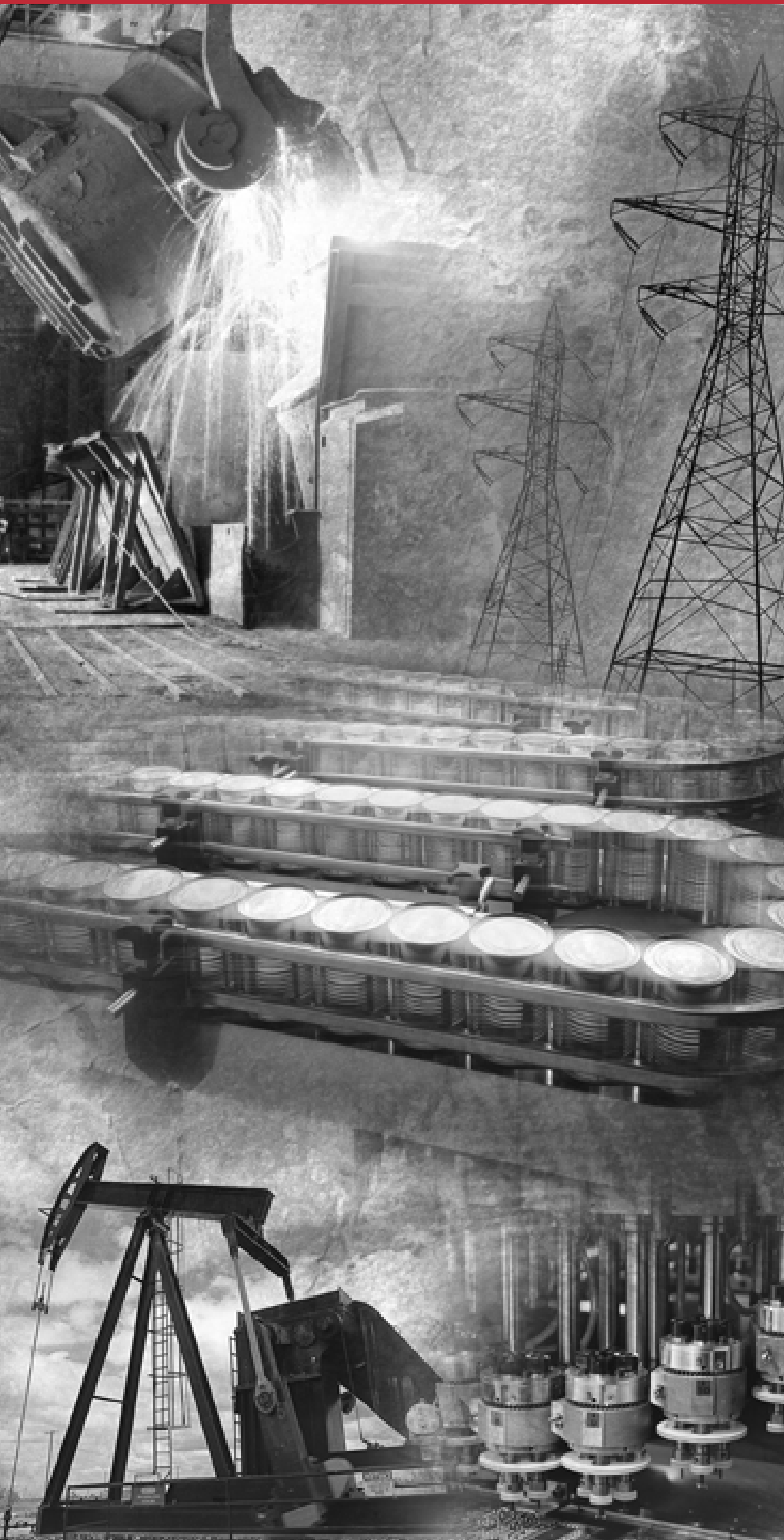
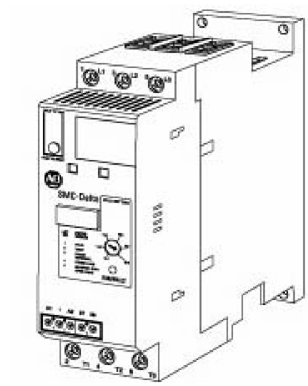


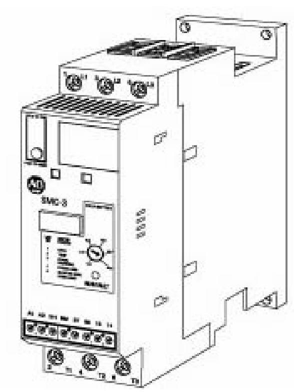
Allen-Bradley

SMC Controllers

Bulletin 150



SMC-Delta



SMC-3

Application and Product Guide

Rockwell Automation

Important User Information

Because of the variety of uses for the products described in this publication, those responsible for the application and use of this control equipment must satisfy themselves that all necessary steps have been taken to assure that each application and use meets all performance and safety requirements, including any applicable laws, regulations, codes and standards.

The illustrations, charts, sample programs and layout examples shown in this guide are intended solely for purposes of example. Since there are many variables and requirements associated with any particular installation, Allen-Bradley does not assume responsibility or liability (to include intellectual property liability) for actual use based upon the examples shown in this publication.

Allen-Bradley publication SGI-1.1, *Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control* (available from your local Allen-Bradley distributor), describes some important differences between solid-state equipment and electromechanical devices that should be taken into consideration when applying products such as those described in this publication.

Throughout this manual we use notes to make you aware of safety considerations:

ATTENTION

Identifies information about practices or circumstances that can lead to personal injury or death, property damage or economic loss

Attention statements help you to:

- identify a hazard
- avoid a hazard
- recognize the consequences

IMPORTANT

Identifies information that is critical for successful application and understanding of the product.

Table of Contents

SMC Controllers

The Allen-Bradley SMC™ Controller lines offer a broad range of products for starting or stopping AC induction motors from 1/2 Hp to 25 Hp. The innovative features, compact design, and available enclosed controllers meet world-wide industry requirements for controlling motors. Whether you need to control a single motor or an integrated automation system, our range of controllers meet your required needs.

Two of the controllers from the Allen-Bradley SMC Controller line that are covered in this document, are the SMC-Delta™ and SMC-3™. Some of the key features for each of these controllers are highlighted in the table below:

Features	SMC–Delta Controller	SMC-3 Controller
	200…600V 1…64 A	**200…600V 1…37 A**
Soft start		★
Kickstart		★
Current limit start	★	★
Soft stop		★
Coast-to-rest stop	★	★
Fault aux. - normally open	★	★
Aux. contact		★
Side-mounted aux. contact (optional)	★	★
Fault indication	★	★
Overload protection	★	★
Phase reversal		★
Phase unbalance	★	★
Inside-the-delta control ❶	★	

★ = Available

❶ SMC-Delta requires star-delta (wye-delta) motor

SMC-Delta Smart Motor Controller

Description

The SMC-Delta Smart Motor Controller (SMC) is a compact, multi-functional solid-state controller used on traditional 6-lead star-delta motors. SMC-Delta is a replacement for traditional electro-mechanical motor starting applications.

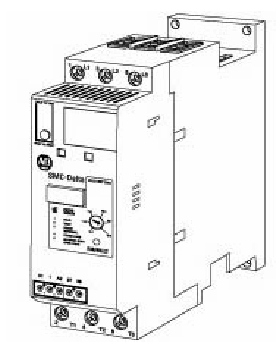
The SMC-Delta controller's power wiring is connected on an inside-the-delta configuration to the 6-lead star-delta motor. Individual connections made in star and delta configurations are no longer necessary, because the SMC-Delta controller applies a reduced voltage start electronically. The current limit setting of the start can be adjusted to meet the application requirements.

Other unique SMC-Delta features used for star-delta applications, are the built-in bypass, silicon-controlled rectifiers (SCRs) controlling all three phases, and a thermal capacity of 350% of nameplate for 15 seconds at 50°C (122°F).

To apply a SMC-Delta controller to a Star-Delta motor, the power wiring from the SMC-Delta is simply wired in an inside delta configuration to the motor. Additionally, the starting current can be adjusted with parameter programming.

The SMC-Delta product line includes current ranges: 3…64 A, 200…600V, 50/60 Hz, meets UL, EN, and IEC standards, and is cULus Listed and CE marked. Control voltage ratings include 24V AC/DC and 100…240V AC. This covers applications up to 40 Hp.

Figure 1.1 SMC-Delta Controller



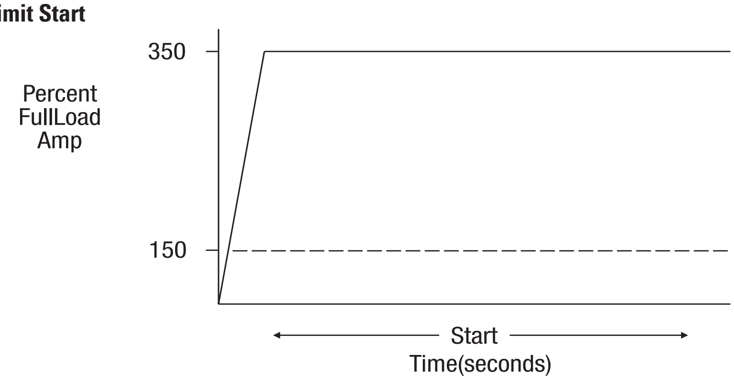
Mode of Operation

The following mode of operation is standard within a single controller:

Current Limit Start

This starting mode is used when it is necessary to limit the maximum starting current. The current setting is DIP switch selectable and can be adjusted from 150…350% of full load amps (FLA). The starting time is adjustable from 2…15 seconds.

Figure 1.2 Current Limit Start



Features

Electronic Overload

The SMC-Delta controller meets applicable requirements as a motor overload protective device. Overload protection is accomplished electronically through an I^2t algorithm.

The overload is DIP switch selectable, providing the user with flexibility. The overload trip class is selectable for OFF or a 10, 15, or 20 protection. A current transformer (CT) monitors each phase. The motor's full load current rating is set by a potentiometer. The overload reset option can be operated either manually or automatically. A remote Cat. no. 193-ER1 reset device can be mechanically attached.

Fault Indication

The SMC-Delta controller monitors both the pre-start and running modes. A single LED is used to display both RUN/ON and FAULT indication. If the controller senses a fault, the SMC-Delta controller shuts down the motor and the LED displays the appropriate fault condition.

The controller monitors the following conditions:

- Overload
- Over-temperature
- Phase Loss/Open Load
- Phase Imbalance
- Shorted SCR

Any fault condition will cause the auxiliary contacts to change state and the hold-in circuit to release. All faults can be cleared by either pressing the reset button or by removing control power. Overload and over-temperature are time-based conditions that may require waiting for some additional cooling time, before reset is possible.

Control Terminal Description

The SMC-Delta contains five (5) control terminals on the front of the controller. These control terminals are described below.

Table 1.A SMC-Delta Control Terminal Description

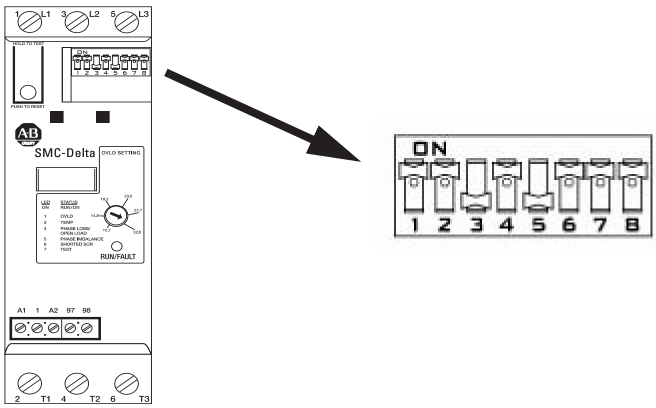
Terminal Number	Description
A1	Control power/Start input
1	Stop input
A2	Control power common
97	N.O. relay - aux. contact for fault indication
98	N.O. relay - aux. contact for fault indication

Auxiliary Contacts

One (1) hard contact is provided as standard with the SMC-Delta controller. The contact is finger safe and is for fault indication.

A side-mounted auxiliary relay #1 can be added as an accessory and is programmable via dipswitch #8, for normal/up-to-speed indication.

DIP Switch Configuration



Position Number	Description
1	Start time
2	Start time
3	Current limit start setting
4	Current limit start setting
5	Overload class selection
6	Overload class selection
7	Overload reset
8	Optional auxiliary relay #1

The following tables describe the SMC-Delta DIP switch programming details:

Table 1.B Start Time

DIP Switch Number		
1	2	Time (seconds)
OFF	OFF	2
ON	OFF	5
OFF	ON	10
ON	ON	15

Table 1.D Current Limit Start Setting

DIP Switch Number		
3	4	Current Limit Setting
OFF	OFF	150%
ON	OFF	250%
OFF	ON	300%
ON	ON	350%

Table 1.F Overload Class Selection

DIP Switch Number		
5	6	Trip Class
OFF	OFF	OFF
ON	OFF	10
OFF	ON	15
ON	ON	20

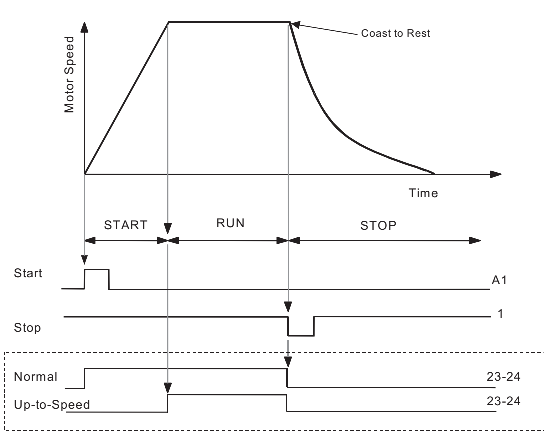
Table 1.C Overload Reset

DIP Switch Number	
7	Reset
OFF	Manual
ON	Automatic

Table 1.E Optional Auxiliary Relay #1

DIP Switch Number	
8	Setting
OFF	Normal
ON	Up-to-speed

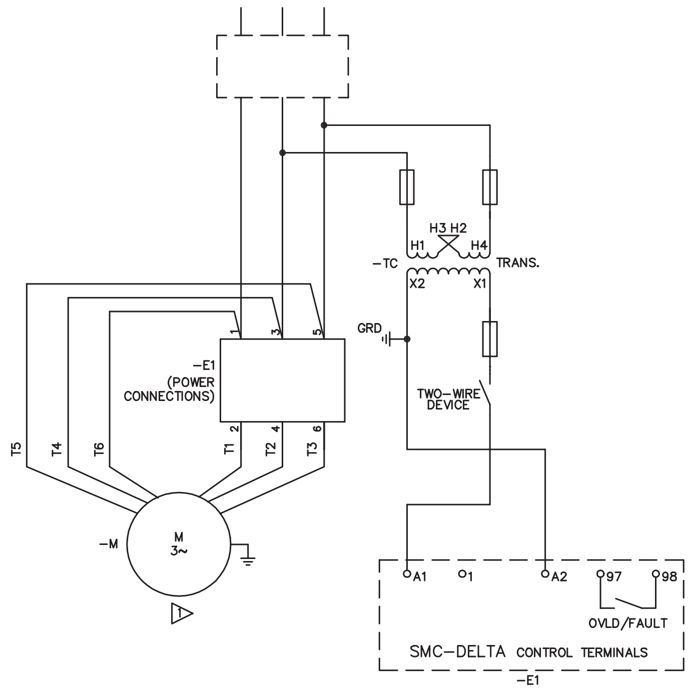
Figure 1.3 SMC-Delta Sequence of Operation



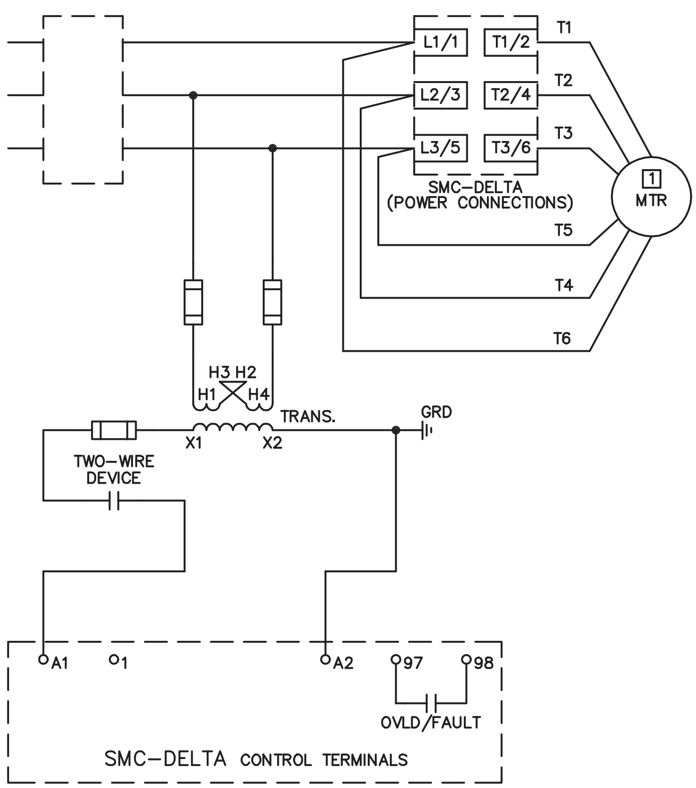
Typical Wiring Diagrams

Two-Wire Configuration

IEC



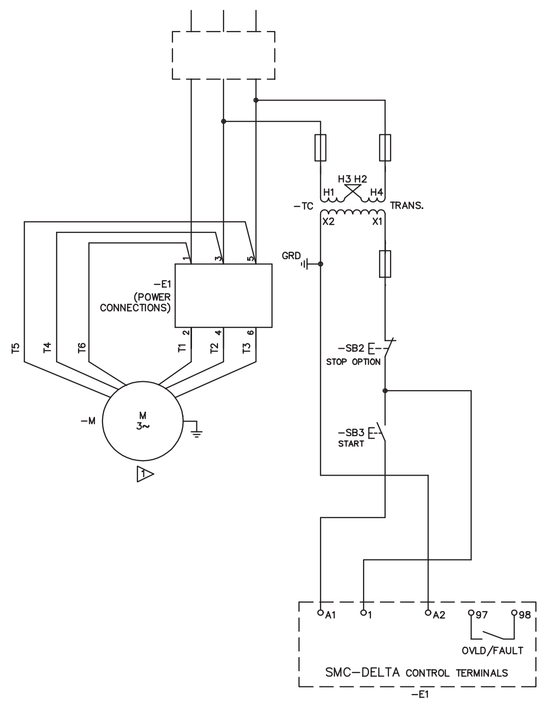
NEMA



Typical Wiring Diagrams, Continued

Three-Wire Configuration

IEC



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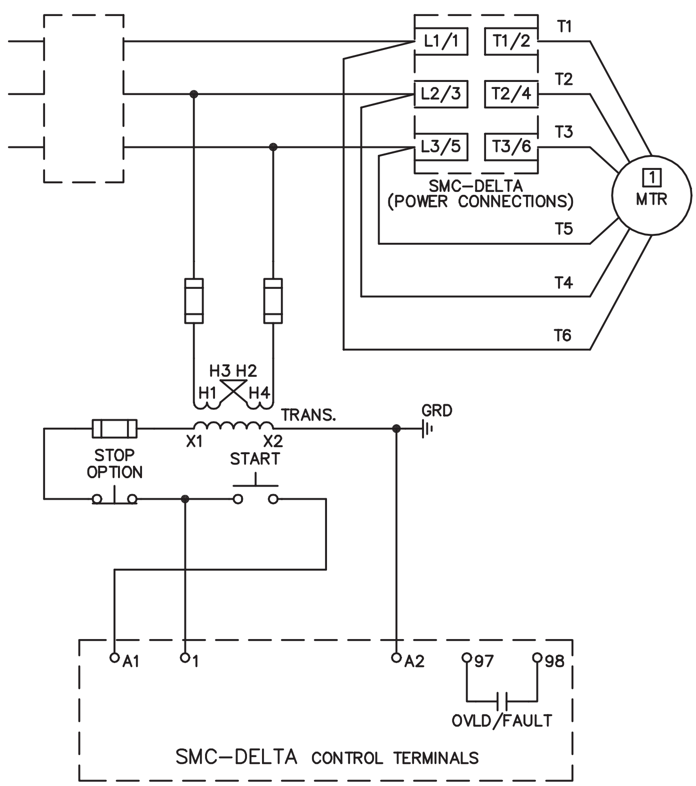
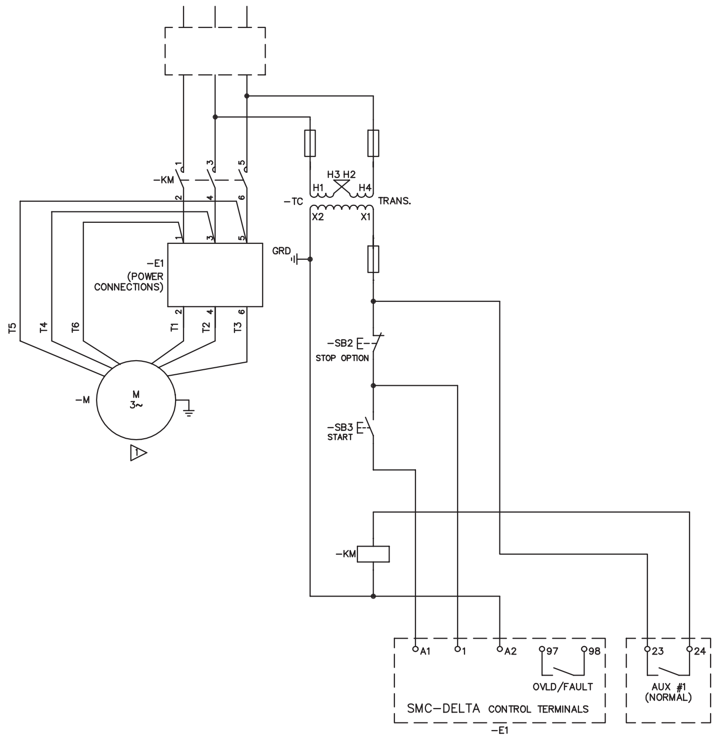


Typical Wiring Diagrams, Continued

Isolation Contactor Configuration

IEC



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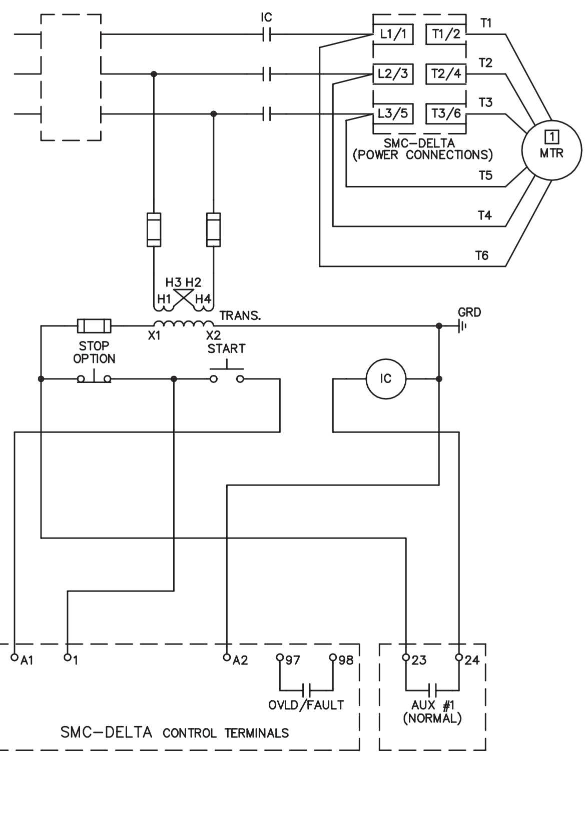
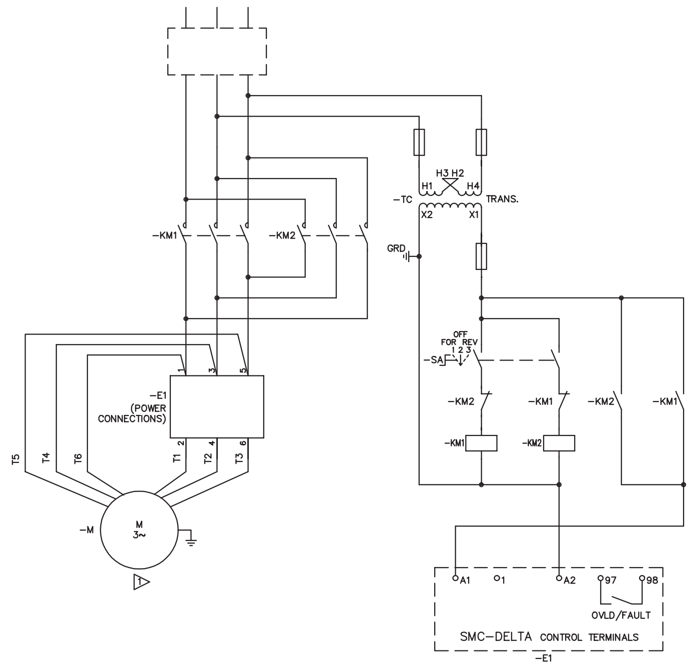


Typical Wiring Diagrams, Continued

Reversing Configuration

Note: Minimum Off time equals 1.0 second

IEC



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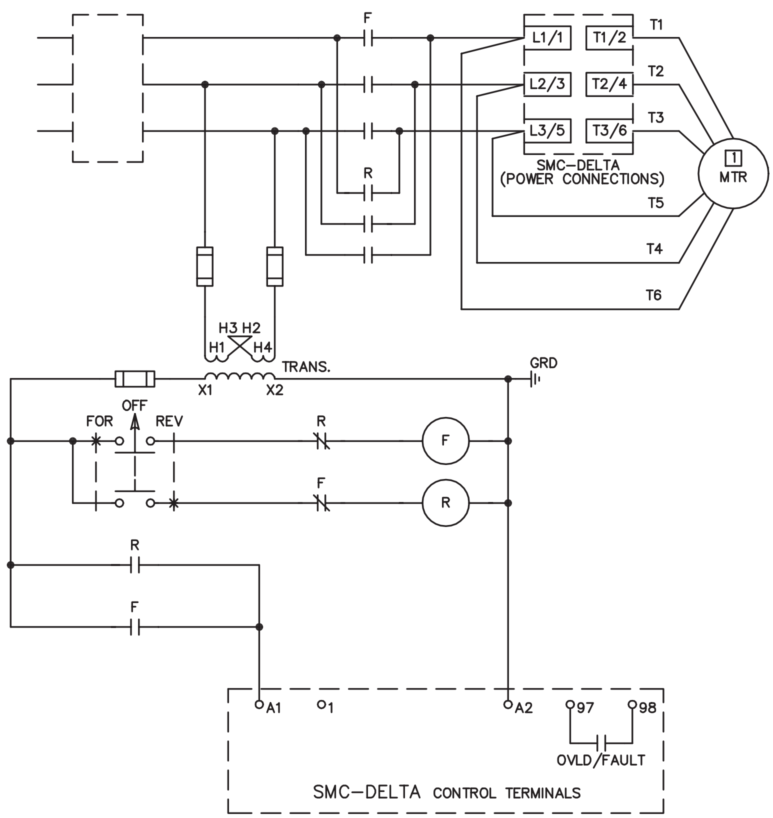


Applications

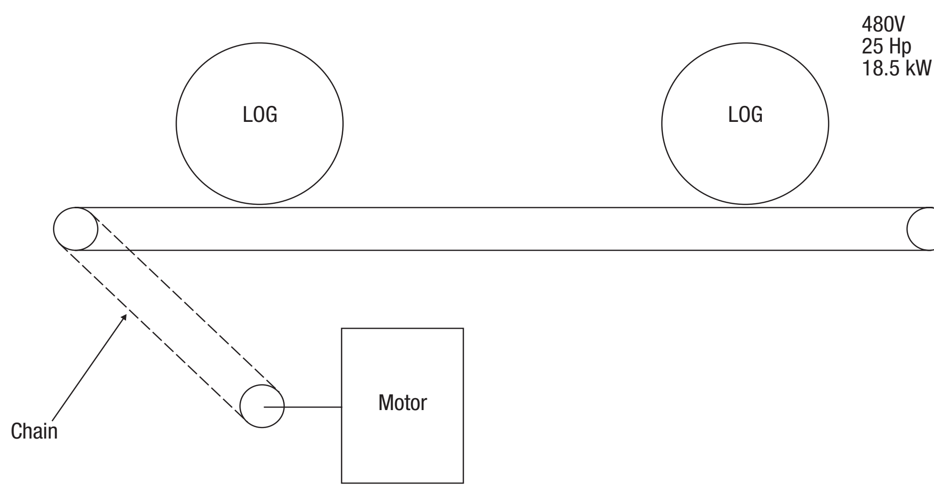
This section describes a few of the many SMC-Delta controller applications.

Illustrations are included to help identify the particular application. Motor ratings are specified but this may vary in other typical applications.

Typical applications include:

- Bridge cranes
- Trolleys
- Monorails
- Shrink wrap machines
- Overhead doors
- Conveyors
- Material handling equipment
- Compressors
- Fans and pumps
- Lifts
- Elevators

Figure 1.4 Conveyor with Current Limit Start



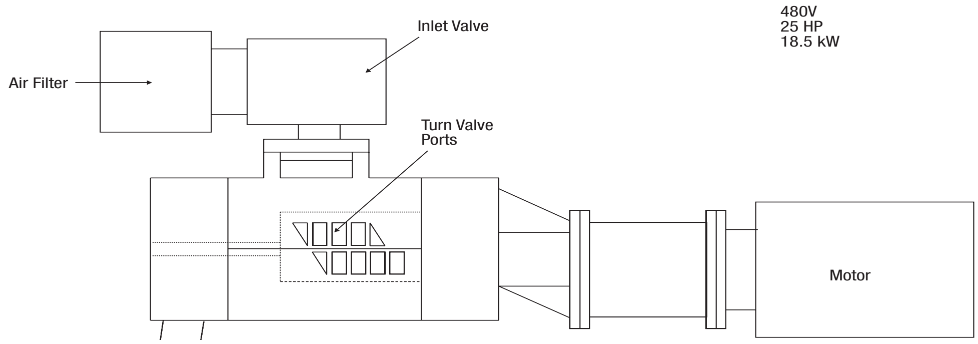
Problem

A conveyor, powered by a Star-Delta motor, is used to continuosly transport logs. The drive chain was breaking due to uncontrolled startup. This caused interruptions in the production schedule and lost productivity. Panel space was very limited.

Solution

Due to its compact design, the SMC-Delta controller was easily installed in the space vacated by the previous starter. A 10-second start was selected. This reduced the starting torque and the shock to the mechanical system.

Figure 1.5 Compressor with Current Limit Start



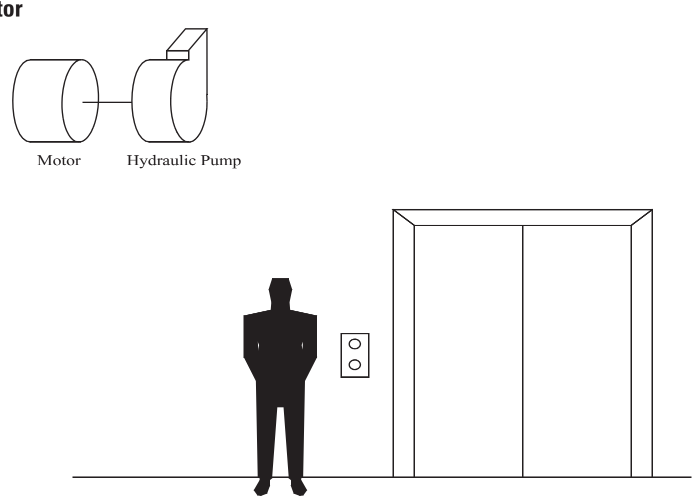
Problem

A compressor OEM shipped its equipment into overseas markets. The compressors were powered by star-delta motors. There were many different voltage and frequency requirements to meet because of the compressor's final destination. Due to power company requirements and mechanical stress on the compressor, a reduced voltage starter was required. This made ordering and stocking spare parts difficult.

Solution

The SMC-Delta controller was installed and set for an 10-second, 350% current limit start, which reduced the voltage to the motor during starting and met the power company requirements. By reducing the voltage, the starting torque was also reduced, minimizing the shock to the compressor. Panel space was saved because of the SMC-Delta controller's built-in overload feature.

Figure 1.6 Passenger Elevator



Problem

A passenger elevator powered by a star-delta motor required a soft start to eliminate the jolt that occurred during an across-the-line start. Due to the size of the enclosure, the soft starter needed to fit in the space vacated by the electromechanical motor starter.

Solution

An SMC-Delta controller with the interface option was installed. The starting time was set for 2 seconds. This reduced the starting torque and eliminated the jolt during the start. The Interface option allowed all control wiring to be connected directly to the SMC-Delta controller, eliminating the need for the electromechanical motor starter. The small size of the SMC-Delta controller allowed it to fit easily into the space vacated by the electromechanical motor starter.

Notes:

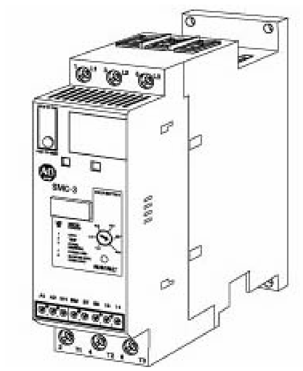
SMC-3™ Smart Motor Controller

Description

The SMC-3 Smart Motor controller is a compact, multi-functional solid-state controller used in reduced voltage motor starting standard three-phase squirrel cage induction motors, and controlling resistive loads. It replaces typical competitive solutions.

The SMC-3 product line includes current ranges: 1…37 A, 200…600V, 50/60 Hz., meets UL, EN, and IEC standards, and is cULus Listed and CE marked. Control voltage ratings include 24V AC/DC and 100…240V AC. This covers applications up to 25 Hp.

Figure 2.1 SMC-3™ Controller



Modes of Operation

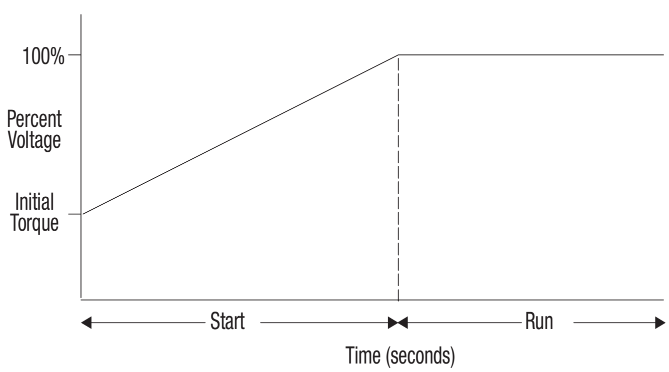
The following modes of operation are standard within a single controller:

- Soft start
- Current limit start
- Kickstart
- Soft stop

Soft Start

Soft start is the most common method of starting. The initial torque setting is DIP switch selectable as a percentage of the locked rotor torque (LRT), ranging from 15…65% of full value. The starting time is customer set, ranging from 2…15 seconds.

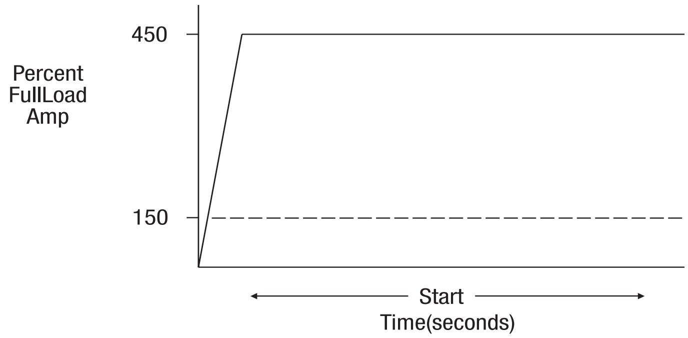
Figure 2.2 Soft Start



Current Limit Start

This starting mode is used when it is necessary to limit the maximum starting current. This is DIP switch selectable and can be adjusted from 150…450% of full load amps. The current limit starting time is customer set, ranging from 2…15 seconds.

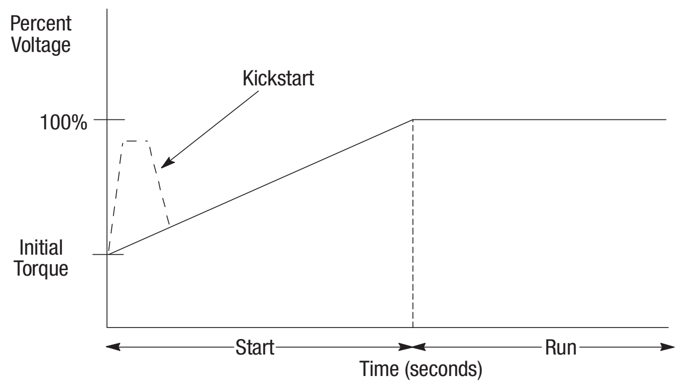
Figure 2.3 Current Limit Start



Selectable Kickstart

The kickstart feature provides a boost at startup to break away loads that may require a pulse of high torque to get started. It is intended to provide a current pulse of 450% of full load current and is user adjustable from 0.0…1.5 seconds.

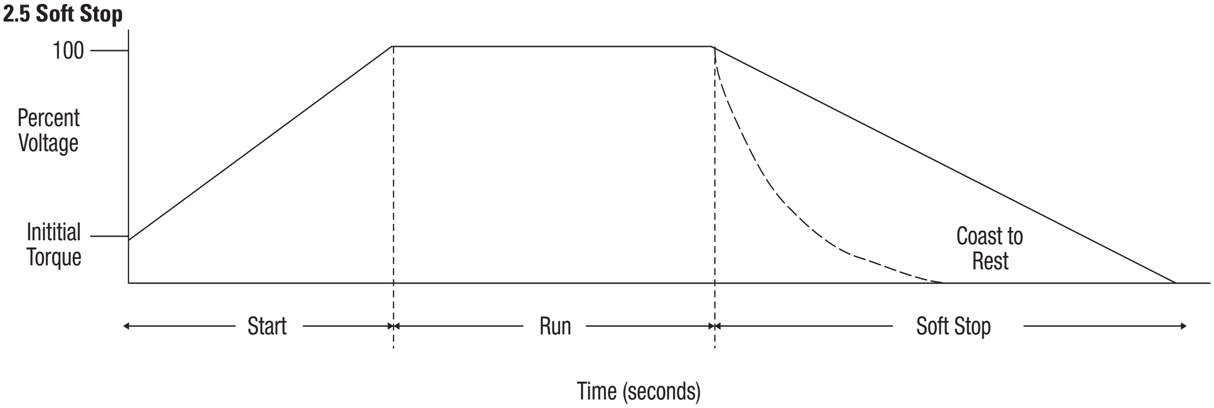
Figure 2.4 Soft Start with Selectable Kickstart



Soft Stop

This function can be used in applications that require an extended coast to rest. When selected, the stop time is either 100, 200, or 300% of the start time. The starting and stopping times are dependently adjusted. The load will stop when the voltage drops to a point where the load torque is greater than the motor torque.

Figure 2.5 Soft Stop



Features

Electronic Overload

The SMC-3 controller meets applicable requirements as a motor overload protective device. Overload protection is accomplished electronically through an I^2t algorithm.

The overload is DIP switch selectable, providing the user with flexibility. The overload trip class is selectable for OFF or a 10, 15, or 20 protection. A CT monitors each phase. The motor's full load current rating is set by a potentiometer. The overload reset option can be operated either manually or automatically. A remote Cat. no. 193-ER1 reset device can be mechanically attached.

Fault Indication

The SMC-3 controller monitors both the pre-start and running modes. A single LED is used to display both RUN/ON and FAULT indication. If the controller senses a fault, the SMC-3 controller shuts down the motor and the LED displays the appropriate fault condition.

The controller monitors the following conditions:

- Overload
- Over-temperature
- Phase reversal
- Phase loss/Open load
- Phase imbalance
- Shorted SCR

Any fault condition will cause the auxiliary contacts to change state and the hold-in circuit to release. All faults can be cleared by either pressing the reset button or by removing control power. Overload and over-temperature are time-based conditions that may require waiting for some additional cooling time, before reset is possible.

Control Terminal Description

The SMC-3 contains eight (8) control terminals on the front of the controller. These control terminals are described below.

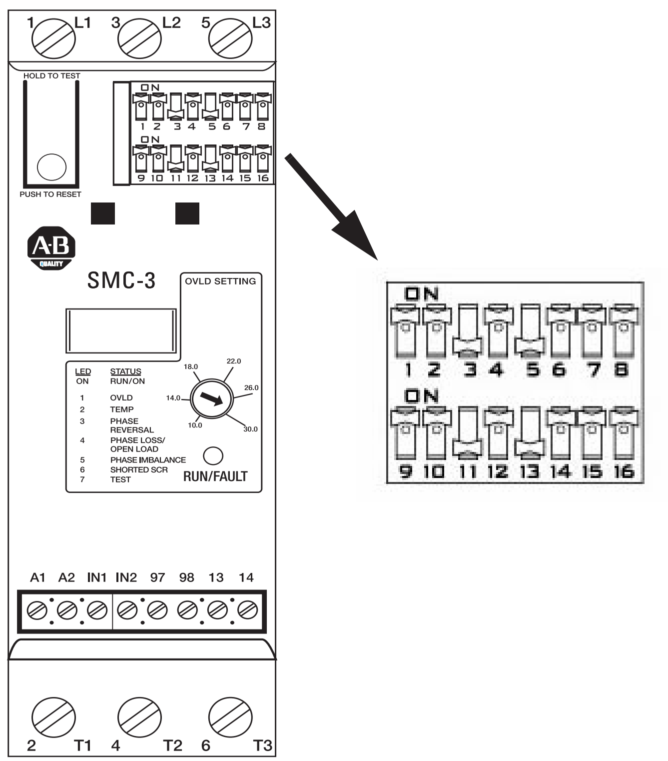
Table 2.A SMC-3 Control Terminal Description

Terminal Number	Description	Terminal Number	Description
A1	Control power input	97	N.O. relay - aux. contact for fault indication
A2	Control power common	98	N.O. relay - aux. contact for fault indication
IN1	Start input	13	N.O. auxiliary relay #1 (normal/up-to-speed)
IN2	Stop input	14	N.O. auxiliary relay #1 (normal/up-to-speed)

Auxiliary Contacts

Two (2) hard contacts are provided as standard with the SMC-3 controller. These contacts are finger safe. The first contact is for fault indication. The auxiliary relay #1 is programmable via dipswitch #14, for normal/up-to-speed indication. A side-mounted additional auxiliary relay #2 can be added as an accessory and programmed via dipswitch #15 for normal/up-to-speed indication.

DIP Switch Configuration



Position Number	Description
1	Start time
2	Start time
3	Start mode (current limit or soft start)
4	Current limit start setting (when selected) or Soft start initial torque setting (when selected)
5	Current limit start setting (when selected) or Soft start initial torque setting (when selected)
6	Soft stop
7	Soft stop
8	Not used
9	Kick start
10	Kick start
11	Overload class selection
12	Overload class selection
13	Overload reset
14	Auxiliary relay #1 (normal or up-to-speed)
15	Optional auxiliary relay #2 (normal or up-to-speed)
16	Phase rotation check

The following tables describe the SMC-3 DIP Switch programming details:

Table 2.B Start Time

DIP Switch Number		
1	2	Time (seconds)
OFF	OFF	2
ON	OFF	5
OFF	ON	10
ON	ON	15

Table 2.C Start Mode (Current Limit or Soft Start)

DIP Switch Number	
3	Setting
OFF	Current limit
ON	Soft start

Table 2.D Current Limit Start Setting (when selected)

DIP Switch Number		
4	5	Current Limit % FLA
OFF	OFF	150%
ON	OFF	250%
OFF	ON	350%
ON	ON	450%

Table 2.E Soft Start Initial Torque Setting (when selected)

DIP Switch Number		
4	5	Initial Torque % LRT
OFF	OFF	15%
ON	OFF	25%
OFF	ON	35%
ON	ON	65%

Table 2.F Soft Stop

DIP Switch Number		
6	7	Setting
OFF	OFF	Coast-to-rest
ON	OFF	100% of start time
OFF	ON	200% of start time
ON	ON	300% of start time

Table 2.G Kick Start

DIP Switch Number		
9	10	Time (seconds)
OFF	OFF	OFF
ON	OFF	0.5
OFF	ON	1.0
ON	ON	1.5

Table 2.H Overload Class Selection

DIP Switch Number		
11	12	Trip Class
OFF	OFF	OFF
ON	OFF	10
OFF	ON	15
ON	ON	20

Table 2.I Overload Reset

DIP Switch Number	
13	Reset
OFF	Manual
ON	Automatic

Table 2.J Auxiliary Relay #1

DIP Switch Number	
14	Setting
OFF	Normal
ON	Up-to-speed

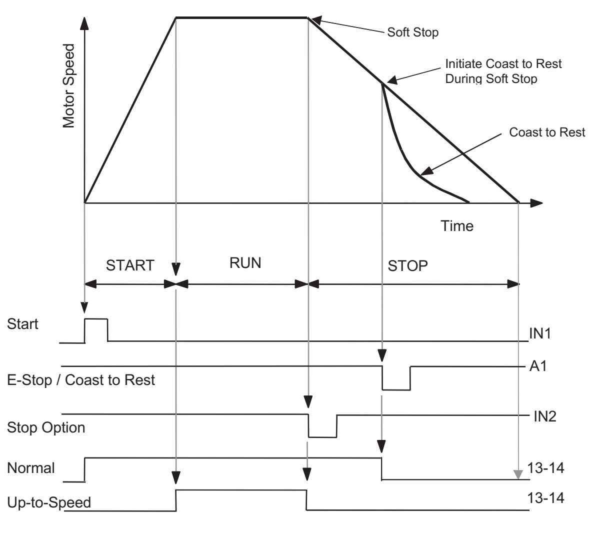
Table 2.K Optional Auxiliary Relay #2

DIP Switch Number	
15	Setting
OFF	Normal
ON	Up-to-speed

Table 2.L Phase Rotation Check

DIP Switch Number	
16	Setting
OFF	Enabled
ON	Disabled

Figure 2.6 SMC-3 Sequence of Operation



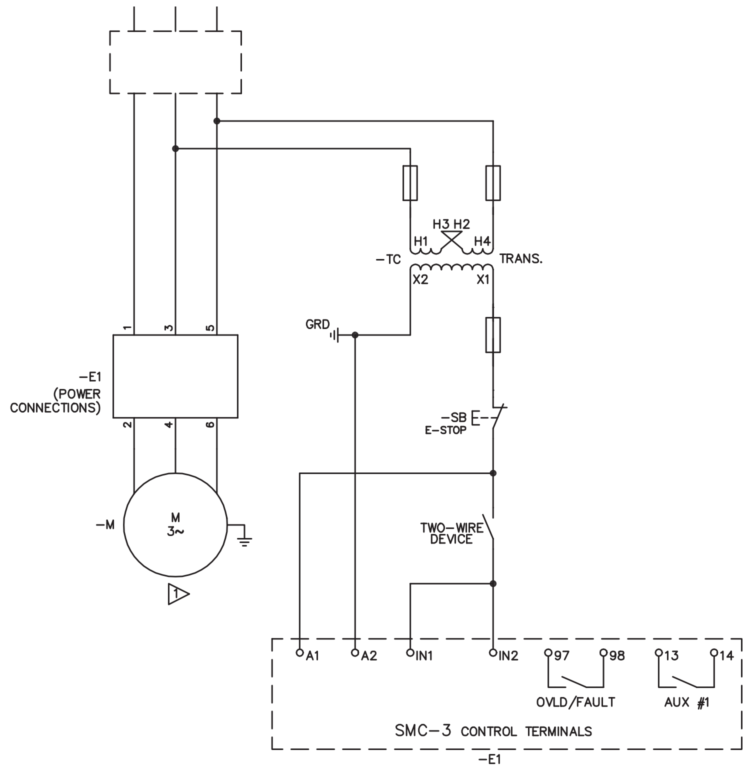
ATTENTION

The user has the ultimate responsibility to determine which stopping mode is best suited to the application and will meet applicable standards for operator safety on a particular machine.

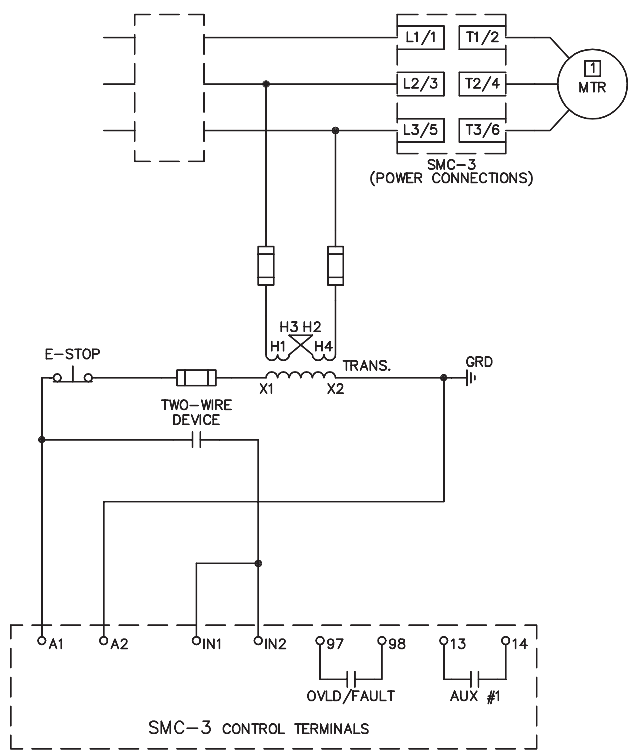
Typical Wiring Diagrams

Two-Wire Configuration

IEC



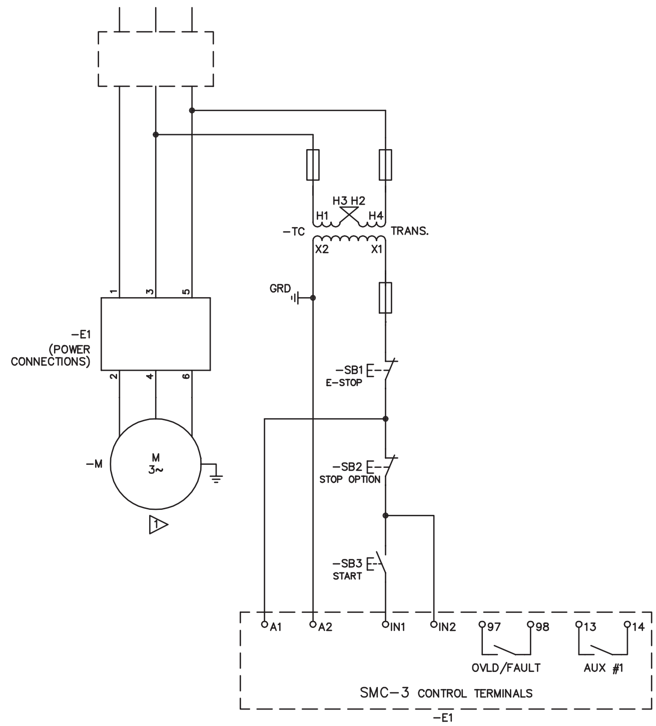
NEMA



Typical Wiring Diagrams, Continued

Three-Wire Configuration

IEC



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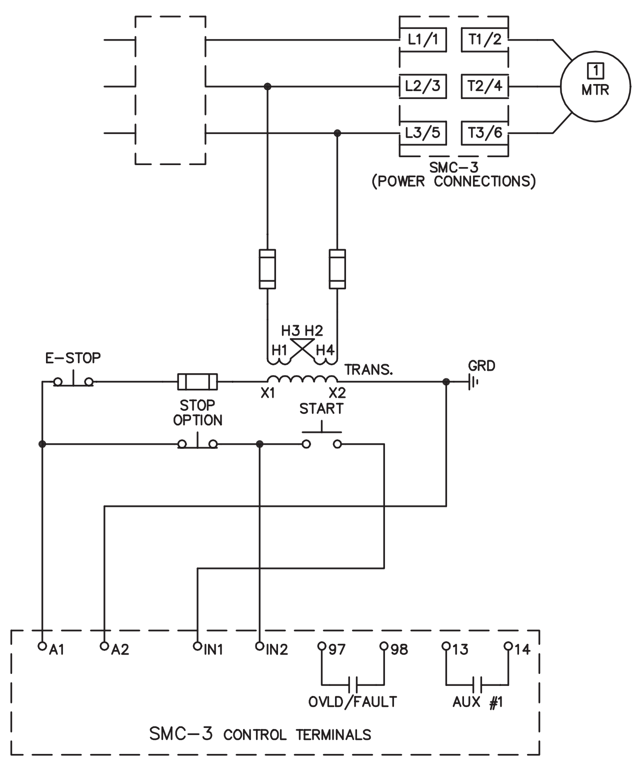
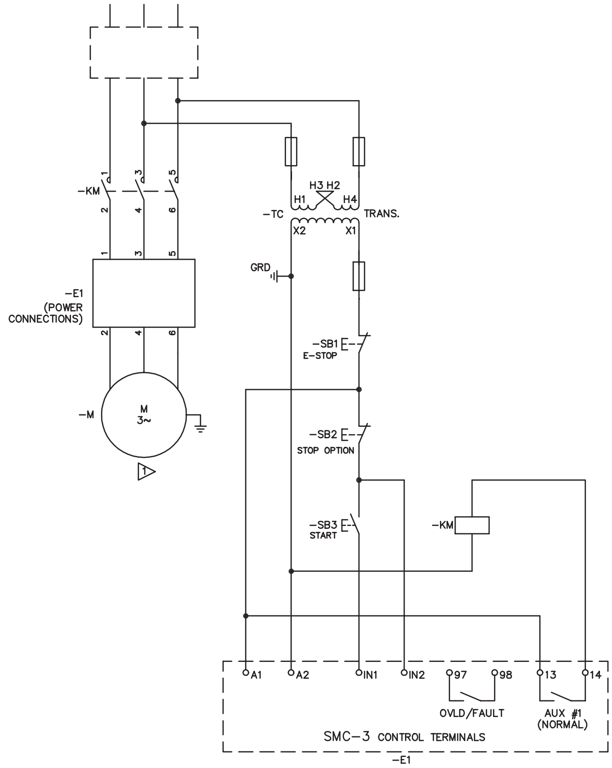


Typical Wiring Diagrams, Continued

Isolation Contactor Configuration

IEC



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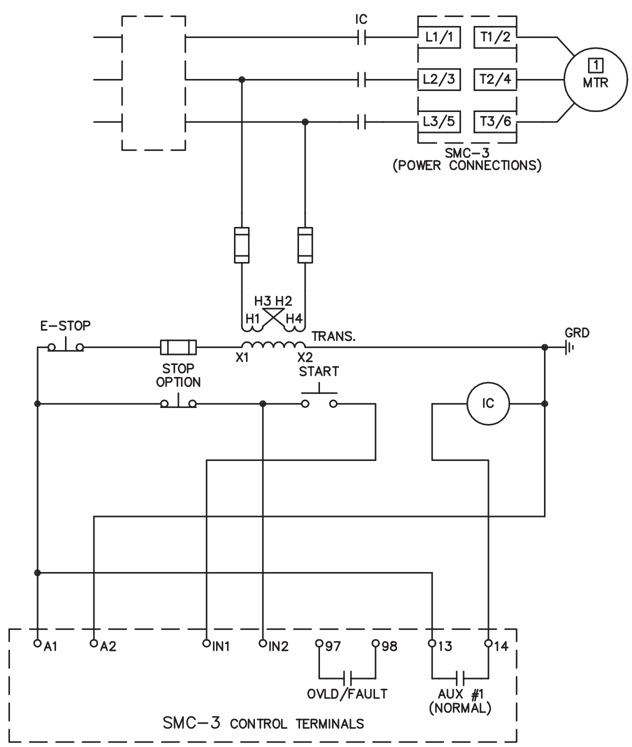
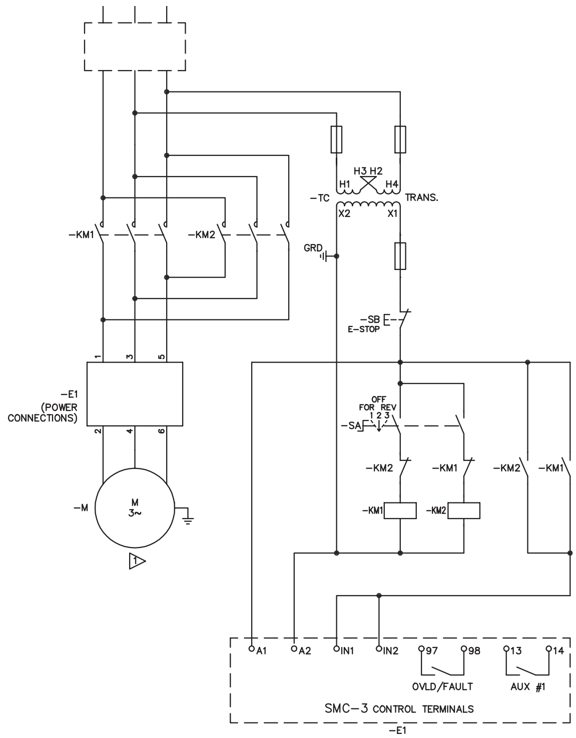


Typical Wiring Diagrams, Continued

Reversing Configuration

Note: Minimum Off time equals 1.0 second

IEC



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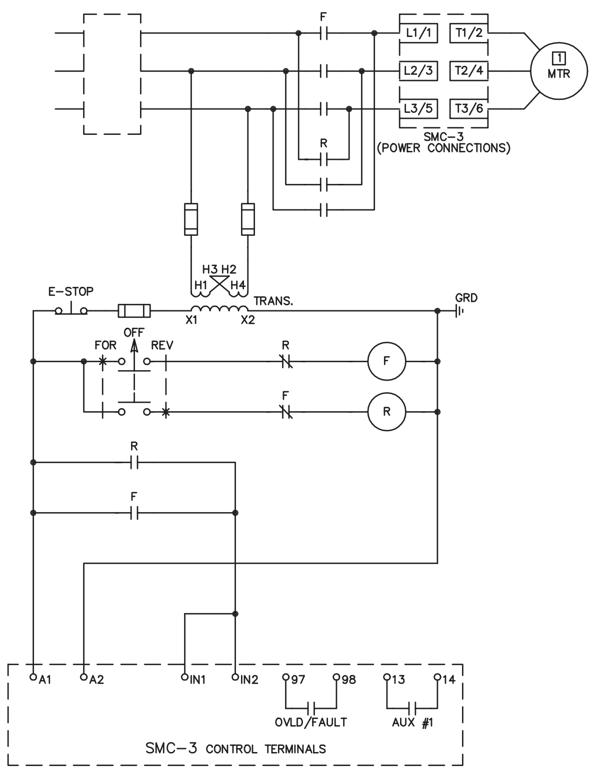


Applications

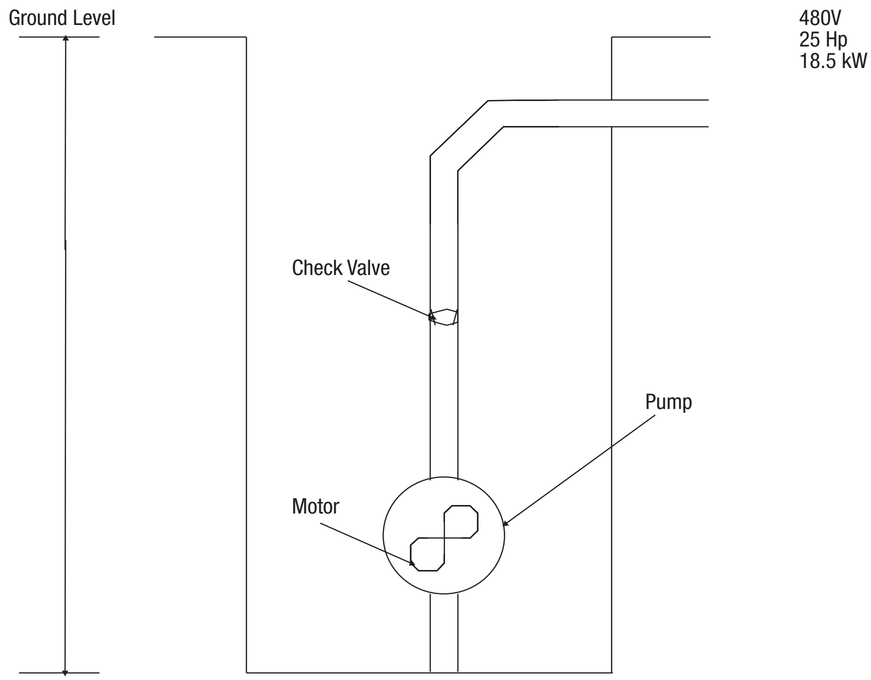
This section describes a few of the many SMC-3 controller applications.

Illustrations are included to help identify the particular application. Motor ratings are specified but this may vary in other typical applications.

Typical applications include:

- Bridge cranes
- Trolleys
- Monorails
- Shrink wrap machines
- Overhead doors
- Conveyors
- Material handling equipment
- Compressors
- Fans and pumps
- Lifts
- Elevators

Figure 2.7 Pump with Soft Start



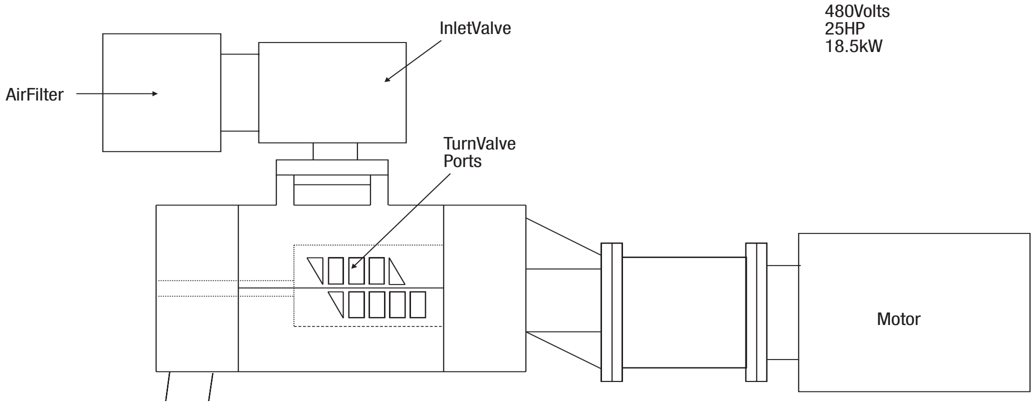
Problem

A municipal water company was experiencing problems with pump impellers being damaged. The damage occurred during an across-the-line start and was caused by the heavy shock to the impeller. The pumping station motor was over 100 feet below ground, making repair costly. An additional concern was frequent line failures, which resulted in single-phasing the motor.

Solution

The SMC-3 controller was installed, providing a controlled acceleration of the motor. The shock to the impeller was reduced by decreasing the torque during startup. The built-in overload saved panel space. The SMC-3 controller's line diagnostics shut off the motor after it detected the pre-start and running single-phase condition. This protected the pump from motor damage.

Figure 2.8 Compressor with Soft Start



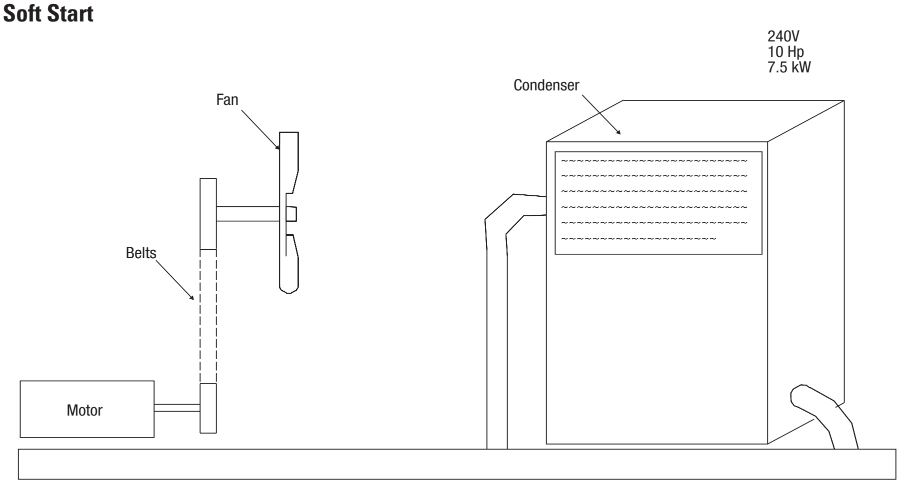
Problem

A compressor OEM shipped its equipment into overseas markets. There were many different voltage and frequency requirements to meet because of the compressor's final destination. Due to power company requirements and mechanical stress on the compressor, a reduced voltage starter was required. This made ordering and stocking spare parts difficult.

Solution

The SMC-3 controller was installed and set for a 15-second soft start, which reduced the voltage to the motor during starting and met the power company requirements. Reducing the voltage, also reduced the starting torque, which minimized the shock to the compressor. The SMC-3 controller has a built-in overload feature which saved panel space.

Figure 2.9 Chiller with Soft Start



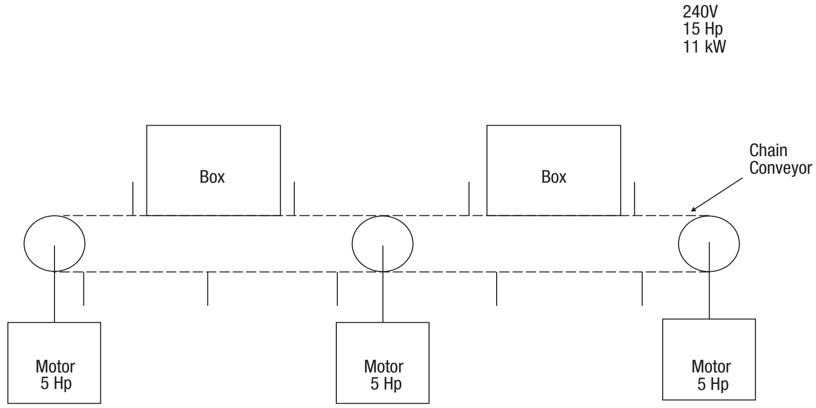
Problem

A belt-driven fan on a chiller was frequently breaking the belt because of high starting torque. Excessive downtime was incurred because the housing had to be removed to replace the belt. A combination across-the-line starter was being used to control the motor. Control panel space was limited. A device that used the same control and line voltages as the starter was required because there was no room in the panel for a control circuit transformer.

Solution

The SMC-3 controller was installed as a retrofit to the chiller. It was set for an 10-second soft start to reduce the snap to the belts as a result of the high starting torque. It also reduced belt "squealing" previously experienced during startup. Because the SMC-3 controller can operate with 240V control and line voltage, a control circuit transformer was not required. The built-in overload protection on the SMC-3 controller further reduced the panel space required. The customer was able to retrofit the controller into the existing panel space.

Figure 2.10 Towline Conveyor with Soft Start



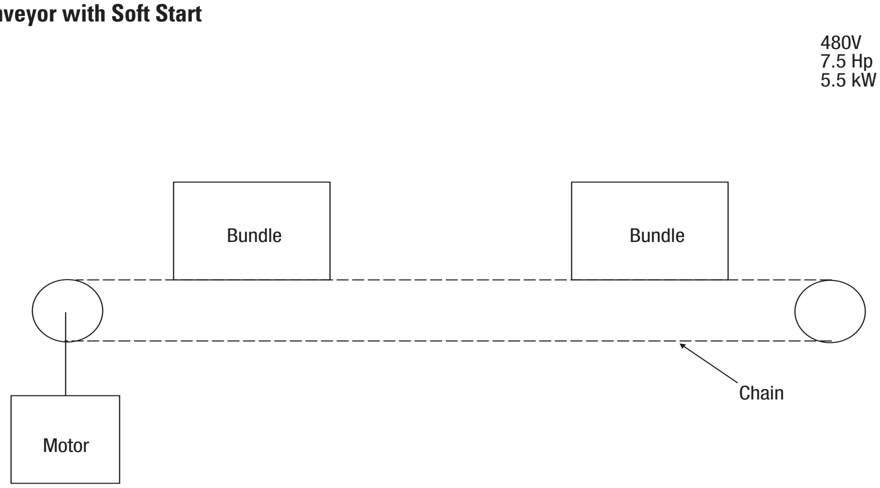
Problem

A towline conveyor in a freight house had three motors, that were effectively "common shaft", to drive the conveying system. Across-the-line starts caused damage to the conveyor and spilled freight on the conveyor.

Solution

The conveyor OEM installed a single SMC-3 controller to provide a smooth acceleration to all three motors, reducing the starting torque of the motors and the mechanical shock to the conveyor and load. The OEM liked the SMC-3 controller because of its ability to control three motors as if they were a single motor, eliminating the need for multiple soft starters.

Figure 2.11 Chain Conveyor with Soft Start



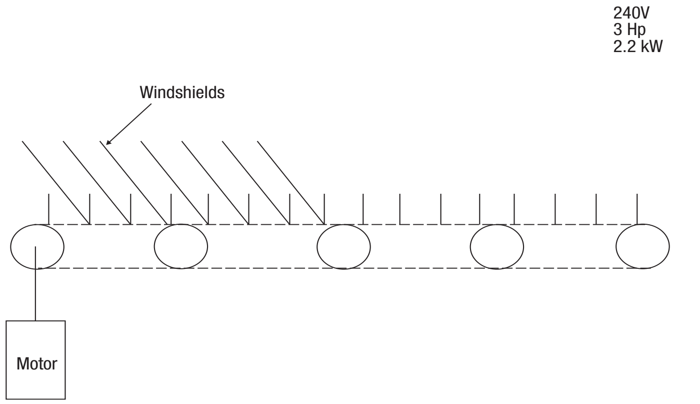
Problem

A chain conveyor was used to transport bundles of paper. The chain was breaking once per day because of high starting torque. Maintenance of the conveyor caused interruptions in the production schedule and lost productivity. Line surges were also a frequent problem.

Solution

The SMC-3 controller was installed. A 10-second soft start was programmed, reducing the starting torque and the mechanical shock to the chain. It was estimated that the SMC-3 controller paid for itself in one week, due to the reduced downtime. A line side protective module (MOV) was installed to suppress the voltage transients.

Figure 2.12 Chain Conveyor with Soft Start and Soft Stop Option



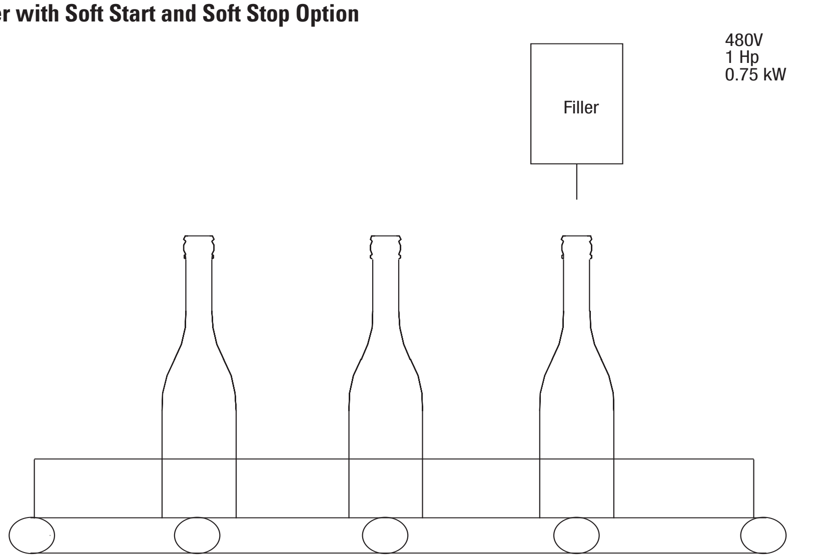
Problem

A chain conveyor was used to transport automobile windshields to a packaging area. The high starting torque would cause the load to shift, damaging the windshields. The stopping of the conveyor also caused shifting problems when the load decelerated quickly. An across-the-line starter was used in this application. Because the cost of downtime was high, a modular controller was required for ease of maintenance.

Solution

The SMC-3 controller with enabled soft stop was installed, reducing the starting torque and decreasing the product shift on startup. The soft stop extended the stopping time, bringing the conveyor to a smooth stop.

Figure 2.13 Bottle Filler with Soft Start and Soft Stop Option



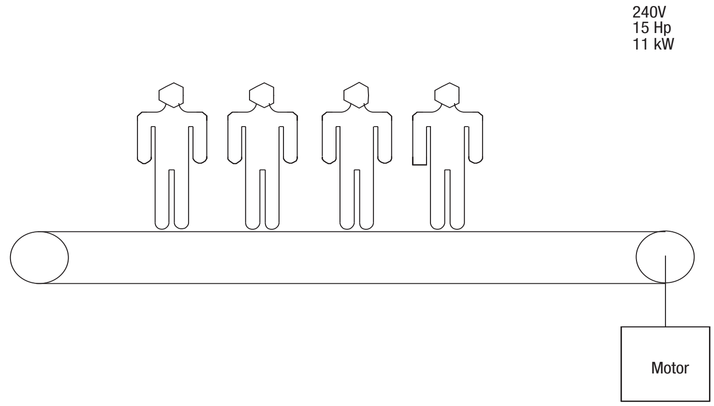
Problem

A bottle filler line had product spillage during starting and stopping. An across-the-line starter was used to start the motor. In addition, the application required an auxiliary contact that would energize when the motor was up to speed.

Solution

The SMC-3 controller was installed and programmed for a 10-second soft start with an 20-second soft stop. The controlled start reduced the starting torque and consequently, the product spillage. The Soft Stop option extended the stopping time, smoothing load shift while stopping. The auxiliary contacts were configured to change state when the motor was up to speed.

Figure 2.14 Power Walk with Soft Start and Soft Stop Option



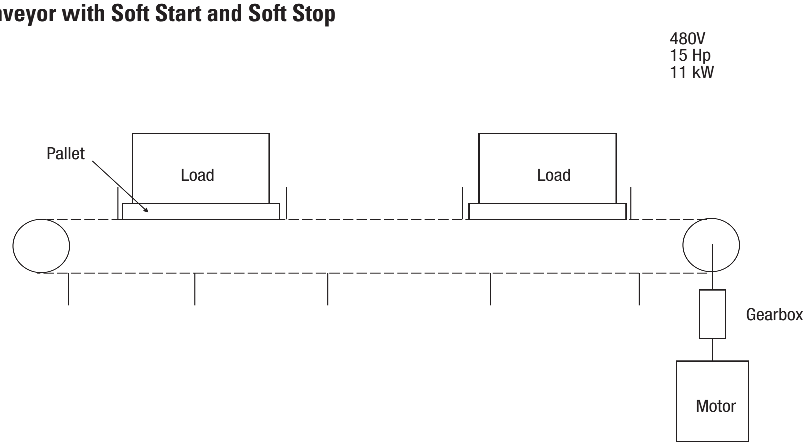
Problem

A power walk in an airport required a soft start to prevent damage to the drive chain gearbox on startup. A soft stop was also required in case the power walk would be shut off while people were on the belt. Several power walks were installed in the airport, and each required its own soft starter. A controller that could be quickly replaced and adjusted was required. Also, panel space was limited.

Solution

The SMC-3 controller with soft stop was installed. An 10-second soft start and a 10-second soft stop were programmed into the controller, facilitating a controlled start and stop. The built-in overload protection eliminated the need for a separate overload relay, thereby saving panel space. In the event that a unit needed replacement, one could be quickly plugged in.

Figure 2.15 Towline Conveyor with Soft Start and Soft Stop



Problem

A towline conveyor at the end of a production line had frequent damage to the gearbox caused by the starting torque from across-the-line starting of the motor. There were also frequent spills during starting and stopping. This towline application had a variety of starting requirements that other soft starters could not satisfy. Investing in a variable speed drive was not cost effective.

Solution

The SMC-3 controller was installed as a retrofit to the existing across-the-line starter. The starting and stopping times were programmed for 10 seconds. The reduced starting torque decreased the shock to the gearbox and kept the load from shifting on startup. The soft stop protected against loads shifting while stopping. The SMC-3 controller met the starting requirements and was a cost-effective solution.

SMC-Delta and SMC-3 Controller Special Application Considerations

Motor Overload Protection

When coordinated with the proper short circuit protection, overload protection is intended to protect the motor, motor controller, and power wiring against overheating caused by excessive overcurrent. The SMC-Delta and SMC-3 controllers meet applicable requirements as a motor overload protective device.

The SMC-Delta and SMC-3 controllers incorporate, as standard, electronic motor overload protection. This overload protection is accomplished via CT monitoring all three phases.

The controller's overload protection is programmable, providing the user with flexibility. The overload trip class is selectable for OFF or a 10, 15, or 20 protection. The trip current can be set to the motor full load current rating.

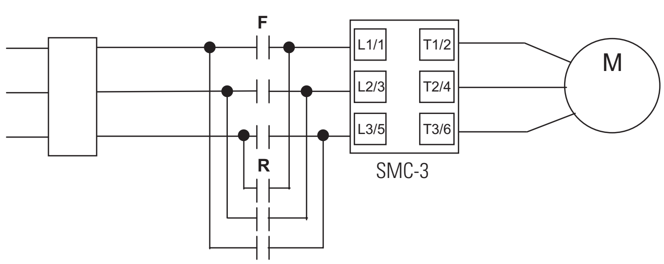
Thermal memory is included to accurately model motor operating temperature. Ambient insensitivity is inherent in the electronic design of the overload.

Reversing Contactors

By using the controller as shown in Figure 3.1, the motor accelerates under a controlled start mode in either forward or reverse.

Notes:	• Minimum transition time for reversing is 1 second.
	• Phase Reversal must be OFF.

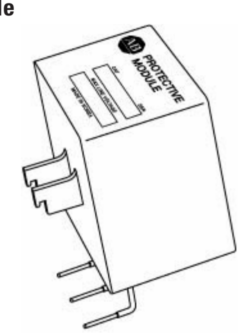
Figure 3.1 Typical SMC-3 Application with a Single-speed Reversing Starter



Use of Protective Modules

A protective module (see Figure 3.2) containing metal oxide varistors (MOVs) and capacitors can be installed to protect the power components from electrical transients and/or electrical noise. The protective modules clip transients generated on the lines and prevent such surges from damaging the SCRs. The capacitors in the protective modules are used to shunt noise energy away from the SMC controller electronics.

Figure 3.2 Protective Module



Use of Protective Modules, Continued

There are two general situations that may occur which would indicate the need for utilizing the protective modules.

1. Transient spikes may occur on the lines feeding the SMC controllers (or feeding the load from the SMC controllers). Lightning can cause spikes. Spikes are also created on the line when devices are attached with current-carrying inductances that are open circuited. The energy stored in the magnetic field is released when the contacts open the circuit. Examples of these are lightly loaded motors, transformers, solenoids, and electromechanical brakes.

2. The second situation arises when the SMC controllers are installed on a system which has fast-rising wavefronts present, although not necessarily high peak voltages. Lightning strikes can cause this type of response. Additionally, if the SMC controllers are on the same bus as other SCR devices, (AC/DC drives, induction heating equipment, or welding equipment) the firing of the SCRs in those devices can cause noise. This high frequency noise can penetrate the SMC controllers through stray capacitance.

ATTENTION

When installing or inspecting the protective module, disconnect the controller from the power source. The protective module should be checked periodically. Inspect for damage or discoloration. Replace if necessary.

Altitude De-rating

Because of the decreased efficiency of fans and heatsinks, it is necessary to de-rate the SMC-Delta and SMC-3 controllers above 2000 meters (6,560 ft). When using the controller above 2000 meters (6,560 ft), the controller amperage value will need to be de-rated.

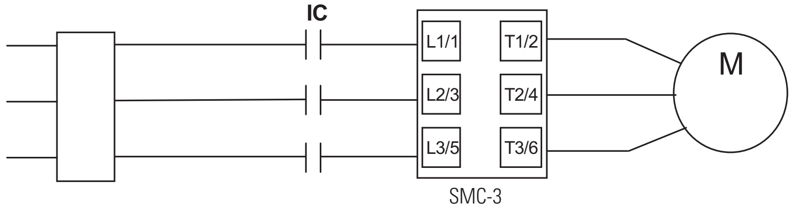
Isolation Contactor

When installed with branch circuit protection, SMC-Delta and SMC-3 controllers are compatible with the National Electric Code (NEC). When an isolation contactor is not used, hazardous voltages are present at the load terminals of the power module even when the controller is turned off. Warning labels must be attached to the motor terminal box, the controller enclosure, and the control station to indicate this hazard.

The isolation contactor is used to provide automatic electrical isolation of the controller and motor circuit when the controller is shut down. Shut down can occur in either of two ways: either manually, by pressing the stop button, or automatically, by the presence of abnormal conditions (such as a motor overload relay trip).

Under normal conditions the isolation contactor carries only the load current. During start, the isolation contactor is energized before the SCRs are gated "on." While stopping, the SCRs are gated "off" before the isolation contactor is de-energized. The isolation contactor is not making or breaking the load current.

Figure 3.3 Typical SMC-3 Connection Diagram with Isolation Contactor



SMC Product Line Applications Matrix

Description

Use this chapter to identify possible SMC-Delta and SMC-3 controller applications. This chapter contains an application matrix which will identify starting and stopping characteristics that may be used in various applications.

Mining and Metals

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Roller conveyors		X	X
Centrifugal pumps	X	X	
Fans	X	X	
Dust collector	X	X	
Chillers	X	X	
Compressor	X	X	
Belt conveyors	X	X	X
Slicer	X	X	

Water/Wastewater Treatment and Municipalities

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal pumps	X	X	
Fans	X	X	
Compressors	X	X	

Petrochemical

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal pumps	X	X	
Screw conveyors	X	X	
Mixers	X	X	
Agitators	X	X	
Compressors	X	X	
Fans	X	X	

Lumber and Wood Products

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Circular saw	X	X	
Edger	X	X	
Conveyors	X	X	X
Centrifugal pumps	X	X	
Compressors	X	X	
Fans	X	X	
Planers	X	X	
Sander	X	X	

Food Processing

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal Pumps	X	X	
Pallitizers		X	X
Agitators		X	
Conveyors		X	X
Fans	X	X	
Bottle Washers		X	X
Compressors	X	X	
Dryers	X	X	
Slicers	X	X	

Pulp and Paper

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Compressors	X	X	
Conveyors	X	X	X
Trolleys		X	X
Dryers	X	X	
Agitators	X	X	
Centrifugal Pumps	X	X	
Mixers	X	X	
Fans	X	X	
Re-Pulper	X	X	

OEM Specialty Machine

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Centrifugal Pumps	X	X	
Washers	X	X	
Conveyors	X	X	X
Power Walks	X	X	X
Fans	X	X	
Twisting/Spinning Machine	X	X	

Transportation and Machine Tool

Applications	SMC-Delta and SMC-3	SMC-3 Only	
	Current Limit	Soft Start	Soft Stop
Material Handling Conveyors	X	X	X
Grinders	X	X	
Centrifugal Pumps	X	X	
Trolleys		X	X
Fans	X	X	
Palletizers	X	X	X
Compressors	X	X	
Die Charger		X	
Rotary Table		X	

Design Philosophy

Philosophy

Allen-Bradley SMC controllers are designed to operate in today's industrial environments. Our controllers are manufactured to provide consistent and reliable operation. Rockwell Automation has more than just an adequate solution to meet your needs; we have the *right* solution. With a broad offering of power device products and application services, Rockwell Automation can effectively address the productivity issues most important to you.

Line Voltage Conditions

Voltage transients, disturbances, harmonics, and noise exist in any industrial supply line. A solid-state controller must be able to withstand these noises and should not be an unnecessary source of generating noise back into the line.

- Ease of selection for the required line voltage is achieved with a design that provides operation over a wide voltage range, at 50/60 Hz, within a given controller rating.
- The controller can withstand 3000V surges at a rate of 100 bursts per second for 10 seconds (IEEE Std. 472). Further, the controller can withstand the showering arc test of 350…1500V (NEMA Std. ICS2-230) for higher resistance to malfunction in a noisy environment.
- An optional MOV module is available to protect SCRs from voltage transients.

Current and Thermal Ratings

Solid-state controller ratings must ensure reliability under the wide range of current levels and starting times needed in various applications.

- SCR packaging keeps junction temperatures below 125°C (257°F) when running at full-rated current to reduce thermal stress and provide longer, more reliable operation.
- The thermal capacity of the SMC-3 and SMC-Delta controllers meet NEMA standards MG-1 and IEC34 (S1).
- Open type operating temperature is 0…50°C (32…122°F) and a de-rating chart is required for 60°C (140°F). Storage temperature is –25…+85°C (–13…185°F). Relative humidity is 5… 95% (non-condensing).

Mechanical Shock and Vibration

Solid-state controllers must withstand the shock and vibration generated by the machinery that they control.

- SMC-Delta and SMC-3 controllers meet the same shock and vibration specifications as electromechanical starters.
- Both products attain the desired requirements of 1.0 G vibration operational and 2.5 G vibration non-operational.
- Both products attain the desired requirements of 15 G shock operational and 30 G shock non-operational.

Noise and RF Immunity

Both products meet Class A requirements for EMC emission levels.

Altitude

Altitudes up to 2000 meters (6560 ft) are permitted without de-rating. The products' allowable ambient temperature must be de-rated for altitudes in excess of 2000 meters (6560 ft). The allowable ambient temperature must be de-rated by –3°C (27°F) per 1000 meters (3280 ft), up to a maximum of 7000 meters (23000 ft). Current ratings of the devices do not change for altitudes that require a lower maximum ambient temperature.

Pollution

Both products are intended for a Pollution Degree 2 environment.

Set-up

Simple, easily understood settings provide identifiable, consistent results.

- For ease of installation, the controllers include compact design and feed-through wiring.
- SMC-Delta and SMC-3 controllers are global products rated at 50/60 Hz.
- All parameter adjustments are made via DIP switches.
- A full line of enclosures is available.

Reduced Voltage Starting

Introduction to Reduced Voltage Starting

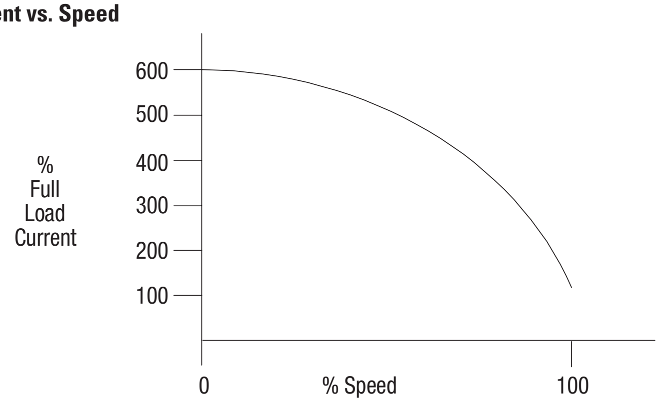
There are two primary reasons for using reduced voltage when starting a motor:

- Limit line disturbances
- Reduce excessive torque to the driven equipment

The reasons for avoiding these problems will not be described. However, different methods of reduced voltage starting of motors will be explored.

When starting a motor at full voltage, the current drawn from the power line is typically 600% of normal full load current. This high current flows until the motor is almost up to speed and then decreases, as shown in Figure 6.1. This could cause line voltage dips and brown-outs.

Figure 6.1 Full Load Current vs. Speed



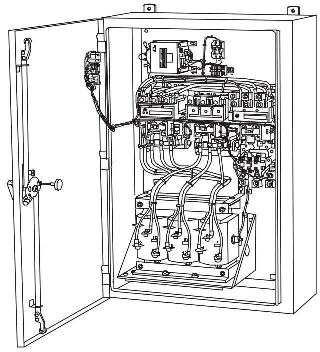
In addition to high starting currents, the motor also produces starting torques that are higher than full load torque. The magnitude of the starting torque depends on the motor design. NEMA publishes standards for torques and currents for motor manufacturers to follow. Typically, a NEMA Design B motor will have a locked rotor or starting torque in the area of 180% of full load torque.

In many applications, this starting torque can cause excessive mechanical damage such as belt, chain, or coupling breakage.

Reduced Voltage

The most widely used method of electromechanical reduced voltage starting is the autotransformer. Wye-delta (Y-Δ), also referred to as star-delta, is the next most popular method.

Figure 6.2 Bulletin 570 Autotransformer



All forms of reduced voltage starting affect the motor current and torque characteristics. When a reduced voltage is applied to a motor at rest, the current drawn by the motor is reduced. In addition, the torque produced by the motor is a factor of approximately the square of the percentage of voltage applied.

For example, if 50% voltage is applied to the motor, a starting torque of approximately 25% of the normal starting torque would be produced. In the previous full voltage example, the NEMA Design B motor had a starting torque of 180% of full load torque. With only 50% voltage applied, this would equate to approximately 45% of full load torque. See Table 6.A for the typical relationship of voltage, current, and torque for a NEMA Design B motor.

Table 6.A Typical Voltage, Current and Torque Characteristics for NEMA Design B Motors

Starting Method	% Voltage at Motor Terminals	Motor Starting Current as a % of:		Line Current as a % of:		Motor Starting Torque as a % of:	
		Locked Rotor Current	Full Load Current	Locked Rotor Current	Full Load Current	Locked Rotor Torque	Full Load Torque
Full Voltage	100	100	600	100	600	100	180
Autotrans.							
80% tap	80	80	480	64	384	64	115
65% tap	65	65	390	42	252	42	76
50% tap	50	50	300	25	150	25	45
Part winding	100	65	390	65	390	50	90
Wye-delta	100	33	198	33	198	33	60
Solid-state	0…100	0…100	0…600	0…100	0…600	0…100	0…180

With the wide range of torque characteristics for the various starting methods, selecting an electromechanical reduced voltage starter becomes more application dependent. In many instances, available torque becomes the factor in the selection processes.

Limiting line current has been a prime reason in the past for using electromechanical reduced voltage starting. Utility current restrictions, as well as in-plant bus capacity, may require motors above a certain horsepower to be started with reduced voltage. Some areas of the world require that any motor above 7-1/2 Hp be started with reduced voltage.

Using reduced voltage motor starting also enables torque control. High inertia loads are a good example of an application in which electromechanical reduced voltage starting has been used to control the acceleration of the motor and load.

Electromechanical reduced voltage starters must make a transition from reduced voltage to full voltage at some point in the starting cycle. At this point, there is normally a line current surge. The amount of surge depends upon the type of transition being used and the speed of the motor at the transition point.

There are two methods of transition: open circuit transition and closed circuit transition. Open circuit transition means that the motor is actually disconnected from the line for a brief period of time when the transition takes place. With closed transition, the motor remains connected to the line during transition. Open circuit transition will produce a higher surge of current because the motor is momentarily disconnected from the line. Examples of open and closed circuit transition currents are shown in Figure 6.3 and Figure 6.4.

Figure 6.3 Open Circuit Transition

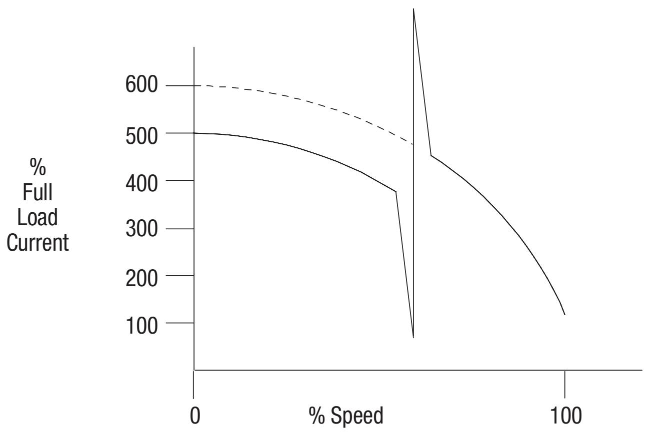
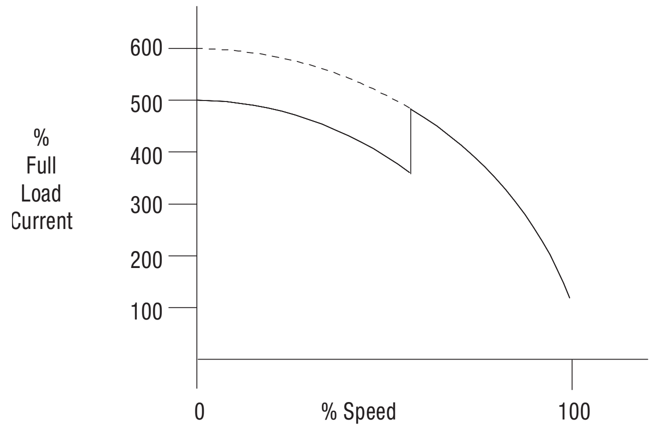


Figure 6.4 Closed Circuit Transition



The motor speed can determine the amount of current surge that occurs at transition. Transfer from reduced voltage to full voltage should occur at as close to full speed as possible. This also minimizes the amount of surge on the line.

The following figures illustrate transition at low motor speed and near full speed. The transition at low speed shows the current surge as transition occurs at 550%, which is greater than the starting current of 400%. The transition near full speed shows that the current surge is 300%, which is below the starting current.

Figure 6.5 Transition at Low Speed

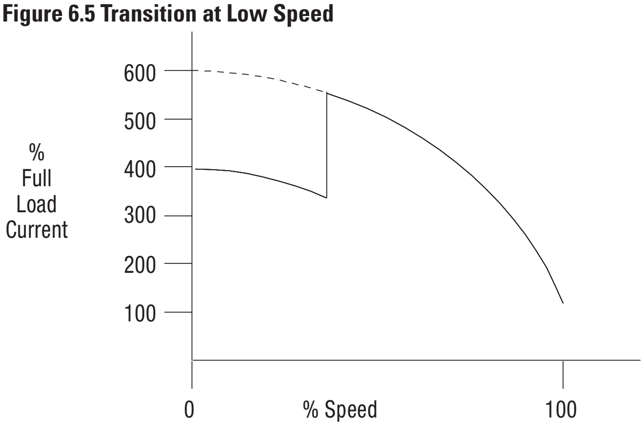
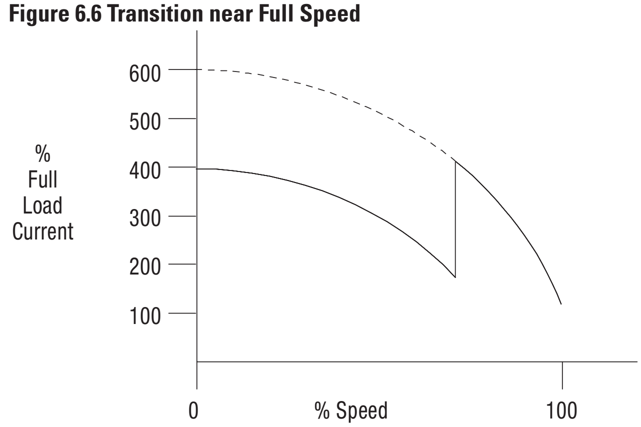


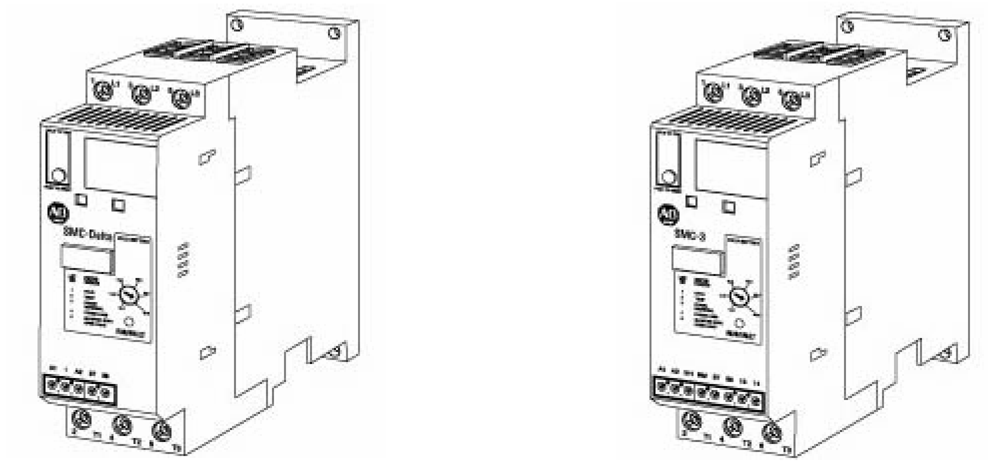
Figure 6.6 Transition near Full Speed



Solid-state

The main function of solid-state controllers is their ability to provide a soft start or stepless reduced voltage start of AC motors. The same principles of current and torque apply to both electromechanical reduced voltage starters and solid-state controllers. Many solid-state controllers offer the choice of four starting modes: soft start, current limit start, dual ramp start, or full voltage start in the same device.

Figure 6.7 SMC-Delta and SMC-3 Controllers

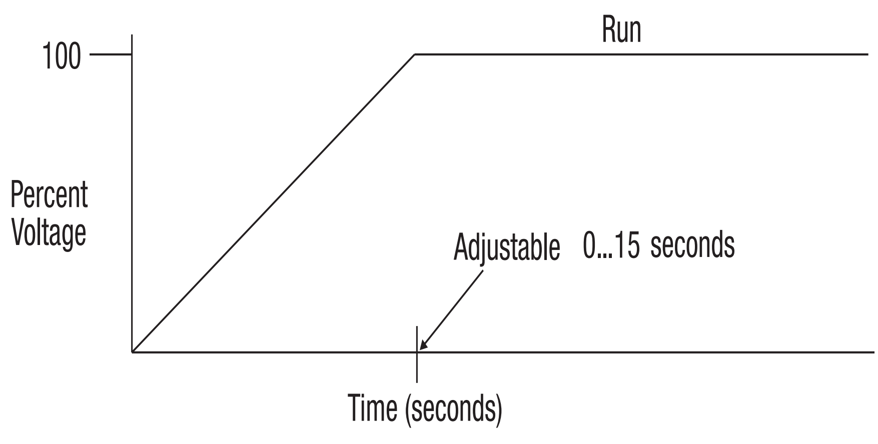


SMC-Delta **SMC-3**

In addition to selecting the starting modes, the solid-state controller allows adjustment of the time for the soft start ramp, or the current limit maximum value, which enables selection of the starting characteristic to meet the application. The most widely used version is the soft start. This method provides a smooth start for most applications.

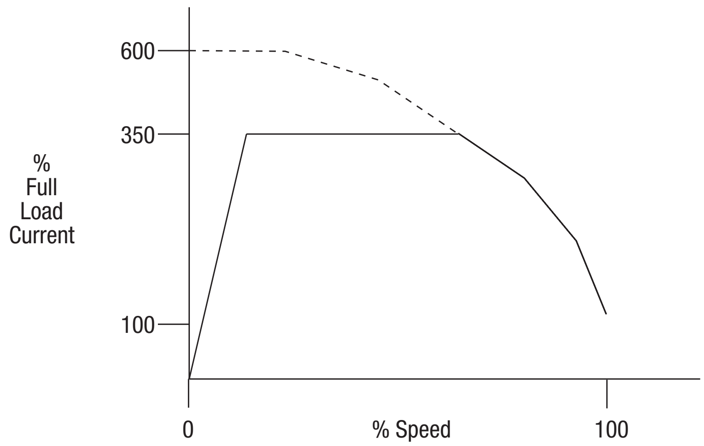
The major advantages of solid-state controllers are the elimination of the current transition point and the capability of adjusting the time to reach full voltage. The result is no large current surge when the solid-state controller is set up and correctly matched to the load, as illustrated in Figure 6.8.

Figure 6.8 Soft Start



Current limit starting can be used in situations in which power line limitations or restrictions require a specific current load. The next illustration shows a 350% current limit curve. Other values may be selected, such as 150%, 250%, or 350%, depending on the particular application. Current limit starting is also used in applications where higher starting torque is required compared to a soft start, which typically starts at less than 300% current. Current limit starting is typically used on high inertia loads, such as ball mills.

Figure 6.9 Current Limit Start



Features available with solid-state controllers include additional protection to the motor and controller, and diagnostics to aid in set-up and troubleshooting. Protection typically provided includes shorted SCR, phase loss, open load, SCR over-temperature, and jammed motor. Appropriate fault messages are displayed to aid in troubleshooting when one of these faults trip out the solid-state reduced voltage controller.

Notes:

Solid-state Starters Using SCRs

Solid-state Starters Using SCRs

In solid-state starters, silicon controlled rectifiers (SCRs - See Figure 7.1) are used to control the voltage output to the motor. A SCR allows current to flow in one direction only. The amount of conduction of a SCR is controlled by the pulses received at the gate of the SCR. When two SCRs are connected back to back (See Figure 7.2), the AC power to a load can be controlled by changing the firing angle of the line voltage (See Figure 7.3) during each half cycle. By changing the angle, it is possible to increase or decrease the voltage and current to the motor. The SMC controllers incorporate a microprocessor to control the firing of the SCRs. Six SCRs are used in the power section to provide full cycle control of the voltage and current. The voltage and current can be slowly and steplessly increased to the motor.

ATTENTION

This chapter uses NEMA design B motors as a basis for the information that it describes.

High efficiency motors with a locked rotor torque between 8…10 and initial surge of 16…24x are more than NEMA Design B motors. Use caution when applying motors other than NEMA design B types.

Figure 7.1 Silicon Controlled Rectifier (SCR)

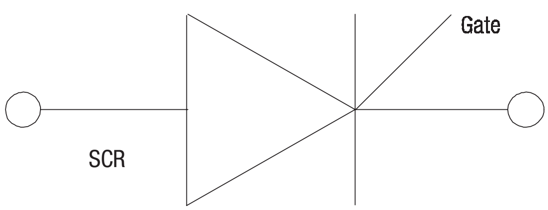


Figure 7.2 Typical Wiring Diagram of SCRs

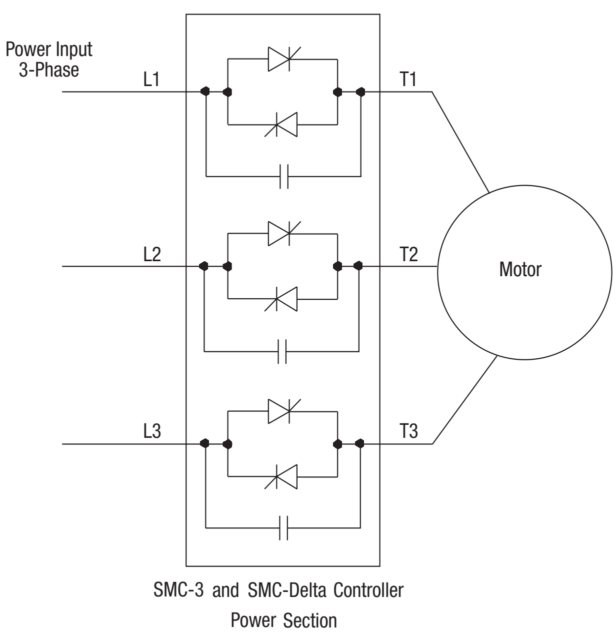
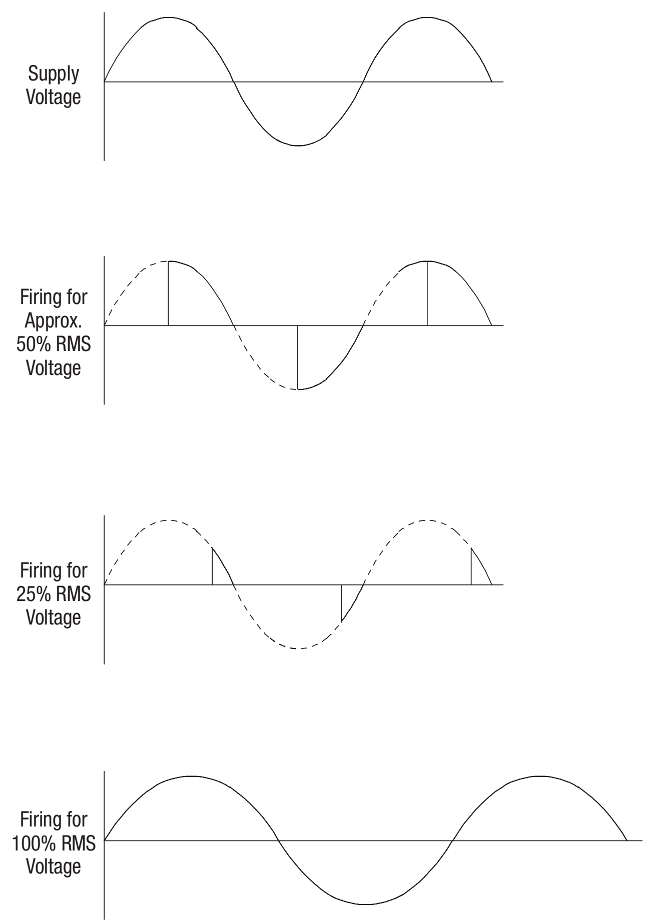


Figure 7.3 Different Firing Angles (Single-phase Simplification)



Notes:

Reference

Introduction

Certain mechanical parameters must be taken into consideration when applying motor controllers. The following section explains these parameters and how to calculate or measure them.

Motor Output Speed/Torque/Horsepower

The speed at which an induction motor operates depends on the input power frequency and the number of poles for which the motor is wound. The higher the frequency, the faster the motor runs. The more poles the motor has, the slower it runs. To determine the synchronous speed of an induction motor, use the following equation:

$$\text{Synchronous Speed} = \frac{60 \times 2 \times \text{Frequency}}{\text{Number of Poles}}$$

Actual full-load speed (the speed at which the motor will operate at nameplate rated load) will be less than synchronous speed. This difference between synchronous speed and full-load speed is called slip. Percent slip is defined as follows:

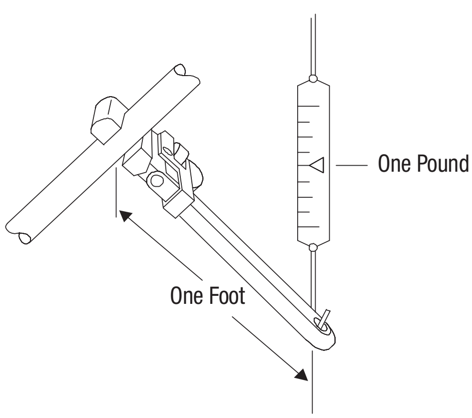
$$\text{Percent Slip} = \frac{\text{Synchronous Speed} - \text{Full Load Speed}}{\text{Synchronous Speed}} \times 100$$

Induction motors are built with slip ranging from less than 5% to as much as 20%. A motor with a slip of less than 5% is called a normal slip motor. Motors with a slip of 5% or more are used for applications requiring high starting torque.

Torque and Horsepower

Torque and horsepower, two important motor characteristics, determine the size of the motor required for a given application. The difference between the two can be explained using a simple illustration of a shaft and wrench.

Figure 8.1 Shaft and Wrench



Torque is merely a turning effort. In the previous illustration, it takes one pound at the end of the one foot wrench to turn the shaft at a steady rate. Therefore, the torque required is one pound × one foot, or one ft-lb. If the wrench were turned twice as fast, the torque required would remain the same, provided it is turned at a steady rate.

Horsepower, on the other hand, takes into account how fast the shaft is turned. Turning the shaft rapidly requires more horsepower than turning it slowly. Thus, horsepower is a measure of the rate at which work is done. By definition, the relationship between torque and horsepower is as follows:

$$1 \text{ horsepower} = 33{,}000 \text{ ft-lbs/min}$$

In the above example, the one pound of force moves a distance of:

$$2 \text{ ft} \times \pi \times 1 \text{ lb} \quad \text{or} \quad 6.68 \text{ ft-lbs}$$

To produce one horsepower, the shaft would have to be turned at a rate of:

$$\frac{1 \text{ Hp} \times 33{,}000 \text{ ft-lbs/min}}{6.28 \text{ ft-lbs/revolution}} = 5{,}250 \text{ rpm}$$

For this relationship, an equation can be derived for determining horsepower output from speed and torque.

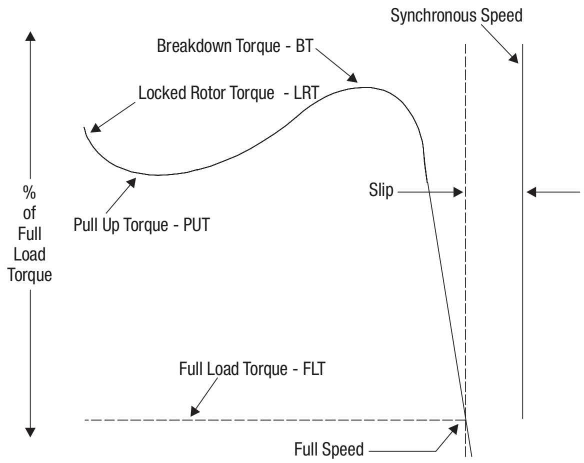
$$\text{Hp} = \frac{\text{rpm} \times 2 \times \text{Torque}}{30{,}000} \quad \text{or} \quad \frac{\text{rpm} \times \text{Torque}}{5{,}250}$$

For this relationship, full-load torque is:

$$\text{Full-load Torque in ft-lbs} = \frac{\text{Hp} \times 5{,}250}{\text{Full-load rpm}}$$

The following graph illustrates a typical speed-torque curve for a NEMA Design B induction motor. An understanding of several points on this curve will aid in properly applying motors.

Figure 8.2 Speed Torque Curve



Locked-Rotor Torque (LRT)

Locked-rotor torque is the torque which the motor will develop at rest for all angular positions of the rotor, with rated voltage at rated frequency applied. It is sometimes known as "starting torque" and is usually measured as a percentage of full-load torque.

Pull-Up Torque (PUT)

Pull-up torque of an induction motor is the minimum torque developed during the period of acceleration from locked rotor to the speed at which breakdown torque occurs. For motors that do not have definite breakdown torque (such as NEMA Design D), pull-up torque is the minimum torque developed, up to rated full-load speed, and is usually expressed as a percentage of full-load torque.

Breakdown Torque (BT)

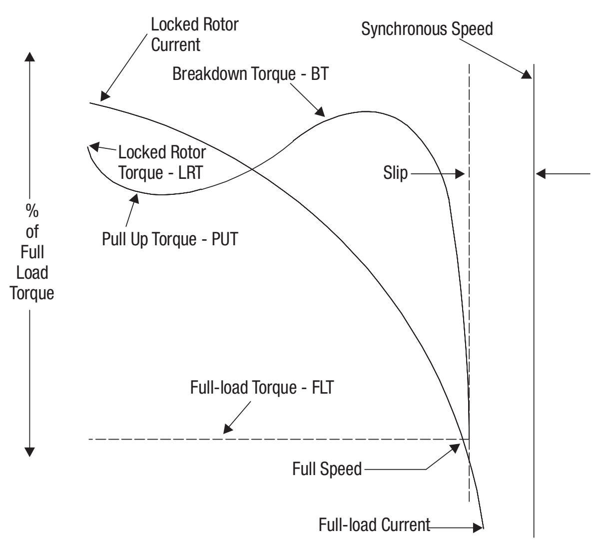
The breakdown torque of an induction motor is the maximum torque the motor will develop with rated voltage applied, at rated frequency, without an abrupt drop in speed. Breakdown torque is usually expressed as a percentage of full-load torque.

Full-load Torque (FLT)

The full-load torque of a motor is the torque necessary to produce its rated horsepower at full-load speed. In foot-lbs, it is equal to the rated horsepower, multiplied by 5250, divided by the full-load speed in rpm.

In addition to the relationship between speed and torque, the relationship of current draw to these two values is an important application consideration. The speed/torque curve is repeated below, with the current curve added, to demonstrate a typical relationship.

Figure 8.3 Speed Torque Curve with Current Curve



Two important points on this current curve require explanation.

Full-load Current

The full-load current of an induction motor is the steady-state current taken from the power line when the motor is operating at full-load torque with rated voltage and rated frequency applied.

Locked-rotor Current

Locked-rotor current is the steady state current of a motor with the rotor locked and with rated voltage applied at rated frequency. NEMA has designed a set of code letters to define locked-rotor: kilovolt-amperes-per-horsepower (kVA/Hp). This code letter appears on the nameplate of all AC squirrel-cage induction motors.

kVA per Horsepower is Calculated as Follows:

For three-phase motors:

$$\text{kVA/Hp} = \frac{1.73 \times \text{Current (in amps)} \times \text{Volts}}{1{,}000 \times \text{Hp}}$$

For single phase motors:

$$\text{kVA/Hp} = \frac{\text{Current (in amps)} \times \text{Volts}}{1{,}000 \times \text{Hp}}$$

Table 8.A NEMA Locked-Rotor Current Code Letters

Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶	Letter Designator	kVA/Hp❶
A	0…3.15	E	4.5…5.0	J	7.1…8.0	N	11.2…12.5	T	18.0…20.0
B	3.15…3.55	F	5.0…5.6	K	8.0…9.0	P	12.5…14.0	U	20.0…22.4
C	3.55…4.0	G	5.6…6.3	L	9.0…10.0	R	14.0…16.0	V	22.4 and up
D	4.0…4.5	H	6.3…7.1	M	10.0…11.2	S	16.0…18.0		

❶ Locked-rotor kVA/Hp range includes the lower figure up to, but not including, the higher figure (i.e., 3.14 is letter "A" and 3.15 is letter "B").

By manipulating the preceding equation for kVA/Hp for three-phase motors, the following equation can be used for calculating locked-rotor current:

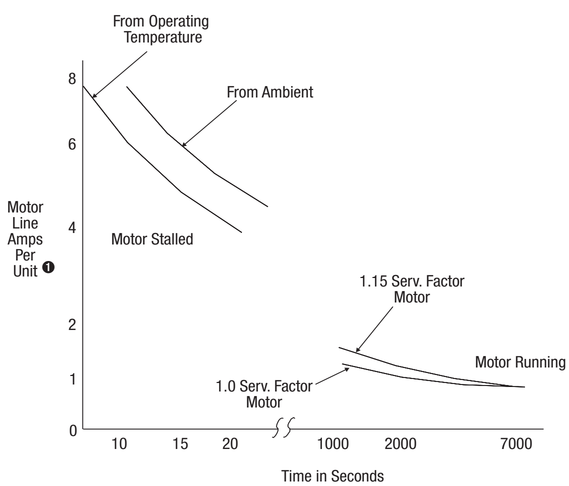
$$\text{LRA} = \frac{1{,}000 \times \text{Hp} \times \text{kVA/Hp}}{1.73 \times \text{Volts}}$$

This equation can then be used to determine the approximate starting current of any particular motor. For instance, the approximate starting current for 7-1/2 Hp, 230 volt motor with a locked-rotor kVA code letter of G would be:

$$\text{LRA} = \frac{1{,}000 \times 7.5 \times 6.0}{1.73 \times 230} = 113\text{ A}$$

Operating a motor in a locked-rotor condition for an extended period of time will result in insulation failure because of the excessive heat generated in the stator. The following graph illustrates the maximum time a motor may be operated at locked-rotor without incurring damage caused by heating. This graph assumes a NEMA Design B motor with Class B temperature rise.

Figure 8.4 Motor Safe Time vs. Line Current - Standard Induction Motors



Motor protection, either inherent or in the motor control, should be selected to limit the stall time of the motor.

❶ Base Amps and Nameplate Amps.

Calculating Torque (Acceleration Torque Required for Rotating Motion)

Some machines must be accelerated to a given speed in a certain period of time. The torque rating of the drive may have to be increased to accomplish this objective. The following equation may be used to calculate the average torque required to accelerate a known inertia (WK2). This torque must be added to all the other torque requirements of the machine when determining the drive and motor's required peak torque output.

$$T = \frac{WK^2 \times (\Delta N)}{308 \times t}$$

Where:
T = Acceleration Torque (ft-lb)
WK^2 = total system inertia (ft-lb^2) that the motor must accelerate.
(This value includes motor armature, reducer, and load.)
ΔN = Change in speed required (rpm)
t = time to accelerate total system load (seconds).

Consult the conversion tables located at the end of this chapter, if required.

The same formula can be used to determine the minimum acceleration time of a given drive, or it can be used to establish whether a drive can accomplish the desired change in speed within the required time period. The transposed formula is:

$$T = \frac{WK^2 \times (\Delta N)}{308 \times t}$$

General Rule:

If the running torque is greater than the accelerating torque, use the running torque as the full-load torque required to determine the motor horsepower.

Calculating Horsepower

The following equations for calculating horsepower are meant to be used for estimating purposes only. These equations do not include any allowance for machine friction, winding or other factors that must be considered when selecting a device for a machine application.

After the machine torque is determined, the required horsepower is calculated using the formula:

$$Hp = \frac{T \times N}{5,250}$$

Where:
Hp = Horsepower
T = Torque (ft-lb)
N = Speed of motor at rated load (rpm)

If the calculated horsepower falls between standard available motor ratings, select the higher available horsepower rating. It is good practice to allow some margin when selecting the motor horsepower.

Inertia

Inertia is a measure of the body's resistance to changes in velocity, whether the body is at rest or moving at a constant velocity. The velocity can be either linear or rotational.

The moment of inertia (WK^2) is the product of the weight (W) of an object and the square of the radius of gyration (K^2). The radius of gyration is a measure of how the mass of the object is distributed about the axis of rotation. Because of this distribution of mass, a small diameter cylindrical part has a much lower inertia than a large diameter part.

Inertia, Continued

$$WK^2 \text{ or } WR^2$$

Where:

WR^2 refers to the inertia of a rotating member that was calculated by assuming the weight of the object was concentrated around its rim at a distance R (radius) from the center (e.g., flywheel).

WK^2 refers to the inertia of a rotating member that was calculated by assuming the weight of the object was concentrated at some smaller radius, K (termed the radius of gyration). To determine the WK^2 of a part, the weight is normally required (e.g., cylinder, pulley, gear).

Torque Formulas

$$T = \frac{Hp \times 5250}{N}$$

Where:
T = Torque (ft-lb)
Hp = Horsepower
N = Speed of motor at rated load (rpm)

$$T = F \times R$$

Where:
T = Torque (ft-lb)
F = Force (lbs)
R = Radius (ft)

$$T\text{ (Accelerating)} = \frac{WK^2 \times (\Delta rpm)}{308 \times t}$$

Where:
T = Torque (ft-lb)
WK^2 = Inertia reflected to the Motor Shaft (ft-lb^2)
Δ rpm = Change in speed
t = Time to accelerate (seconds)

Note: To change ft-lb^2 to in.-lb-s^2: Divide by 2.68 To change in.-lb-s^2 to ft-lb^2: Multiply by 2.68

AC Motor Formulas

$$\text{Sync Speed} = \frac{\text{Freq} \times 120}{\text{Number of Poles}}$$

Where:
Sync Speed = Synchronous Speed (rpm)
Freq = Frequency (Hz)

$$\%\text{ Slip} = \frac{\text{Sync Speed} - \text{FL Speed}}{\text{Sync Speed}} \times 100$$

Where:
FL Speed = Full Load Speed (rpm)
Sync Speed = Synchronous Speed (rpm)

$$\text{Reflected } WK^2 = \frac{(WK^2 \text{ of Load})}{(\text{Reduction Ratio})^2}$$

Where:
WK^2 = Inertia (ft-lb^2)

Torque Characteristics on Common Applications

This chart offers a quick guideline on the torque required to breakaway, start and run many common applications.

Table 8.B Torque Characteristics

Application	Load Torque as Percent of Full Load Drive Torque		
	Break-away	Accel-erating	Peak Run
Agitators:			
Liquid	100	100	100
Slurry	150	100	100
Blowers, centrifugal:			
Valve closed	30	50	40
Valve open	40	110	100
Blowers, positive-displacement, rotary, bypassed	40	40	100
Card machines, textile	100	110	100
Centrifuges (extractors)	40	60	125
Chippers, wood, starting empty	50	40	200
Compressors, axial-vane, loaded	40	100	100
Compressors, reciprocating, start unloaded	100	50	100
Conveyors, belt (loaded)	150	130	100
Conveyors, drag (or apron)	175	150	100
Conveyors, screw (loaded)	175	100	100
Conveyors, shaker-type (vibrating)	150	150	75
Draw presses (flywheel)	50	50	200
Drill presses	25	50	150
Escalators, stairways (starting unloaded)	50	75	100
Fans, centrifugal, ambient:			
Valve closed	25	60	50
Valve open	25	110	100
Fans, centrifugal, hot:			
Valve closed	25	60	100
Valve open	25	200	175
Fans, propeller, axial-flow	40	110	100
Feeders, (belt) loaded	100	120	100
Feeders, distributing, oscillating drive	150	150	100
Feeders, screw, compacting rolls	150	100	100
Feeders, screw, filter-cake	150	100	100
Feeders, screw, dry	175	100	100
Feeders, vibrating, motor-driven	150	150	100
Frames, spinning, textile	50	125	100
Grinders, metal	25	50	100
Ironers, laundry (mangles)	50	50	125

Application	Load Torque as Percent of Full Load Drive Torque		
	Break-away	Accel-erating	Peak Run
Jointers, woodworking	50	125	125
Machines, bottling	150	50	100
Machines, buffing, automatic	50	75	100
Machines, cinder-block, vibrating	150	150	70
Machines, keyseating	25	50	100
Machines, polishing	50	75	100
Mills, flour, grinding	50	75	100
Mills, saw, band	50	75	200
Mixers, chemical	175	75	100
Mixers, concrete	40	50	100
Mixers, dough	175	125	100
Mixers, liquid	100	100	100
Mixers, sand, centrifugal	50	100	100
Mixers, sand, screw	175	100	100
Mixers, slurry	150	125	100
Mixers, solids	175	125	175
Planers, woodworking	50	125	150
Presses, pellet (flywheel)	150	75	150
Presses, punch (flywheel)	150	75	100
Pumps, adjustable-blade, vertical	50	40	125
Pumps, centrifugal, discharge open	40	100	100
Pumps, oil-field, flywheel	150	200	200
Pumps, oil, lubricating	40	150	150
Pumps, oil fuel	40	150	150
Pumps, propeller	40	100	100
Pumps, reciprocating, positive displacement	175	30	175
Pumps, screw-type, primed, discharge open	150	100	100
Pumps, Slurry-handling, discharge open	150	100	100
Pumps, turbine, centrifugal, deep-well	50	100	100
Pumps, vacuum (paper mill service)	60	100	150
Pumps, vacuum (other applications)	40	60	100

Table 8.B Torque Characteristics, Continued

Application	Load Torque as Percent of Full Load Drive Torque		
	Break-away	**Accel-erating**	**Peak Run**
Pumps, vane-type, positive displacement	150	150	175
Rolls, crushing (sugar cane)	30	50	100
Rolls, flaking	30	50	100
Sanders, woodworking, disk or belt	30	50	100
Saws, band, metalworking	30	50	100
Saws, circular, metal, cutoff	25	50	150
Saws, circular, wood, production	50	30	150
Saws, edger (see edgers)			
Saws, gang	60	30	150
Screens, centrifugal (centrifuges)	40	60	125
Screens, vibrating	50	150	70
Separators, air (fan-type)	40	100	100
Shears, flywheel-type	50	50	120
Textile machinery	150	100	90
Walkways, mechanized	50	50	100
Washers, laundry	25	75	100

Notes:

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