Monthly Informative Application Guidelines, with respect to Motors & Drives to keep you better INFORMED.

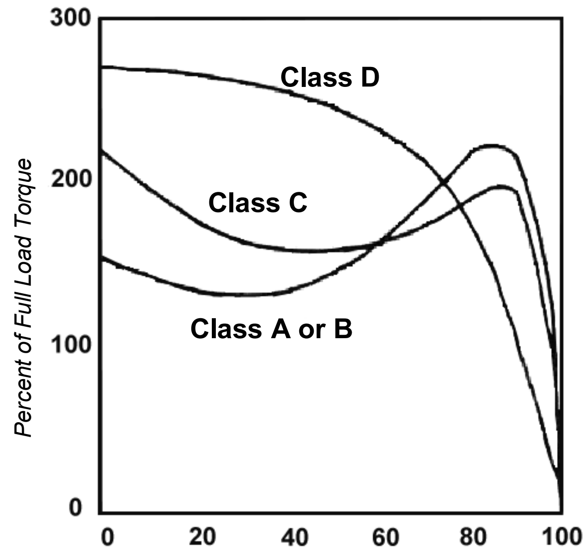
APPLICATION GUIDELINE #28

(Typical Starting Methods for AC Induction Motors – Part 2)

Brought to you by your Motor & Drive Specialists……

Motor Torque

NEMA defines typical speed-torque curves as Class A, B, C and D. Most motors used in the industry are classified as NEMA Design B. The locked rotor torque (LRT) of Class B motors vary. The LRT of a four pole motor varies from 140%, for a 75 hp motor, to 80%, for a 500 hp motor. These are minimum values and actual torque can greatly exceed these values. A Toshiba 75 hp, TEFC, four pole motor has a locked rotor torque of 254%. This may be beneficial in applications requiring high torque but detrimental in applications that have a torque limit.



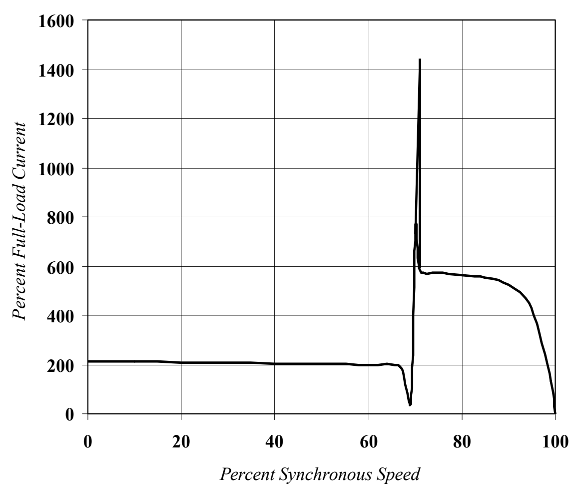
Typical Speed-Torque Curves

Circuit Breakers

Circuit breakers are selected, per the National Electric Code (NEC), with an instantaneous trip maximum setting of 13 times the motor full load amps (MFLA). The 13 times MFLA has generally only been exceeded, causing circuit breakers to trip, during the transition of a reduced voltage, open transition starter. Open transition can produce a high surge because the motor is disconnected from the power source during the transition. A higher surge is produced during transition at lower motor speeds.

With the introduction of Premium Efficiency motors, the problem of breakers tripping during starting has greatly increased in frequency. Circuit breakers are tripping when attempting to start the motor using a full voltage starter. The breakers are tripping on instantaneous peak current when the contactor closes. When using premium efficiency motors, the current surge during transition may also be greatly increased.

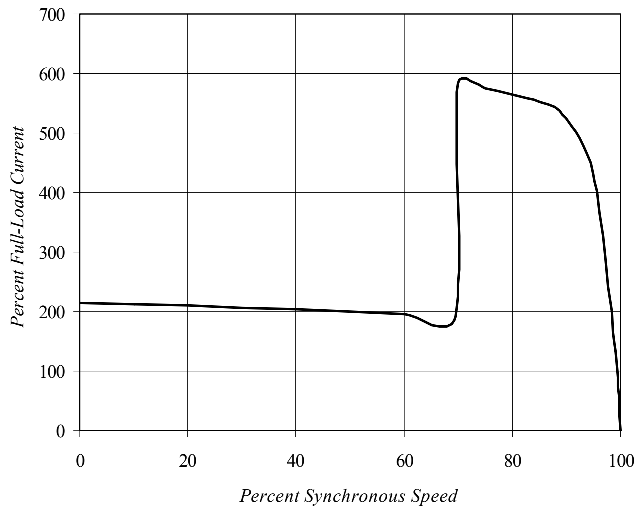
Designs of premium efficiency motors vary by manufacturer. Manufacturing techniques, horsepower rating, synchronous speed, and the power supply influences the amount of inrush current of a motor. The amount of inrush current is a function of its reactance/resistance ratio (X/R). Designing a motor with improved efficiency has resulted in a lower X/R ratio, causing higher inrush currents. Using full voltage starters, the first half cycle peak currents have been recorded as high as 14 to 16 times MFLA. One solution, that is being addressed by a NEC committee, is to increase the breaker maximum trip setting limit. There are concerns regarding protective coordination with other equipment and cabling if this trip setting is increased.



Open Transition

Fuses that will pass the current spike can be used for short circuit protection. However, a fusible disconnect and fuses (including spares) can cost more than a breaker, and a blown fuse can cause a single phase problem.

A reduced voltage, closed transition or solid state starter does not have the transition spike problem. The first half cycle peak current will be reduced by the same percentage as the starting current, reducing the peak current below the breaker's maximum trip setting.



Closed Transition

REDUCED VOLTAGE STARTERS

AC squirrel cage motors are by far the most widely used motor in industry due to their rugged construction and simplicity of design. When squirrel cage motors are started at full line voltage they draw extremely high inrush currents, in the order of 600% of the full load running current, producing a torque that is approximately 150% of the torque at normal running speed. The high inrush current, especially on large motors, may cause problems with the electrical system, such as severe voltage dips for several seconds, as well as coordination problems of protective devices, while the high starting torque may adversely affect the driven machine or destroy material in process. The starting torque produced by an induction motor is approximately proportional to the square of the stator current. For example, a motor drawing 50% rated current produces approximately 25% rated torque. All reduced voltage controllers operate in the same way to reduce the current drawn by the motor (and hence reduce the torque) on starting. This will result in lower peak power requirements from the local utility and prevent damage to the machinery and work in process.

Some reduced voltage controllers lower the starting current and torque by means of an impedance inserted in the start-up circuitry of the motor. The inserted impedance is either resistance or reactance. Autotransformers are used to accomplish the reduced voltage starting characteristics. Another common means used to reduce start-up requirements is accomplished by connecting or reconnecting the leads of multi-lead motors in various combinations which is the method used in the wye-delta starter. Depending on the type of controller used, the motor will produce a different amount of torque on starting for a given value of current drawn from the line. Some controllers provide an adjustment of the starting current and torque as with an autotransformer starter, while others such as part winding and wye-delta controllers have fixed starting values. A higher starting voltage will reduce accelerating time and increase starting torque. A lower starting voltage will cause the accelerating period to be longer and will reduce the torque.

PART WINDING STARTERS

The part winding starter is not a true reduced voltage starter. The part winding starter is designed for motor that has two separate sets of identical windings. The starter energizes half of the motor's windings with full line voltage during starting and then the other half of the windings for a run condition. Typical starting current is 60-65% of the motor's full voltage inrush current and starting torque is approximately 50% of what would be developed at full voltage. The part winding starter is closed transition. This starter is the least expensive of the reduced voltage starters, however, there are several limitations that restrict its use. The motor must have two separate windings, which is standard on most dual (i.e. 230/460V) motors, but these motors are only suitable for part winding starting on the lower voltage (i.e. 230V). Some single voltage motors can be started part winding, but this is uncommon. A special motor may have to be built and would therefore not be a common stock item. Another restriction to the application of a part winding starter is that standard motors have a maximum allowable acceleration time (only half the windings energized) of only one to two seconds (based on motor design).

Applications - Only loads that have low starting torque requirement such as fans and blowers can be started using the part winding starter. The applications are limited by the simple fact that the load must be able to be accelerated from zero to full rated speed in only two or three seconds, with only half the motor capacity. If the load cannot reach full speed before the second winding energizes, the motor's voltage torque and current will jump to full voltage values and defeat the purpose of the starter. The part winding starter is generally an ineffective selection except for two things: it is the least expensive of the reduced voltage starters, and it meets the utility company's statement of "motors over 'X' horsepower must be started by reduced voltage starter."

Operation - A start signal (contact closure) closes the first contactor, connecting one of the motor windings to the line. Assuming that the motor draws 60-65% of normal locked rotor current, it will then develop approximately 50% of normal locked rotor torque. After an adjustable time interval, the second contactor closes, connecting the remaining winding to the line, in parallel with the other winding. The motor then develops normal torque. If the second contactor does not close, damage to the motor windings may occur. To trip the starter off if the motor does not switch to full voltage, Toshiba part winding starters include an incomplete sequence timer. This timer is not standard with most other manufacturers.

Construction - Starters consist of two 3-pole contactors (rated one-half of the horsepower rating of the motor), two solid state timers, one for transition and one for incomplete sequence, and two three phase overload relays (rated one-half of the MFLA).

WYE-DELTA STARTERS

The wye-delta starter does not reduce the voltage applied to the motor itself, but applies a reduced voltage to the motors individual windings by connecting the windings in a wye connection during starting, providing the same effect. On a 460V rated motor, during starting each phase winding only has 58%, or 266V (460V/$\sqrt{3}$) applied across it. At this reduced voltage, the motor will develop 33% (58% squared) of its normal starting torque and current.

Application - Wye-delta starters are used with delta-wound squirrel cage motors that have all leads (6 or 12) brought out to facilitate a wye connection. This starting method is particularly suitable for applications involving long accelerating times or frequent starts. Wye-delta starters are typically used for high inertia loads, although they are applicable in cases where low starting current is necessary and low starting torque is permissible.

Construction - Starters are available in the open transition and the closed transition. The open transition starters include three 3-pole contactors, two adjustable timers, one for transition and one for incomplete sequence, and a three phase overload relay. Closed transition starters include an additional 3-pole contactor, two more timers, and a resistor bank.

Operation - A start signal (contact closure) closes two contactors (wye and shorting contactor) energizing the motor in the wye connection. After an adjustable time interval, the shorting contactor is opened and the delta contactor is then closed, connecting the motor in delta, applying full line voltage to the windings. In starters with open circuit transition, the motor is momentarily disconnected from the line during the transition from wye to delta. With closed circuit transition, the motor remains connected to the line, thus avoiding the current surges associated with open transition. This is accomplished by closing a fourth contactor that connects a set of resistors in parallel with the shorting contactor to maintain a closed circuit during the transition. If the delta contactor does not close, damage to the motor windings may occur. To trip the starter off if the motor does not switch to delta connection, Toshiba wye-delta starters include an incomplete sequence timer. This timer is not standard with most other manufacturers. On closed transition starters, an incomplete sequence timer is provided as standard on Toshiba starters for protection of the resistors, which are only rated for one second duty.