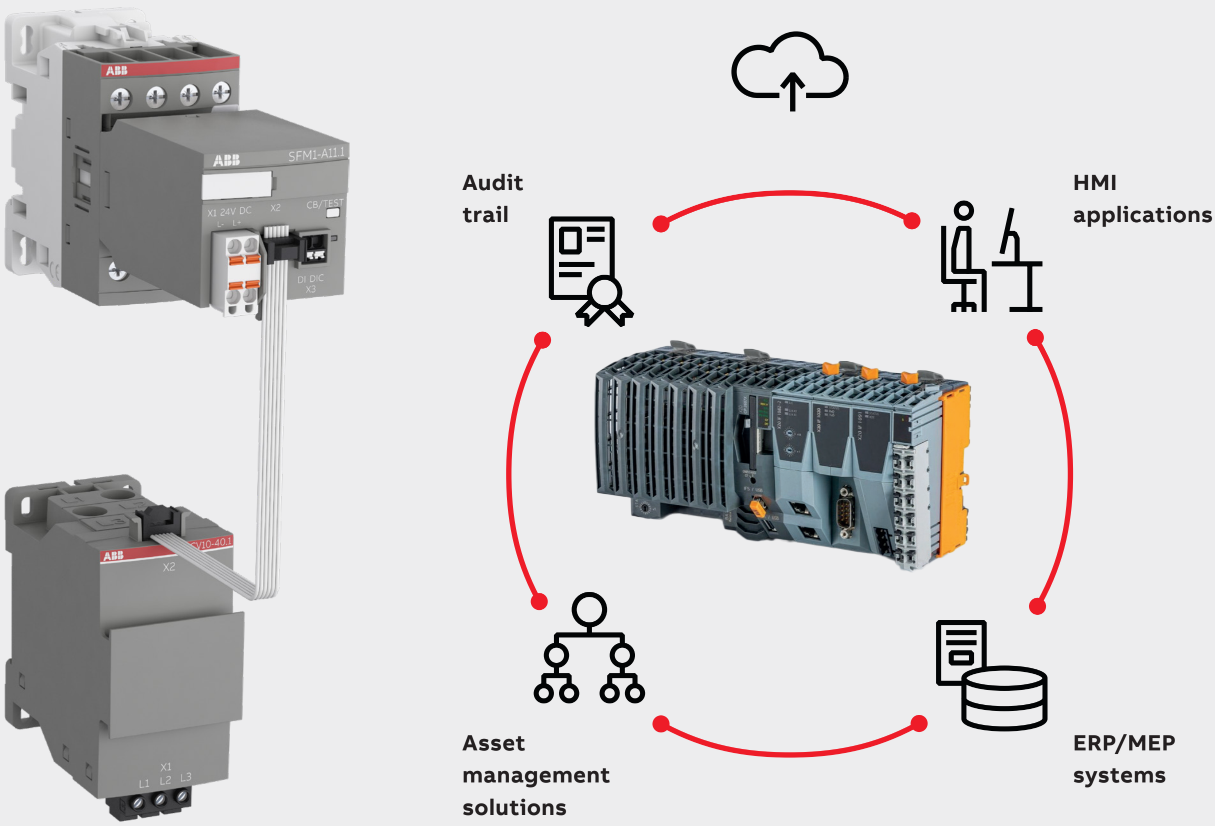
MANUAL

Novolink™ – smart function and sensor modules for AF contactors

Integrated into the B&R X20 system



The all-new ABB Novolink™ devices help digitalize your motor starting solutions and gain insights into the connected loads. They're easy to design into existing wiring plans and connect to standard AF contactors.

Installation is fast and simple, thanks to reduced wiring and fewer components, so your engineering efforts are minimized.

Novolink devices enable predictive maintenance to reduce downtime, as well as increasing efficiencies and boosting cost savings. They're fully integrated into the B&R automation system. And the possibilities open up even more with full remote access to your data, creating new maintenance service and revenue opportunities.

So to simplify engineering, optimize operations, save time and cut costs, think Novolink.

Table of contents

1. Important notice

Target group
This description is intended for use by trained specialists in electrical installation and control and automation engineering who are familiar with the applicable national standards.

Safety requirements
The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

Symbols used in this handbook

	Symbol to indicate a potentially dangerous situation that can cause damage to the UMC or connected devices or to the environment
	Symbol to indicate important information and conditions
	Symbol to indicate a potentially dangerous situation that can cause human injury

Cyber Security Statement
This product is designed to be connected to and to communicate information and data via a network interface. It is your sole responsibility to provide and continuously ensure a secure connection between the product and your network or any other network (as the case may be). You must establish and maintain any appropriate measures (such as, but not limited to, the installation of firewalls, application of authentication measures, encryption of data, installation of anti-virus programs, etc.) to protect the product, the network, its system and the interface against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information.

ABB Ltd and its affiliates are not liable for damages and/or losses related to such security breaches, any unauthorized access, interference, intrusion, leakage and/or theft of data or information.

2. Abbreviations

SCV	Smart Current and Voltage Sensor Module
SC	Smart Current Sensor Module
SFM	Smart Function Module
MS…	Manual Motor Starter
MO…	Manual Motor Starter Magnetic Only

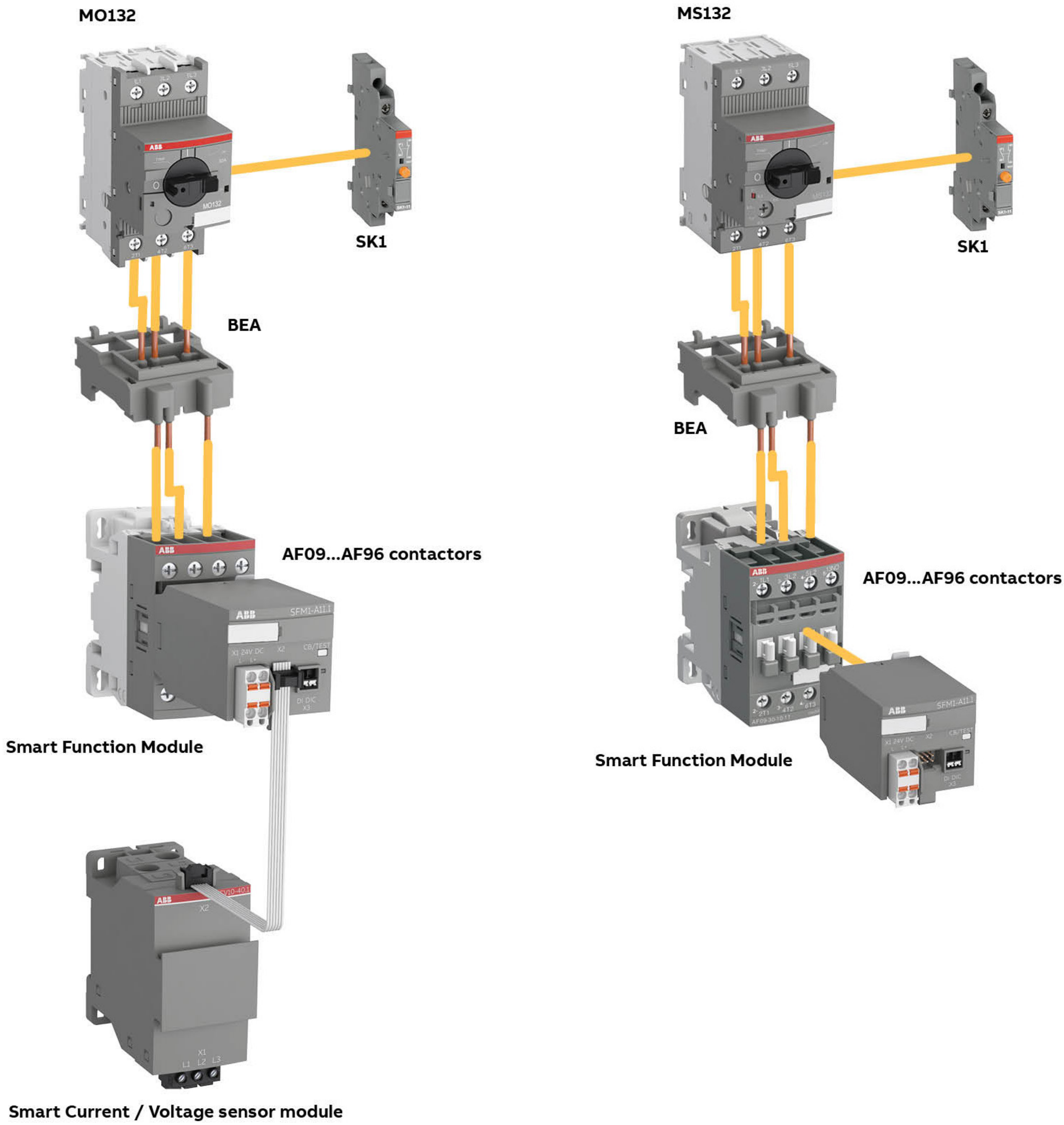
3. System description

3.1 Overview

This handbook describes the Smart Function Module SFM1 and the optional sensor module SCV10-40/SV10-40.1. The SFM1 allows the remote control and monitoring of AF contactors via X20 bus from within a B&R PLC. The optional voltage and current sensor module SCV10-40/SV10-40.1 can be connected to the SFM1 module and provides functions for motor and application protection.

Important Notice
In this document, the SCV sensor module is representative of the two modules SCV10-40 and SC10-40. The SC10-40 module only provides a current measurement. Therefore, if this module is connected to the SFM1, no voltage information and information derived from it (e.g. active power) are available.

The figure below shows the main components and how they can be combined for complete motor starting solutions.



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01: A full-featured solution is shown on the left, consisting of a Direct Online Starter (DOL) with a MO132 as short circuit protection device, AF contactor, SK1, Smart Function Module (SFM) and Smart Current / Voltage sensor module (SCV) including the complete motor protection functions. On the right, a basic solution is shown, with MS132 for motor protection and a Smart Function Module (SFM) for remote control.

3.2 Order codes

Type description	Description	Order code
SFM-CAB-RJTB.1-500	Connection cable RJ45 - X20 Terminal Block of X20BT9400, 5m	1SVM823000R0500
SFM-CAB-S.1-50	Connection cable SFM to Sensor 0.5m	1SVM811000R0050
SFM-CAB-S.1-25	Connection cable SFM to Sensor 0.25m	1SVM811000R0025
SCV10-40.1	Current – Voltage Sensor	1SVM320010R0000
SC10-40.1	Current Sensor	1SVM310010R0000
SFM1-A11.1	Advanced Function Module with X2X	1SVM120012R0000

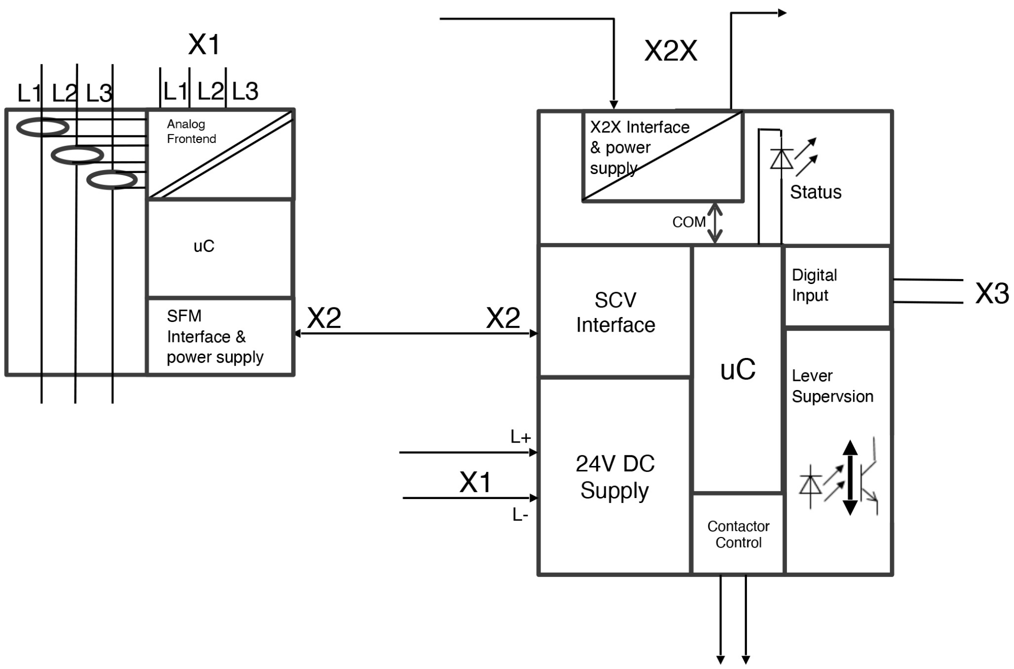
3.3 Smart function module (SFM)

The Smart Function Module SFM1 can be snapped onto AF09 – AF96 contactors with 24V coil voltage. The module is equipped with two X2X interfaces for incoming and outgoing connections. The module and contactor are supplied via 24 V DC that are supplied to the SFM1 module.

One digital input makes it possible to pick up an auxiliary signal, e.g. from a short circuit protection device such as the MO132. The auxiliary signal can be read out from the PLC and used for various purposes. A sensor module can be optionally connected to the SFM1 via flat cable.

The AF contactor is mechanically linked with a lever, which in turn provides visual feedback of the contactor position on the front of the SFM. The lever also allows to operate the contactor for test purposes. The status LED displays the operation state of the SFM1 itself.

SFM is fully integrated into the B&R Automation studio, which makes using the SFM/SCV easy. The HWX file offers the possibility to configure both modules and select the process values that should be transmitted cyclically between the SFM1 and the PLC. Values can also be requested as acyclic by the PLC.



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02: Block diagram of SFM1 and SCV. Both devices are connected with a serial interface to exchange data.

3.4 Smart current and voltage sensor module (SCV)

The SCV10-40 is an intelligent sensor unit for measuring voltage, current, frequency and further derived physical quantities such as cos phi, real power, etc. (please refer to section 8.3 for details).

It is equipped with feed through current sensors to measure the current in all three phases of the connected load. It also offers the option to measure the line to line voltage of the three phases up to 690 V AC.A ribbon cable connects the SCV10 with the SFM1 module and is also supplied from there.

The SCV10-40 offers thermal overload protection according to IEC/EN 60947 for 1/3 phase induction motors. Relevant parameters like the trip class and nominal current can be configured from within the PLC.

4. Installation

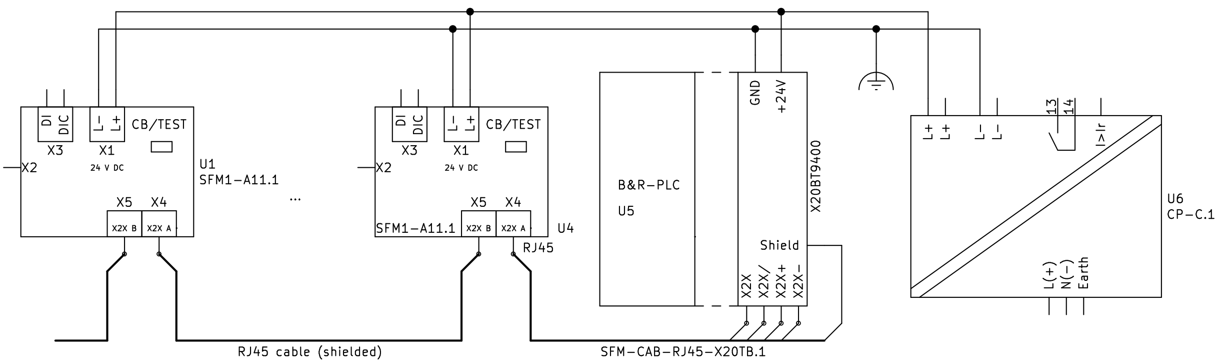
4.1 Assembly and disassembly

Assembly
The SCV10-40 can be mounted on any standard DIN rail. No tools are required. Alternatively, it can be mounted on a mounting place using screws. See dimensional drawing in the appendix for details. The SFM1 must be snapped on an AF contactor until a click is heard.

Disassembly
The white lock must be pulled before unmounting the SFM1 from the contactor. Ensure contactor is voltage free. Bus connection to subsequent devices is interrupted.

4.2 Connecting the SFM modules with the X20 system

The following diagram shows the general wiring concept of a system of SFM1 modules. It only focuses on the fieldbus part.



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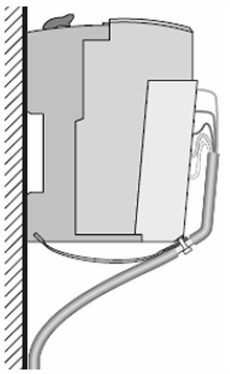
03: To connect the X20BT9400 to the first SFM1 module, use the readymade cable SFM-CAB-RJTB.1.

On one side, the SFM-CAB-RJTB has a cable shield clamp which is latched to the terminal block. All the required wires are already connected to the X20 terminal block. Cable ties are used to press the shield against the grounding plate. The other side of the cable has a RJ45 plug which can be directly connected to the SFM1 module.

Mount the terminal block to the bus module.

Connect the shield to the foreseen bus module's ground connection using the cable lug as shown in the following figure



Only the communication interface of the SFM1 module is powered with the supply provided by the X20BT9400 module. The contactors are supplied with via X1 of the SFM1 module. See block diagram above for details

Check the connection examples of the X20BT9400 module on how to supply the X2X bus. Adjust the readymade SFM-CAB-RJTB wring according to your needs.

For the SFM to SFM module, use a shielded RJ45 cable. For details, see the chapter on technical data. It is not required to terminate the bus after the last module.

4.3 Supported AF contactors and accessories

The SFM1 module can be mounted on all 24V supplied AF09 to AF96 contactors as described in the table below.

Size 1	Size 2	Size 3	Size 3.5
AF09ww-xx-yy-zz	AF26ww-xx-yy-zz	AF40ww-xx-yy-zz	AF80ww-xx-yy-zz
AF12ww-xx-yy-zz	AF30ww-xx-yy-zz	AF52ww-xx-yy-zz	AF96ww-xx-yy-zz
AF16ww-xx-yy-zz	AF38ww-xx-yy-zz	AF65ww-xx-yy-zz	
zz= coils 11, 21 and 30	zz= coils 11, 21 and 30	zz= coil 11	zz= coil 11
Terminal: Screw, Push-in	Terminal: Screw, Push-in	Terminal: Screw	Terminal: Screw

ww: Denotes NEMA products
xx: 22, 30
yy: Number and type of auxiliary contacts
.

Contactor coil is supplied via X1 of the SFM1 module. There must be no voltage supplied via A1/A2 to the contactor.

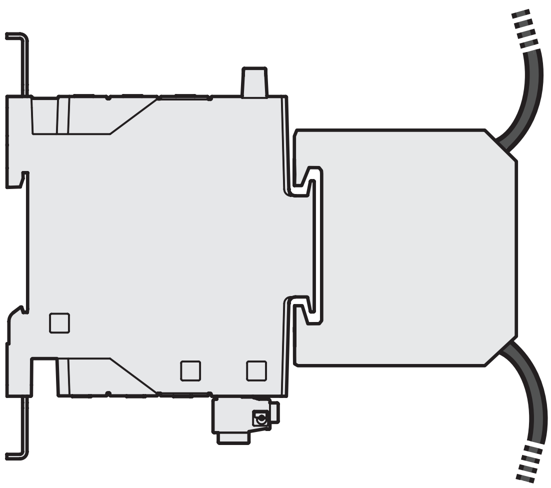
4.4 Connecting the SFM1 to 24 V supply

The SFM1 must be supplied with 24 V DC. The 24 V DC are used to power the contactor coil as well as to power the module itself (excluding the communication part). It is possible to loop through the 24 V DC to the next module to simplify the overall wiring.

The polarity of the 24 V DC is important. In case of the wrong polarity, the contactor switches on without any bus command.

4.5 Using the DIN-rail at the front of the Sensor Module

It is possible to mount lightweight devices such as terminal blocks on front of the sensor module.



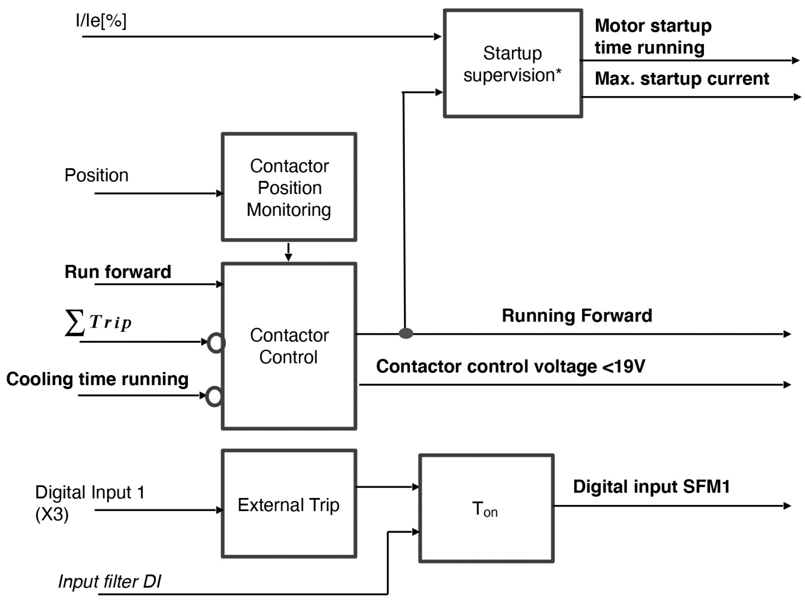
The maximum weight of the devices mounted on the SC/SCV module must not exceed 50 grams.

5. Description of functions

This chapter provides an overview of the various functions and how to configure them.

5.1 Motor management functions

This subsection describes the motor management related functions. The following figure provides an overview of the general function.



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04: General dataflow of the motor management related functions. The parameters are shown in italics. The command and monitoring signals are shown in bold.
*) The startup time supervision function is only available if the SCV module is present.

5.1.1 Mechanical switching test

On the front face of the SFM1, the plunger indicates the mechanical position of the AF contactor. This plunger is directly mechanically interlocked with the AF contactor and makes it possible to mechanically operate the contactor for test purposes. To operate the contactor, push down the lever with a screwdriver.

Pushing the plunger to operate the contactor can be done at any time by a person with access to the SFM1 module. Prevent unintended motor starts with safety measures, e.g. locking the panel door.

Recommended screw driver for test:

Screwdriver type		
	⊖ 0.6 x 3.5 mm	⊖ 0.4 x 2.5 mm

5.1.2 Remote control of the AF contactor / switching the motor on or off

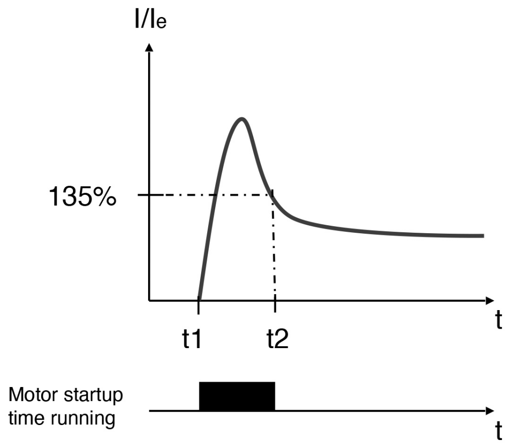
The AF contactor can be remotely switched on and off from the PLC. The switching operation is supervised with the help of the built-in lever supervision, and the mechanical checkback information is available via a bus. On the PLC, a suitable reaction for a mismatch between the actual command and the actual checkback must be implemented.

5.1.3 External trip input

The digital input is intended to monitor the status of an external short circuit protection device (fuse, MO, etc.). The status of this input is available in the PLC and a suitable reaction can be implemented (e.g. reset ON command bit and log a diagnosis message in the system event log). The DI filter time can be adjusted.

5.1.4 Startup time supervision

This function supervises the motor startup time, and is only available if the SCV module is present. The real motor startup time is considered as the time t2-t1 in seconds, i.e. the time when the motor was started (t1), and the current falls below 135% (t2) again. In case the defined threshold is not reached, a replacement value is set, depending on the trip class (5E ->1.5s, 10E -> 3s, 20E -> 6s, 30E -> 9s).



The motor startup time can be used to realize monitoring or protection functions in the PLC that should only be active during motor startup, or after motor startup.

5.2 Monitoring and protection functions

The SFM1, together with the SCV module, provides the protection functions listed in the table below. In order for the monitoring and protection functions to work, the network type and the nominal network frequency must be set.

5.2.1 Thermal overload protection

The SFM1 together with the SCV protects single- and three-phase AC motors in compliance with IEC 60947-4-1. The tripping class can be set to class 5E, 10E, 20E or 30E. The advanced thermal motor model considers both the copper and iron parts of the motor, thus providing the best protection of the motor. The thermal overload protection can be switched on and off.

Before an overload trip occurs, a pre-warning can be generated in the PLC by monitoring the thermal load in %. During high overload situations, this prewarning might be raised just a few seconds before the actual trip happens.

The thermal model calculates an estimate of the 'time to trip' under the current load conditions. If the motor is switched off, the time to trip shows 6,553 seconds (in which case it never trips). If the motor is running, the predicted trip time is updated regularly. The smaller the value the earlier the trip occurs.

After an overload trip, the remaining cooling down time (i.e. time to restart) is calculated regularly and is available to the user. The motor can be restarted if the cooling time is 0 seconds.

After a trip has occurred, the 'time to cool' is calculated. Restarting of the motor is either possible after fixed time or after the thermal load has fallen below a configured threshold. An automatic restart of the motor can be activated once the motor has cooled down sufficiently.

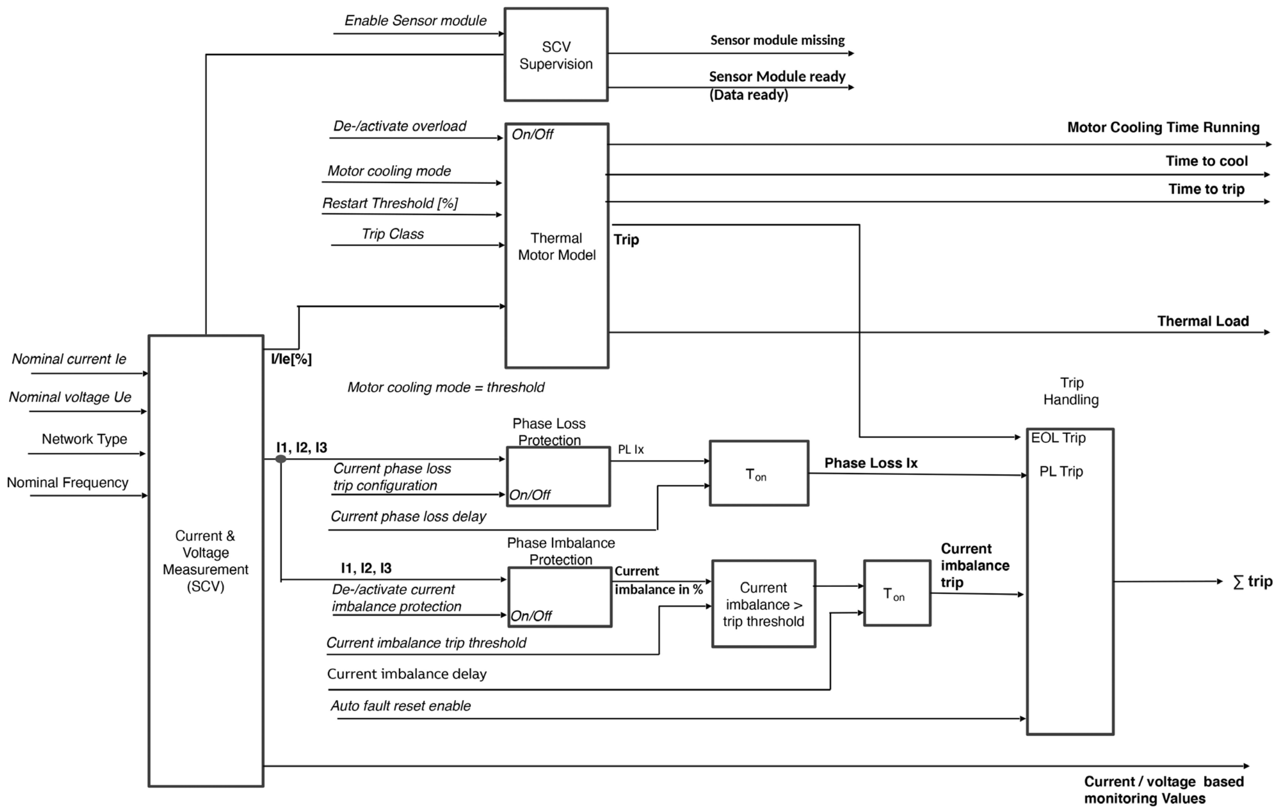
5.2.2 Phase loss protection

This function protects motors against the extreme situation where a complete phase is lost. An undetected phase loss can cause motor damage because of the sudden increase of current in the two remaining phases. This function is based on the motor current and detects a phase loss while the motor is running. If enabled, the thermal overload protection performs an accelerated trip during phase loss.

5.2.3 Current imbalance protection

The current imbalance protection protects the motor against a current imbalance between the different phases. The imbalance trip level must be carefully adjusted to protect the motor windings against overheating. Observe any rules or guidelines provided by the motor manufacturer.

If activated, the SFM trips the contactor as soon as the measured imbalance is above the configured trip threshold for longer than a configurable delay time.



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05: block diagram showing the signal flow of the thermal overload protection as well as the current and voltage-based measurement values. Parameter are shown in italics. Measured values available on the X2X bus are shown in bold.

Related parameters:

- Trip Class
- Nominal current I_e
- De-/activate overload protection
- Motor cooling mode
- Motor cooling time
- Restart threshold
- Auto fault reset
- Current phase loss trip configuration
- Current phase loss delay
- Activate/deactivate current imbalance protection
- Current imbalance trip threshold
- Current imbalance delay

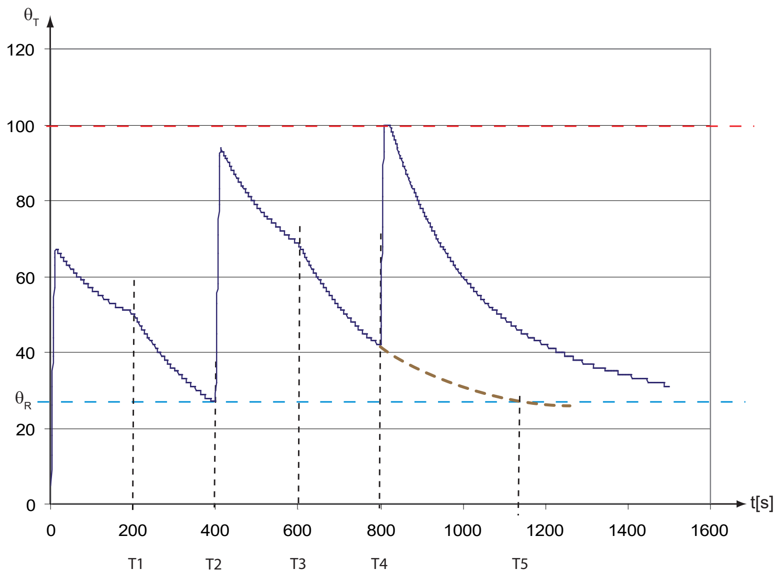
5.2.4 Phase sequence monitoring

This monitoring function can be used to prevent connected equipment from rotating in the wrong direction. The reaction to an incorrect phase sequence must be programmed in the PLC. Phase sequence information is not available in single phase operation mode.

5.2.5 Cyclic motor starting

Some applications require periodic start/operation/stop cycles. Setting up such applications requires care when selecting the cooling down times or defining the shortest possible start period. In the next diagram, three successive start cycles are displayed. In each cycle, the motor starts at 700% Ie. This high load lasts for about 7 seconds. Then the current goes back to Ie within 6 seconds and stays at 100% Ie for about 180 seconds. At T1 the motor is switched off and cools down for 200 seconds. The next start takes place at T2. During this cycle the motor also cools down for 200 s, but the calculated thermal motor load is already above 40%. The third start at T4 leads, as expected, to a thermal overload trip.

For cyclic operation modes it is important to keep the cycles long enough to allow the motor to cool down sufficiently. For cyclic start patterns it is better to select the cooling mode option 'Restart Level', which allows a restart based on the thermal load level. In the case shown below, the third start would then be allowed at T5 at the earliest.



Θ_T: Therminal load of the motor
Θ_R: Configured restart level
T_x: Switching time
t: Time

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06: Trend of the calculated motor temperature after several starts. The motor trips after the third start because the motor was started too frequently within the given time

5.2.6 Protection of connected equipment

Measured values are available for further processing in the PLC. Equipment problems that can be detected based on significant changes of electrical quantities are as follows:

Monitored equipment	Observed change	Potential problem
Pump	Cos phi / active power too low	Dry running pump
Pump	Motor current too high	Clogged filters, closed valve
Conveyor belt	Cos phi / active power too low	Belt broken
Conveyor belt	Current / active power too high	Belt overloaded / locked
Fan	Cos phi / active power too low	Fan idling, fan defective
Crusher, mixer	Motor current / active power too high	Blocked equipment
Gearboxes	Motor current / active power too high	Jamming, locking, missing lubrication
Heaters	Active power too low, current too low	Heating not working, heating coil broken

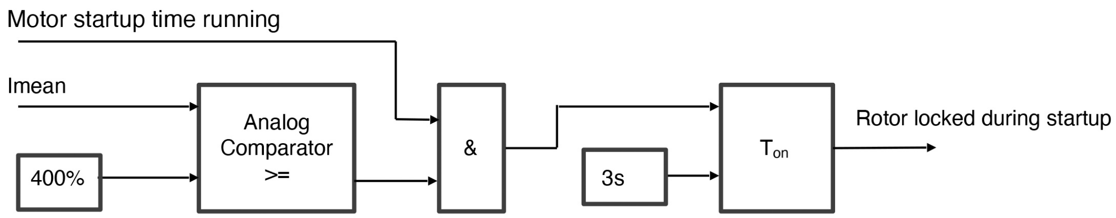
Typically, one or more measured values will be compared against application specific threshold values. In case the values are out of range, a signal is generated which then might be delayed for some time and be used to trigger further actions, such as the creation of an event log entry, or stopping or starting the motor.

Not related to specific equipment functions like listed below can be implemented based on available process data:

Function in PLC	Required process data	Description
Stall protection	Motor current Motor startup time running	Equipment sensitive against locked rotors (e.g. agitators) can be protected by supervising the motor startup current during the startup phase. If the current is too high for a longer time, the motor can be stopped faster than the thermal model would otherwise react
Jam protection	Motor current Motor startup time running	If the motor is in normal operation (startup time over) the current can be monitored to not reach a critical value.
Prevent frequent starts	Time between starts	Some equipment sensitive against too frequent starts can be protected by ensuring a minimum time passed before a new start is possible. Alternatively, the number of starts is limited to certain number per hour.
Load shedding in case of instable supply	Voltage	If voltage is below a certain threshold, loads that are not required can be switched off to stabilize supply
Idle load detection	Cos phi / active power	In some cases, idle loads can be simply switched off to save energy or for other process-related reasons.
Voltage phase imbalance	Voltage imbalance	If the phase imbalance is above a defined threshold load, user-defined actions may be triggered.
Voltage / Current threshold	Line voltages Currents	If the average voltage or current is above or below threshold a user defined actions can be triggered.

Because such tasks are mostly application-specific, the raw electrical values are provided to the PLC and the application programmer can implement the required behavior in the PLC.

A principal PLC program to detect a locked rotor during motor startup could be implemented as follows:



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07: Simplified program to detect a locked rotor based on process data delivered from the SFM1 + SCV module.
Functionality must be implemented in a PLC program, and thresholds must be adjusted to application-specific needs.

Value	Description
Current	The current in all three phases is measured using a true RMS measurement algorithm. Available measurement values: • Current L1, L2, L3 as % of I_e or in absolute value • Mean current of all three values in % of I_e or as absolute value • Mean current at last trip in in % of Ie or as absolute value • Current imbalance in %. $I_{avg} = \frac{I_1 + I_2 + I_3}{3}$ $Unbalance\ \% = 100\ \frac{max(\|I_1 - I_{avg}\|,\|I_2 - I_{avg}\|,\|I_3 - I_{avg}\|)}{I_{avg}}$ • Total Harmonic Distortion (THD) in % based on current. THD is calculated as the ratio between the rms amplitude of the N harmonics and the rms amplitude of the fundamental frequency. $THD = \frac{\sqrt{I_2^2 + I_3^2 + ... + I_N^2}}{I_1}$ Where I1 is the fundamental, I2 the second harmonic, I3 the third harmonic and so on. • Earthfault in % of I_e. It is calculated as follows: $Ifault\ [\%] = 100 * \frac{\|\vec{i_1} + \vec{i_2} + \vec{i_3}\|}{\sqrt{2} \cdot I_n}$ Where $\vec{i_1}, \vec{i_2}, \vec{i_3}$ are the current Phasors on each phase. I_c is the sensors configured nominal current. • Frequency as absolute value Motor related values: • Thermal load in %. In case the value reaches 100 % the motor will be tripped. • Time to trip in seconds if the motor continues to operate under the current load conditions • Time to cool in seconds until a motor restart is possible.
Voltage	The voltage between the three phases is measured using a true RMS measurement algorithm. Available measurement values: • Phase to phase voltage $U_{L1/L2}$, $U_{L2/L3}$, $U_{L3/L1}$ as absolute values • Voltages $U_{L1/N}$, $U_{L2/N}$, $U_{L3/N}$ measured between a phase and the virtual star point created internally in the SCV module. • Voltage imbalance in multiples of 0.1 % $V_{avg} = \frac{V_1 + V_2 + V_3}{3}$ $Unbalance\ \% = 100\ \frac{max(\|V_1 - V_{avg}\|,\|V_2 - V_{avg}\|,\|V_3 - V_{avg}\|)}{V_{avg}}$ • Total Harmonic Distortion (THD) in % based on voltage. THD is calculated as the ratio between the rms amplitude of the N harmonics and the rms amplitude of the fundamental frequency. $THD = \frac{\sqrt{V_2^2 + V_3^2 + ... + V_N^2}}{V_1}$ Where V1 is the fundamental, V2 the second harmonic, V3 the third harmonic and so on
Power / cos phi	Based on current, voltage and phase angle further electrical quantities are provided: Available measurement values: • Cos phi in phase 1, 2 and 3 • Active power for phase 1, 2 and 3 • Apparent power for phase 1, 2 and 3

5.3 Communication-related functions

This section describes parameters related to the communication behavior itself.

Function	Description
Module supervised	In case a module is missing, the PLC service mode is entered
OSP mode	See B&R manuals

5.4 Maintenance data

The SFM1 and/or the SVC module offer the following features:

Value	Description
Operating hours	The operating hours of the load (i.e. when the contactor was switched on). The counter can be reset from the PLC e.g. in case the motor was replaced.
Standstill hours	The stand-still hours of the load (i.e. when the contactor was switched off). The counter can be reset from the PLC, e.g. in case the motor was replaced.
Switching counter	The number of operations of the AF contactor are counted. In the case of a motor load, this counter is equal to the number of motor starts. The counter can be reset from the PLC, e.g. in case the contactor was replaced.
Number of overall trips	The counter can be reset from the PLC, e.g. after maintenance.
Number of thermal overload trips	The counter can be reset from the PLC, e.g. after maintenance.

6. Error handling, maintenance and service

Within this chapter, you will find the following information
- Error handling of the SFM1 and SCV
- Detailed explanation of all error and diagnosis messages
- Functions related to maintenance and service

Error handling of the SFM1
When the SFM1 detects a trip condition, the trip becomes latched. Once a trip becomes latched, it remains latched even if the underlying fault condition is eliminated until acknowledged by a fault reset command via X2X bus. The setting of the 'Auto fault reset' parameter determines how the SFM1 manages protection trips.
- Off (the default setting): A protection trip must be acknowledged by the user. This can be done via fieldbus only.
- On: A protection trip, current phase unbalance trip and a current phase loss trip is automatically acknowledged without intervention of either a human operator or the remote PLC if the trip condition has gone (e.g. cooling time over).

Fault history
No fault history is stored in the SFM1. Event logs must be built in the PLC.

SFM1 fault indication
The SFM1 offers the following possibilities for indicating a trip or fault.
- Indication via LEDs on the SFM.1. The red fault LED is switched on in the event of a trip and remains on until the trip is acknowledged.
- Signaling via X2X: In the event of a trip the related bit in the cyclic communication telegram is set to logical-1.

Fault messages

The following table lists all diagnosis and fault messages and potential root causes for the fault. It gives a first indication of where to look for a fault and how to fix it.

Indication	Created in	Source / root cause	Possible cause / suggested action
Thermal overload (leads to trip)	SFM+SCV	Load side	Trip due to thermal overload of the motor. Check process conditions Check if the cooling time is too short Check Ie and trip class settings
Phase loss (leads to trip)	SFM+SCV	Supply side Load side Contactor	At least one phase current is below the phase loss threshold Check for blown fuse Check for loose contacts Check contact wear
Current unbalance above threshold (leads to trip)	SFM+SCV	Load side Supply side	Unsymmetrical load or network Bad wiring, loose contacts Check supply/load side. Check wring
Thermal model reached warning level	PLC[1]	Load Side	Thermal model reached warning level. If the overload condition persists, a trip soon follows. Check motor load condition Check for mechanical problems
Check-back error	PLC[1]	Wiring, Contactor	Expected feedback from a contactor is missing after the checkback time was over. Check wiring of auxiliary contact to the correct SFM input. Check contactor Increase checkback time
Motor current below low current threshold	PLC[1]	Process Load side Load side mechanics	Motor current is below user-defined threshold, e.g. in the case of the motor running idle, a dry-running pump, or broken conveyer belt. Check motor load and motor / process conditions. Wait until cooling time is over
Motor current above high current threshold		Load side	Motor current above threshold caused e.g. by jammed equipment Check process conditions (remove blocking cause). Wait until cooling time is over.
Earth fault (external or internal sensor) above trip threshold	PLC[1]	Load side electrical	Connection between one or more phases and ground Check wiring / motor (isolation problem) Increase trip delay time at startup to overcome condensation problems
Line frequency not detected	SFM+SCV	Supply side	Frequency out of range. Check supply side.

Indication	Created in	Source / root cause	Possible cause / suggested action
Self-test HW (leads to trip)	SFM+SCV	Electronics	Hardware fault detected. SmartFunctModuleHWFault SensorModuleHWFault Replace module
SCV module missing (leads to trip)	SFM	Electronics	Communication cable not connected. Cable break or SCV module hardware error
Underload Power	PLC[1]	Load side mechanics	The motor load is too low. Check the load, e.g. if a pump is running dry or a conveyer load is broken.
Overload Power	PLC[1]	Load side mechanics	The motor load is too high. Check if the load is blocked or tight.
Voltage Out of Spec	PLC[1]	Load side	The supply voltage is too low or too high. Check the motor supply.
THD too high	PLC[1]	Supply side	The harmonics on the supply side are too high. Check your network.
Cooling time running	SFM+SCV	Process, Load side	Motor was tripped due to thermal overload. Restart is possible after cooling time is over
Parameter out of range (leads to trip)	SFM+SCV	Electronics, Configuration	Someone tried to write a parameter which is outside the specifications Check the parameter number that is causing the problem and change the value.
Motor operation hour exceeded	PLC[1]	Load side mechanical	Max. motor operation hours reached. Perform motor maintenance. Reset counter
Motor stand still hours exceeded	PLC[1]	Load side	Motor did not run for a long time Start motor to check everything is still fine
Line frequency out of range	PLC[1]	Supply side	Check supply
Wrong phase sequence (reversal)	PLC[1]	Supply side, Load side	Phase order is not L1/L2/L3.
Contactor control voltage <19V	SFM	Contactor	24V supply too weak Bad wiring, too small wire diameter Check mounting of SFM1
Contactor output short circuit (leads to trip)	SFM	Contactor	Contactor failure SFM coil connectors shorted

[1] Fault detection and handling within the PLC are not implemented by default. They are application-specific and need to be developed as a part of the B&R automation project.

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LED on front of SFM1 module

Green Off Single flash Blinking On	 No power to module RESET mode PREOPERATIONAL mode RUN Mode
Red Off Double flash	 Module supply not connected or everything OK Bus supply is too low or not connected
Orange (Red + Green)	Protection Trip
Red, Orange single flash	Invalid firmware

7. Parameters and data structures on the communication bus

All the data listed below is defined in the HWX file and can be configured in the B&R Automation Studio.

7.1 Monitoring data

Word	Byte	Bit	Description	Parameter name	Register / access
0	0	0	Digital input X3	DigitalInputX3	0 / r
		1	Running Forward (DOL)	RunningForward	
		1	Reserved		
		3	Reserved		
		4	Data ready (sum status)	SumStatusDataReady	
		5	Summary fault	SumFault	
		6	Contactor control voltage < 19V	ContactorVoltageLow	
		7	Parameter out of range	ParameterOutOfRange	
	1	0	HW Error Smart Function Module	SmartFunctionModuleHWFault	1 / r
		1	Contactor output driver short circuit (i.e. current >2A for >2s)	ContactorOutputSortCircuit	
		2 - 7	Reserved	–	
1	0	0	Sensor Module ready (data ready)	SensorModuleReady	30 / r
		1	Sensor module missing	SensorModuleMissing	
		2	Current imbalance trip	CurrentImbalanceTrip	
		3	Current phase loss	CurrentPhaseLossTrip	
		4	Overload trip (thermal model)	OverloadTrip	
		5	Motor cooling time running	CoolingTimeRunning	
		6	Motor startup time running	StartupTimeRunning	
		7	Phase sequence I status	PhaseSequenceCurrent	
	1	0	Phase sequence U status	PhaseSequenceVoltage	31 / r
		1	Current phaseloss trip L1	CurrentPhaseLossTripL1	
		2	Current phaseloss trip L2	CurrentPhaseLossTripL2	
		3	Current phaseloss trip L3	CurrentPhaseLossTripL3	
		4	HW Fault Sensor Module	SensorModuleHWFault	
		5	Line frequency not detected	LineFrequencyNotDetected	
		6	Reserved	–	
		7	No voltage measurement sup-ported by this sensor module	NoVoltageMeasurementSup-ported	

7.2 Command data

Word	Byte	Bit	Description	Parameter name	Register / access
0	0	0	0: Contactor OFF	RunForward	2 / w
			1: Contactor ON		
		1 - 3	Reserved		
		4	Trip Reset	ResetErrors	
		5	Reset switching counter contactor A	ResetCounterContactorA	
		6	Reset motor run hours	ResetMotorRunHours	
		7	Reset Motor stand still hours	ResetMotorStandStillHours	
	1	0	Reset number of thermal trips	ResetNoOfThermalTrips	3 / w
		1	Reset number of all trips	ResetNoOfAllTrips	
		2-4	Reserved		
		5	Testposition. If set to 1 (true) there will be no trip in case of phase loss or phase imbalance.	Test Position	
		6,7	Reserved		

*) Reserved bits should be set to zero

7.3 Parameters and measured values

—

Parameters

Group	Parameter	Options	Datatype	Min.	Max.	Default	Register / access
B&R standard parameter	Module supervised	0: Off, 1: On	BOOL	0	1	0	
OSP (operator set predefined)	OSP configuration	0: hold last valid value 1: replace by static value	BOOL	0	1	1	
I/O module	Select sensor module	0: Off, 1: SCV10-40 2: SC10-40	BOOL	0	1	On	ModulOnOffPar 400 / w
Control function	Control function	DOL	UINT8	0	0	DOL	ControlFunctionPar 404 / w
Network Type	Network type	0: 3 phase 1: 1 phase	UINT8	0	1	3 phase	Measure3PPar 408 / w
Frequency	Frequency	0: 50Hz, 1: 60Hz	UINT8	0	1	50Hz	BaseFrequencyPar 412 / w
Overload protection	Setting nominal current I_e	[0.01A]	UINT16	20	4000	0.05A	SettingIePar 420 / w
Motor overload protection	Trip class	0: 5E, 1: 10E, 2: 20E, 3: 30E	UINT8	0	3	10E	TripClassPar 424 / w
	Trip configuration	0: Off, 1: On	BOOL	0	1	Trip	ConfigOverloadPar 416 / w
Current imbalance	Trip threshold	[%]	UINT8	0	100	50	CurrImbalancePar 432 / w
	Trip delay	[0.1s]	UINT8	0	255	0.5s	CurrImbalanceDelayPar 436 / w
	Trip configuration	0: Off, 1: On	BOOL	0	1	Trip	ConfigCurrImbalancePar 428 / w
Current phase loss	Trip delay	[0,1s]	UINT8	0	255	0.5s	CurrPhaseLossDelayPar 442 / w
	Trip Configuraton	0: Off, 1: On	BOOL	0	1	Trip	ConfigCurrPhaseLossPar 440 / w
Motor cooling	Cooling mode	0: Time, 1: Load	BOOL	0	1	Time	MotorCoolingModePar 472 / w
	Cooling time	[s]	UINT16			120	MotorCoolingTimePar 476 / w
	Restart level in % (of thermal load)	[%]	UINT8			30	MotorRestartLevelPar 480 / w
Auto fault reset	Auto failure reset	0: Off, 1: On	BOOL	0	1	Off	AutoFaultResetAllowedPar 488 / w

—

Measured values

Value	Physical unit	Data type	Register
Current I_L1 (RMS)	[mA]	UDINT32	IrmsL1Abs 112 (r)
Current I_L2 (RMS)	[mA]	UDINT32	IrmsL2Abs 116 (r)
Current I_L3 (RMS)	[mA]	UDINT32	IrmsL3Abs 120 (r)
Current Imean (RMS)	[mA]	UDINT32	IrmsMeanAbs 128 (r)
Startup current Imax average (RMS)	[mA]	UDINT32	Max. startup current [mA] 134 (r)
Current at last trip (RMS)	[mA]	UDINT32	Max. startup current [mA] 138 (r)
Current I_L1 (RMS)	[% * Ie]	UINT16	IrmsL1 100 (r)
Current I_L2 (RMS)	[% * Ie]	UINT16	IrmsL2 104 (r)
Current I_L3 (RMS)	[% * Ie]	UINT16	IrmsL3 108 (r)

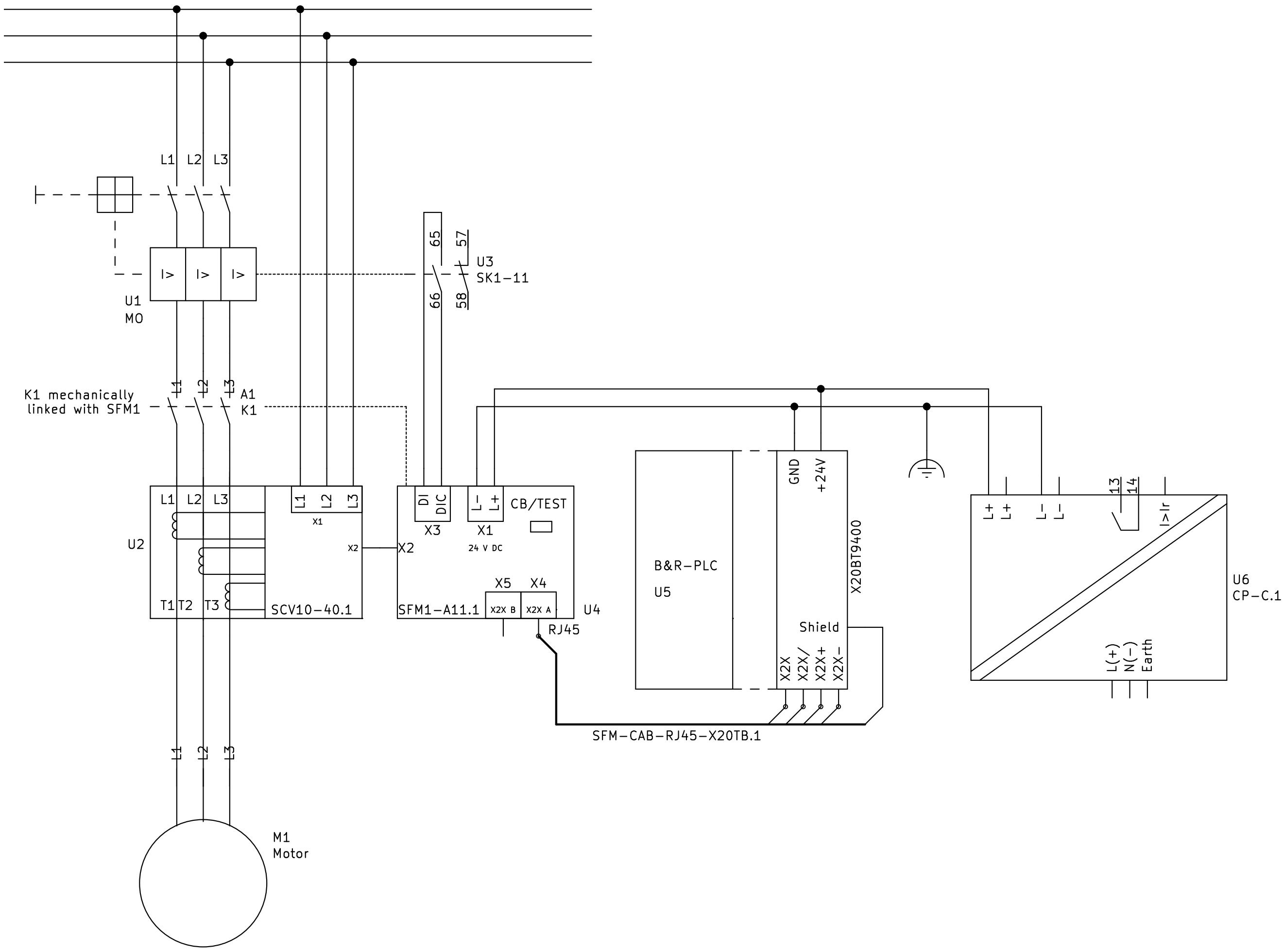
Value	Physical unit	Data type	Register
Current Imean (RMS)	[% * Ie]	UINT16	IrmsMean 124 (r)
Startup current Imax average (RMS)	[% * Ie]	UINT16	ImaxStartup 132 (r)
Current at last trip (RMS)	[% * Ie]	UINT16	IatLastTrip 136 (r)
Phase to phase U_{L1_L2} (RMS)*)	[0.1 V]	UINT16	UrmsLineToLineUG12 148 (r)
Phase to phase U_{L2_L3} (RMS)*)	[0.1 V]	UINT16	UrmsLineToLineUG23 152 (r)
Phase to phase U_{L3_L1} (RMS)*)	[0.1 V]	UINT16	UrmsLineToLineUG31 156 (r)
Phase to N U_{L1_N} (RMS)*)	[0.1 V]	UINT16	UrmsPhaseVoltageUG1 160 (r)
Phase to N U_{L2_N} (RMS)*)	[0.1 V]	UINT16	UrmsPhaseVoltageUG2 164 (r)
Phase to N U_{L3_N} (RMS)*)	[0.1 V]	UINT16	UrmsPhaseVoltageUG3 168 (r)
Cos Phi / Phase L1*)	[0.01]*)	INT8	PF_L1 180 (r)
Cos Phi / Phase L2*)	[0.01]	INT8	PF_L2 184 (r)
Cos Phi / Phase L3*)	[0.01]	INT8	PF_L3 188 (r)
Current imbalance in %	[%]	UINT16	Iimbalance 140 (r)
Voltage imbalance in %*)	[0.1%]*)	UINT16*)	Uimbalance 176*) (r)
Active power L1*)	[W]	DUINT32	ActivePowerL1 192 (r)
Active power L2*)	[W]	DUINT32	ActivePowerL2 196 (r)
Active power L3*)	[W]	DUINT32	ActivePowerL3 200 (r)
Apparent power L1*)	[VA]*)	DUINT32	ApparentPowerL1 204 (r)
Apparent power L2*)	[VA]*)	DUINT32*)	ApparentPowerL2 208*) (r)
Apparent power L3*)	[VA]	DUINT32	ApparentPowerL3 212 (r)
THD current	[0.1%]	UINT8	CurrentTHD 220 (r)
THD voltage *)	[0.1%]	UINT8	VoltageTHD 221 (r)
Frequency	[0.1 Hz]	UINT16	Frequency 177 (r)
Earthfault current in %	[% * Ie]	UINT16	EarthFaultCurrent 222 (r)
Thermal load in %	[%]	UINT16	ThermalLoad 216 (r)
Time to trip in seconds	[s]	UINT16	TimeToTrip 217 (r)
Time to cool in seconds	[s]	UINT16	TimeToCool 218 (r)
Mechanical switching counter contactor A (DOL)	#	UDINT32	MechSwitchCountA 224 (r)
Number of thermal trips	#	UINT16	NoOfThermalTrips 225 (r)
Number of all trips	#	UINT16	NoOfAllTrips 226 (r)
Motor startup time	[100ms]	UINT16	MotorStartupTime 144 (r)
Motor run hours	[s]	UDINT32	MotorOperationHours 145 (r)
Motor stand still hours	[s]	UDINT32	MotorStandStillHours 146 (r)
Wrong parameter number	#	UINT16	WrongParameterNumber 20 (r)

*) Only available if the SCV10-40 module is connected. Otherwise zero is returned.

8. Applications and sample circuit diagrams

8.1 Three phase motor application with SFM1 + SCV, AF contactor and MOx

This application shows the usage of the SFM1 and SCF10 module to control and protect a 3-phase motor. Set motor protection-related parameters according to the motor nameplate.



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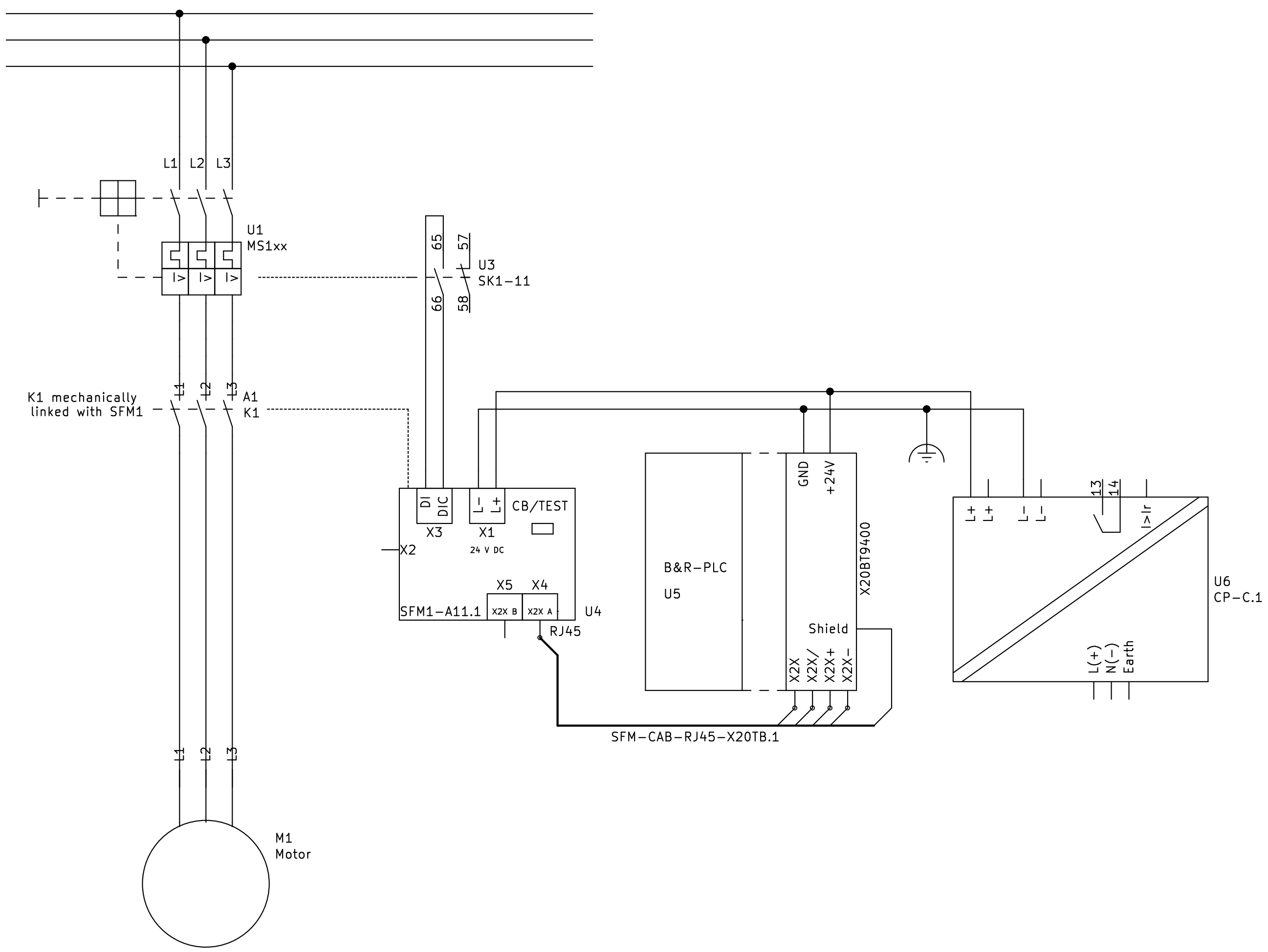
08: Direct online starter with voltage/current measurement and short circuit protection with MO1xx.

8.2 Three phase motor application with SFM1, AF contactor and MS… for motor protection

This application shows the usage of the SFM1 module to control the motor and a standard MS… to protect a 3-phase motor. Disable the motor model for this application.

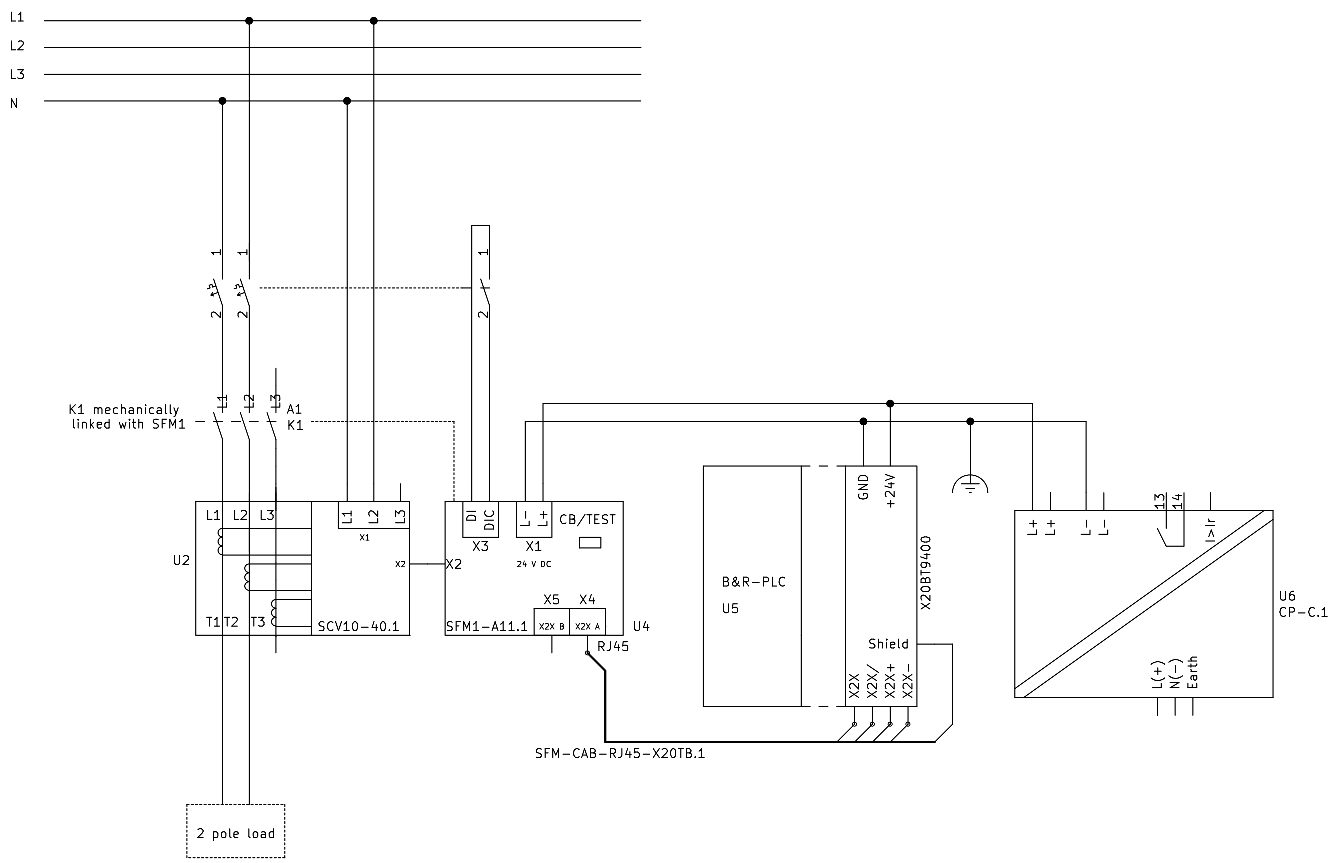


—
09: Direct online with thermal overload protection and short circuit protection realized by MS1xx. SFM1 is basically used as remote control and monitoring unit of the AF contactor.

8.3 Two-pole loads with SFM1, AF contactor and MCB

This application shows the usage of the SFM1 and SCV10 module to control and protect a single-phase load. Set load related protection parameter according the application needs. Disable the phase loss protection and set parameter 'network type' to 1 phase mode. Alternatively, also a MO13x or any other short circuit protection solution can be used for short circuit protection.

The voltage and current connection of the SCV10 must be connected to the same phase (here L1 shown) to ensure correct operation.



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10: Principle circuit diagram for a two-pole load.

9. Technical data

Data at Ta = 25 °C and rated values, unless otherwise indicated

9.1 Smart function module

X2X Interface (X4, X5)		
Rated control supply voltage U_s	according to B&R X20 system specification	
Rated control supply voltage U_s tolerance	according to B&R X20 system specification	
Typical current / power consumption (delivered by X2X link power supply output from X20BT9400)	30 mA / 600 mW	
Recommended RJ45 cable	Cat 5e SF/UTP AWG 26 / 1:1 connection Cat 6 S/FTP AWG 27 / 1:1 connection	
Max. distance between nodes Max. distance from X20-BT9400 to first SFM1	20 m	
Max. number of nodes on one X20-BT9400	8	
Max. length of total network from start to last module with 8 modules	160 m	
Grounding	according to B&R X20 system specification, the accessory SFM-CAB-RJTB provides the required grounding of shield	
Minimum cycle time The minimum cycle time defines how far the bus cycle can be reduced without communication errors occurring. Note that very fast cycles decrease the idle time available for handling monitoring, diagnostics and acyclic commands.	300 us	
Contactor supply circuit SFM1 (X1)		
Rated control supply voltage U_s	24 V DC	
Rated control supply voltage U_s tolerance	22 … 31.2 V incl. ripple It must be ensured that the minimum supply voltage is available at the last contactor in a supply chain.	
Typical current / power consumption (AF coil current not considered)	20 mA / 480 mW (SCV40-10 module) 20 mA / 480 mW (SC40-10 module)	
Reverse polarity protection	no	
Short circuit protection of contactor control outputs	yes	
Max. load current for AF contactor	coordinated with supported AF contactor types	
Min. power failure buffering time	10 ms	
Digital Input (X3)		
Number of digital inputs	1	
Supply for digital inputs	internal	
Isolation	no	
Input signal bounce suppression	configurable (see module parameters)	
Typical input current at nominal supply	7.5 mA	
Max. voltage loss at closed external auxiliary contact	max. 2 V	
Max. cable length	10 m	
General data		
MTBF	on request	
Duty time	100 %	
Dimensions	see dimensional drawings	
Weight	0.11 kg	
Mounting	Snapping on AF09 – AF96	
	AF09(Z)...-nn	AF40...-11
	AF12(Z)...-nn	AF52...-11
	AF16(Z)...-nn	AF65...-11
	AF26(Z)...-nn	AF80...-11
	AF30(Z)...-nn	AF96...-11
	AF38(Z)...-nn	
	nn = 11, 21, 30	
Mounting position	on AF contactor. 1-4, 5: max. current = AC-3 current of contactor	
Minimum distance to other units	0 mm for side to side mounting 5 mm to metal parts (e.g. control panel wall)	
Material of housing	UL 94 V0	
Degree of protection	IP20	

Electrical connection X1, X3		X1	X3
Push-In	1x	0.2...2.5 mm² 24...12 AWG	0.2...1.5 mm² 24...16 AWG
	1x	0.25...2.5 mm²	0.2...1.5 mm²
	1x	0.25...2.5 mm²	0.2...0.75 mm²
	1x	0.2...2.5 mm² 24...12 AWG	0.2...1.5 mm² 24...16 AWG
Spring	1x	0.2...2.5 mm² 24...12 AWG	0.2...1.5 mm² 24...16 AWG
	1x	0.25...2.5 mm²	0.2...1.5 mm²
	1x	0.25...2.5 mm²	0.2...0.75 mm²
Screwdriver type		0.6 x 3.5 mm	0.4 x 2.5 mm
Tightening torque		10 mm	8 mm
Electrical connection X2		use ready-made cables, see accessories.	
Max cable length		0.5 m	
Basic insulation		300 V	
Ensure safe distance from motor wires and other high voltage cables.			

9.2 Smart voltage and current sensor module

Input circuit		**SCV10-40**	**SC10-40**
Nominal frequency		50/60 Hz (45 ... 65 Hz)	
Measurement method		true RMS (up to 13th harmonics)	
Number of phases		1/3	
Nominal measuring range current		0.2 to 40 A AC	
Measured current range		$0.2 \times I_e \ldots 15 \times I_e$	
Nominal voltage range	3 phase	150 to 690 V AC ± 10 %	-
	1 phase	90 to 400 V AC ±10 %	-
Measurement accuracy given at Ta=25 °C, 50/60 Hz	I_{rms} (range $0.2 * I_e \le 0.75*I_e$)	±3 %	
	I_{rms} (range $0.75 * I_e \le 2*I_e$)	±1,5 %	
	I_{rms} (range $>2 * I_e \le 15*I_e$)	±3 %	
	U_{rms}	±1.5 %	-
	power factor ≥ 0.5 (inductive)	typ. ±1.5% (I_{rms} > 3 A)	-
	apparent power	typ. ±3 %	-
	active power (cos phi > 0.5)	typ. ±5 %	-
	frequency (50/60 Hz)	±1.5 %	-
	current imbalance	typ ±10 % (condition: I_{mot} > 150 mA)	
	voltage imbalance	±10 %	-
	voltage total harmonic distortion (THD)	±5 %	-
	current total harmonic distortion (THD)	±10 % (condition: I_{mot} > 1A)	
Measurement range of earth fault current		> 20% of I_e	
Earth fault current		I_e < 1.0 A : ±25 % (condition: I_{mot} > 100 mA and I_{earth} > 80 mA) I_e >1.0 A : ±10 % (condition: I_{mot} > 200 mA and I_{earth} > 200 mA)	
Supported network types		1/3 phase, grounded networks	
Trip classes, selectable by parameter		5E, 10E, 20E, 30E	
Tripping time for phase loss		determined by parameter CurrPhaseLossDelayPar. adjustable from 0 … 25.5 s	
Load per phase		approx. 30 mΩ	
Short-circuit protection		provided by external short-circuit protection device, e. g. MO, MCB, MCCB or fuse. Refer also to ABB coordination tables available here: www.lowvoltage-tools.abb.com/soc/	
Max cross-section of wires. Use isolated wires only!		16 mm²	

Input circuit		SCV10-40	SC10-40
Conductor holes in the current transformers		13 mm	
Performance under short-circuit conditions Coordination type 2 I_q: Rated conditional short circuit current	Iq	100 kA 80 kA	
		500 V AC 690 V AC	
	fuse	200 A gG 200 A gG	
Additional information relating to cULus approval		suitable for use on circuits capable of delivering not more than 100 kA rms, symmetrical, 600 V AC maximum, when protected by 100 A, class K5/RK5 fuses, use fuses only	
Electrical connection X1			
Connecting capacity	1x	0.2...2.5 mm² 24...12 AWG	
	1x	0.2...2.5 mm² 24...12 AWG	
	1x	0.2...2.5 mm²	
	1x	0.2...2.5 mm²	
Stripping length		8 mm	
Screwdriver type		0.6 x 3.5 mm	
Tightening torque		0.5...0.6 Nm	
General data			
MTBF		on request	
Duty time		100 %	
Dimensions		see dimensional drawings	
Weight		0.23 kg	
Mounting		DIN rail (IEC/EN 60715), snap-on mounting without any tool screw mounting with mounting clips screw mounting with screws (M4)	
Mounting position		any	
Minimum distance to other units		-	
Material of housing		UL 94 V2	
Degree of protection		IP20	

9.3 Common technical data

Environmental data (common)			
		SFM1	**SCV**
Ambient temperature ranges	operation	-25 to +60°C	
	storage	-40 to +70°C	
Damp heat, cyclic (IEC/EN 60068-2-30)		6 x 24 h cycle, 55 °C, 95 % RH	
Climatic class IEC/EN 60721-3-3		3K3 (no condensation, no ice formation) Relative humidity 5 % - 95 %, no condensation	
Vibration, sinusoidal		4 g, 5-300 Hz	
Shock		15 g, 11 ms	
Isolation data of contactor module in combination with contactor (and sensor module)			
Rated insulation voltage U_i	acc. to IEC 60947-4-1	690 V	
	acc. to UL / CSA	600 V	
Rated impulse withstand voltage U_{imp} SFM: Control supply, bus / mains contactor SCN: X2 (voltage input) to control supply, bus		6 kV	
Basic insulation		according to technical data of contactor	
Protective separation pollution degree 3		L/N: 277 V AC L/L: 480 V AC	
Protective separation pollution degree 2		L/N: 400 V AC L/L: 690 V AC	
Pollution degree		3	
Overvoltage category		III	
Installation altitude without derating		max. 2000 m	
Deratings at high altitudes		on request	
Standards / Directives			
Standards		IEC/EN 60947-1:2020 (Ed. 6.0) / EN 60947-1:2007 + A1:2011 + A2:2014 IEC/EN 60947-4-1:2019 UL 60947-4-1:2014 (Ed. 3) UL 60947-1:2013 (Ed. 5)	
Low Voltage Directive		no. 2014/35/EU	
EMC directive		no. 2014/30/EU	
RoHS directive		no. 2011/65/EU incl. 2015/863/EU	

Electromagnetic compatibility				
Emission requirements	radio interference voltage	EN 61000-6-4	X	
		EN 61000-6-3		X
	radio interference field strength	CISPR 11	class A	class B
Immunity requirements	electrostatic discharge	EN 61000-4-2	6 kV contact 8 kV air	
	radiated, radio frequency electromagnetic field amplitude modulated	EN 61000-4-3	10 V/m (80-6000 MHz)	
	electrical fast transients (burst)	EN 61000-4-4	2 kV (power supply lines) 1 kV (signal lines)	
	surge, unsymmetrical / symmetrical	EN 61000-4-5	1 kV / 0.5 kV (DC-supply) 2 kV / 1 kV (measurement lines)	
	conducted disturbance, induced by radio frequency, common mode, amplitude modulated	EN 61000-4-6	10 V	

Performance data	
Cycle time in contactor module: “switch on signal” received via X2X until contactor control voltage set to 24 V DC	typ. 5 ms
Update rate of measurement values provided from sensor module and available for X2X communication	typ. 25 ms

According to the current interpretation of applicable Chinese law the Novolink devices described in this manual are imported as industrial automation equipment (they cannot be used without a PLC) and do not need CCC certification.

9.4 Technical drawings

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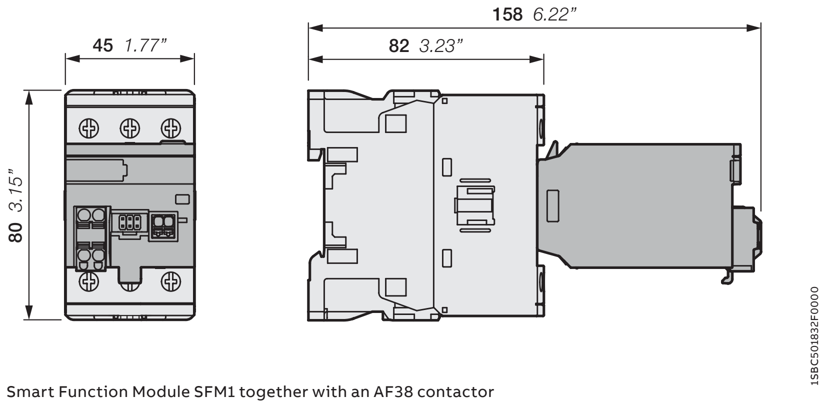
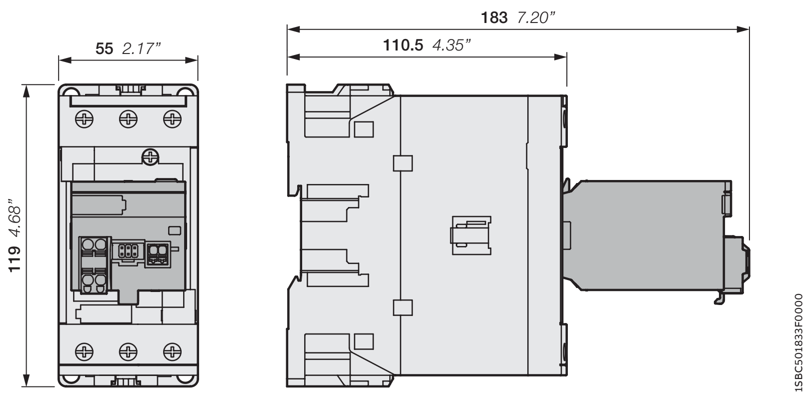
Dimensional drawings

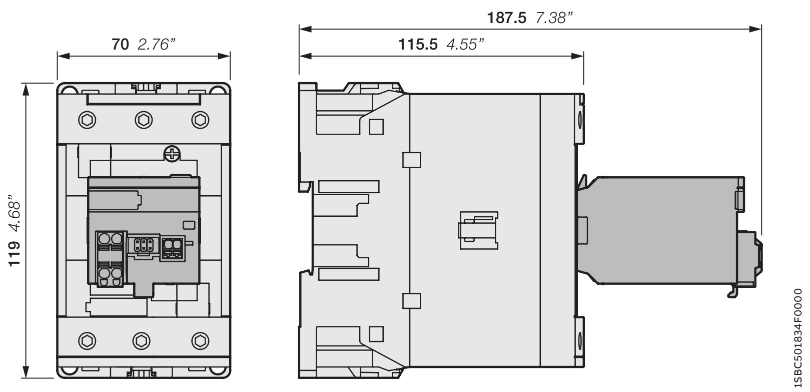
in **mm** and inches



Smart Function Module SFM1 together with an AF38 contactor



Smart Function Module SFM1 together with an AF40 contactor



Smart Function Module SFM1 together with an AF80 contactor

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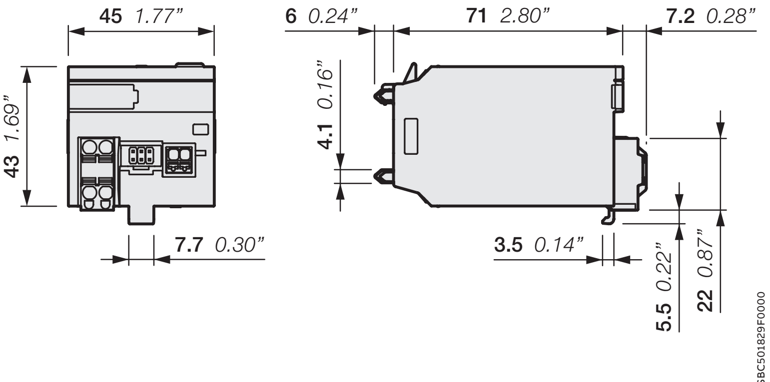
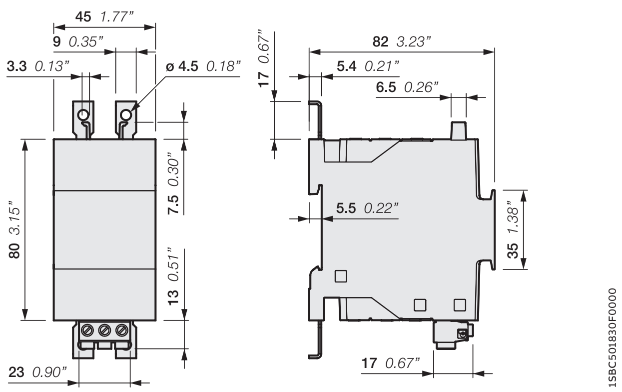
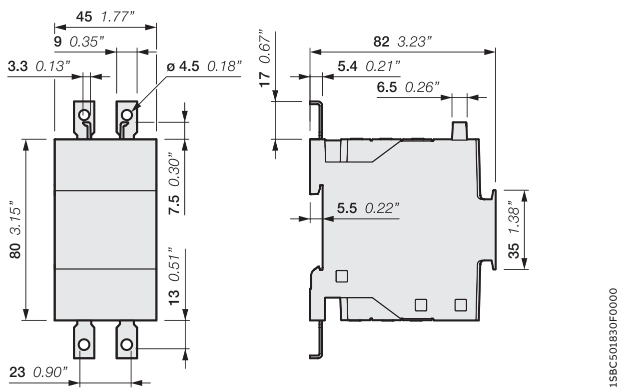
Dimensional drawings
in **mm** and inches



Smart Function Module SFM1

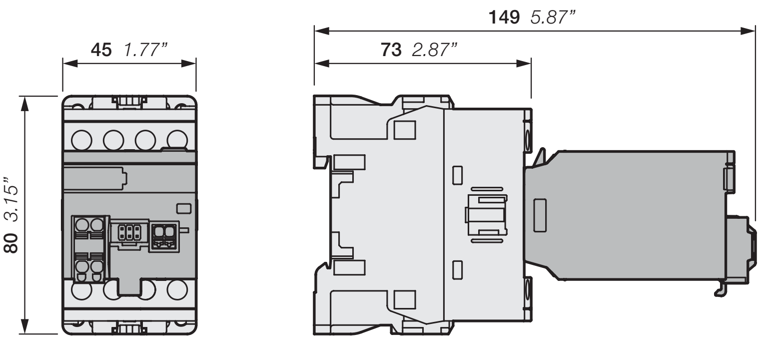


Smart Current and Voltage Sensor Module SCV10-40



Smart Current Sensor Module SC10-40

1SBC501830F0000



Smart Function Module SFM1 together with an AF09 contactor

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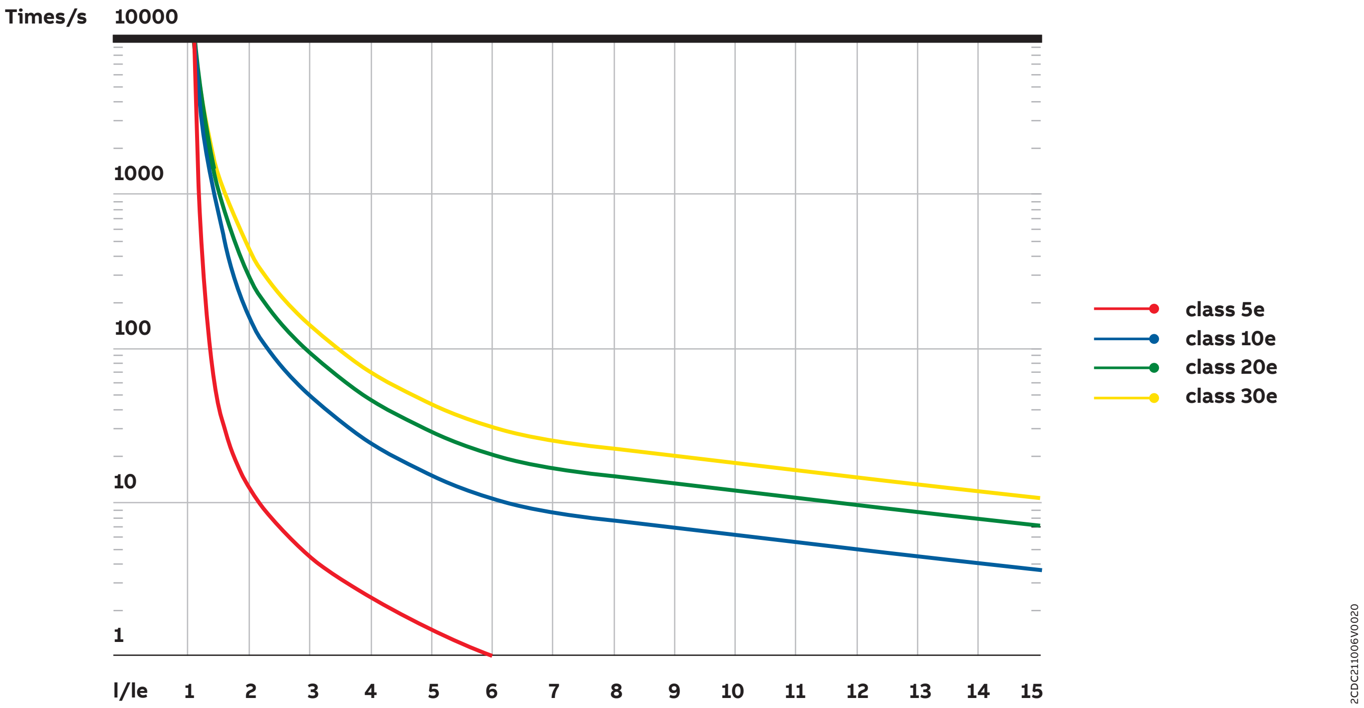
Tripping curves for warm motor for three-phase and single-phase symmetrical loads



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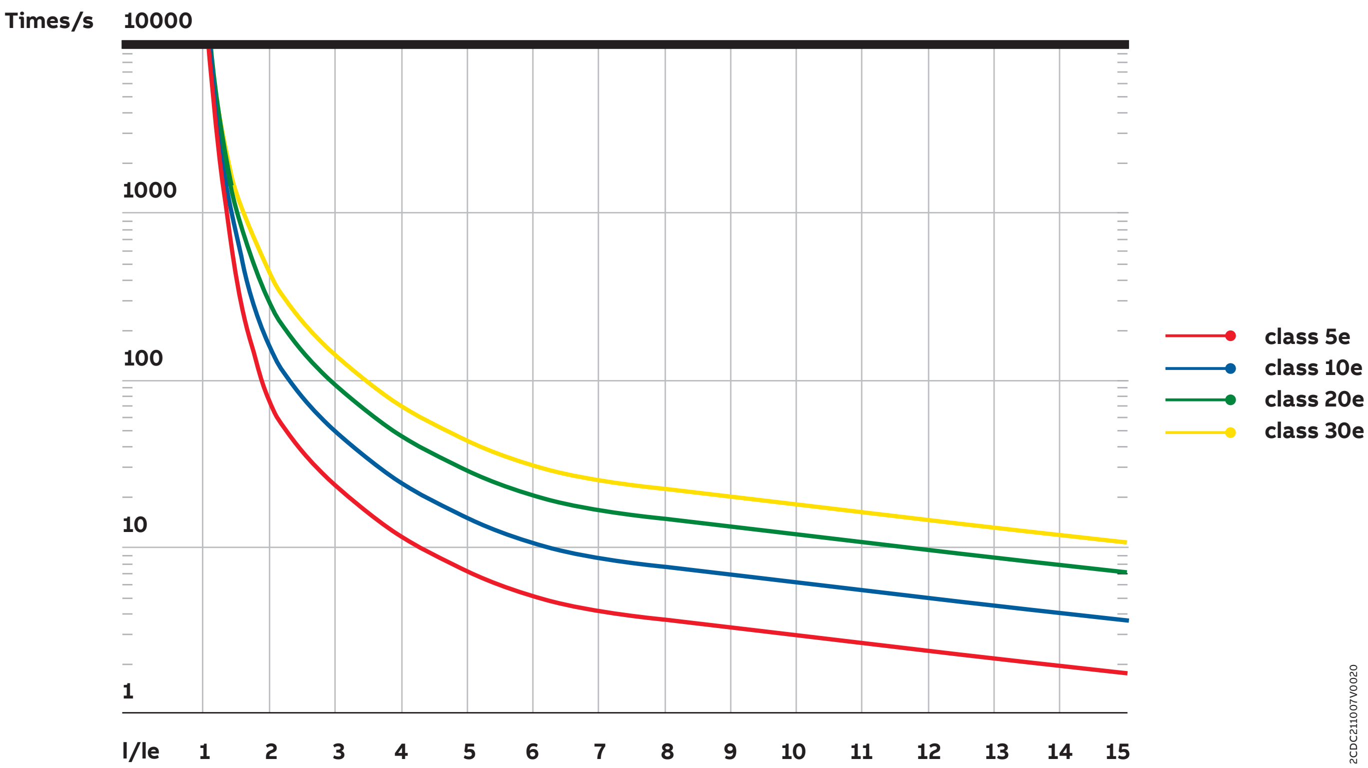
Tripping curves for cold motor for three-phase and single-phase symmetrical loads



10. Software license information

10.1 Free Modbus library

A portable Modbus implementation for Modbus ASCII/RTU.

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10.2 CMSISv4 software library

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11. Revisions

Rev.	Page (P) Chapt. I	Description	Date dept. / init.
1.2	All	Public version	1.10.2020 DESTO/CPE
1.3	All	Update for SC10-40	Dec/2021 DESTO/CPE

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ABB STOTZ-KONTAKT GmbH
Eppelheimer Strasse 82
69123 Heidelberg, Germany

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