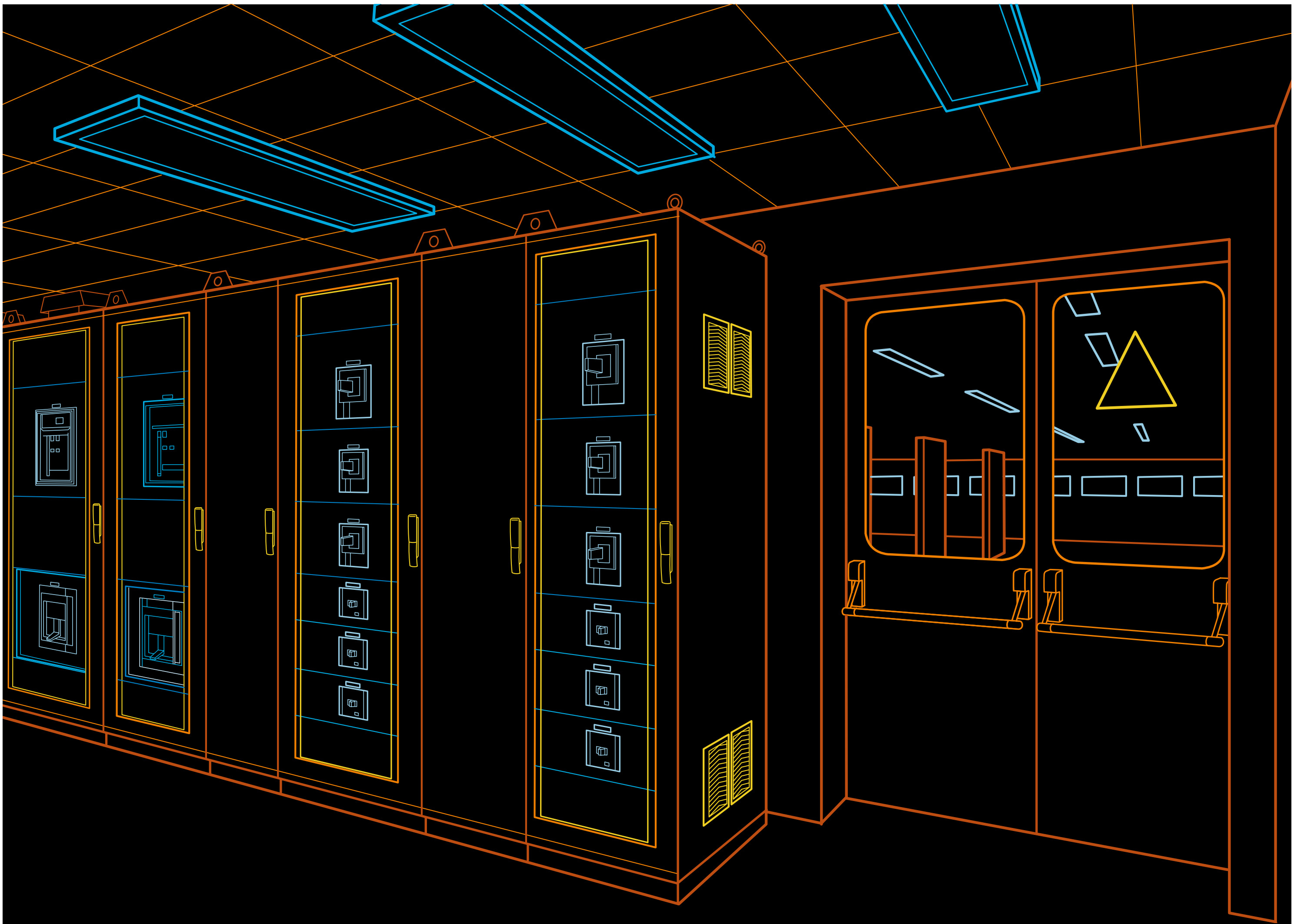

Technical Application Papers No.11

Guidelines to the construction of a low-voltage assembly complying with the Standards IEC 61439 Part 1 and Part 2

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Guidelines to the construction of a low-voltage assembly complying with the Standards IEC 61439 Part 1 and Part 2

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Introduction

An electrical assembly is a combination of more protection and switching devices, grouped together in one or more adjacent cases (column).
In an assembly the following parts can be distinguished: a case, called enclosure by the Standards, (it has the function of support and mechanical protection of the housed components), and the electrical equipment, formed by the internal connections and by the incoming and outgoing terminals for the connections to the plant.
As all the components of an electrical system, also assemblies shall comply with the relevant product standard.

As far as Standards are concerned, an evolution has occurred with the replacement of the former IEC 60439-1 with the Stds. IEC 61439-1 and IEC 61439-2. These Standards apply to all the low-voltage switchgear and controlgear assemblies (for which the rated voltage does not exceed 1000 V in case of a.c. or 1500 V in case of d.c.).
Throughout this document, the term assembly is used for a low-voltage switchgear and controlgear assembly.

This Technical Application Paper has the purpose of:
1) describing the main innovations and changes introduced in the new Standard as regards structure, definitions and contents (e.g.: methods of verification of assemblies and relevant application conditions), paying particular attention to the performance verifications as regards: temperature-rise limits, short-circuit withstand strength and dielectric properties;
2) giving a document which includes useful information for the realization and certification of LV assemblies in compliance with the Standards IEC 61439.

This document is divided into seven main parts:
- introduction and description of the new Stds. IEC 61439;
- definition of the rated electrical characteristics, of IP and IK degrees and of the forms of internal separation for an assembly;
- standard prescriptions as regards: temperature-rise, short-circuit withstand strength and dielectric properties (clearance or creepage distances);
- prescriptions for the protection against direct and indirect contact;
- instructions for construction, handling, transport and final installation of assemblies;
- properties and performances (design verifications) of assemblies and a guide for the carrying out of routine verifications (assembly type-approval);
- an example of choice of products (circuit-breakers, conductors, distribution system, busbars and structure) for the construction of ArTu assemblies.

1 Standards on low voltage assemblies and relevant applicability

The recent publication of the new Standard IEC 61439 has imposed an evolution and a refinement of the concept of switchgear and controlgear assembly, which has remained actually unchanged since 1990 when "Factory Assembled Boards" concept was replaced by TTA (Type-Tested Assemblies) and PTTA (Partially-Type-Tested Assemblies).
The new Standard still considers an assembly as a standard component of the plant, such as a circuit-breaker or a plug-and-socket, although it is constituted by the assembling of more apparatus, grouped together in one or more adjacent units (columns).
In an assembly the following parts can be distinguished: a case, called enclosure by the Standards, (it has the function of support and mechanical protection of the housed components), and the electrical equipment, formed by the internal connections and by the incoming and outgoing terminals for the connections to the plant).
Such system shall be assembled in order to meet the safety requirements and satisfy as much as possible the functions for which it has been designed.

From this point of view, in Italy, the Law 46/90 and now the Ministerial Decree 37/08 oblige manufacturers to undersign a declaration of conformity to the "rule of the art" for each action carried out on a plant excepted for ordinary maintenance. In the mandatory enclosures to this Declaration, in the list of the materials installed or changed, the assembly which has undergone actions is frequently mentioned.
As already known, to comply with the Article 2 of the Italian Law 186 dated 1st March 1968, the equipment and plants realized in compliance with CEI EN Standards are considered in accordance with the "rule of the art". Therefore, as all the components of an electrical plant, also the assembly shall comply with the relevant product Standard. On this subject Stds. IEC 61439-1 and 2 have recently entered in force at international level, acknowledged within the corresponding Italian Standards CEI EN 61439-1 and 2.
These Standards apply to the low voltage assemblies for which the rated voltage does not exceed 1000 V in case of a.c. or 1500 V in case of d.c.).
IEC 61439-1 gives the general rules for LV assemblies, whilst the other parts to be issued concern the specific typologies of assemblies and are to be read together with the general rules.

The envisaged parts are the following ones:
- IEC 61439-2: "Power switchgear and controlgear assemblies (PSC-assemblies)";
- IEC 61439-3: "Distribution boards" (to supersede IEC 60439-3);
- IEC 61439-4: "Assemblies for construction sites" (to supersede IEC 60439-4);
- IEC 61439-5: "Assemblies for power distribution" (to supersede IEC 60439-5);
- IEC 61439-6: "Busbar trunking systems" (to supersede IEC 60439-2).

Two other documents published by IEC about swithchgear and controlgear assemblies are still available:
- the Std. IEC 60890 which represents a method of temperature rise assessment by calculation;
- the Std. IEC/TR 1117 which represents a method for assessing the short-circuit withstand strength by calculation or by the application of design rules.

This document, after a survey of the situation from the point of view of prescriptions and rules, takes into consideration the ArTu assemblies in compliance with the Std. IEC 61439-2.

1.1 The Std. IEC 61439-1

As already said, the new package of Standards, defined by IEC through code 61439, consists of the basic Standard 61439-1 and by the specific Standards referred to the assembly typology. The first Standard deals with the characteristics, the properties and the performances which are in common to all the assemblies then considered in the relevant specific Standard.
This is the present structure of the new IEC 61439:

1) IEC 61439-1: "Low-voltage switchgear and controlgear assemblies - Part 1: "General rules";
2) IEC 61439-2: "Power switchgear and controlgear assemblies";
3) IEC 61439-3: "Distribution boards";
4) IEC 61439-4: "Assemblies for construction sites";
5) IEC 61439-5: "Assemblies for power distribution";
6) IEC 61439-6: "Busbar trunking systems".

As regards the declaration of conformity, each specific assembly typology shall be declared in compliance with the relevant product standard (that is the PSC-assemblies shall be declared complying with IEC 61439-2; the distribution boards in compliance with IEC 61439-3).
The passage, from the previous Std. IEC 60439 to the present IEC 61439, shall occur as follows: The "old" Std. 60439-1 shall be gradually superseded by the new Standards 61439-1 and 2, which are already available, but shall remain in force up to 31st October 2014 for the Power Switchgear and Controlgear assemblies (also called PSC-assemblies).
After that date, the new PSC assemblies shall have to comply only with the new Standards.
The period of validity for the Std. 60439-1 and for the other ones 60439-X extends up to 2014, for the con-

struction of the other special assemblies (construction sites, busbar trunking systems, distribution, etc.), since for the time being these new standards are only envisaged, scheduled but non available yet.
The basic Standard establishes the requirements for the construction, safety and maintenance of the electrical assemblies by identifying the rated characteristics, the service environmental conditions, the mechanical and electrical requirements and the prescriptions relevant to the performances.

The former Std. dated 1990 divided the assemblies into two types, defining them TTA (type-tested assemblies) and PTTA (partially type-tested assemblies), according to their total or partial compliance with the laboratory type tests. The new Standard eliminates this dualism replacing it with the concept of "conforming" assembly, that is any assembly which complies with the design verifications prescribed by the Standard itself.

To this purpose, the Standard introduces three different but equivalent types of verification (design verifications) of requirements of conformity for an assembly; they are:

- 1) verification by laboratory testing (formerly called type tests and now verification by testing);
- 2) verification by calculation (using old and new algorithms);
- 3) verification by satisfying design rules (analysis and considerations which are independent from the tests; verification by physical/analytical criteria or design deductions).

The different characteristics (temperature-rise, insulation, corrosion etc.) can be guaranteed by using any of these three methods; following one way or the other to guarantee the conformity of the assembly is unimportant.
Since it is not always possible to choose possible one of the three methods, Table D.1 of the Annex D of the Standard (see Table 1.1) lists for each characteristic to be verified which one of the three types of verification may be used.

Table 1.1

No.	Characteristics to be verified	Clauses or subclauses	Verification options available		
			Verification by testing	Verification by calculation	Verification by satisfying design rules
1	Strength of materials and parts of the assembly:	10.2			
	Resistance to corrosion	10.2.2	YES	NO	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	NO	NO
	Resistance of insulating material to normal heat	10.2.3.2	YES	NO	NO
	Resistance of insulating materials to abnormal heat and fire due to internal electric effects	10.2.3.3	YES	NO	NO
	Resistance to ultraviolet (UV) radiation				
	Lifting	10.2.4	YES	NO	NO
	Mechanical impact	10.2.4	YES	NO	NO
	Marking	10.2.6	YES	NO	NO
		10.2.7	YES	NO	NO
2	Degree of protection of the enclosures	10.3	YES	NO	YES
3	Clearances and creepage distances	10.4	YES	YES	YES
4	Protection against electric shock and integrity of protective circuits:	10.5			
	Effective continuity between the exposed conductive parts of the assembly and the protective circuit	10.5.2	YES	NO	NO
	Effectiveness of the assembly for external faults	10.5.3	YES	YES	YES
5	Installation of switching devices and components	10.6	NO	NO	YES
6	Internal electrical circuits and connections	10.7	NO	NO	YES
7	Terminals for external conductors	10.8	NO	NO	YES
8	Dielectric properties:	10.9			
	Power-frequency withstand voltage	10.9.2	YES	NO	NO
	Impulse withstand voltage	10.9.3	YES	NO	YES
9	Temperature-rise limits	10.10	YES	YES	YES
10	Short-circuit withstand strength	10.11	YES	YES	YES
11	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES
12	Mechanical operation	10.13	YES	NO	NO

As it can be noticed, for some characteristics, such as the resistance to corrosion or to mechanical impact only the verification by testing is accepted; instead, for other characteristics such as temperature-rise and short-circuit, the three verification modalities are all accepted: testing, calculation or design rules.
Another important change in the new Standard is the better specification of the manufacturer figure. In particular two "ways of being" are defined for the manufacturer: the "original" manufacturer and the "assembly" manufacturer.
The first one is the subject who has carried out initially the original design of the series to which belongs the assembly to be completed and to this purpose has carried out the design verifications (formerly type tests), the derivation calculations or the design rules, to cover all the available possibilities for the assembly verification.
It is evident that the highest and most performing the layouts that the original manufacturer is able to "standardize" and to propose, the greater the possibilities for him to have his assemblies constructed and consequently to make a good profit.
The second one, identified as "assembly" manufacturer, is the subject who really builds the assembly, that is who gets the different parts and components and mounts them as required, thus carrying out the completed assembly, mounted and wired, exploiting one of the design opportunity already mentioned, ready to use, offered by the "original" manufacturer.
The Standard still accepts that some phases of the fitting of assemblies are carried out also out of the manufacturer's laboratory or workshop (on site or on machine board), but the Std. instructions must be complied with.
From an operational point of view, the manufacturers and the panel builders, i.e. the end manufacturers, could use as usual the products sold in kits and included in the catalogues of the "original" manufacturers, for assembling according to the arrangement they need.

To summarize, the "original" manufacturer shall:
- design (calculate, design and carry out) the desired assembly line;
- test some prototypes belonging to that assembly line;
- pass these tests to demonstrate the compliance with the mandatory prescriptions of the Standard;
- derive from the tests other configurations by calculation or other evaluations or measurements;
- add other configurations obtained without testing but thanks to suitable "design rules";
- collect all the above mentioned information and make them available for the end customer by means of catalogues, slide rules or software, so that he can build the new assembly and use it and manage it as best as possible, by carrying out the suitable controls and maintenance.

The list of the design verifications prescribed by the Standard under the responsibility of the "original" manufacturer who, in compliance with Table 1.1, shall decide how to perform them includes the following:
Verification of the characteristics relevant to construction:
- Strength of materials and parts of the assembly;
- Degrees of protection IP of the assembly;
- Clearances and creepage distances;
- Protection against electric shock and integrity of protective circuits;
- Incorporation of switching devices and of components;
- Internal electrical circuits and connections;
- Terminals for external conductors.

Verifications of the characteristic relevant to the performance:
- Dielectric properties (power-frequency withstand voltage at 50 Hz and impulse withstand voltage);

- Verification of temperature-rise limits;
- Short-circuit withstand strength;
- Electromagnetic compatibility (EMC);
- Mechanical operation.

Instead, the "assembly" manufacturer shall have the responsibility of:

- the choice and the fitting of the components in full compliance with the given instructions;
- the performance of the routine verification on each manufactured assembly;
- the assembly certification.

The list of the routine tests prescribed by the Standard under the responsibility of the "assembly" manufacturer includes the following:

Characteristics pertaining to construction:

- Degrees of protection IP of the enclosure;
- Clearances and creepage distances;
- Protection against electric shock and integrity of protective circuits;
- Incorporation of switching devices and of components;
- Internal electrical circuits and connections;
- Terminals for external conductors;
- Mechanical operation.

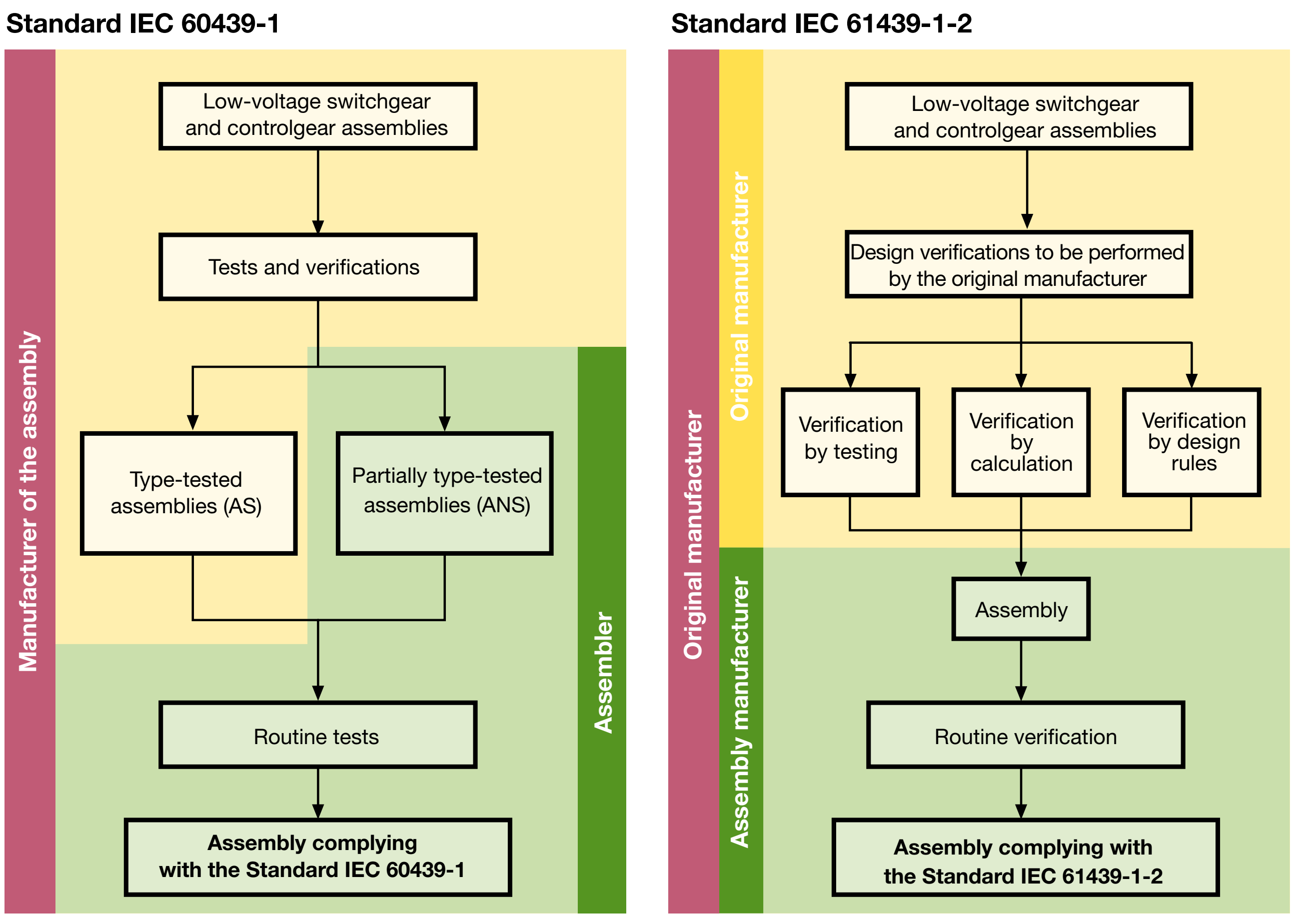
Characteristics relevant to the performance:

- Dielectric properties (power-frequency withstand voltage at 50 Hz and impulse withstand voltage);
- Wiring, operational performance and function.

These verifications can be carried out in any sequence. The fact that the routine verifications are carried out by the "assembly" manufacturer does not exempt the panel builder from verifying them after the transport and the erection of the assembly.

The main changes and news, introduced by the IEC 61439 in comparison with former IEC 60439, can be summarized with the diagrams shown in Figure 1.1:

Figure 1.1



2 Rated electrical characteristics of an assembly

Rated voltage (U_n)
Highest nominal value of the a.c. (r.m.s) or d.c. voltage, declared by the assembly manufacturer, to which the main circuit(s) of the assembly is (are) designed to be connected. In three-phase circuits, it is the voltage between phases.

Rated operational voltage (U_e)
it is the rated voltage of a circuit of an assembly which combined with the rated current of this circuit determines its application. For three-phase circuits such voltage corresponds to the voltage between phases.
In an assembly there are usually a main circuit with its own rated voltage and one or more auxiliary circuits with their own rated voltages.
The manufacturer of the assembly shall state the limits of voltage necessary for correct functioning of the circuits inside the assembly.

Rated insulation voltage (U_i)
it is the voltage value of a circuit of an assembly to which test voltages (power frequency withstand voltage) and the creepage distances are referred.
The rated voltage of each circuit shall not exceed its rated insulation voltage.

Rated impulse withstand voltage (U_{imp})
it is the peak value of an impulse voltage which the circuit of an assembly is capable of withstanding under specified conditions and to which the values of clearances are referred. It shall be equal to or higher than the values of the transient overvoltages occurring in the system in which the assembly is inserted.

To this purpose the Standard IEC 61439-1 offers two tables:
- Table G.1 (see Table 2.1) shows the preferential values of the rated impulse withstand voltage at the different points of the plant as a function of the operational voltage to earth;
- Table 10 (see Table 2.2) gives the values of the test voltage corresponding to the voltage withstand voltage as a function of the altitude of testing.

Table 2.1

Correspondence between the rated voltage of the supply system and the rated withstand voltage, in case of protection against overvoltages with surge-protective devices complying with the Standard IEC 60099-1

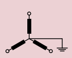
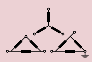
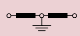
Maximum value of rated operational voltage to earth a.c. (r.m.s. value) or d.c V	Nominal voltage of the supply system (≤ rated insulation voltage of the equipment) V				Preferred values of rated withstand voltage (1.2/50 μs) at 2000 m kV			
					Overvoltage category			
					IV	III	II	I
	a.c. r.m.s. value	a.c. r.m.s. value	a.c. r.m.s. value or d.c	a.c. r.m.s. value or d.c	Origin of installation (service entrance) level	Distribution circuit level	Load (appliance equipment) level	Specially protected level
50	-	-	12.5, 24, 25, 30, 42, 48	-	1.5	0.8	0.5	0.33
100	66/115	66	60	-	2.5	1.5	0.8	0.5
150	120/208 127/220	115, 120 127	110, 120	220-110, 240-120	4	2.5	1.5	0.8
300	220/380 230/400 240/415 260/440 277/480	220, 230 240, 260 277	220	440-220	6	4	2.5	1.5
600	347/600 380/660 400/690 415/720 480/830	347, 380, 400 415, 440, 480 500. 577, 600	480	960-480	8	6	4	2.5
1000	-	660 690, 720 830, 1000	1000	-	12	8	6	4

Table 2.2

Rated impulse withstand voltage U_{imp} kV	Impulse withstand voltages									
	U1,2/50, a.c. peak and d.c. kV					R.m.s. value a.c. kV				
	Sea level	200 m	500 m	1000 m	2000 m	Sea level	200 m	500 m	1000 m	2000 m
2.5	2.95	2.8	2.8	2.7	2.5	2.1	2	2	1.9	1.8
4	4.8	4.8	4.7	4.4	4	3.4	3.4	3.3	3.1	2.8
6	7.3	7.2	7	6.7	6	5.1	5.1	5	4.7	4.2
8	9.8	9.6	9.3	9	8	6.9	6.8	6.6	6.4	5.7
12	14.8	14.5	14	13.3	12	10.5	10.3	9.9	9.4	8.5

Rated current of the assembly (I_{nA})
It is a new characteristic introduced by the Std. IEC 61439 and normally indicates the maximum incoming permanent and allowable load current or the maximum current which an assembly is capable of withstanding. The rated current shall be withstood in any case, provided that the temperature-rise limits stated by the Standard are complied with.

Rated current of a circuit (I_{nC})
It is the current value to be carried out by a circuit without the temperature-rise of the various parts of the assembly exceeding the limits specified according to the testing conditions of Clause 7.

Rated short-time current (I_{cw})
it is the r.m.s. value of the current for the short-circuit test for 1 s time; such value, declared by the manufacturer does not imply the opening of the protective device and is the value which the assembly can carry without damage under specified conditions, defined in terms of current and time. Different I_{cw} values can be assigned to an assembly for different times (e.g. 0.2 s; 3 s).

Rated peak withstand current (I_{pk})
it is the peak value of the short-circuit current, declared by the manufacturer of the assembly, which the assembly is capable of withstanding under the specified conditions.

Rated conditional short-circuit current (I_{cc})
it is the r.m.s. value of prospective short-circuit current, stated by the manufacturer, which that circuit, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of the device under the specified test conditions.

Rated diversity factor (RDF)
it is the per unit value of the rated current, assigned by the assembly manufacturer, to which outgoing circuits of an assembly can be continuously and simultaneously loaded taking into account the mutual thermal influences.
The rated diversity factor can be stated:
- for groups of circuits;
- for the whole assembly.

The rated diversity factor is: $\frac{\sum Ib}{\sum In}$

The rated diversity factor multiplied by the rated current of the circuits (In) shall be equal to or higher than the assumed loading of the outgoing circuits (Ib).
The rated diversity factor is applicable to the outgoing circuits of the assembly and demonstrates that multiple functional units can be partially loaded.
When the manufacturer states a rated diversity factor, this factor shall be used for the temperature-rise test, otherwise reference shall be made to the values recommended by the Standard 61439-1 in Annex E.

Rated frequency
value of frequency to which the operating conditions are referred. If the circuits of an assembly are designed for different values of frequency, the rated frequency of each circuit shall be given.

3 Classification of assemblies

Assemblies may be classified according to different factors:
by the constructional typology, by the external design, by the installation conditions, by the function carried out.

3.1 Open-type and enclosed assemblies

According to the constructional typology the Standard IEC 61439-1 distinguishes between open-type and enclosed assemblies.

- **Enclosed assembly**
  An assembly is enclosed when there are protected panels on all its sides so as to provide a degree of protection against direct contact not lower than IPXXB (see Chapter 4). Assemblies intended to be installed in common environments shall be of enclosed type

- **Open-type assembly**
  An assembly, with or without front covering, in which the live parts of the electrical equipment are accessible. Such assemblies can be used only in places where skilled persons have access for their use.

3.2 External design

From the point of view of the external design assemblies are classified in:

- **Cubicle-type (column)**
  Used for large distribution and control equipment; mechanically joined multi-cubicle-type assemblies are obtained by combining side by side more cubicle-type assemblies.

- **Desk-type**
  Used to control complex machines or plants in mechanical, iron and steel and chemical industries.

- **Box-type**
  Intended to be mounted on a vertical plane, both jutting out as well as built-in; such assemblies are used mainly for the department or area distribution in industrial or service sector environments.

- **Multi-box-type**
  A combination of boxes, generally of protected type and with fixing flanges, each housing a functional unit which may be an automatic circuit-breaker, a starter, a socket completed with a blocking or protective circuit-breaker. Thus a combination of box-compartments is obtained; these are mechanically joined together with or without a common supporting frame; the electrical connections between two adjacent boxes pass through openings in the adjoining faces.

3.3 Conditions of installation

According to the conditions of installation assemblies can be divided into:

- **Assembly for indoor installation**
  Assembly which is designed for use in locations where the normal service conditions for indoor use as specified in the Std. IEC 61439-1 are fulfilled, that is:

Environmental conditions for indoor installation

Table 3.1

Relative humidity	Ambient air temperature	Altitude
50% (at a maximum temperature of 40° C) 90% (at a maximum temperature of 20° C)	Maximum temperature ≤40° C	Not higher than 2000 m
	Maximum temperature average over a period of 24 h ≤35° C	
	Minimum temperature ≥-5° C	

- **Assembly for indoor installation**
  Assembly which is designed for use in locations where the normal service conditions for outdoor use as specified in the Std. IEC 61439-1 are fulfilled, that is:

Environmental conditions for outdoor installation

Tabella 3.2

<table>
<tr><th>Relative humidity</th><th>Ambient air temperature</th><th>Altitude</th></tr>
<tr><td rowspan="4">100% temporarily (at the maximum temperature of 25° C))</td><td>Maximum temperature ≤40° C</td><td rowspan="4">Not higher than 2000 m</td></tr>
<tr><td>Maximum temperature average over a period of 24 h ≤35° C</td></tr>
<tr><td>Minimum temperature ≥-25° C in a temperate climate</td></tr>
<tr><td>Minimum temperature ≥-50° C in an arctic climate</td></tr>
</table>

- **Stationary assembly**
  Assembly which is designed to be fixed at its place of installation, for instance to the floor or to a wall, and to be used at this place.

- **Movable assembly**
  Assembly which is designed so that it can readily be moved from one place of use to another.

3.4 Functional classification

According to the functions for which assemblies are intended for, they can be classified into the following typologies:

- **Primary distribution switchgear assemblies**
  Primary distribution switchgear assemblies, also called Power Centers (PCs), are usually immediately on the load side of MV/LV transformers or generators. These assemblies include one or more incoming units, bus ties and a relatively reduced number of outgoing units.

- **Secondary distribution switchgear assemblies**
  Secondary distribution assemblies include a large category of assemblies intended for power distribution and are usually provided with one incoming unit and many outgoing units.

- **Motor control switchgear assemblies**
  Motor control switchgear assemblies are intended for the control and centralized protection of motors; as a consequence they include the relevant switching and protection equipment and the auxiliary control and signaling equipment. They are also called Motor Control Centers (MCC).

- **Control, measurement and protection assemblies**
  Control, measurement and protection assemblies are usually constituted by banks containing mainly equipment intended for the control, switching and measurement of industrial installations and processes.

- **On-board assemblies**
  On-board assemblies, also called automation assemblies, are similar to the previous ones from a functional point of view; they are intended for the machine interface with the power supply source and with the operator. Further prescriptions for assemblies which are an integral part of the machine established by the Standards series IEC 60204.

- **Assemblies for construction sites**
  Assemblies for construction sites have different dimensions, ranging from the simple socket-outlet units to distribution boards in metal enclosure or insulating material.
  These assemblies are usually mobile or however transportable.

4 Degree of protection IP of an assembly

The code IP indicates the degree of protection of the provided by an enclosure against access to hazardous parts, ingress of solid foreign objects and ingress of water. The code IP represents the identification system of the degrees of protection in compliance with the prescriptions of the Std. IEC 60529.

The Table below shows, in details, the meaning of the different numerals and letters

Figure 4.1

IP 6 5 C H

Code letters	International protection
First characteristic numeral	Numerals 0 to 6, or letter X
Second characteristic numeral	Numerals 0 to 8, or letter X
Additional letter (optional)	Letters A, B, C, D
Supplementary letter (optional)	Letters H, M, S, W

Table 4.1

	Protection of equipment	Against access to hazardous part with
First characteristic numeral (access of solid foreign objects)	**0**	non-protected
	1 ≥ 50 mm diameter	back of hand
	2 ≥ 12,5 mm diameter	finger
	3 ≥ 2,5 mm diameter	tool
	4 ≥ 1 mm diameter	wire
	5 dust-protected	wire
	6 dust-tight	wire
Second characteristic numeral (ingress of water)	**0** non-protected	
	1 vertically dripping	
	2 dripping (15 tilted)	
	3 spraying	
	4 splashing	
	5 jetting	
	6 powerful jetting	
	7 temporary immersion	
	8 continuous immersion	
Additional letter (optional)	**A**	back of hand
	B	finger
	C	tool
	D	wire
Supplementary letter (optional)	**H** High-voltage apparatus	
	M Motion during water test	
	S Stationary during water test	
	W Weather conditions	

The additional letter indicates the degree of protection of persons against access to hazardous parts.
The additional letters are used only:
- if the actual protection against access to hazardous parts is higher than that indicated by the first characteristic numeral;
- or, if only the protection against access to hazardous parts is indicated, the first characteristic numeral shall be replaced by the letter X.

For example, this higher protection could be provided by barriers, openings of suitable shape or distances inside the enclosure.

4.1 Degree of protection IP of ArTu assemblies

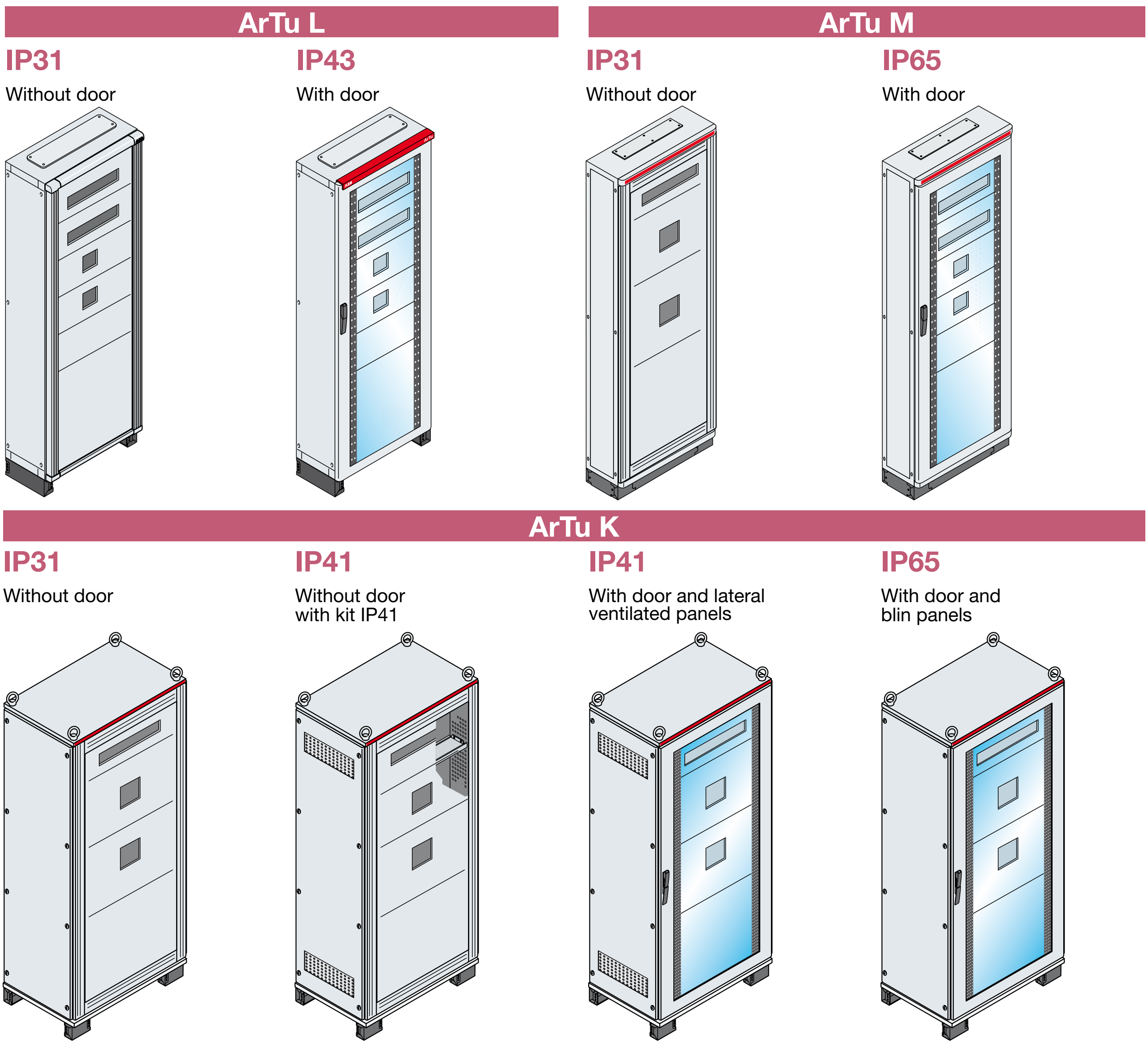
As regards assemblies, when not otherwise specified by the manufacturer, the degree of protection is valid for the whole assembly, mounted and installed as in ordinary use (with door closed).
The manufacturer can also indicate the degrees of protection relevant to special configurations which may be present in service, such as the degree of protection with doors open and the one with apparatus removed or racked out.

For the assemblies intended for indoor installation, in environments where no risk of ingress of water exists, the Standard requires at least the following degrees of protection: IP 00, IP 2X, IP 3X, IP 4X, IP 5X, IP 6X.

For the enclosed assemblies, the degree of protection IP shall be ≥ 2X after the installation, in compliance with the instructions given by the manufacturer of the assembly. The degree IP for the front and the rear part shall be at least equal to IP XXB. As regards the assemblies intended for outdoor installation and without additional protection, the second numeral of the IP code shall be at least equal to 3.

Hereunder are the degrees of protection which can be obtained with ABB SACE ArTu assemblies.

Figure 4.2



4.2 Degree of protection IP and installation environment

At present there are no Standards which correlate the degree of protection IP with the installation environment of assemblies, apart from special environments with explosion risk (CEI 64-2).

As an indication, the following table derived from the Guide UTE C 15-103 shows the relation between the environments and the degrees of protection of ABB SACE assemblies of ArTu series.

It should be kept in mind that ArTu assemblies manufactured by ABB SACE are for indoor installation.

Table 4.2

Industrial factories	IP31-41	IP43	IP65
accumulators (fabrication)		•	
acids (fabrication and storage)		•	
alcoholic liquids (storage)		•	
alcohol (fabrication and storage)		•	
aluminium (fabrication and storage)			•
animals (breeding)			•
asphalt bitumen (storage)			•
breweries			•
lime (furnaces)			•
coal (warehouses)			
fuels (fabrication and storage)			•
paper (storage)	•		
paper (fabrication)		•	•
paper (preparation of paste)			•
cardboard (fabrication)		•	
bottling lines			•
tar (treatment)		•	
quarries			•
cellulose (fabrication of objects)	•		
cellulose (fabrication)			•
cement works			•
chlorine (fabrication and storage)		•	
coking plants			•
glues (fabrication)		•	
combustible liquids (stores)		•	
tanneries			•
fertilizers (fabrication and storage)			•
chromium plating (factories for)		•	
pickling			•
detergents (fabrication)			•
distilleries		•	
electrolysis		•	
explosives (fabrication and storage)			•
joinery			•
ironmongery (fabrication)	•		
iron (fabrication and treatment)			•
spinning mills			•
cheese-making			•
gas (factories and storage)	•		
gypsum (fabrication and storage)			•
foam rubber (fabrication, transformation)			•
cereals (factories and storage)			•
fats (treatment of fatty bodies)			•
hydrocarbons (extraction)		•	•
inks (fabrication)	•		

Industrial factories	IP31-41	IP43	IP65
metal engraving		•	
wool (carding of)			•
dairies			•
laundries		•	•
public wash-houses			•
wood (working of)			•
halogen liquids (use)	•		
flammable liquids (storage and use)	•		
spirits (fabrication)	•		
machines (machine rooms)	•		
butchers			•
magnesium (fabrication, processing and storage)	•		
plastic materials (fabrication)			•
slaughter houses			•
bricks (factory for)			•
metals (treatment of metals)		•	
thermal motors (tests)	•		
ammunitions (deposits)		•	
nickel (treatment of the minerals)		•	
oil (extraction)	•		
leather (fabrication and storage)	•		
furs (scutching)			•
paint (fabrication and storage)		•	
powder factory			•
chemicals (fabrication)	•		•
perfumes (fabrication and storage)	•		
oil refineries			•
copper (treatment of the minerals)	•		
rubbish (treatment)			•
welds		•	
cured meat factories			•
soaps (fabbrication)	•		
sawmills			•
silk and hair (preparation)			•
grain or sugar silos			•
soda (fabrication and storage)		•	
fabrics (fabrication)			•
dyeing factories			•
printing works	•		
paints (fabrication and use)		•	
clothes (deposits)	•		
glassworks		•	
zinc (zinc processing)	•		
sulphur (treatment)			•
sugar refineries			•

4.3 Degree of protection IP and temperature-rise

The degree of protection of an assembly affects the capacity of dissipating heat: the higher the degree of protection is, the less the assembly manages to dissipate heat. For this reason it is advisable to use a degree of protection suitable for the installation environment.
For example, by using an assembly type ArTu K with door and ventilated side panels a degree of protection equal to IP41 is guaranteed, whereas when blind side panels are used the degree is IP65.

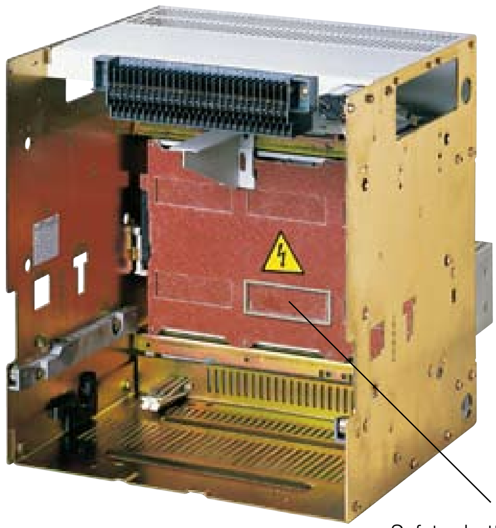
Both the assemblies guarantee the inaccessibility to the circuit-breakers through the front door; however, the assembly with ventilated side panels guarantees better ventilation than the assembly with blind side panels. As a consequence, it is preferable to use the former where the installation environment allows it.

4.4 Degree of protection IP of removable parts

The removal of movable parts in an installed assembly can be carried out in two different situations:
1) the withdrawal of the removable part of a component (e.g.: withdrawable circuit-breaker, withdrawable switch-disconnector, fuse holders) arranged for such possibility, for fixing, control or maintenance;
2) the removal of a fixed part, such as flanges, panels, covers or base strips, to carry out electric works, such as the realization of new incoming or outgoing lines or the replacement of existing cables.
In the first case, the same degree IP as before the removal shall be maintained, which generally is IP2X; the safety shutters, positioned on the fixed part of withdrawable air circuit-breakers, allow to comply with this specification (see Figure 4.3). If the degree IP had been higher (e.g.: IP44, IP55 or other), the movable part would have been inside the enclosure which, once reclosed, shall restore such condition.

In the case of electric works, if after the removal of a fixed part by using a tool the original degree of protection were not maintained, suitable measures - as prescribed by EN 50110-1 and the relevant national Standards - shall be taken in order to guarantee an adequate safety level for the operators.

Figure 4.3



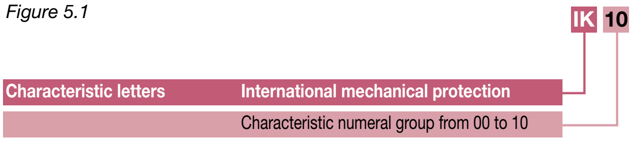
5 Degree of protection IK of enclosures

The degree IK indicates the level of protection provided by the enclosure for the equipment against harmful mechanical impacts and it is checked through standardized test methods.

The IK code is the coding system used to indicate the degree of protection guaranteed against harmful mechanical impacts, in compliance with the prescriptions of the Std. IEC 62262 dated 2002.

The degree of protection of the enclosure against impacts is indicated by the IK code as follows:

Figure 5.1



Each characteristic numerical group represents an impact energy value as shown in the table 5.1.

Usually the degree of protection is applied to the whole enclosure. If parts of the enclosure have different degrees of protection, these shall be indicated separately.

5.1 Degree of protection IK of ArTu assemblies

As regards ArTu assemblies, the degree of protection IK is valid for the whole assembly, mounted and installed as in ordinary use (with door closed).
The degrees of protection against external mechanical impacts (IK code) of ArTu series are given below.

Figure 5.2

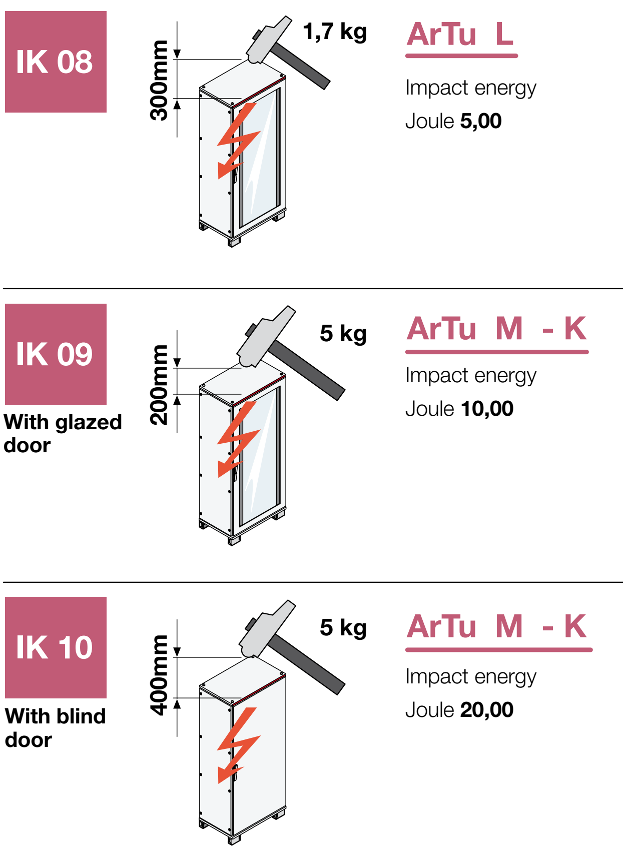


Table 5.1

Relationship between the degree of protection IK and the impact energy

IK code	IK00	IK01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	IK10
Impact Energy in joule	(*)	0,14	0,2	0,35	0,5	0,7	1	2	5	10	20

(*) Not protected according to the Standard

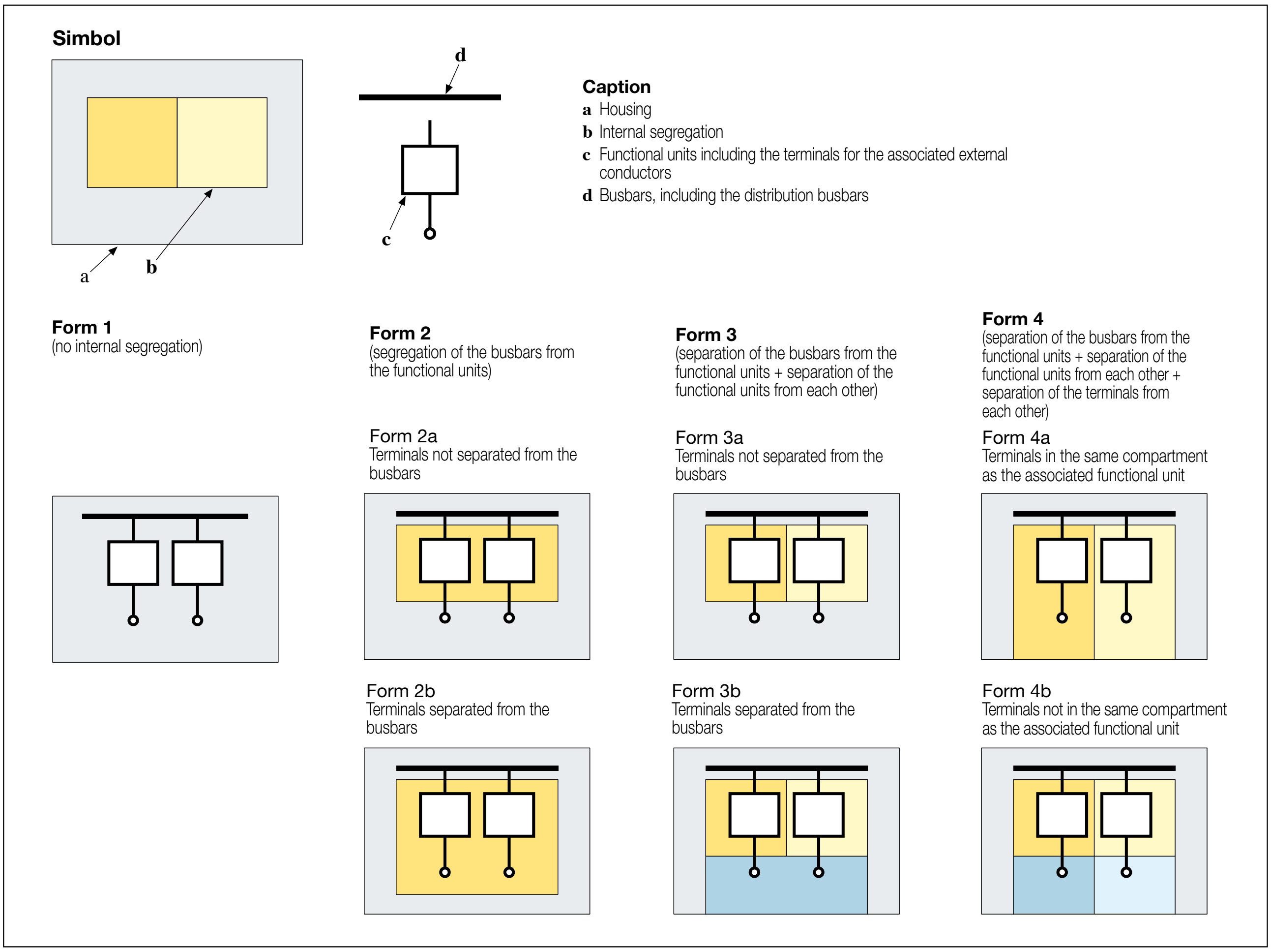
6 Forms of internal separations

By form of separation the type of subdivision provided inside the assembly is intended.
Separation by means of barriers or partitions (metallic or non metallic materials) is aimed at:
- ensuring protection against direct contact (at least IPXXB), in case of access to a part of the assembly cut off from the power supply, as to the rest of the assembly still supplied;
- reducing the probability of striking and propagation of an internal arc;
- preventing the passage of solid foreign bodies between different parts of the assembly (degree of protection IP2X at least).

By partition, the separating element between two compartments is intended, whereas the barrier protects the operator from direct contacts and from the effects of the arc of the breakers in the normal access direction.

The following table given in the Std. IEC 61439-2 highlights the typical separation forms which can be obtained by using barriers or partitions:

Table 6.1



By means of a suitable kit, ABB SACE switchgear assemblies type ArTu can realize the following forms of separation:

Form 1 no internal separation
Form 2 covers form 2a, form 3a of the Standard
Form 3 covers form 3b of the Standard
Form 4 covers form 4b of the Standard

7 Verification of the temperature-rise limits inside an assembly

7.1 Introduction

The verification of the temperature-rise limits imposed by the Standard IEC 61439-1 can be carried out according to one or more of the following methods:
- verification test with current (in laboratory);
- deduction from design rules;
- algebraic calculation.

As a matter of fact, the Standard IEC 61439-1 prescribes compliance with the same temperature-rise limits of the previous version, limits which must not be exceeded during the temperature-rise test. These temperature-rise limits are applied taking into consideration an ambient temperature which must not exceed +40 °C and its average value referred to a 24 hour period shall not exceed +35 °C.

Hereunder, Table 7.1 shows for the different components of the assembly, the temperature-rise limits given by the Standard.

Tabella 7.1

Parts of assemblies	Temperature-rise K
Built-in components [a]	(*) In accordance with the relevant product Standard requirements for the individual components or, in accordance with the manufacturer's instructions f), taking into consideration the temperature in the assembly
Terminals for external insulated conductors	70 [b]
Busbars and conductors	Limited by: - mechanical strength of conducting material [g]; - possible effects on adjacent equipment; - permissible temperature limit of the insulating materials in contact with the conductor; - the effect of the temperature of the conductor on the apparatus connected to it; - for plug-in contacts, nature and surface treatment of the contact material.
Manual operating means:	
- of metal	15 [c]
- of insulating materials	25 [c]
Accessible external enclosures and covers:	
- metal surfaces	30 [d]
- insulating surfaces	40 [d]
Discrete arrangements of plug and socket-type connections	Determined by the limits of those components of the related equipment of which they form part [e]

[a] The term "built-in components" means:
- conventional switchgear and controlgear;
- electronic sub-assemblies (e.g. rectifier bridge, printed circuit);
- parts of the equipment (e.g. regulator, stabilized power supply unit, operational amplifier).

[b] The temperature rise limit of 70 K is a value based on the conventional test of 10.10. An ASSEMBLY used or tested under installation conditions may have connections, the type, nature and disposition of which will not be the same as those adopted for the test, and a different temperature rise of terminals may result and may be required or accepted. Where terminals of the built-in component are also the terminals for external insulated conductors, the lower of the corresponding temperature-rise limits shall be applied.

[c] Manual operating means within assemblies which are only accessible after the assembly has been opened, for example draw-out handles, which are operated infrequently, are allowed to assume a 25 K increase on these temperature-rise limits.

[d] Unless otherwise specified in the case of covers and enclosures which are accessible but need not be touched during normal operation, an increase in the temperature-rise limits by 10 K is permissible. External surfaces and parts over 2 m from the base of the ASSEMBLY are considered inaccessible.

[e] This allows a degree of flexibility in respect to equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.

[f] For temperature-rise tests according to 10.10 the temperature-rise limits have to be specified by the Original Manufacturer taking into account any additional measuring points and limits imposed by the component manufacturer.

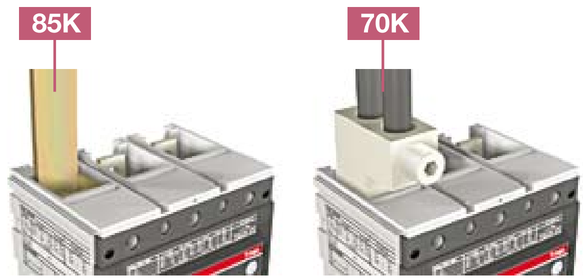
[g] Assuming all other criteria listed are met a maximum temperature rise of 105 K for bare copper busbars and conductors shall not be exceeded.

Nota: 105 K relates to the temperature above which annealing of copper is likely to occur. Other materials may have a different maximum temperature rise.

(*) As far as circuit-breakers inside assemblies are concerned, the temperature-rise limits are the following ones:
- 70 K if an insulated conductor is connected to the terminal;
- 85 K for the terminals of ABB circuit-breakers, if they are not directly connected to insulated conductors (the temperature-rise 85 K is always referred to an ambient temperature outside the assembly of 35°C).

Figure 7.1

Connection with busbar | **Connection with PVC-insulated cable**



7.2 Thermal verification of the assembly

The aim of this document is to provide the panel builders who use ABB assemblies with an aid allowing the verification of the temperature-rise inside the assemblies according to criteria complying with the Std. IEC 61439.
As regards the temperature-rise limits, from the point of view of assembly certification, it is possible to follow one of the three new available procedures, and in particular:

1) the verification test (formerly defined type-test), in which the temperature rises reached and maintained under service conditions are measured at pre-defined points inside the prototype assemblies actually tested with current at laboratory. Then these values are compared with the admissible ones (shown in the Table 7.1); if the measured values are lower than or equal to the admissible ones, the test is considered as passed with those current values and under that determined conditions around (ambient temperature, humidity, etc.);

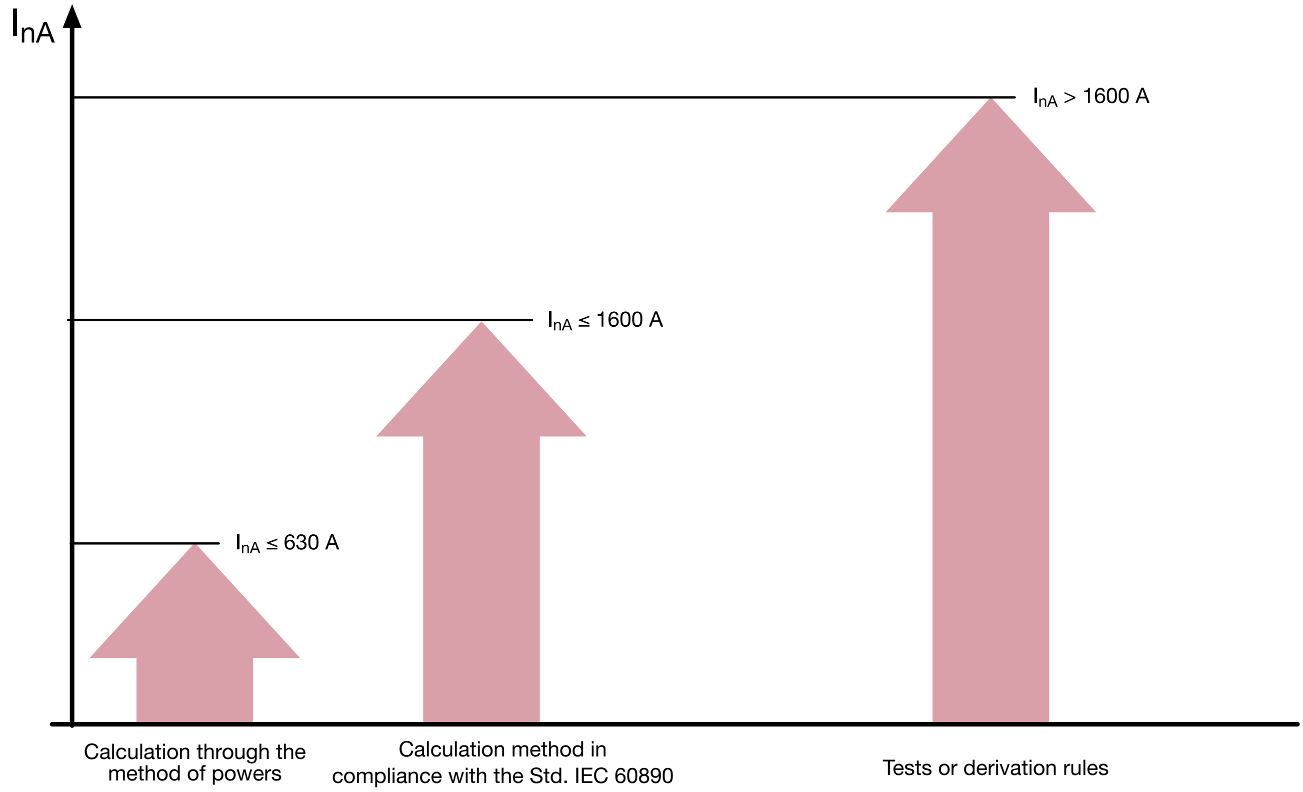
2) the derivation (from a cabled assembly tested) of similar variants; this procedure, applicable only if the data obtained by testing are available, defines how non-tested variants can be verified by derivation from similar assembly arrangements verified by test.
The derived assemblies are considered in compliance if, compared with the tested arrangements, they have:
    - the functional units of the same type (e.g.: same electrical diagrams, apparatus of the same size, same arrangements and fixing, same assembling structure, same cables and wiring) as the functional units used for the test;
    - the same type of construction as used for the test;
    - the same or increased overall dimensions as used for the test;
    - the same or increased cooling conditions as used for the test (forced or natural convection, same or larger ventilation openings);
    - the same or reduced internal separation as used for the test (if any);
    - the same or reduced power losses in the same section as used for the test;
    - the same or reduced number of outgoing circuits for every section.

3) the verification of the temperature rise through calculation. In this case the laboratory tests are not to be considered and mathematical algorithms of thermodynamic type – which are already in use since years by panel builders - are exploited. These methods of pure calculation are two, distinct and independent between them and alternative to tests. They are:

    a) the so called “method of the powers” based on not-exceeding the upper limit of thermal power loss capability in a determined enclosure.
    To establish the value of losses, in watt, the temperature rise in the empty assembly is simulated by inserting some adjustable heating resistors, which shall make the enclosure reach its thermal steady state.
    Once the thermal steady state has been reached and after verifying that the temperature rise limits are included in the defined range, for each enclosure, the maximum value of the thermal power loss can be obtained.
    This method is affected by some limitations and in particular is applied to switchgear assemblies:
    - with a single compartment and with current up to 630 A;
    - with homogeneous distribution of the internal losses;
    - in which the mechanical parts and the equipment installed are arranged so that air circulation is not significantly impeded;
    - in which the conductors transport currents exceeding 200 A and the structural parts are so arranged that the losses due to eddy currents are negligible;
    - in which the rated current of the circuits shall not exceed 80% of the rated conventional free air thermal current (Ith) of the switching devices and electrical components included in the circuit.

    b) the calculation algorithm of the Std. IEC 60890, applicable to multiple compartment assemblies with rated current up to 1600 A (formerly up to 3150 A).
    In this case procedures of algebraic calculation without experimental data are used.
    It is a calculation procedure which leads to the tracing, from bottom to top, of the thermal map of the assembly under steady state conditions, according to temperature values which grow linearly and reach their maximum value exactly at the top of the enclosure.
    Thus, through the total power loss, it is possible to evaluate the temperature rise at different levels, inside the assembly, from bottom to top.

Figure 7.2



By using calculation methods only it is possible to verify the compliance with the temperature rise limits of assemblies having rated currents
- not exceeding 630 A, through the method of powers
- not higher than 1600 A, through the Std. IEC 60890

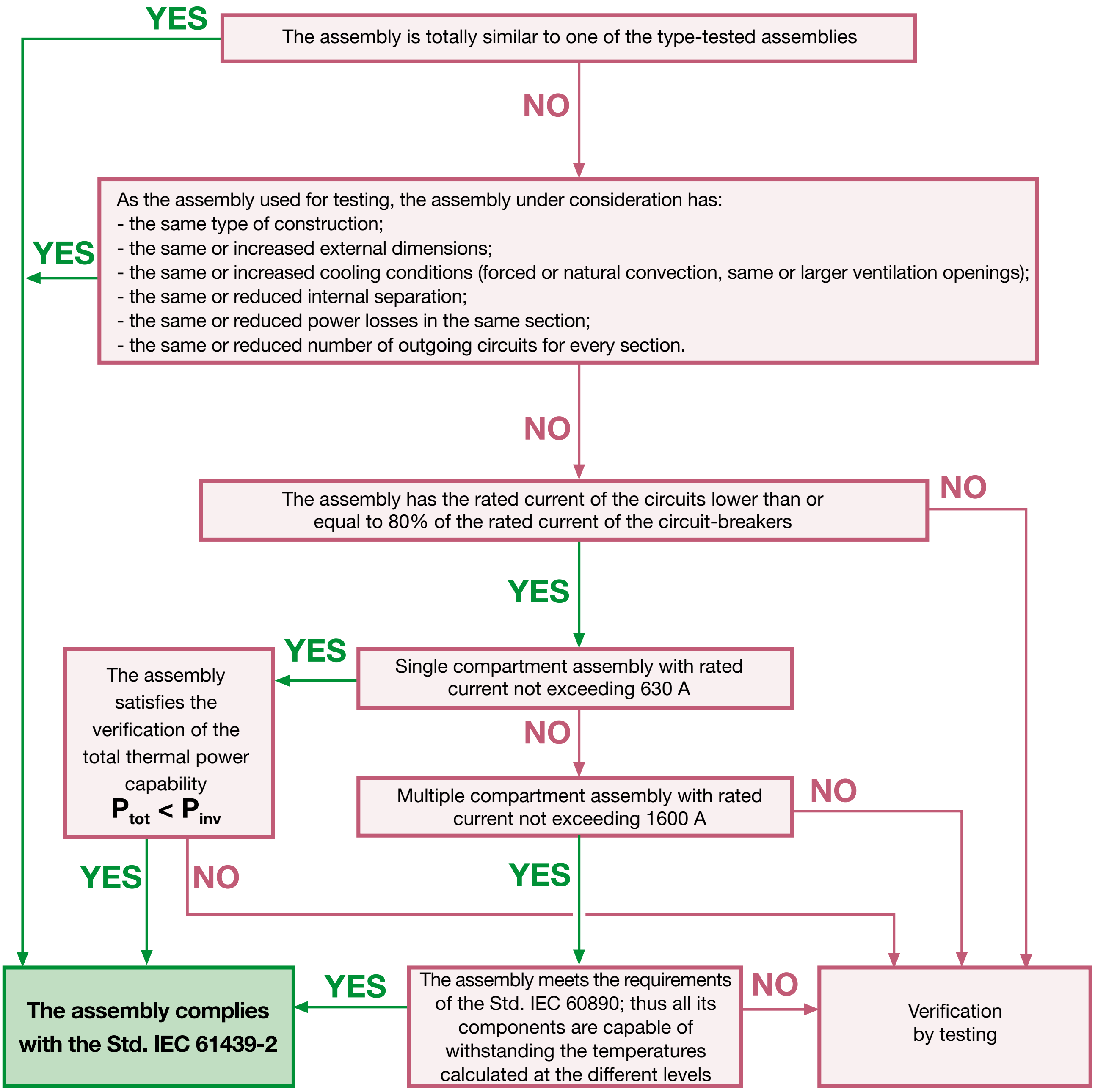
Verification of the temperature rise can be carried out through type tests or derivation rules, without any limit regarding the assembly power or current.

The method followed in this document is based on the calculation of the air temperature rise inside the assembly, according to the above mentioned Std. IEC 60890.
The above mentioned Standard and the IEC 61439-1 establishes that the calculation method is applicable only when the following conditions are met:
- the rated current of the assembly circuits shall not exceed 80% of the rated current (in free air) of the protective devices and of the electrical components installed in the circuit;
- there is an approximately even distribution of power loss inside the enclosure and there are no obstacles preventing its dispersion towards the outside of the assembly;
- the mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded;
- the installed assembly is designed for direct or alternating currents up to and including 60 Hz, with the total of supply currents not exceeding 1600 A;
- the conductors carrying currents exceeding 200 A and the structural parts are so arranged that eddy current losses are negligible;
- for the enclosures with ventilation openings, the cross-section of the air outlet openings is at least 1.1 times the cross-section of the air inlet openings;
- there are no more than three horizontal partitions for each section of the assembly;
- should the enclosures with external ventilation openings be divided into compartments, the surface of the ventilation openings in every internal horizontal partition shall be at least equal to 50% of the horizontal section of the compartment.

In applications with segregated assemblies not all the hypotheses of applicability of the IEC 60890 are met; however it has been decided to use this calculation method also in these cases because, being valid also for assemblies in insulating material, it results conservative in the case of metal structures.

The thermal verification of the assembly (through calculation or derivation rules) can be summarized by the following diagram.

Figure 7.3



7.3 Calculation of the temperature rises in compliance with the Std. IEC 60890

Figure 7.4 shows the different methods of installation taken into consideration in the Std. IEC 60890.

Calculation of the powers generated by the different components and dissipated inside the assembly

The calculation of the power losses reported in the configurations shown is carried out by taking into account the effective powers dissipated by the different components.

Circuit-breakers

Given the power losses at the rated current (In) shown in the following tables and the current which actually flows through the circuit-breakers (Ib), it is possible to calculate the effective power losses of the equipment:

$$P(I_b) = P(I_n)\left(\frac{I_b}{I_n}\right)^2$$

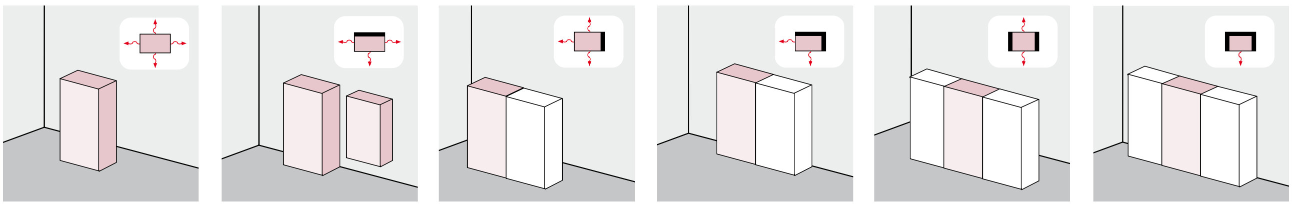
The values thus obtained must be increasde by a factor depending on the circuit-breaker type.

This coefficient is used to take into account the connections which carry current to the circuit-breakers.

Table 7.2

Type of circuit-breaker	Air and large moulded-case circuit-breakers (T7)	Moulded-case circuit-breakers	Miniature circuit-breakers
Coefficient of increase (C)	1,3	1,5	2

Figure 7.4



Separate enclosure exposed on all sides | Separate enclosure wall-mounted assembly | First or last enclosure exposed | First or last enclosure wall-mounted assembly | Central enclosure exposed | Central enclosure wall-mounted assembly

Table 7.3

Power loss – SACE Tmax XT molded-case circuit-breakers

Total power loss (3/4poles) [W]

Trip unit	In [A]	XT1 F	XT1 P	XT2 F	XT2 P/W	XT3 F	XT3 P	XT4 F	XT4 P/W
TMD TMA TMG MA MF	1,6			6	7,14				
	2			7,14	8,28				
	2,5			7,41	8,55				
	3			8,28	9,69				
	4			7,41	8,55				
	6,3			9,99	11,7				
	8			7,71	9,12				
	10			8,85	10,26				
	12,5			3,15	3,72				
	16	4,5	4,8	3,99	4,56				
	20	5,4	6	4,86	5,7				
	25	6	8,4						
	32	6,3	9,6	7,71	9,12			13,32	13,32
	40	7,8	13,8	11,13	13,11			13,47	14,16
	50	11,1	15	12,27	14,25			14,04	14,76
	63	12,9	18	14,55	17,1	12,9	15,3	15,9	17,28
	80	14,4	21,6	17,4	20,52	14,4	17,4	16,56	18
	100	21	30	24,24	28,5	16,8	20,4	18,72	20,88
	125	32,1	44,1	34,2	41,91	19,8	23,7	22,32	25,92
	160	45	60	48,45	57	23,7	28,5	26,64	32,4
	200					39,6	47,4	35,64	44,64
	250					53,4	64,2	49,32	63,36

F: fixed W: withdrawable P: plug-in

Table 7.4

Power loss – Tmax molded-case circuit-breakers

Total power loss (3/4poles) [W]

		T11P	T1	T2		T3		T4		T5		T6		T7 S,H,L		T7 V	
Trip unit	In [A]	F	F	F	P	F	P	F	P/W	F	P/W	F	W	F	W	F	W
	1			4,5	5,1												
	1,6			6,3	7,5												
	2			7,5	8,7												
	2,5			7,8	9												
	3,2			8,7	10,2												
	4			7,8	9												
	5			8,7	10,5												
	6,3			10,5	12,3												
	8			8,1	9,6												
	10			9,3	10,8												
	12,5			3,3	3,9												
	16	1,5	4,5	4,2	4,8												
TMF	20	1,8	5,4	5,1	6			10,8	10,8								
TMD	25	2	6	6,9	8,4												
TMA	32	2,1	6,3	8,1	9,6			11,1	11,1								
MA	40	2,6	7,8	11,7	13,8												
MF	50	3,7	11,1	12,9	15			11,7	12,3								
	63	4,3	12,9	15,3	18	12,9	15,3										
	80	4,8	14,4	18,3	21,6	14,4	17,4	13,8	15								
	100	7	21	25,5	30	16,8	20,4	15,6	17,4								
	125	10,7	32,1	36	44,1	19,8	23,7	18,6	21,6								
	160	15	45	51	60	23,7	28,5	22,2	27								
	200					39,6	47,4	29,7	37,2								
	250					53,4	64,2	41,1	52,8								
	320									40,8	62,7						
	400									58,5	93						
	500									86,4	110,1						
	630											92	117				
	800											93	119				
	10			1,5	1,8												
	25			3	3,6												
	63			10,5	12												
PR221	100			24	27,2			5,1	6,9								
PR222	160			51	60			13,2	18								
PR223	250							32,1	43,8								
PR231	320							52,8	72	31,8	53,7						
PR232	400									49,5	84			15	27	24	36
PR331	630									123	160,8	90	115	36	66	60	90
PR332	800											96	125	57,9	105,9	96	144
	1000											150		90	165	150	225
	1250													141	258	234,9	351,9
	1600													231	423		

F: fixed W: withdrawable P: plug-in

Table 7.5

Power loss – Emax and X1 series air circuit-breakers

Total power loss (3/4poles) [W]

	X1B-N		X1L		E1B-N		E2B-N-S		E2L		E3N-S-H-V		E3L		E4S-H-V		E6H-V	
Iu [A]	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W
In=630	31	60	61	90														
In=800	51	104	99	145	65	95	29	53			22	36						
In=1000	79	162	155	227	96	147	45	83			38	58						
In=1250	124	253	242	354	150	230	70	130	105	165	60	90						
In=1600	203	415			253	378	115	215	170	265	85	150						
In=2000							180	330			130	225	215	330				
In=2500											205	350	335	515				
In=3200											330	570			235	425	170	290
In=4000															360	660	265	445
In=5000																	415	700
In=6300																	650	1100

F: fixed W: withdrawable P: plug-in

The values shown in the Tables refer to balanced loads, with phase currents equal to In, and are valid for both three- as well four-pole circuit-breakers and switch-disconnectors. For the latter the current in the neutral is null by definition.

For further information and in-depth examinations reference shall be made to the relevant product technical catalogues

Distribution busbars

The busbars present in the column under examination must be considered when calculating the power loss. The length may be obtained approximately by checking the switchboard front.

The power dissipated by the busbars may be obtained by the following relation:

$$P(I_b) = P(I_n)\left(\frac{I_b}{I_n}\right)^2 \cdot L_{tratto} \cdot 3$$

where:
- $P(I_n)$ is the power loss per unit of length at the rated current and its value can be obtained either from the Table B.2 of the Std. IEC 60890 reported below or from the manufacturer's catalogue
- $(L_{section} \cdot 3)$ is the length of the bar section which pass through the column being considered, multiplied by 3 since the circuit is three-phase.

For the calculations present in this document, the Table B.2 of the Std. IEC 60890 (see Table 7.6) has been used considering around the bar an air temperature of 55°C.

Operating current and power loss of bare bars run vertically without direct connections to the equipment

Table 7.6

Height x thickness	Cross-sectional area of bar (Cu)	Maximum admissible temperature by the conductor: 85 °C															
		Air temperature inside the assembly around the conductors 35° C								Air temperature inside the assembly around the conductors 55 °C							
		from 50 Hz to 60 Hz AC				DC and AC up to 16 2/3 Hz				from 50 Hz to 60 Hz AC				DC and AC up to 16 2/3 Hz			
		operating current	power losses (1)	operating current	power losses (1)	operating current	power losses (1)	operating current	power losses (1)	operating current	power losses (1)	operating current	power losses (1)	operating current	power losses (1)	operating current	power losses (1)
mm x mm	mm^2	A*	W/m	A**	W/m	A*	W/m	A**	W/m	A*	W/m	A**	W/m	A*	W/m	A**	W/m
12 x 2	23,5	144	19,5	242	27,5	144	19,5	242	27,5	105	10,4	177	14,7	105	10,4	177	14,7
15 x 2	29,5	170	21,7	282	29,9	170	21,7	282	29,9	124	11,6	206	16,0	124	11,6	206	16,0
15 x 3	44,5	215	23,1	375	35,2	215	23,1	375	35,2	157	12,3	274	18,8	157	12,3	274	18,8
20 x 2	39,5	215	26,1	351	34,8	215	26,1	354	35,4	157	13,9	256	18,5	157	12,3	258	18,8
20 x 3	59,5	271	27,6	463	40,2	271	27,6	463	40,2	198	14,7	338	21,4	198	14,7	338	21,4
20 x 5	99,1	364	29,9	665	49,8	364	29,9	668	50,3	266	16,0	485	26,5	266	16,0	487	26,7
20 x 10	199	568	36,9	1097	69,2	569	36,7	1107	69,6	414	19,6	800	36,8	415	19,5	807	37,0
25 x 5	124	435	34,1	779	55,4	435	34,1	78	55,6	317	18,1	568	29,5	317	18,1	572	29,5
30 x 5	149	504	38,4	894	60,6	505	38,2	899	60,7	368	20,5	652	32,3	369	20,4	656	32,3
30 x 10	299	762	44,4	1410	77,9	770	44,8	1436	77,8	556	27,7	1028	41,4	562	23,9	1048	41,5
40 x 5	199	641	47,0	1112	72,5	644	47,0	1128	72,3	468	25,0	811	38,5	469	24,9	586	38,5
40 x 10	399	951	52,7	1716	88,9	968	52,6	1796	90,5	694	28,1	1251	47,3	706	28,0	1310	48,1
50 x 5	249	775	55,7	1322	82,9	782	55,4	1357	83,4	566	29,7	964	44,1	570	29,4	989	44,3
50 x 10	499	1133	60,9	2008	102,9	1164	61,4	2141	103,8	826	32,3	1465	54,8	849	32,7	1562	55,3
60 x 5	299	915	64,1	1530	94,2	926	64,7	1583	94,6	667	34,1	1116	50,1	675	34,4	1154	50,3
60 x 10	599	1310	68,5	2288	116,2	1357	69,5	2487	117,8	955	36,4	1668	62,0	989	36,9	1814	62,7
80 x 5	399	1170	80,7	1929	116,4	1200	80,8	2035	116,1	858	42,9	1407	61,9	875	42,9	1484	61,8
80 x 10	799	1649	85,0	2806	138,7	1742	85,1	3165	140,4	1203	45,3	2047	73,8	1271	45,3	1756	74,8
100 x 5	499	1436	100,1	2301	137,0	1476	98,7	2407	121,2	1048	53,3	1678	72,9	1077	52,5	1756	69,8
100 x 10	999	1982	101,7	3298	164,2	2128	102,6	3844	169,9	1445	54,0	2406	84,4	1552	54,6	2803	90,4
120 x 10	1200	2314	115,5	3804	187,3	2514	115,9	4509	189,9	1688	61,5	2774	99,6	1833	61,6	3288	101,0

* one conductor per phase   ** two conductors per phase   (1) single length

Incoming and outgoing assembly cables

The power loss of the cable section which enter the assembly must be calculated separately.
The variability in length of these section causes their power to be negligible in some cases, or decisive in others for the correct calculation of the power loss inside the assembly.

Their power loss can be determined by the following relation:

$$P(I_b) = P(I_n)\left(\frac{I_b}{I_n}\right)^2 \cdot L_{tratto} \cdot 3$$

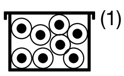
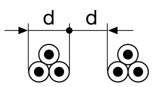
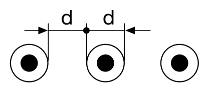
where:

- $P(I_n)$ is the power loss per unit of length at the rated current and its value can be taken either from the Table B.1 of the Std. IEC 60890 (see Table 7.7) or from the catalogue of the manufacturer
- ($L_{section} \cdot 3$) is the length of the cable section inside the assembly or inside the column under consideration multiplied by 3 since the circuit is three-phase; this length may be approximately determined by inspection of the switchboard front.

For the calculations in this document the Table B.1 of the Std. IEC 60890 (see Table 7.7) has been used considering an air temperature around the cable equal to 55°C.

Operating currents and power losses of insulated conductors

Table 7.7

Cross-sectional area (Cu)	Maximum admissible temperature by the conductor: 70 °C											
	 (1)											
	Air temperature inside the enclosure around the conductors											
	35 °C		55 °C		35 °C		55 °C		35 °C		55 °C	
	Operating current	**Power losses (2)**	**Operating current**	**Power losses (2)**	**Operating current**	**Power losses (2)**	**Operating current**	**Power losses (2)**	**Operating current**	**Power losses (2)**	**Operating current**	**Power losses (2)**
mm^2	A	W/m	A	W/m	A	W/m	A	W/m	A	W/m	A	W/m
1,5	12	2,1	8	0,9	12	2,1	8	0,9	12	2,1	8	0,9
2,5	17	2,5	11	1,1	20	3,5	12	1,3	20	3,5	12	1,3
4	22	2,6	14	1,1	25	3,4	18	1,8	25	3,4	20	2,2
6	28	2,8	18	1,2	32	3,7	23	1,9	32	3,7	25	2,3
10	38	3,0	25	1,3	48	4,8	31	2,0	50	5,2	32	2,1
16	52	3,7	34	1,6	64	5,6	42	2,4	65	5,8	50	3,4
25					85	6,3	55	2,6	85	6,3	65	3,7
35					104	7,5	67	3,1	115	7,9	85	5,0
50					130	7,9	85	3,4	150	10,5	115	6,2
70					161	8,4	105	3,6	175	9,9	149	7,2
95					192	8,7	125	3,7	225	11,9	175	7,2
120					226	9,6	147	4,1	250	11,7	210	8,3
150					275	11,7	167	4,3	275	11,7	239	8,8
185					295	10,9	191	4,6	350	15,4	273	9,4
240					347	12,0	225	5,0	400	15,9	322	10,3
300					400	13,2	260	5,6	460	17,5	371	11,4

(1) Each desidered layout, with the specific values, refers to a group of bunched conductors (six conductors loaded at 100%).
(2) Single length.

Temperature-rise calculation
The value of the temperature-rise inside the assembly can be calculated by means of ABB SACE software tools such as DOC.

The parameters required by the software are the following:
- linear dimensions of the switchboard (height, length, width);
- methods of installation (exposed separate, separate wall-mounted, ...);
- air inlet surface;
  (the Std. IEC 60890 prescribes an air outlet area at least equal to 1.1 times the inlet, otherwise the inlet area must be reduced of 10 % in relation with the actual one)
- ambient temperature;
- number of horizontal partitions;
- total power loss.

Using the same method or tool, the air temperature at mid height and at the top of the assembly to be constructed is calculated.

At this point, once the thermal map of the inside of the assembly from bottom to top has been drawn, if for each apparatus installed it results that the corresponding temperature at the fixing point remains equal to or lower than the admissible one, which is declared by the manufacturer, the whole assembly shall be considered as successfully verified.
For this specification too, a reduction of the loads in a range within 80% of the rated current of the protective devices is necessary.

Note
From the compliance of an assembly to the Std. IEC 60890 other arrangements can be derived by means of analyses and physical deductions of conservative type. Such arrangements can be accepted if:
- they use a structure with bigger linear dimensions;
- they are positioned in an air-conditioned environment with ambient temperature < 35 °C average value;
- they use a method of installation which allows greater ventilation of the assembly;
- they use a device for the forced ventilation of the assembly.

If required, these parameters can be inserted in the temperature-rise calculation so that a precise thermal map of the assembly can be defined.

On the other hand, the different degrees of protection and the different forms of separation cannot be taken into account to obtain lower temperature values.

7.4 Examples of temperature rise calculation

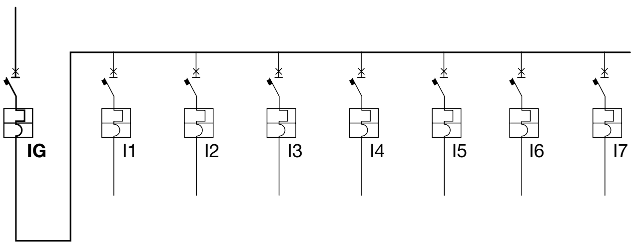
The following pages present four examples of temperature rise calculation according to the method described in the Std. IEC 60890.

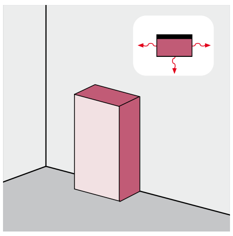
Each example is composed of:
- single-line diagram;
- schematization of the switchboard front with the bar layout;
- detail of the busbars (length, cross-sectional area, current, power loss);
- detail of the circuit-breakers (model, size, current, power loss, terminals, version);
- detail of the cables (length, cross-section, current, power loss);
- air temperatures calculated through ABB software DOC.

Example No. 1

Single-line diagram

Figure 7.5





Switchboard front

Figure 7.6

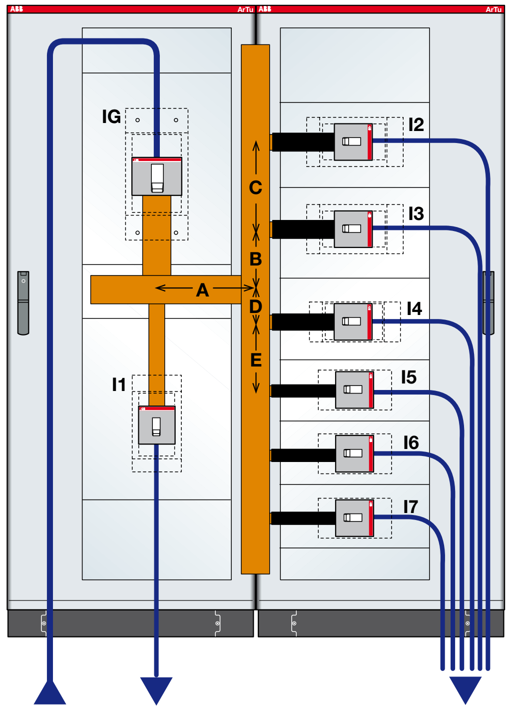


Table 7.8

Circuit-breakers	Type	Terminal	In [A]	Ib [A]	P(In) [W]	P(Ib) [W]
IG	T7H1600 (F)	Rear	1600	1200	231	168,92
I1	T5H400 (F)	Rear	400	320	58,5	56,16
I2	T5H400 (F)	Rear	400	300	58,5	49,36
I3	T5H400 (F)	Rear	400	300	58,5	49,36
I4	T4H250 (F)	Rear	250	200	41,1	39,46
I5	T2H160 (F)	Rear	125	60	36	12,44
I6	T2H160 (F)	Rear	125	0	36	0
I7	T2H160 (F)	Rear	125	0	36	0
Total power loss of the circuit-breakers						**375,7**

Version: F= fixed

Table 7.9

Busbar	Cross-section [mm]x[mm]	Length [mm]	Current Ib [A]	P(Ib) [W]
A	100x10	300	880	18
B	100x10	200	600	5,6
C	100x10	300	300	2,1
D	100x10	100	280	0,6
E	100x10	250	60	0,1
Total power loss of the busbars				**26**

Table 7.10

Cable	Cross-section [mm2]	Length [mm]	Current Ib[A]	P(Ib) [W]
IG	5x240	2400	1200	205,3
I1	240	500	320	15,2
I2	240	2100	300	56
I3	240	1800	300	48
I4	120	1500	220	41,3
I5	50	1100	60	5,5
Total power loss of the cables				**371,3**

Table 7.11

Power loss				Dimensions [mm]			0 horizontal partitions	Temperatures obtained °C (Ambient temperature = 25 °C)	
Busb.	Apparatus	Cables	Total	A [mm]	L [mm]	P [mm]		Height [m]	DOC
26	375,7	371,3	773	2000	1600	700	Exposed separate	2	49
								1	42

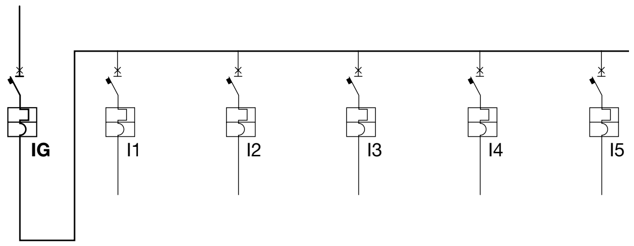
Table 7.12

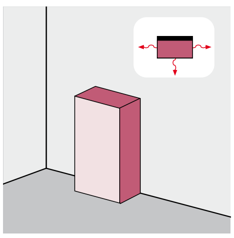
Example No.1	
Structure	**ArTu K**
Separation	**Not-separated**
Degree of protection	**IP65**
Assembly	**Wall-mounted, separate**

Example No. 2

Single-line diagram

Figure 7.7





Switchboard front

Figure 7.8

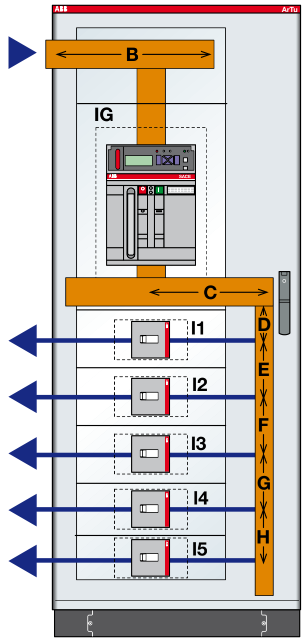


Table 7.13

Circuit-breaker	Type	Terminals	In [A]	Ib [A]	P(In) [W]	P(Ib) [W]
IG	E2N1600 (W)	Horizontal	1600	1214	215	160,9
I1	T2S160 (F)	Horizontal	160	50	51	7,47
I2	T2S160 (F)	Horizontal	160	50	51	7,47
I3	T2S160 (F)	Horizontal	160	50	51	7,47
I4	T2S160 (F)	Horizontal	160	50	51	7,47
I5	T2S160 (F)	Horizontal	160	50	51	7,47
Total power loss of the circuit-breakers						**198,3**

Versions: F = fixed – W = withdrawable

Tabella 7.14

Busbar	Cross-section [mm] x [mm]	Length [mm]	Current Ib [A]	P (Ib) [W]
B	3x(60x10)	360	1214	21,2
C	3x(60x10)	480	1214	28,2
D	80x10	100	1214	13,8
E	80x10	200	1164	25,5
F	80x10	200	150	negligible
G	80x10	200	100	negligible
H	80x10	200	50	negligible
Total power loss of the busbars				89

Table 7.15

Power loss				Dimensions [mm]			3 horizontal partitions	Temperatures obtained °C (Ambient temperature = 25 °C)	
Busb.	Apparatus	Cables	Total	A [mm]	L [mm]	P [mm]		Height [m]	DOC
89	198,3	0	287,3	2000	800	900	Wall-separate	2	46,7
								1	41,2

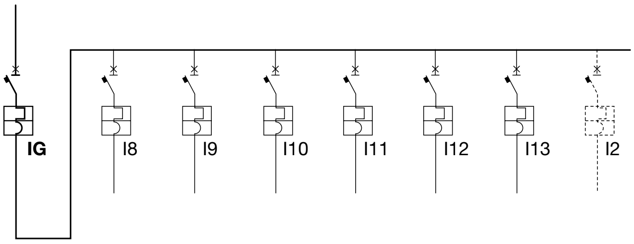
Table 7.16

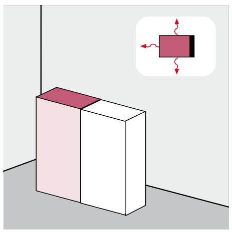
Example N°2	
Structure	**ArTu K**
Separation	**Form 3a**
Degree of protection	**IP65**
Assembly	**Wall-mounted separate**

Example No. 3

Single-line diagram

Figure 7.9





Switchboard front

Figure 7.10

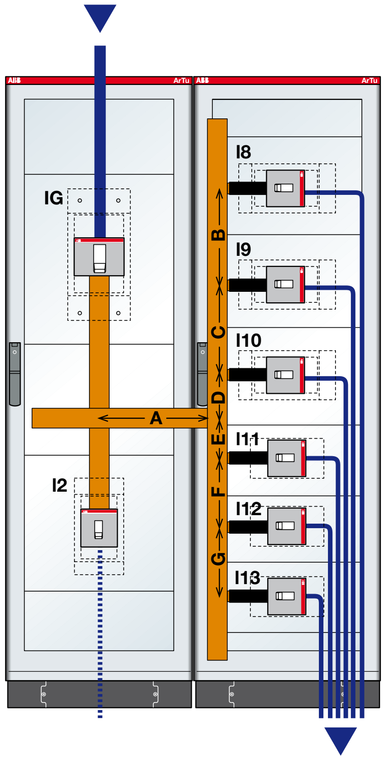


Table 7.17

Circuit-breaker	Type	Terminals	In [A]	Ib [A]	P(In) [W]	P(Ib) [W]
IG	T7H1600 (F)	Rear	1600	1360	231	217
I8	T5H400 (F)	Rear	400	320	58,5	56,2
I9	T5H400 (F)	Rear	400	320	58,5	56,2
I10	T4H250 (F)	Rear	250	200	41,1	39,46
I11	T2H160 (F)	Rear	160	125	51	46,7
I12	T2H160 (F)	Rear	160	125	51	46,7
I13	T2H160 (F)	Rear	160	125	51	46,7
Total power loss of the circuit-breakers						**509**

Versions: F = fixed

Table 7.18

Busbar	Cross-section [mm²]	Length [mm]	Current Ib [A]	P (Ib) [W]
A	2x80x10	360	1360	35,2
B	2x80x10	400	360	2,7
C	2x80x10	400	720	11
D	2x80x10	50	940	2,3
E	2x80x10	150	420	1,4
F	2x80x10	200	280	0,8
G	2x80x10	200	140	negligible
Total power loss of the busbars				**54**

Table 7.19

Cable	Cross-section [mm²]	Length [mm]	Current Ib [A]	P (Ib) [W]
IG	5x240	400	1360	44
I8	240	1800	360	69,3
I9	240	1400	360	54
I10	120	1000	220	28
I11	70	800	140	17
I12	70	600	140	12,7
I13	70	400	140	8,5
Total power loss of the cables				**234**

Table 7.20

Power loss				Dimensions [mm]			3 horizontal partitions	Temperatures obtained °C (Ambient temperature = 25 °C)	
Busb.	Apparatus	Cables	Total	A [mm]	L [mm]	P [mm]		Height [m]	DOC
54	509	234	797	2000	1400	800	Covered one side	2	64
								1	55

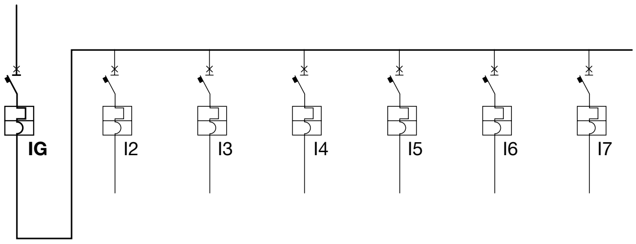
Table 7.21

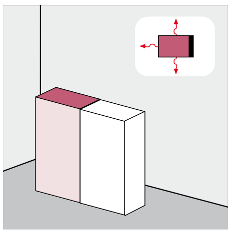
Example No. 3	
Structure	**ArTu K**
Separation	**Form 4**
Degree of protection	**IP65**
Assembly	**Exposed, covered one side**

Example No. 4

Single-line diagram

Figure 7.11





Switchboard front

Figure 7.12

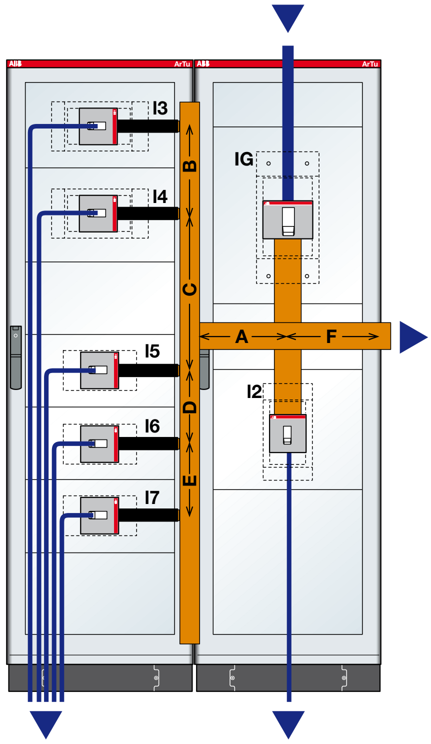


Tabella 7.22

Circuit-breaker	Type	Terminals	In [A]	Ib [A]	P(In) [W]	P(Ib) [W]
IG	T7S1600 (F)	Rear	1600	1140	231	152,45
I2	T5N400 (F)	Rear	400	320	58,5	56,2
I3	T4N250 (F)	Rear	250	200	41,1	39,46
I4	T4N250 (F)	Rear	250	200	41,1	39,46
I5	T2N160 (F)	Rear	160	125	51	46,7
I6	T2N160 (F)	Rear	160	125	51	46,7
I7	T1N160 (F)	Rear	125	100	45	43,2
Total power loss of the circuit-breakers						**424**

Versions: F = Fixed

Table 7.23

Busbar	Cross-section [mm²]	Length [mm]	Current Ib [A]	P (Ib) [W]
A	2x80x10	360	780	11,6
B	40x10	400	210	3,1
C	40x10	400	420	12,4
D	40x10	50	360	1,1
E	40x10	150	230	1,4
F	40x10	200	100	0,3
Total power loss of the busbars				30

Table 7.24

Cable	Cross-section [mm²]	Length [mm]	Current Ib [A]	P (Ib) [W]
IG	5x240	400	1140	31
I2	240	400	360	15,5
I3	120	1800	210	46,2
I4	120	1500	210	38,5
I5	70	1100	130	20
I6	70	900	130	16,4
I7	70	700	100	10
Total power loss of the cables				**177,6**

Table 7.25

Power loss				Dimensions [mm]			3 horizontal partitions	Temperatures obtained °C (Ambient temperature = 25 °C)	
Busb.	Apparatus	Cables	Total	A [mm]	L [mm]	P [mm]		Height [m]	DOC
30	424	177,6	631,6	2000	1400	800	Covered one side	2	57
								1	50

Table 7.26

Esempio N°4	
Structure	**ArTu K**
Separation	**Form 4**
Degree of protection	**IP65**
Assembly	**Exposed, covered one side**

8 Verification of performances under short-circuit conditions

The electric switchboard shall be built so as to resist the thermal and dynamic stresses deriving from the short-circuit current up to the assigned value. Furthermore, the switchgear assembly may be protected against the short-circuit currents by means of automatic circuit-breakers or fuses which can be installed either in the assembly or in its supply side.

When placing the order, the user shall specify the short-circuit conditions at the point of installation.

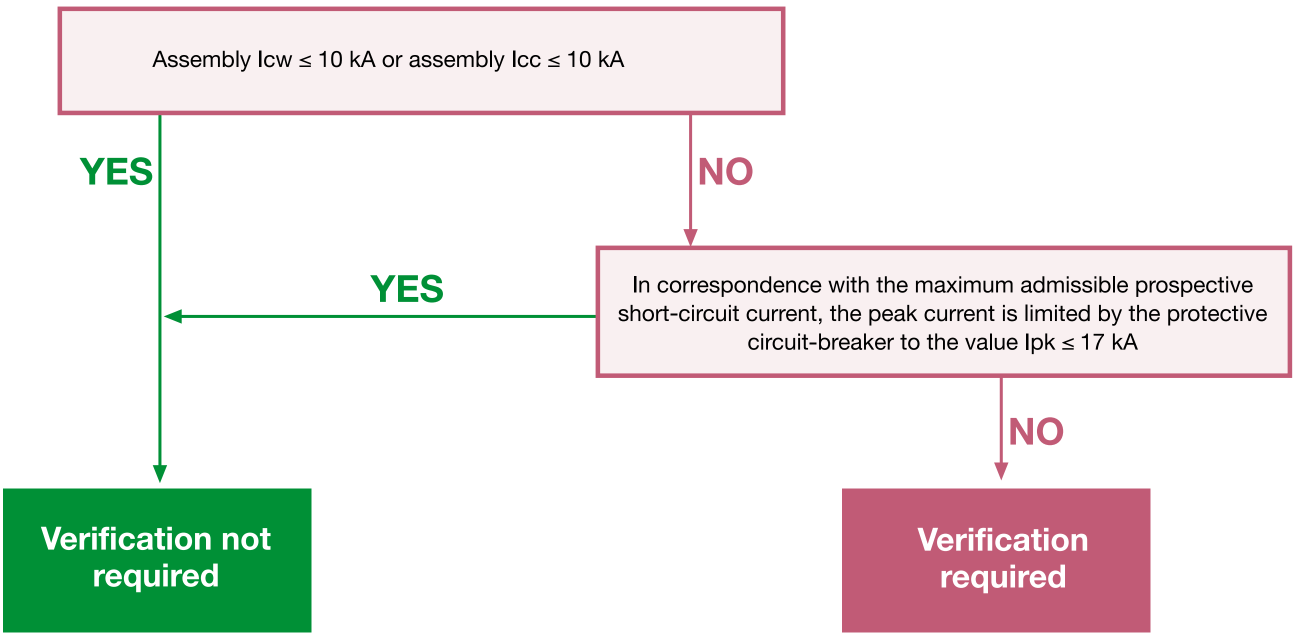
This chapter takes into consideration the following aspects:
- the need or not to carry out the verification of the short-circuit withstand inside the assembly;
- the suitability of a assembly for a plant according to the prospective short-circuit current of the plant and of the short-circuit parameters of the assembly;
- the suitability of the busbar system according to the short-circuit current and to the protection devices;
- the verification of the short-circuit withstand of the assembly by applying the design rules defined in the IEC 61439-1.

8.1 Verification of short-circuit withstand

The verification of the short-circuit withstand is dealt with by the recent Stds. IEC 61439-1 and 2; in particular the cases in which the verification must be carried out and the different types of verification are specified.
Verification of the short-circuit withstand is not necessary in the following cases:
- for an assembly with rated short-time current or rated conditional short-circuit current not higher than 10 kA;
- for assemblies protected by current limiting devices with a peak limited current not exceeding 17 kA, in correspondence with the maximum admissible prospective short-circuit current at the terminals of the incoming circuit of the assembly;
- for the auxiliary circuits of the assembly provided to be connected to transformers whose rated power does not exceed 10 kVA with a rated secondary voltage not lower than 110 V, or whose rated power does not exceed 1.6 kVA with secondary rated voltage lower than 110 V, and whose short-circuit voltage is not lower than 4%;
- all other circuits have to be verified.

Therefore the need to verify the short-circuit withstand can be summarized as follows:

Figure 8.1



As regards the details about the performance of the short-circuit test, reference should be made directly to the Std. IEC 61439-1.

The following Table shows for the different protective devices and for the most common plant voltages the values which approximately represent the maximum prospective short circuit-current in [kA], such that the limited peak does not exceed 17 kA, so that the short-circuit withstand test must not be carried out.

Table 8.1

Circuit-breaker		Rated voltage of the plant			
Typology	Rated current In [A]	230Vac	415Vac	500Vac	690Vac
S200	≤63	20	10	-	-
S200M	≤63	25	15	-	-
S200P	≤25	40	25	-	-
S200P	32-63	25	15	-	-
S800	≤125	50	50	15(In≤80A) 10(In≤80A)	6(In≤80A) 4.5(In≤80A)
S290	≤125	25	15	-	-
T1	<160	50	35	15	6
T1	160	37	33	15	6
T2	≤32	120	85	50	10
T2	≤50	120	85	39	10
T2	≤63	120	65	30	10
T2	80 -160	120	50	29	10
T3	63	37	20	18	8
T3	80	27	18	17	8
T3	100	21	16	15	8
T3	125-160	18	15	14	8
T3	200-250	16	14	13	8
T4	20	200	200	150	80
T4	32-50	200	200	150	55
T4	80	200	100	48	32
T4	100-320	200	24	21	19
T5 T6 T7	320-1600	10	10	10	10

The short-circuit value shown in the Table above shall be compared with the breaking capacity of the circuit-breaker for the different versions available.

8.2 Short-circuit current and suitability of the assembly to the plant

The verification of the short-circuit current withstand is mainly based on two parameters of the assembly, which are:

- admissible rated short-time withstand current I_{cw};
- rated conditional short-circuit current I_{cc}.

According to one of these two values it is possible to establish whether the assembly is suitable for being installed in a determined point of the plant.

It must be verified (if necessary through back-up) that the breaking capacities of the equipment inside the assembly are compatible with the short-circuit current values of the plant.

Rated short- time withstand current I_{cw} is the r.m.s. value of the current relating to the short-circuit test for 1 s without openings of the protections, declared by the assembly manufacturer, that can be carried by the assembly without damage under specified conditions, defined in terms of a current and time. Different Icw values for different times (e.g. 0.2 s; 3 s) may be assigned to an assembly.

From the test (if passed) which allows to define the I_{cw} value it is possible to obtain the specific let-through energy (I^2t) withstood by the assembly (this relation is valid by hypothesizing an adiabatic phenomenon which cannot exceed 3 seconds):

$$I^2t = I_{cw}^{\ 2} \cdot t \text{ (generically } t = 1s).$$

The Standard defines also the admissible rated peak current Ipk as the short-circuit peak current value, declared by the assembly manufacturer, that can be carried by the assembly itself under specified conditions. The value of current peak to determine the electrodynamic stresses shall be obtained by multiplying the short-time current by the factor "n" according to Table 7 of the Std. IEC 61439-1. The values for the factor "n" are given in Table 8.2.

$$I_{pk} = I_{cw} \cdot n$$

Table 8.2

R.m.s. value of the short-circuit (in kA)	cosφ	n
I ≤ 5	0.7	1.5
5 < I ≤ 10	0.5	1.7
10 < I ≤ 20	0.3	2
20 < I ≤ 50	0.25	2.1
50 < I	0.2	2.2

The values in this Table take into account the majority of applications. In particular areas, e.g. near transformers or generators, the power factor can take lower values and consequently, in these cases, the maximum peak value of the prospective current may become the limiting factor, instead of the r.m.s. value of the short-circuit current.

The rated conditional short-circuit current I_{cc} is the value of the prospective short-circuit current, declared by the assembly manufacturer, that can be withstood by the assembly for the total operating time (clearing time) of the short-circuit protective device under specified conditions.

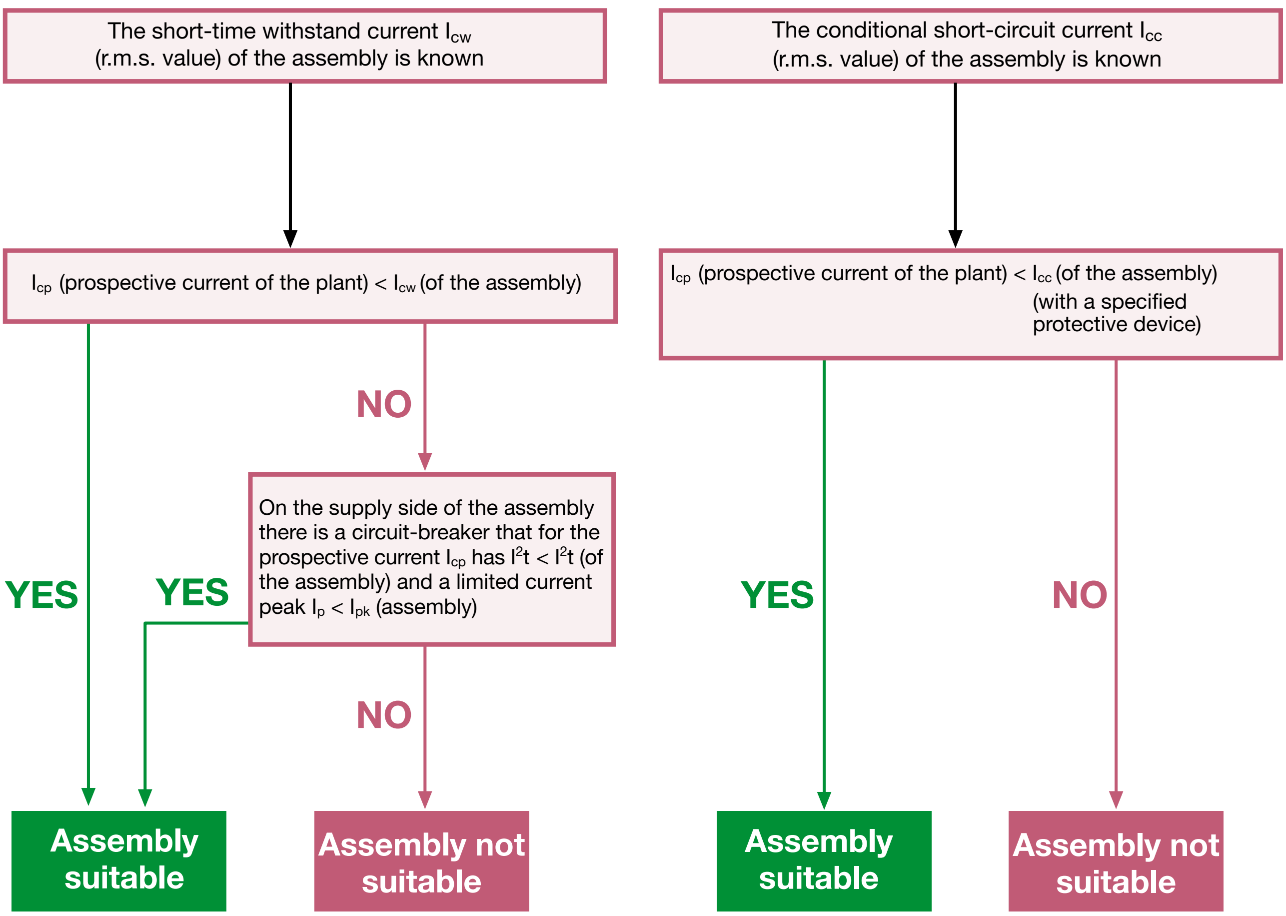
The I_{cc} shall be equal to or higher than the r.m.s. value of the prospective short-circuit current (I_{cp}) for a time limited by the trip of the short-circuit protective device which protect the assembly.

By means of the I_{cw} or I_{cc} values and the prospective short-circuit current of the plant it is possible to establish whether the assembly is suitable for being installed in the plant.

The following diagrams show the method to determine the compatibility of the assembly with the plant[1]

[1] It shall be verified that the breaking capacities of the equipment inside the assembly are compatible with the short-circuit current values of the plant.

Figura 8.2



Example

Data of the existing plant:

V_n= 400 V
f_n = 50 Hz
I_{cp}= 35 kA

By assuming to have in an existing plant an assembly with an I_{cw} equal to 35 kA and that, in the installation point of the plant, the prospective short-circuit current is equal to 35 kA.

Considering now deciding to increase the power of the plant and that the short-circuit value rises up to 60 kA.

Plant data after power increase:

U_n= 400 V
f_n = 50 Hz
I_{cp}= 60 kA

Since the I_{cw} of the assembly is lower than the short-circuit current of the plant, in order to verify that the existing assembly is still compatible it is necessary to:

- determine the values of I^2t and Ip let through by the circuit-breaker on the supply side of the assembly;
- verify that the protective devices positioned inside the assembly has the adequate breaking capacity, individually or for back-up.

I_{cw} = 35 kA from which:

- $I^2t_{\ assembly}$ = 35^2x1 =1225 MA^2s;
- $I_{pk\ assembly}$ = 35 x 2,1 = 73.5 kA (see Table 8.2).

Assuming that on the supply side of the assembly a new molded-case circuit breaker Tmax T5H (Icu=70 kA at 415V) is installed:

- $I^2t_{\ CB} < 4\ MA^2s$;
- $I_{p\ CB} < 40$ kA.

since:

- $I^2t_{\ assembly} > I^2t_{\ CB}$
- $I_{pk\ assembly} > I_{p\ CB}$

The assembly (structure and busbar system) turns out to be suitable.

As regards the circuit-breakers positioned inside the assembly, let us suppose that they are molded-case circuit-breakers type Tmax T1,T2,T3 version N with Icu=36 kA at 415V.

From the back-up tables it can be noticed that the circuit-breakers inside the assembly result suitable for the plant since their breaking capacity is increased to 65 kA by the circuit-breaker T5H on the supply side.

8.3 Choice of the distribution system in relation to the short-circuit withstand strength

The dimensioning of the distribution system of the assembly is carried out by taking into account the rated current passing through it and the prospective short-circuit current of the plant.

The manufacturer usually provides tables which allow the choice of the busbar cross-section according to the rated current and which give the distances the busbar supports must be placed at to guarantee the short-circuit withstand.

The distribution systems which can be used inside ArTu assemblies are described in the technical catalogue issued by ABB SACE ”Distribution Switchgear - General Catalogue”; they are:

busbars with shaped section up to:
- 3200 A (IP65);
- 3600 A (IP31)

drilled flat busbars up to:
- 4000 A (IP65);
- 4460 A (IP31)

flexible busbars up to:
- 1250 A (IP65);
- 1515 A (IP31)

Unifix cabling system up to 400 A;
distribution frames up to 400 A.

To select the distribution system compatible with the short-circuit data of the plant the following procedure must be taken:

- **If known the protective devices positioned on the supply side of the distribution system under examination**

from the value of the Icw of the distribution system the following is obtained:

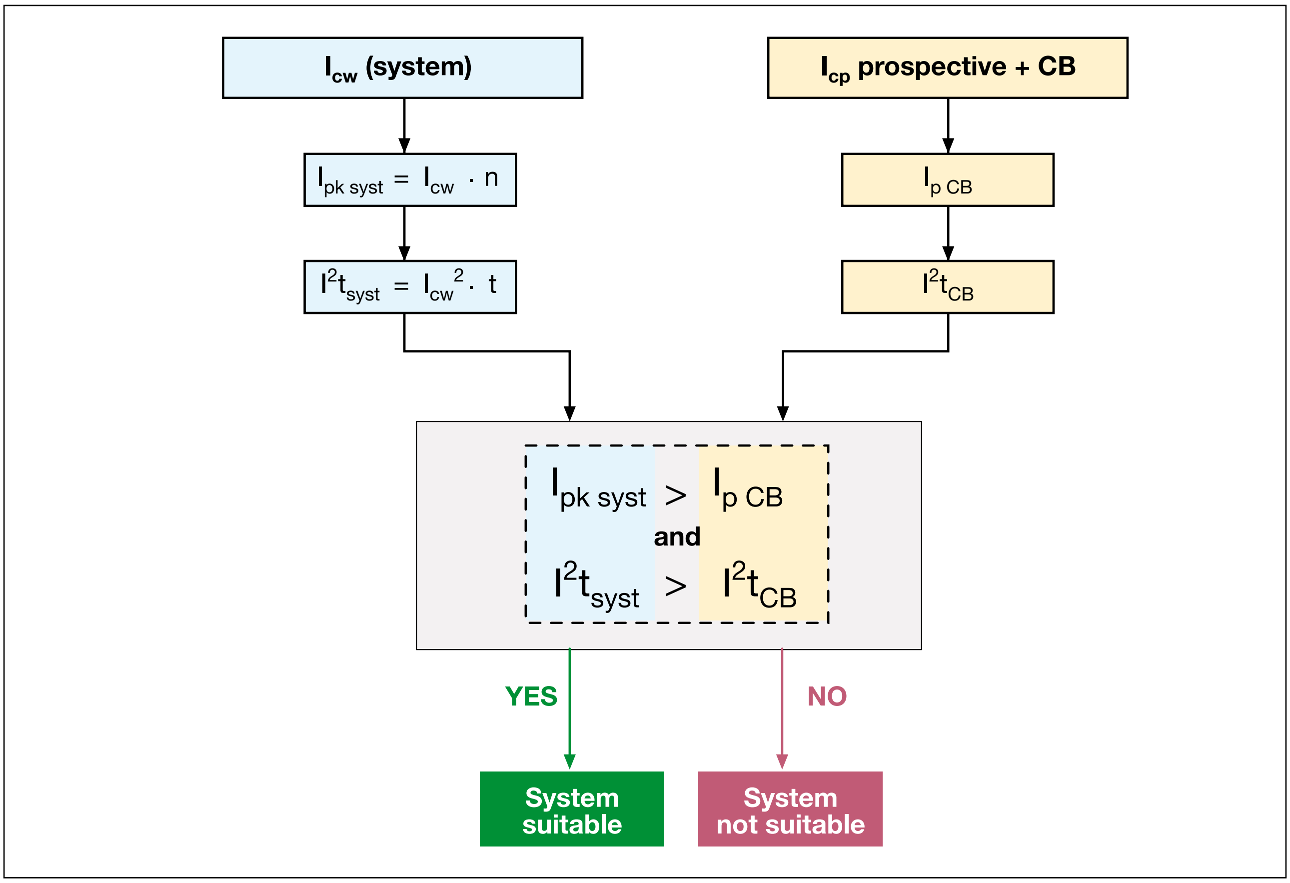
- $I_{pk\ syst} = I_{cw} \cdot n$
  (where n is the factor derived from Table 8.2)
- $I^2t_{syst} = I_{cw}^{\ 2} \cdot t$
  (where t is equal to 1 s).

In correspondence with the value of the prospective short-circuit current of the plant the following is determined:

- the value of the peak current limited by the circuit-breaker $I_{p\ CB}$;
- the specific energy let-through by the circuit-breaker I^2t_{CB}

If $I_{p\ CB} < I_{pk\ syst}$ and $I^2t_{CB} < I^2t_{syst}$ then the distribution system is suitable.

Figure 8.3



Example

Plant data:

U_n=400 V
f_n=50 Hz
I_{cp}=65 kA

Assuming that a 400 A busbar system with shaped section is needed.
According to the catalogue issued by ABB SACE "Distribution Switchgear - General Catalogue" a possible choice could be:
BA0400 In 400 A (IP65) with Icw = 35kA.

Assuming that a molded-case circuit-breaker Tmax T5H400 In 400 is positioned on the supply side of the busbar system, from the I_{cw} of the busbar system the following is obtained:

- $I_{pk\ syst} = I_{cw} \cdot 2,1 = 73,5$ [kA]
- $I^2t_{syst} = I_{cw}^2 \cdot t = 35^2 \cdot 1 = 1225$ [(kA)²s]

From the current limiting curves and the let-through energy curves of the circuit-breaker T5400 In 400, to a prospective short-circuit current I_{cp} equal to 65 kA, the following values correspond:

- $I_{p\ CB} < 40$ kA
- $I^2t_{CB} < 4$ [(kA)²s]

Since:

- $I_{p\ CB} < I_{pk\ syst}$
- $I^2t_{CB} < I^2t_{syst}$

the busbar system is suitable for the plant.

- **If the protective devices positioned on the supply side of the distribution system under examination is not known, it shall be necessary to verify that:**

I_{cp} (prospective current) < I_{cw} (distribution system)

Sections of conductor on the supply side of the device

The Std. IEC 61439-1 states that inside assembly, the conductors (including the distribution busbars) placed between the main busbars and the supply side of the individual functional units, as well as the components making up these units, can be sized on the basis of the reduced short-circuit stresses which are generated on the load side of the short-circuit protection device of the unit.

This may be possible if the conductors are arranged so that, under normal service conditions, the internal short-circuit between phases and/or between phases and earth is to be considered a remote possibility; it is preferable for these conductors to be of massive and rigid construction.

As an example, the Standard in the Table 4 (see Table 8.3 of this document), indicates conductors and prescriptions for the installation which allow the remote hypothesis of a short-circuit between phases and/or between phases and earth to be taken into consideration.

If these conditions are found or when an internal short-circuit can be considered a remote hypothesis, the procedure described above can be used to check the suitability of the distribution system to the short-circuit conditions, where these are determined according to the characteristics of the circuit-breaker positoned on the load side of the busbars.

Tabella 8.3

Type of conductor	Requirements
Bare conductors or single-core conductors with basic insulation, for example cables according to IEC 60227-3.	Mutual contact or contact with conductive parts shall be avoided, for example by use of spacers.
Single-core conductors with basic insulation and a maximum permissible conductor operating temperature of at least 90 °C, for example cables according to IEC 60245-3, or heat-resista nt thermo-plastic (PVC) insulated cables according to IEC 60227-3.	Mutual contact or contact with conductive parts is permitted where there is no applied external pressure. Contact with sharp edges shall be avoided. These conductors may only be loaded such that an operating temperature of 80 % of the maximum permissible conductor operating temperature is not exceeded.
Conductors with basic insulation, for example cables according to IEC 60227-3, having additional secondary insulation, for example individually covered cables with shrink sleeving or individually run cables in plastic conduits	No additional requirements
Conductors insulated with a very high mechanical strength material, for example Ethylene Tetrafluoro Ethylene (ETFE) insulation, or double-insulated conductors with an enhanced outer sheath rated for use up to 3 kV, for example cables according to IEC 60502.	
Single or multi-core sheathed cables, for example cables according to IEC 60245-4 or IEC 60227-4.	

Example

Plant data:

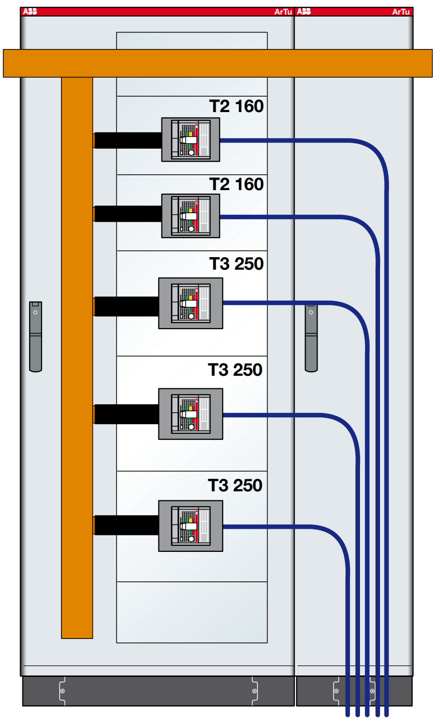
U_n = 400 V
f_n = 50 Hz
I_{cp} = 45 kA

Take into consideration the assembly in the figure, where the vertical distribution busbars are derived from the main busbars.
These are 800 A busbars with shaped section as reported in the General Distribution Switchgear Catalogue:
In 800, (IP65)
I_{cw} max 35 kA.

Being a rigid system with spacers, for the Std. IEC 61439 a short-circuit between the busbars is a remote possibility. However it is necessary to verify that the stresses reduced by the circuit-breakers on the load side of the system are compatible with the switchgear assembly.

Let us suppose that in the compartments there are the following circuit-breakers:
Tmax T3S250
Tmax T2S160

Figure 8.4



It must be checked that, in the case of a short-circuit on any output, the limitations caused by the circuit-breaker, are compatible with the busbar system.
It must therefore be verified that the circuit-breaker which limits the peak and energy less represents a sufficient limit for the busbar system.
In our case this is the T3S250 In250.
Therefore we carry out the check in the same way as in the previous paragraph:

from the I_{cw} of the busbar system it turns out that
- $I_{pk\ syst} = I_{cw}$. n = 35 . 2.1 = 73.5 [kA]
- $I^2t_{\ syst} = I_{cw}^{\ 2}$. t = 35^2 . 1 = 1225 [$(kA)^2s$]

From the limiting curves and the specifc let-through energy of the T3S250 In 250, it results that to a prospective short-circuit current Icp of 45 kA the following corresponds:
- $I_{p\ CB}$ < 30 kA
- $I^2t_{\ CB}$ <2 [$(kA)^2s$]

Since:
- $I_{p\ CB} < I_{pk\ syst}$
- $I^2t_{\ CB} < I^2t_{\ syst}$

the busbar system results to be compatible with the assembly.

8.4 Short-circuit verification by design-rules

In compliance with the new Std. IEC 61439-1, the compliance of the assembly under short-circuit conditions can be proved in addition to laboratory tests (I_{cw}) also by applying appropriate design-rules, which are pointed out in the following Table (Table 13 of the Std. IEC 61439-1).

No laboratory tests are required if, by comparing the assembly to be checked with a reference design project (already tested) using the Table above, "YES" are the answers to the prescriptions relevant to the comparison.

As it can be deduced from the Table, the derived arrangements are according to the tests performed on a reference project because only thanks to these it is possible to obtain a defined short-time current (I_{cw}) which in its turn allow to get the other two variables admissible of the assembly system, that is:

- peak current (I_{pk});
- specific let-through energy which the assembly can withstand (I^2t).

Table 8.4

Item No.	Requirements to be considered	YES	NO
1	Is the short-circuit withstand rating of each circuit of the ASSEMBLY to be assessed, less than or equal to, that of the reference design?		
2	Is the cross sectional dimensions of the busbars and connections of each circuit of the ASSEMBLY to be assessed, greater than or equal to, those of the reference design?		
3	Is the spacing of the busbars and connections of each circuit of the ASSEMBLY to be assessed, greater than or equal to, those of the reference design?		
4	Are the busbar supports of each circuit of the ASSEMBLY to be assessed of the same type, shape and material and have, the same or smaller spacing, along the length of the busbar as the reference design?		
5	Are the material and the material properties of the conductors of each circuit of the ASSEMBLY to be assessed the same as those of the reference design?		
6	Are the short-circuit protective devices of each circuit of the ASSEMBLY to be assessed equivalent, that is of the same make and series [a] with the same or better limitation characteristics (I^2t, I_{pk}) based on the device manufacturer's data, and with the same arrangement as the reference design?		
7	Is the length of unprotected live conductors, in accordance with 8.6.4, of each non-protected circuit of the ASSEMBLY to be assessed less than or equal to those of the reference design?		
8	If the ASSEMBLY to be assessed includes an enclosure, did the reference design include an enclosure when verified by test?		
9	Is the enclosure of the ASSEMBLY to be assessed of the same design, type and have at least the same dimensions to that of the reference design?		
10	Is the enclosure of the ASSEMBLY to be assessed of the same design, type and have at least the same dimensions to that of the reference design?		
'YES' to all requirements – no further verification required. 'NO' to any one requirement – further verification is required, see 10.11.4 and 10.11.5.			
[a] Short-circuit protective devices of the same manufacture but of a different series may be considered equivalent where the device manufacturer declares the performance characteristics to be the same or better in all relevant respects to the series used for verification, e.g. breaking capacity and limitation characteristics (I2t, Ipk), and critical distances.			

9 Verification of the dielectric properties of the assembly

Among the main performance characteristics (design verifications) of an assembly system, in addition to the thermal and the short-circuit withstand strength just examined, there is the verification of the dielectric properties.

With regard to this, the new version of the Std. IEC 61439 has introduced a double compliance, by confirming again the power-frequency withstand voltage (U_i) property and by adding the new impulse withstand voltage (U_{imp}).

It is important to point out that the increasing sequence affecting the different voltages which characterize an assembly starts with U_e, the operational voltage as a function of the actual value operating in a definite plant, continues with U_n, the rated voltage of the assembly considered and declared in the relevant catalogue, carries on with U_i, the assembly rated insulation voltage to which dielectric tests are referred and finishes with U_{imp}, the rated impulse withstand voltage which represents the maximum peak which the system is able to withstand; this peak value is assigned by the original manufacturer of the system, by means of proper design verifications.

9.1 Power frequency withstand voltage test

The developments of the Standard go towards a certain technical simplification.
As regards the r.m.s. values of the test voltages to be applied in laboratories (see Table 8 of the IEC 61439-1 shown below), it can be noticed that they have been reduced in comparison with the former edition, but leaving the possibility of carrying out the verification of the main circuits both in alternating current as well as in continuous current however keeping to the canonical ratio 1.41.

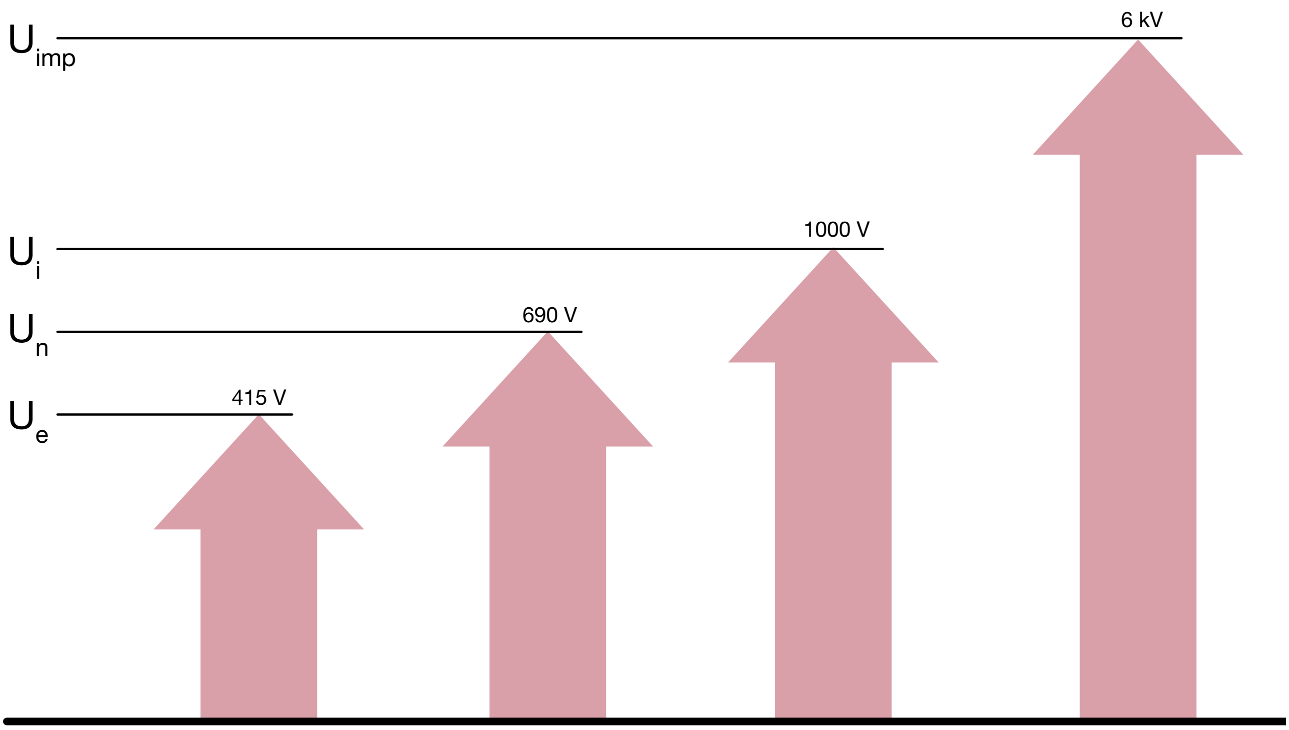
Table 9.1

Rated insulation voltage U_i line to line a.c. or dc. V	Dielectric test voltage a.c. r.m.s. value V	Dielectric test voltage[b] d.c V
Ui ≤ 60	1 000	1 415
60 < Ui ≤ 300	1 500	2 120
300 < Ui ≤ 690	1 890	2 670
690 < Ui ≤ 800	2 000	2 830
800 < Ui ≤ 1 000	2 200	3 110
1 000 < Ui ≤ 1 500 [a]	-	3 820

[a] For d.c. only

[b] Test voltages based on 4.1.2.3.1, third paragraph, of the IEC 60664-1.

Figure 9.1



This test in alternating current and at 50 Hz frequency, which allows defining the rated insulation voltage Ui, is necessary and exclusive, since no alternative verifications are admitted neither by applying calculation or design rules; as a consequence this is a mandatory test for the original manufacturer.
After the disconnection both on the supply as well as on the load side of all the active circuits, the test is carried out in two different stages, both on the main circuits as well as on the auxiliary circuits.
In particular, as regards the first circuits, two different procedures are defined for the application of the test voltage:
- first to all the active circuits connected together and the earthed enclosure (1st test)
- then to each main pole and the other poles and the earthed enclosure connected together (2nd test).

The test voltage generated by suitable laboratory equipment, is applied by means of the classic safety clamps to the parts to be tested. The method described, which implies the application of a slope with values increasing up to a maximum to be maintained each time for five seconds, highlights a further reduction in the times of application of the voltage test (before 1 minute was required).

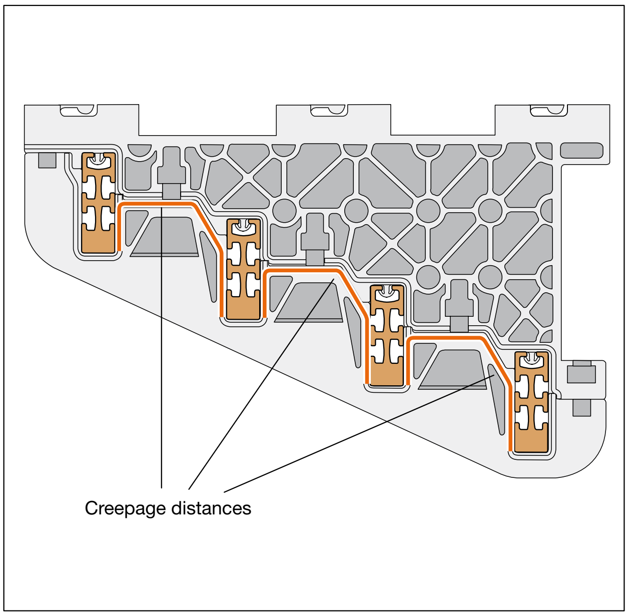
For the auxiliary circuits, which usually have working voltages lower than the main circuits, the new Std. IEC 61439 defines Table 9 (see Table 9.2).

Table 9.2

Rated insulation voltage U_i (line to line) V	Dielectric test voltage a.c. r.m.s V
Ui ≤ 12	250
12 < Ui ≤ 60	500
60 < Ui	2 Ui + 1000 with a minimum of 1500

Analogous to the voltage test in alternating current just described, there is the verification of the minimum creepage distances inside the assembly; this prescription involves all the internal components provided with insulated parts both between the active parts that to earth. The critical points which deserve more attention are usually the busbar holder supports and the insulated terminals.

Figure 9.2



As usual, this procedure shall take into account also the type of insulating material and the relevant comparative tracking index CTI (in Volt) expressing the maximum withstand voltage which can be withstood without discharges. The most valuable is the product (glass, ceramic material) the highest is this index (600 and over) and the lowest is the relevant material group.

Table 9.3

Material group	CTI (comparative tracking index)		
I		> 600	
II	600	> CTI	> 400
IIIa	400	> CTI	> 175
IIIb	175	> CTI	> 100

The above mentioned can be summarized in the following Table, which shows the minimum creepage distances in mm for each component housed in the assembly, as a function of the rated insulation voltage U_i, of the pollution degree and of the material group.

Direct measurement of such segments rarely highlights critical situations, since the normal mechanical and geometrical tolerances exceed abundantly these values.

Table 9.4

Rated insulation voltage U_i V	Minimum creepage distances mm							
	Pollution degree							
	1 Material group	2 Material group			3 Material group			
	I	I	II	IIIa e IIIb	I	II	IIIa	IIIb
32	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
40	1.5	1.5	1.5	1.5	1.5	1.6	1.8	1.8
50	1.5	1.5	1.5	1.5	1.5	1.7	1.9	1.9
63	1.5	1.5	1.5	1.5	1.6	1.8	2	2
80	1.5	1.5	1.5	1.5	1.7	1.9	2.1	2.1
100	1.5	1.5	1.5	1.5	1.8	2	2.2	2.2
125	1.5	1.5	1.5	1.5	1.9	2.1	2.4	2.4
160	1.5	1.5	1.5	1.6	2	2.2	2.5	2.5
200	1.5	1.5	1.5	2	2.5	2.8	3.2	3.2
250	1.5	1.5	1.8	2.5	3.2	3.6	4	4
320	1.5	1.6	2.2	3.2	4	4.5	5	5
400	1.5	2	2.8	4	5	5.6	6.3	6.3
500	1.5	2.5	3.6	5	6.3	7.1	8.0	8.0
630	1.8	3.2	4.5	6.3	8	9	10	10
800	2.4	4	5.6	8	10	11	12.5	
1000	3.2	5	7.1	10	12.5	14	16	
1250	4.2	6.3	9	12.5	16	18	20	
1600	5.6	8	11	16	20	22	25	

9.2 Impulse withstand voltage test

Only optional in the past, the impulse test which allow defining the rated impulse withstand voltage U_{imp}, is now a necessity thus demonstrating the strategy of the Standards directed to increasing the importance of such performance.
In addition to the ordinary temporary overvoltages, usually incoming from the supply line, the plants and the relevant assemblies are prospective victims of peaks and transient not-linear overvoltages due to atmospheric causes (fulminations) both direct, when they affect materially the structure, as well as indirect, when their effect is generated by the electromagnetic fields induced around the impact point of the lightning. The capability of the assemblies to withstand such stresses depends all on the dielectric strength of the air between the two live parts carrying the impulse. Formerly such performance was defined only by experimental testing; according to the new IEC 61439 also a verification by "design rule" is possible as an alternative and with the same validity of testing.

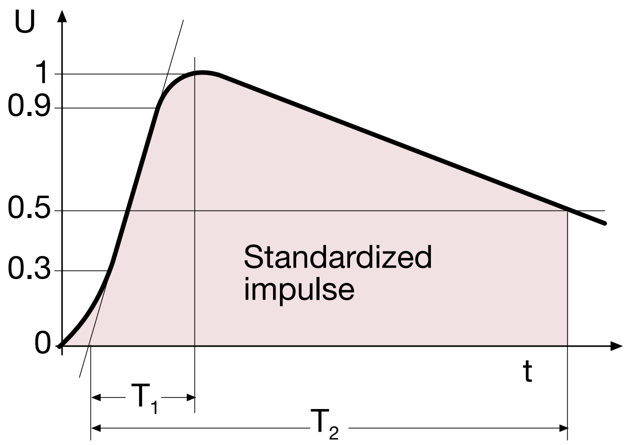
The test requires the application of the impulse withstand voltage 1.2/50 μs (see Figure 9.3) in compliance with a particular procedure.
The impulse voltage shall be applied five times at intervals of 1 second minimum between
- all the circuits connected together and the enclosure connected to earth
- each pole, the other poles and the earthed enclosure connected together.

Once defined the profile of the impulse, the other value allowing the verification is the peak one, which represents the absolute maximum of the function.

The present tendency, which is evident in the Tables of the IEC 61439-1, enhances some round figures such as sex, eight, ten and twelve kV.

The direct test is performed according to a specific Table (Table 10 of the IEC 61439-1, shown below) which suggests the alternative between effective impulse, alternating voltage (r.m.s. value) and direct voltage, with the value defined as a function of the altitude and consequently of the quality of the ambient air around the assembly under test.
The test is passed if no discharges are detected.

Figure 9.3



T1: peak time = 1.2 μs

T2: time at half value of U = 50 μs

Table 9.5

Rated impulse withstand voltage U_{imp} kV	Impulse withstand voltages									
	U1,2/50, a.c. peak and d.c. kV					R.m.s. value a.c. kV				
	Sea level	200 m	500 m	1 000 m	2 000 m	Sea level	200 m	500 m	1 000 m	2 000 m
2,5	2,95	2,8	2,8	2,7	2,5	2,1	2	2	1,9	1,8
4	4,8	4,8	4,7	4,4	4	3,4	3,4	3,3	3,1	2,8
6	7,3	7,2	7	6,7	6	5,1	5,1	5	4,7	4,2
8	9,8	9,6	9,3	9	8	6,9	6,8	6,6	6,4	5,7
12	14,8	14,5	14	13,3	12	10,5	10,3	9,9	9,4	8,5

The verification by design rule (in alternative to test) shall confirm that the clearances between all the live parts and the parts subject to the risk of discharge are at least 1.5 times the values specified in Table 1 of the IEC 61439-1 shown hereunder.
The safety factor 1.5 takes into consideration manufacturing tolerances.

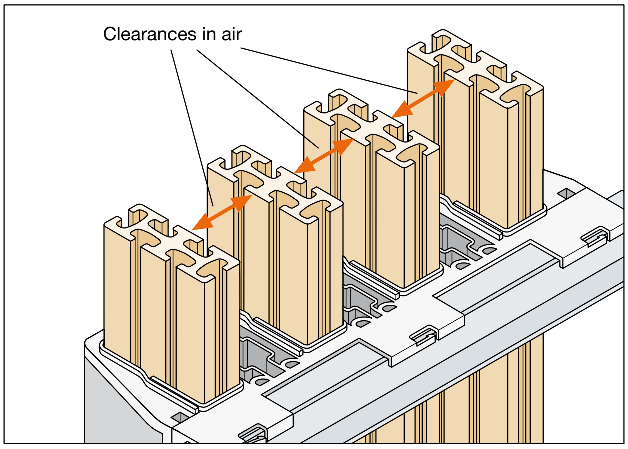
Table 9.6

Rated impulse withstand voltage U_{imp} kV	Minimum clearance in air mm
≤ 2,5	1,5
4,0	3,0
6,0	5,5
8,0	8,0
12,0	14,0

[a] Based on inhomogeneous field conditions and pollution degree 3.

The minimum clearances shall be verified by measurement or verification of measurements on design drawings.

Figure 9.4



It is evident that to guarantee that the whole assembly has a determined U_{imp}, in addition to the test or to the design rule verification which confirm this characteristic, also each component installed inside the assembly shall have an equal or higher U_{imp} value.

Since years the ArTu system guarantees both 50 Hz dielectric withstand as well as impulse voltage withstand; in particular:

- versions L and M have:
  - * Un = 690 V
  - * Ui = 1000 V
  - * Uimp = 6 kV wall-mounted and 8 kV floor- mounted

- version K has
  - * Un and Ui = 1000 V
  - * Uimp = 8 kV

10 Protection against electric shocks

The following prescriptions are aimed at ensuring that the protective measures required are taken when the assembly is installed in the electrical plant, in compliance with the relative standards.

10.1 Protection against direct contact

Protection against direct contact can be obtained both by means of the assembly construction itself as well as by means of complementary measures to be used during installation.
The protective measures against direct contact are:

- **Protection by insulation of live parts**
  Live parts shall be completely covered with an insulation which can only be removed by destruction.
  This insulation shall be made of suitable materials capable of durably withstanding the mechanical, electrical and thermal stresses to which the insulation may be subjected in service.
  Paints, varnishes, lacquers and similar products used alone are generally not considered suitable for providing adequate insulation for protection against direct contact.

- **Protection by barriers or enclosures**
  All external surfaces shall provide a degree of protection against direct contact of at least IPXXB.
  Horizontal top surfaces of accessible enclosures having a height equal to or lower than 1.6 m shall provide a degree of protection of at least IPXXD.
  The distance between the mechanical means provided for protection and the live parts they protect shall not be less than the values specified for the clearances and creepage distances.
  All barriers and enclosures shall be firmly secured in place. Taking into account their nature, size and arrangement, they shall have sufficient stability and durability to resist the strains and stresses likely to occur in normal service without reducing clearances.

- **Protection by obstacles**
  This measure applies to open-type assembly.

10.2 Protection against indirect contact

The user shall indicate the protective measure which is applied to the installation for which the ASSEMBLY is intended.
The protective measures against indirect contact are:

- **Protection by using protective circuits**
  A protective circuit (coordinated with a device for automatic supply disconnection) can be realized either separately from the metal enclosure or the enclosure itself can be used as part of the protective circuit.
  The exposed conductive parts of an assembly which do not constitute a danger either because they cannot be touched on large surfaces or grasped with the hands because they are of small size (e.g. screws, nameplates, etc.) need not be connected to the protective circuits.
  Manual operating means, such as levers, handles and other metal devices, shall be either electrically connected in a secure manner with the parts connected to the protective circuits or provided with additional insulation adequate for the maximum insulation voltage of the assembly. Metal parts covered with a layer of varnish or enamel cannot generally be considered to be adequately insulated to comply with these requirements.
  For lids, doors, cover plates and the like, the usual metal screwed connections and metal hinges are considered sufficient to ensure continuity provided that no electrical equipment requiring earthing is attached to them. In this case the live parts shall be connected by a protective conductor with cross-section at least equal to the maximum cross-sectional area of the phase conductor which supplies the assembly.
  The cross-sectional area of protective conductors (PE, PEN) in an assembly intended to be connected to external conductors shall be determined through one of the following methods:

a) the cross-sectional area of the protective conductor shall not be less than the appropriate value shown in the following Table.

Table 10.1

Cross-section of the phase-conductor S (mm)	Minimum cross-section of the corresponding protective conductor S (mm)
S ≤ 16	S
16 < S ≤ 35	16
35 < S ≤ 400	S/2
400 < S ≤ 800	200
S > 800	S/4

If a non-standard value results from the application of Table 10.1 the larger standardized cross-section nearest to the calculated value shall be used.

The values of this Table are valid only if the protective conductor (PE, PEN) is made of the same material of the phase conductor. If not, the cross-sectional area of the protective conductor (PE, PEN) is to be determined in a manner which produces a conductance equivalent to that which results by applying Table 10.1.

For PEN conductors, the following additional requirements shall apply:
- the minimum cross-sectional area shall be 10 mm² for a copper conductor and 16 mm² for an aluminium one;
- the cross-sectional area of the PEN conductor shall not be lower than that of the neutral conductor*;
- the PEN conductors need not be insulated within an assembly;
- the structural parts shall not be used as a PEN conductor. However, mounting rails made of copper or aluminium may be used as PEN conductors;
- for certain applications in which the current in the PEN conductor may reach high values, for example large fluorescent lighting installations, a PEN conductor having the same or higher current carrying capacity as the phase conductors may be necessary; this shall be subject of special agreement between manufacturer and user.

* The minimum cross-sectional area of the neutral in a three-phase circuit plus neutral shall be:
- for circuits with a phase conductor of cross-sectional area S ≤ 16 mm², 100% of that of the corresponding phases;
- for circuits with a phase conductor of cross-sectional area S > 16 mm², 50% of that of the corresponding phases with 16 mm² minimum.

It is assumed that the neutral currents do not exceed 50% of the phase currents.

b) the cross-sectional area of the protective conductor (PE, PEN) may be calculated with the aid of the following formula:

$$S_P = \frac{\sqrt{I^2 t}}{k}$$

This formula is used to calculate the cross-section of the protective conductors necessary to withstand the thermal stresses caused by currents of duration in a range between 0.2s and 5s, where:
Sp is the area of the section expressed in mm²;
I is the r.m.s. value of the fault current (in AC) flowing through the protective device, expressed in A, for a fault of negligible impedance;
t is the trip time of the breaking device in seconds;
k is a factor whose value depends on the material of the protective conductor, on the insulation and on other elements, as well as on the initial and final temperature.

Table 10.2

Values of factor k for insulated protective conductors not incorporated in bare cables or bare protection conductors in touch with cable coatings.

		PVC	XLPE EPR Bare conductors	Butyl rubber
Final temperature		**160 °C**	**250 °C**	**220 °C**
K for conductor	copper	143	176	166
	aluminium	95	116	110
	steel	52	64	60

Note: it is presumed that the initial temperature of the conductors is 30°C.

The exposed conductive parts of a device which cannot be connected to the protective circuit through its own fixing means, shall be connected to the protective circuit of the assembly by means of a conductor, whose cross-section shall be chosen according to the following Table:

Tabella 10.3

Rated operational current I_n (A)	Minimum cross-sectional area of the equipotential protective conductor (mm²)
$I_n \leq 20$	S
$20 < I_n \leq 25$	2.5
$25 < I_n \leq 32$	4
$32 < I_n \leq 63$	6
$63 < I_n$	10

S: cross-sectional area of the phase conductor

- **Protection realized with measures other than the use of protective circuits**
  Electrical assemblies can provide protection against indirect contact by means of the following measures which do not require a protective circuit:
  a) electrical separation of the circuits;
  b) full insulation.

10.3 Management in safety of the assembly

The use of the assembly shall guarantee the usual safety protections, both in case of operation as well as in case of replacement of small components, such as lamps and fuses, on behalf of ordinary personnel, if such procedure is followed.
More complex and dangerous operations may be performed by authorized personnel only and are related to the carrying out of particular procedures and the use of particular safety components, as regards the accessibility of the assembly, for:
- inspections and controls;
- maintenance;
- extension works also in the presence of live parts.

11 Practical indications for the construction of assemblies

11.1 Construction of electrical assembly

Mounting of the different mechanical and electrical components (enclosures, busbars, functional units, etc.) which constitute the assembly system defined by the original manufacturer shall be carried out in compliance with the instructions (technical catalogue/assembly instruction manual) of the manufacturer.

After the preparation of the loose parts to be assembled, the first step is constructing the metal work structure. When considering ArTu assembly, the structure can be already available as monobloc structure, and this is the case of ArTu M, or to be made up as for ArTu L and K.

For small and medium size assemblies the insertion of the components inside the assembly can be carried out more easily by arrange the enclosure horizontally on suitable trestles. Thus, working in this way it is possible to avoid keeping arms up and legs bent as it would be instead with an enclosure in vertical position.

A further advantage as regards the internal accessibility is obtained by working without the metal side panels of the structure, thus leaving bare the whole internal wiring system.
Obviously, it is suitable to proceed by mounting the apparatus from the centre towards the outside, connecting the cables little by little and inserting them in the relevant cable ducts.
Already at this stage, particular attention shall be paid to respect the minimum creepage distances and clearances between the different live parts and the exposed conductive part.

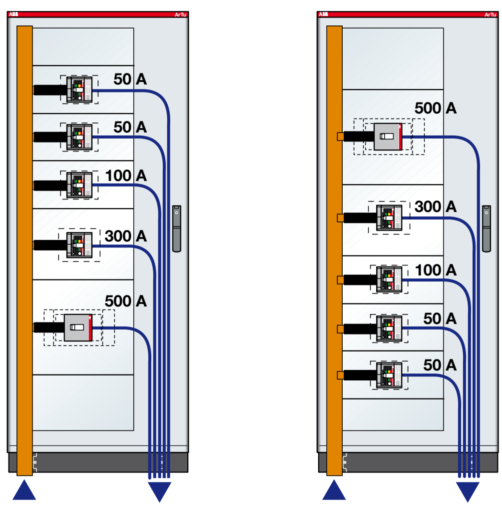
11.2 Positioning of the circuit-breakers

Here are some general indications for the best positioning of the circuit-breakers inside the assembly.
It is the panel builder that, since he better knows the details of the plant, the installation place and the actual use, can design the switchboard front in an optimal way.

- A good rule is trying to position the circuit-breakers so as to shorten the paths of the higher currents, thereby reducing the power loss inside the assembly with undoubted benefits from the thermal and economical point of view.

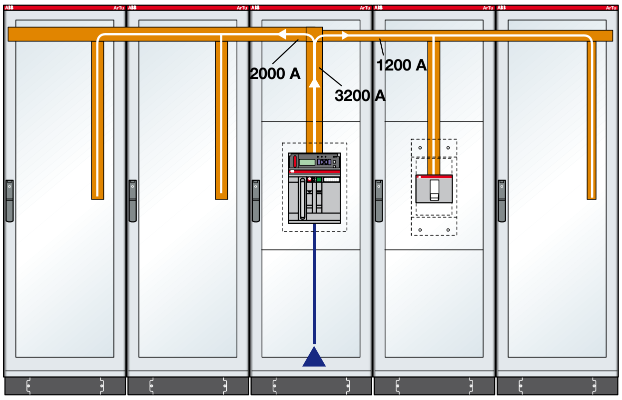
Figure 11.1

Recommended positioning method:	Positioning method NOT recommended:
The HIGHEST current (500 A) takes the SHORTEST path	The HIGHEST current (500 A) takes the LONGEST path



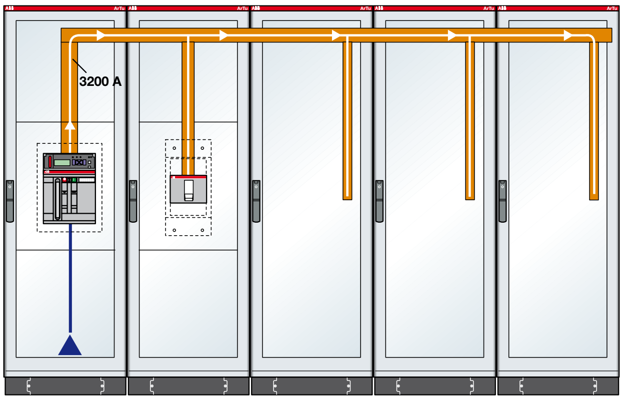
- In the case of assemblies with a lot of columns, where possible it is advisable to position the main circuit-breaker in the central column.
  In this way the current is immediately divided into the two branches of the assembly and the cross-sectional area of the main distribution busbars can be reduced.

Figure 11.2



In the example given in the figure, the main busbar system can be sized for 2000 A, with a considerable economic advantage.

Figure 11.3



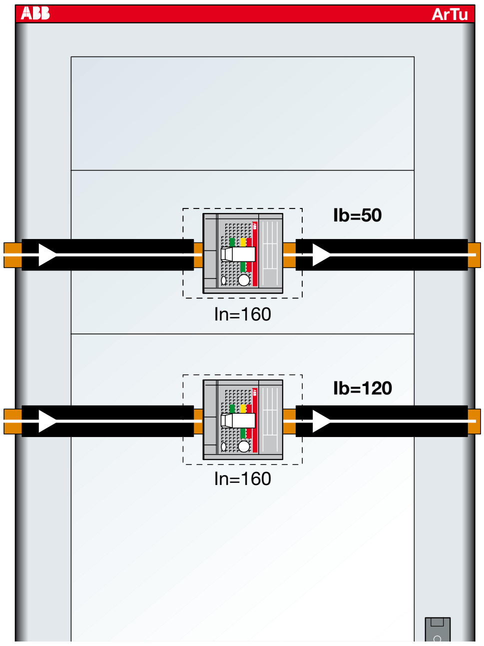
In this case, on the other hand, the main busbar system must be sized to carry 3200 A.

- It is advisable to position the largest and consequently the heaviest circuit-breakers at the bottom. This allows greater stability of the assembly, especially during tran sport and installation.

- In electric assembly the temperature varies vertically:
  - the lowest areas are the coldest ones;
  - the highest areas are the hottest ones.

For this reason, it is advisable to place the apparatus passed through by a current close to the rated value at the bottom (more loads) and at the top the apparatus passed through by a current far from the rated value (more discharges).

Figure 11.4



- To facilitate the operation of large apparatus it is advisable to place them at a distance of 0.8 to 1.6 m from earth.

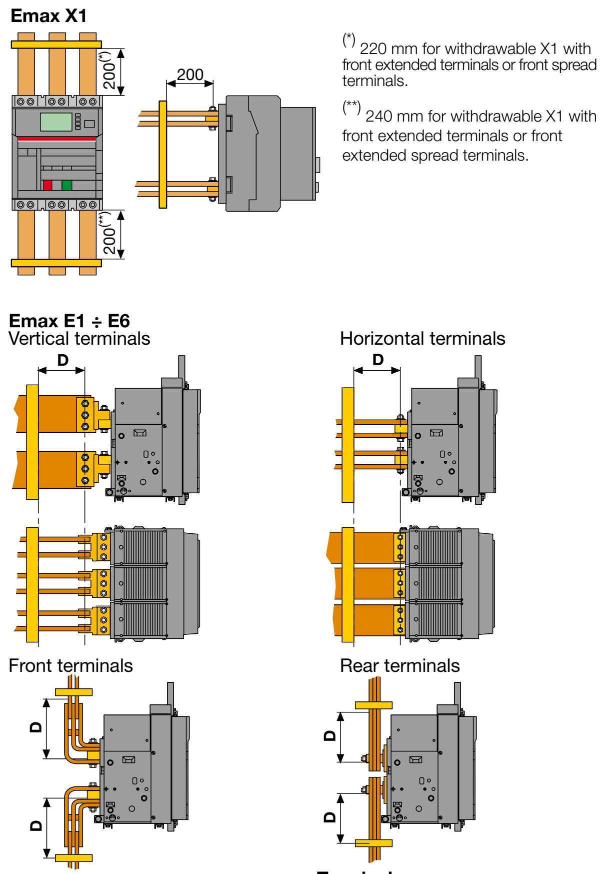
11.3 Anchoring of the conductors near to the circuit-breakers

It is necessary for the cables and busbars inside the assemblies to be fixed to the structure. In fact, during a short-circuit, the electrodynamic stresses generated in the conductors could damage the terminals of the circuit-breakers.

Emax

Figure 11.5 gives for Emax air circuit-breakers an example of the maximum distance in mm (D) at which the first anchor plate of the busbars connecting to the circuit-breaker shall be positioned according to the type of terminal and making reference to the highest admissible value of short-circuit current and of its relevant peak. For further details reference shall be made to the technical catalogues and the circuit-breakers manuals.

Figure 11.5

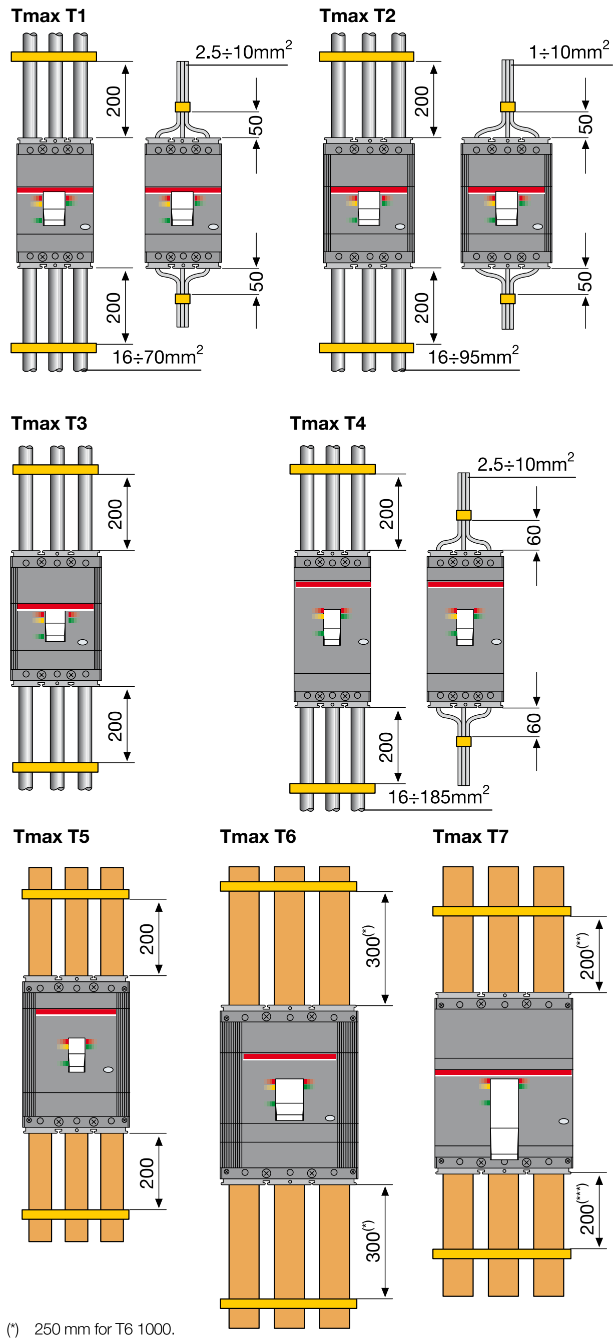


Emax	Horizontal terminals D [mm]	Vertical terminals D [mm]	Front terminals D [mm]	Flat terminals D [mm]
E1-E2	250	250	-	-
E3-E4-E6	150	150	-	-
E1-E6	-	-	250	250

Tmax

Figure 11.6 gives for Tmax molded-case circuit-breakers an example of the suggested maximum distance in mm at which the first anchor plate shall be positioned according to the type of terminal and making reference to the highest peak current value admitted for the circuit-breaker. For further details reference shall be made to the technical catalogues and the circuit-breakers manuals.

Figure 11.6



(*) 250 mm for T6 1000.

(**) 220 mm for T7, withdrawable with front extended terminals or front extended spread terminals.

(***) 240 mm for T7, withdrawable with front extended terminals or front extended spread terminals.

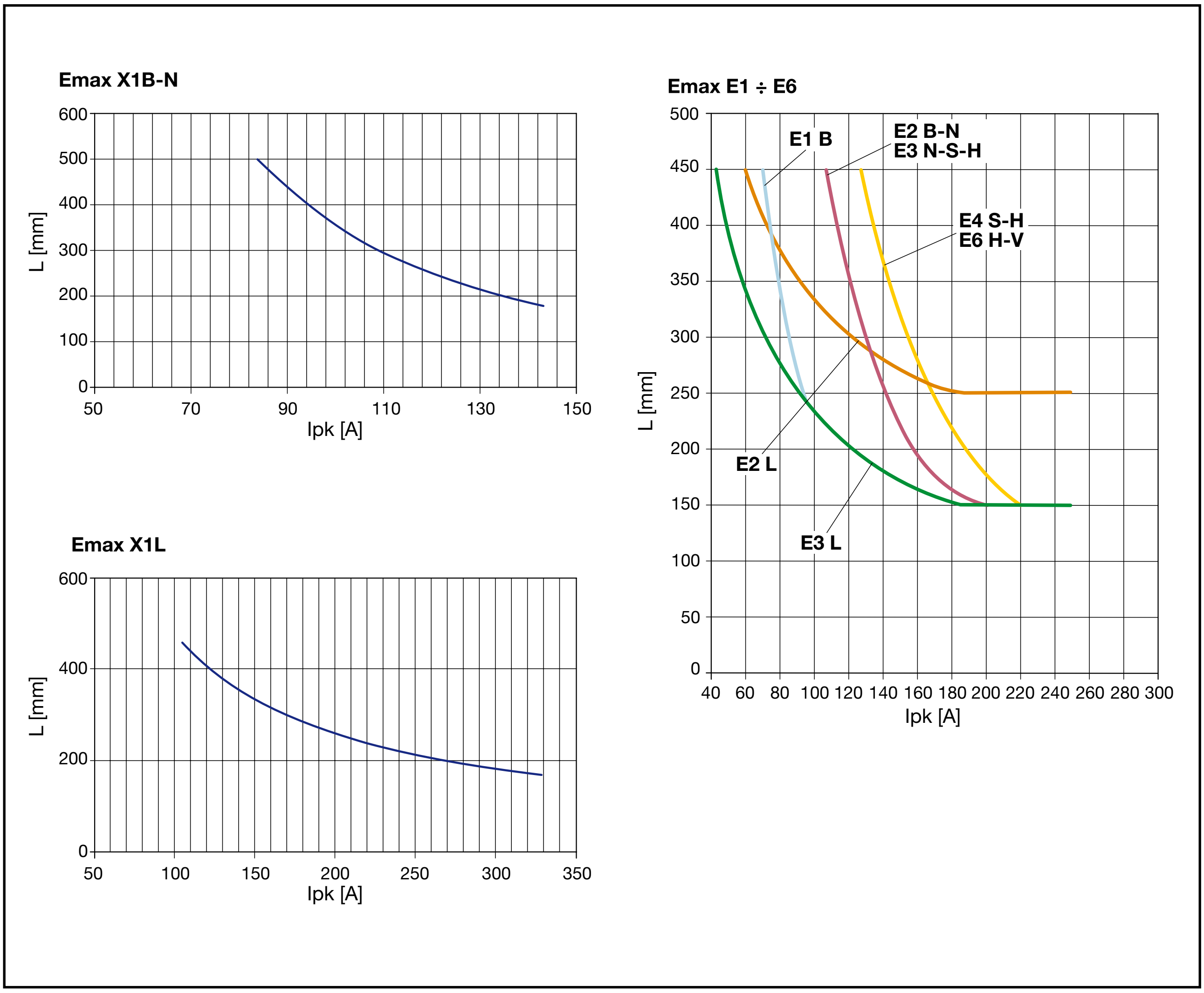
Hereunder are the diagrams which give the maximum distances admitted between the terminals of the circuit-breaker and the first anchor plate of the conductors according to the maximum prospective short-circuit current peak and the circuit-breaker typology.

With conductors the following is meant:
- cables, for values of current up to and including 400 A;
- cables or equivalent bars listed in Table 12 of the Std. IEC 61439-1, for values of current higher than 400 A but not exceeding 800 A;
- bars, for values of current higher than 800 A and not exceeding 4000 A.

This distinction has been made in compliance with Tables 11 and 12 of the Std. IEC 61439-1. If specific requirements demand or prescribe the use of bars also for currents lower than 400 A, the distances which can be derived from the diagrams are not subject to variations, whereas the distances referred to the use of bars are not valid when cables are used.

Emax
- Positioning distance suggested for the first anchor plate of the busbars according to the maximum prospective short-circuit current peak. Circuit-breaker with horizontal and vertical terminals.

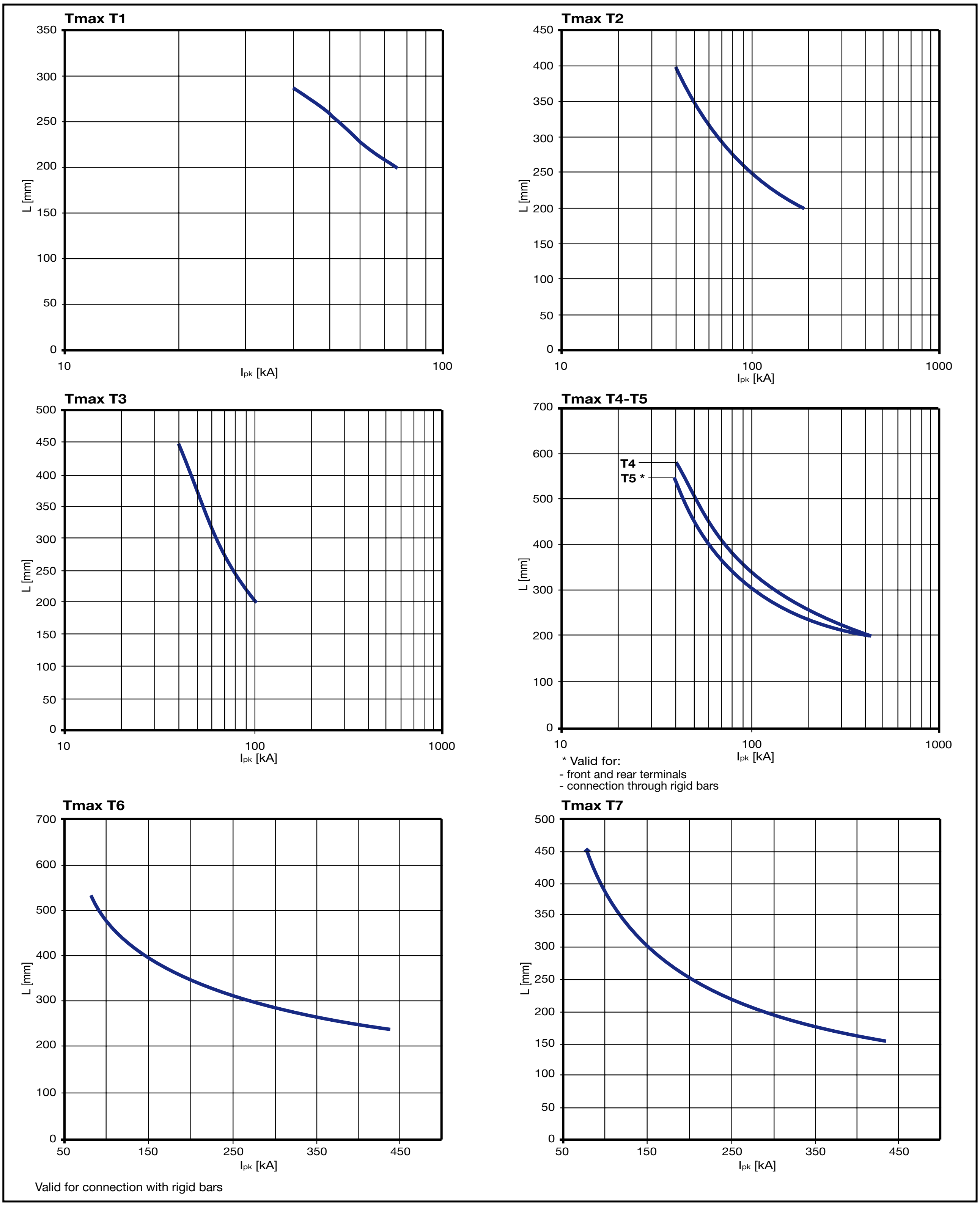
Figure 11.7



Tmax

- Positioning distance suggested for the first anchor plate of the conductors according to the maximum prospective short-circuit current peak.

Figura 11.8



11.4 Indications for the connection of the circuit-breakers to the busbar system

In order to get a connection allowing an adequate heat exchange between the terminals and the distribution system of the assembly, ABB SACE gives some indications about the minimum cross-sectional area for the cables and busbars to be used.

Table 11.1 below refers to the molded-case circuit-breakers series Tmax T and SACE Tmax XT and Table 11.2 to the air circuit-breakers series Emax and Emax X1.

The cross-sectional area of the cables and busbars shown in the Tables 11.1 and 11.2 are those used to determine the current carrying capacity in free air of the circuit-breakers in compliance with the product Std. IEC 60947-2.

Table 11.1

Circuit-breaker Tmax T	In [A]	Cables [n //] x [mm²]	Busbars [n //] x [mm] x [mm]
T2	≤ 8	1	
T2-T4	10	1,5	
T1-T2	16	2,5	
T1-T2-T4	20	2,5	
T1-T2-T4	25	4	
T1-T2-T4	32	6	
T1-T2-T4	40	10	
T1-T2-T4	50	10	
T1-T2-T3-T4	63	16	
T1-T2-T3-T4	80	25	
T1-T2-T3-T4	100	35	
T1-T2-T3-T4	125	50	
T1-T2-T3-T4	160	70	
T3-T4	200	95	
T3-T4	250	120	
T4-T5	320	185	
T5	400	240	
T5	500	2x150	2x30x5
T5-T6	630	2x185	2x40x5
T6	800	2x240	2x50x5
T6-T7	1000	3x240	2x60x5
T7	1250	4x240	2x80x5
T7	1600	5x240	2x100x5

Circuit-breaker SACE Tmax XT	In [A]	Cables [n //] x [mm²]
XT2	≤ 8	1
XT2	10	1,5
XT2	12,5	2,5
XT1-XT2-XT4	16	2,5
XT1-XT2-XT4	20	2,5
XT1-XT4	25	4
XT1-XT2-XT4	32	6
XT1-XT2-XT4	40	10
XT1-XT2-XT4	50	10
XT1-XT2-XT3-XT4	63	16
XT1-XT2-XT3-XT4	80	25
XT1-XT2-XT3-XT4	100	35
XT1-XT2-XT3-XT4	125	50
XT1-XT2-XT3-XT4	160	70
XT3-XT4	200	95
XT4	225	95
XT3-XT4	250	120

Table 11.2

Circuit-breaker Emax X1	Vertical terminals [n //] x [mm]x [mm]	Horizontal terminals [n //] x [mm] x [mm]
X1 B/N/L 06	2x40x5	2x40x5
X1 B/N/L 08	2x50x5	2x40x5
X1 B/N 10	2x50x8	2x50x10
X1 L 10	2x50x8	2x50x10
X1 B/N 12	2x50x8	2x50x10
X1 L 12	2x50x8	2x50x10
X1 B/N 16	2x50x10	3x50x8

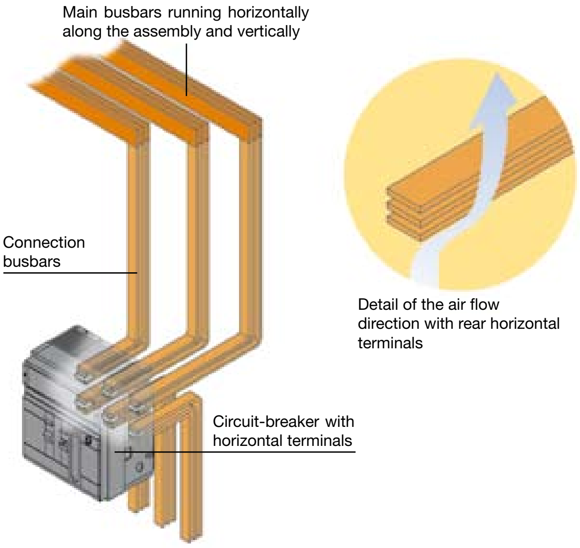
Circuit-breaker Emax	Vertical terminals [n //] x [mm x mm]	Horizontal and front terminals [n //]x[mm x mm]
E1B/N 08	1x(60x10)	1x(60x10)
E1B/N 12	1x(80x10)	2x(60x8)
E2B/N 12	1x(60x10)	1x(60x10)
E2B/N 16	2x(60x10)	2x(60x10)
E2B/N 20	3x(60x10)	3x(60x10)
E2L 12	1x(60x10)	1x(60x10)
E2L 16	2x(60x10)	2x(60x10)
E3S/H 12	1x(60x10)	1x(60x10)
E3S/H 16	1x(100x10)	1x(100x10)
E3S/H 20	2x(100x10)	2x(100x10)
E3N/S/H 25	2x(100x10)	2x(100x10)
E3N/S/H 32	3x(100x10)	3x(100x10)
E3L20	2x(100x10)	2x(100x10)
E3L 25	2x(100x10)	2x(100x10)
E4H/V 32	3x(100x10)	3x(100x10)
E4S/H/V 40	4x(100x10)	6x(60x10)
E6V 32	3x(100x10)	3x(100x10)
E6H/V 40	4x(100x10)	4x(100x10)
E6H/V 50	6x(100x10)	6x(100x10)
E6H/V 63	7x(100x10)	-

To obtain a better dissipation of heat by exploiting thermal convention*, it is advisable to use rear vertical terminals which, in comparison with the horizontal ones, impede less natural air circulation (see Figure 11.9) thus increasing heat dissipation.

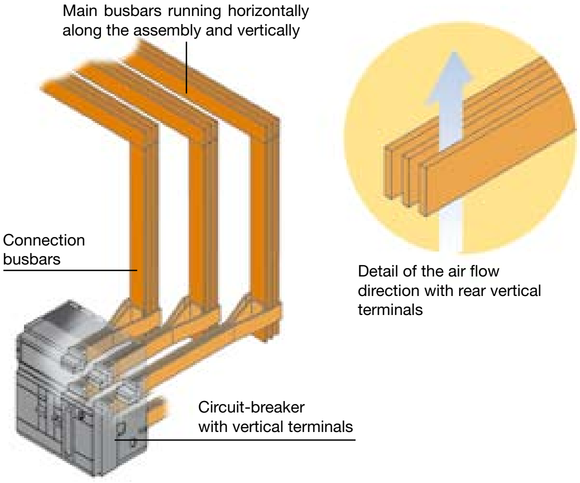
* Phenomenon based on the convective motion of the air which, by heating, tends to move upwards

Figure 11.9

Circuit-breaker with horizontal terminals and vertical main busbars



Circuit-breaker with vertical terminals and vertical main busbars

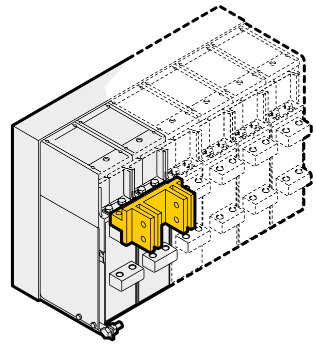


As shown in Figure 11.9 the use of vertical terminals involves a complicated connection with the system of the main busbars vertically arranged and running horizontally along the assembly. This problem does not occur with the same busbar system when the terminals of the circuit-breakers are horizontal, since both busbars and terminals are oriented according to two simple connection plans.

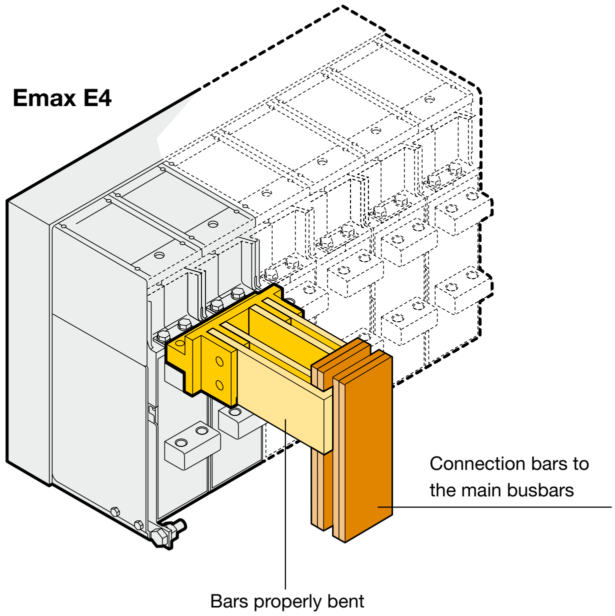
To facilitate the connection among the vertical terminals of Emax E4 circuit-breakers and that of the connection bars to the main busbars it is possible to use bars suitably bent as Figure 11.10 shows.

Figure 11.10

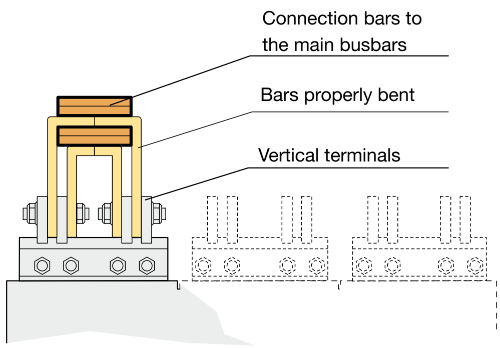
Vertical terminals for Emax E4 (detail relevant to 1 pole)



Emax E4

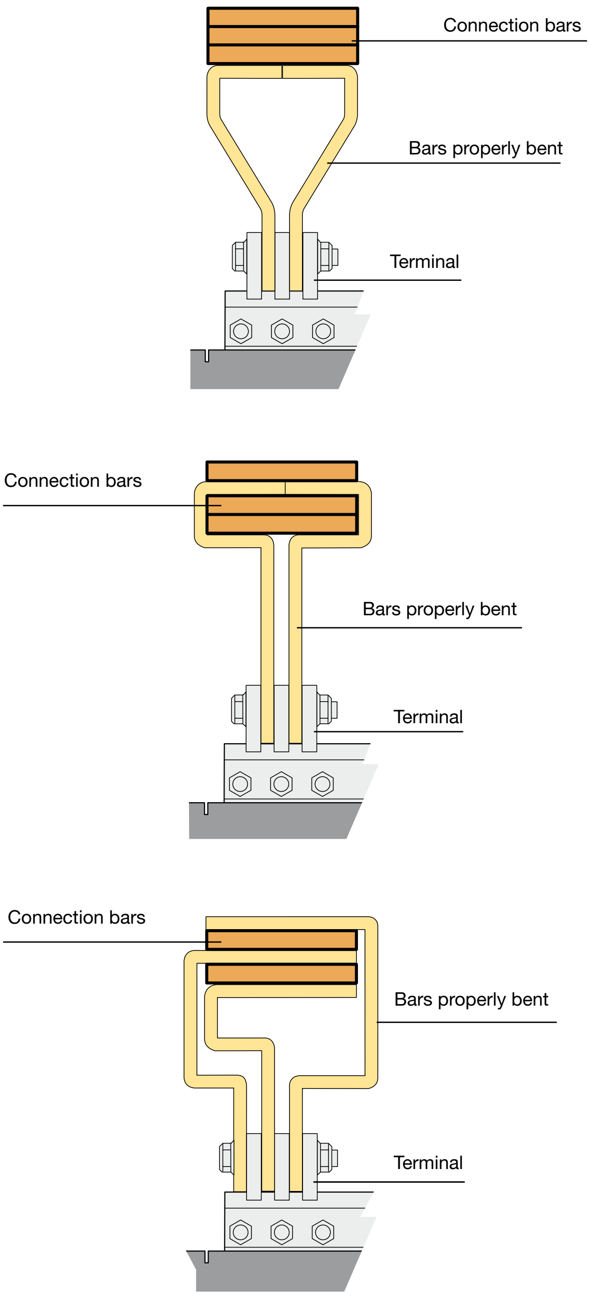


Top view



As further example, Figure 11.11 shows three other pictures representing a possible solution for the connection of the vertical terminals to the connection bars for Emax E3 circuit-breakers.

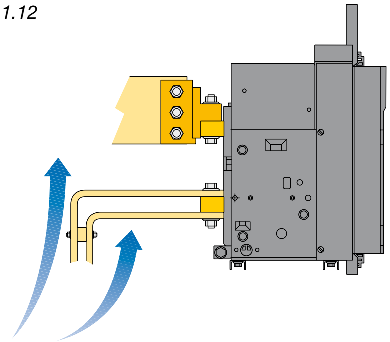
Figure 11.11



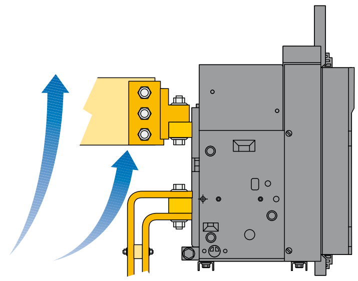
When in the presence of upper vertical terminals and lower terminals of other type, or however when in the presence of different upper and lower terminals, it is necessary to adopt solutions which do not impede air circulation towards the upper terminals.

As Figure 11.12 shows, the lower terminals shall not divert the air flow too much and prevent it from reaching the upper terminals thus causing the loss of the benefits of cooling by convection.

Figure 11.12



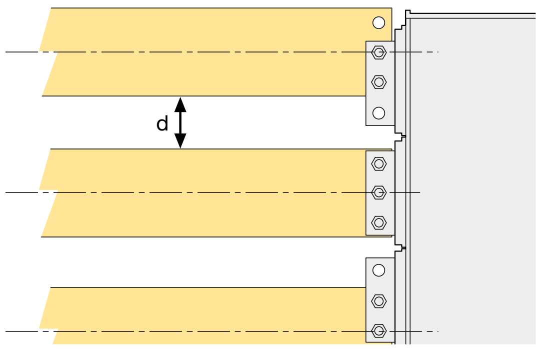
Lower connection with rear horizontal terminals.
Air circulation near to the upper terminals (vertical) Is limited.



Lower connection with front terminals.
Air circulation near to the upper terminals (vertical) is only partially reduced.

Generally speaking, to reduce heating at the circuit-breaker terminals, the positioning of the busbars gets a remarkable importance. Taking into account that, the more the clearance between the busbars, the more heat they dissipate and that the upper middle terminal is usually that with the most problems from a thermal point of view, to reduce heating - for example when considering three-pole circuit-breakers - it is possible to take out of alignment the external connections with respect to the terminals so as to increase the distance "d" (see Figure 11.13).

Figure 11.13



11.5 Indications for the installation distances of the circuit-breakers

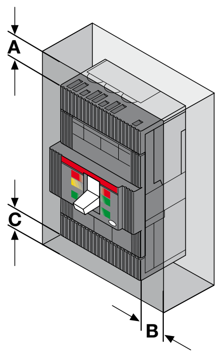
The Std. IEC 61439-1 assigns the circuit-breaker manufacturer the task of defining the indications and the prescriptions for the installation of these devices inside the assembly.

Hereunder are, for ABB SACE circuit-breakers series Tmax T, SACE Tmax XT, Emax X1 and Emax, the indications relevant to the distances to be complied with in the installations up to 690V a.c.; such distances are those specified in the circuit-breaker technical catalogues and in the installation manuals to which reference shall be made for further analysis.

Figure 11.14

Tmax T

Insulation distances for installation in metal cubicle

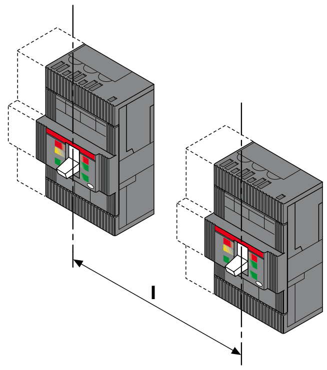


Tmax	A [mm]	B [mm]	C [mm]
T1	25	20	20
T2	25	20	20
T3	50	25	20
T4	30 (*)	25	25 (*)
T5	30 (*)	25	25 (*)
T6	35 (**)	25	20
T7	50 (**)	20	10

(*) For Un ≥ 440V: A = 60 mm and C = 45 mm
(**) For Un ≥ 440V (T6 and T7) or T6 L (Un < 440V): A = 100 mm
Note: For the insulation distances of 1000 V circuit-breakers, ask ABB SACE.

Distance between two circuit-breakers side by side

For assembling side by side or superimposed check that the connection bars or the connection cables do not reduce the air insulation distance.



Minimum centre distance between two circuit-breakers side by side

	CB width [mm]		Centre distance I [mm]	
Tmax	**3 poles**	**4 poles**	**3 poles**	**4 poles**
T1	76	101	77	102
T2	90	120	90	120
T3	105	140	105	140
T4	105	140	105 (*)	140 (*)
T5	140	184	140 (**)	184 (**)
T6	210	280	210	280
T7	210	280	210	280

(*) For Un ≥ 500V: I (3 poles) = 145 mm; I (4 poles) = 180 mm.
(**) For Un ≥ 500V: I (3 poles) = 180 mm; I (4 poles) = 226 mm.

Minimum distance between two superimposed circuit-breakers

For superimposed assembling check that the connection bars or the connection cables do not reduce the air insulation distance.

Tmax	H [mm]
T1	80
T2	90
T3	140
T4	160
T5	160
T6	180
T7	180

Note: The dimensions shown apply for operating voltage Un up to 690 V. The distances to be respected must be added to the maximum overall dimensions of the various different versions of the circuit-breakers, including the terminals. For 1000 V versions, please ask ABB SACE.

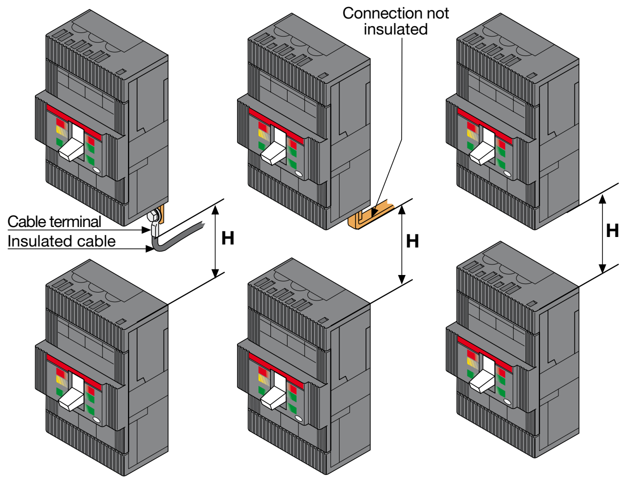


Figure 11.15

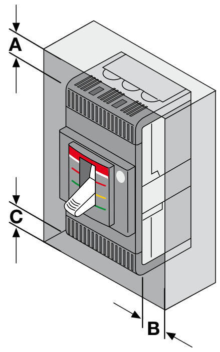
SACE Tmax XT

Insulation distances for installation in metal cubicle

Un ≤ 440 V

SACE Tmax	A [mm]	B [mm]	C [mm]
XT1	25	20	20
XT2 (*)	30	20	25
XT3	50	20	20
XT4 (*)	30	20	25

(*) For Un > 440V : A = 50 mm and C = 45 mm

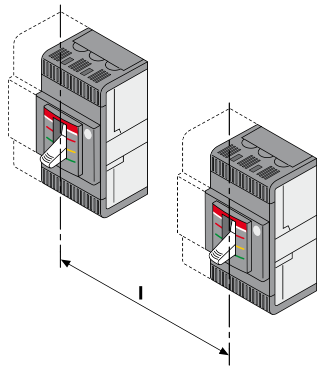


Distance between two circuit-breakers side by side

For side by side mounting check that the busbars or the connection cables do not reduce clearances.

Minimum centre distance between two circuit-breakers side by side

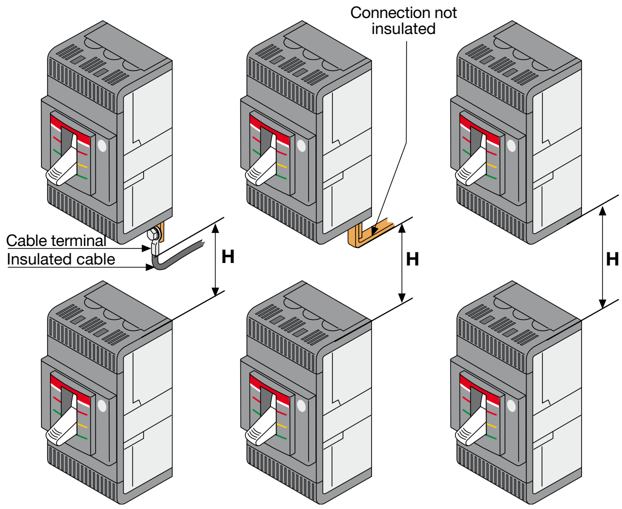
SACE Tmax	CB width [mm]		Centre distance I [mm]	
	3 poles	4 poles	3 poles	4 poles
XT1	76	102	76	102
XT2	90	120	90	120
XT3	105	140	105	140
XT4	105	140	105	140



Minimum distance between two superimposed circuit-breakers

For superimposed mounting check that the busbars or the connection cables do not reduce clearances.

SACE Tmax	H [mm]
XT1	80
XT2	120
XT3	140
XT4	160

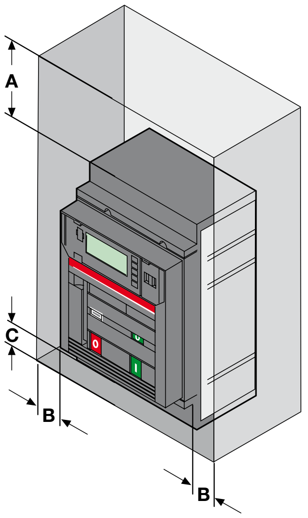


Note: The distances to be respected must be added to the maximum overall dimensions of the various different versions of the circuit-breakers, terminals included.

Figure 11.16

Emax X1

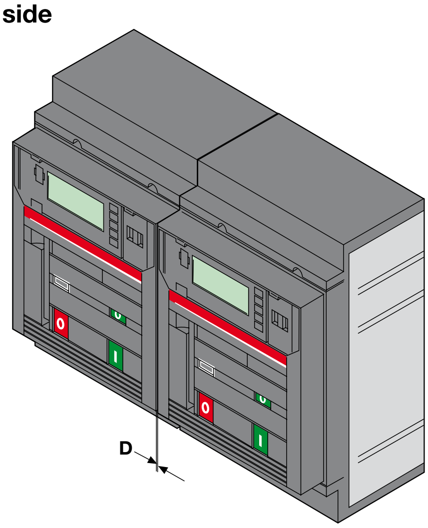
Insulation distances for installation in metal cubicle



	Emax	A [mm]	B [mm]	C [mm]
Un < 440V	X1 fixed version	50	20	10
	X1 withdrawable version	50	-	-
440 V ≤ Un≤ 690V	X1 fixed version	100	20	10
	X1 withdrawable version	100	-	-

Note: For the connections it is advisable to use insulated cables or bars, or to carry out specific type tests on the installation. For the insulation distance of the circuit-breakers up to 1000 V, please ask ABB SACE.

Distances between two circuit-breakers mounted side by side



Emax	CB width [mm] 3 poles	CB width [mm] 4 poles	Distance D [mm] 3 poles	Distance D [mm] 4 poles
X1	210	280	0	0

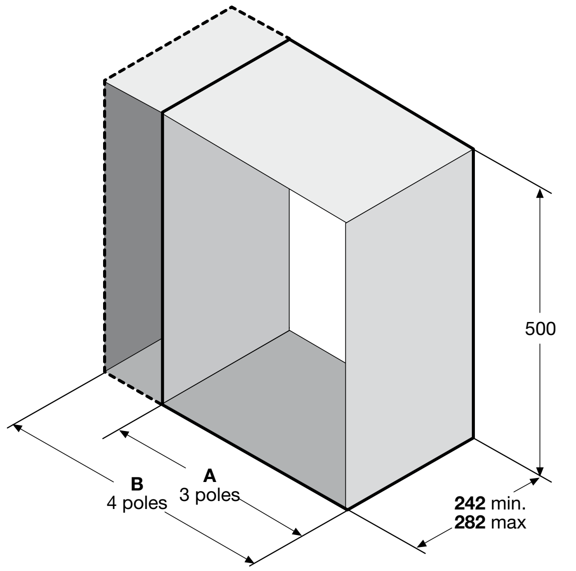
Figure 11.17

Emax E1to E6

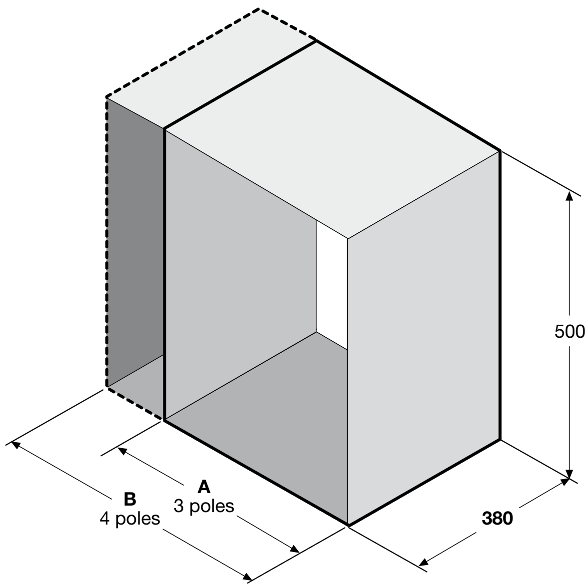
Dimensions of the compartment

Emax	A [mm]	B [mm]
E1	400	490
E2	400	490
E3	500	630
E4	700	790
E4f	-	880
E6	1000	1130
E6f	-	1260

Emax - fixed version



Emax – withdrawable version



11.6 Other logistical and practical indications

When assembling assembly, attention shall be paid to gravity too.

Experience and common sense show that is advisable:

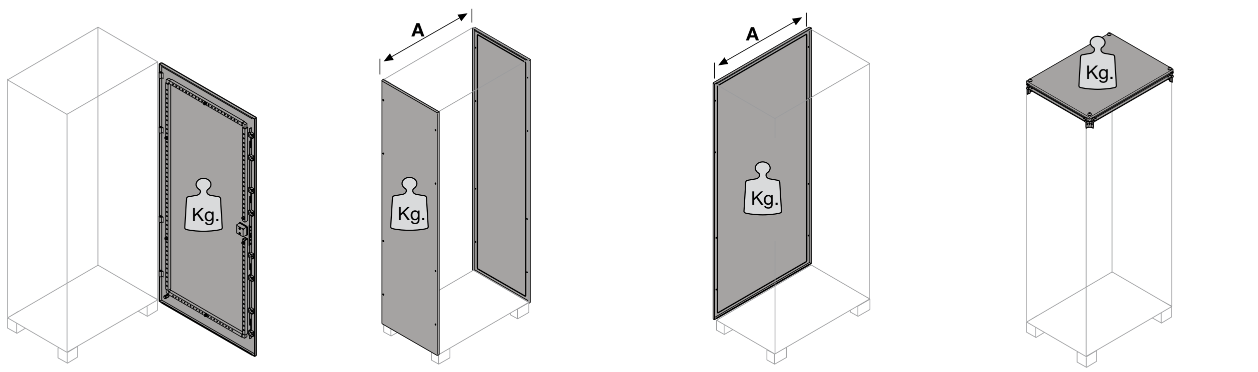
- to distribute homogeneously and comfortably the different components inside the assembly in the full respect of ergonomics, of their use and of their possible repairing or replacement;
- to keep low the global center of gravity by positioning the heaviest equipment at the bottom, so that the maximum static stability can be achieved;
- to avoid overloading of the moving doors, so that frictions are not increased and the functionality and endurance of the hings are not compromised;
- not to exceed the maximum fixing capacity of the rear and side panels reported in the assembling information sheets.

Here are some figures showing the static loading capacity of the different panels of ABB assembly.

However it is advisable to position transformers, bigger-size and consequently heavier circuit-breakers and ventilation motors, if any, at the bottom, so that a better stability of the assembly is ensured above all during transport and installation.

After internal mounting has been completed, the sides, covers and closing doors of the metalwork structure are fastened. Then, the whole is lifted to the vertical position and after a last visual inspection the assembly becomes available for final testing (routine tests).

Figure 11.18

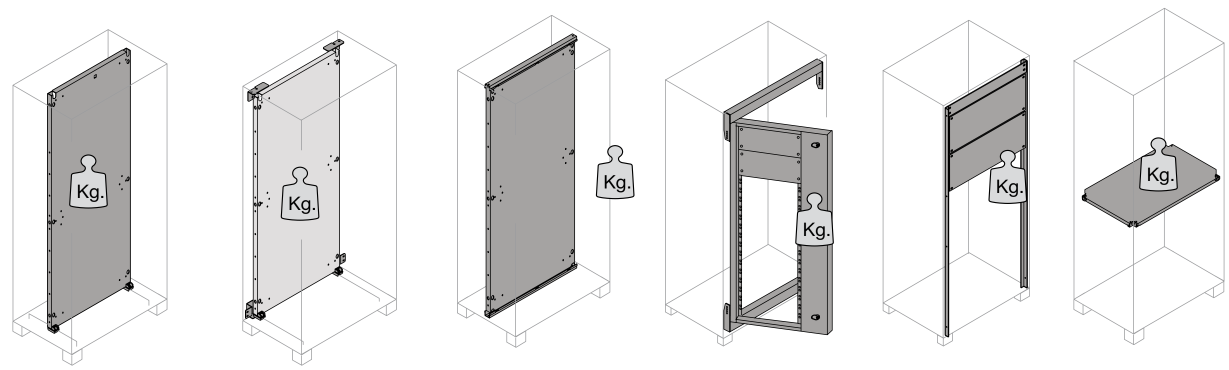


Kg.
50

A (mm)	Kg.
>800	90
≤≤800	110

A (mm)	Kg.
>800	90
≤800	110

Kg.
40

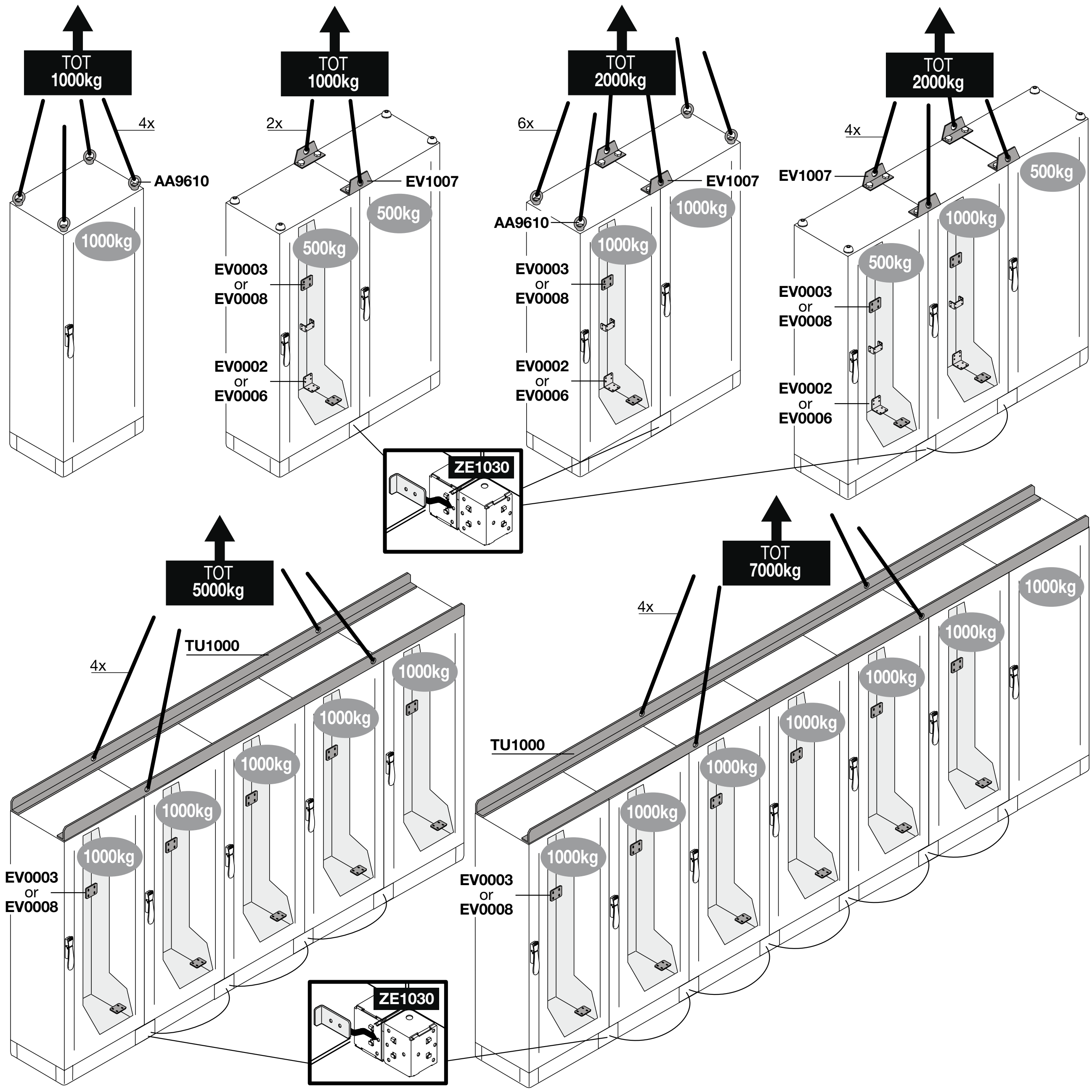


Kg.	Kg.	Kg.	Kg.	Kg.	Kg.
500	600	500	90	90	120

11.7 Handling, transport and final installation

In case of large power or automation systems, another critical situation is represented by the coupling of more compartments to get a bank of assemblies.
Here is the mechanical connection which must be particularly painstaking, because of the remarkable stresses which the metalwork structures transmit each other, above all in the delicate phase of loading and transport.
Once again the importance of the assembly sheets emerges; they must be clear, detailed and complete, with all the information regarding tightening, relevant operation sequences, as well as the indication of the errors which are likely due to carelessness or inaccuracy.
The following Figure highlights some points which require particular concentration from panel builders; attention shall be paid to the proper fixing which block to one another and in safety the metalwork structures. Particular attention shall be paid to the upper box shown in the figure and available in some versions.

Figure 11.19



Generally, this junction box is not suitable to support the whole weight of the under hanging switchboard. As a consequence it shall be mounted only after the switchboard has been lifted (as shown in Figure 11.20) and positioned where required.

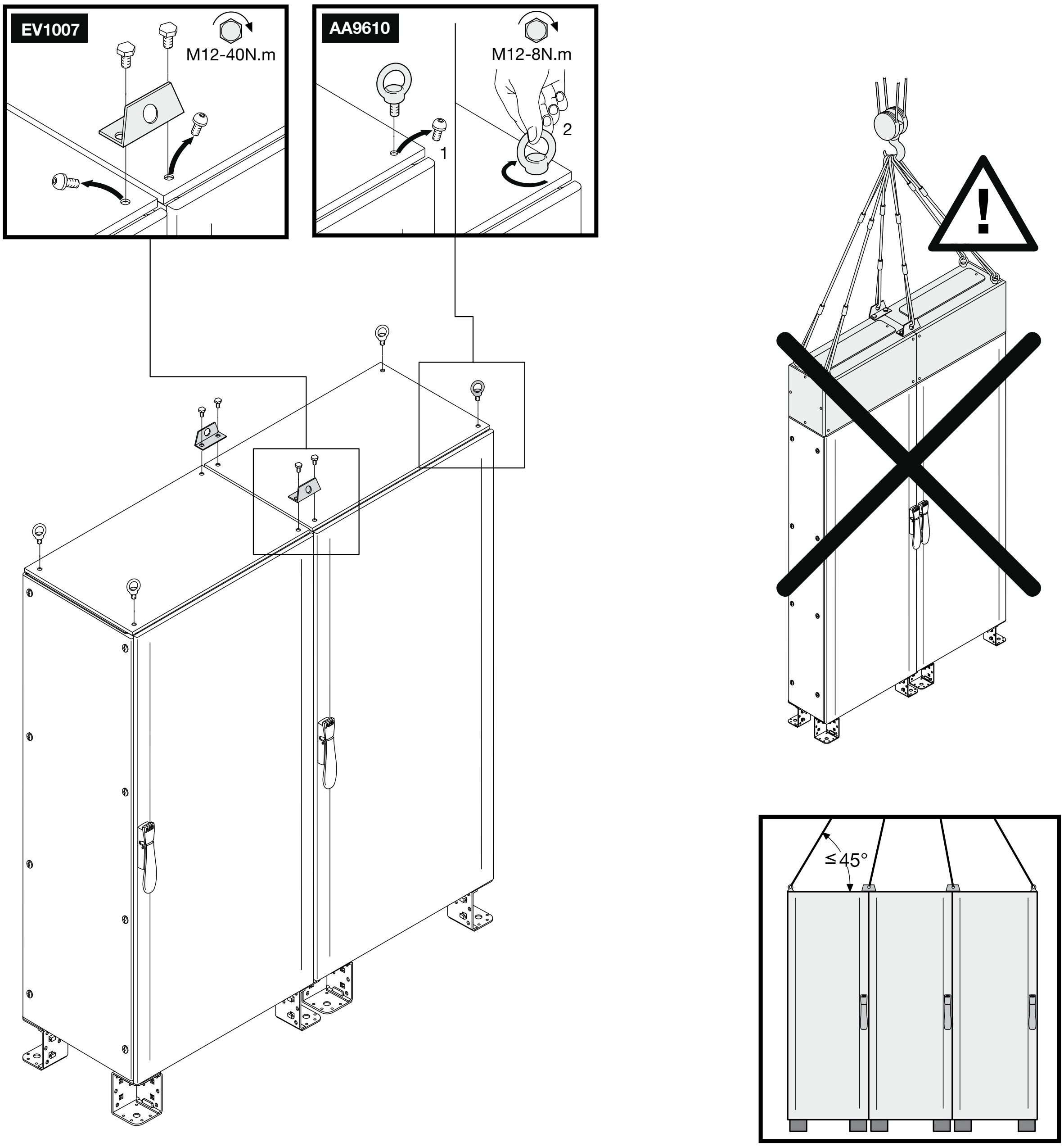
When connecting more compartments the necessity of complying with the maximum static carrying capacity emerges both to guarantee an adequate resistance to vibrations as well as to allow proper lifting and transport to the final place of installation.

Usually the maximum values allowed are sufficient to meet also the heaviest cramming, without taking particular measures.

Figure 11.19 shows some arrangements involving also large overall dimensions and big weights. It should be noticed that every cubicle may have different loading capacity as regards weight and, for each configuration, the relevant methods for fixing, rope pulling and lifting are prescribed.

The new Std. IEC 61439-1 prescribes a specific test to be carried out at the laboratory to verify the lifting capacity.

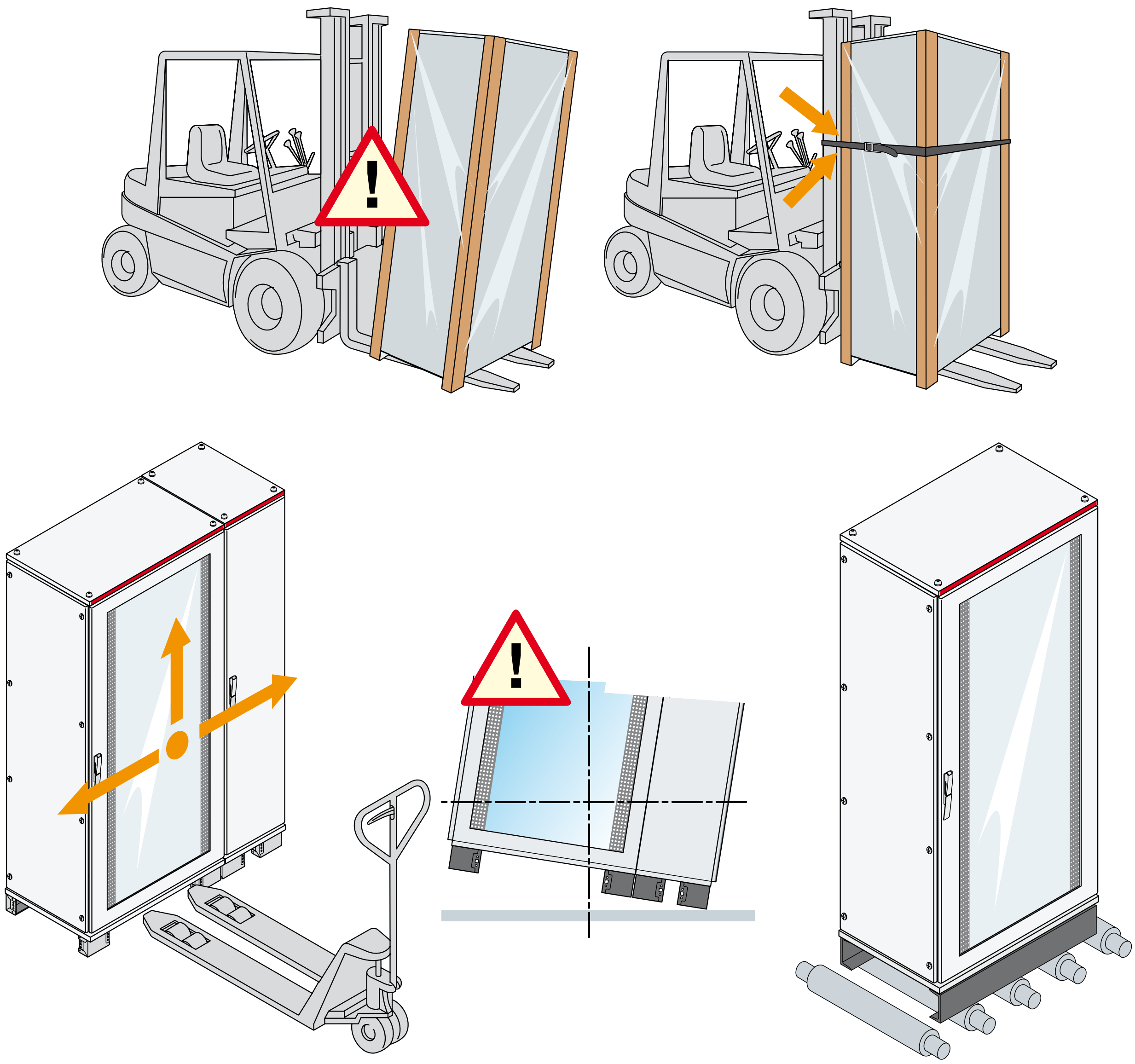
Figure 11.20



The switchboard, once wired and assembled, must be transported safely and easily, both when leaving the workshop of the panel builder as well as when entering the installation premises.
Due to the big overall dimensions and weights, it is advisable to follow suitable procedures and to use mechanical means "ad hoc", as well as to pay particular attention while moving the assembly, so that the losses of balance, vibrations, shocks and risks of overturning of the switchboard are controlled and reduced to a minimum.

The ArTu system has been specifically designed to minimize such inconveniences.
The properly dimensioned base strips of the metalwork structures afford an user-friendly insertion of the forks of the forklift trucks for lifting, after which the vertical anchoring of the switchboard to the side of the fork is advisable (see Figure 11.21). The absence of protrusions and sharp edges prevents any further risk of lesions or contusions for the operators.

Figure 11.21



11.8 Interventions on assemblies in service

During standard handling and operation of assemblies, already positioned and in service in the plant or on-board, some intrusive interventions may be necessary on them because of faults, normal ageing of the components, modifications or process extensions and more.
Access to assemblies is possible for:
- *inspection and other similar operations:*
    - *visual inspection;*
    - *inspection of the switching and protection devices;*
    - *setting of relays and trip units;*
    - *conductor connections and markings;*
    - *adjusting and resetting;*
    - *replacement of fuse-links;*
    - *replacement of indicating lamps;*
    - *measuring (of voltage and current, with suitable tools);*
    - maintenance (also upon agreement between manufacturer-panel builder and user-customer);
    - extension works either under or not under voltage (relevant national Standards , EN 50110-1 and relevant amendments).

To this purpose it should be kept in mind that the present IEC Standards make a distinction between standard routine interventions, when just switching and control operations are carried out, and out-and-out electrical interventions, when the personnel operate directly on or close to live parts (either under or not under voltage) with consequent electrocution hazards.

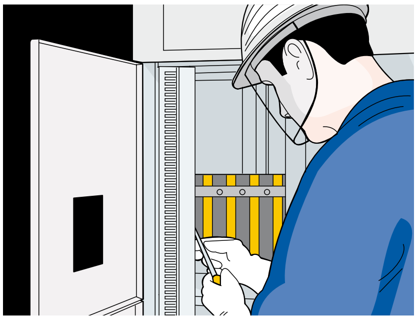
The following illustration shows some examples of both situations.

From the definitions above it results that, as ABB SACE during the whole manufacturing process of circuit-breakers, metalwork structures and other auxiliary parts, also panel builders manufacturing the assembly do not carry out any electrical work. In fact, under such conditions, metal and insulating parts are handled but when they are not supplied yet; thus, since there are no electrocution hazards for definition, it cannot be considered as an electrical work.

Figure 11.22

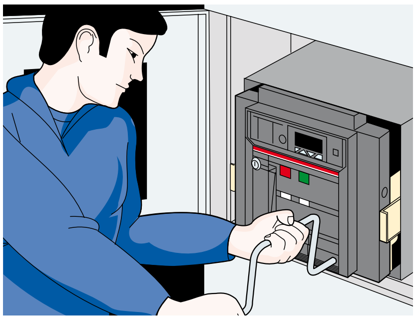
These are electrical works

Repair



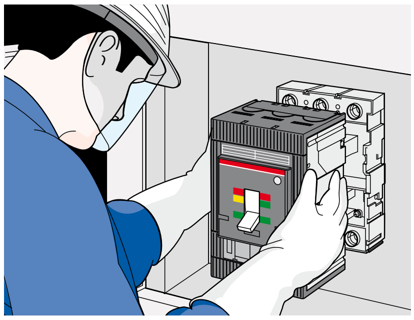
Assembly under voltage

Replacement



Work not under voltage performed complying with the Std. CEI 11-27

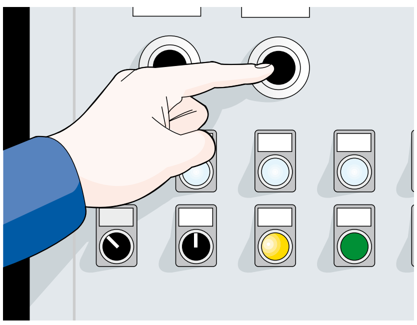
Replacement



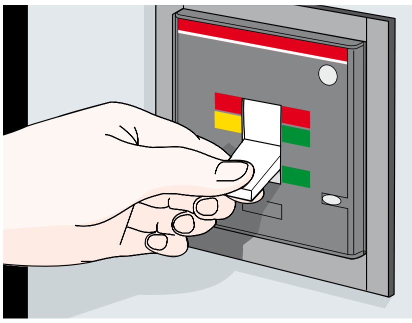
Assembly under voltage

These are not electrical works

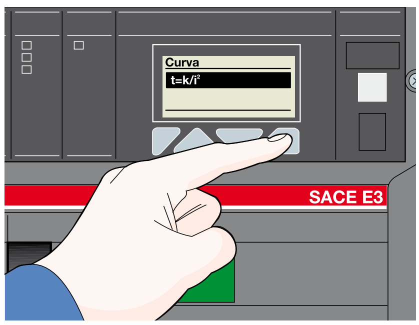
Operations



Circuit-breaker switching



Settings



12 Guide to the certification of assemblies

12.1 Compliance of assemblies to the Standards

ABB offers a system of assemblies subject to a series of tests allowing assemblies in compliance with IEC Standards to be constructed performing routine verifications (assembly testing) only, without any further laboratory tests. To this purpose it is necessary to use ABB SACE metalwork structures (with the relevant accessories), ABB SACE circuit-breakers (miniature, molded-case or air circuit-breakers) and ABB SACE distribution systems and to observe the choice criteria and the mounting instructions of the different components.

Here are summarized the verifications specified by the Standard IEC 61439-1 to be carried out by the original manufacturer and the additional ones to be performed by the assembly manufacturer.
The original manufacturer carries out the design verifications (formerly type tests), that is:
- Strength of materials and parts of assemblies;
- Degree of protection IP;
- Clearances and creepage distances;
- Protection against electric shock and integrity of protection circuits;
- Installation of switching devices and components;
- Internal electrical circuits and connections;
- Terminals for external conductors;
- Dielectric properties (power frequency withstand voltage at 50 Hz and impulse withstand voltage);
- Verification of temperature-rise limits;
- Short-circuit withstand strength;
- Electromagnetic compatibility (EMC);
- Mechanical operation.

As already seen, the original manufacturer derives the assembly by "design rules" or by calculation applying particular algorithms and/or physics principles.
Instead, to the assembly manufacturer, the routine verifications (testing) are left, which includes some visual inspections and the only real instrumental test, that is the dielectric test.
- Dielectric properties (power frequency withstand voltage at 50 Hz and impulse withstand voltage).

12.2 Main verifications to be carried out by the original manufacturer

Verification of temperature-rise
From the poin of view of verification of the temperature-rise limits, it is possible to certify the assembly either
1) by laboratory testing with current, or
2) by applying the proper design rules, or
3) by algorithms for the calculation of the temperature-rise (for further details see Chapter 7).

Verification of dielectric properties
As specified in the Standard, the performance of this type test on the assembly parts which have already been type-tested in compliance with the relevant Standards is not required if the dielectric withstand has not been compromised during assembling operations.

As regards ABB assemblies and enclosures, their dielectric properties are shown in Table 12.1.

These characteristics are to be considered already verified, provided that the mounting instructions have been properly followed.

Table 12.1

		Rated voltage	Insulation voltage	Rated impulse withstand voltage
ArTu L	Wall-mounted D=200 mm	up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 6 kV
	Floor-mounted D=250 mm	up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 8 kV
ArTu M	Wall-mounted D=150/200 mm	up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 6 kV
	Floor-mounted D=250 mm	up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 8 kV
ArTu K		up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 12 kV
Enclosures SR2		up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 6 kV
Enclosures AM2		up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 8 kV
Enclosures IS2		up to 1000V AC/1500V DC	up to 1000V AC/1500V DC	up to 12 kV

Verification of short-circuit withstand strength
The Chapter 8 of this Technical Application Paper deals with short-circuit current withstand strength.
As specified by the Standard, verification of the short-circuit withstand strength is not necessary:
1. when the verification turns out to be unnecessary making reference to the flow charts of clause 8.1;
2. for the auxiliary circuits of the assembly provided to be connected to transformers with rated power not exceeding 10 kVA, with secondary rated voltage not lower than 110 V, or not exceeding 1.6 kVA with secondary rated voltage lower than 110 V and when the short-circuit voltage in both cases is not lower than 4%;

In particular, for the distribution system (see general catalogue of distribution switchgear) the short-circuit withstand strength is verified by the positive result in the flow charts of clause 8.3 and by the correct compliance with the mounting instructions.

For the different assembly typologies the following characteristics shall be verified:

Table 12.2

		Rated short-time withstand current Icw		
		phase-to-phase	phase-to-neutral	Rated peak withstand current I_{pk}
ArTu L	Wall-mounted D=200 mm	25 kA (1s)	9 kA (1s)	52.5 kA
	Floor-mounted D=250 mm	25 kA (1s)	21 kA (1s)	74 kA
ArTu M	Wall-mounted D=150/200 mm	25 kA (1s)	9 kA (1s)	52.5 kA
	Floor-mounted D=250 mm	35 kA (1s)	21 kA (1s)	74 kA
ArTu K		105 kA (1s) - 50 kA (3s)	60 kA (1s)	254 kA
Enclosures IS2		65 kA (1s)	39 kA (1s)	143 kA

Verification of the short-circuit withstand strength of the protective circuit

Table 12.3

Verification of the effective connection of the exposed conductive parts of the assembly and of the protective circuit	By complying with the assembling instructions of the metal components, the effective earth continuity between the exposed conductive parts is verified, with negligible resistance values
Short-circuit withstand strength of the protective circuit: phase-earthing busbar	By complying with the assembling instructions and the indications on page 44 and 45 of this technical paper the short-circuit withstand strength of the protective circuit is verified

Maximum short-circuit withstand strength phase-earthing busbar for structure		
ArTu L	Wall-mounted D=200 mm	9 kA (1s)
	Floor-mounted D=250 mm	21 kA (1s)
ArTu M	Wall-mounted D=150/200 mm	9 kA (1s)
	Floor-mounted D=250 mm	21 kA (1s)
ArTu K		60 kA (1s)
Enclosures IS2		39 kA (1s)

Verification of the creepage distances and clearances
By complying with the mounting and erection instructions for ABB SACE metalwork structures and circuit-breakers, the creepage distances and clearances are guaranteed.

Verification of mechanical operation
By complying with the mounting instructions for ABB SACE metalwork structures and circuit-breakers, the mechanical operation is ensured.

Verification of the degree of protection
By complying with the mounting instructions for ABB SACE metalwork structures and circuit-breakers the following degrees of protection are verified:

Table 12.4

		Without door	With door and ventilated side panels	Without door with kit IP41	With door
ArTu L	Wall-mounted D=200 mm	IP 31	-	-	IP 43
	Floor-mounted D=250 mm	IP 31	-	-	IP 43
ArTu M	Wall-mounted D=150/200 mm	-	-	-	IP 65
	Floor-mounted D=250 mm	IP31	-	-	IP 65
ArTu K		IP 31	IP 41	IP 41	IP 65
Enclosures SR2		-	-	-	IP 65
Enclosures AM2		-	-	-	IP 65
Enclosures IS2		-	-	-	IP 65

12.3 Routine verifications (testing) to be carried out by the assembly manufacturer

The routine tests, sometimes called testing of the assembly, prescribed and defined by the Std. IEC 61439-1, shall be carried out on the assembly by the manufacturer, after assembling and wiring.
These verifications are intended to detect faults in materials and workmanship faults of the components and/or in the assembly construction.
A good result of the routine tests allows the issue of a positive test report (testing and inspection report).

Procedures and performance modalities of routine verifications
The assembly manufacturer can fine a procedure regarding:
- test conditions (skilled personnel, area of the workshop destined for testing, etc.) and safety measures;
- reference documents (technical dossiers, mounting instructions, technical standards, etc.);
- identification of the material and visual inspections, mechanical and electrical checks;
- dielectric tests;
- check on the means of protection and verification of the service continuity of the protective circuit;
- measurement of the insulation resistance as an alternative to the dielectric test;
- the final documentation (test report).

In any case it is important to point out that, although the routine tests are usually carried out in the workshop of the assembly manufacturer or of the panel builder, the installer is not exempt from the obligation of making sure that after transport and installation the switchgear assembly has not undergone any damage or modification so that it no longer meets the requirements already verified by the routine tests.

Test conditions and safety measures
It is recommended that the assemblies ready to undergo the individual tests inside the workshop are positioned in separate areas where only qualified personnel have free access.
Should this not be possible, for example for space reasons, the area for the tests must be marked off by barriers, notices or visible barriers.
Of course the verifications can only start after assembling.

During the verification of the dielectric properties, for example during the applied voltage test, the insulating gloves provided must be worn and the suitable pistol type push rods with retractile tips must be used. The operator's body and arms should be suitably protected, except when the voltage is applied at an adequately safe distance.

Here are some rules for carrying out the individual tests in safety.
Before testing:
- position the assembly a suitable area;
- install the protection barriers properly;
- make the assembly power supply connections properly (earth and power supply);
- make the joined connections according to the same principles (interconnection between exposed conductive parts and connections to earth);
- make sure that the safety devices used function perfectly (e.g. the emergency push button, the flashing danger-signaling devices, etc.);
- make sure that inside the area reserved for testing there are no unauthorized persons.

During testing:
- in the event of a suspension of the tests, even if temporary, it is necessary that the equipment being tested is disconnected;
- for verifications or electrical measurements to be carried out under voltage, it is necessary that the person in charge is aware of dangers, that the measuring instruments used meet the safety requirements and that suitable protective devices and means are used (e.g. insulating gloves, etc.);
- cables or electric equipment shall not be left outside the marked off testing area.

Reference documents

The elements specific to the switchgear assembly to be tested, to which the tester can duly refer, are the diagrams (single-line, functional, mimic diagrams, etc.), the drawings (switchboard front, overall dimensions, etc.) and the particular specifications received with the assembly.

In addition to the latest edition of the technical Standards which the assembly is declared to comply with, the inspector, may also refer to the Stds. IEC 60529 (degrees of protection provided by enclosures) and to IEC 60664-1(rules for insulation coordination of equipment).

12.4 Routine verifications in compliance with the Std. IEC 61439

Routine verifications represent the final technical intervention of the assembly manufacturer before the delivery of the switchgear assembly completed and before invoicing and shipment to the customer. The Standard describes the verifications in the following order:

- **Degree of protection IP provided by an assembly enclosure**
  It represents the first routine test prescribed by the Std. IEC 61439-1.
  Actually it is reduced to a visual inspection.

- **Clearances and creepage distances**
  Clearances usually results, also at visual inspection, quite higher than necessary.
  As regards creepage distances, reference shall be made to the values defined by the Standard (shown in Table 9.6, clause 9.2 of this Technical Application Paper); for further details reference shall be made to clause 12.6 of the Technical Application Paper, “Routine verification of impulse withstand voltage”.

- **Protection against electric shock and integrity of the protection circuits**
  It is based on a visual inspection and on some verifications of the correct mechanical tightness on a random basis. The proper realization of the protective circuit is verified:
  - visually (e.g. checking of the presence of devices which guarantee contact for earthing conductor continuity etc.);
  - mechanically (checking of connection tightness on a random basis);
  - electrically (verification of the circuit continuity).

  The tools used are a tester and a torque wrench.

- **Incorporation of built-in components**
  The real correspondence of the installed equipment with the assembly manufacturing instructions is checked.

- **Internal electrical circuits and connections**
  Verification on random basis of correct tightening of terminals is required.

- **Terminals for external conductors**
  Correspondence of cables and terminals is checked according to the wiring diagram.

- **Mechanical operation**
  On a random basis levers, pushbuttons and any possible mechanical actuating element are operated.

- **Dielectric properties**
  See clause 12.6.

- **Wiring, operational performance and function**
  The nameplate is checked and, if necessary, electrical operation and any possible safety interlocks shall be verified by test.

12.5 Further checks during testing

Further checks to be carried out during testing may be:

Visual inspections

They are carried out visually taking into account:

a) compliance of the assembly with diagrams, designations, drawings and type of enclosures, number and characteristics of equipment, cross-sectional area of conductors and presence of identification marks on cables and devices (initialing, inscriptions on plates, etc.);

b) presence of components which allow the degree of protection (roofs, seals) and the absence of faults on the enclosure (cuts, perforations which might jeopardize the degree of protection) to be guaranteed;

c) compliance with the specific prescriptions, if required in the assembling list, such as:
   - coating or treatment of busbars (resin coating, silver plating, etc.);
   - type of cable (fireproof, ecological, etc.);
   - completion spare parts;
   - painting check (color, thickness, etc.).

Mechanical checks

They shall be carried out complying with the relevant documents, making reference to the following specifications:

- correct assembling of the equipment (connections and, on a random basis, proper tightening of the connections);
- positioning and tightening of nuts and bolts;
- mechanical locks and controls (rack-in locking devices, mechanical interlocks, key interlocks and manual operating mechanisms for the removal of circuit-breakers and switch-disconnectors by using the operating levers and accessories provided with the assembly);
- closing and possible blocks of the doors and adhesion of the dust-proof seals to the assembly structure.

Electrical checks

Functional tests consist in checking the correct functioning of all the circuits (electrical and electromechanical) by simulating, as far as possible, the different service conditions of the assembly.

For example, tests on current and voltage circuits can be carried out by supplying the secondary circuits of the CTs and VTs, without disconnecting the CTs from the circuit.

Electrical checks may include the verification of the proper operation of circuits and equipment, in particular:

- control, signaling, alarm, trip and reclosing circuits;
- lighting and heating circuits, if present;
- protection and measuring circuits (overcurrent, overvoltage, earth, residual current trip units, contactors, ammeters, voltmeters, etc.);
- terminals and contacts available in the terminal box;
- insulation control devices (also creepage distances and clearances must be verified at level of connections and adaptations carried out at workshop).

To carry out these checks, in addition to the normal mechanical tools used for assembling, also some electrical tools are necessary. A periodical calibration is necessary to obtain reliable results.

The tools generally used are:

- a tester or multimeter;
- a test bench (AC and DC) to supply the assembly during the test of the operation under voltage;
- a torque wrench (to check that the correct tightening torques have been applied to the connections) and other tools.

12.6 Further details on routine verifications of dielectric properties

These tests are intended to verify the insulation, the excellence of the insulating materials and correct connection of the equipment being tested.
During testing, for switchgear assemblies exceeding 250 A, the test voltage at 50 Hz frequency is applied for 1 second, at the different polarities and with the r.m.s. values defined by the Standard (see Tables 9.1 and 9.2 at clause 9.1 of this Technical Application Paper);
for 690 V ≤ Ui ≤ 800 V the test voltage value is 2000 V.
These tests need not be made on the auxiliary circuits protected by devices with a rating not exceeding 16 A or when the circuits have previously passed an electrical function test.

Dielectric test
Once disconnected the assembly on both the supply as well as on the load side, the voltage test is applied with all the protection and switching apparatus closed, or the test voltage shall be applied successively to the different circuits of the assembly.
For this test, a voltage generator at industrial frequency (dielectrometer) may be used.
The test is satisfactory if during voltage application neither punctures or flashovers occur.
All current-consuming devices (windings, power supply, measuring instruments, measurement modules, electronic residual current circuit-breakers, etc.) in which the application of test voltages would cause damages shall be disconnected.

In particular, for ABB devices the following information shall be taken into account:

Table 12.5

Residual current releases

Circuit-breaker	Residual current release	Operation to be carried out
Tmax T1-T2-T3	RC221	Turn the special selector on the release front to Test-position. Disconnect YO2 trip coil
Tmax T1-T2-T3 T4-T5 (4-pole only)	RC222	Turn the special selector on the release front to Test-position. Disconnect YO2 trip coil
Tmax T3 e T4 (4-pole only)	RC223	Turn the special selector on the release front to Test-position. Disconnect YO2 trip coil
Tmax T1..T7	RCQ-RCQ020/A (rated current up to 800A)	Manual disconnection
Emax X1 (rated current up to 800 A)	RCQ020/A	Manual disconnection
Emax E1..E3 (rated current up to 2000A)	RCQ	Manual disconnection

Electronic trip units

Circuit-breakers	Trip units	
Tmax T2-T4-T5-T6	PR221-PR222DS/P	No operation
	PR222DS/PD-PR223DS e EF	Disconnect, if any, the rear connectors X3 and X4
Tmax T7 Fixed version	PR231-PR232	No operation
	PR331	Disconnect, if any, wiring relevant to: T5, T6, K1, K2, W3, W4, 98S, 95S
	PR332	Disconnect, if any, wiring relevant to: T5, T6, T7, T8, T9, T10, K1, K2, K11, K12, K13, K14, K15, K21, 98S, 95S, W1, W2, W3, W4, C1, C2, C3, C11, C12, C13
Tmax T7 Wthdrawable version	PR231-PR232 PR331-PR332	Take the circuit-breaker to the racked-out position
Emax X1 Fixed version	PR331	Disconnect, if any, wiring relevant to: T5, T6, K1, K2, W3, W4, 98S, 95S
	PR332-PR333	Disconnect, if any, wiring relevant to: T5, T6, T7, T8, T9, T10, K1, K2, K11, K12, K13, K14, K15, K21, 98S, 95S, W1, W2, W3, W4, C1, C2, C3, C11, C12, C13.
Emax X1 Wthdrawable version	PR331-PR332-PR333	Take the circuit-breaker to the racked-out position
Emax E1-E6 Fixed version	PR121	Disconnect, if any, wiring relevant to: T5, T6, K1, K2, W3, W4
	PR122-PR123	Disconnect, if any, wiring relevant to: T5, T6, T7, T8, K1, K2, K3, K4, K5, K6, K7, K8, K9, K10, K11, K12, K13, K14, K15, W1, W2, W3, W4, C1, C2, C3, C11, C12, C13, D1, D2, D13, D14, R1, R2, 37, 38.
Emax E1-E6 Wthdrawable version	PR121-PR122-PR123	Take the circuit-breaker to the racked-out position

Measurement modules

Circuit-breaker and trip unit	Measurement module	Operation to be carried out
Emax equipped with PR122 or PR123 Fixed version	PR120/V	Turn the special selector to the Test-position marked as “Insulating Test”
Emax X1 equipped with PR332 or PR333 Tmax T7 equipped with PR332 Fixed version	PR330/V	Turn the special selector to the Test-position marked as “Insulating Test”

Furthermore, all the accessories of the circuit-breakers connected directly to the mains shall be disconnected (undervoltage releases, shunt opening releases, shunt closing releases, measurement modules, motor operating mechanisms, etc.).
For further details and in-depth studies about the indications and the operations to be carried out as regards ABB SACE devices and accessories, reference shall be made to the relevant technical product manuals.

Routine verification of the insulation resistance
In compliance with the Std. IEC 61439-1, as an alternative to the applied voltage test, for switchgear assemblies up to 250 A only, the measurement of the proper insulation resistance is sufficient.
This test is carried out by applying a voltage of 500 V between the circuits and the exposed conductive part and the result is positive if, for each circuit tested, the insulation resistance is higher than 1000 ohm/V, referred to the rated voltage to earth for each circuit.
Also in this case, the equipment absorbing current must be disconnected.
A resistance measuring device (mega ohmmeter or megger) can be used for this test.

Routine impulse voltage withstand test (clearances)
Under testing this verification is carried out by comparing the real clearances between the live parts and the exposed conductive part with the minimum distance values defined by the Standard:
- if the real clearances exceed more than 1.5 times the minimum distances prescribed by the Standard, in correspondence with the expected U_{imp}, a visual inspection is sufficient;
- if the real clearances have values in a range from 1 to 1.5 times the minimum distances prescribed by the Standard a calibrated measure is sufficient;
- if the minimum clearances defined by the Standard are not complied with, a further impulse withstand test must be carried out.

12.7 Final documentation and end of tests

Up to now in Italy the specific role of the panel builder has not been defined from the juridical point of view.
As for ABB SACE, he is a generic “builder of handmade products”, who shall manufacture according to the state of the art, apply the nameplate, apply the CE mark (for Europe only) and finally invoice and sell to a customer.
Compliance with the technical Standards (IEC 61439) is not mandatory, but it is a declaration of conformity, that is a condition sufficient but not necessary according to the state of the art.
This Technical Application Paper is based on the Standards and consequently it suggests solutions according to the state of the art.

From a strictly juridical point of view, the manufacturer who supplies the assembly shall mandatory:
- construct it according to the state of the art;
- apply the nameplate and the CE mark (for supplies in Europe) so that they can be clearly seen and read;
- enclose the use and maintenance manuals of the components and of the assembly itself (usually provided with them);
- draw up and file (without providing them if not required) the technical dossier (Low Voltage Directive);
  draw up and hand over convenient invoice to the customer.

In addition to the above, the technical Standards IEC 61439 require for the assembly:
- total compliance with the design, assembling and verification procedures described in the relevant dossiers (IEC 61439-1 together with the specific dossier or the dossiers relevant to the assembly considered);
- application of a more complete nameplate with, in addition to the CE marking, the name of the manufacturer and the serial number, also the manufacturing year and the specific reference technical Standard;
- in the enclosure, a specific technical documentation showing the characteristics and the rated performances and all the other recommendations and indications for an optimal use

Even if not expressly required neither by the law nor by the Standards, to guarantee quality and completeness, for verification testing it is useful to use analytical modules, in which all the verifications are registered, also the detail ones. In this way it is possible to remove one after the other the different items from the check list to be sure that all the required operations have been carried out.

An example of report document, summarizing the verifications required and the result obtained for each of them to get an assembly complying with the Std. IEC 61439, is given in Annex A.

13 Example of construction of an ArTu assembly

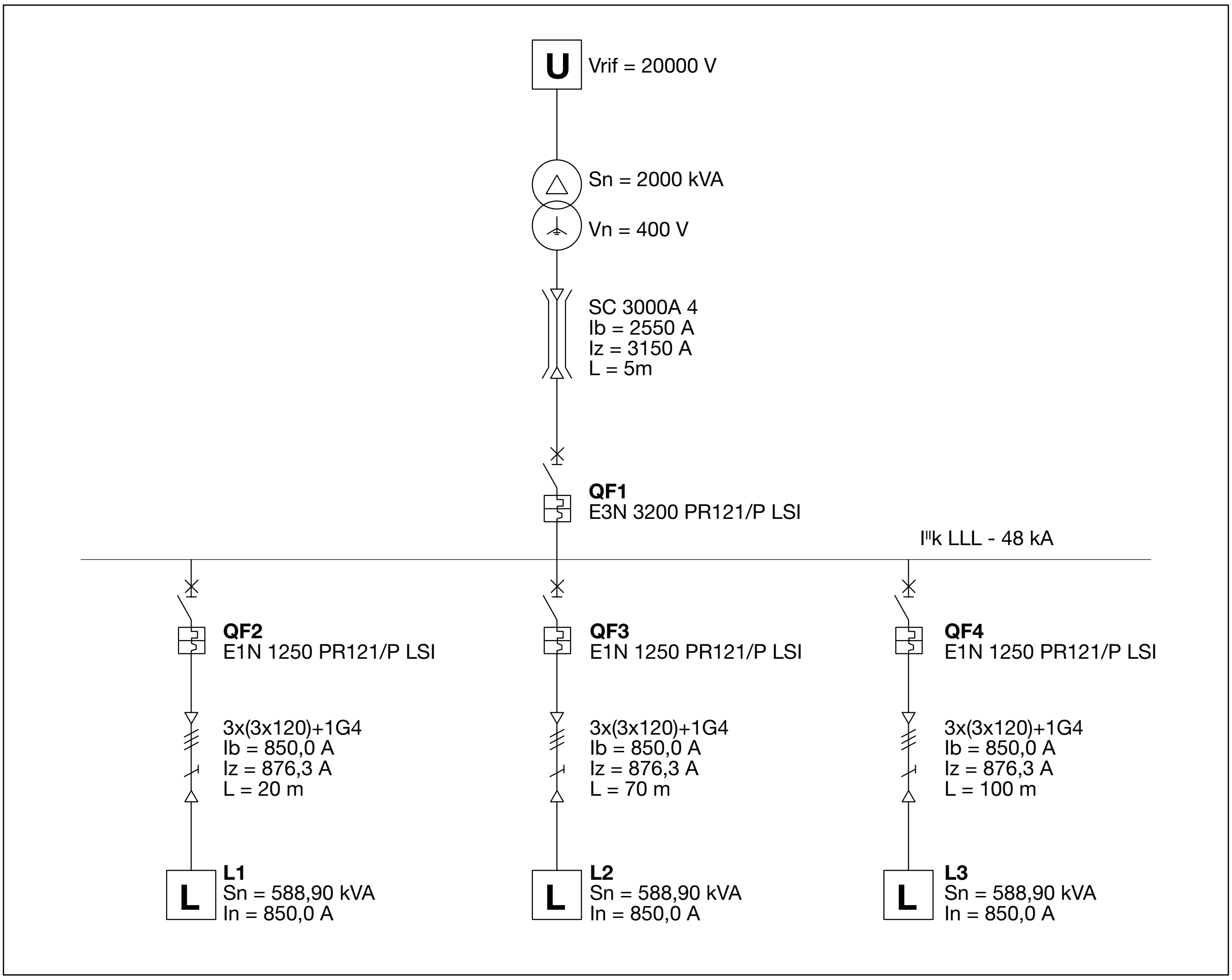
This section has the aim of helping the panel builder and the designer in the construction of ABB SACE ArTu assemblies.

To this purpose, starting from the single-line diagram of a plant, it is possible to arrive - by selecting the suitable components - to the construction of an assembly and to the relevant declaration of conformity with the Std. IEC 61439-2.
Characteristics of the assembly, according to the specification:
- "not separated" assembly;
- IP 65;
- exposed wall-mounted.

13.1 Single-line diagram

Let us suppose that realization of a main distribution assembly is required, to be placed immediately on the load side of a 2000kVA MV/LV transformer. Three 850A outgoing feeders from this assembly supply other distribution assemblies, but they are not dealt with.
Due to reasons of selectivity with other circuit-breakers of assemblies on the load side, air circuit-breakers have been chosen branched from the busbars.
The main distribution busbar short-circuit current is 48 kA.

Figure 13.1



13.2 Selection of the circuit-breakers and of the conductors external to the assembly

Circuit-breakers

As shown in the single-line diagram, the circuit-breakers chosen are:

1 Emax E3N3200 PR121/P-LSI In 3200 (main circuit-breaker of the assembly QF1);

3 Emax E1N1250 PR121/P-LSI In 1250 (circuit-breakers for the three outgoing feeders QF2, QF3, QF4).

Conductors

Incoming, from the transformer:

1 bus duct with Iz = 3150 A; L = 5 m

Outgoing from the assembly, hypothesizing overhead installation on perforated trays, there are:

1 cable L = 20m 3x(3x120) Iz = 876,3 A;

1 cable L = 70m 3x(3x120) Iz = 876,3 A;

1 cable L = 100m 3x(3x120) Iz = 876,3 A.

13.3 Switchboard front, distribution system and metalwork structure

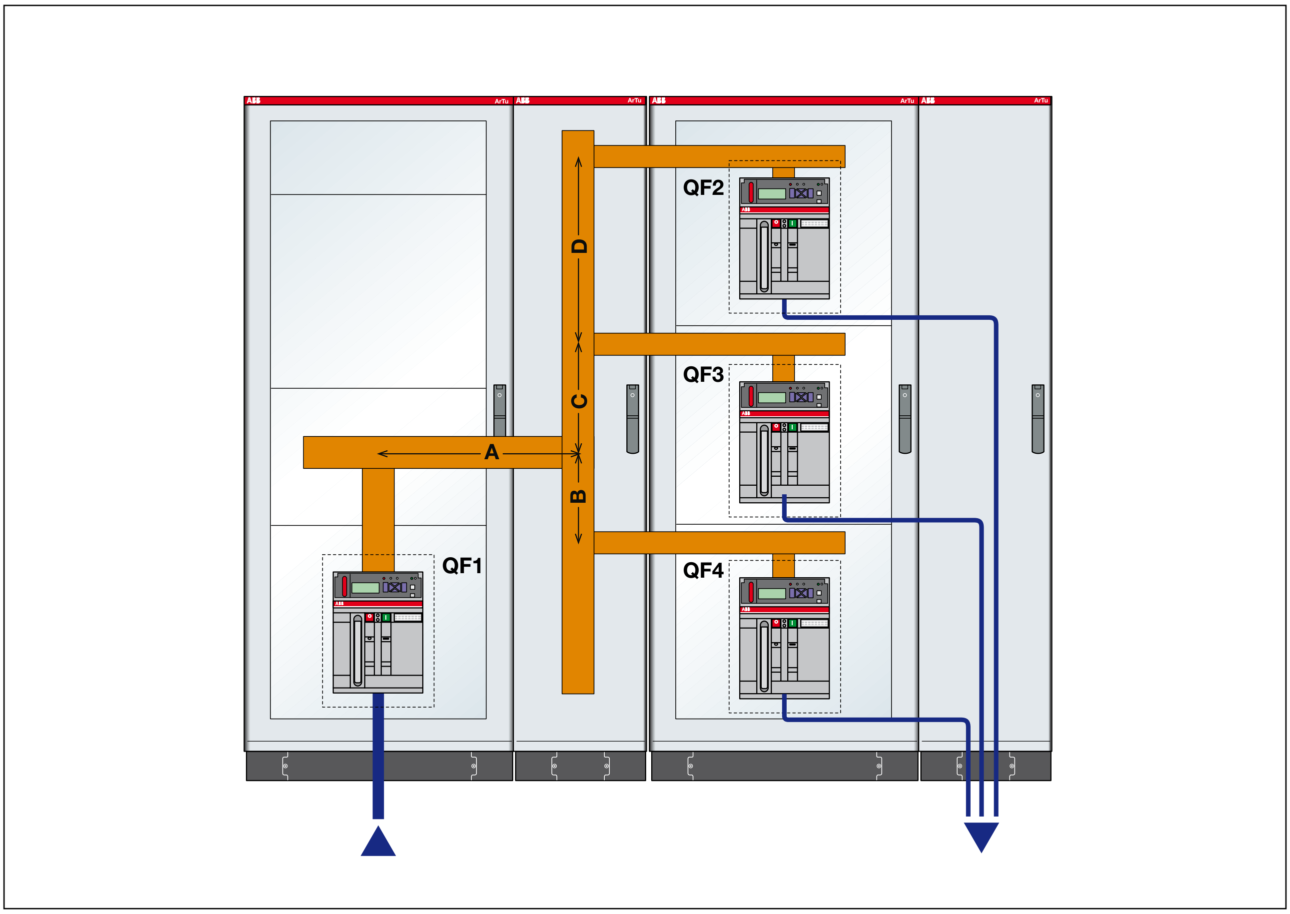
With regard to the positioning of the equipment, it has been decided to locate the main circuit-breaker in one column, and the three outgoing feeders in another one.

Since the power supply comes from below, it has been decided to position the circuit-breaker QF1 at the bottom.

The switchgear assembly is of “not-separated” type.

A possible layout of the busbars and of the circuit-breakers is shown in the following figure:

Figure 13.2



Distribution system

As regards the busbars inside the assembly, by first approximation, they are selected according to the size of the circuit-breaker:

Main distribution busbar system
(circuit-breaker QF1)
(From the "Distribution Switchgear - General catalogue")

BA2000 In=3200 A (IP65) I_{cw} max =100 kA

To get an I_{cw} value suitable to the short-circuit current of the plant:

5 busbar holders **PB3201** at a maximum distance of 425mm (I_{cw} =50 kA) must be positioned.

Being in the presence of non-current limiting air circuit-breakers, the I_{cw} value of the distribution system shall be higher than the prospective Icp at the busbars.

Branch busbars of the circuit-breakers
(circuit-breakers QF2, QF3, QF4)
(From the "Distribution Switchgear - General catalogue")

BA1250 In= 1250 A (IP65) I_{cw} max = 75 kA

To get an Icw value suitable to the short-circuit current of the plant:

5 busbar holders **PB1601** at a maximum distance of 425mm (I_{cw} =50 kA) must be positioned.

Joining pieces between circuit-breakers and busbars
(circuit-breakers QF2, QF3, QF4)
Table 11.2 of clause 11.4 of the Technical Application Paper shows the cross-sectional areas of the busbars for the connection of the circuit-breakers:

E3N32 3200 A cross-sectional area 3x(100x10)
E1N12 1250 A cross-sectional area 1x(80x10)

Moreover, according to the terminal types, the maximum anchoring distance of the first anchor plate, shown at clause11.3 of the Technical Application Paper, shall be respected.

Joints for busbars
As indicated in the "Distribution switchgear. General catalogue" the following joints are necessary:

Joint from 3200 busbar to 3200 busbar, T joint, **AD1073**
Joint from 3200 busbar to 1250 busbar, **AD1078.**

Earthing busbar
As shown on page 44 and 45 of this technical Application Paper, the earthing busbar shall have a minimum cross-sectional area equal to ¼ of the cross-section of the main busbars. Therefore a bar 50x10 has been chosen.

Metalwork structure
As regards the metalwork structure, an ArTu K series assembly with door (IP 65) is used.
In order to house the circuit-breakers, the vertical busbar system and the outgoing cables the following is used:
2 columns for the circuit-breakers;
2 cable containers, one for the busbar system and one for the outgoing cables.

For a correct selection of the structure it is advisable to consult the "Distribution switchgear. General catalogue" where:
- to house Emax E1-E2-E3 circuit-breakers a switchgear assembly with 800mm depth and 600mm width and one installation kit **KE3215** are required.

The cable container has obviously 800mm depth and 300mm width.

In the general catalogue for distribution switchgear the fixing crosspieces for busbars with shaped section can be found:
- for the 3200 A horizontal busbars (**BA2000**) the selected type of installation is number 5, for which the correct choice is two components **TV6221** and one **TV8011**;
- for the 3200 A vertical busbars (**BA2000**) the selected type of installation is number 2, for which the correct choice is **TV8101** component;
- for the 1250 A horizontal busbars (**BA1250**) the selected type of installation is number 5, for which the correct choice is two components **TV6221** and one **TV8011**.

As specified in the general catalogue for distribution switchgear, the metalwork structure shall be completed by the side-by-side kits (**AD 1014**).

13.4 Compliance with the Std. IEC 61439-2

It is necessary to verify the compliance of the assembly with the Std. IEC 61439-2.

Thermal verification of the switchgear assembly

With reference to clause 10.10.3 of the Std. IEC 61439-1, since the configuration of the assembly to be constructed is similar to that of a laboratory-tested assembly having, in particular:

- the same type of construction as that used in the test;
- larger external dimensions than those chosen for the test;
- the same cooling conditions as those used during the test (natural convection and the same ventilation openings);
- the same internal separation form as that used for the test;
- less dissipated power in the same enclosure in comparison with the tested one;
- the same number of outgoing circuits for each enclosure.

the temperature rise limits result to be verified.

The main difference is represented by the positioning of the main circuit-breaker QF1.
In the tested assembly this circuit-breaker is positioned in the top part, whereas in the assembly to be constructed it is in the bottom part. Since there are no other equipment inside this column and having positioned the circuit-breaker in a cooler area than that of the tested assembly, it can be thought that this change **does not modifies the performances of the assembly in a crucial way** (from the thermal point of view).

Verification of dielectric properties

The dielectric properties of the assembly under examination are the same as those declared by the ArTu system provided that the mounting instructions of each single component are properly followed.

To this purpose, it is up to the assembler to provide so that the positioning of every single part (delivered loose and with the relevant fixing supports) is carried out in compliance with the Standards.
It should be kept in mind that increasing the separation form involves a proportional reduction in the internal assembling areas and that the use of extraneous parts (metal parts made to measure, any possible containers or locking metal terminals) as well as the insertion of electrical components with metal enclosures (such as cards, starters, monitors, shields and so on) may reduce or jeopardize the dielectric withstand of the whole.

To verify the product specifications, ABB SACE has carried out the appropriate verification tests both in alternate current at 50 Hz as well as with impulse frequency, with the following performances:

- rated voltage U_n = 400 V;
- insulation voltage U_i = 1000 V;
- rated impulse withstand voltage U_{imp} = 8 kV.

Verification of the short-circuit withstand

Thanks to the choices made for the busbars and the circuit-breakers, and following correctly the mounting instructions, the short-circuit withstand is verified up to the value declared in the catalogue.

In addition to the fixing distances between the busbars and the relevant busbar holders, it is necessary to comply with mechanical tightening values between busbars and holders, checking that they are in the range between the minimum and the maximum values required. Moreover, it is necessary to comply with the maximum wiring distances accepted between the incoming or outgoing terminal of the apparatus and the first busbar holder; such distances have been examined and are reported in the specific Tables of clause 11.3 of this document. In the case under consideration, particular derivations by design rules are not required, since the rated short-time withstand current of the arrangement reaching an I_{cw} value equal to **50kA** results to be sufficient.

Verification of the short-circuit withstand of the protection circuit

By respecting the mounting instructions of the metal components, the real electric continuity between the exposed conductive parts with negligible resistance values is verified. If, as from design, a cross-sectional area for the earthing busbars is chosen by applying the Table of the Standard or by calculating it in full compliance with the maximum I^2t value of the materials, also the short-circuit withstand of the protection circuit is verified.

Verification of clearances and creepage distances

By respecting the assembling and mounting instructions of ABB SACE metalwork structures and circuit-breakers, handed over with each product, the adequate creepage distances and clearances are guaranteed.
In each case, the verification tests after mounting allow the detection and correction, whenever necessary, of any possible fault of position and distance both between the live parts as well as towards the exposed conductive parts.
This control is recommended above all in case of layouts in form 3 and 4.

Verification of mechanical operation

This is one of the routine tests which verify the correctness of the connections which supply the remote control, setting and safety systems of the switchgear assembly, the plant or the machine.

By following the mounting instructions of ABB SACE metalwork structures and circuit-breakers, mechanical operation is verified.

Verification of the degree of protection

By complying with the mounting instructions of metalwork structures, circuit-breakers and relevant frames, sealing and fairleads supplied with ABB SACE equipment, it is possible to obtain a degree of protection IP up to **IP65**.

Verification of continuity

The Std. IEC 61439 prescribes earthing of all the accessible exposed conductive parts of the assembly. During the verification test an in-depth visual inspection shall be carried out on these connections, which may be bolted, welded or other.

Since years the ArTu system fully meets this requirement thanks to a single connection to earth for the metalwork structure (generally along one of the bus riser). In fact, simple mechanical fixing between panels, covers, nameplates, eyebolts etc. by means of bolts and screws, when appropriately laboratory-tested, is considered more than sufficient also to ensure galvanic continuity to earth.

In this way, it is possible to get over the problems of corrosion, contact, transmission of the zero potential energy to all the dangerous parts.

Annex A: Forms for the declaration of conformity and test certificate

DECLARATION OF CONFORMITY
LOW VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES IN COMPLIANCE WITH THE STANDARD IEC 61439-2 (CEI EN 61439-2)

The Company ....

With the premises at ....

Builder of the switchgear assembly ....

....

declares, under its own responsibility, that the above mentioned switchgear assembly has been constructed according to the state of the art and in compliance with all the specifications provided by the Standard IEC 61439-2.

Also declares that ABB SACE components have been used, and respect has been paid to the selection criteria and assembling instructions reported in the relevant catalogues and on the instruction sheets, and that the performances of the material used declared in the above-mentioned catalogues have in no way been jeopardized during assembling or by any modification.
These performances and the verifications carried out therefore allow us to declare conformity of the switchgear assembly under consideration/in question with the following requirements of the Standard:
Constructional requirements:
- Strength of materials and parts of the assembly
- Degree of protection
- Clearances and creepage distances
- Protection against electric shock
- Incorporation of switching devices and components
- Internal electrical circuits and connections
-Terminals for external conductors

Performance requirements
- Dielectric properties
- Temperature-rise limits
- Short-circuit withstand strength
- Electromagnetic compatibility (EMC)
- Mechanical operation

finally, declares, under its own responsibility, that all the routine verifications prescribed by the Standard have been carried out successfully, and precisely:
Design specifications:
- Degree of protection of the enclosure
  - Clearances and creepage distances
  - Protection against electric shock and integrity of protective circuits
  - Incorportation of switching devices components
  - Internal electrical circuits and connections
  - Terminals for external conductors
  - Mechanical operation.

Performance specifications:
- Dielectric properties
  - Wiring, operational performance and function.

Date and Place .... Signature ....

.... (Full name and function of the person in charge of signing on behalf of the manufacturer)

TEST CERTIFICATE
LOW VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES – IN COMPLIANCE WITH THE ROUTINE VERIFICATIONS PRESCRIBED BY THE STANDARD IEC 61439-2 (CEI EN 61439-2)

The Company ....

With the premises at ....

Manufacturer of the assembly ....

....

issues the following

TEST CERTIFICATE
attesting with this document that all the technical verifications prescribed by the Standards applicable to the product and in particular those in the Standard IEC 61439-2 (CEI EN 61439-2) have been carried out, as well as that all the legal and statutory obligations required by the provisions in force have been fulfilled.

Date and Place ....

....

Signature ....

(Full name and function of the person in charge of signing on behalf of the manufacturer)

CE DECLARATION OF CONFORMITY
LOW VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES IN COMPLIANCE WITH THE STANDARD IEC 61439-2
(CEI EN 61439-2)

The Company ....

With the premises at ....

Manufacturer of the assembly ....

....

declares, under its own responsibility, that the switchgear assembly

type dsignation ....

serial no ....

reference Standard IEC 61439-2
year of affixing CE marking ....

conforms to what is foreseen by the following European Community directives (including the latest modifications thereto), as well as to the relative national implementation legislation

Reference no.	**Title**
Directive 2006/95/CE,	Low Voltage Directive
Directive EMC 2004/108/CE	Electromagnetic Compatibility Directive (1)
93/68/CEE	CE Marking Directive

And that the following harmonized Standard has been applied

Std. code	**edition**	**title**
CEI EN 61439-1	I	IEC 61439-1 (CEI EN 61439-1) Low voltage switchgear and controlgear assemblies Part 1: General Rules
CEI EN 61439-2	I	IEC 61439-2 (CEI EN 61439-2) Low voltage switchgear and controlgear assemblies Part 2: Power switchgear and controlgear assemblies

(1) Omit this Directive in the cases where compliance with the same is not required.

Date and Place ....

....

Signature ....

(Full name and function of the person in charge of signing on behalf of the manufacturer)

CHECK-LIST- ROUTINE VERIFICATIONS

Customer...

Plant ....

Order/Assembly: ....

Checking operations	Verified	Result	Operator
1) Construction			
a) degree of protection of the enclosure			
b) clearances and creepage distances			
c) protection against electric shock and integrity of protective circuits			
d) incorporation of switching devices and components			
e) internal electrical circuits and connections			
f) terminals for external conductors			
g) mechanical operation.			
2) Performance			
a) dielectric properties			
b) wiring, operational performances and function.			

Verification carried out by:	During assembling	After assembling

TEST REPORT – ROUTINE VERIFICATION (TESTING)

Customer...

Plant ....

Order no. ....

Type designation and identification number of the switchgear assembly

Assembly drawing ....

Functional diagram ....

Other diagrams..

Rated operational voltage ....

Routine verification tests carried out in compliance with the Std. IEC 61439-2 (CEI EN 61439-2)

	Result
- degree of protection of the enclosure;	
- clearances and creepage distances;	
- protection against electric shock and integrity of protective circuits;	
- incorporation of switching devices and components;	
- internal electrical circuits and connections;	
- terminals for external conductors;	
- mechanical operation.	
- dielectric properties;	
- wiring, operational performances and function.	

Tests carried out at ....

In the presence of Mr ....

Having passed the above tests, the switchgear assembly under consideration results in compliance with the Std. IEC 61439-2 (CEI EN 61439-2).

Technical Application Papers

QT1
Low voltage selectivity with ABB circuit-breakers

QT2
MV/LV trasformer substations: theory and examples of short-circuit calculation

QT3
Distribution systems and protection against indirect contact and earth fault

QT4
ABB circuit-breakers inside LV switchboards

QT5
ABB circuit-breakers for direct current applications

QT6
Arc-proof low voltage switchgear and controlgear assemblies

QT7
Three-phase asynchronous motors Generalities and ABB proposals for the coordination of protective devices

QT8
Power factor correction and harmonic filtering in electrical plants

QT9
Bus communication with ABB circuit-breakers

QT10
Photovoltaic plants

QT11
Guidelines to the construction of a low-voltage assembly complying with the Standards IEC 61439 Part 1 and Part 2

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