

Slow Speed Applications Using a Soft Starter

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Many applications could benefit from the ability to adjust the speed of a process while operating. Reasons for this include positioning, checking or adjusting alignment, or inspecting equipment, such as a band saw. There are several methods you can use to obtain slow speed control in applications, including variable-frequency drives, soft starters, and mechanical gearing.



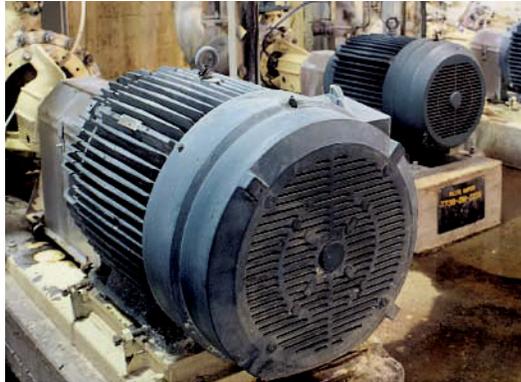
Slow speed plays a big role for workers and machinery during startup. Alignment of moving machinery at a slow speed helps reduce the number of trials to see whether adjustments are correct without having to go to full speed. The ability to start at a slow speed can also decrease the risk of an accident.

There are times you want to move product at slower speeds for proper positioning. An example of this is braking to slow speed, and then coming to a more accurate stop.

While the advantages of a slow-speed operation are numerous, slow speed comes with several considerations:

- Thermal capacity of the motor
- Thermal capacity of the starter
- Additional requirements of the motor branch supply

Motor Factors



Understanding motor design characteristics helps you to design effective systems for slow speed operation, especially for applications that require slow speed for an extended duration. The type of enclosures used and thermal ratings of the motors affect a motor's ability to operate at slow speed effectively.

For example, on an open drip proof (ODP) motor, the attached cooling fan blades move as fast as the motor turns. The slower the motor turns, the less the fan blades will turn, producing insufficient cooling of the motor. When this happens, you may need to use an external fan.

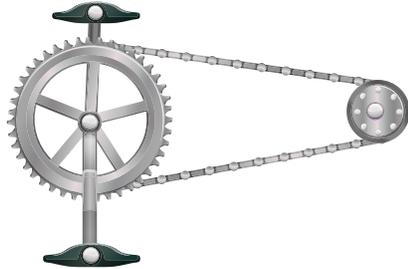
Inverter duty-rated motors are on the other end of the spectrum. These motors are designed to handle the heat generated by the voltage spikes of drives during slow speeds for a longer period of time. To assist with keeping the motor cool at low speeds, inverter duty-rated motors may also be totally enclosed blower-cooled (TEBC). When you pair motors with the correct drive, you can produce full torque at zero speed. Inverter-duty rated motors can also be used in totally enclosed non-ventilated (TENV) and totally enclosed fan cooled (TEFC) type enclosures.

To assist you in selecting a motor, NEMA has rated insulation classes A, B, F, and H for motors. IEC follows the same insulation class ratings with few exceptions. These exceptions are essentially temperature ratings for the motor. The classes reflect the amount of thermal protection provided by the varnish that protects the windings and other electrical components of the motor. The ambient temperature, the motor temperature rise while running, and winding hot spots at full speed must all have the appropriate insulation class.

For every 10 °C increase above the insulation class, the motor life is reduced by 50%.

Slow Speed Methods

You can use various methods to lower the speed of a process, including using a variable frequency drive (VFD) or a soft starter. Mechanical gearing is another option.



Mechanical gearing uses ratios of gears to accomplish the appropriate speed. One basic example of mechanical gearing is the gears on a bicycle. Changing the gear ratio from the front chain ring connected to the rear cassette cogs allows the bicyclist to change the speed depending on the revolutions per minute (RPM) of the crank arm and the selection. This change is accomplished by using a simple lever to activate the derailleur. The same is true with motors, belts, chains, or even gear-to-gear to determine the produced speed. The difference between the input and output rotational speed is the gear ratio—input RPM/output RPM—for example, $1800/600 = 3:1$. Adjusting the gear ratio will provide the desired output speed.

VFD control uses frequency to control slow speed. Motor synchronous speed is a function of applied frequency and the number of poles on the motor. This example helps you to understand the point of frequency adjustment: $N = 120F/P$, where $N = \text{RPM}$, $F = \text{applied frequency}$, $P = \text{number of motor poles}$.

Because the number of poles of a particular motor does not change, changing the frequency changes the speed of the motor. The VFD has the ability to operate at slow speeds while simultaneously providing up to full torque, depending on the control.

The rest of this white paper will focus on how soft starters behave and perform slow-speed motor control.

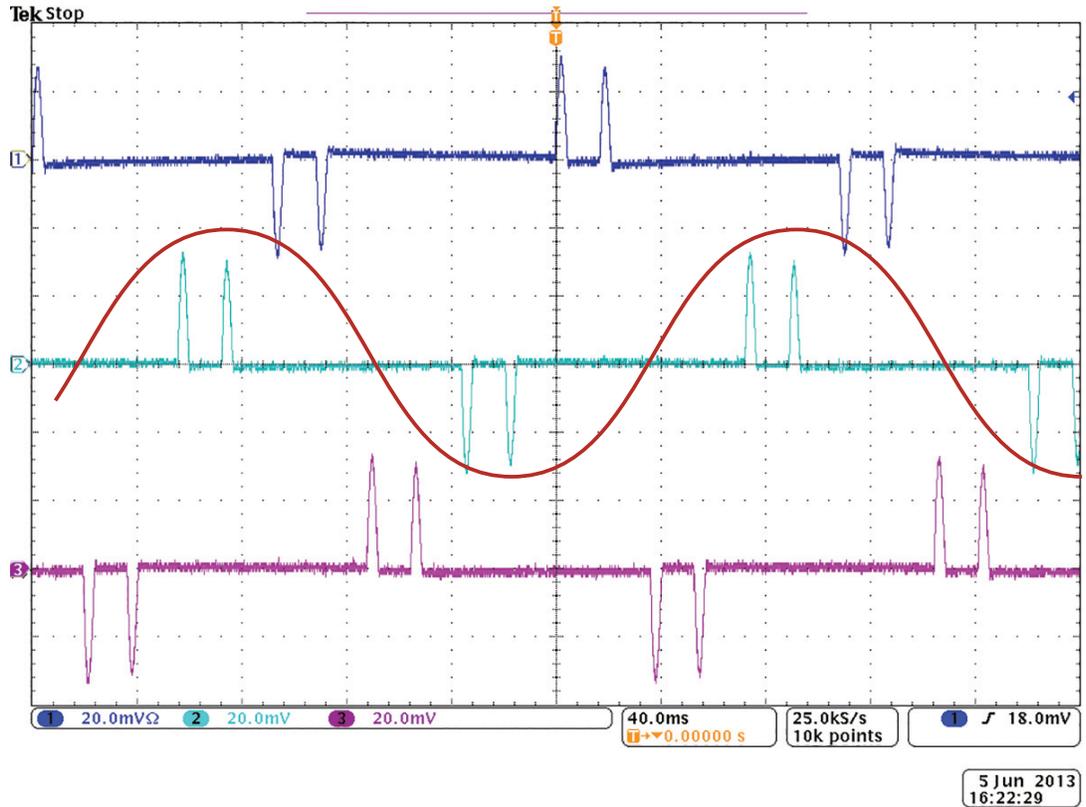
Soft Starter Control

Unlike a drive, a soft starter does not directly control the frequency of the motor.

There are several ways of operating a motor at a slow speed by using a soft start.

One of the ways is to use a method known as cycle skipping, as shown in [Figure 1](#). This cycle skipping is typical of many soft starts where the current pulses are controlled by the silicon-controlled rectifier (SCR) and fired for portions of every few line cycles, allowing for slow speed control. A pseudo sine wave output to the motor is formed. Torque during slow speed with this method is limited.

Figure 1 - Soft Start with Cycle Skipping



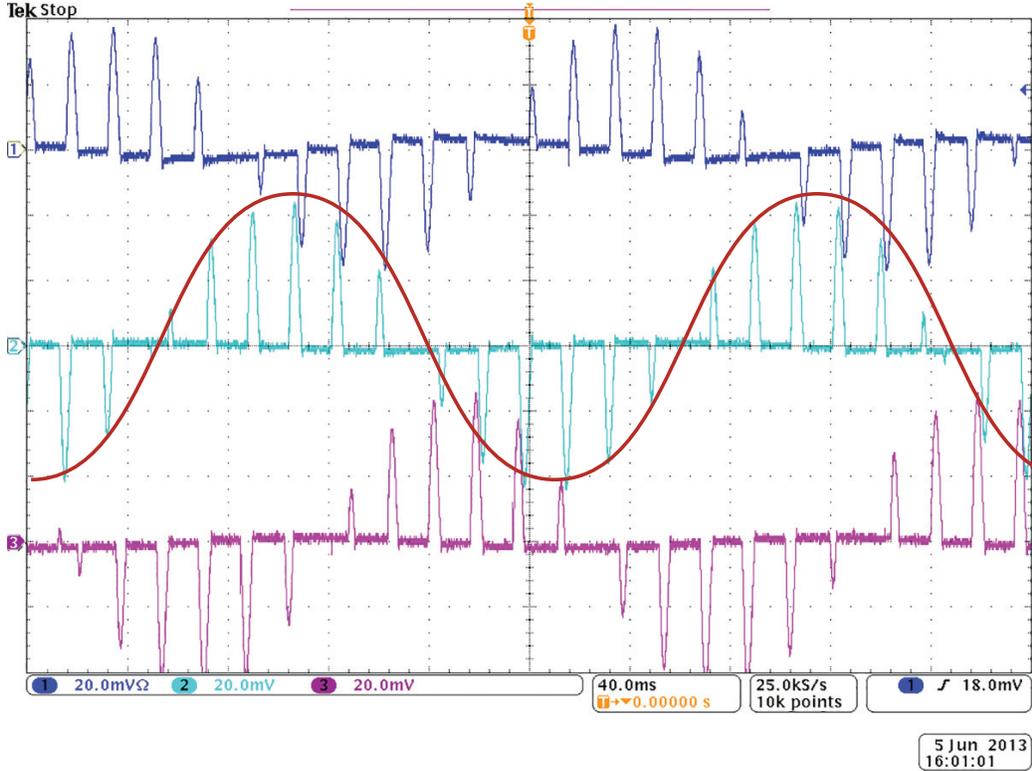
Another way to control slow speed is by using an SMC-50 soft starter. The resulting slow speed current curve is shown in [Figure 2](#). The SMC-50 soft starter has an adjustable forward and reverse capability from 1...15% of full speed. In other words, if the motor is running at full speed at 1800 rpm, the SMC-50 soft starter can be selected to run from -270...+270 rpm. The soft starter behaves similarly to a VFD in how it controls the slow speed; however, soft starters are not drives.

Instead of skipping cycles and then firing the thyristors (SCRs), the magnitude and duration of the current pulse is controlled every cycle. The produced pseudo sine wave provides more stable control and programmable slow speed. A patented algorithm allows torque to be more controlled and developed in this method than in the cycle skipping method.

Unlike the typical soft starting methods in which percent resultant torque is approximately the square of the voltage that is applied, the torque at slow speed is higher. The slow speed resultant torque is higher due to firing every cycle. This method provides a stable method of slowly rotating a motor shaft forward or in reverse without using a reversing contactor.

The firing consistency translates to less wear and tear on windings. In addition, the consistent control equates to lower disruption to the power source.

Figure 2 - SMC-50 Slow Speed Current Curve

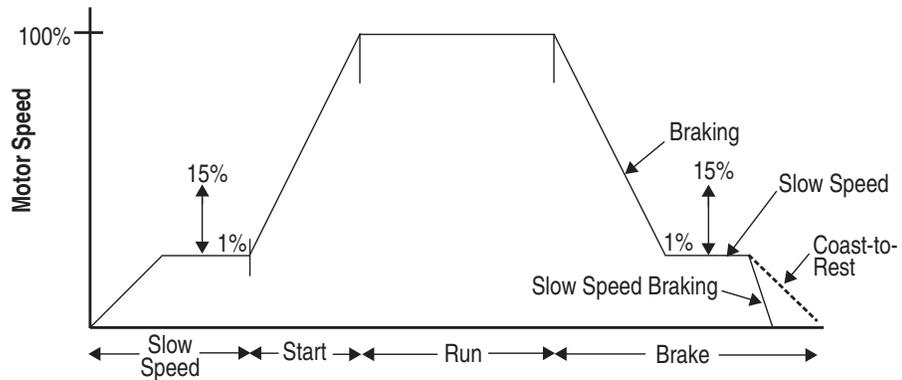


Typically, for soft starters, the longer the time in slow speed, the more current is being drawn from the motor, and the hotter the SCRs get. Running slow speed on soft starters can only be done for short periods of time due to heat buildup in the motor and the SCRs.

Soft Starter Slow Speed Examples

You can use slow speed with the soft starter for applications that require basic controlled-position starting and stopping. [Figure 3](#) shows how the soft starter could start at slow speed, then transition to full speed, and then brake to slow speed. Slow speed can then be held until a stop command is provided. Remember that slow speed operation is limited thermally.

Figure 3 - Slow Speed with Controlled-position Stop



You can use the same method for slow speed for positioning or alignment, and then stopping from slow speed. You can use slow speed in either forward or reverse directions. With slow speed, in reverse, you can unplug material in applications that use a hopper, such as a rock crusher. The temporary reverse direction may be what is needed to keep the process working. Reversing can be done without the use of reversing contactors.

Another choice to solve this problem is to stop and turn off the system. A person may physically have to go into the hopper, unplug it, and then restart the system. The process of shutting down and restarting costs time and lost revenue.

A third option to run the motor in reverse is to swap the motor leads either at the motor or at the soft starter. With larger motors, the cables get bigger, making it more difficult to swap phases. This is an extremely inefficient method, especially when you compare it to the soft starter solution.

A simple jogging function is shown in [Figure 4](#). The ability to move product in forward and reverse directions, without the use of mechanical reversing contactors, reduces the number of mechanical parts that are required and reduces the overall footprint of the setup.

Figure 4 - Jogging Functionality



Other Applications for Slow Speed

- Reversing direction of a pump—unclogging the inlet of a pump without the need to send someone to clear the inlet saves time and money.
- Low-pressure testing—getting the pump to flow just enough to check the system may be all that you need to do without the possibility of causing damage with the pump full on.
- Mill application—adjusting and checking saw blade alignment by using slow speed.
- Grain—when an end user would like to verify a grain bucket without having to stop the process.
- Basic positioning—a door on a tumbler for adding or dumping product. You can use slow speed to get to the right position to stop or to slow enough to complete the process without stopping.
- Maintenance of equipment—lubrication of gears and mechanical parts can be done at slow speed.

Conclusion

The ability to operate at slow speed is helpful in many applications, such as braking, positioning, and alignment, and inspection. To successfully perform slow speed applications, you need to take into account duration of the operation, type and ratings of motors, and the control method. Mechanical means, VFDs, and soft starters are the most common ways of providing slow speed.

While drives can provide speed variation from zero to full speed and anywhere in between, for applications of simple positioning, alignment, or inspection, the soft starter is the practical and most cost effective method.

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