SMC-50 Offers New Control Advances, Including Sensorless Linear Acceleration

Rockwell Automation

Given increasing costs and environmental awareness, energy conservation is a growing concern, and the need for energy efficiency throughout a plant or manufacturing floor is a priority. According to the US Department of Energy, motors consume 64% of domestic manufacturers total electricity. Motors that run pumps and fans comprise greater than half of the load. Worldwide, pumps account for 20 % of the total electrical demand. More and more attention is paid to starting methods of motors as a cost savings to the bottom line by controlling the demand charges imposed by the local electric utility company. These savings can be seen by the reduction of wasted energy from using just enough energy to start motors.

Some of the options for starting a motor include using contactors, variable frequency drives (VFDs), or soft starters such as the SMC (Smart Motor Controller), Rockwell Automations family of soft starters (SMC-Dialog, SMC-Flex and SMC-3). There are options for using contactors for starting, which are either on or off, such as a wye-delta start, multi-speed starters, autotransformer starters, and other similar starters. Direct On Line (DOL) starting can be done simply with a contactor and an overload relay. A VFD used to be the primary solution for torque control or linear speed applications; a VFD uses voltage and frequency to control starting, running, and stopping a motor.

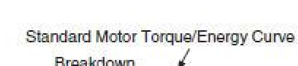
The SMC family of Rockwell Automation soft starters performs multiple start functions, such as soft start, current limit, pump control, slow speed, and full-voltage starting. For stopping, the SMC is able to perform pump stop, smart motor braking, and soft stop. Slow speed is possible in one of two selected speeds. All of this is performed with an integrated bypass contactor as standard, using an SMC-3 or SMC-Flex, reducing the need for over sizing the starter due to the silicon-controlled rectifier (SCR) used for starting and stopping the motor. Once up to speed, the bypass carries the load.

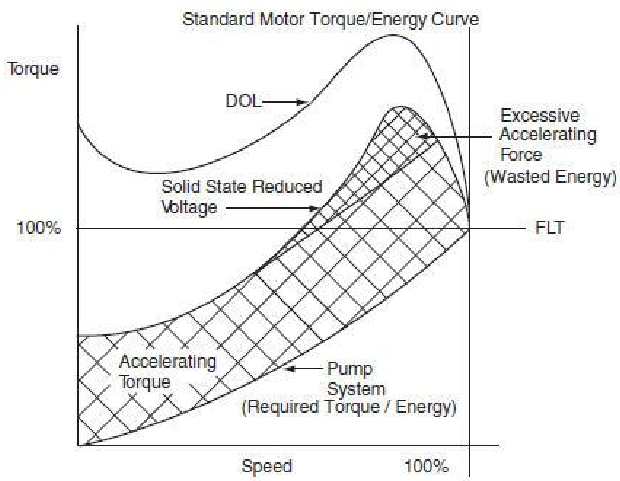
While the SMC-Flex and SMC-3 are suitable for most applications, the need for true torque and speed control starting of centrifugal pumps and high-inertia loads has led to the development of a new soft start technology by Rockwell Automation. The new functionality of linear speed and torque control can be found in the new SMC-50 fully solid-state SMC.

All of the key features of the SMC-Flex, SMC-Dialog, and the SMC-3 are now incorporated in a completely solid-state device (no integral bypass), plus expandable options for control. Which means one SMC, can now perform most of the starting functions for a given motor, whether linear acceleration is needed, or just a soft start. This gives the customer the ability to start and control a wide range of load types all with one controller.

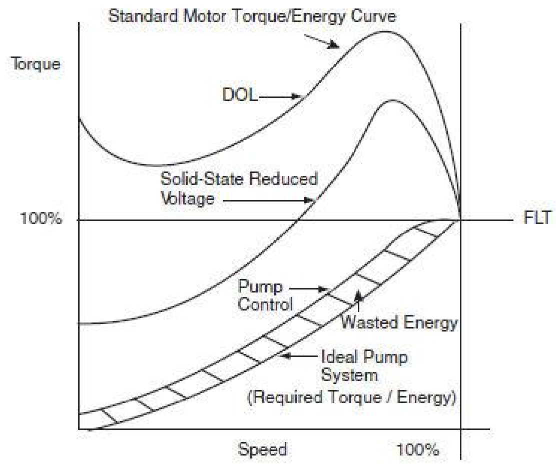
Energy effectiveness with appropriate starting method.

When starting a typical NEMA Design B motor, the energy used can be viewed using these common, torque/speed curves of a pump system using a DOL, Soft Start, Pump Control and Torque Control method. Acceleration torque is the difference between applied torque and the load. The goal is to have the smallest acceleration torque to achieve the most efficient start.

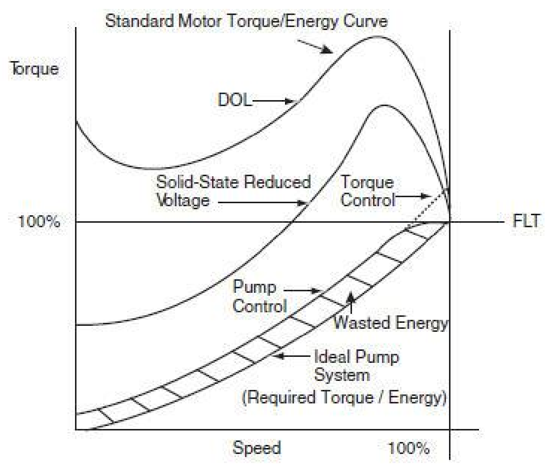




Soft Start reduces the overall energy required to start the load although some excess torque remains.



Using the Pump Control option of the SMC-50 will provide even more control, which provides an even larger reduction in energy usage at startup.



The enhanced Torque Control algorithm provides even tighter control, providing just enough control for a smooth start.

The SMC-50 performs the same as the SMC-Flex in soft start and pump control starting modes. The change in flow in a pump application using pump control allows smoother starts and stops, thereby reducing water hammer. With the SMC-50, there are also options for torque control and linear speed control to provide even greater control in pumping and other applications, thereby reducing energy usage even more. For more information on the SMC-Flex controller with pump control, please see the white paper SMC-Flex Controller with Pump Control , publication 150-WP003.

By selecting the proper starting method, you will be able to reduce the amount of energy consumed, saving money. Matching the start/stop profile to the load enables the greatest savings.

What does the SMC-50 offer and how can it assist with energy and starting options?

Less Energy Consumption: When it comes to starting lightly loaded motors, typical DOL starters use more energy than needed in the start process. With the SMC-50, the linear and torque control allows the starting process to use just enough energy to get the process accomplished.

Energy Savings: In addition to selecting the proper starting method using the SMC-50, Rockwell Automation has also implemented an energy saver parameter that allows the SMC-50 to use less energy during the running operation of lightly loaded motors. With the motor power factor level entered in the Energy Saver parameter, the SMC-50 will monitor the motor load with its internal feedback circuitry. Because SCRs control the output voltage, motor power losses may be reduced by decreasing the motor terminal voltage. The percentage of energy savings can also be monitored or viewed via a metering parameter.

Metering System: The SMC-50 provides a complete set of metering features, allowing the customer to better monitor the performance of the application. This provides the opportunity to make process adjustments to improve performance and energy efficiency.

Current The RMS current value is provided for each phase, plus the average current of all three.

Voltage The RMS line-to-line and line-to-neutral voltage values are provided while the motor is running and when stopped. The average of all three is also provided.

Line Frequency Measures and provides user access to the line frequency (Hz).

Power Real, reactive, and apparent power values are calculated for each phase plus the total for all three phases. In addition, the current power demand and the maximum power demand is provided.

Power Factor The value of the power factor is provided for each phase and as a total of all three.

Peak Starting Current The SMC-50 stores the peak average RMS motor current consumed for the last five start cycles.

Total Harmonic Distortion (THD) The SMC-50 calculates and provides user access to the THD for the three line voltages and three motor currents, along with the average value of each.

Voltage Unbalance The calculation of the voltage unbalance signal is provided.

Current Imbalance The calculation of the current imbalance signal is provided.

Energy Savings The SMC-50 provides the percentage of energy saved when it is running the motor in the Energy Savings mode.

Motor Torque Electromechanical motor torque is calculated based on current and voltage feedback from the motor.

Motor Speed The SMC-50 provides a calculated estimate of motor speed in percent of full speed when operating in the linear speed acceleration starting or deceleration stopping mode.

Elapsed Time & Elapsed Time 2 An elapsed time meter is provided to account for the total accumulated hours the motor has been running. The meter can be reset by the user. Elapsed Time 2 cannot be user reset and will hold after 50,000 hours have elapsed.

Running Time The running time meter accumulates time (in hours) from the point the motor start command is given up to the point when the motor stop command is issued. When a new start command is given, the meter resets to zero and begins accumulating time again.

Actual Start Time The unit stores the actual time it takes to complete a start cycle (motor start command issued until motor is up-to speed). The last five start times are stored as parameters for user access and in the Alarm Buffer as events.

Total Starts The total starts counter increments on every successful start (no prestart fault occurred) and cannot be reset. The maximum value is 30,000.

SMC-50 starting methods

Linear Speed

Linear Speed is used for easy starting and stopping using a linear ramp. Regardless of the load type, this starting method will start the motor in the given time, without using an external tachometer. Typical parameters that need to be adjusted are: changing the start mode from the default Soft Start to Linear Speed, and setting the ramp time if a time other than the default 10 seconds is needed.

Once up to speed, the motor is at full voltage, and the linear speed control is no longer in effect until a stop command with linear speed is selected. The proprietary algorithm allows the controller to utilize just enough energy for starting and stopping, regardless of the load size. You will not need a dual ramp mode to do a linear start when the load changes. What this means is that you do not have to change your settings on the SMC-50 to accommodate different percentage of loads. The algorithm does all the work, making linear speed the easiest starting method on the SMC-50.

For applications that may need to control the level of current, a current limit feature is provided for linear speed starts and stops. If the current limit is reached, the SMC-50 will drop out of linear speed control until the current falls below the current limit setting.

Torque Ramp

Torque Ramp offers true torque control using a proprietary algorithm. The ramp goes from an initial starting torque to a maximum torque level. By default, the starting torque is set to 100% and the maximum torque is set to 250%. As with Linear Speed, the ramp time is also adjustable from the default 10 seconds. However, unlike linear speed, the time of the ramp may vary depending on the load.

To assist with the torque ramp, the controller uses an automatic tuning process that measures motor parameters such as resistance and inductance. This tuning process also detects the motor connection (line or delta).

Having adjustability of the initial and maximum torque of a defined ramp time, provides the user precise control when starting the motor. Compared to the Soft Start mode which uses a voltage ramp, torque control is much more linear and potentially will result in less stress on the mechanics of the system and provide the proper torque to start the motor. Constant acceleration torque is provided for both constant and variable torque loads.

Full Voltage

This starting method essentially uses the SMC-50 as a solid-state contactor, perhaps for high duty cycles. Full current and full voltage is utilized at the start. A customer may choose to do this as a troubleshooting aid, or to utilize the diagnostics of the SMC-50 versus a traditional electromechanical starter.

Current Limit

By limiting the current, the SMC-50 can assist meeting utility demand requirements, limit line disturbances and meet internal plant distribution limitations. Keep in mind, limiting the current also limits the amount of torque to the motor when starting. Current Limit Start can be used in conjunction with Soft Start, Torque Control and Linear Speed.

Soft Start

Soft Start ramps up the voltage linearly to start the motor. Starting torque is proportional to the square of the applied voltage.

$$\textbf{\% Torque} \propto \textbf{\% Voltage}^2$$

Given the above equation, a 60% reduction in the applied voltage will result in approximately an 84% reduction in generated torque. In this example, 40 % voltage is used. $(0.4)^2 = 0.16$ or 16% of Locked Rotor Torque will be present. The current during the start is directly related to the voltage applied to the motor.

$$\frac{Voltage\ (applied)}{Line\ Voltage} = \frac{Current\ (drawn)}{Current\ (maximum)}$$

Pump Control

Unlike actual torque control found with the Torque Ramp option, Pump Control starts a pump by utilizing a proprietary algorithm that controls the accelerating/decelerating torque of the pump motor. This reduces the surges created in a fluid piping system, reducing both water hammer and pump cavitation.

Slow Speed Control

The SMC-50 has an enhanced option for speed control of ±15 % of zero speed. Some soft starters in the market can only provide fixed slow speeds, typically one or two settings. Having the ability to select the precise speed is very useful. Positioning material on a conveyor would be a great example of a use of this function. The new SMC-50 will give you more control of your system, when the system needs it. Note: entering a negative value will cause the motor to turn in the opposite direction.

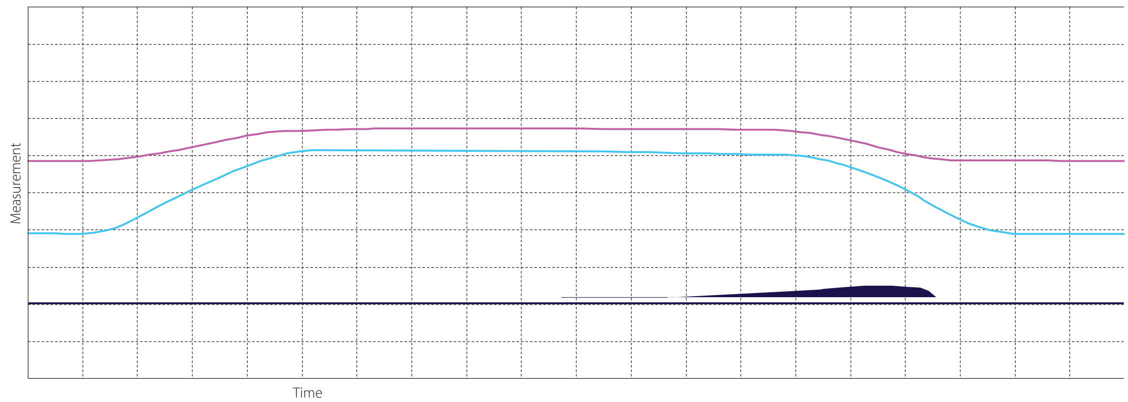
Scope plot comparisons

Following are starting comparisons of linear speed, torque start, pump start and soft start.

Load: Centrifugal Pump
% Load: 65%
Initial torque: 0
Ramp Time: 10 s

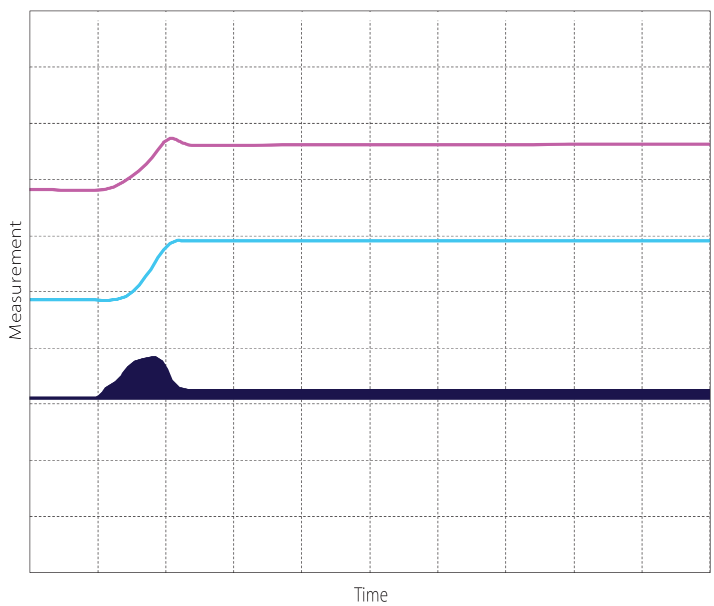
The pump load was chosen as one of the more dynamic starting characteristics. Valve type, placement of the valves, length of piping runs, direction of runs, etc., will determine the specific starting characteristics for a given pump motor. One of the benefits of the SMC-50 is that you can use any starting method with the same unit without having to purchase a different control module.

Figure 1 - Linear Speed Start and Stop Mode; Load Type = Pump



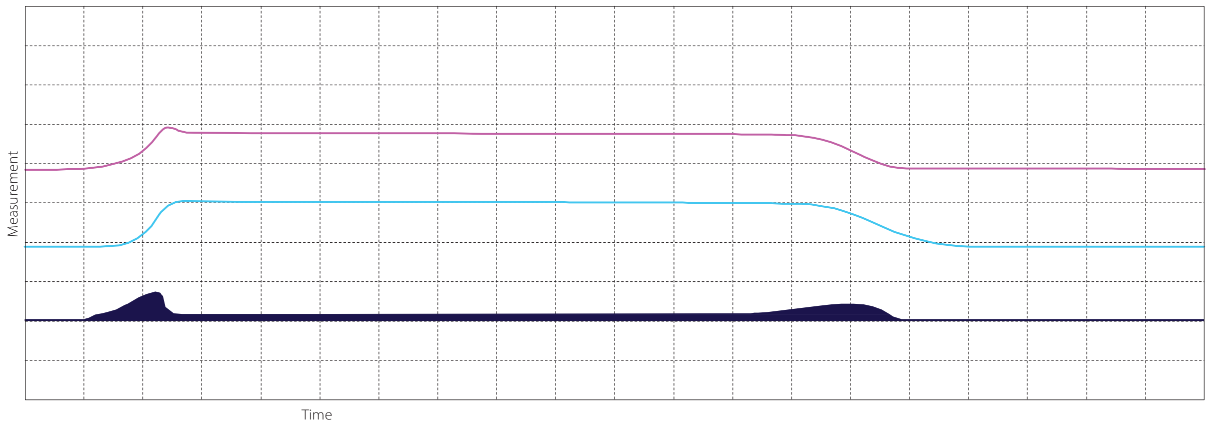
Note the smooth motor torque curve with no excessive torque. By using linear acceleration and deceleration to start and stop the pump, just enough energy is utilized to provide a smooth start and stop, regardless of the load. In stopping, you can see how long the SMC-50 controls the torque in this mode.

Figure 2 - Torque Start Mode; Load Type = Pump



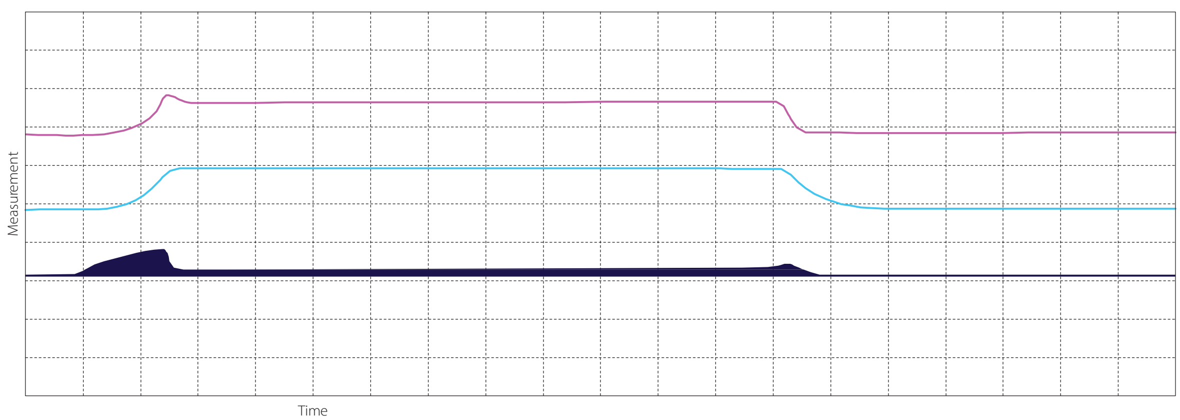
Torque start provides a solid method of bringing the pump motor up to speed with a linear torque ramp from beginning to end of the ramp. The motor speed curve will be linear when the load matches the torque profile in time.

Figure 3 - Pump Start and Stop Mode; Load Type = Pump



In pump start and stop mode, the motor is brought up to speed efficiently using a form of torque control that uses the algorithm and the microprocessor of the SMC-50. This enables smooth starts and stops in centrifugal pump applications, thereby reducing water hammer.

Figure 4 - Soft Start and Stop Mode; Load Type = Pump



The soft start mode illustrates the current is being ramped up in proportion to the voltage ramp. Depending on system dynamics, the soft start may work fine in reducing water hammer, keeping in mind the principles of the soft start using voltage to control the start. Stopping is accomplished by linearly decelerating the voltage.

When would you use linear acceleration or torque ramp?

Linear Acceleration:

- Not load dependent
- Ease of use
- No external tachometer needed

Torque Ramp:

- Fully configurable torque ramps
- Constant acceleration rate
- Ability to develop only the torque needed for accelerating the load

Like soft start, pump control uses a slower speed in the beginning of the ramp while building quickly to full speed near the end of the ramp. Being load dependent, the starts and stops can be shorter than the time set. If a customer would like to have a start less dependent on load, the Linear Speed ramp is also an option. A linear ramp, whether from linear speed or from torque ramp, will provide an even start from 0 to full speed. Torque control provides a linear ramp if the torque profile matches the load torque profile in time.

Torque Ramp and Linear Speed both provide linear acceleration, providing a smooth and efficient start. Acceleration rate is the same at the beginning and end of the ramp. A benefit of these two methods, like traditional soft start methods, is a reduction in system mechanical stress. Development of only the energy/torque needed for that application to accelerate the load will be used.

The preceding graphs illustrate different start methods on a centrifugal pump load. These curves are very similar to what is found in centrifugal fan or blower applications with the same load values, since these are also variable torque loads. Variable torque loads require an increase in acceleration torque as speed increases. A load that increases exponentially would be better suited for linear or torque-controlled starts. Since the beginning and ending torque levels can be adjusted in the SMC-50, linear acceleration ramps are executable.

By comparing the torque start and the linear start graphs, you can see the linearity of the motor speed as motor accelerates from 0 to full speed. Using soft start or pump control, you will see lower acceleration rates in the beginning of the start and higher acceleration rates toward the end of the start. Linear speed is not load dependent.

High inertia loads such as band saws, centrifuges, mixers, flywheels, rock crushers, and hammer mills have better controlled starts using the torque ramp or linear speed control. The acceleration from 0 to full speed will be consistent and linear and will result in less stress on the system in addition to easier starting of the loads.

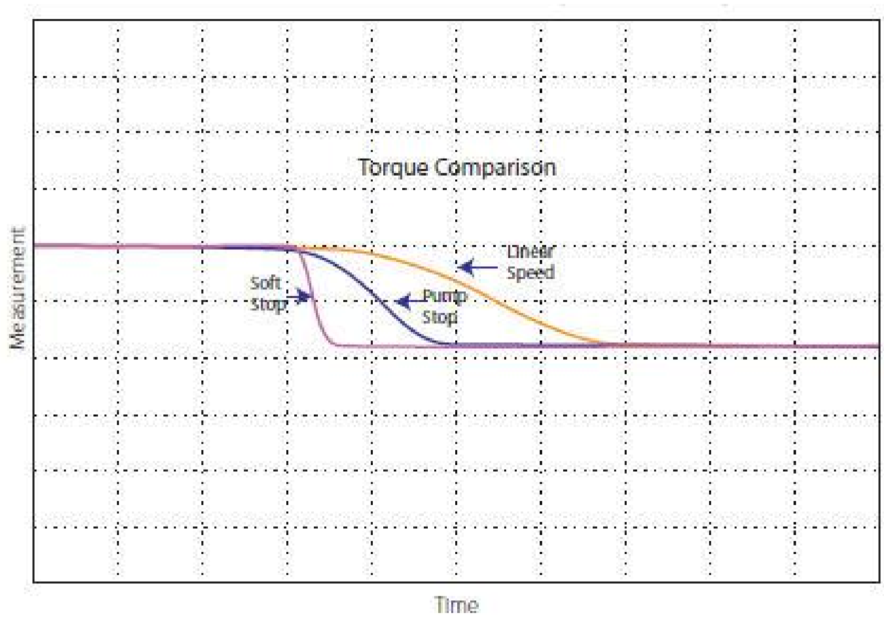
Applications with conveyors are greatly enhanced using either torque control or linear acceleration, resulting in smooth starts and a reduction in product damage during the start acceleration. In fan and conveyor systems, a linear start helps to minimize belt slippage on conveyors or fan loads.

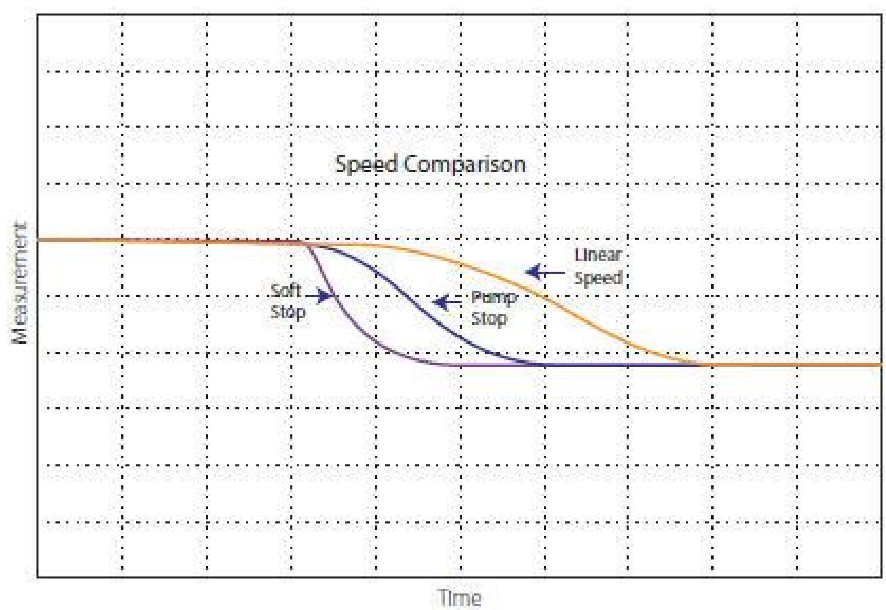
The proprietary algorithm on the SMC-50 allows the user to adjust the linear acceleration and deceleration of a motor. Why is this important? In pumping applications, the need to prevent water hammer is essential. The water hammer causes excessive vibrations in the system, causing damage to the mechanical system. In addition, extra energy would be wasted if the conventional methods are used in the starting process. With the use of the proprietary algorithm and design of the new SMC-50, the reduction of wasted energy in the starting and stopping cycles is at the fingertips of the user.

Difference in stopping methods

Stopping control is just as important as starting; this is especially true in a pumping application. In a pumping application, a lack of control during stopping will result in water hammer. The differences between soft stop, pump, and linear speed are illustrated in the next two scope plots. Given the same settings as before:

Load:	Centrifugal Pump
% Load:	65%





Notice the characteristics of the motor torque and motor speed when stopping. In this specific example, soft stop mode, in comparison to the motor speed, the torque drops to minimum torque at about ° of the deceleration time. During pump stop, the torque drops off in approximately Ω the deceleration time. Linear Speed during the stop provides the most torque control for approximately 2/3 of the deceleration time.

Actual time differences in the torque and speed curves of different stopping modes will vary depending on the system dynamics and the load. For example, linear speed will boast a torque curve that follows the profile of the load.

When to use a drive vs. an SMC?

An SMC will have control only when starting and stopping. A drive has the control throughout the start, stop, and run time with limited motor torque impact. A drive generates more heat and, depending on unit size, may cost more. If the application concern is only starting and stopping, the SMC is a good selection. If more control is needed beyond the point of starting, stopping, and the range of ±15 % for slow speed, a drive is more appropriate.

Conclusion

The SMC-50 adds more options to the feature-full Rockwell Automation Allen-Bradley family of smart motor controllers. The latest development offers an end user the opportunity to have one device that can do all the features of previous models, but adds linear speed, torque control and adjustable slow speed. No more swapping out control modules to try different starting methods. Just change a parameter, and the process can begin. In addition, a powerful assortment of power monitoring parameters that can assist the plant manager in controlling costs are part of the SMC-50 platform.

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