

Technical note

Starting methods for AC motors

Reducing electrical and mechanical stress at start-up

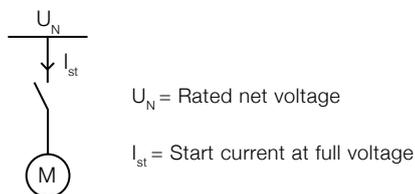
The starting current of an AC motor can vary from 3 to 7 times the nominal current. This is because a large amount of energy is required to magnetise the motor enough to overcome the inertia the system has at standstill. The high current drawn from the network can cause problems such as voltage drop, high transients and, in some cases, uncontrolled shutdown. High starting current also causes great mechanical stress on the motor's rotor bars and windings, and can affect the driven equipment and the foundations. Several starting methods exist, all aiming to reduce these stresses.

The load, the motor and the supply network determine the most appropriate starting method. When selecting and dimensioning the starting equipment and any protective devices, the following factors must be taken into account:

- The voltage drop in the supply network when starting the motor
- The required load torque during start
- The required starting time

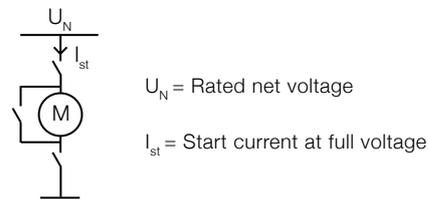
Direct-on-line (DOL) start

Direct on line starting is suitable for stable supplies and mechanically stiff and well-dimensioned shaft systems. It is the simplest, cheapest and most common starting method. Starting equipment for small motors that do not start and stop frequently is simple, often consisting of a hand operated motor protection circuit breaker. Larger motors and motors that start and stop frequently, or have some kind of control system, normally use a direct-on-line starter which can consist of a contactor plus overload protection, such as a thermal relay.



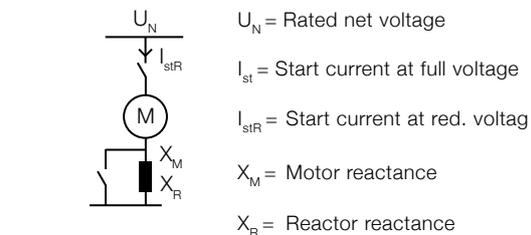
Star-Delta (Y/D) starting

Most low voltage motors can be connected to run at either 400 V with delta connection or at 690 V with star connection. This flexibility can also be used to start the motor with a lower voltage. Star/delta connection gives a low starting current of only about one-third of that during direct-on-line starting, although this also reduces the starting torque to about 25%. The motor is started with Y-connection and accelerated as far as possible, then switched to D-connection. This method can only be used with induction motors delta connected for the supply voltage.



Reactor start

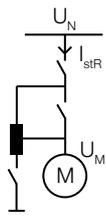
By connecting a coil with an iron core (a reactor) in series with the motor during start, the starting current is limited in proportion with the voltage. However, this also means a substantial (quadratic) reduction in the available starting torque. The advantage of this method is its low cost in comparison with other methods.



$$I_{stR} = \left(\frac{U_N}{X_M + X_R} \right) \quad T_{stR} = \left(\frac{I_{stR}}{I_{st}} \right)^2 T_{st}$$

Auto transformer start

The effect of auto transformer start is similar to that of reactor start. Using a transformer to limit the voltage reduces the starting current and the torque, but less so than the reactor start. The method is more expensive than reactor start.

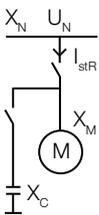


U_N = Rated net voltage
 I_{st} = Start current at full voltage
 I_{stR} = Start current at red. voltage
 U_M = Motor voltage

$$I_{stR} = \left(\frac{U_M}{U_N}\right)^2 I_{st} \quad T_{stR} = \left(\frac{I_{stR}}{I_{st}}\right) T_{st}$$

Capacitor start

By storing the power required for magnetisation in capacitor banks, it is possible to start with full starting torque without disturbing the network. To avoid over-compensation, the capacitor bank must be uncoupled after start-up. The disadvantages of this method are the high cost, and the large space requirement of the capacitor banks.



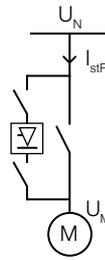
U_N = Rated net voltage
 I_{stR} = Start current w/capacitor
 X_N = Net reactance
 X_C = Capacitor bank reactance
 X_M = Motor short circuit reactance

$$I_{stR} = \frac{U_N}{\sqrt{3} \left(X_N + \frac{X_C X_M}{X_C + X_M} \right)} \quad T_{stR} = \frac{\frac{X_C X_M}{X_C + X_M}}{X_N + \frac{X_C X_M}{X_C + X_M}} T_{st}$$

Soft starters

Soft starters are based on semiconductors, which, via a power circuit and a control circuit, initially reduces the motor voltage, resulting in lower motor torque. During the starting process, the soft starter progressively increases the motor voltage so that the motor becomes strong enough to accelerate the load to rated speed without causing torque or current peaks. Soft starters can also be used to control the stopping of a process.

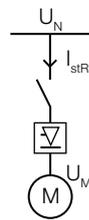
Soft starters are less costly than frequency converters but like frequency converters, they may inject harmonic currents into the grid, disrupting other processes.



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Frequency converter start

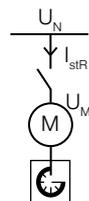
Although a frequency converter is designed for continuous feeding of motors, it can also be used for start-up only. The frequency converter enables low starting current because the motor can produce rated torque at rated current from zero to full speed. As the price of frequency converters continues to drop, they are increasingly being used in applications where soft starters would previously have been used. However in most cases they are still more expensive than soft starters, and like these, they inject harmonic currents into the network.



U_N = Rated net voltage
 I_{stR} = Start current at red. voltage
 U_M = Motor voltage

Rheostat starting

Rheostat starting can only be used with slip ring motors. On these motors, the resistance of the rotor circuits can be increased with an external resistor. This method is usually chosen when the supply net is weak and the required starting torque and moment of inertia are very high. By switching in the additional resistances in steps, normally 4 to 7 steps, the desired acceleration torque can be obtained. The normal DOL starting equipment also required.



U_N = Rated net voltage
 I_{stR} = Start current at red. voltage
 U_M = Motor voltage