B. Reduced Voltage Motor Starting

Although voltage dip often causes various problems, a controlled reduction in voltage at the motor terminals can be beneficial when it is used to reduce the starting kVA of a motor in applications where the reduced motor torque is acceptable. Reducing motor starting kVA can reduce the size of the required generator set, lessen the voltage dip, and provide a softer start for the motor loads. Make sure, however, that the motor will develop sufficient torque to accelerate the load under reduced voltage conditions. Also, any starter that makes a transition between “start” and “run” can cause an inrush condition nearly as severe as across–the–line starting — unless the motor is at or near synchronous speed at transition. This may cause unacceptable voltage dip and potentially starter drop–out.

A Comparison of Motor Starting Methods

Table 7–1 compares the effects of full voltage, auto–transformer, and resistor starting on a 50 horsepower, Design B, Code G motor. As can be seen, autotransformer starting requires less motor starting capacity from the generator set. Resistor starting actually requires more kW (engine power) than across–the–line starting.

	TYPE OF STARTER		
	AUTOTRANSFORMER	**RESISTOR**	**FULL VOLTAGE**
% of applied voltage (tap)	65	50	100
% of full voltage (multiplier)*	0.42	0.50	1.0
Starting kVA with reduced voltage starter	295** x 0.42 = 123.9	295** x 0.50 = 147.5	295** x 1.0 = 295
Starting kW with reduced voltage starter (kVA x PF)	123.9 x 0.36***= 43.4	147.5 x 0.8****= 118	295x 0.36***= 106.9
Run kVA	46	46	46
Run kW	41	41	41

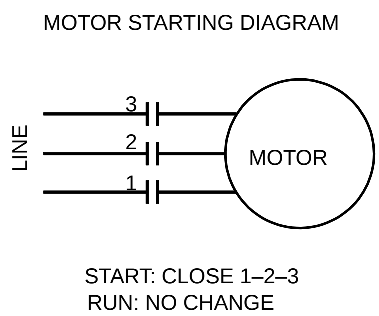
* See Table 3–4
** See Table 3–5 and multiply horsepower of 50 by the factor of 5.9 for Code Letter G.
*** See Table 3–6
**** See SPF for Resistor in Table 3–4

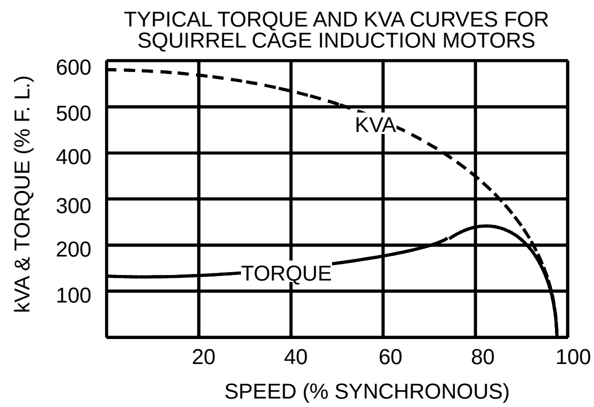
Table 7–1. Reduced Voltage Motor Starting Comparison

Full Voltage Motor Starting

Starting: Full voltage, across–the–line starting is typical unless it is necessary to reduce motor starting kVA because of the limited capacity of the generator set or to limit voltage dip during motor starting. There is no limit to the HP, size, voltage, or type of motor.

Application Notes: This method is most common because of its simplicity, reliability, and initial cost. Note on the kVA and torque curves that starting kVA remains fairly constant until the motor almost reaches full speed. Also note that kW peaks at about 300 percent of rated kW near 80 percent of synchronous speed.

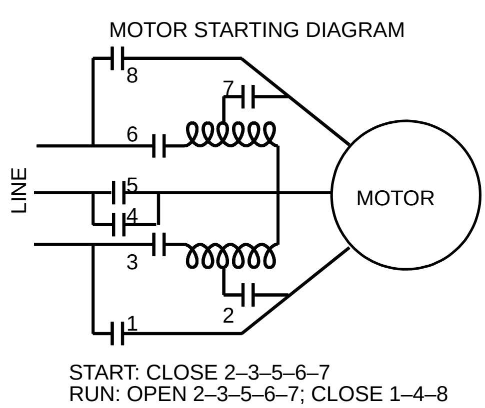


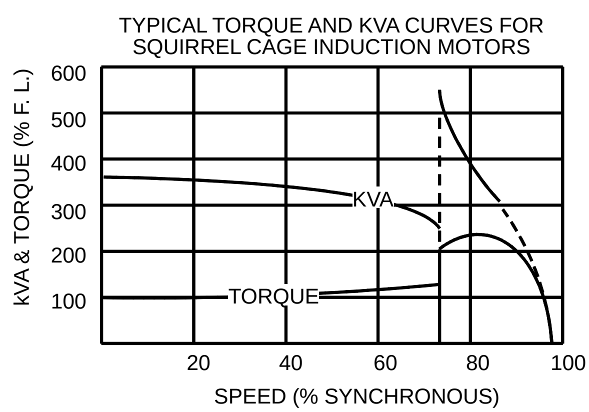


Autotransformer Motor Starting, Open Transition

Starting: The autotransformer is in the circuit only during starting to reduce voltage to the motor. The opening of the circuit during transition can cause severe transients, which may even be able to cause nuisance tripping of circuit breakers.

Application Notes: Open transition switching of reduced voltage starters should be avoided in generator set applications, especially when the motors are not brought up to full speed at the time of transition. The reason for this is that the motor slows down and gets out of synchronization during the switching transition. The result is similar to paralleling generator sets out of phase. The kVA drawn immediately after switching can exceed starting kVA. Also note that the starting power factor is lower when an autotransformer is used.



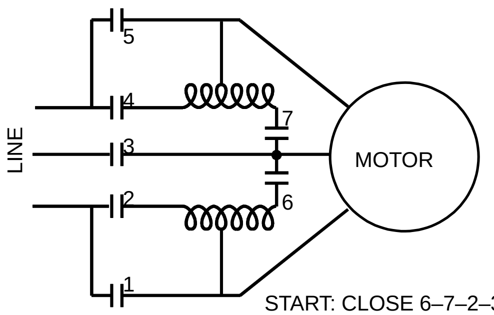


Autotransformer Motor Starting, Closed Transition

Starting: The circuit is not interrupted during starting. During transfer, part of the autotransformer winding remains in the circuit as a series reactor with the motor windings.

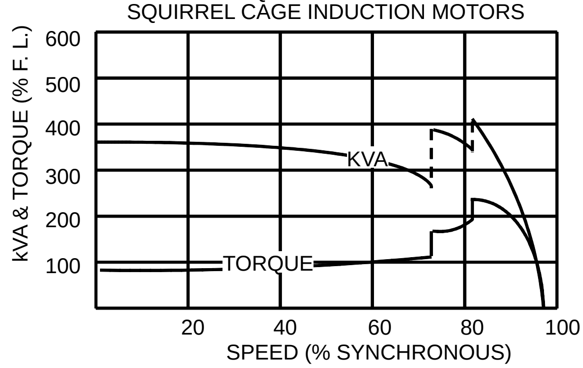
Application Notes: Closed transition is preferred over open transition because of less electrical disturbance. The switching, however, is more expensive and complex. It is the most commonly used reduced voltage starting method for large motors with low load torque requirements, such as sewage lift pumps and chillers. The principle advantage is more torque per current than with other reduced voltage starting methods. Operation can be automatic and/or remote. Also note that the starting power factor is lower when an autotransformer is used.

MOTOR STARTING DIAGRAM



START: CLOSE 6–7–2–3–4
TRANSFER: OPEN 6–7
RUN: CLOSE 1–5

TYPICAL TORQUE AND KVA CURVES FOR SQUIRREL CAGE INDUCTION MOTORS

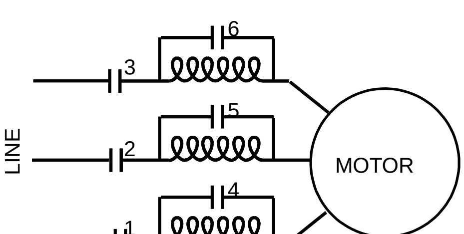


Reactor Motor Starting, Closed Transition

Starting: Reactor starting has the advantage of simplicity and closed transition, but results in lower starting torque per kVA than with autotransformer starting. Relative torque, however, improves as the motor accelerates.

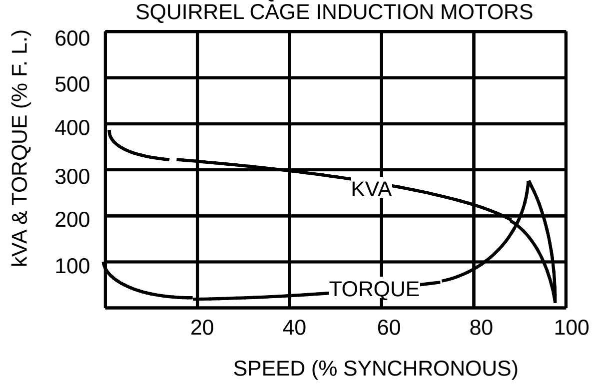
Application Notes: Reactor starting is generally not used except for large, high–voltage or high–current motors. The reactors must be sized for HP and voltage and may have limited availability. Typically, reactor starting costs more than autotransformer starting for smaller motors, but is simpler and less expensive for larger motors. Starting power factor is exceptionally low. Reactor starting allows a smooth start with almost no observable disturbance on transition and is well suited for applications such as centrifugal pumps or fans.

MOTOR STARTING DIAGRAM



START: CLOSE 1–2–3
RUN: CLOSE 4–5–6

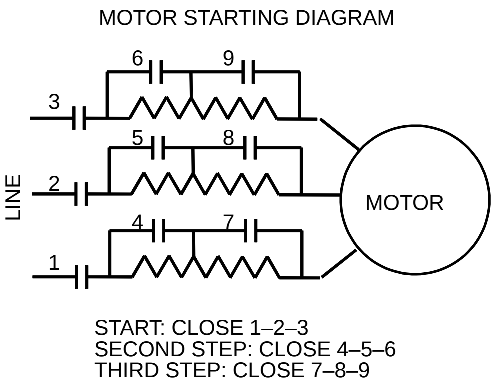
TYPICAL TORQUE AND KVA CURVES FOR SQUIRREL CAGE INDUCTION MOTORS

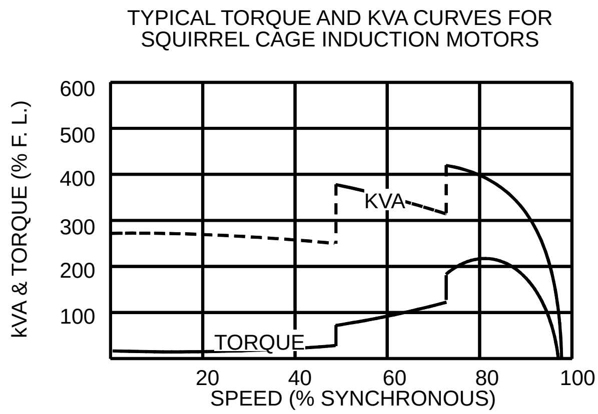


Resistor Motor Starting, Closed Transition

Starting: Resistor starting is occasionally used for smaller motors where several steps of starting are required and no opening of motor circuits between steps is allowed.

Application Notes: Also available as a stepless transition starter which provides a smoother start. Resistor starting is usually the least expensive with small motors. Accelerates loads faster because the voltage increases with a decrease in current. Has a higher starting power factor.





Star–Delta Motor Starting, Open Transition

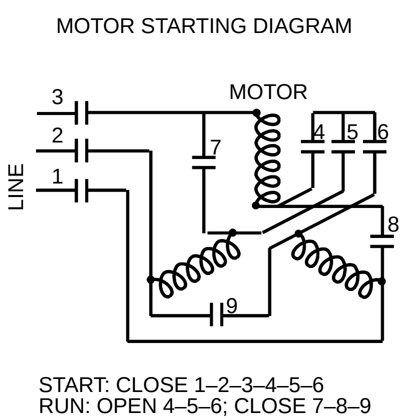
Starting: Star–Delta starting requires no autotransformer, reactor, or resistor. The motor starts star–connected and runs delta–connected.

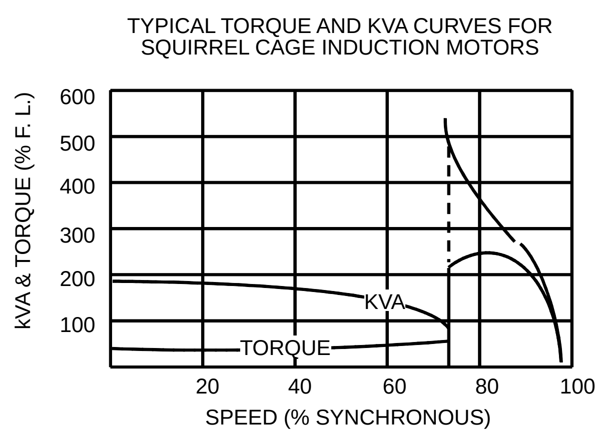
Application Notes: This starting method is becoming more popular where low starting torques are acceptable. It has the following disadvantages:

1. Open transition. Closed transition is available at extra cost.

2. Low torque.

3. No advantage when the motor is powered by a generator set unless the motor reaches synchronous speed before switching. In applications where the motor does not reach synchronous speed, the generator set must be sized to meet the surge.



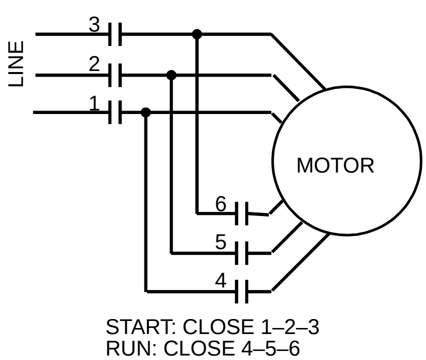


Part Winding Motor Starting, Closed Transition

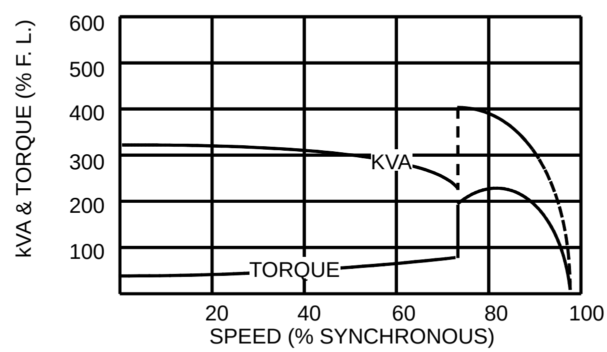
Starting: Part winding starting is less expensive because it requires no autotransformer, reactor, or resistor and uses simple switching. Available in two or more starting steps depending on size, speed, and voltage of motor.

Application Notes: Automatically provides closed transition. First, one winding is connected to the line; after a time interval, the second winding is paralleled with the first. Starting torque is low and is fixed by the motor manufacturer. The purpose of part winding is not to reduce starting current but to provide starting current in smaller increments. There is no advantage to this method if the motor is powered by a generator set unless the motor can reach synchronous speed before transition to the line.

MOTOR STARTING DIAGRAM



TYPICAL TORQUE AND KVA CURVES FOR SQUIRREL CAGE INDUCTION MOTORS

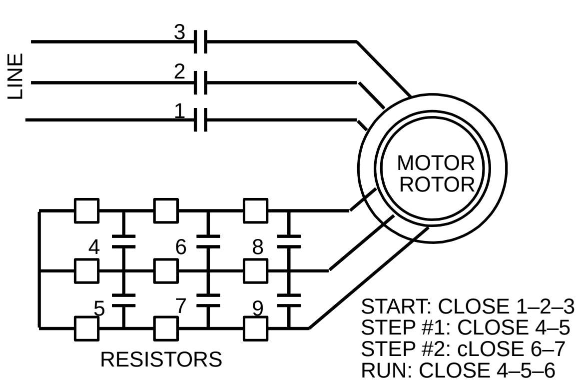


Wound Rotor Motor Starting

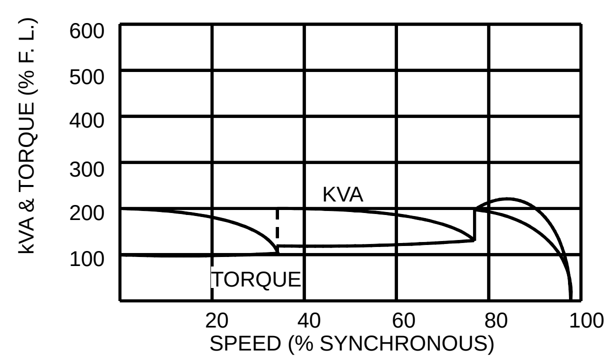
Starting: A wound rotor motor can have the same starting torque as a squirrel cage motor but with less current. It differs from squirrel cage motors only in the rotor. A squirrel cage motor has short circuit bars, whereas a wound rotor motor has windings, usually three–phase.

Application Notes: Starting current, torque, and speed characteristics can be changed by connecting the proper amount of external resistance into the rotor. Usually, wound rotor motors are adjusted so that the starting kVA is about 1.5 times running kVA. This is the easiest type of motor for a generator set to start.

MOTOR STARTING DIAGRAM



TYPICAL TORQUE AND KVA CURVES FOR WOUND ROTOR MOTORS



Synchronous Motor Starting

Starting: Synchronous motors can use most of the starting methods discussed. Synchronous motors rated 20 HP and greater have starting characteristics similar to wound rotor motors.

Application Notes: Synchronous motors are in a class by themselves. There are no standards for performance, frame size, or connections. Motors rated 30 HP or less have high locked rotor currents. They can be used in applications where power factor correction is desired. (Use the standard code letter when the actual letter is not known.)

General Application Note

If the reduced voltage motor starter has a time or rate adjustment, adjust the settings to obtain about two seconds between taps. This allows time for the motor to approach rated speed and thus reduce the peak kVA at the time of switching, as shown below. Note that at the minimum setting there is not much improvement over full voltage starting.

In some applications the inrush current is so low that the motor shaft will not start to turn on the first tap, nor even the second. For those applications there is little reduction of starting kVA from the standpoint of the generator set.