EBOOK

Where do I start?

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

RIGHT FROM THE START

AuCom
MOTOR CONTROL SPECIALISTS

We get lots of questions regarding how to select and implement the best soft start solution. In this eBook we've compiled the answers to a number of the most common topics to help you make the most of soft start in your application.

There's more information on our website, or you can follow us on Twitter @softstarters. You can also talk to your local distributor of AuCom products. A directory is available at www.aucom.com.

Thanks for reading.

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RIGHT FROM THE START

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Soft Starter Model Selection

There are several steps involved in selecting the soft starter model most appropriate for your installation. Bypass type, the motor connection method, start duty and operating conditions must all be considered.

BYPASSED OR NON-BYPASSED?

While soft starters operate full time to control and protect the motor, the soft starter power section may be bypassed when the motor is in run mode.

The advantages of bypassing the soft starter while in run mode are:

- Greater operating efficiency (>99.5%)
- Reduced heat in the enclosure (eliminates the need for enclosure ventilation)

Many soft starters include an internal bypass contactor. Those that don't can be bypassed externally if desired. In this case, the FLC rating of the soft starter will be increased because the power circuit is not operating during the run mode and is thus cooler at the beginning of the next start.

DECIDE HOW THE MOTOR WILL BE CONNECTED

Soft starters are typically connected in In-line configuration (also called 3 wire connection). However, many soft starters also allow connection in the Inside Delta configuration (also called 6 wire connection). A 6 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 - and allows the starter to control a motor larger than its normal full load current rating.

When using inside delta connection a main contactor or shunt tip 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 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 method.

DETERMINE THE START DUTY AND OPERATING CONDITIONS

Some machines such as centrifugal pumps are easy to start and require lower low starting current. Others such as rock crushers require higher starting currents. Consider the machine you are starting and determine the required level of start duty. Soft start suppliers can advise on duty selection. Please contact us if you would like assistance to determine the appropriate start duty for your application.

Next consider the operating conditions including starts per hour, ambient temperature and altitude.

Consult the soft start catalogue or brochure and select the ratings table that reflects how the soft starter will be installed and operated. Select a soft start model with a FLC rating greater than or equal to the motor FLC at the appropriate application duty.

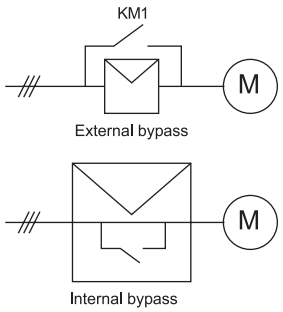
System Design

The following topics are all important considerations when designing a system to ensure maximum efficiency and reliability.

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.

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)

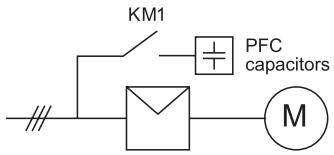
SCRs are most susceptible to overvoltage damage when in the off state. A main contactor disconnects the SCRs from the supply when the motor is not running, preventing possible damage.

Main contactors should be AC3 rated for the motor FLC.

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. A soft starter status relay can be used to control the contactor.

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) = √3 x Vline x 0.8 x motor no load current

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.

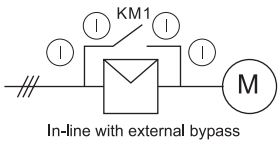
HOW DO I SELECT CABLE WHEN INSTALLING A SOFT STARTER?

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

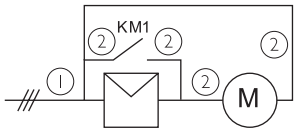
Supply cable rating

> nominal fuse/MCCB rating

> motor FLC x 1.2



In-line with external bypass



Inside delta with external bypass

Inside delta motor circuit cable rating

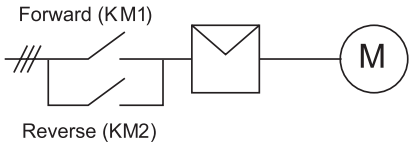
> motor FLC x 0.7

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.

Advanced soft starter applications

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.

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.

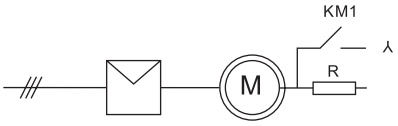
CAN CAN SLIP-RING MOTORS BE STARTED WITH A SOFT STARTER?

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.



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

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

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

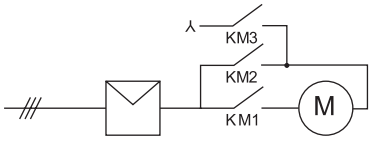
Where V_R= open circuit rotor voltage

I_R= full load rotor current

HOW DO TWO-SPEED MOTORS WORK AND CAN I USE A SOFT STARTER TO CONTROL THEM?

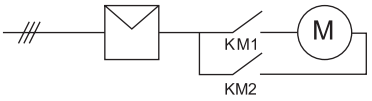
Soft starters can be applied to the two most common types of two-speed motor. In both cases, separate motor protection must be provided for low and high speed operation.

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.



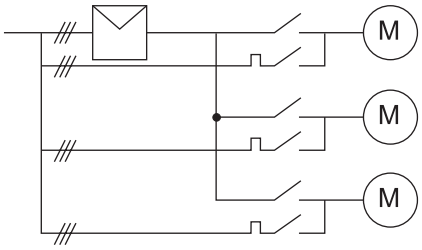
PAM (pole amplitude modulated) motors alter the speed by effectively changing the stator frequency using external winding configuration. Soft starters are not suitable for use with this type of two-speed motor.

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



CAN ONE SOFT STARTER CONTROL MULTIPLE MOTORS FOR PARALLEL STARTING?

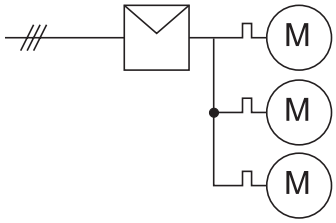
Yes. The circuit configuration and soft starter selection depends on the application.

1. Each motor must have its own overload protection.

2. If the motors are the same size and are mechanically coupled, a soft starter with a constant current start profilecan 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.



General tech tips (Appendix)

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

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 (eg accidental touching by hand)	Protected against vertically falling drops of water (eg condensation)
2	Protected against solid objects greater than 12 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 (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.

NEMA RATINGS

NEMA 250 is a 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

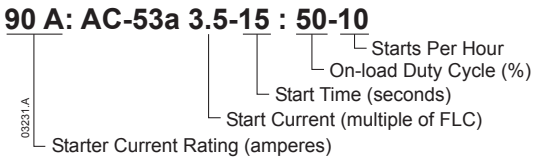
AC53 UTILISATION CODES

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.

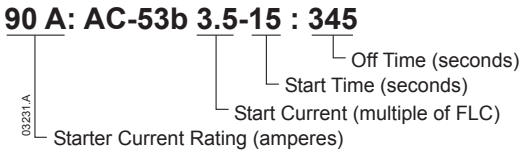


AC53B Utilisation Code

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.



Notes

Have you read our 'Get your motor running' series?

The starting function of motors is often misunderstood, impacting motor performance and compromising energy efficiency.

We've developed a series of technical white papers to provide a detailed introduction to the theory of starting motors, based on the work of electronics design expert Mark Empson, co-founder of AuCom Electronics.

The following topics are covered throughout the five part series:

- Reduced voltage starting of three phase induction motors
- Differing start torque requirements of machines and motor loads
- Motor starting solutions
- Solid state soft starters
- Variable frequency control

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