Starter Ratings

Starter contactors are rated according to size and type of load they handle. The National Electrical Manufacturers Association (NEMA) and the International Electrotechnical Commission (IEC) are two organizations that rate contactors and motor starters. NEMA is primarily associated with equipment used in North America. IEC, on the other hand, is associated with equipment sold in many countries including the United States. International trade agreements, market globalization, and domestic and foreign competition have made it important for controls manufacturers to be increasingly aware of international standards.

NEMA

NEMA ratings are maximum horsepower ratings, according to the National Electrical Manufacturers Association ICS2 standards. NEMA starters and contactors are selected according to their NEMA size. These sizes range from size 00 to size 9.

NEMA Size	Continuous Amp Rating	HP 230 VAC	HP 460 VAC
00	9	1	2
0	18	3	5
1	27	7	10
2	45	15	25
3	90	30	50
4	135	50	100
5	270	100	200
6	540	200	400
7	810	300	600
8	1215	450	900
9	2250	800	1600

NEMA motor-control devices have generally become known for their very rugged, heavy-duty construction. Because of their rugged design NEMA devices are physically larger than IEC devices. NEMA motor starters and contactors can be used in virtually any application at their stated rating, from simple “ON” and “OFF” applications to more-demanding applications that include plugging and jogging. To select a NEMA motor starter for a particular motor one need only know the horsepower and voltage of the motor. If there is considerable plugging and jogging duty involved, however, even a NEMA-rated device will require some derating.

Motor Matched Sizes

Siemens also has what are called Motor Matched sizes available on some Siemens motor starters. The ratings for these devices fall in between the ratings of normal NEMA sizes. This allows the user to more closely match the motor control to the actual application. The following table shows Motor Matched sizes available.

MM Size	Continuous AMP Rating	HP 230 VAC	HP 460 VAC
1¾	40	10	15
2½	60	20	31
3½	115	40	75
4½	210	75	150

IEC

Not all applications require a heavy-duty industrial starter. In applications where space is more limited and the duty cycle is not severe, IEC devices represent a cost-effective solution. IEC devices are rated for maximum operational current as specified by the International Electrotechnical Commission in publication IEC 158-1. IEC does not specify sizes. Utilization categories are used with IEC devices to define the typical duty cycle of an IEC device. AC-3 and AC-4 are the categories of most interest for general motor-starting applications.

Utilization Category	IEC Category Description
AC1	Non-inductive or slightly inductive loads.
AC2	Starting of slip-ring motors
AC3	Starting of squirrel-cage motors and switching off only after the motor is up to speed. (Make LRA, Break FLA)
AC4	Starting of squirrel-cage motors with inching and plugging duty. Rapid Start/Stop. (Make and break LRA)
AC11	Auxiliary (control) circuits.

Definite Purpose

Definite Purpose (DP) contactors have certain characteristics which must be taken into consideration. DP contactors were designed for specific applications where the operating conditions are clearly defined. These operating conditions include full load amps, locked rotor amps, noninductive amps (resisitive load), number of power poles, duty cycle, and the total number of expected operations.

DP contactors are sized by the motor full-load amps (FLA) and locked rotor amps (LRA). FLA is the amount of current the motor draws at full speed, under full mechanical load, at rated voltage. LRA is the maximum current the motor will draw at the instant full-line voltage is applied to the motor. DP contactors are well suited for loads found in the following areas:

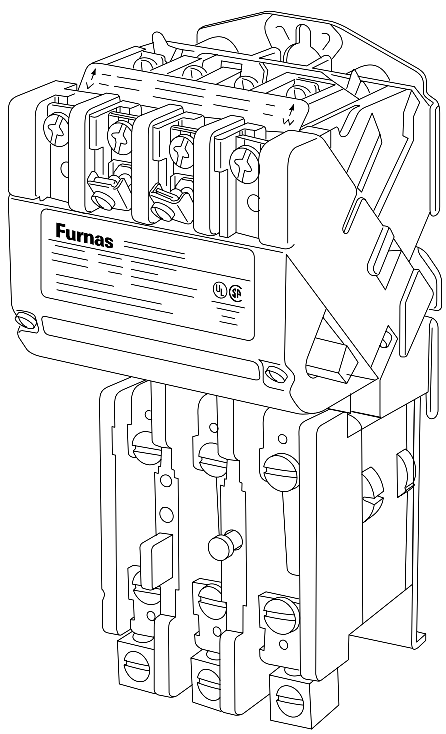
- Heating, Ventilating, and Air Conditioning (HVAC)
- Farm Equipment and Irrigation
- Environmental Control Systems
- Office Equipment
- Pool and Spa Controls
- Welding Equipment
- Medical Equipment
- Food-Service Equipment

Other Organizations

There are several other organizations that have developed standards and tests for electrical equipment. Underwriters Laboratory (UL), for example, specifies a maximum horsepower rating for which a contactor can be used. The contactor is tested by Underwriters Laboratory using test procedure U.L. 508. All Siemens contactors are rated in accordance with at least one of the previous organizations' test procedures. Some carry multiple ratings. For example, Furnas INNOVA starters meet or exceed NEMA and UL standards. Siemens SIRIUS starters meet or exceed NEMA, IEC, and UL standards.

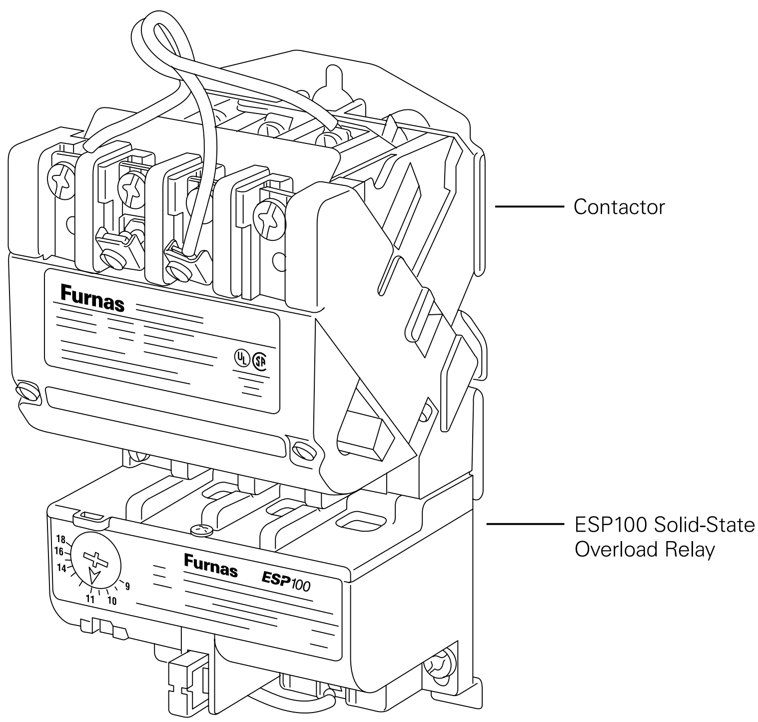
Furnas INNOVA PLUS Starters

Furnas INNOVA PLUS™ starters are available in NEMA sizes 0 through 4. They are available up to 100 HP. Furnas INNOVA PLUS starters are available with Class 10 or 20 ambient-compensated bimetal overload relays.



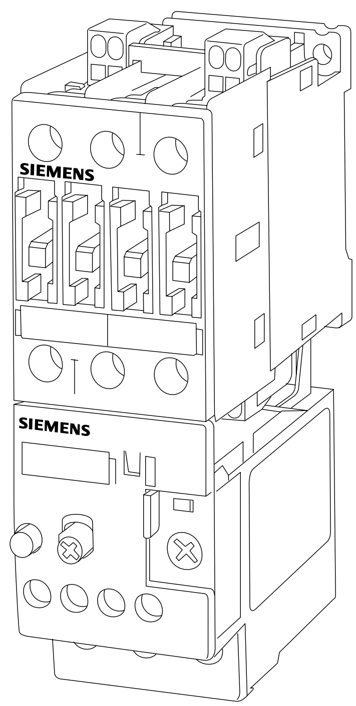
ESP100 Starters

The Furnas ESP100™ starters use the same contactor as the INNOVA PLUS™ starters. The ESP100 starters are supplied with a Class 10, 20, or 30 ESP100 solid-state overload relay. The ESP100 overload relay protects 3Ø motors with FLA of ¼ ampere through 135 amperes. From ¼ ampere to 10 amperes the overload has a 4:1 FLA range, i.e.; 2½ - 10 amperes. Above 10 amperes the range is 2:1. The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amperes. The ESP100 also protects the motor against phase loss. The ESP100 trips within three seconds of loss of one of the power-supply phases.



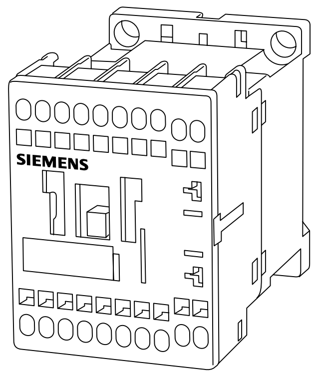
SIRIUS Type 3R Starters

SIRIUS 3R is a complete modular, building-block system. The system includes a structured range of contactors and overload relays covering loads up to 95 amps in four frame sizes. These four frame sizes are referred to as S00 (12A), S0 (25A), S2 (50A), and S3 (95A). A feature of the SIRIUS product line is a narrow mounting width. An S3 contactor rated at 75 HP, for example, is only 70mm (2.75”). SIRIUS 3R contactors and overload relays can operate in ambient temperatures up to 140°F (60°C). This, along with the smaller size, allows more units to be packed into a panel without overheating the components.

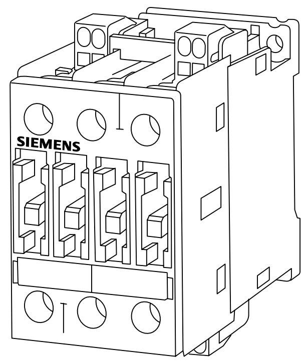


CAGE CLAMP™

Size S00 contactors and overload relays are available with CAGE CLAMP™ connections on power and control-circuit terminals. Size S0, S2, and S3 contactors and overload relays have CAGE CLAMP™ connections on the control-circuit terminals only.



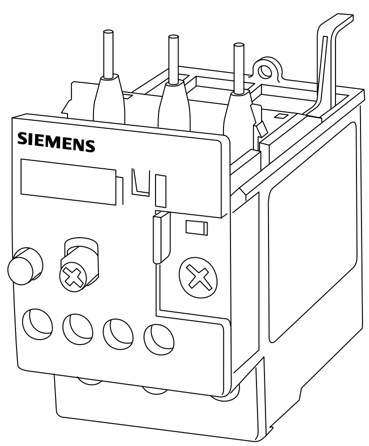
Contactor with
CAGE CLAMP™



Contactor with
Screw Terminals

Overload Relays

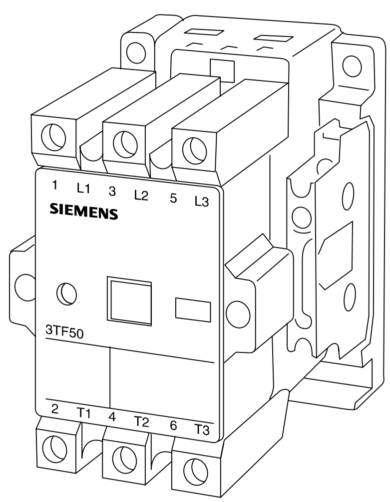
SIRIUS 3R overload relays provide Class 10 overcurrent protection for both AC and DC motors. Ambient-compensated bimetal strips prevent the overload relay from nuisance tripping when the panel temperature is higher than the ambient temperature of the motor. The design of the overload relay also includes a differential trip bar that causes the unit to trip faster in the event of a phase-loss condition. An optional remote-reset module (not shown) is available.



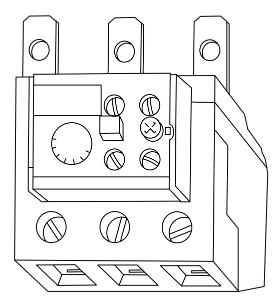
World Series Type 3TF Starters

The World Series starters are supplied with a type 3TF contactor and overload relay. World Series starters are available in horsepower ratings from 100 to 500 HP at 460 VAC. Auxiliary contacts are provided for use in the control circuit. World Series type 3TF contactors are available with various enclosures. Additional auxiliary contacts can be added. Coil voltages for the electromagnetic coil range from 24 to 600 VAC.

The overload relay is a Class 10 relay that uses a bimetal strip unit and heater element to detect overloads. Each phase monitors current. The unit has a full-load amps adjustment, test button, and reset button. The full-load amps adjustment corresponds to the range of the motor full-load ampere rating. The test button is to ensure the overload relay is functioning properly. The reset button is used to reset a trip. It can be either automatic or manual reset. There is also a trip indicator.



3TF50 Contactor



3UA Overload Relay

Overload Relay Selection

The following chart is useful in selecting the correct contactor and overload-relay combination. The chart reflects the maximum horsepower rating using Underwriters Laboratory test procedure U.L. 508 and the appropriate overload relay.

Contactor	Max HP (at 460 VAC)	Overload Relay
3TF50	100	3UA60
3TF51	100	3UA61
3TF52	125	3UA62
3TF53	150	3UA62
3TF54	200	3UA66
3TF55	250	3UA66
3TF56	300	3UA66
3TF57	400	3UA68
3TF68	500	3UA68

Review 5

1. ___________ is an organization primarily associated with rating equipment used in North America and ___________ is associated with rating equipment used in many countries including the U.S.

2. A NEMA Size ___________ starter is rated for 200 HP at 460 volts .

3. IEC utilization category ___________ applications are described as the starting of squirrel-cage motors and switching off only after a motor is up to speed.

4. Furnas INNOVA PLUS™ starters are available in NEMA sizes 0 through ___________ .

5. The ESP100 trips within ___________ seconds of loss of one of the power-supply phases.

6. The maximum load current of a size S2 SIRIUS 3R starter is ___________ amps.

7. The correct overload relay for a 3TF54 contactor is ___________ .

Multi-Speed and Reversing Starters

Full-voltage AC magnetic multi-speed controllers are designed to control squirrel-cage induction motors for operation at two, three, or four different constant speeds, depending on motor construction. The speed of a constant-speed motor is a function of the supply frequency and the number of poles and is given in the following formula:

$$\text{Synchronous Speed in RPM} = \frac{120 \times \text{Frequency}}{\text{Number of Poles}}$$

The speed in RPM is the synchronous speed or the speed of the rotating magnetic field in the motor stator. Actual rotor speed is always less due to slip. The design of the motor and the amount of load applied determine the percentage of slip. This value is not the same for all motors. A motor with four poles on a 60 hertz AC line has a synchronous speed of 1800 RPM. This means that, after allowing for slip, the motor is likely to run at 1650 to 1750 RPM when loaded.

$$1800 = \frac{120 \times 60}{4}$$

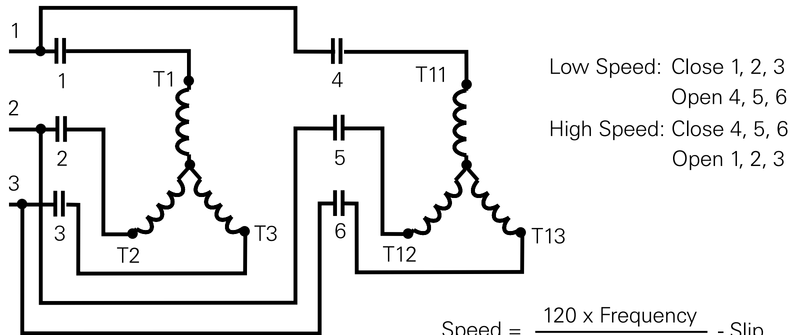
An induction motor with two poles on a 60 hertz AC line, however, would run at twice that speed.

When motors are required to run at different speeds, the motor's torque or horsepower characteristics will change with a change in speed. The proper motor must be selected and correctly connected for the application. In these applications, there are three categories.

Constant Torque (CT)
Variable Torque (VT)
Constant Horsepower (CHP)

Separate-Winding

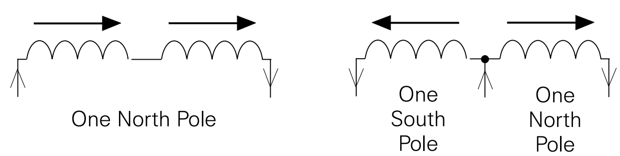
There are two basic methods of providing multi-speed control using magnetic starters: separate-winding motors and consequent-pole motors. Separate-winding motors have a separate winding for each speed. The speed of each winding depends on the number of poles. The low-speed winding is wound for more poles than the high-speed winding. The motor cost is higher than consequent pole, but the control is simpler. There are many ways multi-speed motors can be connected depending on speed, torque, and horsepower requirements. The following schematic shows one possible connection of a two-speed, two-winding, wye-connected motor.



$$\text{Speed} = \frac{120 \times \text{Frequency}}{\text{Number of Poles}} - \text{Slip}$$

Consequent-Pole Motors

Consequent-pole motors have a single winding for two speeds. Taps can be 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. Four-speed motors have two reconnectable windings.

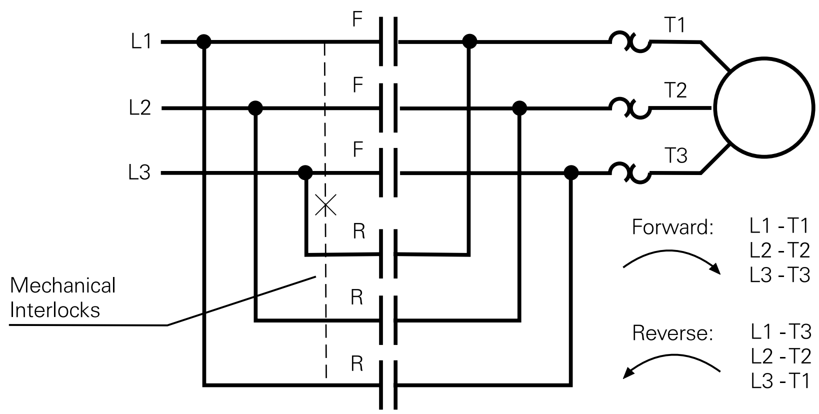


Speed Selection

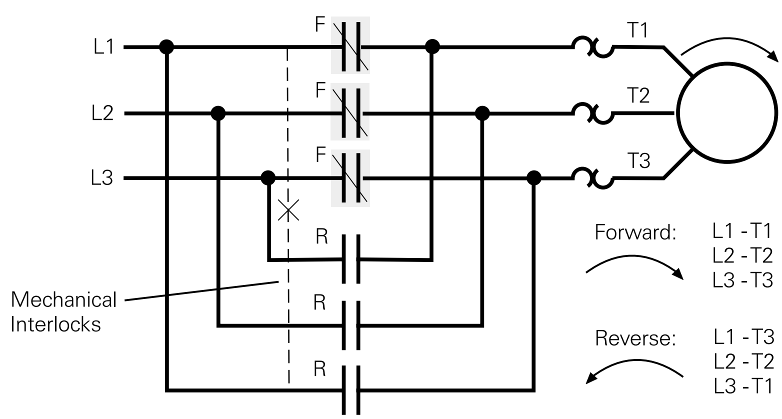
There are three control schemes of speed selection for multi-speed motors: selective control, compelling control, and progressive control. Selective control permits motor starting at any speed and to move to a higher speed the operator depresses the desired speed pushbutton. Compelling control requires the motor to be started at the lowest speed, then the operator must manually increment through each speed step to the desired speed. With progressive control the motor is started at the lowest speed and automatically increments to the selected speed.

Reversing

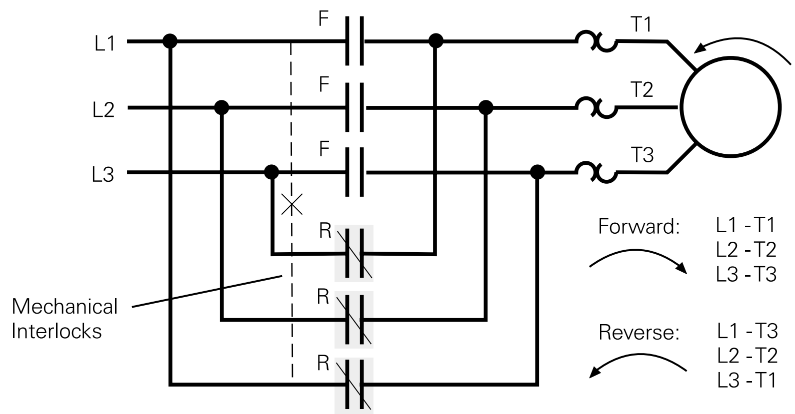
Many applications require a motor to run in both directions. In order to change the direction of motor rotation, the direction of current flow through the windings must be changed. This is done on a three-phase motor by reversing any two of the three motor leads. Traditionally T1 and T3 are reversed. The following illustration shows a three-phase reversing motor circuit. It has one set of forward (F) contacts controlled by the "F" contactor, and one set of reverse (R) contacts controlled by the "R" contactor.



When the "F" contacts are closed, current flows through the motor causing it to turn in a clockwise direction.

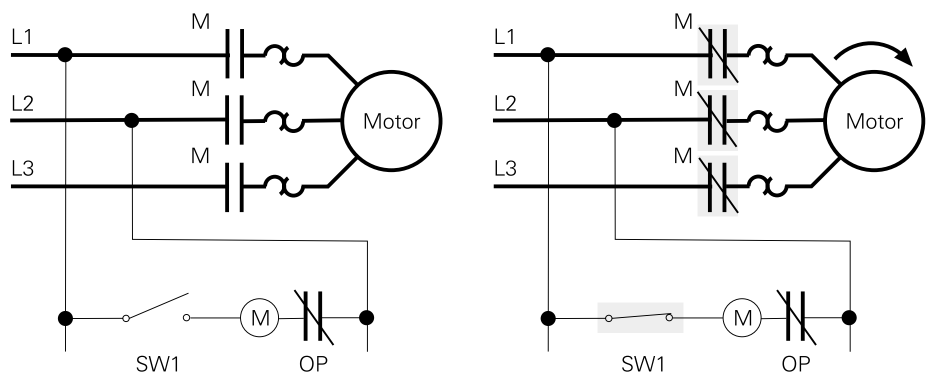


When the “R” contacts are closed, current flows through the motor in the opposite direction causing it to rotate in a counterclockwise direction. Mechanical interlocks prevent both forward and reverse circuits from being energized at the same time.

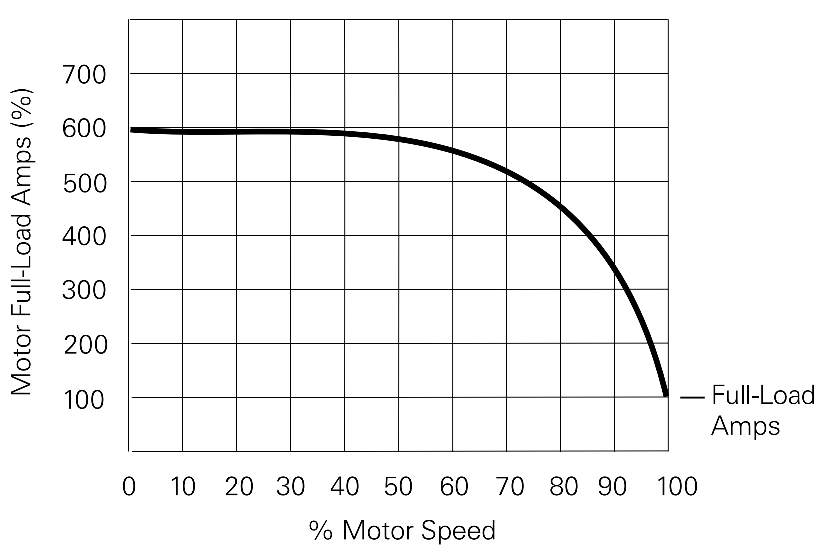


Full-Voltage Starting

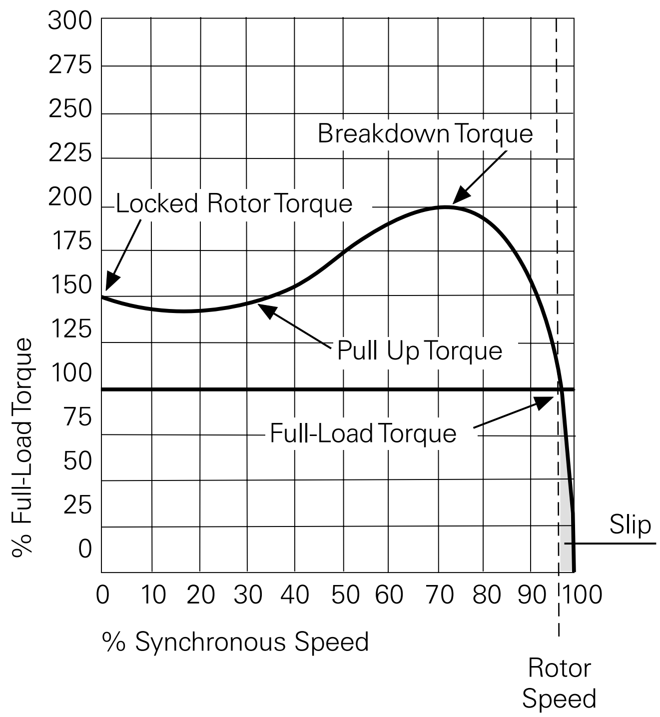
The most common type of motor starting is full-voltage starting. The motor is placed directly across the line with this method.



With this type of starter the motor receives the full-line voltage. When a motor is started with full voltage, starting current can be as high as 600% of full-load current on standard squirrel cage motors. It can be even higher on high efficiency motors. There are situations where this method of starting is not acceptable. On large motors the high starting current is reflected back into the power lines of the electric utility, causing lights to flicker and in more serious situations can cause computers to malfunction. Many power companies in the U.S. require reduced-voltage starting on large-horsepower motors.



Another potential problem with applying full-voltage starts is the high torque developed when power is first applied to the motor. This can be as high as 175% to 200% of full-load torque on a standard NEMA B type motor. Many applications require the starting torque to be applied gradually. A conveyor belt, for example, requires the starting torque to be applied gradually to prevent belt slipping or bunching.



Reduced-Voltage Starting

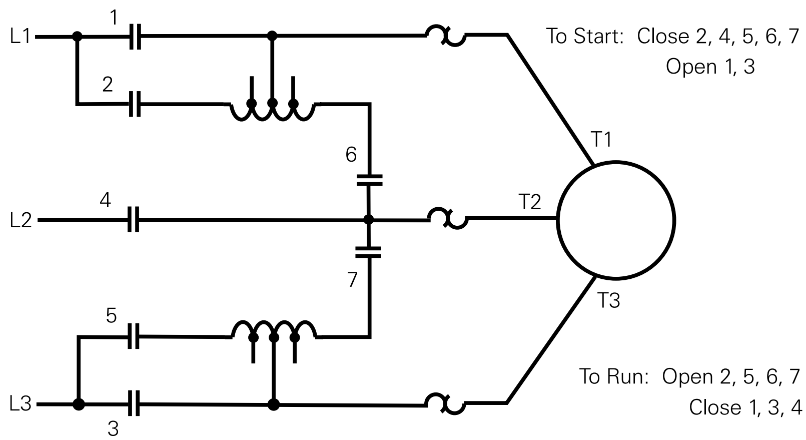
In general, starting methods which deviate from full-voltage starting by providing a lower starting voltage are referred to as reduced-voltage starting. Reduced-voltage starting should be used when it is necessary to limit the initial inrush of current or it is desired to reduce the starting torque of a motor.

Reduced-voltage starting reduces the starting voltage of an induction motor with the purpose of confining the rate of change of the starting current to predetermined limits. It is important to remember that when the voltage is reduced to start a motor, current is also reduced, which also reduces the amount of starting torque a motor can deliver. Several methods are available for reduced-voltage starting. The application or the type of motor generally dictates the method to use. A few of the methods offered by Siemens are described in the following paragraphs.

Autotransformer Reduced-Voltage Starters

Autotransformer reduced-voltage starters provide the highest starting torque per ampere of line current and is one of the most effective means of starting a motor for an application in which starting current must be reduced with a minimum sacrifice of starting torque. Autotransformers have adjustable taps to reduce starting voltage to 50%, 65%, or 80% of full-line voltage.

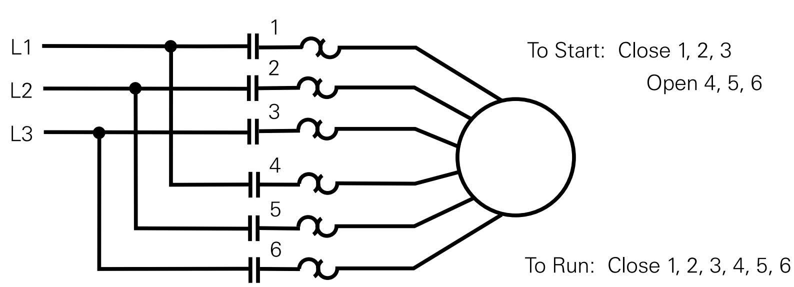
Applications: Blowers, Pumps, Compressors



Part-Winding Starters

Part-winding, reduced-voltage starters are used on motors with two separate parallel windings on the stator. The windings used during start draw about 65 - 80% of rated locked rotor current. During run each winding carries approximately 50% of the load current. Part-winding, reduced-voltage starters are the least-expensive type of reduced-voltage starters and use a very simplified control circuit. However, they require special motor design and are not suitable for high inertia loads. There is no adjustment of current or torque.

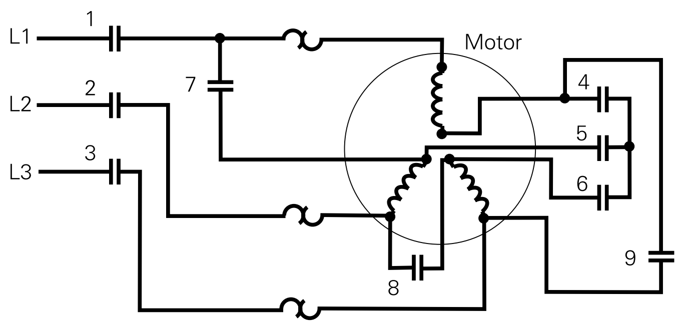
Applications: Pumps, Fans, Refrigeration, Compressors



Wye-Delta Starters

Wye-delta, reduced-voltage starters are applicable only with motors having stator windings not connected internally and all six motor leads available. Connected in a wye configuration, the motor starts with reduced starting line current. The motor is reconfigured to a delta connection for run. This type of starter is a good method for applications requiring frequent starts. The starting torque is lower compared to other methods of reduced voltage starters.

Applications: Central Air Conditioning Equipment, Compressors



To Start: Close 1, 2, 3, 4, 5, 6
Open 7, 8, 9

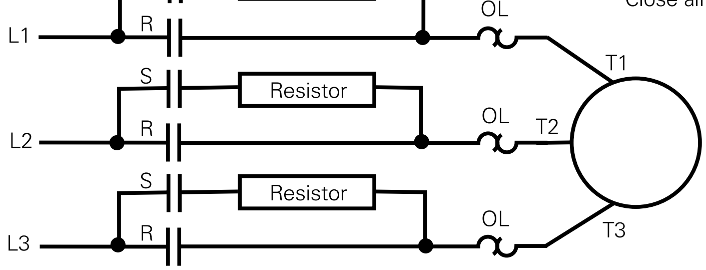
To Run: Open 4, 5, 6
Close 7, 8, 9

Primary Resistance Starter

This is a simple and effective starting method. The motor is initially energized through a resistor in each of the three incoming lines. Part of the voltage is dropped through the resistors. The motor receives 70% to 80% of the full-line voltage. As the motor picks up speed, the motor sees more of the line voltage. At a preset time a time-delay relay closes a separate set of contacts, shorting out the resistors and applying full voltage to the motor. This type of reduced voltage starting is limited by the amount of heat the resistors can dissipate.

Applications: Conveyors, Belt-Driven and Gear Drive Equipment

To Start: Open all R Contacts
Close all S Contacts



To Run: Close all R Contacts

Review 6

1. ___________ - ___________ ___________ is a method of providing multi-speed control that utilize taps brought out from a reconnectable winding.

2. With ___________ ___________ the motor is started at the lowest speed and automatically increments to the selected speed.

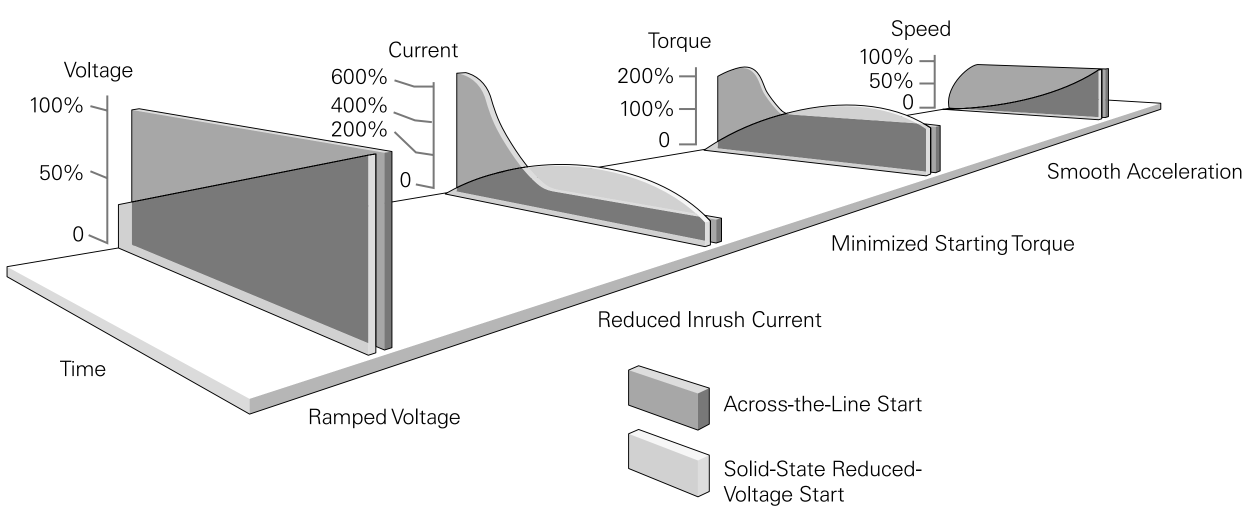
3. In general, starting methods which deviate from full-voltage starting by providing a lower starting voltage are referred to as __________ __________ __________ .

4. ___________ reduced-voltage starters have adjustable taps to reduce starting voltage to 50%, 65%, or 80% of full line voltage.

Solid-State Reduced-Voltage Controllers

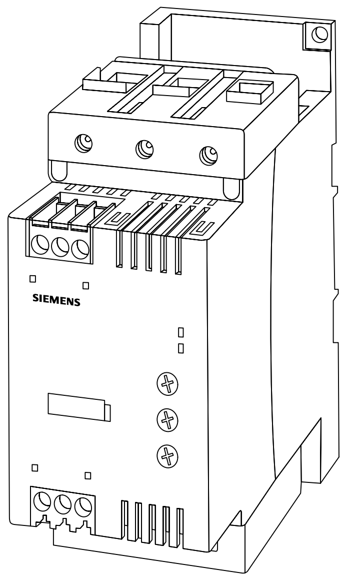
Solid-state or soft-start controllers also use reduced voltage starting. These controllers are more advanced and allow greater control of the starting, running, and stopping of an AC motor than the electromechanical starters discussed in the previous section. Reduced-voltage electromechanical starters start a motor in steps by first applying a reduced voltage followed by full voltage.

Solid-state reduced-voltage controllers, however, can apply voltage gradually from some low intial volatge to 100% voltage. The following graph compares a solid-state reduced-voltage controller to a full- voltage (across-the-line) starter. By applying voltage gradually, the motor experiences reduced inrush current and speed is accelerated smoothly. In addition, just enough torque can be applied to start and accelerate the motor. This is beneficial for loads that have problems with the initial jerk and rapid acceleration of across-the-line starting.



SIRIUS 3R Soft-Start Controls

SIRIUS 3R controllers provide gradual voltage starting and stopping.SIRIUS 3R soft-start controls are compact and compliment the rest of the SIRIUS line. The compact design allows the controls to be DIN rail mounted and integrated with any combination of other controls, such as, overloads, contactors, and motor starter protectors. SIRIUS 3R soft-start controls are available for motors up 75HP at 575 volts. A cost saving advantage of the SIRIUS 3R controller is the ability of one model to handle voltages from 200 to 460 volts.

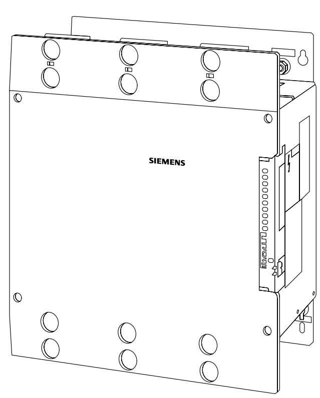


Three-Phase Models for Motors up to:

25HP @ 200V
30HP @ 230V
60HP @ 460V
75HP @ 575V

SIKOSTART

SIKOSTART controllers are used in applications of up to 1000 horsepower. Like the SIRIUS 3R, SIKOSTART provides gradual voltage starting and stopping.

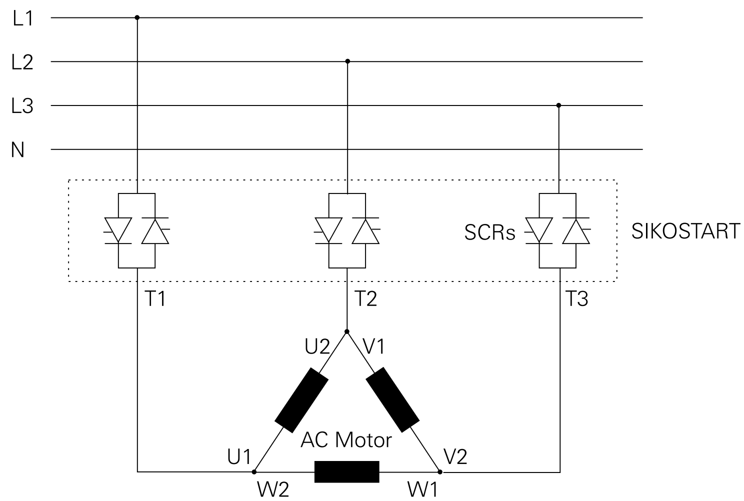


Three-Phase Models for Motors up to:

350HP @ 200V
400HP @ 230V
800HP @ 460V
1000HP @ 575V

SIKOSTART Wired Inline

SIKOSTART can easily be wired conventionally in line with the motor windings. In this configuration the controller sees full motor current.



SIKOSTART Wired Inside the Delta

On motors that have all leads available, the SIKOSTART controller can also be wired inside the delta connection of the motor. This offers a significant cost advantage. Current inside the delta of an AC motor is approximately 57% of nominal motor current. With this configuration a smaller SIKOSTART controller can be selected.