Data Bulletin

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Altistart® 48 Soft Start
With Torque Control System (TCS)

INTRODUCTION

Soft starting an AC motor refers to any one of several starting methods that limit the starting current and torque of the motor. The method discussed in this paper is limited to reduced-voltage starters, and is referred to as soft starting. Most soft starters use voltage control to limit the motor-starting current and torque by continuously ramping the applied motor voltage when starting and stopping. Other reduced-voltage starting techniques cause a step change in the applied motor voltage, using electromechanical contactor switching.

Soft starters incorporate microprocessor-based designs and sophisticated algorithms to control motor voltage, current, and torque output. The latest technological improvements offer better motor torque performance, keypad programming capabilities, serial communication, and reduced physical size. This paper discusses previous and new technologies associated with soft starters, limited to the following topics:

- Benefits of soft starters
- Previous technology of soft starters
- New technology in soft starters with torque control
- Advantages of torque control

BENEFITS OF SOFT STARTERS

Soft starters are ideal for meeting utility restrictions for limiting the inrush current while starting high-horsepower motors. Soft starters also provide a multitude of benefits for process and machine applications, due to their smooth output voltage ramp, torque limiting, and overriding adjustable current limit feature. These features enable improved processes and reduced machine maintenance. Typical motor loads that are good candidates for use with soft starters include centrifugal pumps, fans, batch centrifuges, unloaded rock crushers, unloaded compressors, and lightly-loaded conveyors.

The benefits of using soft starters on these types of motor loads are:

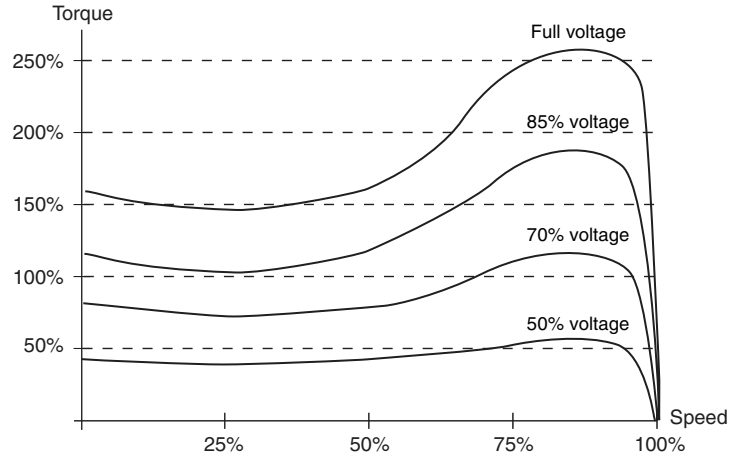
- Minimized voltage sags on the distribution system when starting
- Minimized nuisance circuit breaker tripping or fuse blowing when starting
- Lowered peak demand charges from the utility
- Alleviation of water hammer on pumping applications
- Elimination of belt slippage on fan loads
- Reduction of mechanical stress on drive-train components
- Smooth acceleration of conveyors

A complete motor-protection scheme is an integral part of most soft starters, while many electromechanical, reduced-voltage starters require additional devices to provide the same protection. Specifying and applying soft starters is easier for many motor applications.

PREVIOUS TECHNOLOGY OF SOFT STARTERS

Until now, soft starter designs controlled motor voltage with an overriding current limit during starting, which produced a varying motor torque output during acceleration. The motor torque was strictly a function of the applied motor voltage controlled by a timed, linear acceleration ramp. This resulted in an infinite number of families of speed torque curves, a sample of which is shown in Figure 1. For a given load point, the available torque to accelerate the load changed with both the applied voltage and motor speed.

Figure 1: Sample Reduced Voltage Speed Torque Profile



This type of voltage control soft-starts the motor; but the motor torque does not increase linearly, due to the speed/torque characteristics of a squirrel cage induction motor with fixed frequency and reduced voltage applied. The torque developed by an AC squirrel cage induction motor is reduced by the square of the voltage reduction.

$$T_{rv} = T_{fv} \times (V_{rv} / V_{fv})^2$$

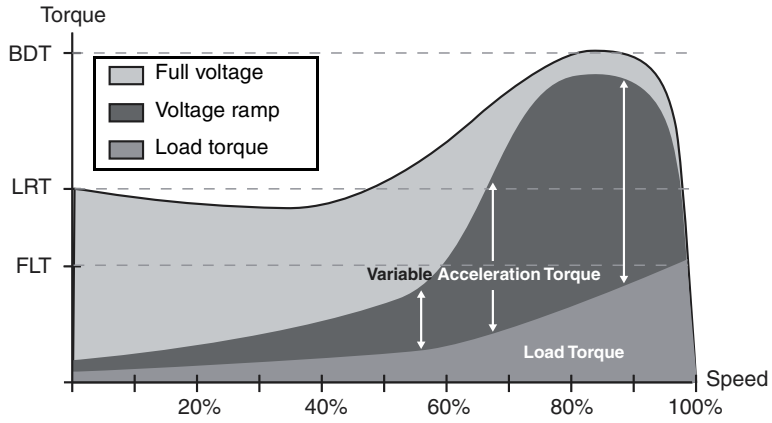
T_{rv} = torque @ reduced voltage
T_{fv} = torque @ full voltage
V_{rv} = voltage @ reduced voltage
V_{fv} = voltage @ full voltage

Example: A NEMA B motor typically produces 150% of its full-load torque when started across the line (full voltage). If it is started at 70% of its full-voltage rating, then it only develops $(0.70)^2$, or 49%, of its normal starting torque; or approximately 74% of its full-load torque.

The disadvantage of this type of starting is that the acceleration torque produced by the motor is not constant. (The acceleration torque is the difference between the torque produced by the motor and the torque required by the load to keep moving at a constant speed or load torque.) Using previous-technology soft starters, the acceleration torque is lowest at the beginning and greatest at approximately 85–90% of motor speed,

resulting in an acceleration rate that starts slow and finishes fast (see Figure 2).

Figure 2: Previous-Technology Soft Starters



The deceleration ramp is also a timed, linear voltage ramp from full voltage to zero volts. There is no actual control of the deceleration of the motor load, since the synchronous speed of the motor does not change. The decrease in speed is due to the interaction between the increase in motor slip versus the motor load. This makes it impractical to control the deceleration of a constant torque load; however, it is possible to decelerate variable torque loads.

For variable torque-loaded motors where the load is only 60–80% of the motor full-load torque, there is very little decrease in speed at the beginning of the deceleration ramp. Once 30–50% of the timed ramp expires, the motor is voltage starved enough that the load torque and motor slip result in a 10–15% speed change. After that point, the motor torque falls very rapidly, resulting in abrupt motor deceleration. Decelerating a centrifugal pump load in this manner causes problems when it is necessary to coordinate the motor shaft deceleration rate with a check valve closing. The abrupt speed change often results in the check valve slamming shut, creating water hammer.

NEW TECHNOLOGY IN SOFT STARTERS WITH TORQUE CONTROL

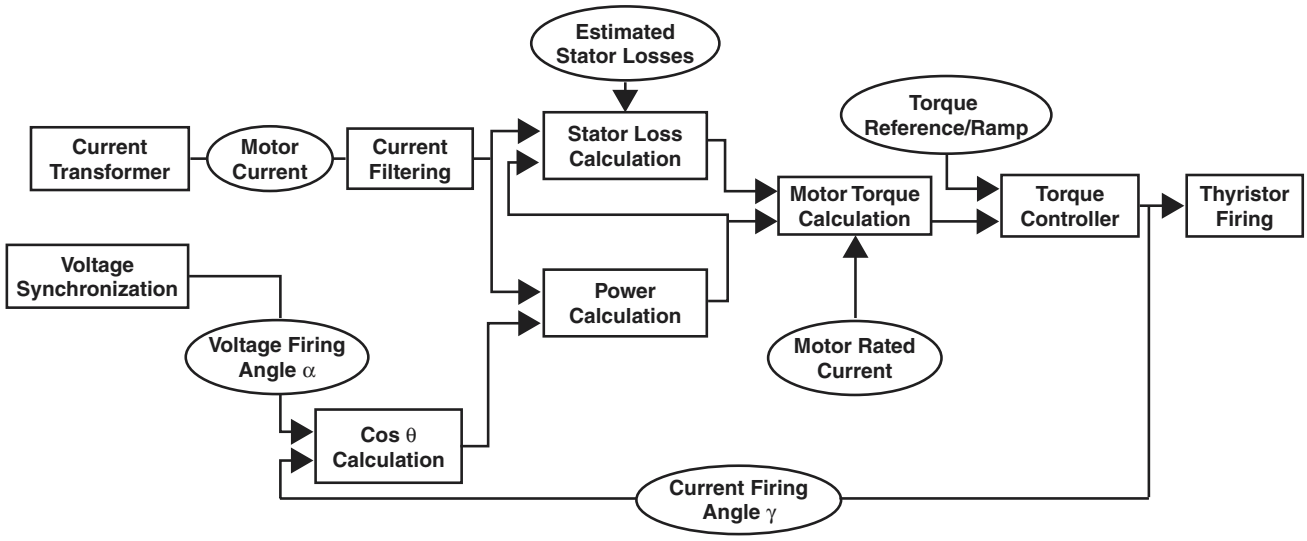
Schneider Electric's Altistart 48 Soft Start (ATS48) offers keypad display/programming, serial communication, and an exclusive torque control system (TCS). Previous-generation soft starters required an external tachometer feedback signal to maintain constant acceleration torque; but the new technology of the Altistart 48 product line integrates torque control into the soft starter. The logic-based torque control system relies on a proprietary control algorithm to maintain constant accelerating and decelerating torque. The algorithm uses information about motor voltage and current to determine the power and power factor. From this, the soft starter derives real stator power, stator losses, and as a result, real power delivered to the rotor. Power to the rotor is used to calculate actual motor torque.

If torque control is enabled, the acceleration and deceleration ramps of the ATS48 starter are no longer based strictly upon time and motor voltage levels, but follow the torque ramp as long as the motor load does not exceed the current limit setting.

A functional block diagram of the ATS48 torque control system is shown in Figure 3 on page 4. The "torque reference/ramp" block represents the motor

nominal torque, initial torque, and torque limit values entered using the keypad. The torque controller uses these torque values, along with the entered torque ramp time, to generate a desired motor torque. The torque controller is then used to control the thyristor firing, according to the actual motor torque versus the desired value. The motor torque is no longer strictly dependent on an applied motor voltage or the speed-torque characteristics of the motor, but is increased according to a timed ramp. Initial torque, torque limit, and acceleration time values are all user-adjustable for maximum flexibility and adaptability to varying loads.

Figure 3: Functional Block Diagram of Torque Control



ADVANTAGES OF TORQUE CONTROL

The ATS48 torque control system provides many application advantages, such as:

- Development of only the torque needed to accelerate the load
- Constant acceleration rate, independent of motor load
- Configurable torque ramp that provides constant acceleration torque for either variable- or constant-torque loads
- Motor torque set and displayed with the keypad to coordinate with the application
- Linear torque control of acceleration and deceleration ramps for variable torque loads (such as pumps and fans)
- Deceleration ramp starting at the motor load torque point, to maximize the linear deceleration ramp for all pump loads
- No external, motor-speed feedback device required

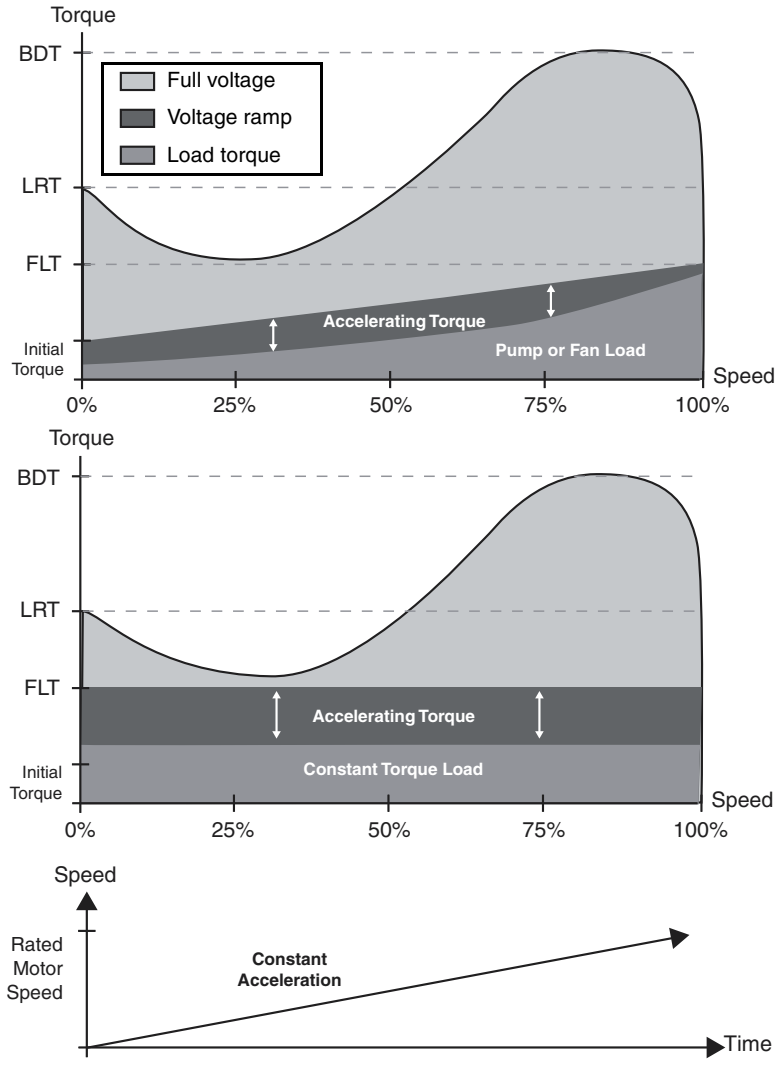
The Altistart 48 soft starter, with its torque control system (TCS), is microprocessor-based, making it very versatile. The starter can vary the thyristor-switching pattern to accommodate several different acceleration and deceleration ramp types, as demanded by a variety of applications. It can be configured to provide constant acceleration torque for either constant- or variable-torque loads. This allows a linear acceleration ramp for smooth, constant acceleration from zero to full speed (see Figure 4).

The constant acceleration torque makes it easier to determine the application requirements for higher inertial loads, such as punch presses, centrifuges, band saws, crushers, and compressors. Previous-technology

soft starters required point-by-point comparisons of the load curve to the motor curves. The constant acceleration torque also ensures a smooth, steady acceleration of conveyors, reducing the possibility of material spillage or breakage during acceleration.

Variable-torque loads, like centrifugal pumps, require acceleration torque that increases with speed, based on the affinity laws. The Altistart 48 soft starter may be configured to increase the motor torque linearly over time, starting from a user-selectable, initial motor torque-percentage value, to full-load motor torque. This configuration provides a linear acceleration ramp for centrifugal pumps and fans. A linear acceleration ramp helps coordinate check-valve opening with the motor/pump acceleration, eliminating water hammer. It also eliminates belt slippage on fan loads, reducing machine wear and maintenance.

Figure 4: Altistart 48 Soft Start with TCS



The Altistart 48 soft starter also provides a linearly-decreasing torque ramp for deceleration of centrifugal pump loads. A gradual reduction in speed makes it possible to coordinate check-valve closing without causing water hammer. The soft starter continuously monitors the motor load torque, and when a stop command is given, it starts the deceleration ramp at that load-

torque point. This monitoring allows for a linear deceleration ramp on pump loads, even when the motor is only 60–70% loaded. Previous-generation soft starters did not always perform satisfactorily in decelerating this type of load, which was often illustrated by noisy water hammer. The Altistart 48, however, prevents water hammer when the pump stops.

SUMMARY

The Altistart 48 soft starter, with its unique torque control system, offers AC induction motor-starting performance that is unmatched by other reduced-voltage methods available. This superior performance is provided by technological design improvements, with no added cost to the end user. The major power components of the Altistart 48 soft starter are no different than those used by previous-technology soft starters. The difference is how the control algorithms are implemented to control torque during acceleration and deceleration. The Altistart 48 soft starter offers more flexibility to adapt to the user's specific application needs.

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