SOFT START TECH TIPS

What you need to
know to select the
ideal soft start solution

AuCom

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Typical Motor FLCs

If you don't have accurate information on your motor's start current characteristics, the table below can help you estimate the likely full load current for a particular motor size. This information can help when choosing a soft starter, but will not provide an optimised solution because the characteristics of different motors can vary considerably.

Motor Power		Current rating at different voltages				
kW	HP	230 V	400 V	440 V	500 V	690 V
7.5	10	27	15.5	13.7	12	8.9
11	15	39	22	20.1	18.4	14
15	20	52	30	26.5	23	17.3
18.5	25	64	37	32.8	28.5	21.3
22	30	75	44	39	33	25
25	35	85	52	45	39	30
30	40	103	60	51	45	34
37	50	126	72	64	55	42
45	60	150	85	76	65	49
55	75	182	105	90	80	61
75	100	240	138	125	105	82
90	125	295	170	146	129	98
110	150	356	205	178	156	118
132	180	425	245	215	187	140
140	190	450	260	227	200	145
147	200	472	273	236	207	152
150	205	483	280	246	210	159
160	220	520	300	256	220	170
185	250	595	342	295	263	200
200	270	626	370	321	281	215
220	300	700	408	353	310	235
250	340	800	460	401	360	274
257	350	826	475	412	365	280
280	380	900	510	450	400	305
295	400	948	546	473	416	320
300	410	980	565	481	420	325
315	430	990	584	505	445	337
335	450	1100	620	518	472	355
355	480	1150	636	549	500	370
375	500	1180	670	575	527	395
400	545	1250	710	611	540	410
425	580	1330	760	650	574	445
445	600	1400	790	680	595	455
450	610	1410	800	690	608	460
475	645	1490	850	730	645	485
500	680	1570	900	780	680	515

560	760	1750	1000	860	760	570
600	800	1875	1085	937	825	625
650	870	2031	1176	1015	894	677
700	940	2187	1266	1093	962	729
750	1000	2343	1357	1172	1031	781
800	1070	2499	1447	1250	1100	833
850	1140	2656	1537	1328	1168	885
900	1250	2812	1628	1406	1237	937
950	1275	2968	1718	1484	1306	989
1000	1340	3124	1809	1562	1375	1041

IP Ratings

What are they?

IEC 60529 specifies ingress protection ratings for enclosures. These ratings describe the level of protection against dust and liquids entering the enclosure.

IP ratings consist of two numbers. The first number describes the protection against solid objects and the second number describes the level of protection against entry of liquids.

IP	Solids	Liquids
0	No protection.	No protection.
1	Protected against solid objects greater than 50 mm (e.g. accidental touching by hand).	Protected against vertically falling drops of water (e.g. condensation).
2	Protected against solid objects greater than 12 mm (e.g. fingers).	Protected against direct sprays of water up to 15° from vertical.
3	Protected against solid objects greater than 2.5 mm (e.g. tools or wires).	Protected against sprays of water up to 60° from vertical.
4	Protected against solid objects greater than 1 mm (e.g. tools and small wires).	Limited protection against water sprayed from all directions (limited ingress permitted).
5	Limited protection against dust (some ingress but no harmful deposit).	Limited protection against low pressure jets of water from all directions (limited ingress permitted).
6	Complete protection against dust.	Protected against strong jets of water (limited ingress permitted).
7		Protected against the effects of immersion in water between 15 cm and 100 cm.
8		Protected against extended immersion in water under pressure.

NEMA Ratings

What are they?

NEMA 250 is a product standard that addresses many aspects of enclosure design and performance.

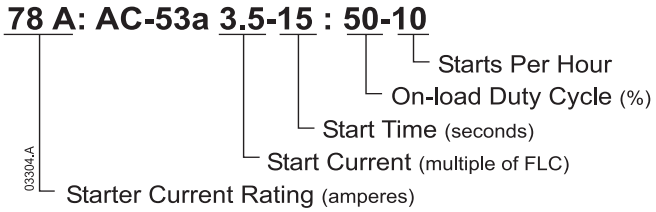
NEMA	Protection against solid objects	Approx IP equivalent
1	Indoor, protection from contact.	IP23
2	Indoor, limited protection from dirt and water.	IP30
3	Outdoor, some protection from rain, sleet, windblown dust and ice.	IP64
3R	Outdoor, some protection from rain, sleet and ice.	IP32
4	Indoor or outdoor, some protection from windblown dust, rain, splashing water, hose-directed water and ice.	IP66
4X	Indoor or outdoor, some protection from corrosion, windblown dust, rain, splashing water, hose-directed water and ice.	IP66
6	Indoor or outdoor, some protection from ice, hose-directed water, entry of water when submerged at limited depth.	IP67
12	Indoor, protection from dust, falling dirt and dripping non-corrosive liquids.	IP55
13	Indoor, protection from dust, spraying water, oil and non-corrosive liquids.	IP65

What are AC53 Utilisation Codes?

The AC53a Utilisation Code defines the current rating and standard operating conditions for a non-bypassed soft starter.

The soft starter's current rating determines the maximum motor size it can be used with. The soft starter's rating depends on the number of starts per hour, the length and current level of the start, and the percentage of the operating cycle that the soft starter will be running (passing current).

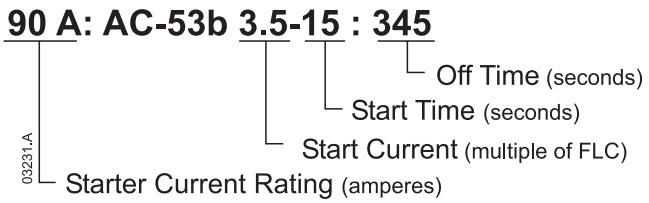
The soft starter's current rating is only valid when used within the conditions specified in the AC53a code - the soft starter may have a higher or lower current rating in different operating conditions.



The AC53b Utilisation Code defines the current rating and standard operating conditions for a bypassed soft starter (internally bypassed, or installed with an external bypass contactor).

The soft starter's current rating determines the maximum motor size it can be used with. The soft starter's rating depends on the number of starts per hour, the length and current level of the start, and the amount of time the soft starter will be off (not passing current) between starts.

The soft starter's current rating is only valid when used within the conditions specified in the AC53b code - the soft starter may have a higher or lower current rating in different operating conditions.

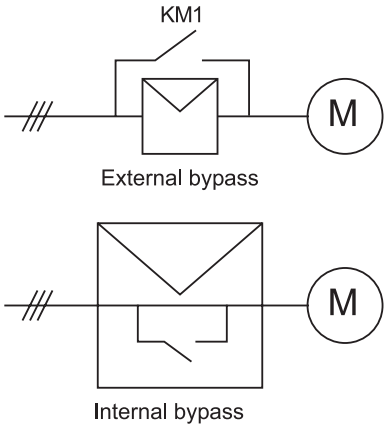


Bypass Contactors

When and how should they be used?

Bypass contactors bridge out a soft starter's SCRs when the motor is running at full speed. This eliminates heat dissipation from the SCRs during run state.

Some soft starters include built-in bypass contactors, others require an external bypass contactor.



Bypass contactors:

- allow soft starters to be installed in sealed enclosures
- eliminate the cost of forced-air cabinet ventilation
- save energy by eliminating SCR losses during run

Bypass contactors should be AC1 rated for the motor FLC. The AC1 rating is adequate because the bypass contactor does not carry start current or switch fault current.

What is the Maximum Cable Length?

The maximum distance between the starter and motor is determined by the voltage drop and the cable capacitance.

Voltage drop at the motor terminals must not exceed the limit specified in local electrical regulations when the motor is running fully loaded. Cabling should be sized accordingly.

Cable capacitance can be a factor for cable runs that are longer than 500 m. Consult the soft starter manufacturer for advice - you will need to provide details about mains voltage, mains frequency and the soft starter model.

Cable Selection

How do I select cable when installing a soft starter?

Cable selection criteria vary according to the nature of the circuit and the location of the soft starter within the circuit.

1. Supply cable rating
   - nominal fuse/MCCB rating
   - motor FLC x 1.2

2. Inside delta (six-wire) motor circuit cable rating
   - motor FLC x 0.7

Note: Cable current ratings may need to be derated to account for installation factors (grouping, ambient temperature, single or parallel cabling etc). Always follow the manufacturer's instructions.

Inside Delta Connection

What is it and why would I use it?

Inside delta connection (also called six-wire connection) places the soft starter SCRs in series with each motor winding. This means that the soft starter carries only phase current, not line current. This allows the soft starter to control a motor of larger than normal full load current.

When using an inside delta connection, a main contactor or shunt trip MCCB must also be used to disconnect the motor and soft starter from the supply in the event of a trip.

Inside delta connection:

- simplifies replacement of star-delta starters because the existing wiring can be used
- may reduce installation cost

Soft starter cost will be reduced but there are additional cabling and main contactor costs. The cost equation must be considered on an individual basis.

Only motors that allow each end of all three motor windings to be connected separately can be controlled using the inside delta connection method.

Not all soft starters can be connected in inside delta.

Main Contactors

When and how should they be used?

Soft starters can be installed with or without a main contactor.

A main contactor may be required to meet local electrical regulations. It provides physical isolation when the starter is not in use and in the event of a soft starter trip.

Even in the off state SCRs do not offer a high degree of isolation due to leakage through the SCR and protection networks.

A main contactor protects the soft starter SCRs from severe overvoltage situations (e.g. lightning strikes).

SCRs are most susceptible to overvoltage damage when in the off state. A main contactor disconnects the SCRs from the supply when the motor is not running, preventing possible damage.

Main contactors should be AC3 rated for the motor FLC.

Power Factor Correction

Can it be used with soft starters?

Individual power factor correction capacitors can be used with soft starters, provided that they are installed on the input side of the soft starter and switched in using a dedicated contactor when the motor is running at full speed. The contactor should be AC6 rated for the motor full load current.

Connecting power factor correction capacitors to the output of a soft starter will cause equipment failure due to severe overvoltage. This overvoltage is created by resonance between the inductance of the motor and the power factor capacitance.

PFC capacitors can be sized using the following formula:

$$\text{kVA (Cap)} = \frac{\sqrt{3} \times V_{line} \times 0.8 \times \text{motor no load current}}{1000}$$

Type 1 Circuit Protection

How do I achieve Type 1 protection of a soft starter?

Type 1 protection requires that, in the event of a short circuit on the output of a soft starter, the fault must be cleared without risk of injury to personnel. There is no requirement that the soft starter must remain operational after the fault.

Type 1 protection is provided by HRC fuses or a MCCB that form part of the motor branch circuit.

As a minimum, the protection method must be able to sustain the required motor start current.

Maximum fuse ratings for Type 1 motor protection are specified in UL and IEC standards.

IP	Rating (% Motor FLC)
Fuse (non-time delayed)	300%
Fuse (time delayed)	175%

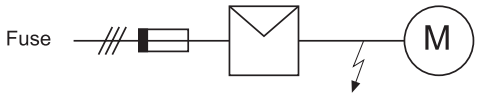
Type 2 Circuit Protection

How do I achieve Type 2 protection of a soft starter?

Type 2 protection requires that in the event of a short circuit on the output of a soft starter the fault must be cleared without risk of injury to personnel or damage to the soft starter.

Type 2 protection is achieved by using semiconductor fuses. These fuses must be able to carry motor start current and have a total clearing $I^2t <$ the I^2t of the soft starter SCRs.

Semiconductor fuses for Type 2 circuit protection are additional to HRC fuses or MCCBs that form part of the motor branch circuit protection.



Refer to the soft starter's user manual for semiconductor fuse recommendations.

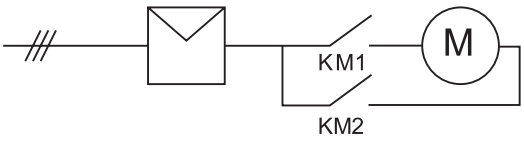
Two-speed Motors

How do they work and can I use a soft starter to control them?

Soft starters can be applied to the two most common types of two-speed motor. In both cases, separate motor protection must be provided for low and high speed operation.

Dahlander motors are special purpose motors often applied to two-speed compressor or fan applications. The motor windings are externally configured using contactors for high speed (dual star) and low speed (delta) operation.

Dual-winding motors have two separate pole configurations (e.g. 4 pole / 8 pole) on a common shaft. Each pole configuration (speed) is selected using an external AC3 rated contactor.

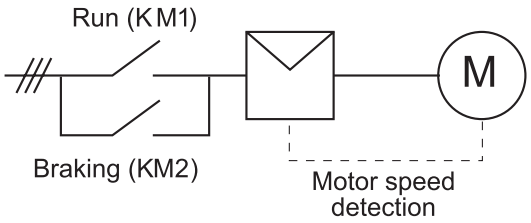


Soft Braking

What is it and when would I use it?

Soft braking is one of two techniques used by soft starters to shorten motor stopping time. The other technique is DC braking.

Soft braking uses reversing contactors on the input of the soft starter. When the soft starter receives a stop command, it operates the reversing contactors and the motor is effectively soft started in the reverse direction. This applies a braking torque to the load.



Compared to DC braking, soft braking:

- causes less motor heating
- provides more braking torque for a given current

Soft braking is better for extremely high inertia loads.

DC Braking

What is it and how is it used?

DC braking uses DC injection to slow the motor.

When the soft starter receives a stop command, it slows the motor to approximately 70% of full speed. The starter then applies maximum brake torque to stop the motor in the programmed time.

Compared with soft braking, DC braking:

- does not require the use of a DC brake contactor
- controls all three phases so that the braking currents and associated heating is evenly distributed through the motor

Slip-ring Motors

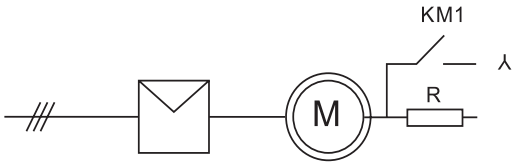
Can they be started with a soft starter?

Yes, provided that the torque available from the motor under the new configuration is sufficient to accelerate the load. This may be difficult to determine and a trial may be required.

Soft starting is not suitable for applications where:

- the slip-ring motor was installed to deliver speed control
- the load requires extreme start torque

To develop starting torque, some resistance must remain in the rotor circuit during motor starting. This resistance must be bridged out using a contactor (AC2 rated for rotor current) once the motor is running close to full speed.



Rotor resistance (R) can be sized using the following formula:

$$R \text{ (per phase)} = 0.2 \times \frac{V_R}{\sqrt{3} \times I_R}$$

$$\text{Power (per phase)} = \frac{(20\% \times \text{motor kW})}{3}$$

Where:

V_R = open circuit rotor voltage

I_R = full load rotor current

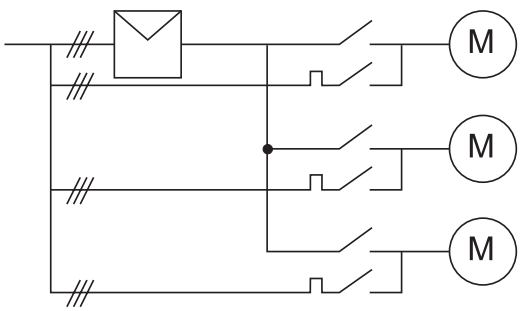
Sequential Starting

Can I use one soft starter to separately control multiple motors?

Yes, one soft starter can control two motors in sequence. However, the control and wiring is complex and expensive and any saving in soft starter cost is often outweighed by additional component and labour costs.

In order to use a soft starter in a sequential starting situation:

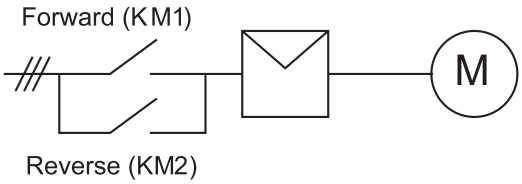
1. Each motor must have a separate:
   - main contactor
   - bypass contactor
   - overload protection
2. The soft starter must be suitably rated for the total start duty.



Reversing

Can soft starters be used to reverse motor direction?

On their own, soft starters cannot run motors in reverse direction at full speed. However, forward and reverse operation can be achieved by using a forward and reverse contactor arrangement.



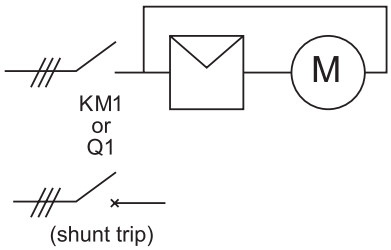
Some soft starters also provide a part speed function that runs the motor at slow speed in either forward or reverse, without a reversing contactor. However, reverse operation is limited to short periods at a fixed slow speed.

Replacing Star-Delta Starters

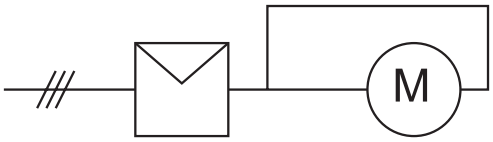
Can I replace a star-delta starter with a soft starter?

Yes.

If the soft starter is capable of inside delta connection, simply connect it in place of the star-delta starter.



If the soft starter is not capable of inside delta connection, connect the delta connection to the output side of the soft starter.



Minimising Start Current

What start current can I expect if I use a soft starter?

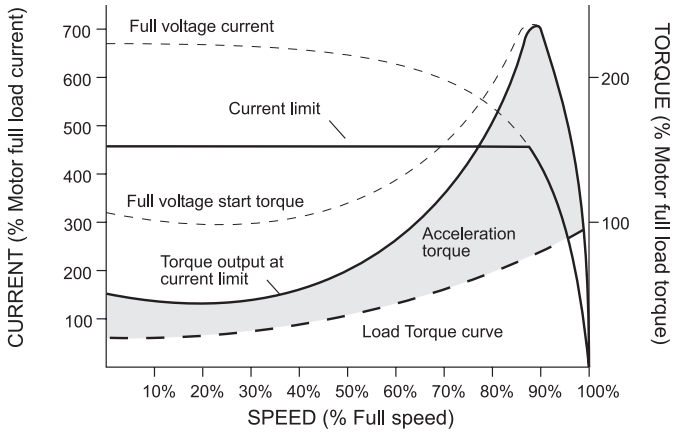
Soft starters can limit start current to any desired level. However, the minimum level of start current for a successful start depends on the motor and load.

To start successfully, the motor must produce more acceleration torque than the load requires, throughout the start. Reducing the start current also reduces the torque produced by the motor.

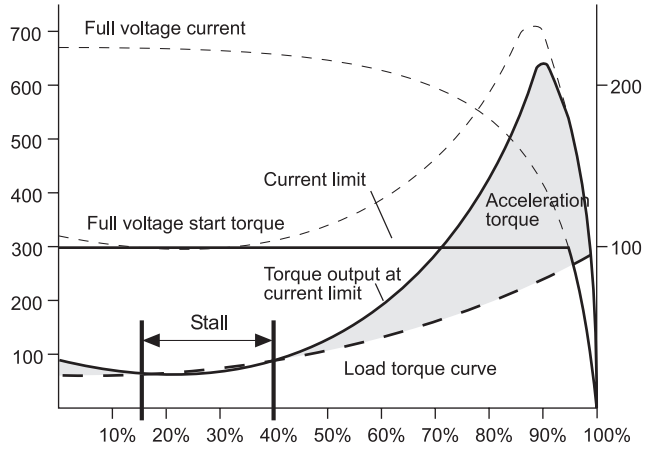
The start current can only be lowered to the point where the torque output remains just greater than the load torque requirement.

The likely start current can be estimated from experience, but more precise predictions require analysis of motor and load speed/torque curves.

Successful Start:



Unsuccessful Start:

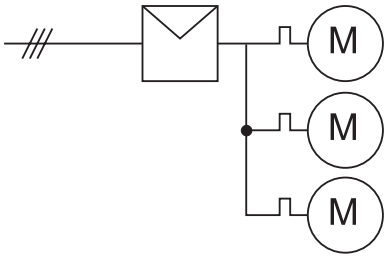


Parallel Starting

Can I use one soft starter to control multiple motors?

Yes. The circuit configuration and soft starter selection depends on the application.

1. Each motor must have its own overload protection.



2. If the motors are the same size and are mechanically coupled, a constant current soft starter can be used.
3. If the motors are different sizes and/or the loads are not mechanically interlocked, a soft starter with a timed voltage ramp (TVR) start profile should be used.
4. The combined motor FLCs must not exceed the soft starter FLC.

How do I install into a sealed enclosure?

Soft starters can be installed in sealed enclosures provided the ambient temperature within the enclosure will not exceed the soft starter's rated temperature.

Heat generated within the enclosure must be dissipated, either through the enclosure's walls or by ventilation. When calculating the heat generated in the enclosure, all heat sources must be considered (e.g. soft starter, fuses, cabling, switchgear etc). The enclosure should be protected from direct sunlight to prevent external heating.

To minimise heating, most soft starters are installed in bypassed configuration.

Harmonics

Are they an issue for soft start applications?

Harmonics are voltages and currents that create unwanted heating in motors, cables and other equipment. Harmonics can also disrupt operation of electronic equipment.

Harmonic generation by soft starters is insignificant and only occurs during starting or soft stopping. IEC 60947-4-2 (8.3.2.1.1) states "harmonic emissions are of short duration during starting, and there are no significant emissions in the FULL-ON state".

No special actions or filtering are required.

Extreme Operating Conditions

How do I select the right soft starter for extreme conditions?

The published ratings for soft starters assume a particular operating environment. If the soft starter needs to operate outside the assumed conditions, the rating must be revised.

Typical factors include:

- Start current
- Start time
- Start frequency (number of starts per hour)
- Duty cycle
- Ambient temperature
- Altitude

Soft Starters

What are the key benefits of soft start?

Soft start enhances motor start performance in many ways including:

- smooth acceleration without the torque transients associated with electromechanical reduced voltage starters
- voltage or current is applied gradually, without the voltage and current transients associated with electromechanical reduced voltage starters
- lower start currents and/or shorter start times because constant current control gives higher torque as motor speed increases
- easy adjustment of start performance to suit the specific motor and load
- precise control over the current limit
- consistent performance even with frequent starts
- reliable performance even if load characteristics vary between starts (e.g. loaded or unloaded starts)

In addition to superior starting performance, soft starters also provide a range of features not available from other reduced voltage starters. These features include:

- soft stop (which helps eliminate water hammer)
- braking
- motor and system protection
- metering and monitoring
- operating history and event logs
- communication network integration

The extra features built into soft starters can reduce the overall installed cost of the equipment and reduce the long-term maintenance requirement.

Star-delta Starters

How does soft start compare with star-delta starting?

Compared with star-delta starters, soft starters are much more flexible and provide a smooth start with no risk of transients.

Star-delta starters offer limited performance because:

- start torque cannot be adjusted to accommodate motor and load characteristics
- there is an open transition between star and delta connection that results in damaging torque and current transients
- they cannot accommodate varying load conditions (e.g. loaded or unloaded starts)
- they do not provide soft stop

The main advantages of star-delta starters are:

- they may be cheaper than a soft starter
- when used to start an extremely light load, they may limit the start current to a lower level than a soft starter (however, severe current and torque transients may still occur).

Primary Resistance Starters

How does soft start compare to primary resistance starting?

Compared with primary resistance starters, soft starters are more flexible and reliable.

Primary resistance starters offer limited performance because:

- start torque cannot be fine-tuned to match motor and load characteristics
- current and torque transients occur at each voltage step
- they are large and expensive
- liquid resistance versions require frequent maintenance
- start performance changes as the resistance heats up, so multiple or restart situations are not well controlled
- unable to accommodate changing load conditions, e.g. loaded or unloaded starts
- they cannot provide soft stop

Auto-transformer Starters

How does soft start compare to auto-transformer starting?

Compared with auto-transformer starters, soft starters are much more flexible and provide a much smoother start.

Auto-transformer starters offer limited performance because:

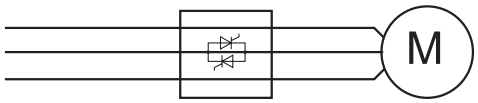
- they offer only limited ability to adjust start torque to accommodate motor and load characteristics
- there are still current and torque transients associated with steps between voltages
- they are large and expensive
- they are especially expensive if high start frequency is required
- they are unable to accommodate changing load conditions. e.g. loaded or unloaded starts
- they are unable to provide soft stop

Soft Starter Formats

Are all three phase soft starters the same?

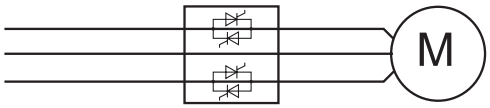
No. There are different styles of soft starter which control the motor in different ways and offer different features.

Single phase torque controllers



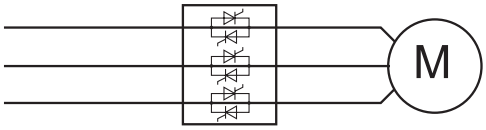
These devices reduce torque shock at start but do not reduce start current. Also known as torque controllers, these devices must be used in conjunction with a direct-on-line starter.

Two phase starters



These devices eliminate torque transients and reduce motor start current. The uncontrolled phase has slightly higher current than the two controlled phases during motor starting. They are suitable for all but severe loads.

Three phase soft starters



These devices control all three phases, providing the optimum in soft start control. Three phase control should be used for severe starting situations.

Motor Thermal Capacity

What is motor thermal capacity?

A motor's thermal capacity is the maximum time a motor can run at locked rotor current from cold. Thermal capacity is also referred to as "maximum locked rotor time" or "maximum DOL start time". This information is usually available from the motor datasheet.

Flying Loads

Can soft starters control an already rotating motor (flying load)?

Yes, soft starters can start motors that are already rotating.

In general, the faster the motor is still rotating, the shorter the start time will be.

If the motor is rotating in the reverse direction, it will be slowed to a standstill and then accelerate forwards.

No special wiring or soft starter setup is required.

Contact AuCom or your distributor for advice on the most energy efficient motor control choice for you.

For more information visit:
www.aucom.com

AuCom
123 Wrights Road,
Christchurch, New Zealand
+64 3 338 8280
www.aucom.com