Which Motor Starting Method Should You Select?

Starting Solutions: Solid-state Controllers vs. Electromechanical Starters

Rockwell Automation

Allen-Bradley

Win the Productivity Race through Effective Power Product Selection

INDUSTRY OVERVIEW

Introduction

Productivity can be improved in many ways. Purchasing new machines and developing new processes are the most obvious ways to increase your productivity. However, maximum start-up time is one area that can be improved which may be overlooked. The proper method of starting motors can result in reduced downtime and increased productivity.

This publication addresses the selection of electro-mechanical and solid-state methods of starting AC induction motors. After a brief review of the history of starting AC motors and technology, the key issues involving trade-offs of the various starting methods are described.

History

Electromechanical starting has been available since the AC induction motor was invented. Initially the manual starter was more predominant than the electromechanical. The manual starters are still available and are used in specific applications. Today electromechanical starting is preferred either in full voltage or reduced voltage for starting three-phase AC motors.

Solid-state controllers are a relatively new way to start motors. In the early 1970s, solid-state controllers began to replace electromechanical reduced voltage starters. Although solid-state controllers can be used for full voltage starting, the majority of applications use solid-state controllers for soft starting or stepless reduced-voltage starting of AC motors.

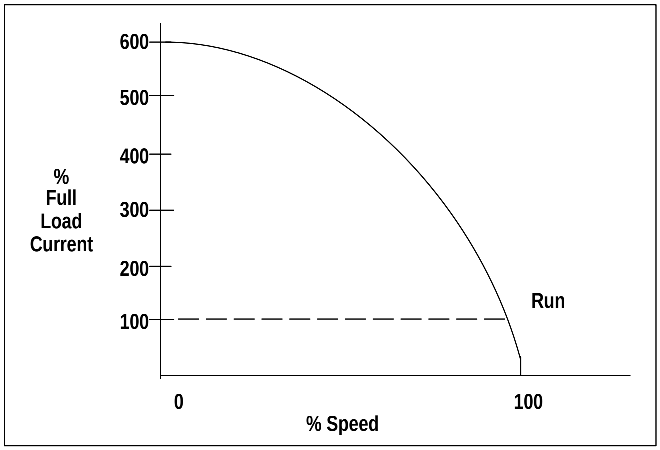
INDUSTRY SOLUTIONS

Full Voltage Starters

Full voltage starting is the most widely used way to start motors. These starters have specific voltage and current ratings and can be used on a wide range of motors. The control input of the full voltage starter is its coil. The user must select a starter with a coil voltage properly that is coordinated with the control voltage available.

When starting a motor, 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 1 on page 2.

Figure 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 has a locked rotor or starting torque that is about 180% of full load torque.

Reduced Voltage Starters

In the United States, the most widely used method of electromechanical reduced voltage starting is the auto-transformer type. Part winding starting is the next most popular method. In the rest of the world, Wye-Delta (Y-Δ), also referred to as Star-Delta, is the predominant form of reduced voltage starting.

All forms of reduced voltage starting affect the motor current and torque characteristics. When 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 reduced by a factor that is approximately the square of the percentage voltage reduction.

For example, if 50% voltage is applied to the motor, a starting torque that is 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. Table 1 shows the typical relationship of voltage, current, and torque for a NEMA Design B motor.

Table 1
Typical Voltage, Current, and Torque Characteristics for NEMA Design B Motors

Starting Method	% Voltage at Motor Terminals	Motor Starting Current as of % of:		Line Current as % of:		Motor Starting Torque as of % of:	
		Locked Rotor Current	Full Load Current	Locked Rotor Current	Full Load Current	Locked Rotor Current	Full Load Current
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	45	81
Star-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 methods, selection of the electromechanical reduced voltage starter is more application-dependent. In many instances, available torque becomes the factor in the selection process.

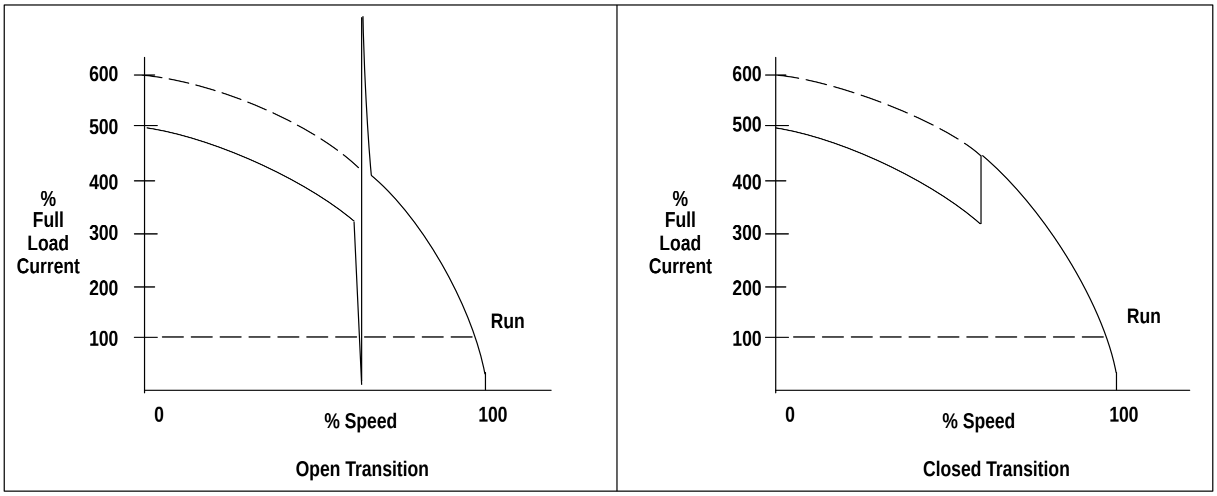
Limiting line current has been the main reason for using electromechanical reduced voltage starting. Utility current restrictions, as well as in-plant bus capacity, may require motors above a certain horsepower to be started with reduced voltage. Some areas of the world require that any motor above 7-1/2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

A second reason for using reduced voltage motor starting is to control torque. For example, electromechanical reduced voltage starting has been used on high inertia loads to control the acceleration of the motor and load.

Electromechanical reduced voltage starters must make the 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 on the type of transition being made and the speed of the motor at the transition point.

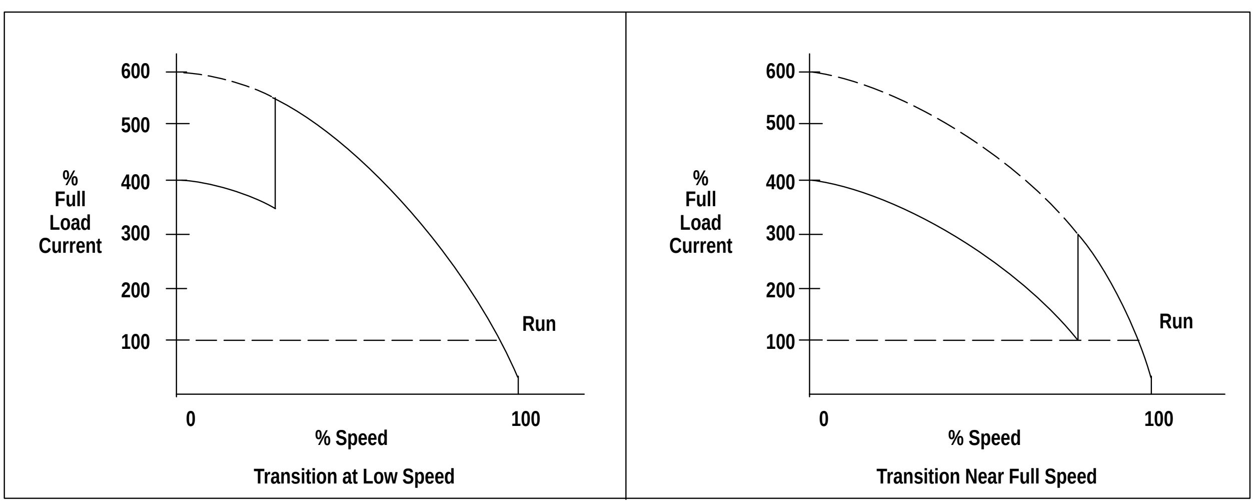
There are two methods of transition, namely, open circuit transition and closed circuit transition. Open transition means that the motor is actually disconnected from the line for a brief period of time while the transition takes place. With closed transition, the motor remains connected to the line during transition. Open transition produces a higher surge of current because the motor is momentarily disconnected from the line. Figure 2 on page 4 shows examples of open and closed transition currents.

Figure 2
Open Circuit Transition vs. Closed Circuit Transition



The motor speed can determine the amount of current surge that occurs at transition. Transition from reduced voltage to full voltage should occur as close as possible to full speed. This helps minimize the amount of surge on the line. Figure 3 illustrates transition both at low motor speed and at 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 3
Transition at Low Speed vs. Transition Near Full Speed



Solid-state Controllers

Solid-state controllers are mainly used to provide soft start or stepless reduced voltage starting of AC motors. The same principles of current and torque apply to both electromechanical reduced voltage starters and solid-state controllers. Solid-state controllers offer the choice of three starting modes in the same device: soft start, current limit, and full voltage.

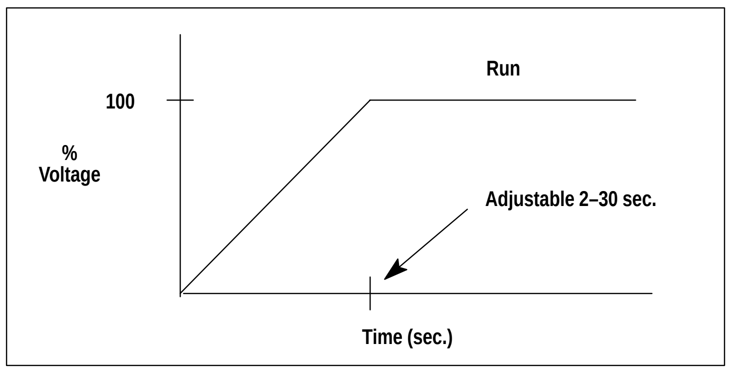
Not only can you select the mode of the solid-state controller, you can also adjust:

- the soft-start ramp time
- the current limit maximum value

The most widely used mode is the soft start. This method provides a smooth start for most applications.

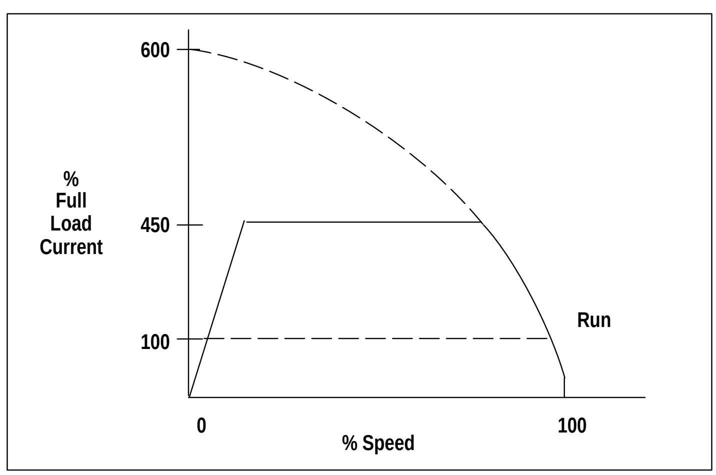
Solid-state controllers eliminate the current transition point, and the time to full voltage can be adjusted usually from two to 30 seconds. The result is no large current surge when the solid-state controller is set up and correctly matched to the load as illustrated in Figure 4.

Figure 4
Soft Start



Current limit can be used where power line limitations or restrictions require a specific current load. Figure 5 shows a 450% current limit curve, though other values can be easily selected. Current limit is also used where higher starting torque is required compared to soft start which typically starts at less than 300% current. An example where current limit is used is on high inertia loads such as ball mills.

Figure 5
Current Limit Acceleration



Solid-state controllers control the voltage applied to the motor — even when the motor is up to speed — because of semiconductors used in the power circuit. This allows solid-state reduced voltage to provide energy savings for motors that run unloaded or lightly loaded for long periods of time. Intelligence within the solid-state controller determines when the motor is lightly loaded. The voltage to the motor can then be reduced by properly controlling the semiconductors until the motor is operating at an optimum point. This same intelligence detects when a load is reapplied and increases the voltage to prevent stalling.

Other available features of 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 line
- SCR overtemperature
- stalled motor

Appropriate LEDs illuminate to aid in troubleshooting when one of these faults trip the solid-state reduced voltage controller.

KEY ISSUES

Address these issues when making decisions about whether to use full voltage starters, electromechanical reduced voltage starters, or solid-state controllers. An educated choice must be made in order to provide a solution that both meets the application requirements and maximizes productivity.

- Can belts, gears, or chains be damaged by across-the-line starting?
- Can the material in process be damaged by sudden starts?
- Can a step change in torque damage the installation?
- What is the minimum torque required to start the load?
- Can higher technology products provide additional benefits?
- Are complicated adjustments required, or can set-up be accomplished with simple settings?
- What diagnostics are available to assist in setup?
- Are there any utility company line current restrictions?
- Are there any in-plant bus current limits?
- What are the cost trade-offs involved when comparing higher starter cost to reduced maintenance or damaged installation?

CORRECT SOLUTIONS

Proper Selection

In terms of solutions there are three major methods of starting AC motors available:

- Full Voltage
- Electromechanical Reduced Voltage
  - Autotransformer
  - Part Winding
  - Wye-Delta
- Solid-state Controller

Proper selection of a starting method is critical to achieving maximum productivity on any motor control application. Consider the installation of each method when matching the requirements of your specific application Table 2 on the following page is a selection guide of the different starting methods to help you select the appropriate product.

Table 2
Motor Starting Selection Guide

	Full Voltage	Autotransformer	Part Winding	Wye-Delta	Solid-state Controllers
Smooth Start	Full Torque	Discrete Steps	Discrete Steps	Discrete Steps	Stepless
Starting Torque Control	None	Limited (1 step)	Limited (1 step)	Limited (1 step)	Stepless Transition
Typical Starting Torque Characteristics (% of Full Load Torque)	180	Choice of 115, 76, 45	81	60	0–180
Limit Starting Current	None	Three Settings	Single Setting	Single Setting	Wide Range
Typical Starting Current (% of Full Load Current)	600	Choice of 480, 390, 300	390	198	0–600
Starting Mode					
Full Voltage	X				X
Reduced Voltage		X	X	X	
Soft Start					X
Current Limit					X
LED Diagnostics	None	None	None	None	Yes
Technology	Electromechanical	Electromechanical	Electromechanical	Electromechanical	Solid-state
Shock and Vibration	Electromechanical Standards	Electromechanical Standards	Electromechanical Standards	Electromechanical Standards	Electromechanical Standards
Energy Saver Function	None	None	None	None	None

Note: The features listed in this guide are available in some products but are not necessarily available in every product.

ALLEN-BRADLEY'S CAPABILITIES

Allen-Bradley has over 85 years of motor control experience. We can effectively assist you in determining the best way to maximize your productivity.

Allen-Bradley has a full complement of power products available. These include the Bulletin 500 line of full voltage motor starters in NEMA sizes 00 through 9. The Bulletin 530 part winding starter is available in NEMA in sizes 1PW through 8PW; the Bulletin 540 Wye-Delta starter NEMA in sizes 1YD through 8YD; and the Bulletin 570 Autotransformer reduced voltage starter in NEMA Sizes 2 through 9. To complete the family of products, Allen-Bradley offers solid-state controllers from 1 to 6,000 horsepower. The most innovative product is the Bulletin 150 Smart Motor Controller (SMC™) with high technology features that include a built-in microcomputer, surface mounted circuit design, self-calibration, three starting modes, and rugged modular packaging.

Allen-Bradley does not have only one solution to meet your needs, we have the *right* solution. With a broad offering of power device products and application services, be assured that Allen-Bradley can effectively address the productivity issues most important to you.

Rockwell Automation

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Allen-Bradley, a Rockwell automation business, has been helping its customers improve productivity and quality for more than 90 years. We design, manufacture and support a broad range of automation products worldwide. They include logic processors, power and motion control devices, operator interfaces, sensors and a variety of software. Rockwell is one of the world's leading technology companies.

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