SOFTDRIVE 200 SERIES DESIGN GUIDE

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ISO 9001:2000
FM 60622

ISO 14001:1996
EMS 76969

Contents

1.0 Warnings

High Voltage Warning

The SAF 200 contains dangerous voltages when connected to line voltage. Only a competent electrician should carry out the electrical installation. Improper installation of the motor or the SAF 200 may cause equipment failure, serious injury or death. Follow this manual, the relevant IEC standard and local safety codes.

Safety Regulations

1. The soft starter must be disconnected from the mains if repair work is to be carried out.

It is the responsibility of the user or the person installing the SAF 200 to provide proper grounding and branch circuit protection according to the relevant IEC standard and local safety codes.

Warning Against Unintended Start

1. The motor can be brought to a stop by means of digital or bus commands while the soft starter is connected to the mains.
   If personal safety considerations make it necessary to ensure that no unintended start occurs, these stop functions are not sufficient.
2. A motor that has been stopped may start if faults occur in the electronics of the soft starter, or if a temporary fault in the supply mains or the motor connection ceases.

Symbols Used in this Manual

When reading this manual you will come across different symbols that require special attention. The symbols used are the following:

NB!
Indicates something to be noted by the reader

Indicates a general warning

Indicates a high voltage warning

Avoiding Soft Starter Damage

Please read and follow all instructions in this manual. Additionally, take special note of the following:

1. Do not connect power factor correction capacitors to the soft starter output. Static power factor correction, if used, must be connected on the mains side of the soft starter.
2. Do not apply incorrect voltages to the SAF 200 control inputs.

Electrostatic Precaution: Electrostatic discharge (ESD). Many electronic components are sensitive to static electricity. Voltages so low that they cannot be felt, seen or heard, can reduce the life, affect performance, or completely destroy sensitive electronic components. When performing service, proper ESD equipment should be used to prevent possible damage from occurring.

2.0 Softdrive 200 Series Overview

2.1 Description

The S2S Electronics Softdrive 200 Series comprises two separate ranges:

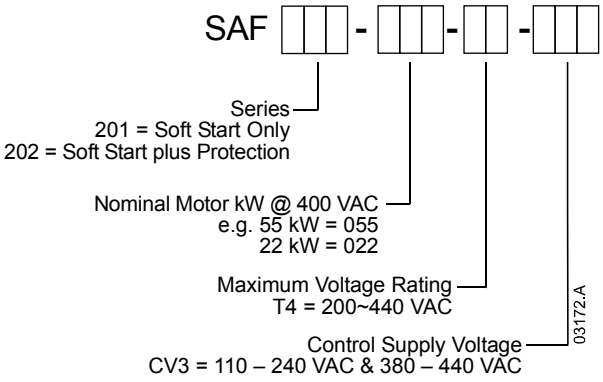
- SAF 201
- SAF 202

SAF 201 and SAF 202 soft starters share a common power and mechanical design, but offer different levels of functionality.
SAF 201 soft starters provide TVR (Timed Voltage Ramp) starting and stopping control and are designed for use with an external motor protection device.
SAF 202 soft starters provide Current Limit starting control, TVR soft stop and include a range of motor protection functions.

NB!
This manual makes reference to SAF 200, SAF 201 and SAF 202. The SAF 200 designation is used when referring to characteristics common to both the SAF 201 and SAF 202 ranges. In all other cases the text refers to the specific range SAF 201 or SAF 202.

SAF 200 soft starters include an integral bypass function that bypasses the soft starter SCRs during run. This minimises heat dissipation during run and makes the SAF 200 suitable for installation within non-ventilated enclosures without the need for an external bypass contactor.

2.2 Ordering Type Codes



2.3 Ratings

SAF 200 Model	Continuous Ratings (Internally bypassed) @ 40 °C Ambient Temperature, <1000 metres ★	
	Normal	Heavy
015	34 A: AC53b 4-6:354	30 A: AC53b 4-20:340
022	48 A: AC53b 4-6:354	40 A: AC53b 4-20:340
030	60 A: AC53b 4-6:354	49 A: AC53b 4-20:340
037	75 A: AC53b 4-6:594	65 A: AC53b 4-20:580
045	85 A: AC53b 4-6:594	73 A: AC53b 4-20:580
055	100 A: AC53b 4-6:594	96 A: AC53b 4-20:580
075	140 A: AC53b 4-6:594	120 A: AC53b 4-20:580
090	170 A: AC53b 4-6:594	142 A: AC53b 4-20:580
110	200 A: AC53b 4-6:594	165 A: AC53b 4-20:580

★ Contact S2S Electronics for other ratings.

Example

For 22 kW model 48 A: AC53b 4-6:354

48 A:	Starter current rating.
AC53b:	Load category for soft starters with SCRs bypassed during run.
4-6:	400% start current for 6 seconds.
354:	354 seconds between the end of one start to the beginning of the next start (ie 10 starts per hour).

2.4 General Technical Data

Mains Supply (L1, L2, L3):

SAF 200-xxx-T4-xxx	3 x 200 VAC ~ 440 VAC (+ 10% / - 15%)
Supply Frequency (at start)	45 Hz - 66 Hz

Control Supply (A1, A2, A3):

SAF 200-xxx-xx-CV3	110 – 240 VAC (+ 10% / - 15%) or 380 – 440 VAC (+ 10% / - 15%)

Control Inputs

Start Terminal N1	Normally Open, 300 VAC max
Stop Terminal N2	Normally Closed, 300 VAC max

Relay Outputs

Main Contactor (Terminals 13 and 14)	Normally Open
	6 A, 30 VDC resistive / 2 A, 400 VAC, AC11
Programmable Relay (Terminals 23 and 24)	Normally Open
	6 A, 30 VDC resistive / 2 A, 400 VAC, AC11

Environmental

Degree of Protection SAF 200-015 to SAF 200-055	IP20
Degree of Protection SAF 200-075 to SAF 200-110	IP00
Operating Temperatures	- 10 ^{o}C / + 60 ^{o}C
Humidity	5% to 95% Relative Humidity
Pollution Degree	Pollution Degree 3
Vibration	IEC 60068 Test Fc Sinusoidal
	4 Hz – 13.2 Hz: ± 1 mm displacement
	13.2 Hz – 100 Hz: ± 0.7 g

EMC Emission

Equipment class (EMC)	Class A
Conducted radio frequency emission	0.15 MHz – 0.5 MHz: < 90 dB (µV)
	0.5 MHz – 5 MHz: < 76 dB (µV)
	5 MHz – 30 MHz: 80-60 dB (µV)
Radiated radio frequency emission	30 MHz – 230 MHz: < 30 dB (µV/m)
	230 MHz – 1000 MHz: < 37 dB (µV/m)

This product has been designed for Class A equipment. Use of the product in domestic environments may cause radio interference, in which case the user may be required to employ additional mitigation methods.

EMC Immunity

Electrostatic discharge	4 kV contact discharge, 8 kV air discharge
Radio frequency electromagnetic field	0.15 MHz – 1000 MHz: 140 dB (µV)
Rated impulse withstand voltage (Fast transients 5/50 ns)	2 kV line to earth
Rated insulation voltage (Surges 1.2/50 µs – 8/20 ms)	2 kV line to earth, 1 kV line to line
Voltage dip and short time interruption	100 ms (at 40% nominal voltage)

Short Circuit

Rated short-circuit current SAF 200-015 to SAF 200-037	5 kA
Rated short-circuit current SAF 200-045 to SAF 200-110	10 kA

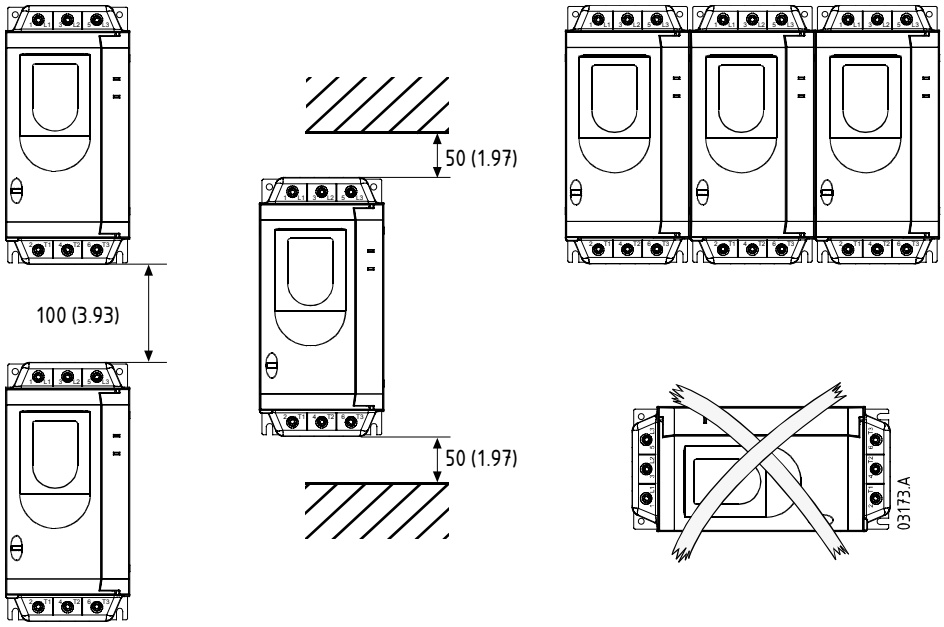
Heat Dissipation

During Start	3 watts / ampere
During Run	< 4 watts

Standards Approvals

C✓	IEC 60947-4-2
CE	IEC 60947-4-2

2.5 Mechanical Installation



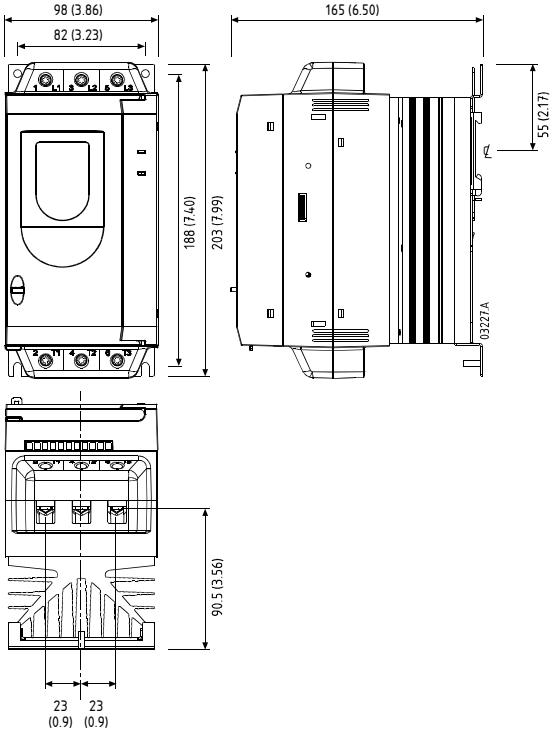
mm (inch)

SAF 200	Din Rail	Foot Mounting
SAF 200-015 ~ SAF 200-030	30 mm	Yes
SAF 200-037 ~ SAF 200-110	Not available	Yes

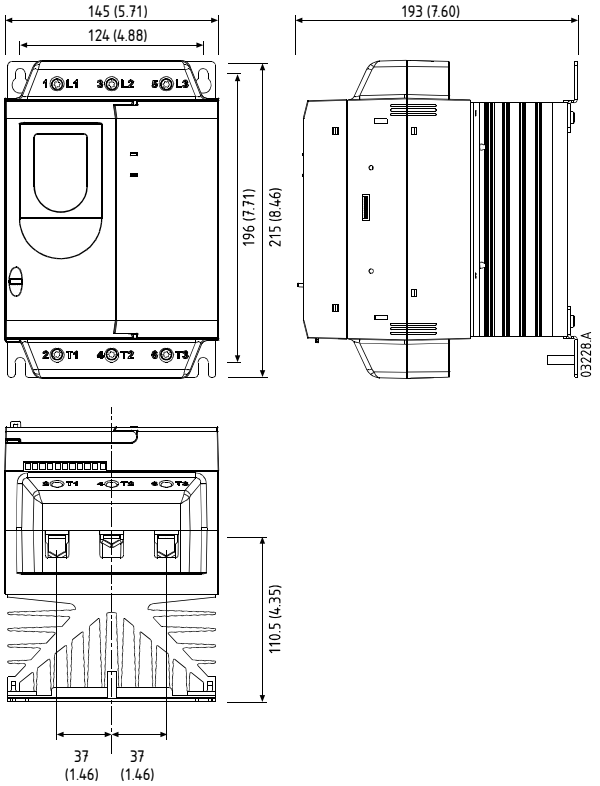
2.6 Dimensions and Weights

All measurements in mm (inch).

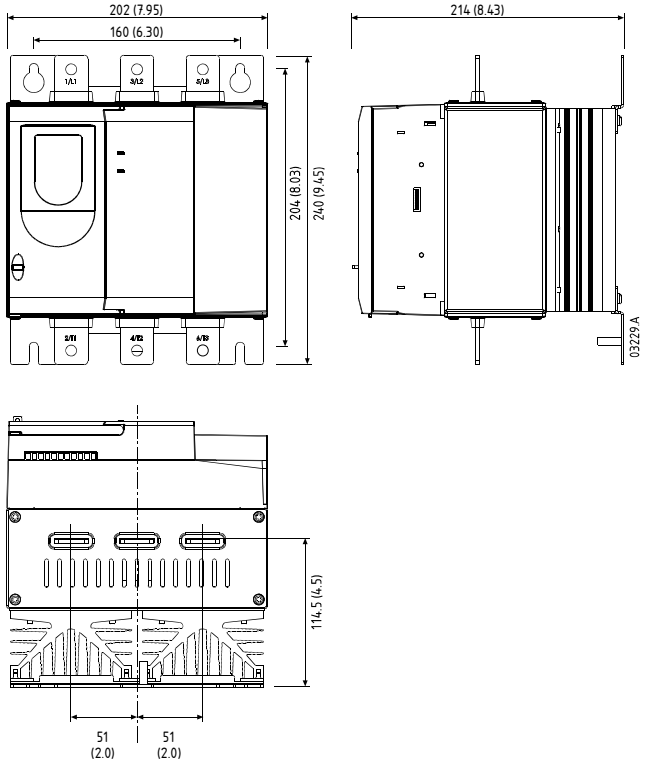
SAF 201-015 ~ SAF 201-030 (2.2 kg / 4.8 lb)
SAF 202-015 ~ SAF 202-030 (2.4 kg / 5.3 lb)



SAF 201-037 ~ SAF 201-055 (4.0 kg / 8.8 lb)
SAF 202-037 ~ SAF 202-055 (4.3 kg / 9.5 lb)



SAF 201-075 ~ SAF 201-110 (6.1 kg / 13.5 lb)
SAF 202-075 ~ SAF 202-110 (6.8 kg / 15.0 lb)



2.7 Cable Size

	mm² (AWG)						mm² (AWG)	
	SAF 200-015 ~ SAF 200-030		SAF 200-037 ~ SAF 200-055		SAF 200-075 ~ SAF 200-110		SAF 200-015 ~ SAF 200-110	
	10 - 35 (8 - 2)	14 (0.55) mm (inch)	25 - 50 (4 - 1/0)	14 (0.55) mm (inch)	N.A.	11 (0.43), 26 (1.02), 8.5 (0.33) mm (inch)	0.14 - 1.5 (26 - 16)	6 (0.24) mm (inch)
	10 - 35 (8 - 2)		25 - 50 (4 - 1/0)		N.A.		0.14 - 1.5 (26 - 16)	
	Torx (T20) 3 Nm 2.2 ft-lb		Torx (T20) 4 Nm 2.9 ft-lb		N.A.		N.A.	
	7 mm 3 Nm 2.2 ft-lb		7 mm 4 Nm 2.9 ft-lb		N.A.		3.5 mm 0.5 Nm max 4.4 in-lb max	

03174.C

75 °C wire. Use copper conductors only.

2.8 Semiconductor Fuses

Semiconductor fuses may be used with SAF 200 soft starters. Use of semiconductor fuses will provide Type 2 coordination and reduce the potential of SCR damage due to transient overload currents and short circuits. SAF 200 soft starters have been tested to achieve Type 2 coordination with semiconductor fuses. The following table provides a list of suitable Bussman fuses. If selecting alternative brands, ensure the selected fuse has a lower total clearing I^2t rating than the SCR, and can carry start current for the full starting duration.

SAF 200 Model	SCR I^2t (A^2s)	Bussman Fuse Square Body (170M)	Fuse Rated Current
SAF 200-015	8000	170M-0116	80 A
SAF 200-022	15000	170M-0117	100 A
SAF 200-030	18000	170M-1319	160 A
SAF 200-037	51200	170M-1319	160 A
SAF 200-045	80000	170M-1320	200 A
SAF 200-055	97000	170M-1321	250 A
SAF 200-075	168000	170M-1322	315 A
SAF 200-090	245000	170M-2621	400 A
SAF 200-110	320000	170M-2621	400 A

2.9 Frequently Asked Questions

- *What is the minimum allowable motor current when using an SAF 201 open loop soft starter?*
  There is no minimum current when using an SAF 201 open loop soft starter.

- *What is the minimum allowable motor current when using an SAF 202 closed loop soft starter?*
  The minimum Motor FLC setting is 50% of the SAF 202 nameplate rating. All the motor protections are based on this setting.

  It is possible to operate an SAF 202 with a small kW motor, for testing purposes. In this case, the motor will effectively start DOL, and the SAF 202 will not protect the motor. The starter will not trip, because there is no undercurrent protection on the SAF 202.

- *What type of motor protection does the SAF 202 have?*
  The SAF 202 has built-in motor overload protection of the electronic "thermal model" type. The motor current is continuously monitored and the expected temperature is calculated based on this monitored current.

  The rate of rise of the calculated motor temperature is determined by the Motor Trip Class setting. The lower this setting, the faster the rate of rise of calculated motor temperature. A Motor Overload trip (x 2 Ready LED flashes) will occur when the calculated temperature reaches 105%. The setting of the Motor Trip Class pot is similar to a motor trip class setting on a standard thermal overload relay.

  An external motor protection device is not required when using an SAF 202 soft starter. The SAF 202 is certified to conform to the IEC 60947-4-2 standard for electronic soft starters. The reliability of the motor protection feature is part of this standard.

- *How do I select an SAF 200 soft starter for duty cycles different from those listed in the standard ratings table?*
  S2S Electronics is happy to advise you on the appropriate starter for different duty cycles.

- *What are the SAF 200 operational ratings before maintenance may be required?*
  The operational ratings for SAF 200 are size-dependent, and are due to the capability of the internal bypass relays:
  Size 1 and 2 (15 ~ 55 kW): 1,000,000 operations
  Size 3 (75 ~ 110 kW): 100,000 operations.

- *When would I use a line contactor?*
  A line contactor may be compulsory for a specific installation. This requirement will be the same whether using a two-phase controlled soft starter or a three-phase controlled soft starter (see Product Note for more detail).

- *When would I use semiconductor fuses?*
  Either when specified for an installation, or when Type 2 coordination is required.

  The SAF 200 is internally bypassed, so the SCRs are in use only during starting and soft stopping.

- *What is the current consumption of the SAF 200 control supply?*
  The steady state consumption of the control supply is 100 mA maximum. However, the short time inrush current at control supply "switch-on" can be as high as 10 A.

- *How can the SAF 202 programmable output relay be used?*
  The programmable output relay provides an N/O contact, which can be used for a “Trip” or “Run” output.

  Trip output:
  The relay operates when the SAF 202 trips on any fault. This can be used to operate a shunt-trip mechanism of an upstream circuit breaker to isolate the motor branch circuit. It could also be used to signal SAF 202 “Trip” status to an automation system.

  Run output:
  The relay operates on completion of start ramp. This can be used to operate a contactor for power factor correction capacitors. It could also be used to signal SAF 202 “Run” status to an automation system.

- *Is the SAF 202 suitable for flying start application?*
  Yes. There is a built-in two second delay between the end of one stop and the beginning of the next start. This delay allows the motor flux to decay, eliminating any chance of the SAF 202 tripping on Power Circuit fault (x 1 Ready LED flash) due to detection of motor back EMF when the start signal is applied. The major effect of a flying start is on the actual time the SAF 202 “current limits”. The ramp-up time will be reduced and is determined by the motor speed on re-application of the start signal.

- *What is the remote start and stop input impedance? Are any special precautions necessary during installation?*
  The N1/N2 input impedance is approximately 400 kΩ @ 300 VAC.

  All control wiring, for long runs, should be either twisted pair or shielded cable with the screen earthed at one end. Control wiring should be separated from power cables by a minimum distance of 300 mm.

  If long cable runs cannot be avoided, the best assurance against noise interference is to install an interposing relay in close proximity to the SAF 200 soft starter.

- *What are the under- and over-frequency trip points for SAF 200 soft starters?*
  The trip points are 40 Hz and 72 Hz. If the frequency falls below 40 Hz or rises above 72 Hz, the soft starter will trip (x 6 Ready LED flashes). These trip points are not adjustable.

  A supply frequency trip will also occur if all three phases from the mains supply are lost, or fall below approximately 120 VAC while the soft starter is running.

  A supply frequency trip will occur if the line contactor drops out during running.

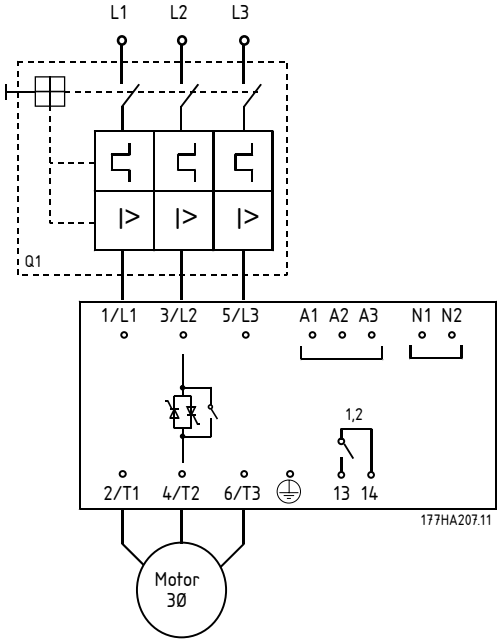
- *Will the motor start DOL if the start ramp of SAF 201 open loop soft starter is set to “full voltage”?*
  No, the SAF 201 will still provide a limited soft start. The voltage is ramped up from 0 to 100% in approximately 0.25 seconds.

3.0 SAF 201 Range

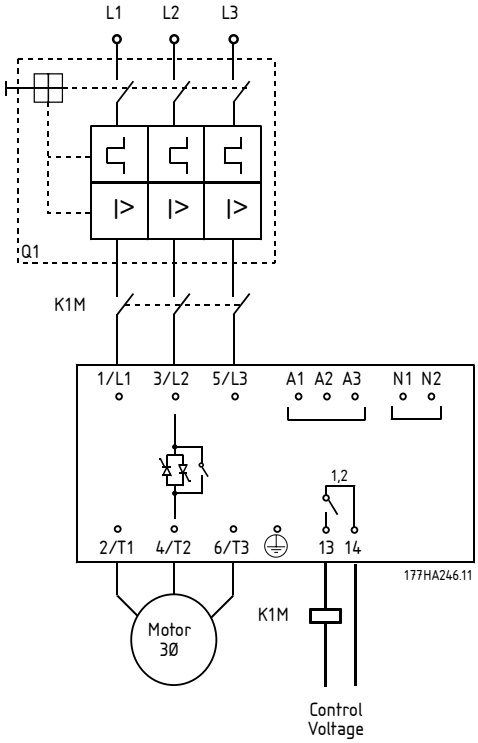
SAF 201 soft starters provide TVR (Timed Voltage Ramp) starting and stopping control and are designed for use with an external motor protection device.

3.1 Electrical Schematic

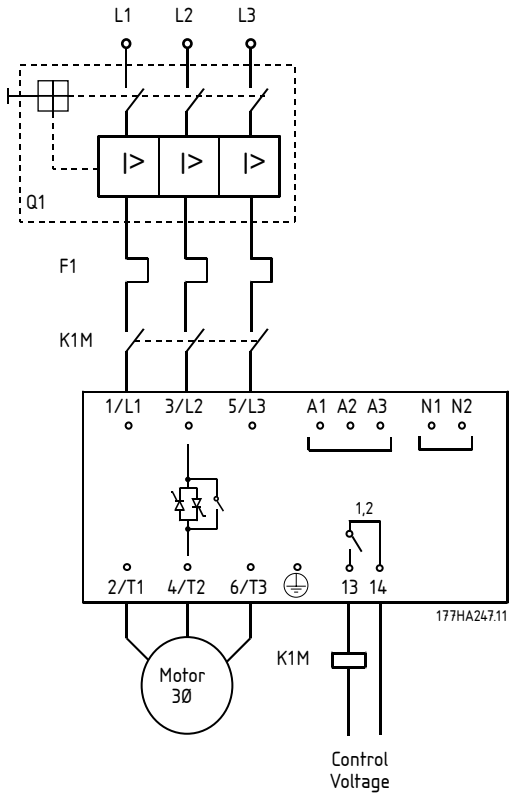
Example 1 – SAF 201 installed with motor protection circuit breaker.



Example 2 – SAF 201 installed with motor protection circuit breaker and line contactor.

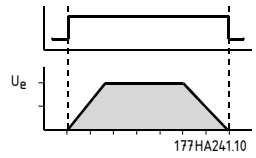


Example 3 – SAF 201 installed with circuit breaker, overload and line contactor.



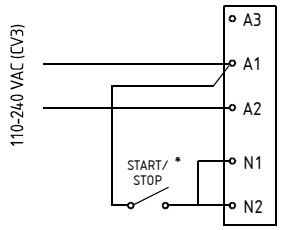
[1] 6 A @ 30 VDC resistive / 2 A 400 VAC AC11

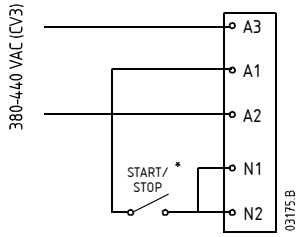
[2] Main Contactor



3.2 Control Circuits

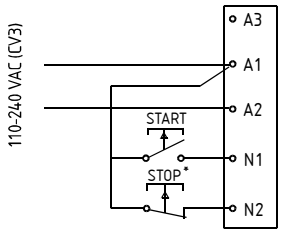
2 Wire Control

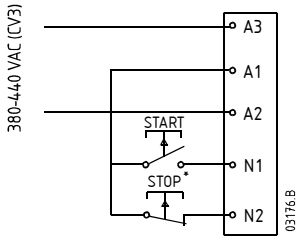




* Also resets the SAF 201

3 Wire Control

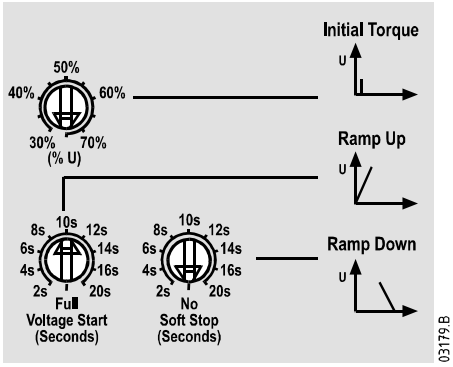




* Also resets the SAF 201

3.3 Functionality

User Adjustments



1 Initial Torque

Value:

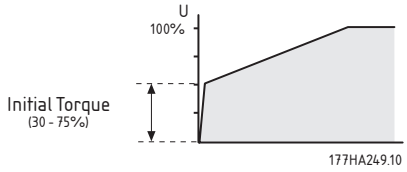
30% – 75% Initial Torque ★ 75%

Function:

Determines the start torque generated by the motor when the start command is first applied.

Description of choice:

Set so that the motor begins to rotate as soon as the start command is given.



2 Ramp Up

Value:

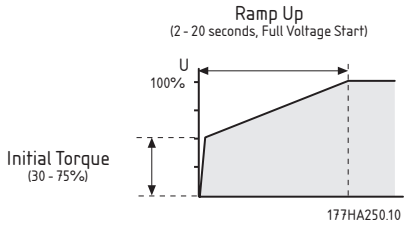
2 – 20 seconds, Full Voltage ★ 10 seconds

Function:

Determines the time taken for voltage to be ramped up to line voltage.

Description of choice:

Set to optimise motor acceleration and/or start current. Short ramp times result in quicker acceleration and higher start currents. Long ramp times result in slower acceleration and lower start current.



3 Ramp Down

Value:

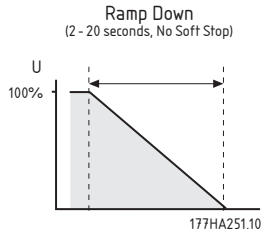
2 – 20 seconds, No Soft Stop ★ No Soft Stop

Function:

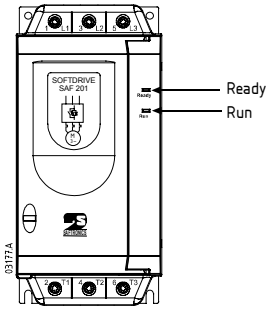
Sets the time of the soft stop voltage ramp. The soft stop function extends motor deceleration time by ramping down voltage supplied to the motor when a stop is initiated.

Description of choice:

Set the ramp time to optimise stopping characteristics for the load.



3.4 Indication



LED	OFF	ON	FLASH
Ready	No control power	Ready	Starter tripped
Run	Motor not running	Motor running at full speed	Motor starting or stopping

3.5 Fault Finding

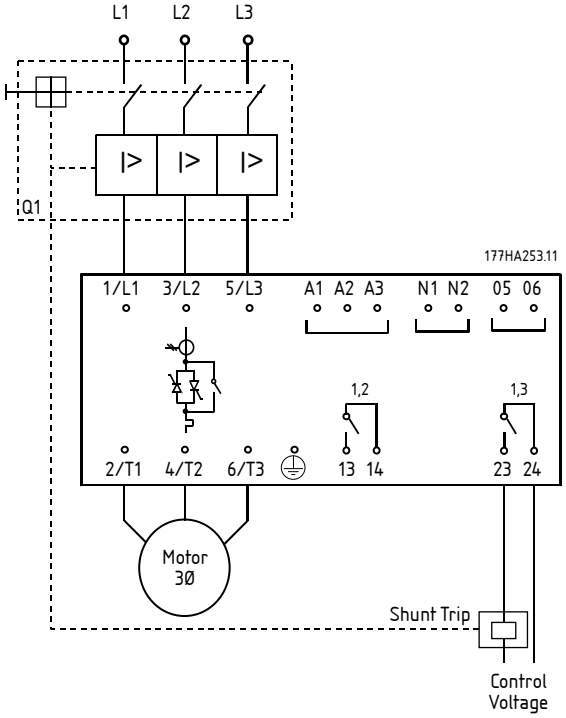
Ready LED	Description
x 1	Power Circuit Fault: Check mains supply L1, L2 and L3, motor circuit T1, T2 and T3 and soft starter SCRs.
x 6	Supply Frequency: Check supply frequency is in range.
x 8	Network Communications Failure (between accessory module and network): Check network connections and settings.
x 9	Starter Communications Failure (between starter and accessory module): Remove and refit accessory module.

4.0 SAF 202 Range

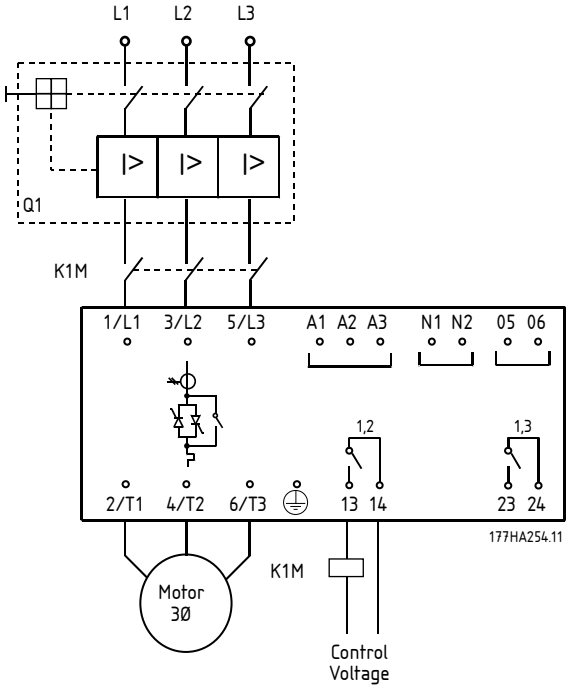
SAF 202 soft starters provide Current Limit control, TVR soft stop and include a range of motor protection features.

4.1 Electrical Schematic

Example 1 – SAF 202 installed with system protection circuit breaker complete with shunt trip device.

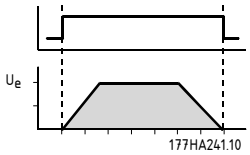


Example 2 – SAF 202 installed with system protection circuit breaker and line contactor.



[1] 6 A @ 30 VDC resistive / 2 A 400 VAC AC11

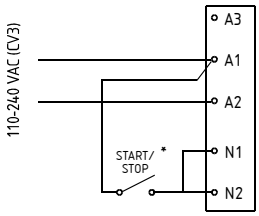
[2] Main Contactor

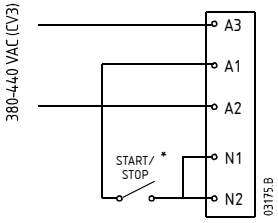


[3] Auxiliary Relay Function = Trip (see Parameter 8)

4.2 Control Circuits

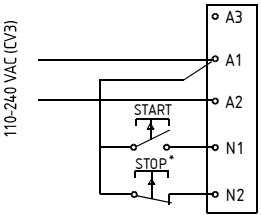
2 Wire Control

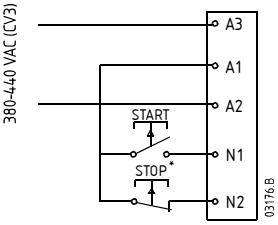




* Also resets the SAF 202

3 Wire Control

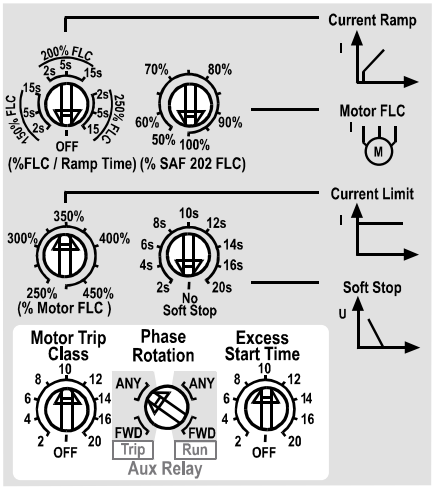




* Also resets the SAF 202

4.3 Functionality

User Adjustments



1 Motor FLC

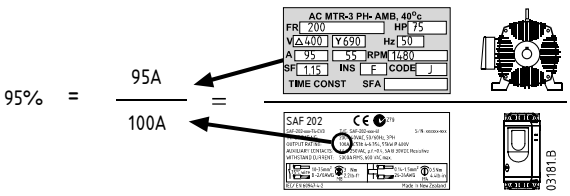
Value:

50% – 100% SAF 202 FLC ★ 100%

Function:

Calibrates the SAF 202 for the Full Load Current of the motor.

Description of choice:



2 Current Limit

Value:

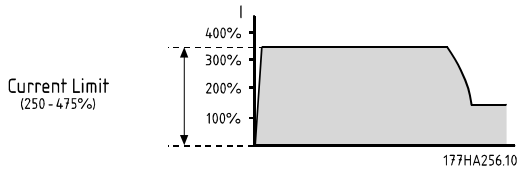
250% – 475% Motor FLC ★ 350%

Function:

Sets the desired starting current limit.

Description of choice:

The current limit should be set so that the motor accelerates easily to full speed.



NB!

Start current must be great enough to allow the motor to produce sufficient torque to accelerate the connected load. The minimum current required to do this is dependent on motor design and load torque requirements.

3 Current Ramp

Value:

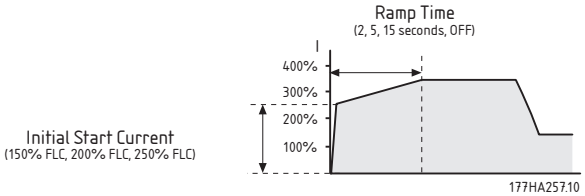
150% Motor FLC (2, 5 or 15 seconds) ★ Off
200% Motor FLC (2, 5 or 15 seconds)
250% Motor FLC (2, 5 or 15 seconds)
Off

Function:

Sets the initial starting current and ramp time for the Current Ramp start mode.

Description of choice:

The Current Ramp start mode modifies the Current Limit start mode by adding an extended ramp.



Typically the Current Ramp start mode would be used in two circumstances.

1. For applications where start conditions vary between starts the Current Ramp mode provides an optimum soft start irrespective of motor loading, eg a conveyor that may start loaded or unloaded.
   In this case make the following settings:
   - Set Parameter 2 *Current Limit* so that the motor can accelerate to full speed when fully loaded.
   - Set Parameter 3 *Current Ramp* so that:
     - the initial start current allows the motor to accelerate when unloaded
     - the ramp time provides the desired starting performance
2. On generator set supplies where a gradual increase in current is required to allow greater time for the generator set to respond to the increased loading.
   In this case make the following settings:
   - Set Parameter 2 *Current Limit* as desired.
   - Set Parameter 3 *Current Ramp* so that:
     - the *Initial Start Current* is lower level than the *Current Limit*

- the ramp time achieves the desired gradual draw of start current

4 Soft Stop Ramp Time

Value:

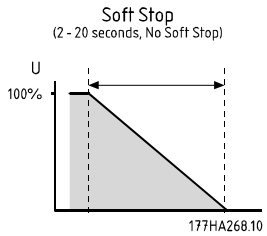
2 – 20 seconds, No Soft Stop ★ No Soft Stop

Function:

Sets the time of the soft stop voltage ramp. The soft stop function extends motor deceleration time by ramping down voltage supplied to the motor when a stop is initiated.

Description of choice:

Set the ramp time to optimise stopping characteristics for the load.



5 Motor Trip Class

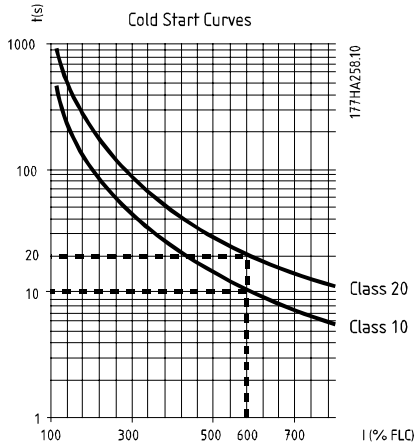
Value:

2 – 20, Off ★ 10

Function:

Calibrates the SAF 202 motor thermal model according to the desired motor trip class.

Description of choice:



6 Excess Start Time Protection

Value:

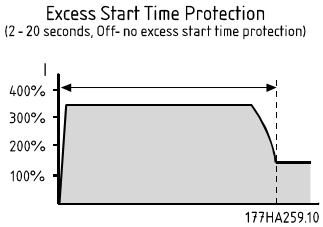
2 – 20 seconds, Off ★ 10 seconds

Function:

Sets the maximum allowable start time.

Description of choice:

Set for a period slightly longer than the normal motor starting time. The SAF 202 will then trip if the start time exceeds normal.



This provides early indication that the application conditions have changed or that the motor has stalled. It can also protect the soft starter from being operated outside its rated start capability.

NB!
Ensure the Excess Start Time protection setting is within the SAF 202 rated capability.

7 Phase Rotation Protection

Value:

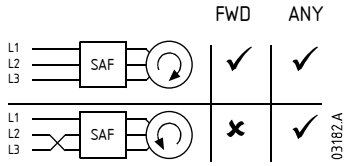
ANY, FWD ★ ANY

ANY = Forward and reverse rotation permitted
FWD = Forward rotation only

Function:

Sets the allowable phase rotation sequence of the incoming supply.

Description of choice:



The SAF 202 itself is phase rotation insensitive. This function allows motor rotation to be limited to one direction only. Set the protection according to application requirements.

8 Auxiliary Relay Function (Terminals 23, 24)

Value:

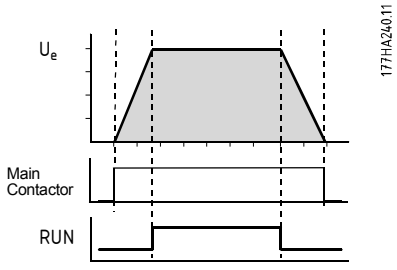
Trip, Run ★ Trip

Function:

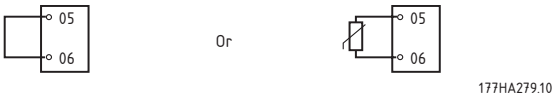
Sets the functionality of the Auxiliary Relay (Terminals 23, 24).

Description of choice:

Set as required, using the combined Phase Rotation/Aux Relay adjustment.

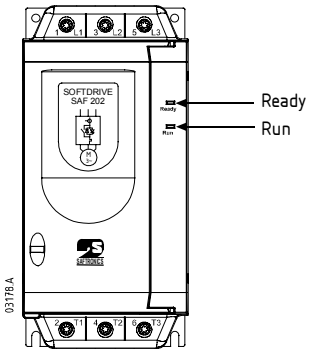


4.4 Motor Thermistor Protection



Motor thermistor cut out value = 2.8 kΩ.

4.5 Indication



LED	OFF	ON	FLASH
Ready	No control power	Ready	Starter tripped
Run	Motor not running	Motor running at full speed	Motor starting or stopping

4.6 Fault Finding

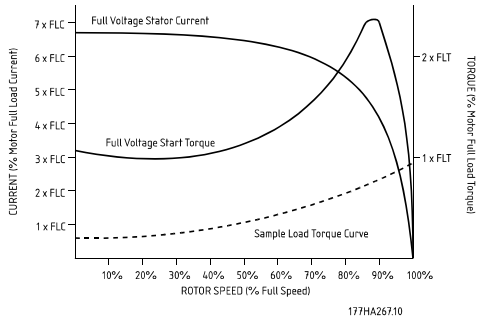
Ready LED	Description
x 1	Power Circuit Fault: Check mains supply L1, L2 and L3, motor circuit T1, T2 and T3 and soft starter SCRs.
x 2	Excess Start Time: Check load, increase start current or adjust Excess Start Time setting.
x 3	Motor Overload: Allow motor to cool, reset soft starter and restart. (SAF 202 cannot be reset until motor has cooled adequately).
x 4	Motor Thermistor: Check motor ventilation and thermistor connection 05 and 06. Allow motor to cool.
x 5	Phase Imbalance: Check line current L1, L2 and L3.
x 6	Supply Frequency: Check supply frequency is in range
x 7	Phase Rotation: Check for correct phase rotation.
x 8	Network Communications Failure (between accessory module and network): Check network connections and settings.
x 9	Starter Communications Failure (between starter and accessory module): Remove and refit accessory module.

5.0 Soft Start Application Guide

This section provides data useful in the selection and application of soft starters.

5.1 Reduced Voltage Starting

When started under full voltage conditions, AC induction motors initially draw locked rotor current (LRC) and produce locked rotor torque (LRT). As the motor accelerates the current falls and the torque increases to breakdown torque before falling to full speed levels. Both the magnitude and shape of the current and torque curves are dependent on motor design.



Motors with almost identical full speed characteristics often vary significantly in their starting capabilities. Locked rotor currents range from as low as 500%, to in excess of 900% of motor FLC. Locked rotor torques range from as low as 70%, to highs of around 230% motor full load torque (FLT).

The motor's full voltage current and torque characteristics set the limits for what can be achieved with a reduced voltage starter. For installations in which either minimising start current or maximising start torque is critical, it is important to ensure that a motor with low LRC and high LRT characteristics is used.

When a reduced voltage starter is used, motor start torque is reduced according to the following formula.

$$T_{ST} = LRT \times \left(\frac{I_{ST}}{LRC} \right)^2$$

T_{ST} = Start Torque
I_{ST} = Start Current
LRC = Motor Locked Rotor Current
LRT = Motor Locked Rotor Torque

Start current can be reduced only to the point where the resulting start torque still exceeds the torque required by the load. Below this point motor acceleration will cease and the motor/load will not reach full speed.

The most common reduced voltage starters are:

- Star/Delta starters
- Auto-transformer starters
- Primary resistance starters
- Soft starters

Star/Delta starting is the cheapest form of reduced voltage starting, however performance is limited. The two most significant limitations are:

1. There is no control over the level of current and torque reduction; these are fixed at one third of the full voltage levels.
2. There are normally large current and torque transients as the starter changes from star to delta. This causes mechanical and electrical stress often resulting in damage. The transients occur because as the motor is spinning and then disconnected from the supply it acts as a generator with output voltage which may be at the same amplitude as the supply. This voltage is still present when the motor is reconnected in delta configuration, and can be exactly out of phase. The result is a current of up to twice locked rotor current and four times locked rotor torque.

Auto-transformer starting offers more control than the star/delta method, however voltage is still applied in steps. Limitations of auto-transformer starting include:

1. Torque transients caused by switching between voltages.
2. Limited number of output voltage taps restricts the ability to closely select the ideal starting current.
3. High price for models suitable for frequent or extended starting conditions.
4. Cannot provide an effective reduced voltage start for loads with varying start requirements. For instance, a material conveyor may start loaded or unloaded. The auto-transformer starter can only be optimised for one condition.

Primary resistance starters also provide greater starting control than star/delta starters. However, they do have a number of characteristics that reduce their effectiveness. These include:

1. Difficult to optimise start performance when commissioning because the resistance value must be calculated when the starter is manufactured and is not easily changed later.
2. Poor performance in frequent starting situations because the resistance value changes as heat is generated in the resistors during a start. A long cool down period is required between starts.

3. Poor performance for heavy duty or extended starts because heat build-up in the resistors changes the resistance value.
4. Cannot provide an effective reduced voltage start for loads with varying start requirements.

Soft starters are the most advanced of the reduced voltage starters. They offer superior control over current and torque as well as incorporating advanced motor protection and interface features. The main starting advantages soft starters offer are:

1. Simple and flexible control over starting current and torque.
2. Smooth control of voltage and current free from steps or transitions.
3. Capable of frequent starting.
4. Capable of handling changing start conditions.
5. Soft stop control to extend motor deceleration times.
6. Braking control to reduce motor deceleration times.

5.2 Types of Soft Start Control

The term 'soft start' is applied to a range of technologies. These technologies all relate to motor starting but there are significant differences in the methods used and the benefits available.
Some of the key differences are described below.

Control philosophy: Soft starters can generally be divided into two groups.

- Timed Voltage Ramp (TVR) systems
- Current controlled systems

TVR starters control voltage applied to the motor in a preset manner and receive no feedback on motor starting current. Control of start performance is provided to the users through settings such as Initial Voltage and Ramp Up Time. Soft Stop is also commonly available and provides the ability to extend motor stopping times.
Current controlled soft starters monitor motor current and use this feedback to adjust voltage so that user specified starting current is maintained. Soft Stop is also provided as are range of motor protection functions.

Power assemblies: Soft starters can provide control of one, two or all three phases.
Single-phase controllers remove the torque shock associated with motor starting but provide no significant current reduction. They must be used with a line contactor and motor overload. They are suitable for very small motors and should only be applied to light applications with low to medium start frequency.

Two-phase controllers control two phases while the third phase is uncontrolled. These controllers provide soft start and current reduction. Care should be taken to ensure that the control algorithms of two-phase controllers balance the output waveform in order to provide a symmetrical waveform. Basic two-phase controllers subject the motor to an asymmetrical output waveform which creates a DC field in the motor. This stationary DC field increases the required start current and increases motor heating. Such unbalanced controllers should not be applied to high inertia loads or in situations with high start frequencies. Three-phase controllers control all phases and are best suited for very large motors.

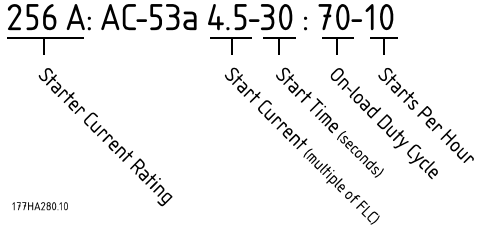
External or internal bypass connection: The SCRs in a soft starter can be bypassed once the motor is up to speed. This reduces heat generation and prevents damage to the SCR from overcurrent or overvoltage events that occur while the motor is running. Some soft starters include built-in bypass contactors while other provide terminals for connection of an external bypass contactor.

5.3 Understanding Soft Starter Ratings

The maximum rating of a soft starter is calculated so the junction temperature of the power modules (SCRs) does not exceed 125 °C. Five operating parameters affect the SCR junction temperature: *Motor Current*, *Start Current*, *Start Duration*, *Number of Starts Per Hour*, *Off Time*. The full rating of a particular soft start model must account for all these parameters. A current rating on its own is not sufficient to describe the capability of a soft starter.

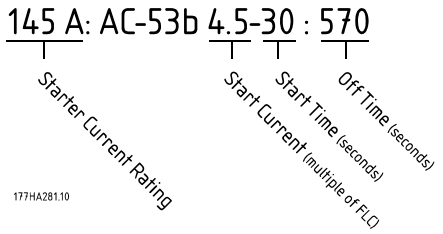
IEC 60947-4-2 details the AC53 utilisation categories for describing a soft starter's ratings. There are two AC53 codes:

1. AC53a: for soft starters used without bypass contactors.
   For example, the following AC53a code describes a soft starter capable of supplying a 256 A run current and a start current of 4.5 x FLC for 30 seconds 10 times per hour where the motor runs for 70% of each operating cycle (operating cycle = 60 minutes / starts per hour).



- *Starter Current Rating*: Maximum FLC rating of the motor to be connected to the soft starter given the operating parameters specified by the remaining items in the AC53a code.
- *Start Current*: The maximum start current that will be drawn during start.
- *Start Time*: The time taken for the motor to accelerate.
- *On-load Duty Cycle*: The percentage of each operating cycle that the soft starter will run.
- *Starts Per Hour*: The number of operating cycles per hour.

2. AC53b: for soft starters used with bypass contactors.
   For example, the following AC53b code describes a soft starter which, when bypassed, is capable of supplying 145 A run current and a start current of 4.5 x FLC for 30 seconds with a minimum of 570 seconds between the end of one start and the commencement of the next.



In summary, a soft starter has many current ratings. These current ratings are dependent on the start current and operational performance required by the application.

To compare the current rating of different soft starters it is important to ensure that operating parameters are identical.

5.4 Model Selection

NB!
To fully understand the model selection procedures it is important to have a good knowledge of the fundamental principles of soft starter ratings. See *Understanding Soft Starter Ratings*.

To select the correct SAF 200 model:

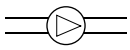
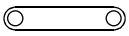
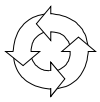
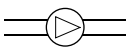
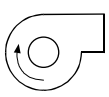
1. Determine whether the application requires a normal duty or a heavy duty rating. The table below can be used as a guide.
2. See the table in *Ratings* and select an SAF 200 model with an FLC rating greater than that of the motor.

Application	Duty
General and Water	
Agitator	Normal
Centrifugal Pump	Normal
Compressor (Screw, unloaded)	Normal
Compressor (Reciprocating, unloaded)	Normal
Conveyor	Normal
Fan (damped)	Normal
Fan (undamped)	Heavy
Mixer	Heavy
Positive Displacement Pump	Normal
Submersible Pump	Normal
Metals and Mining	
Belt Conveyor	Heavy
Dust Collector	Normal
Grinder	Normal
Hammer Mill	Heavy
Rock Crusher	Normal
Roller Conveyor	Normal
Roller Mill	Heavy
Tumbler	Normal
Wire Draw Machine	Heavy
Food Processing	
Bottle Washer	Normal
Centrifuge	Normal
Dryer	Heavy
Mill	Heavy
Palletiser	Heavy
Separator	Heavy
Slicer	Normal
Pulp and Paper	
Dryer	Heavy
Re-pulper	Heavy
Shredder	Heavy
Petrochemical	
Ball Mill	Heavy
Centrifuge	Normal
Extruder	Heavy
Screw Conveyor	Normal
Transport and Machine Tool	
Ball Mill	Heavy
Grinder	Normal
Material Conveyor	Normal
Palletiser	Heavy
Press	Normal
Roller Mill	Heavy
Rotary Table	Normal
Lumber and Wood Products	
Bandsaw	Heavy
Chipper	Heavy
Circular Saw	Normal
Debarker	Normal
Edger	Normal
Hydraulic Power Pack	Normal
Planer	Normal
Sander	Normal

NB!
The above start current requirements are typical and appropriate in most circumstances. However, start torque requirements and performance of motors and machines do vary. Please contact S2S Electronics if the application requires duties other than listed in this manual.

5.5 Typical Applications

SAF 200 soft starters can offer benefits for almost all motor starting applications. Typical advantages are highlighted in the table below.

Application	Benefits
Pumps 	• Minimised hydraulic shock in pipelines during start and stop. • Reduced starting current. • Minimised mechanical stress on motor shaft. • Phase rotation protection prevents damage from reverse pump rotation.
Conveyor Belts 	• Controlled soft start without mechanical shocks, eg bottles on a belt do not fall over during starting, minimised belt stretch, reduced counter balance stress. • Controlled stop without mechanical shocks. Soft stop. • Optimum soft start performance even with varying starting loads, eg coal conveyors started loaded or unloaded. • Extended mechanical lifetime. • Maintenance-free.
Centrifuges 	• Smooth application of torque prevents mechanical stress. • Reduced starting times over star/delta starting.
Compressors 	• Reduced mechanical shock extends the life of the compressor, couplings and motor. • Limited start current enables large compressors to be started when maximum power capacity is limited. • Phase rotation protection prevents operation in reverse direction.
Fans 	• Extended coupling life through reduced mechanical shock. • Reduced start current enables large fans to be started when maximum power capacity is limited. • Phase rotation protection prevents operation in reverse direction.
Mixers 	• Gentle rotation during start-up reduces mechanical stress. • The starting current is reduced.

5.6 Power Factor Correction

If a soft starter is used with static power factor correction it must be connected to the supply side of the starter.

Connecting power factor correction capacitors to the output of the soft starter will result in damage to the soft starter.