1800, or 3600 rpm--or be equipped with an adjustable-speed drive.

The most commonly used AC motors have a squirrel-cage configuration, so named because of the shape of the rotor bar structure.

There is no physical electrical connection to the squirrel-cage.



Three-phase squirrel-cage motor



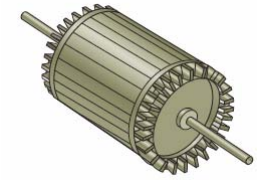
Current in the rotor of a squirrel-cage motor is induced by the rotating magnetic field of the stator.

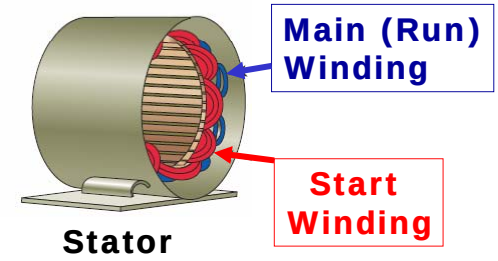
SINGLE-PHASE MOTOR CONNECTIONS

The majority of single-phase AC induction motors are constructed in fractional horsepower sizes for 120- to 240-V, 60-Hz power sources.

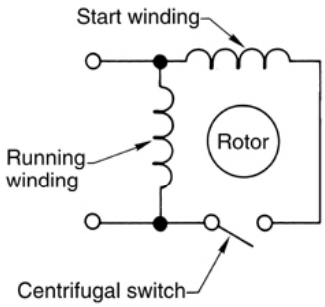
The split-phase motor is most widely used single-phase motor.

Squirrel-Cage Rotor

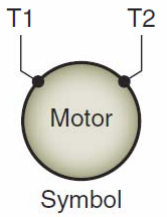




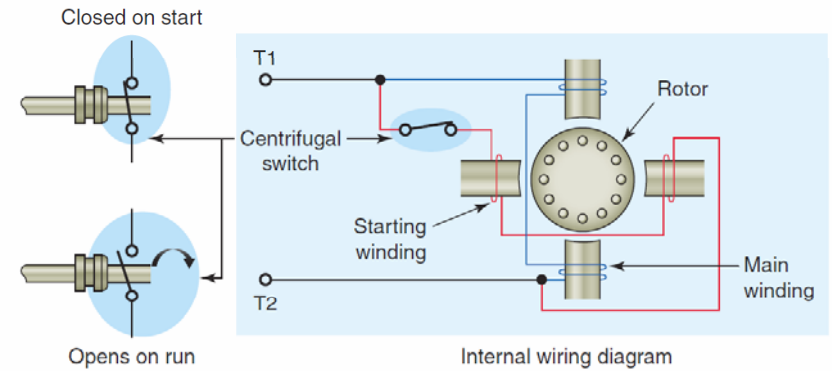
The start and running windings are both energized when the motor is started. When the motor reaches about 75% of its full load speed, the starting winding is disconnected from the circuit.



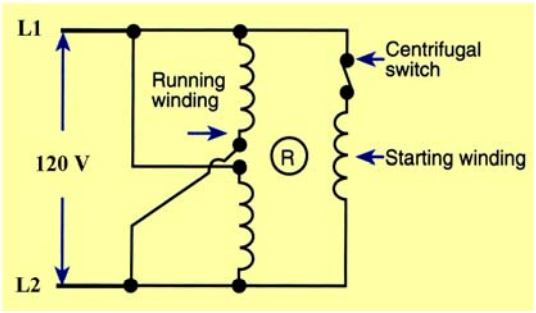
The motor can be reversed by reversing the leads to the starting winding or running winding, but not to both. Generally the industry standard is to reverse the start winding leads.



The starting winding produces a phase difference to start the motor and is switched out by a centrifugal switch as running speed is approached.

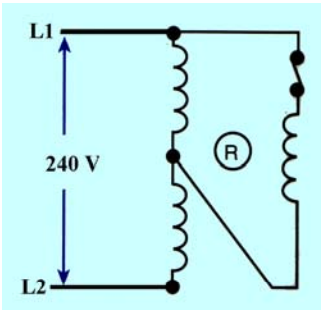


In a *dual-voltage* split-phase motor the running winding is split into two sections and can be connected to operate from a 120 V or 240 V.



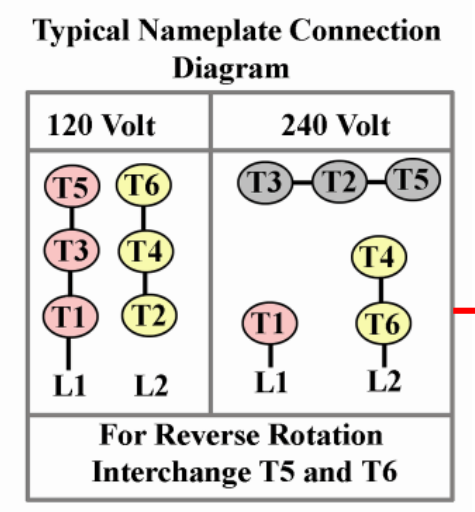
LOW VOLTAGE

Two run windings are connected in parallel.



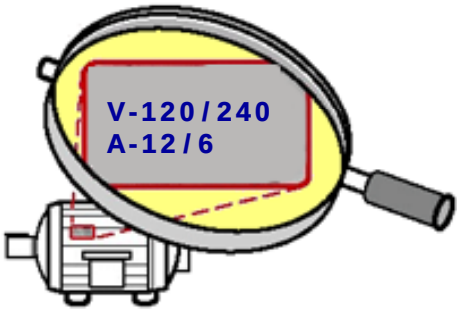
HIGH VOLTAGE

Two run windings are connected in series.

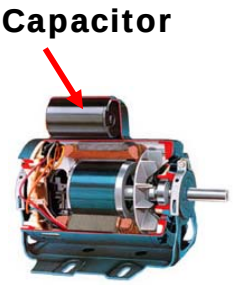


Dual-voltage split-phase motor

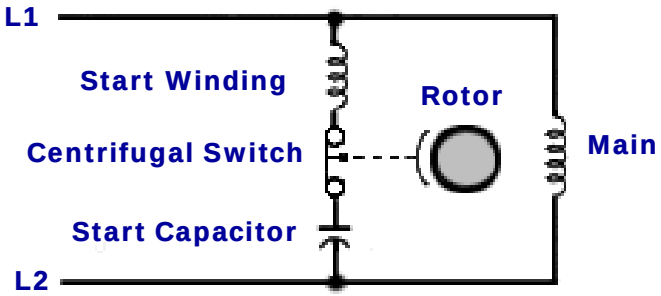
A dual-voltage motor uses the same amount of power and produces the same amount of horsepower when operating from a 120-V or 240-V supply. However, as the voltage is doubled from 120 V to 240 V, the current is cut in half. Operating the motor at this reduced current level allows you to use smaller circuit conductors and reduces line power losses.



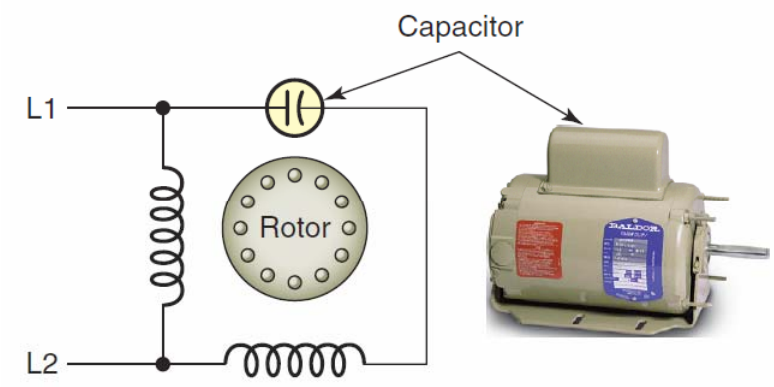
Many single-phase motors use a capacitor in series with one of the stator windings to optimize the phase difference for starting. The result is a *higher starting torque* than a split-phase motor can produce.



With a *"capacitor start"* motor the capacitor is only active during starting



A *"permanent capacitor"* motor uses a capacitor permanently connected in series with one of the stator windings. This design is lower in cost than the capacitor-start motors that incorporate capacitor switching systems.



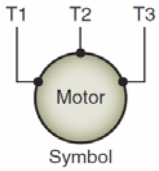
The ***"two-value capacitor"*** motor, has different values of capacitance for starting and running.

THREE-PHASE MOTOR CONNECTIONS

The three-phase AC induction motor is the most common motor used in commercial and industrial applications.

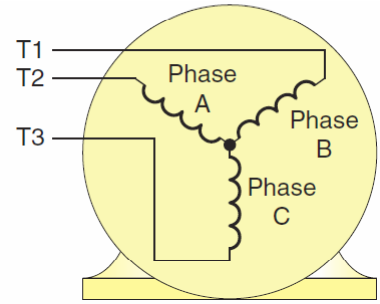
Single-phase large horsepower motors are not normally used because they are inefficient, compared to three-phase motors. In addition, single-phase motors are not self-starting on their running windings, as are three-phase motors.

The individual coils of a 3-phase motor will always be wired together (series or parallel) to produce three distinct windings, which are referred to as Phase A, Phase B; and Phase C.

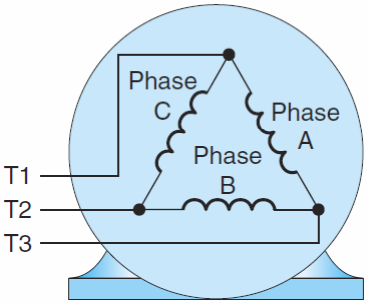


Symbol

All 3-phase motors are wired so that the phases are connected in either wye (Y) or delta (Δ) configuration.

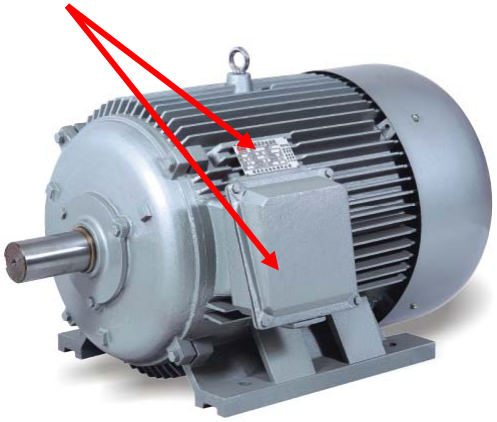


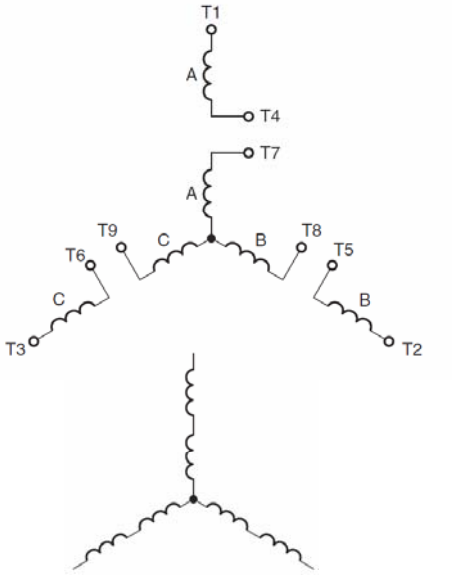
Wye (Y) configuration



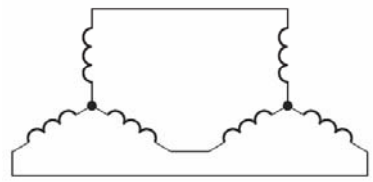
Delta (Δ) configuration

It is common practice to manufacture three-phase motors that can be connected to operate at different voltage levels. The most common multiple-voltage rating for three-phase motors is 208/230/460 V.





Typical terminal identification for a nine lead *dual-voltage* wye-connected 3-phase motor.

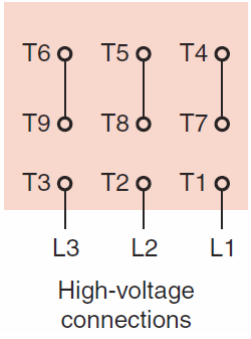


High voltage Wye connection

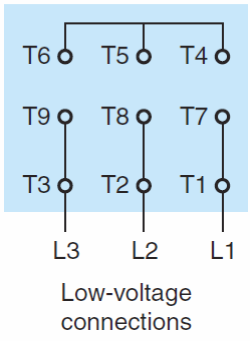
Low voltage Wye connection

Connection table

Voltage	L1	L2	L3	Tie together
Low	1-7	2-8	3-9	4-5-6
High	1	2	3	4-7, 5-8, 6-9



High-voltage connections



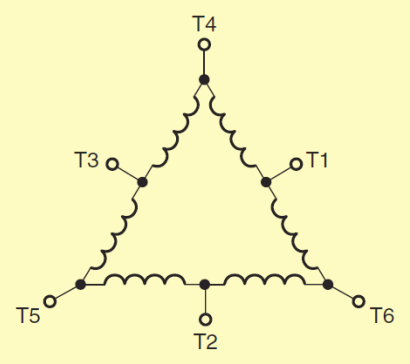
Low-voltage connections

According to NEMA nomenclature nine lead dual-voltage three-phase motors are marked T1 through T9. High voltage and low voltage connections are given in the accompanying connection table and motor terminal board.

Multispeed motors **are designed to provide two separate speed ranges. The speed of an induction motor depends on the number of poles built into the motor and the frequency of the electrical power supply.**

$$RPM = 120\,x\,\frac{Frequency}{Number\ of\ poles}$$

Two-speed motors with single windings can be reconnected, using a controller, to obtain different speeds.

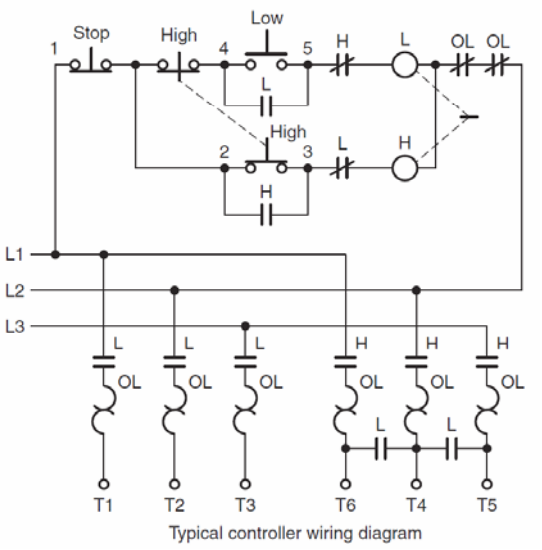


Motor windings

Speed	Line wires	Tie together	Winding connection
Low	T1-T2-T3	T4-T5-T6	2-parallel Y
High	T4-T5-T6	———	Series Δ

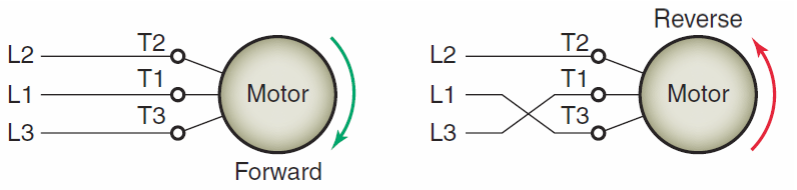
Connection table

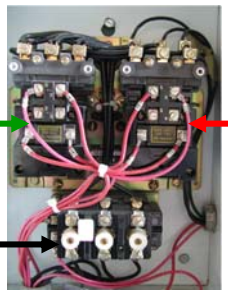
The controller circuitry serves to change the connections of the stator windings.



Typical controller wiring diagram

To reverse the direction of rotation of any three-phase motor simply reverse or interchanging any two of the three main power leads to the motor.





Reversing Motor Starter

FWD Contactor

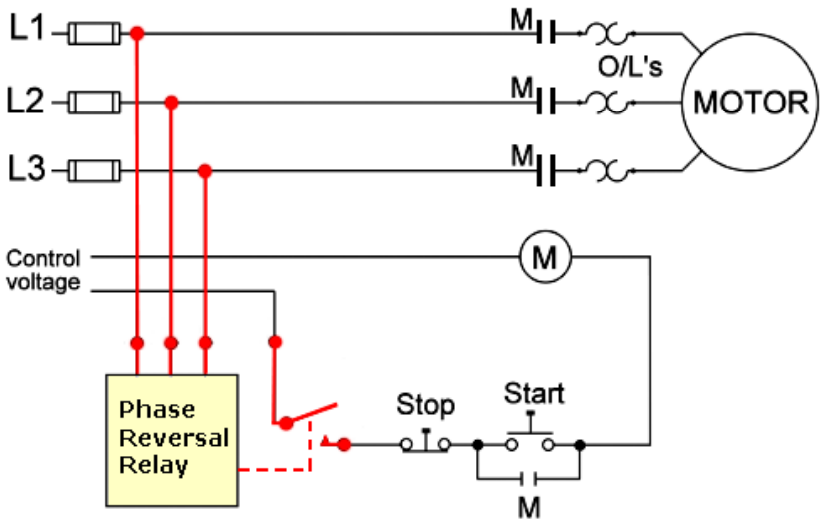
REV Contactor

OL Relay

In certain applications unintentional reversal of motor rotation can result in serious damage.

When this is the case phase failure and phase reversal relays are used to protect motors, machines, and personnel from the hazards of open-phase or reversed-phase conditions.

Typical Phase Reversal Relay circuit



The speed of an AC induction motor depends upon two factors: the number of motor poles and the frequency of the applied power.

In *variable frequency motor drive (VFD)* variable speed of an induction motor is achieved by varying the frequency of the power supply. Standard induction motors can be detrimentally affected when operated by variable frequency drives.

***"Inverter-duty" and "vector-duty"* describes a class of motors that are capable of operation from a variable frequency drive. Low temperature rise in this class of motor is accomplished with better insulation systems, additional active material (iron and copper) and/or external fans for better cooling at low speed operation.**