AuCom

Ready Reckoner

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1 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**	**220-230 V**	**380-400 V**	**440 V**	**500 V**	**660-690 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	25.4
25	35	85	52	45.3	39.4	30.3
30	40	103	60	51.5	45	34.6
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

2 Typical Start Currents

NOTE
These currents and times are a suggestion only and the values required depend on the details of the individual installation (including the characteristics of the starter, motor and load).

Application	Start Current (%FLC)	Start Time (seconds)	Stop Time (seconds)
Agitator	400	20	0
Atomiser	400	20	0
Bottle washer	300	10	0
Centrifuge	450	30	0
Chipper	450	30	0
Compressor			
centrifugal (rotary)			
reciprocating (positive displacement) - loaded	450	30	0
reciprocating - unloaded	400	20	0
screw - loaded	400	20	0
screw - unloaded	350	15	0
Conveyor			
belt	450	30	0
roller	350	15	0
screw	400	20	0
Crusher			
cone	350	15	0
jaw	450	30	0
rotary	350	15	0
vertical impact	350	15	0
Debarker	350	15	0
Dryer	450	30	0
Dust collector	350	15	0
Edger	350	15	0
Fan			
axial (damped)	350	15	0
axial (undamped)	450	30	0
centrifugal (damped)	350	15	0
centrifugal (undamped)	450	30	0
high pressure	450	30	0
Grinder	350	15	0
Hydraulic power pack	350	15	0
Mill			
ball	450	30	0
hammer	450	30	0
roller	450	30	0
Mixer	450	30	0
Pelletiser	450	30	0
Planer	350	15	0
Press	350	15	0
Pump			
bore	300	10	5
centrifugal	350	15	15
positive displacement	400	20	0
slurry	450	30	0
Re-pulper	450	30	0
Rotary table	400	20	0
Sander	400	20	0
Saw			
band	450	30	0
circular	350	15	0

Separator	450	30	0
Shredder	450	30	0
Slicer	300	10	0
Tumbler (see note)	400	20	0

NOTE
The start times and currents for a tumbler vary according to the size of the motor.

FLC <200 A: use 400% FLC for 20 seconds
FLC 200~584 A: use 450% FLC for 30 seconds
FLC >584 A: use 500% FLC for 30 seconds.

3 What are IP ratings?

IEC 60529 specifies 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 (eg accidental touching by hand).	Protected against vertically falling drops of water (eg condensation).
2	Protected against solid objects greater than 12.5 mm (eg fingers).	Protected against direct sprays of water up to 15° from vertical.
3	Protected against solid objects greater than 2.5 mm (eg tools or wires).	Protected against sprays of water up to 60° from vertical.
4	Protected against solid objects greater than 1 mm (eg 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.

4 What are NEMA ratings?

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

NEMA	Protection against solid objects	closest IP equivalent *
1	Indoor, protection from contact.	IP 20
2	Indoor, limited protection from dirt and water.	IP 22
3	Outdoor, some protection from rain, sleet, windblown dust and ice.	IP 55
3R	Outdoor, some protection from rain, sleet and ice.	IP 24
4	Indoor or outdoor, some protection from windblown dust, rain, splashing water, hose-directed water and ice.	IP 66
4X	Indoor or outdoor, some protection from corrosion, windblown dust, rain, splashing water, hose-directed water and ice.	IP 66
6	Indoor or outdoor, some protection from ice, hose-directed water, entry of water when submerged at limited depth.	IP 67
12	Indoor, protection from dust, falling dirt and dripping non-corrosive liquids.	IP 54
13	Indoor, protection from dust, spraying water, oil and non-corrosive liquids.	IP 54

NOTE

* NEMA and IP ratings are not directly equivalent and this information provides an approximate correlation only.

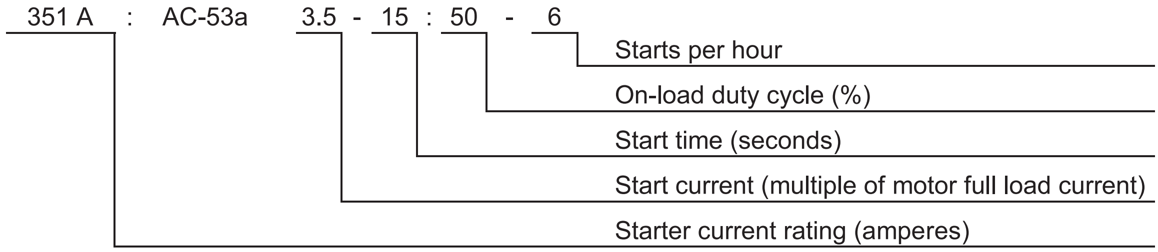
5 What are AC53 Utilisation Codes and what do they show about the soft starter's current rating?

AC53A Utilisation Code

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.

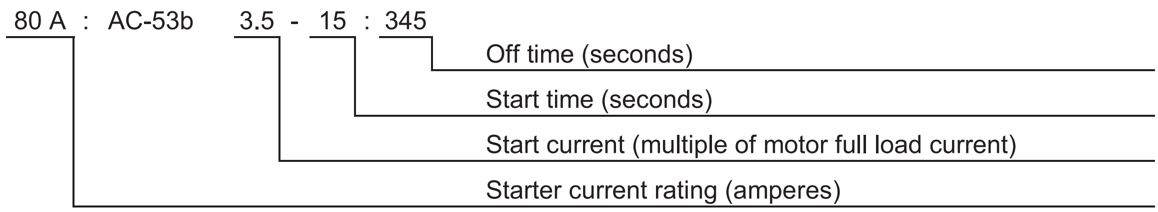


AC53B Utilisation Code

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 in the conditions specified in the AC53b code - the soft starter may have a higher or lower current rating in different operating conditions.



6 What are main contactors?

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

A main contactor:

- May be required to meet local electrical regulations.
- 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.

- Protects the soft starter SCRs from severe overvoltage situations (eg lightning strikes).

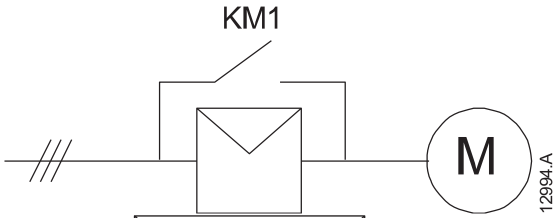
SCRs are most susceptible to overvoltage damage when in the off state. A main contactor disconnects the SCRs from the supply when the motor is not running, preventing possible damage.

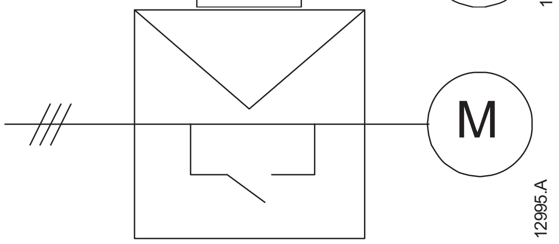
Main contactors should be AC3 rated for the motor FLC.

7 What are bypass contactors?

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:

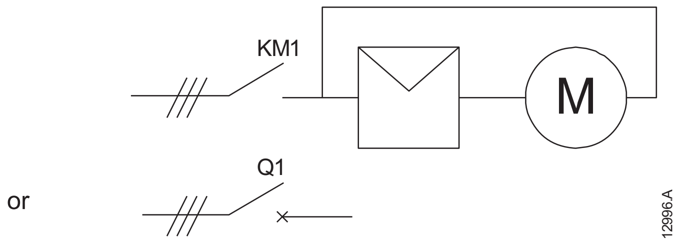
- Allow soft starters to be installed in sealed enclosures
- Eliminate the cost of forced-air cabinet ventilation
- Save energy by eliminating SCR losses during run

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.

8 What is an inside delta connection?

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 cabling 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.

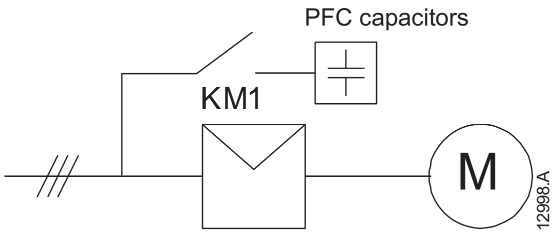
Only motors that allow each end of all three motor windings to be connected separately can be controlled using the inside delta connection method.

Not all soft starters can be connected in inside delta.

9 What is power factor correction?

Individual power factor correction capacitors can be used with soft starters, provided 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.

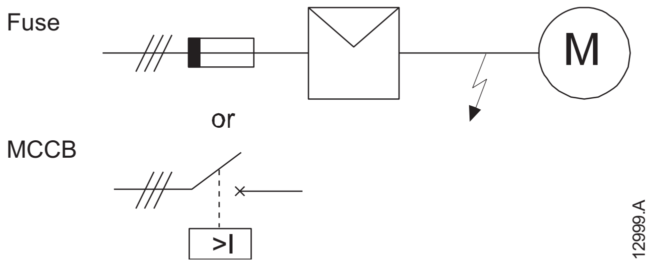


PFC capacitors can be sized using the following formula:

kVA (Cap) = $\sqrt{3}$ x Vline x 0.8 x motor no load current

10 How do I ensure Type 1 circuit protection?

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.

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

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

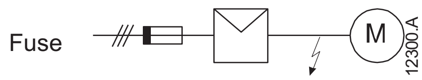
As a minimum, the protection method must be able to sustain the required motor start current.

11 How do I ensure Type 2 circuit protection?

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.

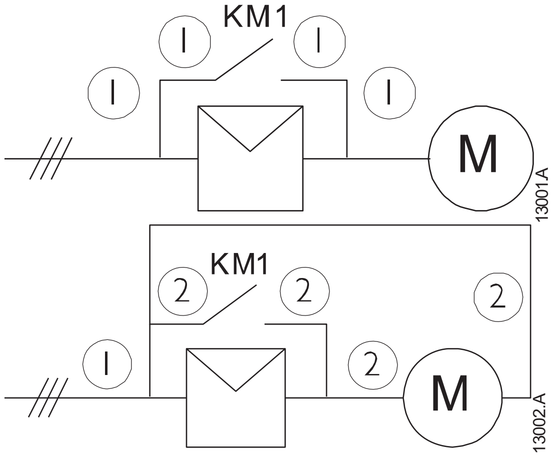


Refer to the soft starter's user manual for semiconductor fuse recommendations.

12 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.

Supply cable rating
> nominal fuse/MCCB rating
> motor FLC x 1.2



Inside delta motor circuit cable rating
> motor FLC x 0.7

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

13 What is the maximum length of cable run between a soft starter and the motor?

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 metres. Consult the soft starter manufacturer for advice - you will need to provide details about mains voltage, mains frequency and the soft starter model.

14 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 electro-mechanical reduced voltage starters.
- Voltage or current is applied gradually, without the voltage and current transients associated with electro-mechanical 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 (eg loaded or unloaded starts).

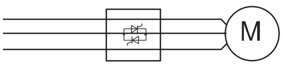
In addition to superior starting performance, soft starters also provide a range of features not available from other reduced voltage starters. This includes areas such as:

- Soft stop (which helps eliminate water hammer)
- Braking
- Motor and system protection
- Metering and monitoring
- Operating history and event logs
- Communication network integration

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

15 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.



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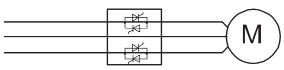
Single phase control
These devices reduce torque shock at start but do not reduce start current. Also known as torque controllers, these devices must be used in conjunction with a direct on-line starter.



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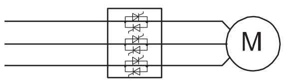
Two phase control
These devices eliminate torque transients and reduce motor start current. The uncontrolled phase has slightly higher current than the two controlled phases during motor starting. They are suitable for all but severe loads.



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

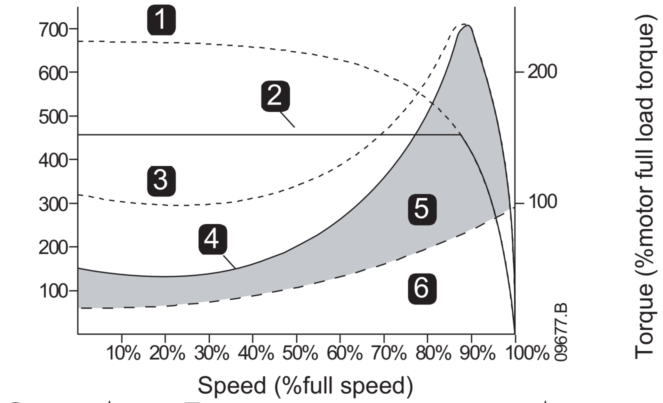
16 What is the minimum start current with a soft starter?

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.

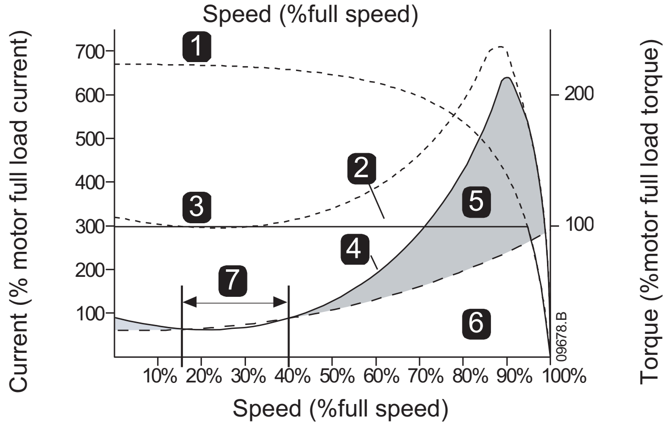
To start successfully, the motor must produce more acceleration torque than the load requires, throughout the start.

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.



1: Full voltage current
2: Current limit
3: Full voltage start torque
4: Torque output at current limit
5: Acceleration torque
6: Load torque



1: Full voltage current
2: Current limit
3: Full voltage start torque
4: Torque output at current limit
5: Acceleration torque
6: Load torque
7: Stall

17 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.

How is the motor thermal model different from other forms of overload protection?

- The motor thermal model offers precise motor protection normally only available from high-end motor protection relays.
- Protection is based on the motor's actual thermal capacity.
- Motor temperature is continually modelled.
- The thermal model accounts for different heating and cooling rates when the motor is in different operating states (starting, running or stopped).
- Both iron and copper losses are modelled.
- The accuracy of the motor thermal model means the motor can be used to its maximum potential without nuisance tripping.

Thermal overload relays are imprecise because:

- The mass of the bimetal strips in the thermal overload is fixed and cannot be altered to match motor characteristics.
- They do not account for iron loss.
- They do not allow for different cooling rates at different stages of motor operation.
- The bimetal strips are affected by their ambient temperature, which is typically different from the motor's ambient temperature.
- Adjustment is imprecise.

Inverse time-current and I^2T electronic overloads offer limited protection because:

- The trip curves do not closely match motor heating.
- Inverse time-current protection does not account for motor temperature before the overload.
- They do not typically allow for differing cooling rates at different stages of motor operation.
- They do not account for iron loss.
- Adjustment is limited.

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- They do not typically allow for differing cooling rates at different stages of motor operation.
- They do not account for iron loss.
- Adjustment is limited.

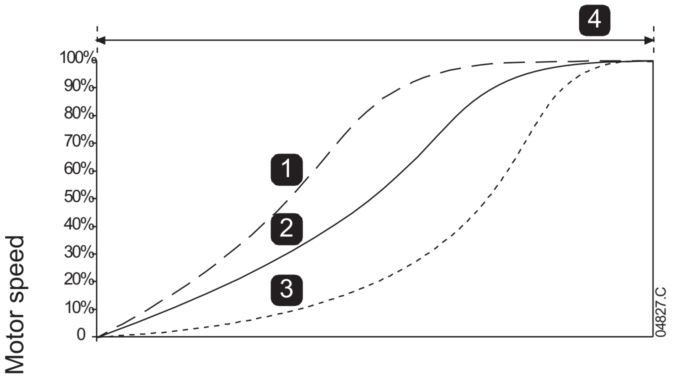
19 What is Adaptive Control?

Adaptive Control is a new intelligent motor control technique that controls current to the motor in order to start or stop the motor within a specified time and using a selected profile.

For soft starting, selecting an adaptive profile that matches the inherent profile of the application can help smooth out acceleration across the full start time. Selecting a dramatically different profile can somewhat neutralise the inherent profile.

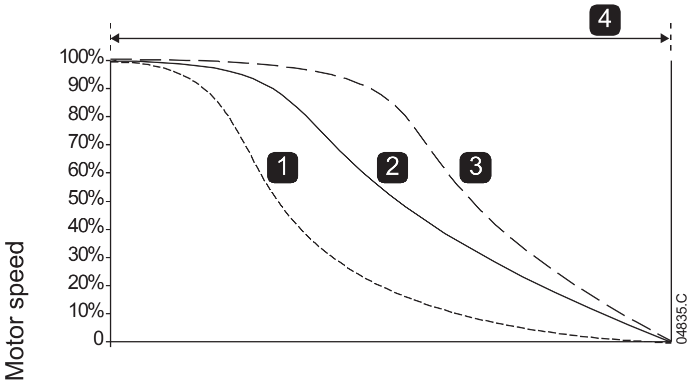
For soft stopping, adaptive control can be useful in extending the stopping time of low inertia loads.

The soft starter monitors the motor's performance during each start, to improve control for future soft starts. The best profile will depend on the exact details of each application. If you have particular operational requirements, discuss details of your application with your local supplier.



Adaptive start profile:

1	Early acceleration
2	Constant acceleration
3	Late acceleration
4	Start time



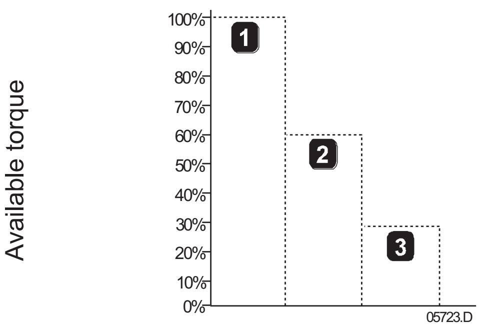
Adaptive stop profile:

1	Early deceleration
2	Constant deceleration
3	Late deceleration
4	Stop ramp time

20 What is Jog?

Jog runs the motor at reduced speed, to allow alignment of the load or to assist servicing. The motor can be jogged in either forward or reverse direction.

The maximum available torque for jog forward is approximately 50%~75% of motor full load torque (FLT) depending on the motor. The torque when the motor is jogged in reverse is approximately 25% to 50% of FLT.



1. Motor FLT
2. Jog forward maximum torque
3. Jog reverse maximum torque

21 What is DC braking 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.

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

22 What is soft braking and how is it used?

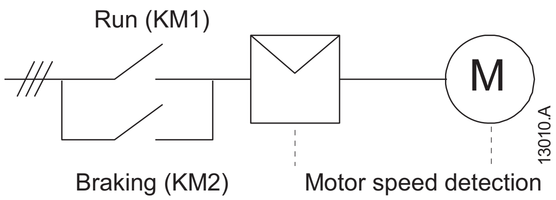
Soft braking is one of two techniques used by soft starters to shorten motor stopping time. The other technique is DC braking.

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:

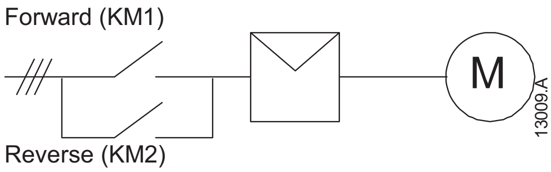
- causes less motor heating
- provides more braking torque for a given current

Soft braking is better for extremely high inertia loads.



23 Can soft starters reverse the 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.

24 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 rotating in the forward direction, 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. Allow for the extended start time when rating the soft starter.

No special wiring or soft starter setup is required.

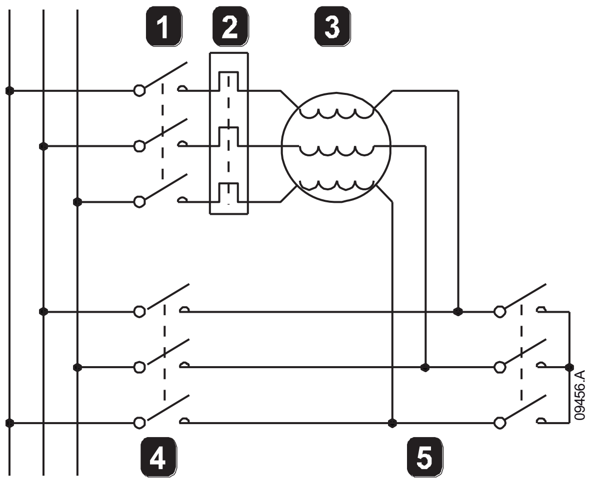
25 How does soft start compare with star/delta starting?

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 (eg loaded or unloaded starts).
- They cannot provide soft stop.

The main advantages of star/delta starters are:

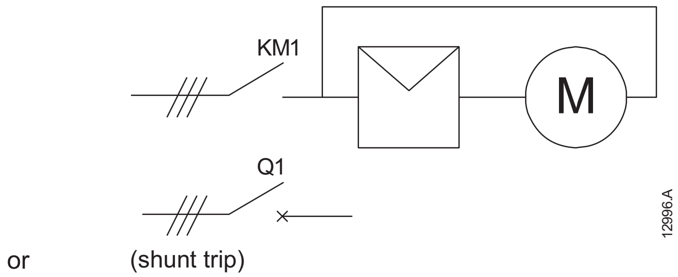
- They may be cheaper than a soft starter.
- When used to start an extremely light load, they may limit the start current to a lower level than a soft starter. However, severe current and torque transients may still occur.



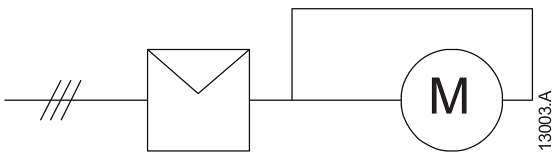
1	Main contactor
2	Thermal overload
3	Motor (three-phase)
4	Delta contactor
5	Star contactor

26 How do I replace a star/delta starter with a soft starter?

If the soft starter supports inside delta connection, simply connect it in place of the star/delta starter.



If the soft starter does not support inside delta connection, connect the delta connection to the output side of the soft starter.

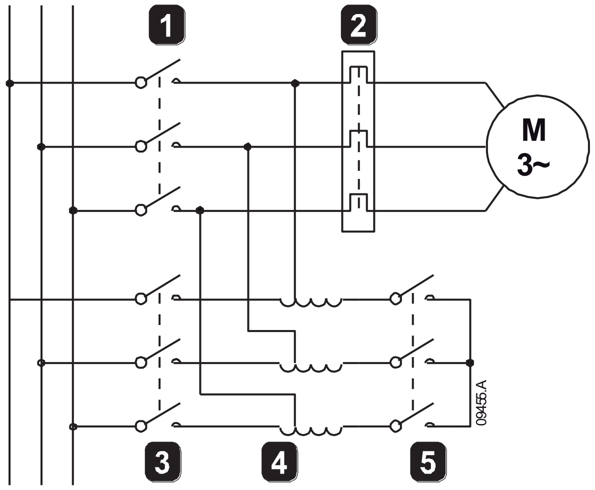


27 How does soft start compare to auto-transformer starting?

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 cannot accommodate changing load conditions (eg loaded or unloaded starts).
- They cannot provide soft stop.



1	Run contactor
2	Thermal overload
3	Start contactor (A)
4	Auto-transformer
5	Start contactor (B)

28 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 situation are not well controlled.
- They cannot accommodate changing load conditions (eg loaded or unloaded starts).
- They cannot provide soft stop.

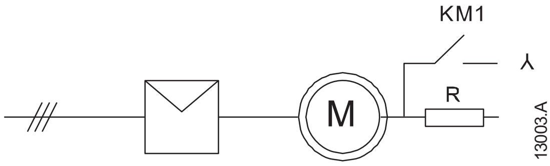
29 Can slip-ring motors be started with a soft starter?

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.



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

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

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

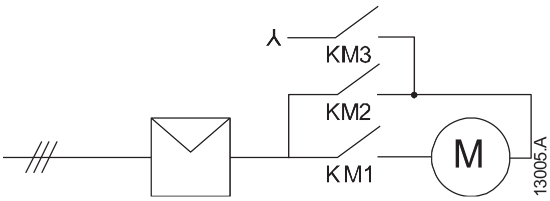
Where V_R= open circuit rotor voltage

I_R= full load rotor current

30 How do two-speed motors work and can I use a soft starter to control them?

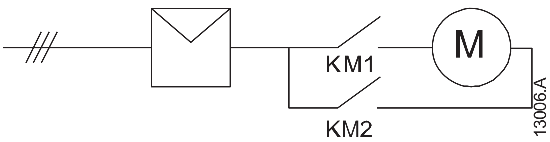
Soft starters can be applied to the two most common types of two-speed motor. In both cases, separate motor protection must be provided for low and high speed operation.

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.



KM1, KM3 = High speed
KM2 = Low speed

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



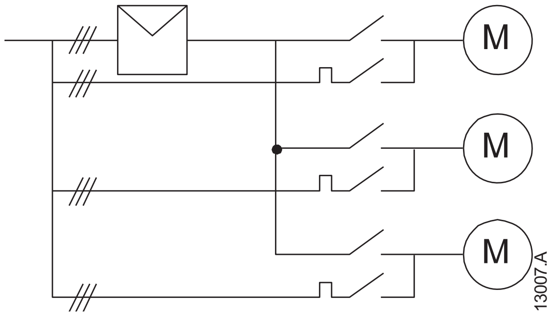
PAM (Pole Amplitude Modulated) motors alter the speed by effectively changing the stator frequency using external winding configuration. Soft starters are not suitable for use with this type of two-speed motor.

31 Can one soft starter control multiple motors separately for sequential starting?

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:

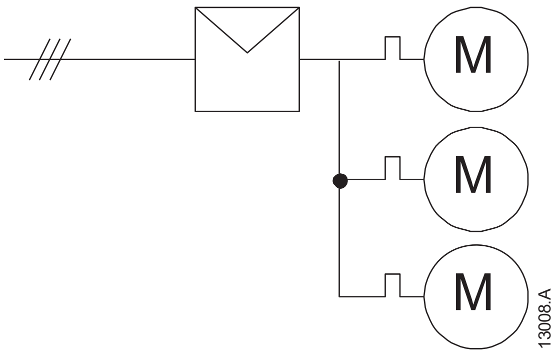
- Each motor must have a separate main contactor, bypass contactor and overload protection
- The soft starter must be suitably rated for the total start duty.



32 Can one soft starter control multiple motors for parallel starting?

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.



33 Which soft starter is best 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 according to the manufacturer's instructions.

Typical factors include:

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

34 How are soft starters installed in 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 (eg soft starter, fuses, cabling and switchgear). The enclosure should be protected from direct sunlight to prevent external heating.

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

35 What are harmonics?

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

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