

White paper

# SACE Tmax XT Circuit-Breaker Terminals and Connection



# Circuit-Breaker Terminals and Connections

## Index

Introduction.....	2
1. Components used for wiring.....	3
1.1. Electrical cables.....	3
1.2. Flexibility of an electrical cable: flexible and rigid cables .....	4
1.3. Cable end: cable terminals (lugs).....	5
1.4. Flexible and rigid bars.....	6
2. Description of terminals .....	7
3. Circuit-breaker wiring.....	9
3.1. SACE Tmax XT1.....	9
3.2. SACE Tmax XT2.....	13
3.3. SACE Tmax XT3.....	17
3.4. SACE Tmax XT4.....	21
Annex A .....	24
A.1 Conversion table: AWG-mm <sup>2</sup> .....	24
A.2 Std. IEC 60947 tables: cross-sectional areas and current carrying capacity .....	24

# Introduction

The reliability but above all the safety of an electrical plant depends not only on the quality of the design and components but also on the methods of installation.

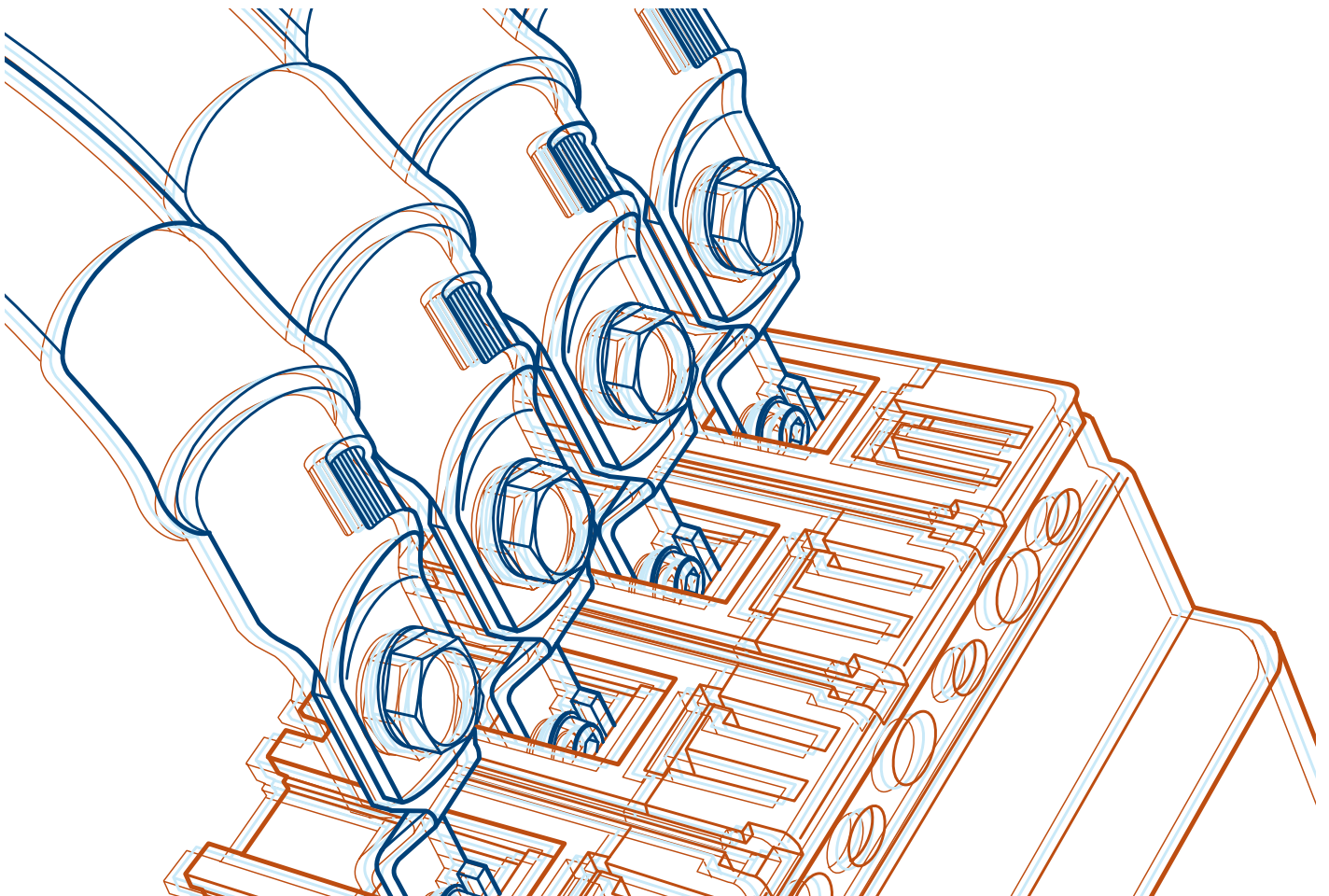
Among the components of an electrical plant, the cables and the bars play an important role. Besides taking into consideration the project (choice of the conductor type, cable sizing and method of installation, etc.), an aspect requiring particular attention is the connection method of the protective device to the terminal.

As a matter of fact it is of fundamental importance to connect properly the cable or the bar to the circuit-breaker taking some particular measures and following some useful advices. Thus, some inconveniences can be avoided, e.g. the problems deriving from local heating near the circuit-breaker terminals, blackening marks on the insulating material and on the conductor, premature aging of the part of cable near to the circuit-breaker, etc. ..., aspects which cannot be neglected since the cable may be the cause of flame ignition with dangerous consequences from the point of view of the safety of people and goods.

For this reason, the analysis presented in the following pages is aimed at giving useful hints for the connection of the cables/bars to the circuit-breaker terminals. This document is accompanied by numerous tables which privilege the information about the connection cable/bar-terminal, trying to limit to the necessary the descriptions of the different components (cables, bars, cable terminals, etc.) already documented by the manufacturing companies.

This White Paper is divided into three main parts:

- components used for wiring: this part gives a description of the components mentioned in this paper;
- ABB SACE offer: this part offers a panorama of the connection terminals of ABB SACE circuit-breakers;
- wiring cable-terminal-circuit-breaker: making use of user-friendly tables this part gives information about the cable/bar connection to the ABB circuit-breakers (maximum cross-section in relation to the terminal, tightening according to the cable size, etc.).



# 1. Components used for wiring

Here are described the main components used to connect the circuit-breakers to the electrical plant. The descriptions are limited to the necessary information since these products are not the main subject of this paper.

## 1.1 Electrical cables

An electrical cable is a component constituted by an assembly of conductors aimed at allowing the current flow.

Cables are generally constituted by one or more elements called cores: therefore a cable can be single-core, that is formed by a single core, or it can be formed by more cores (two-core, three-core and multi-core cables) enclosed in a protective sheath.

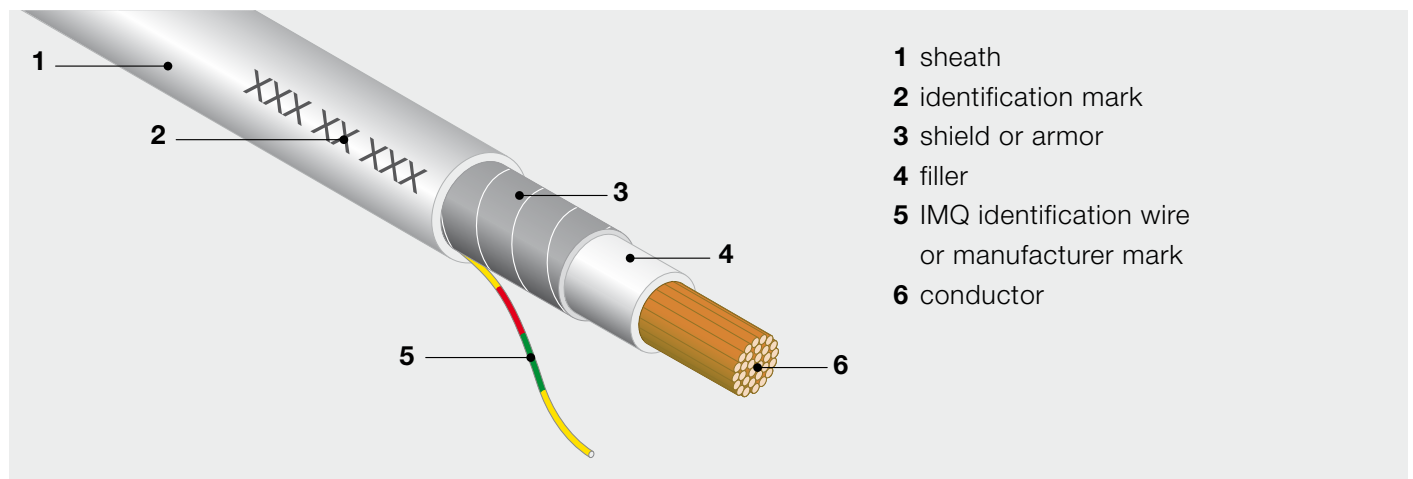
Generally a cable used for LV electrical energy distribution is formed by the following elements (not always in a cable used for electrical wiring all these components are necessarily present):

- **conductor:** metal part, usually in copper (Cu) or aluminium (Al), intended to carry the current;
- **insulating material:** the main function of the insulation is insulating the conductors one from the other and from the

exposed conductive part. According to the type of insulation the service and short-circuit temperature changes. In the low voltage field the cables which are used more can be divided into two main classes:

- insulating cables with elastomeric material (ethylene propylene rubber EPR)
- insulating cables with thermoplastic material (polyvinyl chloride PVC)
- **sheath:** the main function of the sheath is protecting the cables against the external aggression of the environment or of possible chemical agents; besides, in multi-core cables, the sheath encloses the whole of the different cores;
- **shield:** it is constituted of a thin copper strip which has the task of neutralizing the electric fields and the consequent disturbances;
- **armor:** the main function of the armor (if present) is protecting the cable against external agents (chemical agents, humidity, mechanical stresses, etc.); usually the armor is constituted by wires or steel or copper strips;
- **filler:** it has the function of filling the spaces among the cores of multi-core cables giving it a round shape; this material is usually constituted of textile fiber.

Figure 1- Parts constituting a LV energy distribution cable



# 1. Components used for wiring

## 1.2 Flexibility of an electrical cable: flexible cable and rigid cable

A constructional feature diversifying a cable is its flexibility, namely its manageability. Such peculiarity derives mainly from the characteristic of the conductor in addition to the elasticity of the insulation: a cable formed of single wires is more rigid than a very thin braid of wires (strands).

As regards this distinction the conductors have been divided by the Std. IEC 60228 into four classes:

- **Class 1:** solid conductors
- **Class 2:** stranded conductors
- **Class 5:** flexible conductors
- **Class 6:** flexible conductors which are more flexible than those in Class 5.

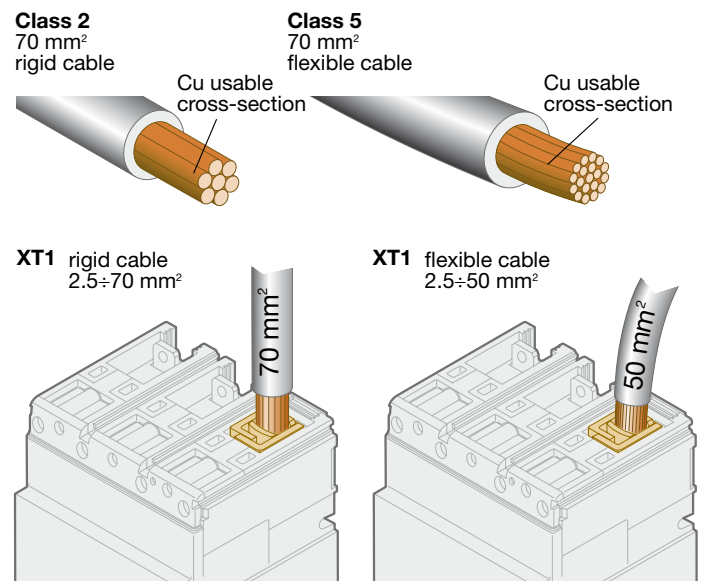
Classes 1 and 2 refer to rigid conductors intended for fixed installation, more precisely solid and stranded conductors for Class 1 and Class 2 respectively; classes 5 and 6 refer to flexible conductors for use in fixed or mobile installations, more precisely Class 5 for flexible cables and Class 6 for very flexible cables.

As regards LV energy distribution the cables more frequently used belong to classes 2 and 5, since the solid conductors of Class 1 represent a solution with limited cross-sectional areas and therefore they cannot carry the currents involved in power distribution.

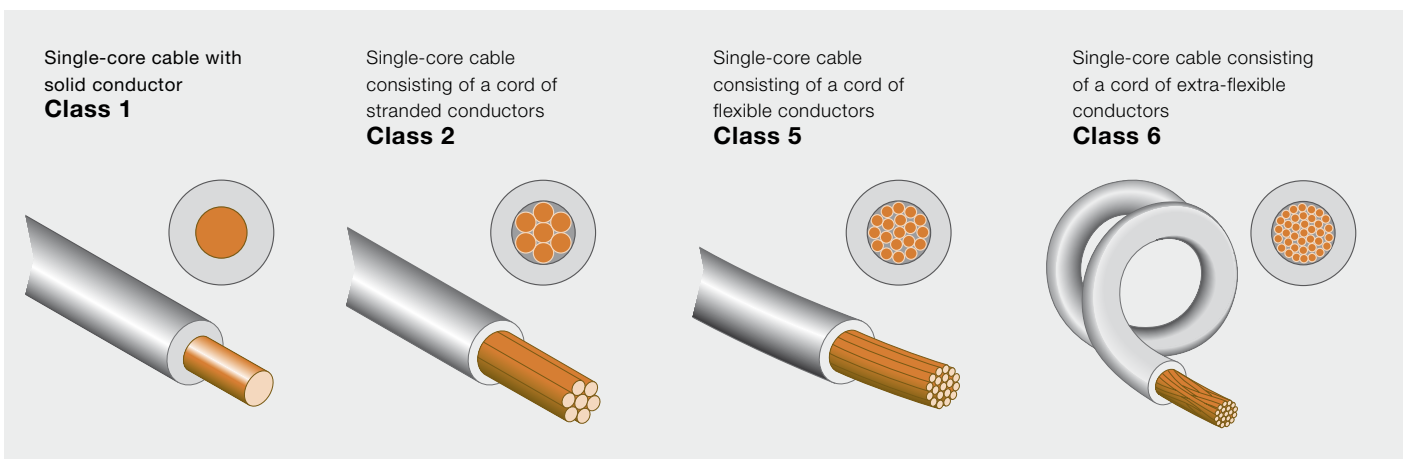
Extra-flexible cables are generally intended for a mobile use, where connections subject to continuous bending (for instance in the robotics field) are required.

With the same copper cross-sectional area (to be meant as quantity of copper necessary for a determined current carrying capacity), a flexible conductor has a diameter bigger than a rigid cable (because of the interstices among the thin and numerous copper strands); for this reason the tables in Chapter 3 – making reference to a defined terminal - show flexible conductors with maximum cross-sectional areas smaller than those of rigid cables\*.

Example:



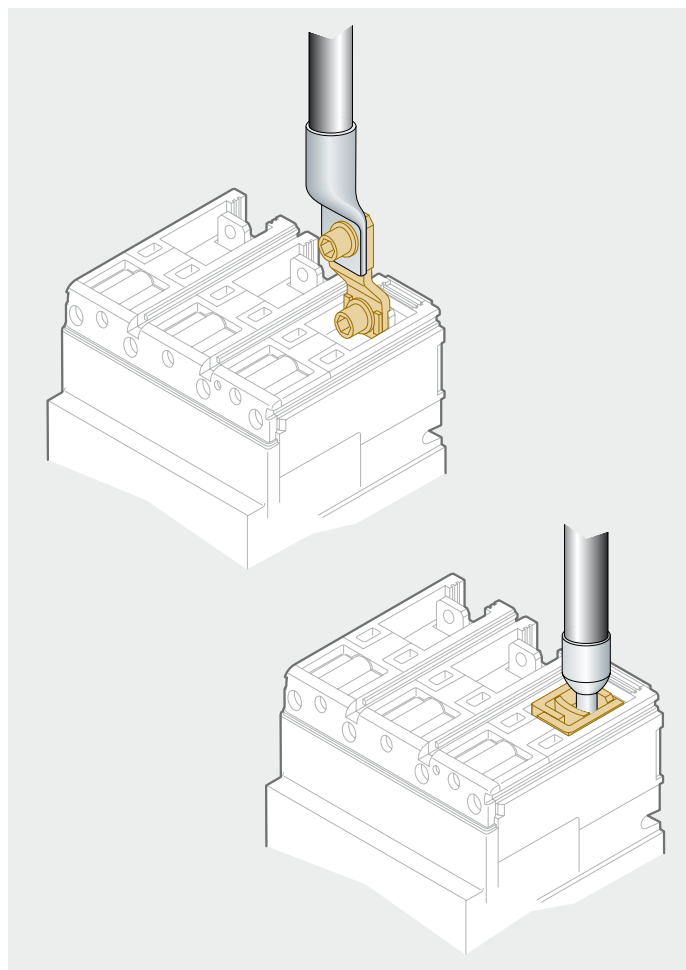
\*however, all the cross-sections given can carry the maximum rated current of the circuit-breaker



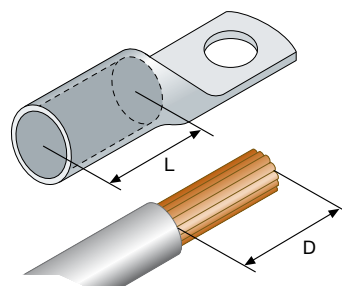
### 1.3 Cable terminals

To connect the cable to the typologies of terminals available for molded-case circuit-breakers it is possible to use lugs, so that a good connection of the cable to the circuit-breaker is ensured. Generally, such connectors are obtained from copper or aluminium tubes and those mainly used in electric power distribution, where the cross-sections involved may be high, are those with “eyelet” end since they allow a solid and firm connection to the terminal.

However, in applications where the cross-sections of the cables are not particularly big, lugs with tube end compatible with the front terminals for cables (FCCu) are also used.



It is very important to crimp the cable to the terminal (a lug shall hold a power cable only) in the proper way, thus avoiding damages to the strands of the conductor or to part of the insulation; all the conducting material shall be contained inside the lug, taking care to strip only the part accepted by the connector.



Crimping, that is the operation of fixing the cable to the terminal, shall be carried out so that the cable does not come out of the lug. In fact, if between the crimped lug and the beginning of the stripping there were a longer space, the disconnection of the cable could be possible.

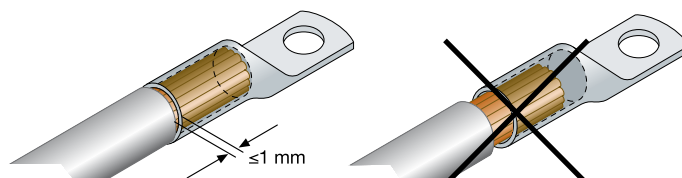
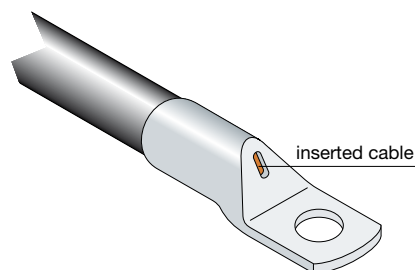


ABB SACE recommends the use of lugs with inspection hole so that the proper insertion of the cable can be checked.



# 1. Components used for wiring

## 1.4 Rigid and flexible bars

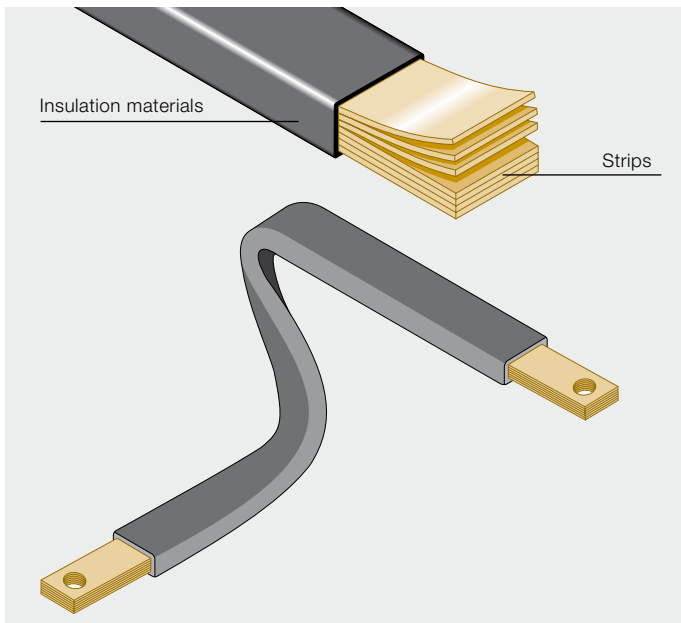
As regards the connections inside electrical switchboards, in some cases the use of the cable can result “not suitable” for the available space.

As a matter of fact, for upper middle powers, the cross-sections of the cables involved, having a high bend radius, make it difficult to assembly the switchboard, but above all reduce the available space inside it, thus causing problems with heat dissipation and air exchange.

In these cases both flexible as well as rigid bars are used.

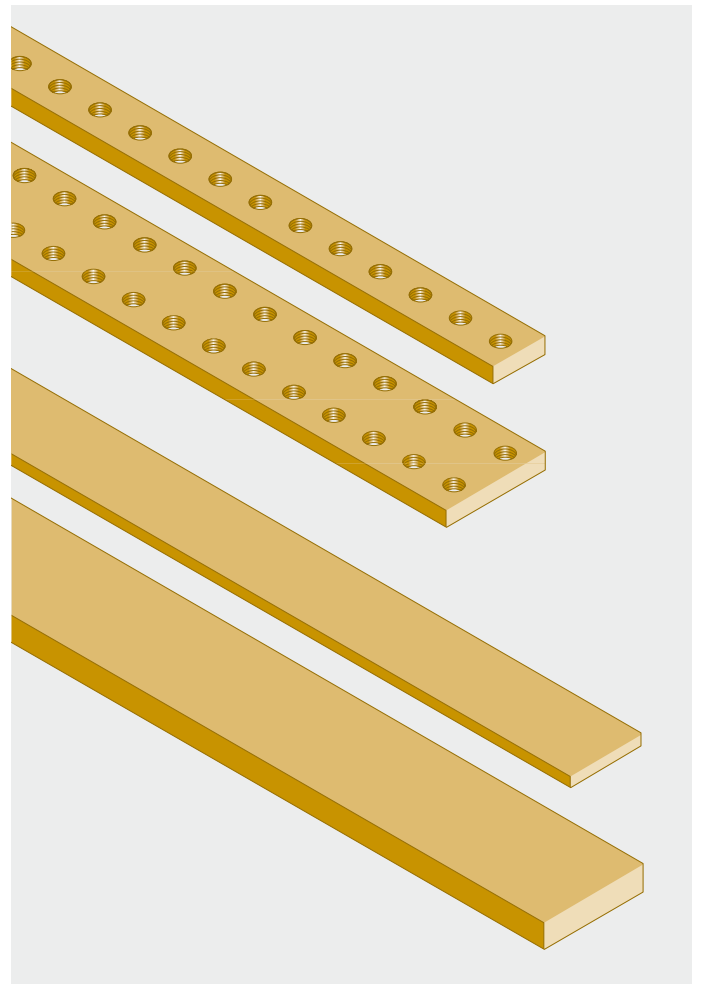
### Flexible bars

Flexible bars consist of bundles of copper or aluminium strips protected by insulating material (the most common is PVC). The main characteristic of this product is certainly the ease of shaping and this peculiarity does not impose limits on the minimum bend radius; therefore, as already mentioned, they allow a reduction in the overall dimensions, thus making easier the assembly of electrical switchboards.



### Rigid bars

Electric bars (bare or insulated), which are chiefly used for high powers, are rigid bars made of copper or aluminium; for the realization of electrical switchboards pre-punched bars, pre-punched and threaded bars or solid bars are mainly used. Very often it is possible to find colored bars, coated with special paints having particular dissipating properties. In fact such products allow an increase in irradiated heat without causing on the other hand a surface thermal insulation.





## 2. Description of connection terminals

Connection terminals allow the circuit-breaker to be connected to the plant in the most suitable way in relation to the installation requirements.

The following terminals can be distinguished:

- front terminals, which allow the connection of cables or bars directly from the circuit-breaker front;
- rear terminals, which allow the installation of the circuit-breakers in segregated switchboards with rear access.

A further categorization can be into:

- terminals for cables: for the connection of bare copper cables
- terminals for the connection of bars and cable lugs.

The circuit-breakers of SACE Tmax XT series can be equipped with the following types of terminals:

- Front terminals (F - Front), intended for the connection of bars and cable lugs: standard supply in the fixed version. These terminals are integral with the fixed/moving contact of the circuit-breaker and do not increase the overall dimensions of the circuit-breaker.
- Front extended terminals (EF – Extended Front), intended for the connection of bars and cable lugs. They are directly fixed to the front terminal F and increase the height of the circuit-breaker. Thanks to their particular form they are suitable for applications where higher heat dissipation is required. If necessary, due to insulation reasons, phase separators are supplied together with the terminal kit.
- Front extended spread terminals (ES), intended for the connection of bars and cable lugs: fixed directly to the front terminal F. Since they increase the pole pitch of the circuit-breaker, they allow the connection of bars with higher dimensions than those which can be connected to the simple front terminals or the front extended terminals. If necessary, due to insulation reasons, phase separators are supplied together with the terminal kit.
- Rear terminals orientated (R): intended for the connection of bars and cable lugs. They allow the connection of bars or cable lugs at the rear. They can be installed in 4 different positions (at intervals of 45°). In the rear terminal kits also low terminal covers are included.

- FC CuAl front terminals (Cu Al Front Cable): terminals intended for the connection of bare copper and aluminium cables.

Both the conductors of Class 2 (stranded conductors) as well as the conductors of Class 5 (flexible conductors) can be connected to these terminals.

The terminal provides one or more holes for the connection of the cable previously “stripped”. Thanks to a security dowel it is possible to connect the cable complying with the given tightening torque. The dowel has a cone-shaped extremity to make easier the tightening of the different cross-sections of the cables.

In the terminals intended for smaller cross-sections, the dowel is replaced with a plate which makes easier the tightening of the smallest cross-sections.

On each terminal the tightening torque values, which depend on the size of the cable to be connected, are directly indicated. It is possible that, for the same terminal, two different values are specified according to the variations in the conductor cross-section.

There are two types of FC CuAl terminals: standard and external.

Standard terminals, once installed, do not increase the total overall dimensions of the circuit-breaker. In some cases standard terminals may require the installation of low terminal covers so that the clearances can be guaranteed.

On the contrary, the external terminals, once installed, increase the total height of the circuit-breakers and usually require mounting of high terminal covers (HTC) so that the proper clearances are maintained. The terminal covers, if necessary, are supplied by default with the kit of terminals.

- FC Cu front terminals: terminals intended for the connection of bare copper cables.

Both the conductors of Class 2 (stranded type) as well as the conductors of Class 5 (flexible type) can be connected to these terminals.

These terminals are usually called loop terminals and provide an area to house the cable and a concave plate, whose function is fixing the cable and ensuring tightening. FC Cu terminals can hold in the same housing one or more copper cables with predefined cross-sections.

FC Cu terminals are standard, in fact their installation does

## 2. Description of connection terminals

not increase the overall dimensions of the circuit-breaker. Generally it is not necessary to use terminals covers, neither high nor low.

Besides, allowing the tightening of flexible or rigid bare copper cables, FC Cu terminals allow also the connection of the cables, usually with reduced cross-sections, crimped with tube lugs.

- Front terminals for flexible bars: terminals intended for the connection of flexible bars.

From a constructional point of view, these terminals are very similar to the FC Cu front terminals, with an only difference in the plate. In fact, the plate is not concave but has a flat surface to adhere perfectly to the bars.

Given the dimension of the single bar, the minimum and maximum number of flexible bars which can be tightened there is indicated in Chapter 3.

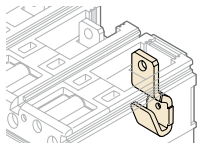
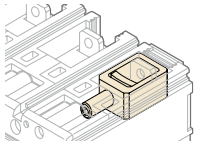
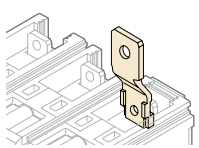
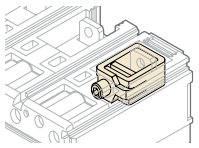
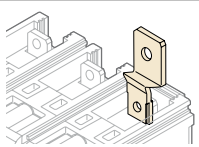
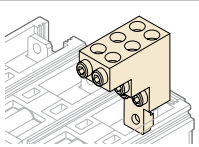
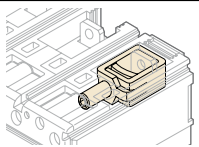
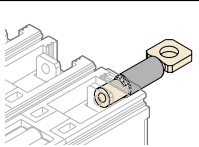
- Multi-cable front terminals: terminals intended for the connection of copper or aluminium cables.

These terminals are particular clamps used to house Cu or Al cables. Their peculiarity is that on the same terminal there are up to six holes for cable connection. For the tightening of each cable, dowels with conical extremity are used.

On each terminal the tightening torque values, which depend on the cross-sectional area of the cable to be connected, are directly indicated. It is possible that, for the same terminal, two different values of tightening torque are specified according to the variations in the conductor cross-section.

Multi-cable terminals are typically external, that is they exceed the volume of the circuit-breaker and demand the use of high terminal covers.

### Terminals

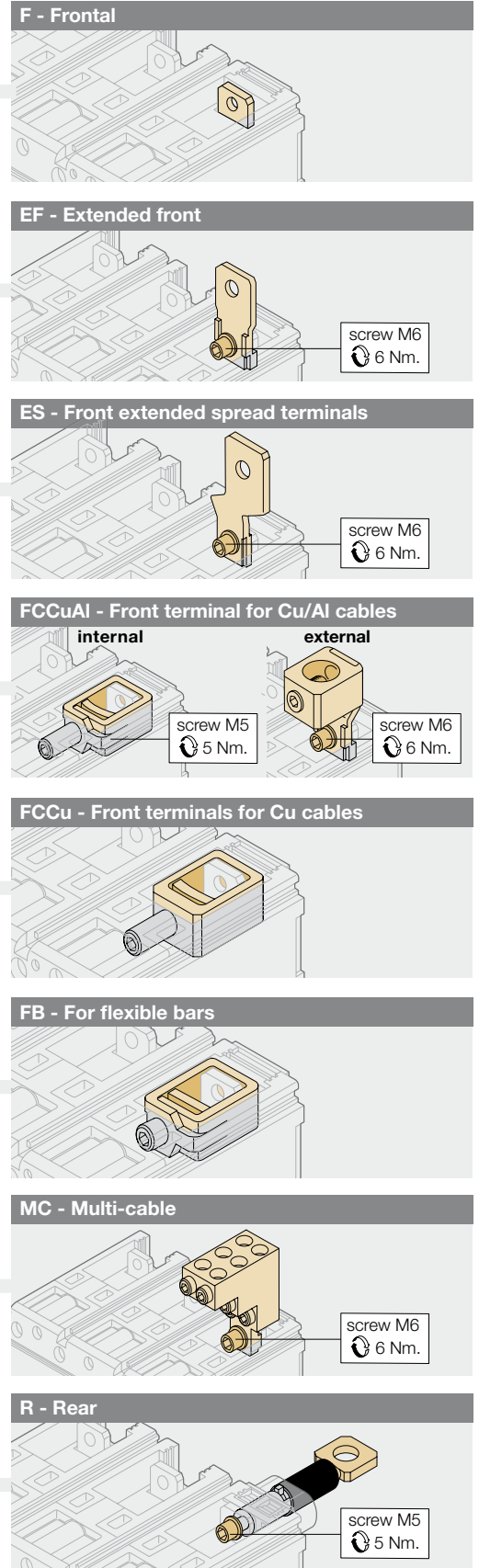
<p>F - Frontal</p> 	<p>FCCuAl - Front terminals for Cu/Al cables</p> 
<p>EF - Extended front</p> 	<p>FB - For flexible bars</p> 
<p>ES - Front extended spread terminals</p> 	<p>MC - Multi-cable</p> 
<p>FCCu - Front terminals for copper cables</p> 	<p>R - Rear</p> 

# 3. Wiring

## SACE Tmax XT1



Figure showing the circuit-breaker with its terminals and the tightening torques of the terminals to the circuit-breaker.



# 3. Wiring

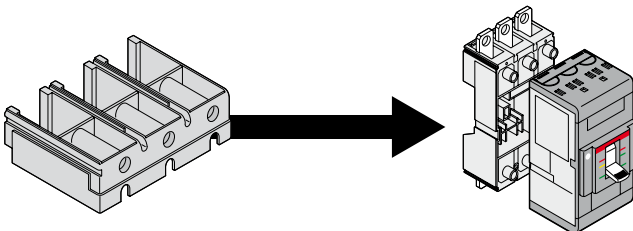
## Tmax XT1

Cables/Bars		FCCuAl				FCCu		MC Multicables		FB Flexibar	
Tipology	Cu/Al cross-section [mm <sup>2</sup> ]	Tipology	Cu/Al cross-section [mm <sup>2</sup> ]	Tipology	Cu/Al cross-section [mm <sup>2</sup> ]	Tipology	Cu cross-section [mm <sup>2</sup> ]	Tipology	Cu cross-section [mm <sup>2</sup> ]	No. of bars	Section
Flexible cables	1x1.5...50	Flexible cables	-	Flexible cables	-	Flexible cables	1x2.5...50 2x2.5...35	Flexible cables	6x2.5...25	Min.	2
Rigid cables	1x1.5...50	Rigid cables	1x35...95	Rigid cables	1x150...240	Rigid cables	1x2.5...70	Rigid cables	6x2.5...35	Max.	9
<b>Terminal</b>											
Typology <b>Internal</b>		Typology <b>External</b>				Typology <b>Internal</b>		Typology <b>External</b>		Typology <b>Internal</b>	
<b>Installation requirement*</b>											
<b>Supply on request</b>											
	100 mm	■				■					■
	200 mm	■				■					■
	50 mm	■				■					■

The terminals ES, FCCuAl, FCCu, FB and MC can be used also with plug-in version thanks to the following adapter:

**Fixed part adapter**

**Plug-in circuit-breaker**



\* 25 mm phase separators are always delivered with the circuit-breakers.

F Front terminals		EF Front extended terminals		ES Front extended spread terminal		R Rear orientable terminals	
		<p>Maximum overall dimensions</p>		<p>Maximum overall dimensions</p>		<p>Maximum overall dimensions</p>	
Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs	
Tightening torques [Nm]	Supplied clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
6	M6	9	M8	9	M8	6	M6
Internal		External				Rear	
■							
■		■					
■		■					

For fixed part of plug in version, the following standard connections are available:

HR-VR Rear orientable terminals		EF - Front extended terminals	
Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
9	M8	9	M8

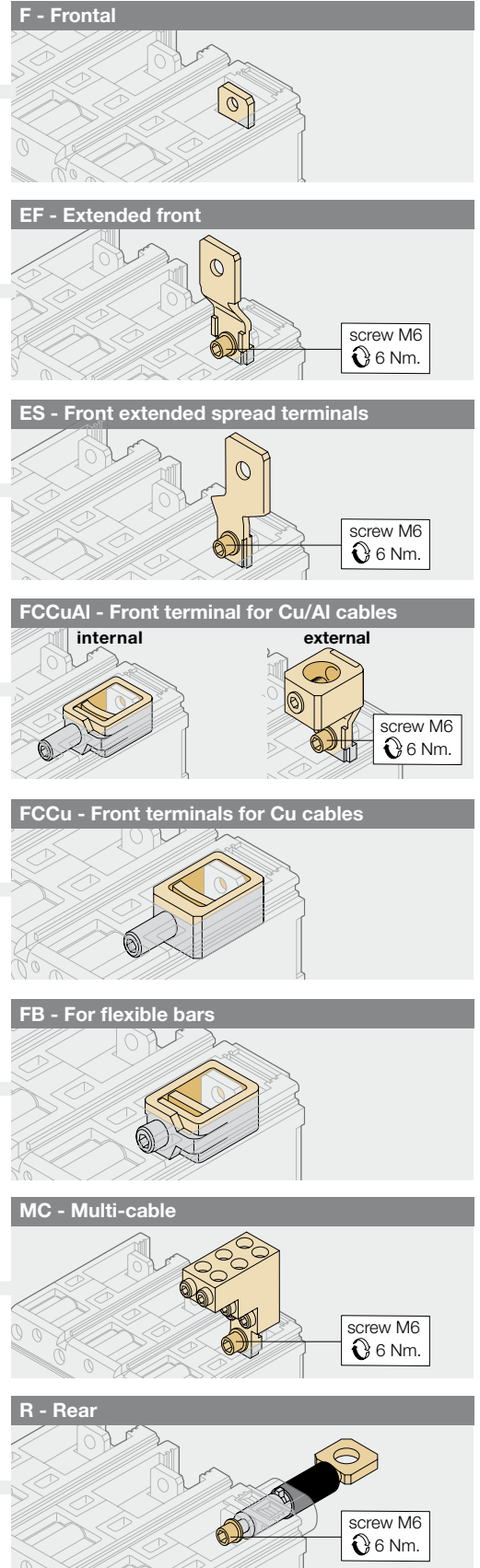


### 3. Wiring

## SACE Tmax XT2



Figure showing the circuit-breaker with its terminals and the tightening torques of the terminals to the circuit-breaker.

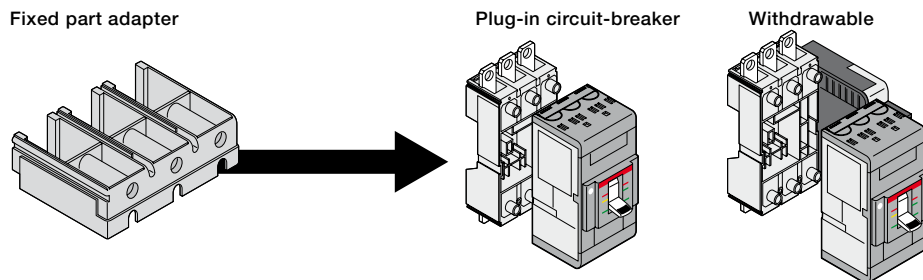


# 3. Wiring

## Tmax XT2

Cables/Bars		FCCuAl				FCCu		MC Multicables			
Tipology	Cu/Al cross-section [mm²]	Tipology	Cu/Al cross-section [mm²]	Tipology	Cu/Al cross-section [mm²]	Tipology	Cu/Al cross-section [mm²]	Tipology	Cu cross-section [mm²]		
Flexible cables	2.5...70	Flexible cables	-	Flexible cables	-	Flexible cables	-	Flexible cables	2.5...70 2x2.5...50		
Rigid cables	2.5...95	Rigid cables	1x70...185	Rigid cables	1x150...240	Rigid cables	2x35...95	Rigid cables	2.5...95		
Internal		External				Internal		External			
Installations requirement*											
Supply on request											
	Phase separator	100 mm	■					■			
		200 mm	■					■			
	Terminal cover	50 mm	■					■			

The terminals ES, FCCuAl, FCCu, FB and MC can be used also with plug-in and withdrawable version thanks to the following adapter:



\* 25 mm phase separators are always delivered with the circuit-breakers.



FB Flexibar		F Front terminals		EF Front extended terminals		ES Front extended spread terminal		R Rear orientable terminals		
No. of bars		Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs		
Min.	2	10x0.8	Tightening torques [Nm]	Supplied clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
Max	9		6	M6	9	M8	18	M10	9	M8
Internal		Internal		External		External		Rear		
■		■		■						
■		■		■						
■		■		■						

For fixed part of plug in and withdrawable version, the following standard connections are available:

HR-VR Rear orientable terminals		EF - Front extended terminals	
Tightening torques [Nm]		Tightening torques [Nm]	
9		9	
Suggested clamping screw		Suggested clamping screw	
M8		M8	

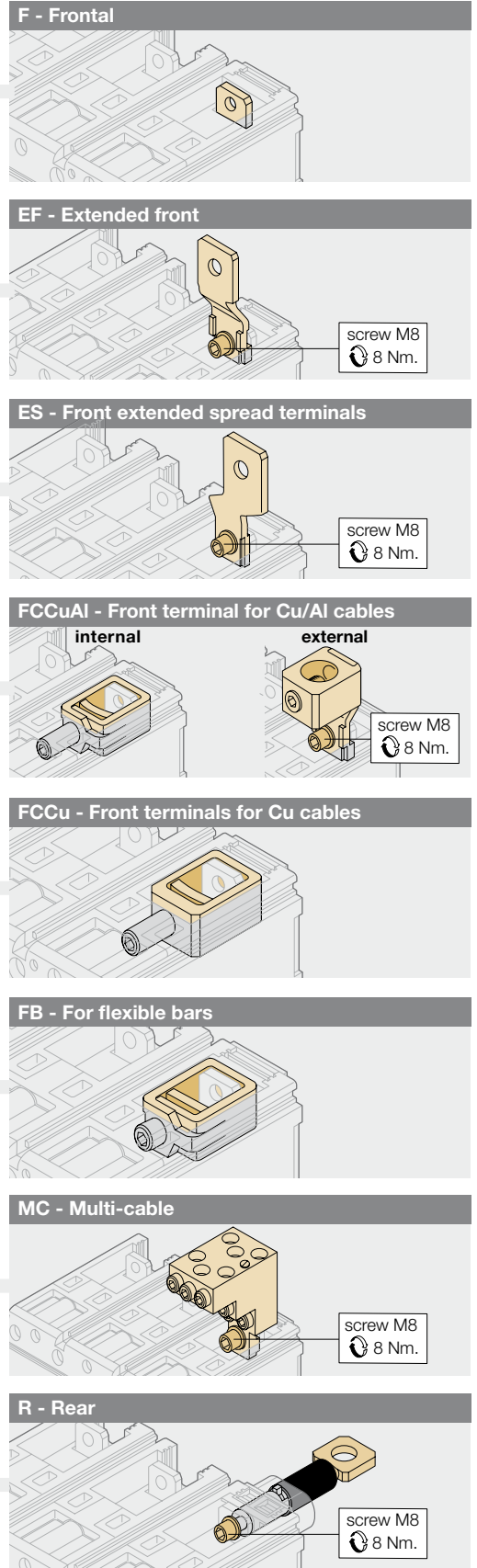


# 3. Wiring

## SACE Tmax XT3



Figure showing the circuit-breaker with its terminals and the tightening torques of the terminals to the circuit-breaker.



# 3. Wiring

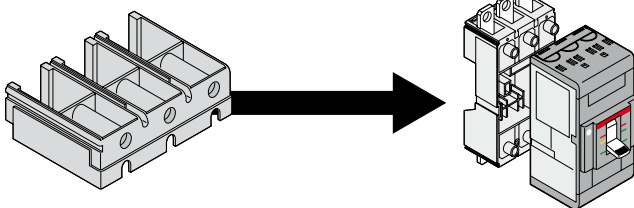
## Tmax XT3

Cables/Bars		FCCuAl						FCCu		MC Multicables			
Typology	Cu/Al cross-section [mm²]	Typology	Cu/Al cross-section [mm²]	Typology	Cu/Al cross-section [mm²]	Typology	Cu/Al cross-section [mm²]	Typology	Cu cross-section [mm²]	Typology	Cu cross-section [mm²]		
Flexible cables	-	Flexible cables	-	Flexible cables	-	Flexible cables	-	Flexible cables	6...150 2x6...70	Flexible cables	6x2.5...25		
Rigid cables	25x150	Rigid cables	1x90...185	Rigid cables	1x150...240	Rigid cables	2x35...150	Rigid cables	1x6...185	Rigid cables	6x2.5...35		
Terminal													
Typology		Internal				External				Internal		External	
Installations requirement*													
Supply on request													
	Phase separator	100 mm	■						■				
		200 mm	■						■				
	Terminal cover	50 mm	■						■				

The terminals ES, FCCuAl, FCCu, FB and MC can be used also with plug-in version thanks to the following adapter:

Fixed part adapter

Plug-in circuit-breaker



\* 25 mm phase separators are always delivered with the circuit-breakers.

FB Flexibar		F Front terminals		EF Front extended terminals		ES Front extended spread terminal		R Rear orientable terminals		
No. of bars		Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs		
Section	2	16x0.8	Tightening torques [Nm]	Supplied clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
Min.			8	M8	18	M10	18	M10	9	M8
Max.	10									
Internal		Internal		External		External		Rear		
■		■		■						
■		■		■						
■		■		■						

For fixed part of plug in version, the following standard connections are available:

HR-VR Rear orientable terminals		EF - Front extended terminals	
Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
9	M8	9	M8

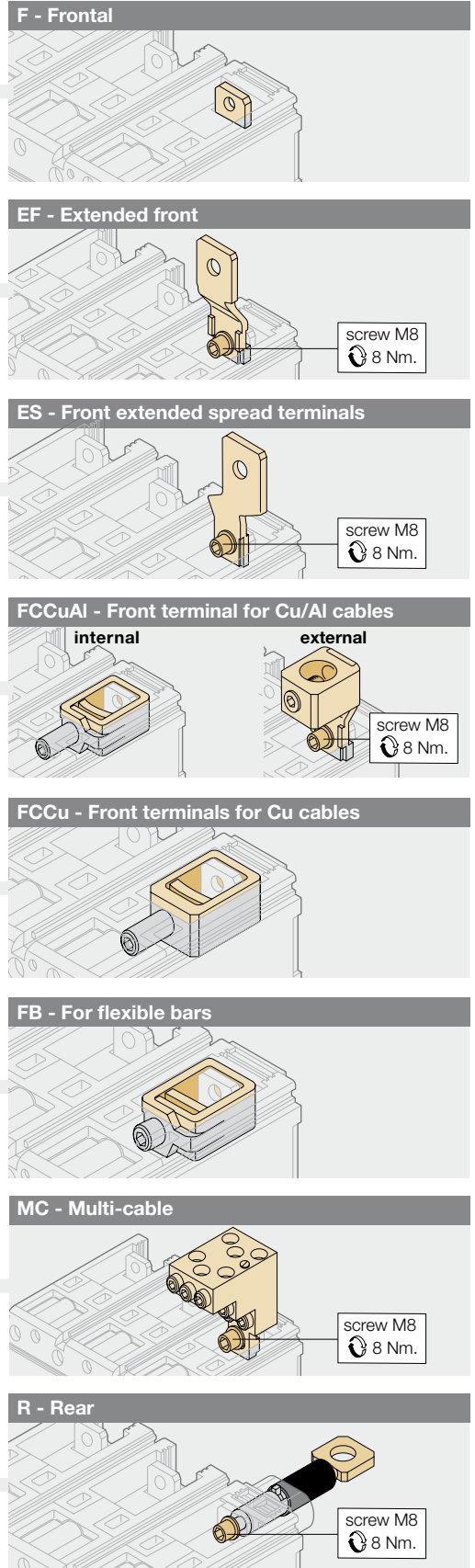


### 3. Wiring

## SACE Tmax XT4



Figure showing the circuit-breaker with its terminals and the tightening torques of the terminals to the circuit-breaker.

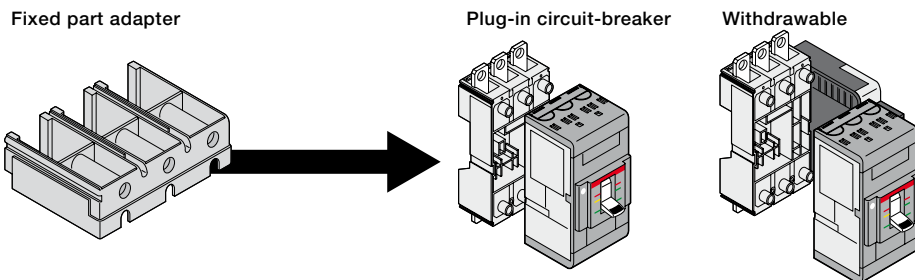


# 3. Wiring

## Tmax XT4

Cables/Bars		FCCuAl				FCCu		MC Multicables		FB Flexibar	
Typology	Cu/Al cross-section [mm <sup>2</sup> ]	Typology	Cu/Al cross-section [mm <sup>2</sup> ]	Typology	Cu/Al cross-section [mm <sup>2</sup> ]	Typology	Cu cross-section [mm <sup>2</sup> ]	Typology	Cu cross-section [mm <sup>2</sup> ]	No. of bars	Section
Flexible cables	2.5x150	Flexible cables	-	Flexible cables	-	Flexible cables	1x6...150 2x6...70	Flexible cables	6x2.5...25	Min.	2
Rigid cables	2.5x185	Rigid cables	2x35...150	Rigid cables	1x150...240	Rigid cables	1x6...185	Rigid cables	6x2.5...35	Max.	10
<b>Terminal</b>											
Typology <b>Internal</b>		Typology <b>External</b>				Typology <b>Internal</b>		Typology <b>External</b>		Typology <b>Internal</b>	
<b>Installation requirement*</b>											
<b>Supply on request</b>											
Phase separator 	100 mm	■				■					■
	200 mm	■				■					■
Terminal cover 	50 mm	■				■					■

The terminals ES, FCCuAl, FCCu, FB and MC can be used also with plug-in and withdrawable version thanks to the following adapter:



\* 25 mm phase separators are always delivered with the circuit-breakers.



F Front terminals		EF Front extended terminals		ES Front extended spread terminal		R Rear orientable terminals	
		Maximum overall dimensions 		Maximum overall dimensions 		Maximum overall dimensions 	
Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs		Bars/Cable lugs	
Tightening torques [Nm]	Supplied clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
8	M8	18	M10	18	M10	9	M8
Internal		External				Rear	
■							
■		■					
■		■					

For fixed part of plug in and withdrawable version, the following standard connections are available:

HR-VR Rear orientable terminals		EF - Front extended terminals	
Tightening torques [Nm]	Suggested clamping screw	Tightening torques [Nm]	Suggested clamping screw
9	M8	9	M8

# Annex A

The following tables are extracts from the Std. IEC60947-1.

Table A1 Approximate relationship between mm<sup>2</sup> and AWG/kcmil

Rated cross-section mm <sup>2</sup>	AWG/kcmil size	Equivalent metric area mm <sup>2</sup>
0.2	24	0.205
0.34	22	0.324
0.5	20	0.519
0.75	18	0.82
1	-	-
1.5	16	1.3
2.5	14	2.1
4	12	3.3
6	10	5.3
10	8	8.4
16	6	13.3
25	4	21.2
35	2	33.6
-	1	42.4
50	0	53.5
70	00	67.4
95	000	85.0
-	0000	107.2
120	250 k cmil	127
150	300 k cmil	152
185	350 k cmil	177
-	400 k cmil	203
240	500 k cmil	253
300	600 k cmil	304

Table A2 Test copper conductors for test currents up to 400 A inclusive

Range of test current		Conductor size	
A		mm <sup>2</sup>	AWG/k cmil
0	8	1.0	18
8	12	1.5	16
12	15	2.5	14
15	20	2.5	12
20	25	4.0	10
25	32	6.0	10
32	50	10	8
50	65	16	6
65	85	25	4
85	100	35	3
100	115	35	2
115	130	50	1
130	150	50	0
150	175	70	00
175	200	95	000
200	225	95	0000
225	250	120	250 k cmil
250	275	150	300 k cmil
275	300	185	350 k cmil
300	350	185	400 k cmil
350	400	240	500 k cmil

Table A2 Test copper conductors for test currents above 400 A and up to 800 A

Range of test current A		Conductors			
		Metric		k cmil	
		Number	Size mm <sup>2</sup>	Number	Size k cmil
400	500	2	150	2	250
500	630	2	185	2	350
630	800	2	240	3	300

Table A2 Test copper conductors for test currents above 400 A and up to 3150 A

Range of test current A		Copper bars		
		Number	Dimensions mm <sup>2</sup>	Dimensions (inches)
400	500	2	30x5	1x0.250
500	630	2	40x5	1.25x0.250
630	800	2	50x5	1.5x0.250
800	1000	2	60x5	2x0.250
1000	1250	2	80x5	2.5x0.250
1250	1600	2	100x5	3x0.250
1600	2000	3	100x5	3x0.250
2000	2500	4	100x5	3x0.250
2500	3150	3	100x10	6x0.250



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