

Technical Application Papers No.6

Arc-proof low voltage switchgear and controlgear assemblies

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Arc-proof low voltage switchgear and controlgear assemblies

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1 Generalities about LV switchgear and controlgear assemblies

1.1 Introduction

In the last years safety in LV electrical installations has taken an increasingly dominant role.

Also from a normative point of view, the panorama has become more complete and a large number of users consider safety in the first place among the necessary requirements for their own plant.

LV switchgear assemblies are undoubtedly the components of the electric installation more subject to the direct intervention of personnel (operations, maintenance, etc.) and for this reason users demand from them higher and higher safety requirements.

In the last years a lot of users have underlined the question of safety in electrical assemblies with reference to one of the most severe and destructive electrophysical phenomenon: the electric arc.

Unlike tripping devices, for which arc phenomena represents one of the standard operating conditions, in LV switchgear the electrical arc is an absolutely anomalous and rare event.

But, if the electric arc occurs inside LV switchgear it generates internal overpressures and results in local overheatings which may cause high mechanical and thermal stresses in the equipment.

Besides, the involved materials can generate hot decomposition products, gases or fumes, which, due to the overpressure, are almost always ejected to the outside of the enclosure thus jeopardizing the operator safety.

The European Directive 2006/95/EC states the fundamental safety requirements for low voltage electric materials (from 50 V to 1000 V in alternating current, from 75 V to 1500 V in continuous current) to be put on the market within the European Community.

Among the essential safety requirements defined by this Directive particular importance is given to the need of taking technical measures to prevent “temperature rises, electric arcs or radiations which may result in hazards” from occurring.

This aspect has always been highly considered for apparatus, but it has been wrongly neglected for electrical switchgear and only in the last 10-15 years it has been catching on both at Italian as well as at international level.



1.2 Standards concerning switchboards and relevant applicability

Low voltage switchboards are defined by the Standard IEC 60439-1 “switchgear and controlgear assemblies”, in short: assemblies.

The Standard gives the following definition: “combination of one or more switching devices together with associated control, measuring, signalling, protective, regulating equipment etc., completely assembled under the responsibility of the manufacturer with all the internal electrical and mechanical interconnections, including structural parts”.

The compliance of an assembly with the state of the art and therefore, presumptively, with the relevant technical Standard, cannot be based only on the fact that the components which constitute it comply with the state of the art and therefore, at least presumptively, with the relevant technical standards: this is necessary but not sufficient.

The components shall be assembled according to determined rules which can guarantee short-circuit withstand strength, compliance with the temperature-rise limits, insulation, etc.

In other words, the whole assembly must be designed, built and tested in compliance with the state of the art.

Since the assemblies under consideration are low voltage equipment, their rated voltage shall not exceed 1000 Va.c. or 1500 Vd.c. As regards currents, neither upper nor lower limits are provided in the application field of this Standard.

The Standard IEC 60439-1 states the construction, safety and maintenance requirements for low voltage switchgear and controlgear assemblies, without dealing with the functional aspects which remain a competence of the designer of the plant for which the assembly is intended.

TYPE-TESTED AND PARTIALLY TYPE-TESTED ASSEMBLIES

The Standard IEC 60439-1 differentiates between two categories of assemblies:

- TTA (Type-Tested Assembly)
- PTTA (Partially Type-Tested Assembly)

The term Type-Tested Assembly (TTA) is used to mean an assembly “conforming to an established type or system without deviations likely to significantly influence the performance from the typical assembly verified to be in accordance with this standard”.

To be declared TTA an assembly shall meet at least one of the following conditions:

1. it is manufactured in a single example and subject to all the type tests required by the Standard;
2. it is similar to another assembly which has been subjected to all the type tests, that is it differs from the tested one only for details considered irrelevant for the results of the same tests and, consequently, for its performances, that is for its nominal characteristics;
3. it is part of a pre-established structural system subjected to type tests in some of the many possible arrangements chosen among the most significative ones which can be obtained by combining the system elements. It is the typical case of assemblies sold as loose components.

The term Partially Type-Tested Assembly (PTTA) is used to mean an assembly “containing both type-tested and non-type-tested arrangements, provided that the latter are derived (e.g. by calculation) from type-tested arrangements which have complied with the relevant tests”.

A PTTA is an assembly which has been subjected to one part of the type tests, whereas the other ones have been replaced by some extrapolations (calculations) based on the experimental results obtained on assemblies which have already passed the type tests.

The distinction between TTA and PTTA is of no weight with respect to the declaration of conformity with the Standard IEC 60439-1, since the assembly must simply comply with it apart from its having been subject - totally (TTA) or partially (PTTA) - to type tests.

1.3 Electrical characteristics of assemblies

The Standard IEC 60439-1 identifies the nominal characteristics to be assigned to each assembly, defines the environmental service conditions, establishes the mechanical requirements and gives prescriptions about:

- insulation
- thermal behaviour
- short-circuit withstand strength
- protection against electrical shock
- degree of protection of the enclosure
- installed components, internal separation and connections inside the assembly
- electronic equipment supply circuits.

Information specified under items a) and b) shall be given on the nameplate according to the Standard.

Information from items c) to t), where applicable, shall be given either on the nameplates or in the technical documentation of the manufacturer:

- a) manufacturer's name or trade mark;
- b) type designation or identification number, or any other means of identification making it possible to obtain relevant information from the manufacturer;
- c) IEC 60439-1;
- d) type of current (and frequency, in the case of a.c.);
- e) rated operational voltages;
- f) rated insulation voltages (rated impulse withstand voltage, when declared by the manufacturer);
- g) rated voltages of auxiliary circuits, if applicable;
- h) limits of operation;
- i) rated current of each circuit, if applicable;
- k) short-circuit withstand strength;
- l) degree of protection;
- m) measures for protection of persons;
- n) service conditions for indoor use, outdoor use or special use, if different from the usual service conditions. Pollution degree when declared by the manufacturer;
- o) types of system earthing (neutral conductor) for which the ASSEMBLY is designed;
- p) dimensions given preferably in the order of height, width (or length), depth;
- q) weight;
- r) form of internal separation;
- s) types of electrical connections of functional units;
- t) environment 1 or 2.

1.4 Classification of assemblies

1.4.1 Constructional types

Switchgear and controlgear assemblies often have a cubicle-type structure which generally stands on floor and which can be divided into sections and compartments. The section is a constructional unit limited between two adjacent vertical planes, whereas the term compartment is used to define a completely enclosed part of a section (sub-section), excepted for the openings necessary for interconnection, control and ventilation (Figure 1).

Figure 1 – Enclosed assembly, built by three sections; each section is in its turn subdivided into more compartments



1.4.2 Primary distribution switchgear (Power Centers)

They are usually installed 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.

¹ The manufacturer is deemed to be the organization taking the responsibility for the complete ASSEMBLY.

There are also present measuring instruments and other switching and control equipment (Figure 2).

Figure 2 – View of a primary distribution switchgear



These assemblies have a sturdy structure to withstand the electrodynamic stresses and the weight of big sized apparatus. As a matter of fact peculiar characteristics of the power center are high rated currents and short-circuit currents.

The constructional type is a cubicle structure, with metal enclosure and sections divided into compartments with selective access.

1.4.3 Secondary distribution switchgear

These assemblies are usually provided with one incoming unit and many outgoing units (Figure 3).

The apparatus housed inside the assembly are mainly molded-case circuit-breakers and/or miniature circuit-breakers.

Figure 3 – Secondary distribution switchgear



The rated currents and the short-circuit currents of secondary distribution switchgear are lower than those of primary distribution switchgear.

The constructional models provide for the use of metal or insulating material enclosures and can be both floor- or wall-mounted, according to dimensions and weight. In case the assemblies are used by unskilled persons, the Standard IEC 60439-3 is to be applied.

The distribution boards (ASD) are subject to the additional prescriptions of the Standard IEC 60439-3.

They are intended to be installed in places where unskilled persons have access for their use, otherwise the general rules of the Standard IEC 60439-1 are applied. The Standard IEC 60439-3 takes into consideration only Type-Tested Assemblies (TTA).

This means that each manufactured product shall comply with a prototype or with a pre-established constructional system, that is, it shall not present deviations which can remarkably modify its performances with respect to the type-tested assembly.

1.4.4 Motor Control Centers (MCC)

Motor Control Centers are intended for the control and centralized protection of motors: they include the relevant switching and protection equipment (independent functional units) and the control and signalling auxiliary equipment.

They are characterized by drawer-units (outgoing units), each of them connected to one motor so that it may be possible to operate in total safety on each single outgoing unit without disconnecting the loads (Figure 4).

Figure 4 – View of a Motor Control Center (MCC)

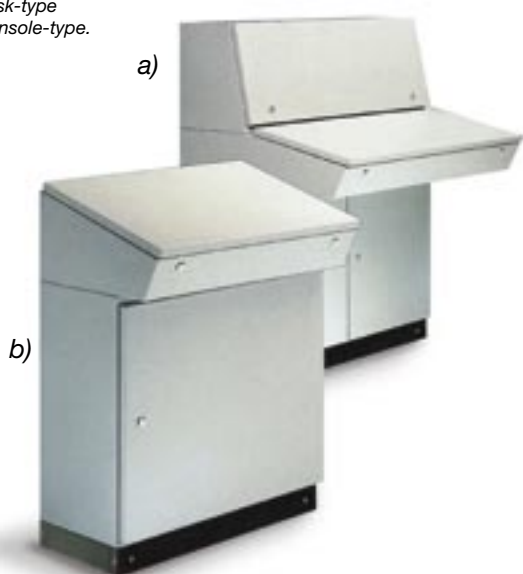


1.4.5 Control, measurement and protection boards

They are usually constituted by banks containing above all apparatus intended for the control, switching and measurement of industrial installations and processes. Usually supported by a metal frame, they have a “desk form” and allow quick access to the commands and easy readability of the instruments (Figure 5).

Figure 5 – Control boards

- a) Desk-type
b) Console-type.



1.4.6 Assemblies for construction sites (ACS)

Assemblies for construction sites have different dimensions, ranging from the simple socket-outlet units to proper distribution boards in metal enclosure or insulating material. These assemblies are usually mobile (Figure 6).

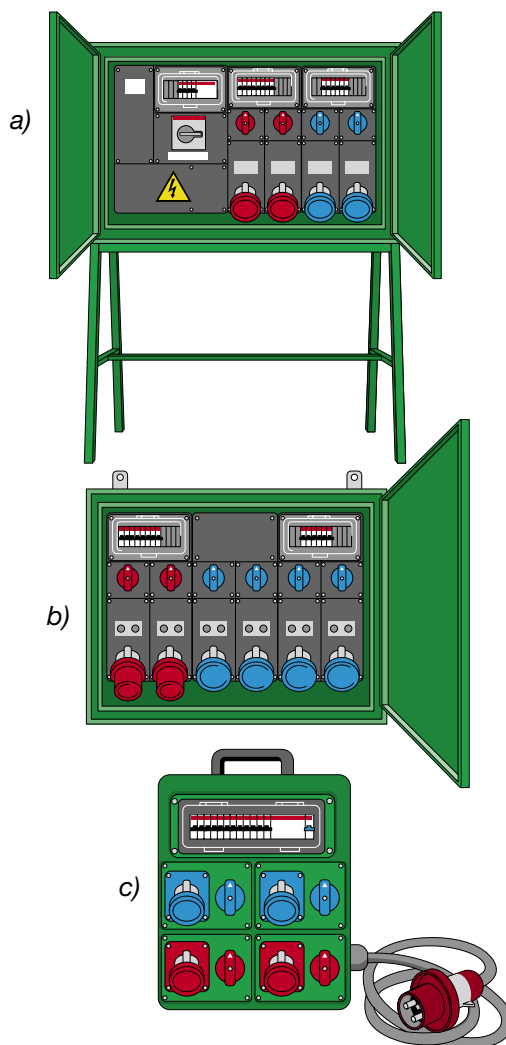
The Standard IEC 60439-4 establishes the particular requirements for this type of assemblies, making specific reference to mechanical strength and resistance to corrosion.

This Standard states that the ACS shall comply with the requirements of the Standard IEC 60439-1 and that the clauses of the Standard IEC 60439-4 either complete, modify or replace the relevant clauses of the general reference Standard.

ACS must be exclusively type-tested low-voltage switchgear and controlgear assemblies (TTA) and consequently each manufactured assembly shall comply with a prototype which has been already subject to all the type tests prescribed by the Standard IEC 60439-4.

Figure 6 – Assemblies for construction sites (ACS)

- a) ACS supported by feet or legs
b) ACS to be mounted on a vertical surface
c) ACS - mobile socket-outlet unit



1.5 Degree of protection IP

The code IP indicates the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects and ingress of water.

The degree of protection of an enclosure is identified, in compliance with the specifications of the Standard IEC 60529, by the code letters IP (International Protection) followed by two numerals and two additional letters.

The first characteristic numeral indicates the degree of protection against ingress of solid foreign objects and against contact of persons with hazardous live parts inside the enclosure.

The second characteristic numeral indicates the degree of protection against ingress of water with harmful effects.

It is easy to understand that the two characteristic numerals influence each other.

The additional letter indicates the degree of protection of persons against access to hazardous parts.

The additional letter is used only if the actual protection against access to hazardous parts is higher than that indicated by the first characteristic numeral; if only the protection against access to hazardous parts is indicated, then 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.

If the indications refer exclusively to the safety of persons against direct contact, both characteristic numerals are omitted and replaced by “XX”; in this case the degree of protection is indicated by the additional letter.

Obviously, also the additional letter is not independent of the two numerals by which it may be preceded, but it is closely connected to them; that is the reason why the additional letter shall be used only if guaranteeing a degree of protection against direct contact higher than that guaranteed by the first characteristic numeral.

The supplementary letter gives supplementary information.

The table below sums up the meaning of the various elements which form the code. For further details reference should be made to the Standard IEC 60529.

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

	Protection of equipment	Against access to hazardous part with:
First characteristic numeral (access of solid foreign objects)	0 non-protected	non-protected
	1 ≥ 50 mm diameter	back of hand
	2 ≥ 12.5 mm diameter	finger
	3 ≥ 2.5 mm diameter	tool
	4 ≥ 1.0 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	
Additional letter (optional)	8 continuous immersion	
	A	back of hand
	B	finger
	C	tool
Supplementary letter (optional)	D	wire
	H High-voltage apparatus	
	M Motion during water test	
	S Stationary during water test	
	W Weather conditions	

1.5.1 Degrees of protection provided by switchgear and controlgear assemblies

As regards assemblies, if not otherwise specified by the manufacturer, the degree of protection is applicable to the whole assembly, mounted and installed as in the ordinary use (closed door). Besides, the manufacturer may indicate the degrees of protection relevant to particular arrangements which may occur during operation, such as the degree of protection with open doors and that one with removed or withdrawn apparatus.

As regards enclosed switchboards, the Standard requires the minimum degree of protection IP 2X or IPXXB for live parts which are not to be touched intentionally and IP4X or IPXXD for readily accessible horizontal surfaces.

As an example the following table shows the minimum degrees of protection required for an assembly to be installed in the listed environments, in compliance with the mentioned Standards.

Type of assemblies/Type of environments	Standards and sub-clause	Minimum degree of protection
Switchgear and controlgear assemblies: enclosed switchboards	IEC 60439-1 sub-clause 2.3.3	Not defined
Assemblies for outdoor installation	IEC 60439-1 sub-clause 7.2.1.3	IPX3
Assemblies with protection by total insulation	IEC 60439-1 sub-clause 7.4.3.2.2	IP2XC
Installations in normal environments		
Live parts which are not to be touched intentionally	IEC60364-4 sub-clause 412.2.1	IPXXB (IP2X)
Live parts which are readily accessible (horizontal top)	IEC60364-4 sub-clause 412.2.2	IPXXD (IP4X)
Installations in locations containing a bath tube or shower basin		
Zone 1 and 2	IEC60364-7 sub-clause 701.512.2	IPX4
Zone 3	IEC60364-7 sub-clause 701.512.2	IPX1
Zone 1-2-3 public baths where water jets are used for cleaning purposes	IEC60364-7 sub-clause 701.512.2	IPX5
Installations for swimming-pools		
Zone 0	IEC60364-7 sub-clause 702.512.2	IPX8
Zone 1	IEC60364-7 sub-clause 702.512.2	IPX5
Zone 2 for indoor locations	IEC60364-7 sub-clause 702.512.2	IPX2
Zone 2 for outdoor locations	IEC60364-7 sub-clause 702.512.2	IPX4
Zone 2 where water jets are used for cleaning purposes	IEC60364-7 sub-clause 702.512.2	IPX5
Installations for rooms and cabins containing sauna heaters	IEC60364-7 sub-clause 703.512.2	IP24
Assemblies for construction sites (ACS)	IEC60439-4 sub-clause 7.2.1.1	IP44

The figure below shows the degrees of protection which can be obtained with ABB SACE ArTu series switchgear

ArTu L

IP31

Without door



IP43

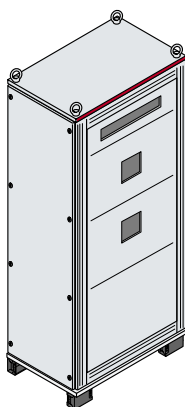
With door



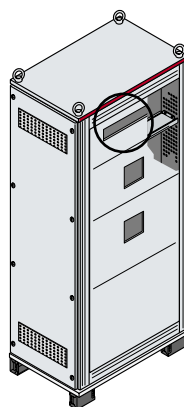
ArTu M - K

IP31

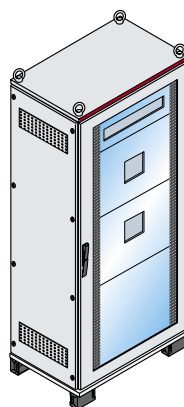
Without door



IP41 Without door with IP41 kit and ventilated panels (ArTu K only)

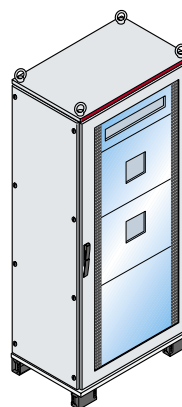


IP41 With door and ventilated panels (ArTu K only)



IP65

With door and blind panels



The figure below shows an application of ABB switchgear series MNS designed for the degree of protection IP41. MNS switchgear series is designed to fulfil the requirements for degrees of protection up to IP54.

Figure 7 - MNS R switchgear with degree of protection IP41



Each characteristic group numeral represents a value of impact energy as the following table shows:

Code IK	Impact energy (Joule)
IK 00	(*)
IK 01	0.14
IK 02	0.2
IK 03	0.35
IK 04	0.5
IK 05	0.7
IK 06	1
IK 07	2
IK 08	5
IK 09	10
IK 10	20

(*) Not-protected according to this Standard.

In general, the degree of protection applies to the complete enclosure. If parts of the enclosure have differing degrees of protection, the latter shall be indicated separately.

Here are the degrees of protection against external mechanical impact (code IK) of ArTu series

IK 08

300mm

1,7 kg

ArTu L

Impact energy
Joule **5.00**

IK 09

200mm

5 kg

ArTu M-K

Impact energy
Joule **10.00**

With glass door

IK 10

400mm

5 kg

ArTu M-K

Impact energy
Joule **20.00**

With blind door

1.6 Degree of protection IK

The code IK indicates the degrees of protection provided by an enclosure to the housed equipment against harmful effects of mechanical impacts verified by standardized test methods complying with the requirements of the Standard IEC 62262.

The degree of protection provided by enclosures against external mechanical impacts is indicated by the code IK as follows:

Characteristic letters	International mechanical protection
	<div style="display: flex; align-items: center;"> <div style="background-color: #e67e22; color: white; padding: 2px 5px; margin-right: 5px;">IK</div> <div style="border: 1px solid #e67e22; padding: 2px 5px; margin-right: 5px;">05</div> </div> <p>Characteristic group numeral from 00 to 10</p>

(*) Not-protected according to this Standard.

1.7 Forms of separation

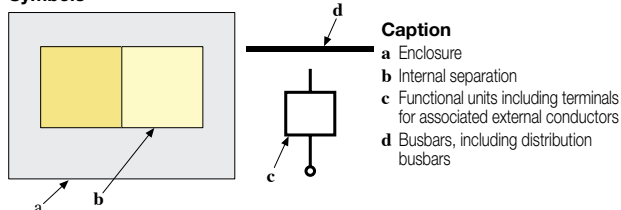
The designation form of separation indicates the type of subdivision provided inside the enclosure. Separations by means of barriers or partitions (metallic or non metallic materials) are aimed at:

- guaranteeing protection against direct contact (minimum degree of protection IPXXB), in case of access to an insulated part of the assembly when voltage is still applied to the rest of the assembly;
- reducing the likelihood of ignition and propagation of an internal arc;
- impeding the passage of solid foreign bodies from one unit of the assembly to an adjacent one (minimum degree of protection IP2X).

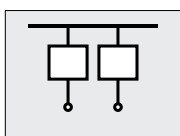
A partition is an element of separation between two cubicles, whereas a barrier protects the operator against direct contact and against the effects of circuit-breaker arcs propagating in the direction of usual access.

The table below, taken from the Standard IEC 60439-1, points out the typical forms of internal separation which can be obtained by using barriers or partitions:

Symbols

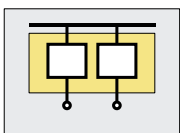


Form 1 (no internal separation)

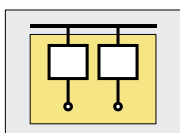


Form 2 Separation of busbars from the functional units

Form 2a Terminals not separated from busbars

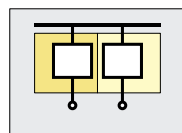


Form 2b Terminals separated from busbars

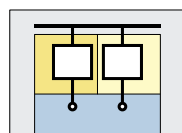


Form 3 Separation of busbars from the functional units – separation of all functional units from one another

Form 3a Terminals not separated from busbars

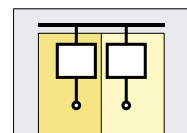


Form 3b Terminals separated from busbars



Form 4 Separation of busbars from the functional units – separation of all functional units from one another – separation of terminals from those of any other functional unit

Form 4a Terminals in the same compartment as the associated functional unit



Form 4b Terminals not in the same compartment as the associated functional unit

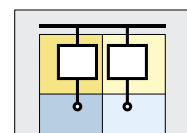


Figure 8 - Structural frame form 4b - view with rear doors open. The metallic separations mounted on the main busbars and on the distribution busbars can be noted, as well as the insulating covers which complete the compartments for cable connection

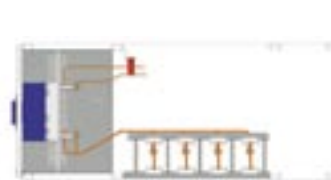


Representation of the structural frames in form 3a, 3b and 4b for switchgear type PC3.0/MNS R

Form 3a



Structural frame of a compartment with moulded-case circuit-breaker in form 3a

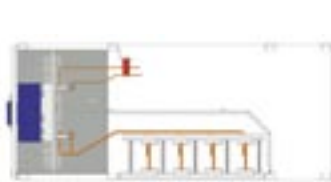


Top view of a column with moulded-case circuit-breaker separated in form 3a

Form 3b



Structural frame of a compartment with moulded-case circuit-breaker in form 3b



Top view of a column with moulded-case circuit-breaker separated in form 3b

Form 4b



Structural frame of a compartment with moulded-case circuit-breaker in form 4b



Top view of a column with moulded-case circuit-breaker separated in form 4b

1.8 Temperature-rise inside assemblies

An excessive temperature-rise inside assemblies represents one of the main problems which are often subject for discussion and to which users pay the most attention.

It is evident that an anomalous heating inside switchgear can jeopardize the safety of people (possible fires) and plants (malfunctioning of the apparatus).

For this reason, the Standard IEC 60439-1 gives a lot of space to the permissible temperature-rise limits in an assembly and to the methods to determine such limits either directly as type test or by analytic extrapolation. The term type test defines the tests intended to assess the validity of a project according to the expected performances.

Such tests are usually carried out on one or more prototypes and the results of these type tests are assumed to obey to deterministic laws. Therefore these results can be extended to all the production, provided that it complies with the design of the tested samples.

The type tests prescribed by the Standard IEC 60439-1 include:

- verification of temperature-rise limits
- verification of the dielectric properties
- verification of the short-circuit withstand strength of the main circuits
- verification of the short-circuit withstand strength of the protective circuit
- verification of the effective connection between the exposed conductive parts and the protective circuit
- verification of clearances and creepage distances
- verification of mechanical operation
- verification of the degree of protection

As said above the verification of temperature-rise limits is one of the most critical aspect for an assembly; the Standard states the temperature-rise limits referred to an average ambient air temperature of $\leq 35^{\circ}\text{C}$ which the switchgear complying with the Standard must not exceed (Table 1).

In TTA the verification of the temperature-rise limits shall be carried out through type tests.

In PTTA an extrapolation, for example complying with IEC 60890, can be made in alternative to type tests.

Table 1: Temperature-rise limits for LV switchgear and controlgear assemblies

Parts of assemblies	Temperature rise (K)
Built in components ⁽¹⁾ (6)	In accordance with the relevant requirements for the individual components, or in accordance with the manufacturer's ⁽⁶⁾ instructions, taking into consideration the temperature inside the ASSEMBLY
Terminals for external insulated conductors	70 ⁽²⁾
Busbars and conductors (7), plug-in contacts of removable or withdrawable parts which connect to busbars	Limited by: <ul style="list-style-type: none"> • mechanical strength of conducting material ⁽⁷⁾ • 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 ⁽³⁾
• of insulating material	25 ⁽³⁾
Accessible external enclosures and covers:	
• metal surfaces	30 ⁽⁴⁾
• insulating surfaces	40 ⁽⁴⁾
Discrete arrangements of plug and socket type connection	Determined by the limits of those components of the equipment of which they form part (5)
<p>(1) The term "built-in components" means:</p> <ul style="list-style-type: none"> - 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). <p>(2) The temperature-rise limit of 70 K is a value based on the conventional type test.</p> <p>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. When the terminals of the built-in components are also the terminals for external insulated conductors, the lower of the corresponding temperature-rise limits shall be applied.</p> <p>(3) 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 higher temperature rises.</p> <p>(4) Unless otherwise specified, in the case of covers and enclosures which are accessible but need not to be touched during normal operation, an increase in the temperature-rise limits by 10 K is permissible.</p> <p>(5) This allows a degree of flexibility in respect of equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.</p> <p>(6) For the temperature-rise tests in accordance with 8.2.1, the temperature-rise limits shall be specified by the manufacturer of the ASSEMBLY.</p> <p>As regards circuit-breakers, the temperature-rise limits are the following:</p> <ul style="list-style-type: none"> - 70 K if an insulated conductor is connected to the terminal. - 85 K for the terminals of ABB circuit-breakers if insulated conductors are not directly connected to them (the temperature-rise of 85 K is always referred to the ambient air temperature of 35°C outside the assembly). <p>(7) Assuming that all the other listed criteria are met, a temperature-rise of 105 K for busbars and bare copper conductors shall not be exceeded. 105 K refers to the temperature over which copper annealing may occur.</p>	

In addition to type tests the Standard requires also some routine tests.

These tests are carried out on each manufactured item to ascertain the lack of rough defects due to materials or assembling. These are non destructive tests and can be carried out in the manufacturer's factory for switchgear and controlgear supplied already wired or at the installation site after assembling.

The routine tests prescribed by the Standard IEC 60439-1³ are:

- visual inspection of the assembly, including inspection of wiring
- electrical operation test
- verification of insulation resistance
- checking of the protective measures and of the electrical continuity of the protective circuits.

² IEC 60439-3, specifically intended for distribution boards (ASD), requires, in addition to the type tests established by IEC 60439-1, the following additional verifications:

- verification of construction and marking
- verification of impact strength
- verification of resistance to rusting and to humidity
- verification of resistance of insulating materials to heat
- verification of resistance of insulating materials to abnormal heat and fire due to internal electrical effects
- verification of mechanical strength of fastening means of enclosures.

³ Analogous tests are prescribed by IEC 60439-3 for distribution boards (ASD).

1.9 Switchgear and controlgear assemblies – special executions

The term “special execution” is used to define switchboards having characteristics not considered in the Standard 439-1, but often required by users according to the characteristics of the plant.

Among the most common available special executions there are:

- arc-proof switchboards
- anti-seismic switchboards
- shock-proof switchboards⁴

The compliance of such switchgear and controlgear assemblies with these requirements is guaranteed by tests specified by international and/or national Standards and not included in the Standard 439-1.

⁴ Obtained through a suitable choice of frames and equipment.

1.9.1 Testing under conditions of arcing due to internal fault

The most widespread international Standard is the Technical Report IEC 61641 (see Annex A).

This test verifies the capability of the switchboards to meet some requirements typically linked to the operator safety under conditions of arcing due to internal fault.

It is a special test which is subject to an agreement between manufacturer and user.

The results of such test are presented in the form of a test report and are not object of a test certificate. The interpretation of the results is subject to an agreement between manufacturer and user.

1.9.2 Seismic qualification testing

Seismic qualification testing is intended to demonstrate the capability of an assembly and of the relevant housed equipment to withstand the stresses resulting from an earthquake keeping the functions required.

The overview of the standards and rules regarding seismic qualification is wide and varied; therefore, it is fundamental to define in advance the performances that the testing object must guarantee.

Among the applicable Standards (different depending on States, environments and functions for which the equipment is intended) the following ones are to be mentioned:

- Uniform Building Code 1997
- Italian Government Decree PCM No. 3274, 20/03/2003 “Primi elementi in materia di criteri generali per la classificazione sismica del territorio nazionale e di normative tecniche per le costruzioni in zona sismica” (“First elements regarding general criteria for the seismic classification of the national territory and technical guidelines for building in seismic areas”)
- IEEE 693-1997 “Recommended Practices for Seismic Design of Substations”
- IEEE 344-1987 “Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations”
- IEC 60980 “Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations”
- IEC 60068-3-3 “Guidance Seismic test methods for equipments”
- IEC 60068-2-6 “Tests- Test Fc: Vibration (sinusoidal)”
- IEC 60068-2-57 “Tests- Test Ff: Vibration – Time history method”

1.9.3 Testing for shock-proof execution

In particular applications, such as for example military ships, LV switchgear and controlgear assemblies are requested to withstand specified vibrations and shocks.

The reference Standards for this type of version are:

- IEC 60068-2-6 / EN 60068-2-6 (vibration)
- IEC 60068-2-27 / EN 60068-2-27 (shock)

In this case too, since the overview of rules and standards is very varied (to remain in the naval field, the shipping registers are numerous and have different specifications) the test shall be carried out by pre-defining the testing modalities and the performances to be guaranteed by the equipment.

2 The electric arc

2.1 Electric arc phenomenon

The electric arc is a phenomenon which takes place as a consequence of a discharge which occurs when the voltage between two points exceeds the insulating strength limit of the interposed gas; then, in the presence of suitable conditions, a plasma is generated which carries the electric current till the opening of the protective device on the supply side.

Gases, which are good insulating means under normal conditions, may become current conductors in consequence of a change in their chemical-physical properties due to a temperature rise or to other external factors.

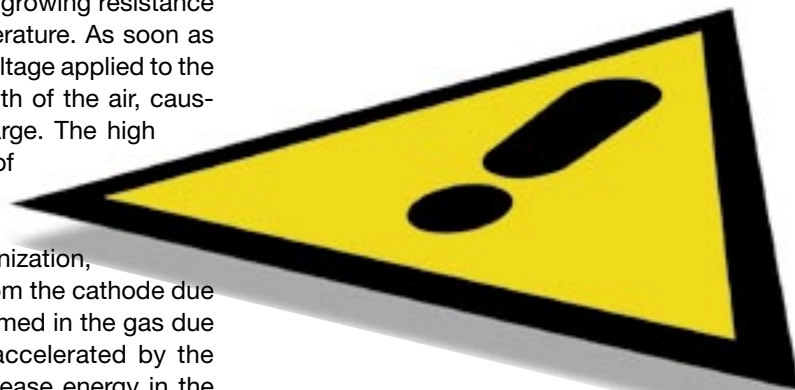
To understand how an electrical arc originates, reference can be made to what happens when a circuit opens or closes. During the opening phase of an electric circuit the contacts of the protective device start to separate thus offering to the current a gradually decreasing section; therefore the current meets growing resistance with a consequent rise in the temperature. As soon as the contacts start to separate, the voltage applied to the circuit exceeds the dielectric strength of the air, causing its perforation through a discharge. The high temperature causes the ionization of the surrounding air which keeps the current circulating in the form of electrical arc. Besides thermal ionization, there is also an electron emission from the cathode due to the thermionic effect; the ions formed in the gas due to the very high temperature are accelerated by the electric field, strike the cathode, release energy in the collision thus causing a localized heating which generates electron emission.

The electrical arc lasts till the voltage at its ends supplies the energy sufficient to compensate for the quantity of heat dissipated and to maintain the suitable conditions of temperature. If the arc is elongated and cooled, the conditions necessary for its maintenance lack and it extinguishes.

Analogously, an arc can originate also as a consequence of a short-circuit between phases. A short-circuit is a low impedance connection between two conductors at different voltages. The conducting element which constitutes the low impedance connection (e.g. a metallic tool forgotten on the busbars inside the enclosure, a wrong wiring or a body of an animal entered inside the enclosure), subject to the difference of potential is passed through by a current of generally high value, depending on the characteristics of the circuit.

The flow of the high fault current causes the overheating of the cables or of the circuit busbars, up to the melting of the conductors of lower section; as soon as the conductor melts, analogous conditions to those present during the circuit opening arise. At that point an arc starts which lasts either till the protective devices intervene or till the conditions necessary for its stability subsist.

The electric arc is characterized by an intense ionization of the gaseous means, by reduced drops of the anodic and cathodic voltage (10 V and 40 V respectively), by high or very high current density in the middle of the column (of the order of 102-103 up to 107 A/cm²), by very high temperatures (thousands of °C) always in the middle of the current column and – in low voltage – by a distance between the ends variable from some microns to some centimeters.



2.2 Effects of the electric arc inside switchgear and controlgear assemblies

In the proximity of the main boards, i.e. in the proximity of big electrical machines, such as transformers or generators, the short-circuit power is high and consequently also the energy associated with the electrical arc due to a fault is high.

Without going into complex mathematical descriptions of this phenomenon, the first instants of arc formation inside a cubicle can be schematized in 4 phases:

- 1.compression phase: in this phase the volume of the air where the arc develops is overheated owing to the continuous release of energy; due to convection and radiation the remaining volume of air inside the cubicle warms up; initially there are temperature and pressure values different from one zone to another;

2.expansion phase: from the first instants of internal pressure increase a hole is formed through which the overheated air begins to go out. In this phase the pressure reaches its maximum value and starts to decrease owing to the release of hot air;

3.emission phase: in this phase, due to the continuous contribution of energy by the arc, nearly all the air is forced out under a soft and almost constant overpressure;

4.thermal phase: after the expulsion of the air, the temperature inside the switchgear reaches almost that of the electrical arc, thus beginning this final phase which lasts till the arc is quenched, when all the metals and the insulating materials coming into contact undergo erosion with production of gases, fumes and molten material particles.

Should the electrical arc occur in open configurations, some of the described phases could not be present or could have less effect; however, there shall be a pressure wave and a rise in the temperature of the zones surrounding the arc.

Being in the proximity of an electrical arc is quite dangerous; here are some data to understand how dangerous it is:

- pressure: at a distance of 60 cm from an electrical arc associated with a 20 kA arcing fault a person can be subject to a force of 225 kg; moreover, the sudden pressure wave may cause permanent injuries to the eardrum;
- arc temperatures: about 7000-8000 °C;
- sound: electrical arc sound levels can reach 160 db, a shotgun blast only 130 db.



Burns

The high temperature levels of the gases produced by the electrical arc and the expulsion of incandescent metal particles may cause more or less severe burns to people.

Flames can cause all degrees of burn up to carbonization: the red-hot solid bodies, such as the metal fragments of the assembly involved, cause third degree burns, superheated steam causes burns analogous to those by hot liquids whereas radiant heat generally causes less severe burns.



Injuries due to ejection of materials

The ejection of metal particles or other loose items caused by the electrical arc can result in severe injuries to the weakest parts of the human body as, for example, the eyes. The materials expelled owing to the explosion produced by the arc may penetrate the cornea and hurt it. The extent of the lesions depends on the characteristics and on the kinetic energy of these objects.

Moreover, the ocular region can sustain injuries to the mucosa because of the gases released by the arc and the emission of ultraviolet and infrared rays can injure the cornea and the retina depending on the radiation wavelengths.



Hearing

As already mentioned, the electrical arc is a real explosion, whose sound may cause permanent injuries to hearing.



Inhalation of toxic gases

The fumes produced by burnt insulating materials and by molten or vaporized metals can be toxic. The fumes are caused by incomplete burning and are formed by carbon particles and by other solid substances suspended in the air.

2.3 Effects of the electrical arc on human beings

From the above, it is evident that the electrical arc represents a hazard source for people and goods. The hazards to which a person is exposed due to the release of energy generated by an arc event are:

- burns;
- injuries due to ejection of materials;
- damages to hearing;
- inhalation of toxic gases.

3 Internal arc-proof switchgear and controlgear assemblies

3.1 Generalities

In LV switchgear there are two types of fault to which the development of currents of remarkable intensity is associated:

- bolted fault
- arc fault.

With the term “bolted” reference is made to a fault in which two or more live parts at different potential get in touch; this is the case of phase-to-phase or phase-to-earth short-circuits to which the circulation of an anomalous current within the ring developed at the fault moment is associated.

On the contrary, an arc fault occurs when there is a reduction in the dielectric strength of the insulating means (air, in LV switchboards) interposed between two or more conducting elements at different potential.

The arc is generated at the moment when, due to the high ionization of the air, there is a breakdown of the dielectric of the medium and the consequent flow of the current through it.

In a bolted fault the most harmful effects are prevalently of electrodynamic type, proportional to I^2 , due to the high intensity of the current and to the low fault resistance involved (the medium in which the fault current flows is a conducting material).

On the contrary, in an arc fault the highest stresses are of thermal type and proportional to $R_a I^2$ owing to the high value taken by the arc resistance R_a ; this because the fault current flows in a medium which is always insulating, even if extremely ionized.

Such stresses manifest themselves essentially in the form of:

- high thermal gradients caused by the quick and intense rise in the air temperature;
- high pressure gradients in the form of pressure wave;
- high ionization of the air with consequent reduction of its insulating strength.

Generally speaking, in a LV assembly designed and tested according to the Standard IEC 60439-1 an arc fault is not very likely to occur; however, should it occur, the consequences would be extremely harmful to both the equipment as well as the personnel (see Chapters 2.2 and 2.3).

The causes of an arc fault can be both technical as well as non technical; among the latter the most frequent are the following:

- **personnel errors**, above all during maintenance operations;
- **installation operations not sufficiently accurate**;
- **inadequate maintenance**, above all in the case of severe environmental conditions.

Among the technical causes of an arc fault in a LV assembly the following ones are to be remembered:

- **breakdown of the insulation** essentially in the proximity of the supports of the busbars and of the plug-in contacts of the withdrawable units (75% of cases);
- **overvoltages** generating disruptive discharges between the points at minimum clearances (15% of cases);
- **constructional defects of the apparatus** (10% of cases).

It is known that the low voltage Standard (IEC 60439-1) requires as type test the verification of the short-circuit withstand strength for the bolted fault, whereas it does not give any precise indication as regards arc faults.

The only indication as regards this matter given by the Standard 439-1 is addressed to the manufacturer who is obliged to provide all the possible precautions aimed at reducing the possibility of arcing inside an assembly. However, there is a guideline document for the verification of the internal arc withstand of LV assemblies very diffused both at Italian as well as at international level. It is the document **IEC 61641** “Enclosed low-voltage switchgear and controlgear assemblies - Guide for testing under conditions of arcing due to internal fault” (see Annex A).

Since it is a Technical Report type 3, this document has not the validity of a Standard and consequently the relevant tests do not represent a mandatory type test to the purpose of obtaining the state of TTA.

Nevertheless, this document represents a solid technical reference as regards the testing modalities, defining the main characteristics of an arc-proof assembly and the requirements it must meet.

According to the document IEC 61641¹ a LV switchgear and controlgear assembly shall:

- limit the risk of injuries/accidents for the personnel in case of internal arc
- limit the damage of the switchboard to the section affected by the fault, thus allowing the not-affected part to be put into safety (emergency operations).

¹ New edition to be published.

3.2 Characteristics of internal arc-proof switchgear and controlgear assemblies

Safety for the operator and for the installation in case of arcing inside LV switchgear can be obtained through three different design philosophies:

1. assemblies mechanically capable of withstanding the electric arc (passive protection)
2. assemblies equipped with devices limiting the effects of internal arcing (active protection)
3. assemblies equipped with current limiting circuit-breakers.

These three solutions (also combined together) have found a remarkable development in the industrial field and have been successfully applied by the main manufacturers of LV switchgear and controlgear assemblies.

As it can be seen hereafter by examining the first two solutions, an “active” protection against arc faults is intrinsically more complex than a “passive” one.

This because of the presence of additional electromechanical/electronic devices⁵ which limit the arcing effects and which, by their nature, may be subject to faults or not-tripping.

3.2.1 Assemblies mechanically capable of withstanding the electric arc (passive protection)

The switchboards which take constructional precautions suitable to the containment of the arc and to the successive outlet of the exhausted gases belong to this type of assemblies.

Two are the peculiar characteristics of these types of switchgear:

- reinforced mechanical frame able to withstand the stresses (overpressures) caused by internal arcing;
- creation inside the assembly of a preferential path for the discharge of the hot gases generated by arcing.

Both characteristics are indispensable to satisfy the safety requirements for the operator and the installation established by the Document IEC 61641.

As a consequence, the manufacturers take design measures to prevent the accidental opening of the doors (or their perforation) due to the pressure wave generated by the arc.

Besides, also the instruments which can be positioned on the doors must be able to withstand an overpressure of about 1 bar ($\approx 1 \text{ kg/cm}^2$) without being ejected and projected outside the switchboard.

The thermal consequences of arcing (exhausted gases at high temperature) are then limited by designing the inside of the switchgear so that the outlet of gases takes place in the top part (over 2 m) and not at lower heights which might be potentially dangerous for the operator.

It is evident that each opening of significant dimensions on the doors might constitute a vent for the gases and result dangerous for the operator; therefore such openings are usually avoided in this type of switchgear.

As already said, in addition to the operator safety, the Document IEC 61641 prescribes that the switchgear shall guarantee also safety for the plant in case of an arc event (see Annex A).

As a consequence, the manufacturer shall adopt additional design measures.

Fundamentally, the switchboard shall be manufactured so as to safeguard its functional part in case of arcing and then to allow putting into safety of the plant once the fault has been eliminated.

A switchboard of this type shall have mainly two design characteristics:

- non-propagation of the arc between two adjacent columns;
- non-propagation of the arc between the compartment housing the bars and that where the apparatus are installed.

The fulfilment of these requirements is the result of the internal division into compartments of the switchboard. As a matter of fact this allows obtaining internal “arc-proof” subdivisions, that is cubicles or compartments where the arc is confined in its place of occurrence, thus avoiding damages to adjacent areas.

3.2.2 Assemblies equipped with devices limiting internal arc effects (active protection)

A design philosophy which is completely different from that just considered consists in guaranteeing the resistance to internal arcing by installing devices limiting the arc.

The approaches in that direction can be of two different types:

- limiting the destructive effects of the arc, once it has occurred, by means of arc detectors
- limiting the destructive effects of the arc, once it has occurred, by means of overpressure detectors.

The first possibility consists in installing in the assembly arc detectors which sense the light flux associated with the electric arc phenomenon.

Once the arc has been detected, these devices send an opening signal to the incoming circuit-breaker, thus guar-

⁵ Arc and/or overpressure detectors

anteering tripping times of the order of 1-2 ms, therefore shorter than those proper of the circuit-breaker.

The operating logic of an arc detector is the following: the occurrence of an arc inside the switchboard is detected by the arc detector because an intense light radiation is associated with this phenomenon. The arcing control system detects the event and sends a tripping signal to the circuit-breaker.

All the above with trip times of a few milliseconds and supplanting the tripping of the CB overcurrent relay which, for example, could be delayed due to current selectivity questions.

Figure 1 shows the possible positions where this device can be installed inside a switchboard.

The ideal solution is that which provides the installation of at least one detector for each column, with the consequent reduction to a minimum of the length of the optical fibers carrying the signal.

In order to prevent from an unwanted tripping caused by light sources independent of the arc (lamps, solar radiation etc.), an additional current sensor is often positioned at the incoming of the main circuit-breaker.

Only in the event of an arc, both the incoming sensor - which detects an "anomalous" current due to the arc fault - as well as the sensor detecting the light radiation as-

sociated with the arc enable the system to intervene and allow the consequent opening of the circuit-breaker.

The second possibility consists in installing overpressure sensors inside the switchboard.

As previously described, the overpressure wave is one of the other effects occurring inside an assembly in case of arcing.

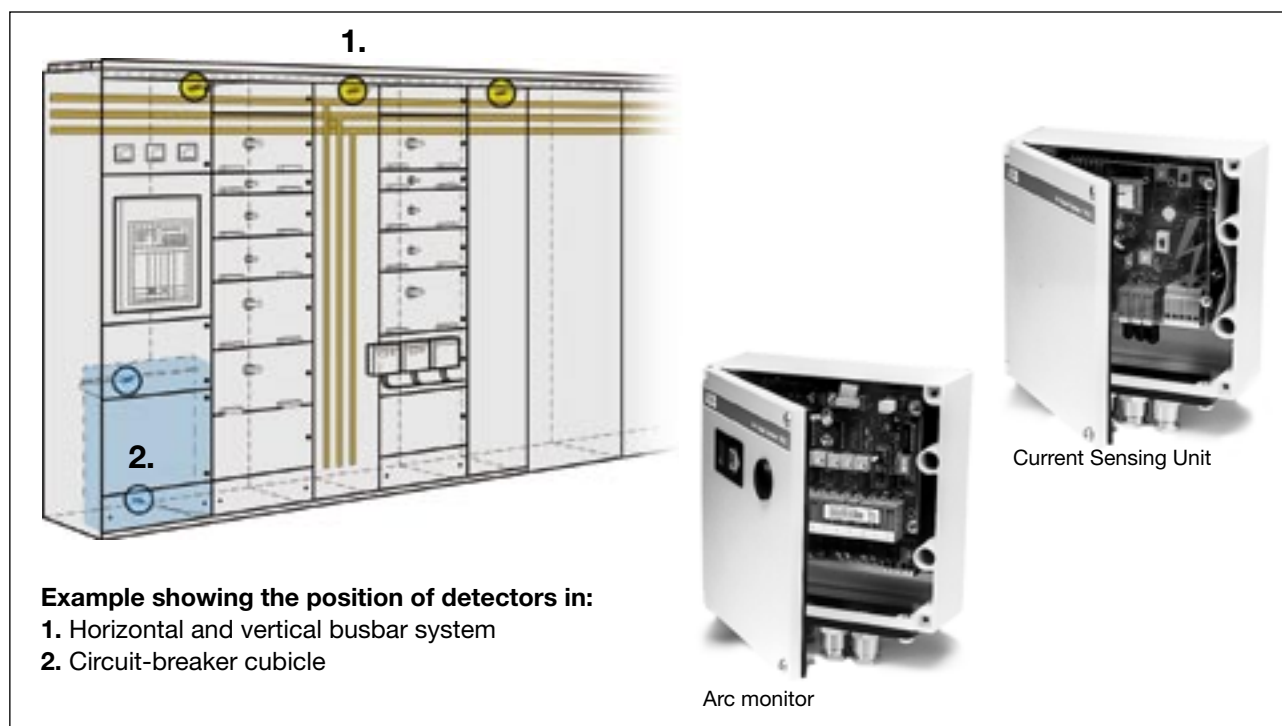
As a consequence it is possible to install some pressure sensors which are able to signal the pressure peak associated with the arc ignition with a delay of about 10-15 ms. The signal operates on the supply circuit-breaker without waiting for the trip times of the selectivity protections to elapse, which are necessarily longer.

Such a system does not need any electronic processing device, since it acts directly on the tripping coil of the supply circuit-breaker.

Obviously it is essential that the device is set at fixed trip thresholds. When an established internal overpressure is reached, the arc detector intervenes.

However, it is not easy to define in advance the value of overpressure generated by an arc fault inside a switchboard.

Figure 1 - Possible positions of arc detectors



3.2.3 Switchgear and controlgear assemblies with current limiting circuit-breakers

A last possibility to limit the effects of an internal arc foresees the installation of current limiting circuit-breakers. In this case two are the possible solutions:

- separating the parts of the installation at high short-circuit current (Figure a);
- limiting - at each incoming section - the short-circuit current and consequently the intensity of a possible arc (Figure b).

In the case a), the current limiting circuit-breaker separates the right and the left part of the plant thus limiting the contribution to the fault (in our case the arc fault) given by the sound part of the plant to the affected one.

Should this be insufficient, the most extreme solution is the b) where each incoming feeder from the transformer has a current limiting circuit-breaker which reduces the energy supplied by each bus riser in the event of an arc fault.

Both these solutions are frequently used in assemblies which are arc-proof from a mechanical point of view (passive protection), when the arc resistance performances of the switchboard (or of part of it) are insufficient for the installation requirements.

For example, if the switchboard under consideration has a mechanical resistance of 65kA to an internal arc and the short-circuit current of the plant is much higher

than 65kA, the solutions of type a) or b) shall be with no doubt fit for guaranteeing safety in case of an internal arc fault.

Fig. a

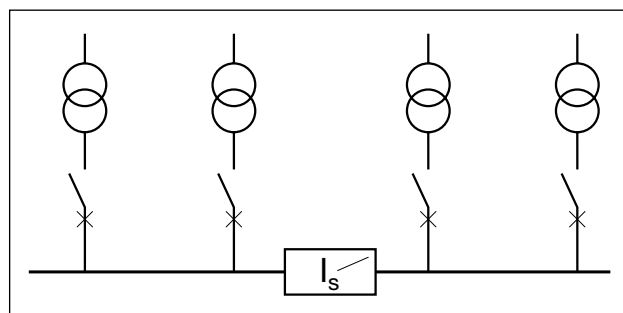
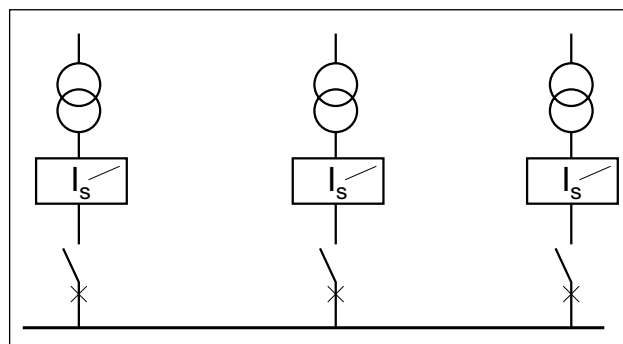


Fig. b



4 ABB SACE arc-proof switchgear

ABB SACE⁶ low voltage switchboards of MNS series are designed and certified to guarantee a passive-type protection against internal arcing by reaching arc withstand values up to 100kA for 0.3s.

MNS switchboards are tested and certified in compliance with the Standard IEC 61641-2007 fulfilling all the seven criteria of the internal arc-proof verification test (see Annex A).

Thanks to careful design choices, in MNS switchgear the arc is confined in the compartment where it ignites, thus guaranteeing not only safety for the operator, but also safeguarding the switchboard by permitting the put into safety of the installation and the quick removal of the compartment where the arc event has occurred.

⁶ Versions MNS3.0, MNS R, MNS iS

Figure 1 Arc-proof switchgear of MNS series



The switchboards of MNS series are available in the following versions, all arc-proof:

- PC3.0/MNS R, main distribution switchboard (Power Center)
- MNS3.0, Motor Control Center
- MN iS “intelligent”, Motor Control Center

The main characteristics of the primary distribution switchboard type PC3.0/MNS R are illustrated below.

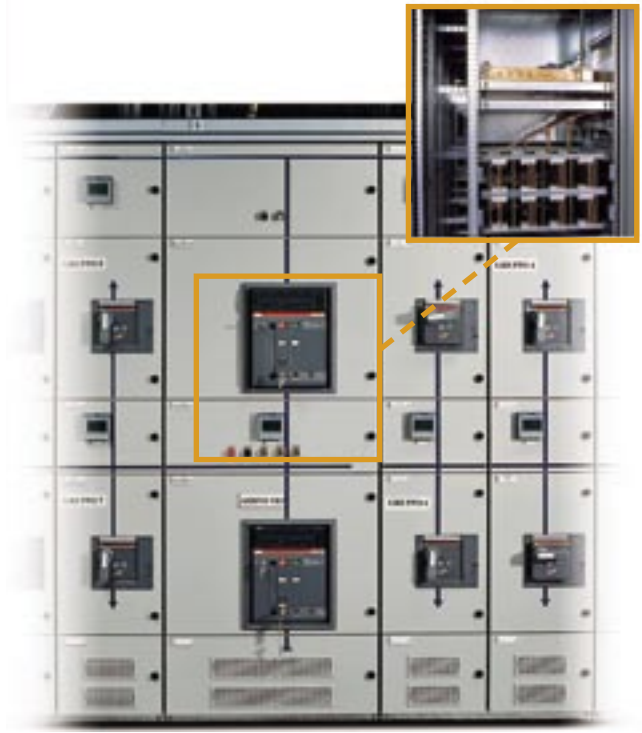
4.1 Constructional and functional characteristics of the switchgear PC3.0/MNS R

Switchgear frame

The PC3.0/MNS R frame is based on modular 2 mm thick steel C sections, pre-drilled at a pitch of 25 mm DIN. Each unit is based on modular elements and consists of:

- circuit-breaker compartments;
- instrument compartments;
- busbar compartment;
- cable compartment.

All compartments are mechanically segregated from the others. The switchgear is pre-set for easy extensions on both sides.



Earthing

The switchgear is provided with a continuous electrolytic copper earthing busbar, with a cross-section suitable for the switchgear short-circuit rating and pre-set on both sides for the connection to the earthing network. The following elements are connected to the earthing busbar:

- the metallic frame structures of the separate compartments;
- the not-live metallic parts of the circuit-breakers;
- the CTs and VTs earthing secondary windings.

The other not-live metallic parts of the apparatus are connected to the earthing busbar by means of the metallic frame of the compartment.

The doors with installed apparatus are connected to the structure by means of flexible copper braids. All the ground connections are made with screws or bolts provided with gripping washers.

Circuit-breaker compartment

The compartment, in the front part of the switchgear, is suitable to house both air as well as moulded-case circuit-breakers. It is accessible through a locked hinged door. The circuit-breakers can be installed in all the available versions, fixed, plug-in and withdrawable, in single or multiple compartments. In order to guarantee the maximum safety level for the operator, the disconnection of air and moulded-case circuit-breakers in withdrawable version can be carried out also with closed door.



Instrument compartment

The instrument compartment as well is positioned in the front part of the switchgear and it can be dedicated to each functional unit or be common to more functional units. It is accessible through a locked hinged door. The measuring instruments, the protection relays and the control and signalling devices are usually mounted on the compartment door, whereas any other auxiliary apparatus, such as circuit-breakers, protection fuses of command circuits and auxiliary relays are placed inside the compartment.

Equipment wiring is made of flexible copper cables and arranged in dedicated wiring channels.

The terminal blocks of each circuit-breaker are separated and properly identified.



Busbar compartment

The busbar compartment is located in the middle section of the switchgear. The main busbars can be located at the top, in the centre or at the bottom of the panel depending on the selected design and they distribute power to the various switchgear units; in some of the existing configurations the main busbars can be directly connected to and supply the circuit-breakers. The distribution busbars are positioned vertically in the column and feed the panel circuit-breakers. The busbar system can be composed by 1, 2 or 3 busbars per phase, according to the requested rated current, short-circuit withstand and environmental conditions in terms of temperature, altitude and humidity.

Busbars are normally bare copper made, but upon request they can be suitably treated: tinned, silver-plated and/or sheathed.

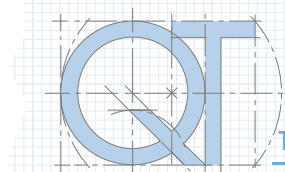


Main busbars

PC3.0/MNS R main busbars are available for currents up to 6300 A. Main busbars, as well as distribution busbars, can be completely segregated (according to the required form of separation).

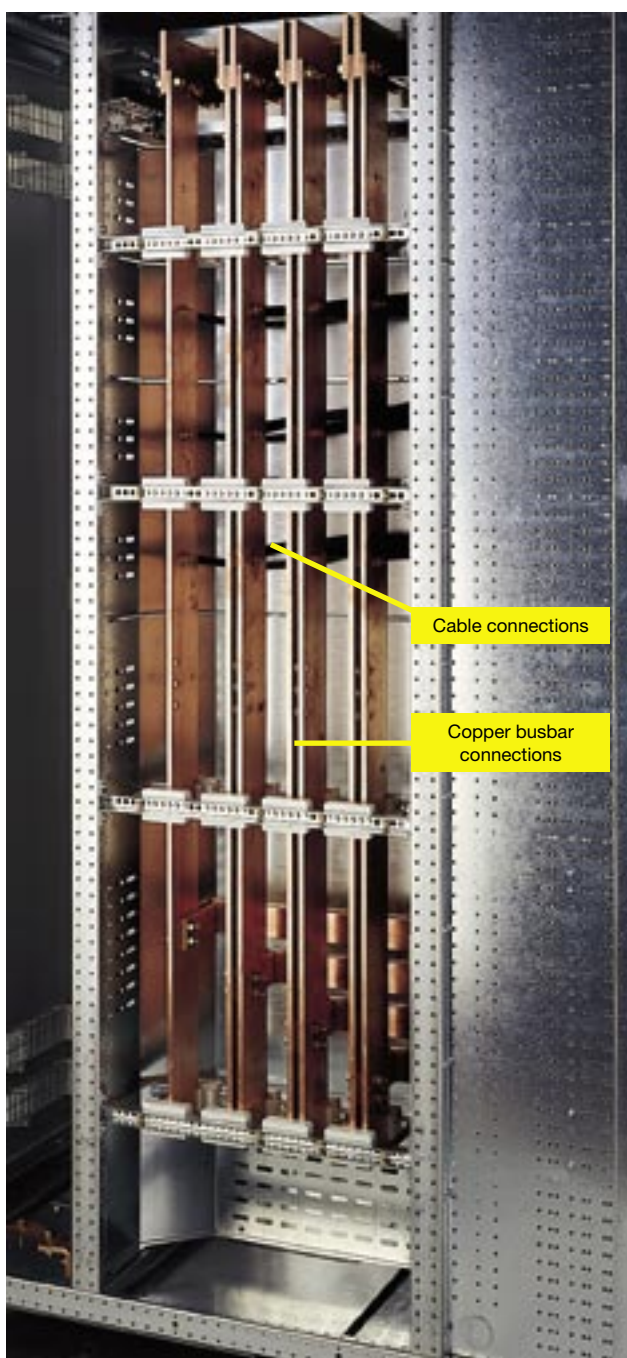
Each PC3.0/MNS R panel can be fitted with three busbar systems simultaneously (top-centre-bottom) each one segregated from the others.





Distribution busbars

PC3.0/MNS R distribution busbars are available for currents up to 4000 A. Distribution busbars, branched directly from the main busbar system, are vertically installed either on the right or on the left in the column. They feed the outgoing circuit-breakers and are connected to them by means of rigid or flexible copper busbars, or cables. In any case, all the connections are suitably sized to withstand the thermodynamic stresses of the fault currents.

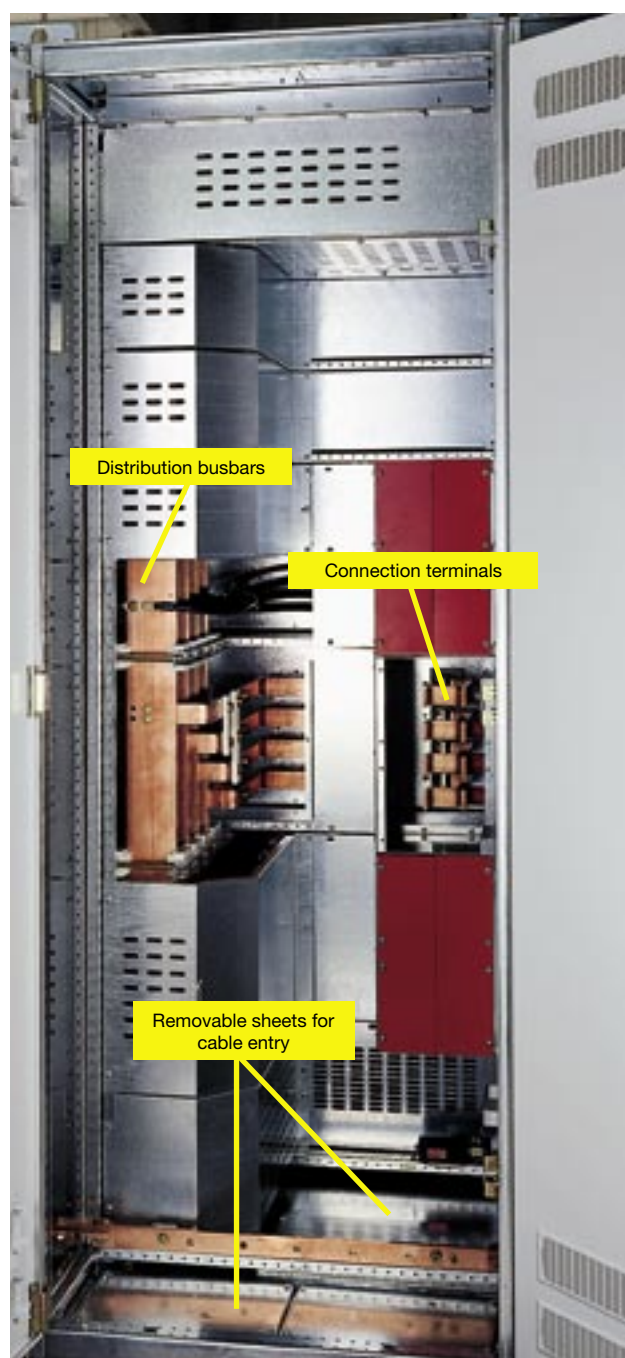


Cable compartment

The cable compartment is located at the rear side of the panel.

It is accessible through locked hinged doors or removable bolted doors. Its purpose is containing:

- power terminals;
- outgoing cables;
- current reducers;
- auxiliary terminal boxes (if any).



Forms of internal separation

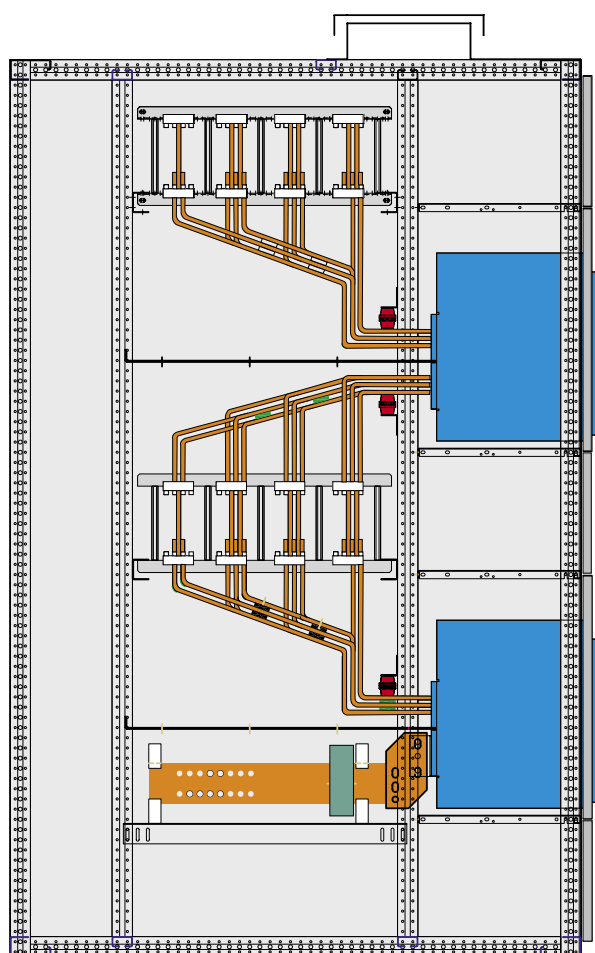
PC3.0/MNS R switchgear allows to achieve forms of internal separation in compliance with the reference Standard IEC 60439-1, Annex D.

The use of these separation forms provides safe access to the internal parts of the switchgear for the operators and prevents as well any possible fault from propagating through the circuits and through the adjacent compartments, to the advantage of service continuity for the installation.



Typical compartments and cross-sections

ABB SACE PC3.0/MNS R switchboards have been designed and built for the installation of both ABB air circuit-breakers type Emax as well as moulded-case circuit-breakers type Isomax and Tmax, in fixed, plug-in and withdrawable versions. They allow the installation of the main ABB apparatus and of the measuring and protection instruments available on the market, according to the different design requirements.



Ventilation

To guarantee an effective natural ventilation of the installed components, PC3.0/MNS R switchgears have been designed so as to create separate air flows in all their internal areas.

Gratings for natural air circulation are placed on the front and rear closing panels in the bottom part of the compartment with air outlet through the gratings on the roof and on the rear closing panel in the top part of the compartment.

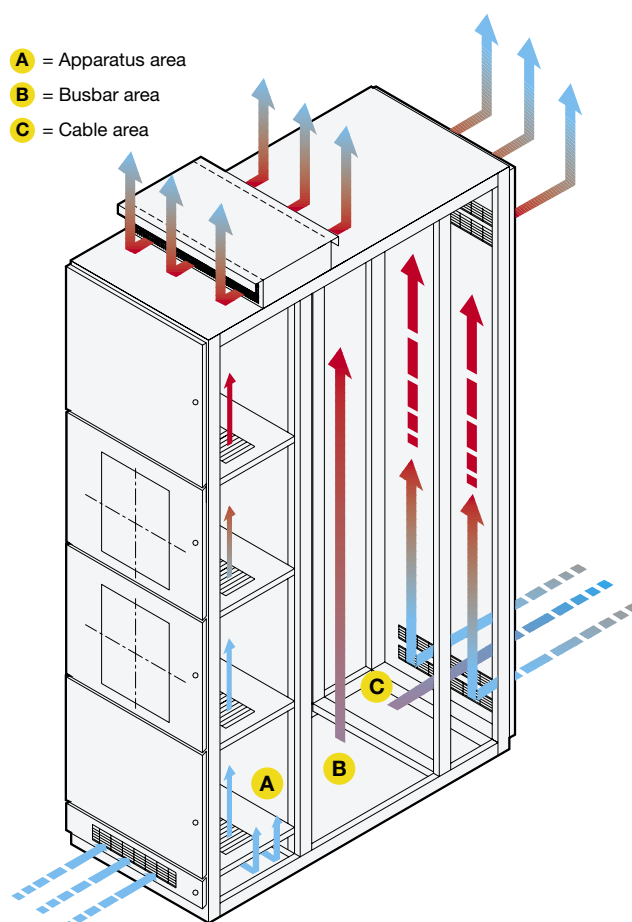


Diagram of natural ventilation of the unit

4.2 Versions of the switchgear type PC3.0/MNS R

Available versions

ABB PC3.0/MNS R switchgears are available, according to the customers' requirements, in the following versions/types:

- for indoor installations;
- top and bottom entry for power cables;
- top and bottom entry for bus ducts;
- top and bottom entry for auxiliary cables;
- standard painting;
- special painting cycle for aggressive environments;
- bare busbars;
- sheathed busbars;
- busbars with protective electrolytic treatment;
- flame-proof cables and wiring;
- flame-proof and alogen free cables and wiring;
- arc-proof;
- degree of protection IP30...54;
- forms of separation 3a, 3b and 4b.

Arc-proof version

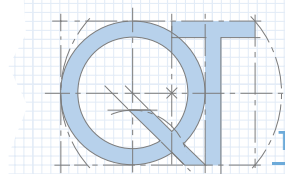
Upon request, in order to achieve the maximum safety levels, a version tested in compliance with the Technical Report IEC 61641 is available. It can withstand the stresses caused by any possible internal arc for short-circuit currents up to 75 kA for 500 ms at 726 V, corresponding to 100 kA for 300 ms, still keeping unchanged the voltage value of 726 V.



Version complying with UL Standards

There is a solution available in compliance with the Standard UL 1558 and intended for the North American market.



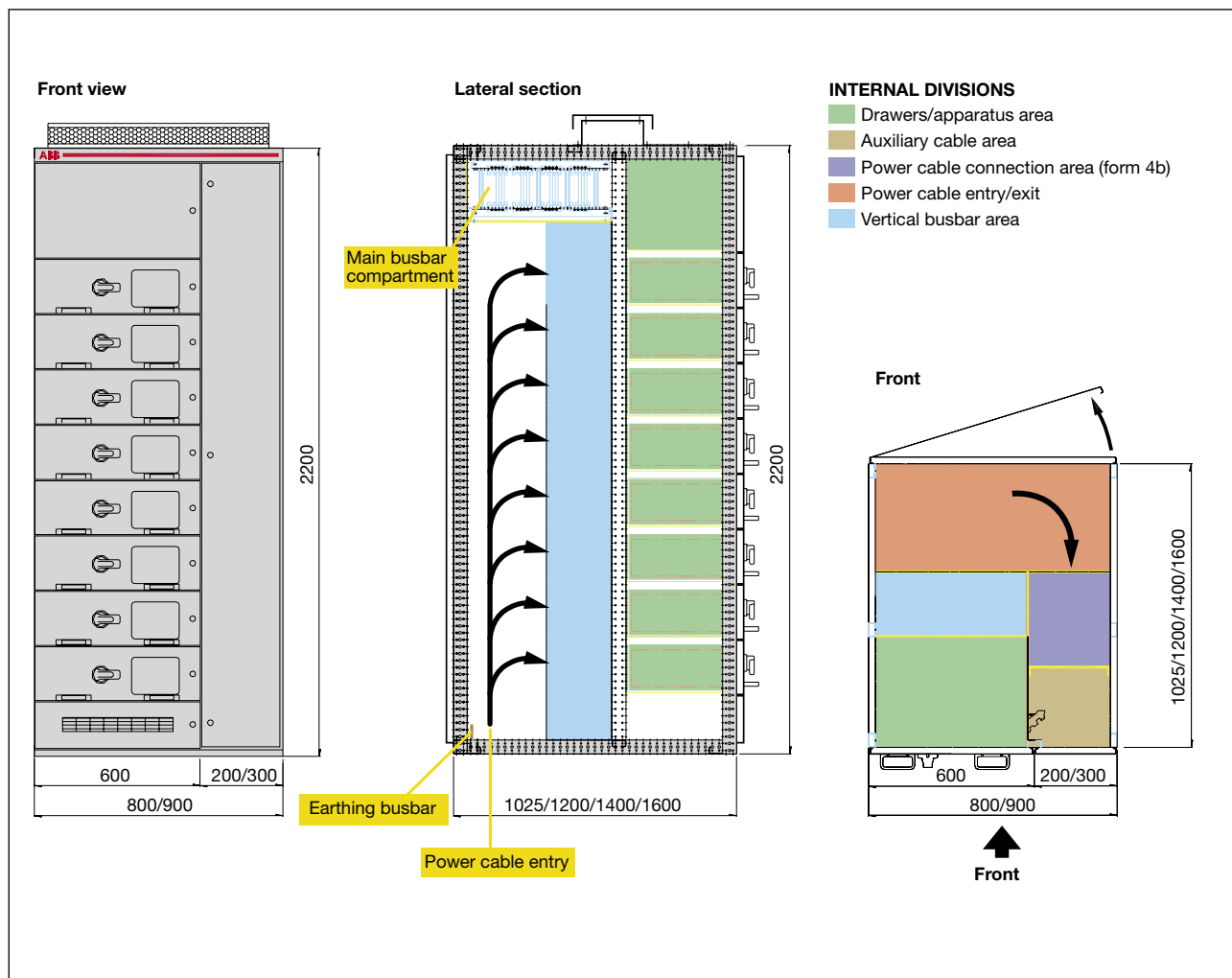


Power Motor Control Center integrated solutions

By means of a busbar transition panel it is possible to build Power Motor Control Centers to supply withdrawable motor control feeder units.

Besides, without transition panels, it is possible to obtain Power Motor Control Centers with withdrawable drawers by using MCC columns with rear access.

In this solution, the auxiliary connections are always accessed from the front, whereas the power connections are available at the back.

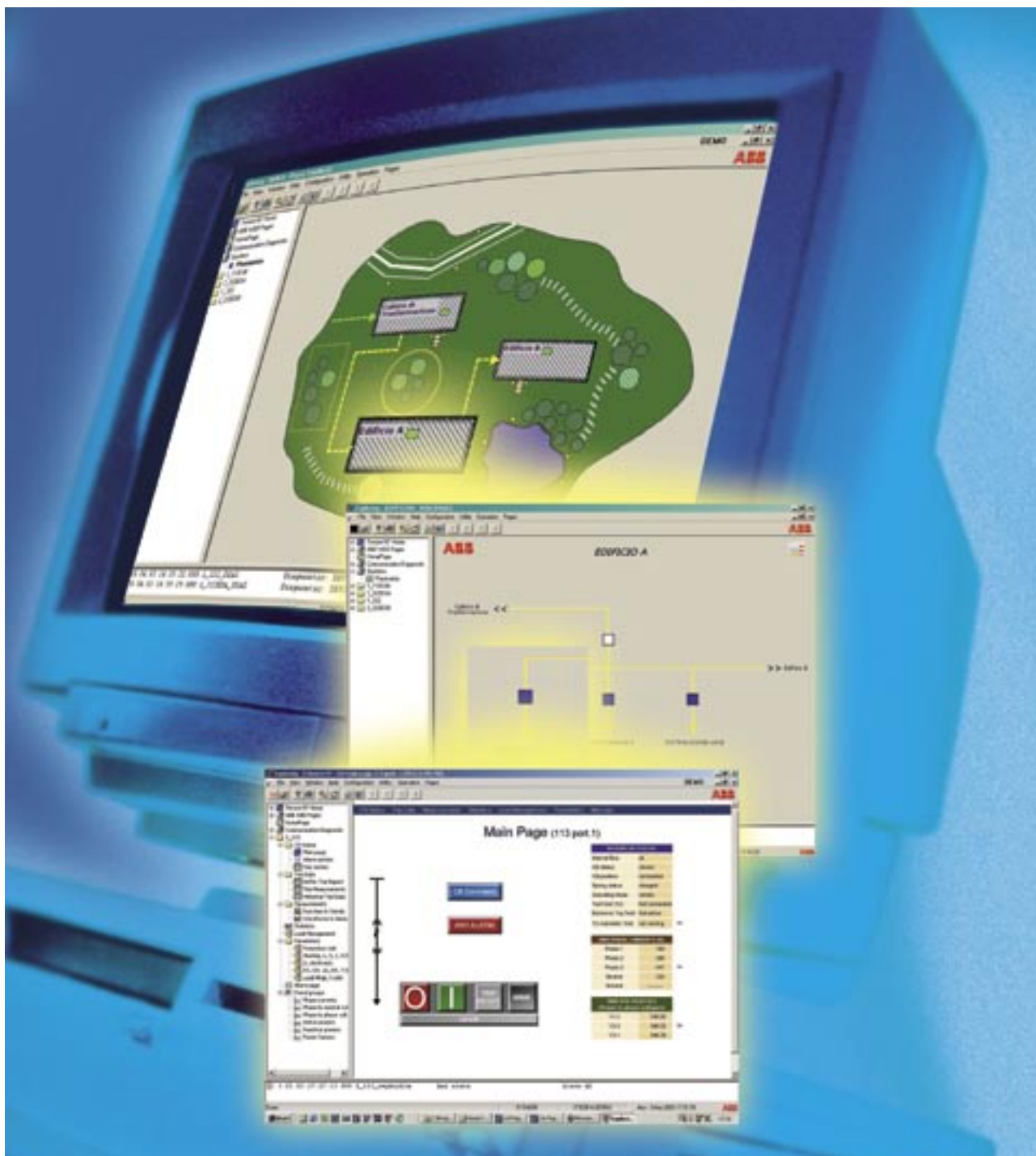


“Intelligent” switchgear

Thanks to the use of electronic releases with dialogue function, the air and moulded-case circuit-breakers installed inside the switchgear can be controlled and managed by a supervision system.

To integrate the moulded-case and air circuit-breakers equipped with electronic releases into a correct instal-

lation management, ABB SACE supplies SD-View 2000, a “ready to use” system consisting of a software which, when installed in a personal computer with standard configuration, allows the full control on the low voltage electrical installation. Modbus® RTU, the recognised standard in the electrical distribution sector, is supplied as communication protocol.



Annex A: Test on an arc-proof switchboard

This Annex describes a test carried out on an arc-proof switchboard.

The purpose of this test is verifying that no solid parts fly off in the area adjacent to the assembly due to internal arcing; the arc is caused by a current with a prospective short-circuit value specified by the manufacturer. More precisely, compliance with the following seven criteria must be assessed:

1. correctly secured doors, covers, etc., do not open;
2. parts which may cause a hazard, do not fly off (this includes both large parts as well as parts with sharp edges);
3. arcing does not cause holes in the freely accessible external parts of the enclosure as a result of burning or other effects;
4. the indicators arranged vertically do not ignite;
5. the equipotential bonding arrangement for the accessible parts of the enclosure is still effective;
6. the arc is limited to a defined area without re-ignition in adjacent areas;
7. after the fault extinction, the isolation or the removal of the functional unit affected by the fault, it is possible to put into safety the sound part of the switchboard (emergency operations). This shall be verified by a dielectric test to be performed at a value which is 1.5 times the rated voltage for the duration of 1 minute.

The test shall be carried out on a test specimen not previously subjected to an arcing test and the mounting conditions shall be as close as possible to those of normal service. The test specimen shall be fully equipped with its internal components and the assigned measure for the protection of person shall be effective.

To verify that gases or ejected solid parts do not cause unwanted effects, indicators constituted by pieces of cotton cloth fitted in mounting frames are used. These indicators shall be placed up to a maximum height of 2m and at a distance of 30cm \pm 5% from the assembly,

facing all the points where gases are likely to be emitted (joints, inspection windows, doors etc.).

The arc has been initiated between the phases by means of a bare copper ignition wire connecting the adjacent conductors across the shortest distance. The arc shall be initiated on three phases so that it can turn into a three-phase fault and the point of initiation shall be chosen so that the effects of the resultant arc produce the highest stresses in the assembly. The wire size depends on the test current.

The initiation points of the arc shall be chosen where, according to experience, an internal arc can form, that is:

- at the connection points of the main busbar systems;
- in the live not insulated parts on the supply side of the switching and protective devices;
- in the areas of cable terminals.

Besides, the ignition wire shall be connected only to accessible bare conductors.

The applied voltage of the test circuit shall be equal to the highest rated voltage of the assembly, with a tolerance of +5% and the prospective short-circuit current, specified by the manufacturer, shall be verified by a calibration oscillogram. The peak value of the current is obtained by multiplying the short-time withstand current by a factor n . The standardized values of factor n and the relevant power factor values are shown in the following table.

RMS value of short-circuit current kA	$\cos\varphi$	n
$I \leq 5$	0.7	1.5
$5 < I \leq 10$	0.5	1.7
$10 < I \leq 20$	0.3	2
$20 < I \leq 50$	0.25	2.1
$50 < I$	0.2	2.2

Note Values of this table represent the majority of applications. In special locations, for example in the vicinity of transformer or generators, lower values of power factor may be found, whereby the maximum prospective peak current may become the limiting value instead of the r.m.s. value of the short-circuit current.

The impedance used to verify the test current shall be the same used during the test.

The test duration is given by the manufacturer. It is chosen according to the time response of the electrical protection devices. If details regarding these devices are not known, a power supply duration of at least 0.1s is applied. Normally this duration should not exceed 0.5s.

A positive test result is obtained when the above mentioned criteria are fulfilled.

Three tests have been carried out:

A. calibration test;

B. test with arc ignition at the terminals of an outgoing unit;

C. test with arc ignition between the main busbars.

A. calibration test

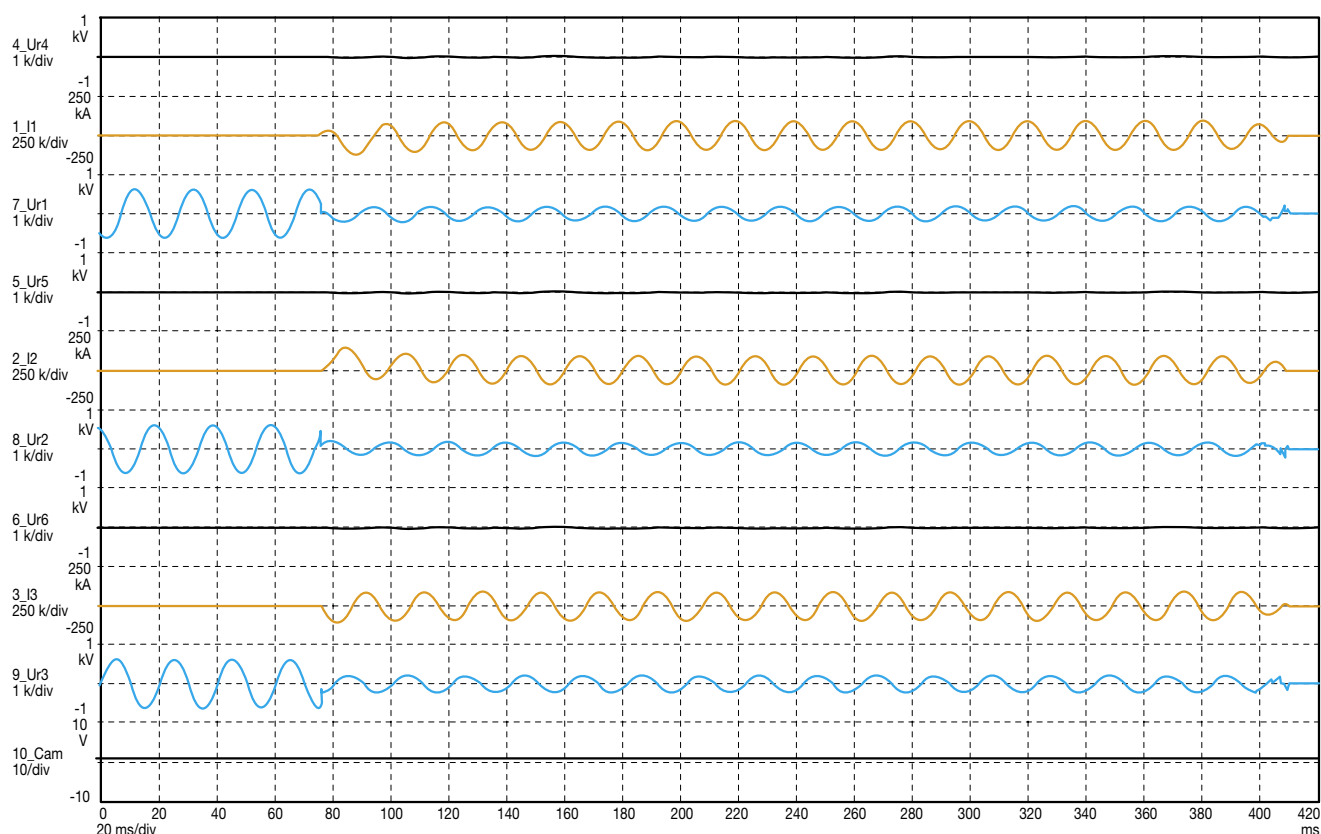
The current carrying capacity of the circuit is verified with 65 kA test current at 462 V (440 V+5%) rated voltage. The table below shows the values measured during the test.

	1_I1	2_I2	3_I3	Average values
Symmetrical current [kA]	65.9	65.0	65.7	65.5
Peak current [kA]	-129	144	-106	
Start [ms]	75.8	76.5	75.9	
End [ms]	409.4	408.5	409.4	
Cosφ				0.16

Legend:

- 1_I1, 2_I2, 3_I3: currents in the three phases
- Cosφ: power factor

The figure below reports the oscillogram showing the line-to-line voltages (7_Ur1, 8_Ur2, 9_Ur3) and the currents (1_I1, 2_I2, 3_I3) in the three phases.



B. test with arc ignition at the terminals of an outgoing unit
After the circuit calibration an arc-proof test shall be carried out applying for 0.3 s a test current of 65 kA at a voltage of 462 V (440 V+5%).

The arc has been initiated between the upper terminals of a circuit-breaker of one of the outgoing units: the duration of the current has resulted to be only 7.7 ms due to self-extinction of the arc. As a consequence also the current value results to be reduced.

The arc has extinguished within the first half of the full intended test duration without being ignited again and therefore, in compliance with the Technical Report IEC 61641, such test shall be repeated using the same point of initiation as for the first test.

Since the arc has extinguished within the first half of the full intended duration also during this repetition, a further test is not required.

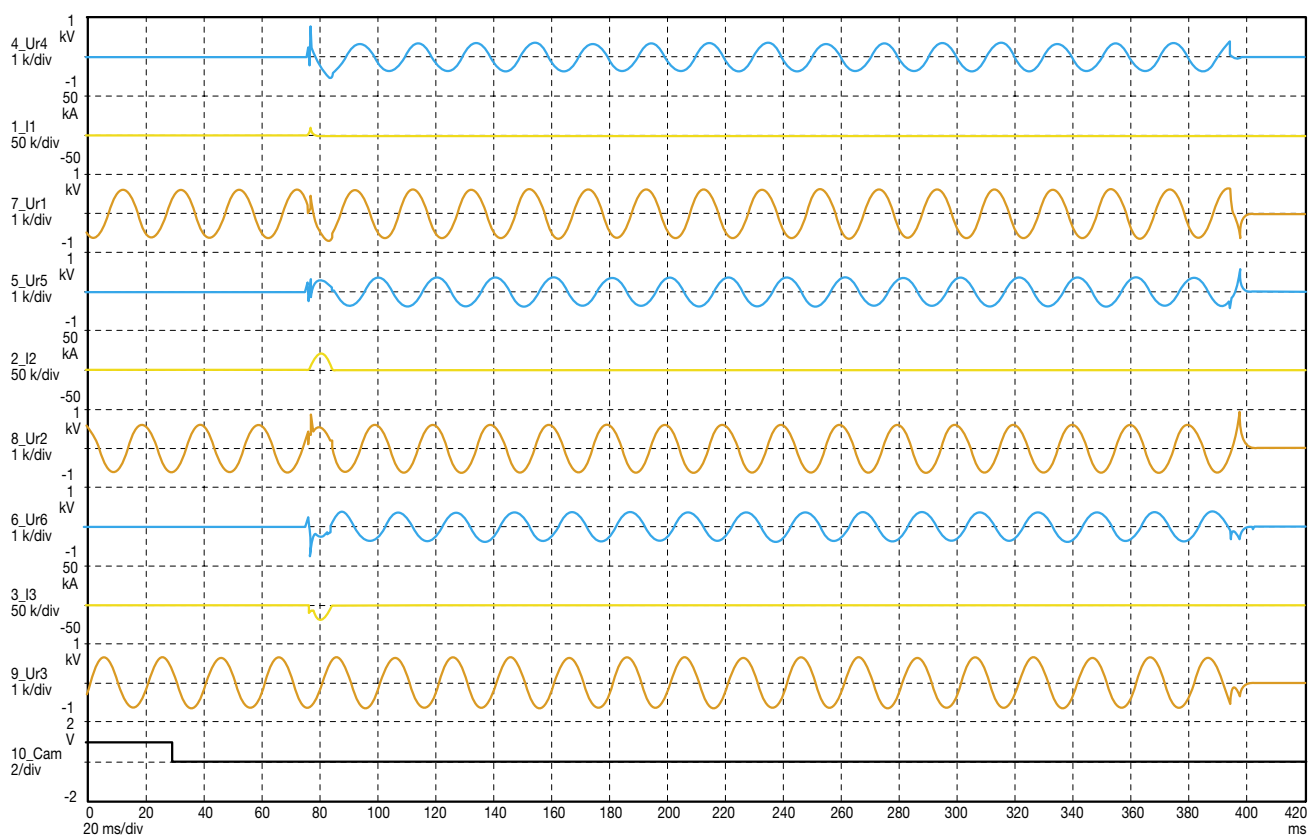
The table below shows the values measured during the test.

	1_I1/4_Ur4	2_I2/5_Ur5	3_I3/6_Ur6
Maximum current [kA]	10.3	19.8	-19.8
Maximum voltage [V]	786	349	-746
Arcing energy [kJ]	1.28	22.7	22.3
Total specific energy [A2s]	4.38E+04	1.43E+06	1.52E+06
Arcing power [W]	6.98E+06	5.52E+06	7.55E+06
Arc duration [ms]	1.1	7.7	7.6

Legend:

- 1_I1, 2_I2, 3_I3: currents in the three phases
- 4_Ur4, 5_Ur5, 6_Ur6: arcing voltages
- Cosφ: power factor

The figure below reports the oscillogram showing the arcing voltages (4_Ur4, 5_Ur5, 6_Ur6), the line-to-line voltages (7_Ur1, 8_Ur2, 9_Ur3) and the currents (1_I1, 2_I2, 3_I3) in the three phases. In the oscillogram the short duration of the currents due to the fast arc extinction can be noticed.



C. test with arc ignition between the main busbars

A further test, always 65 kA at 462 V, is carried out with arc initiation between the main busbars; the actual duration of the current has resulted to be 0.3 s, with temporary self-extinctions of the arc on the phases L1 and L3 and subsequent re-ignition.

The table below shows the values measured in the test.

	1_I1	2_I2	3_I3
Peak current [kA]	55.7	-62.3	46.6
Duration [ms]	301.37	301.37	216.76
Specific energy [A2s]	2.53E+08	2.97E+08	1.12E+08

The figure below reports the oscillogram showing the arcing voltages (4_Ur4, 5_Ur5, 6_Ur6), the line-to-line voltages (7_Ur1, 8_Ur2, 9_Ur3) and the currents (1_I1, 2_I2, 3_I3) in the three phases.

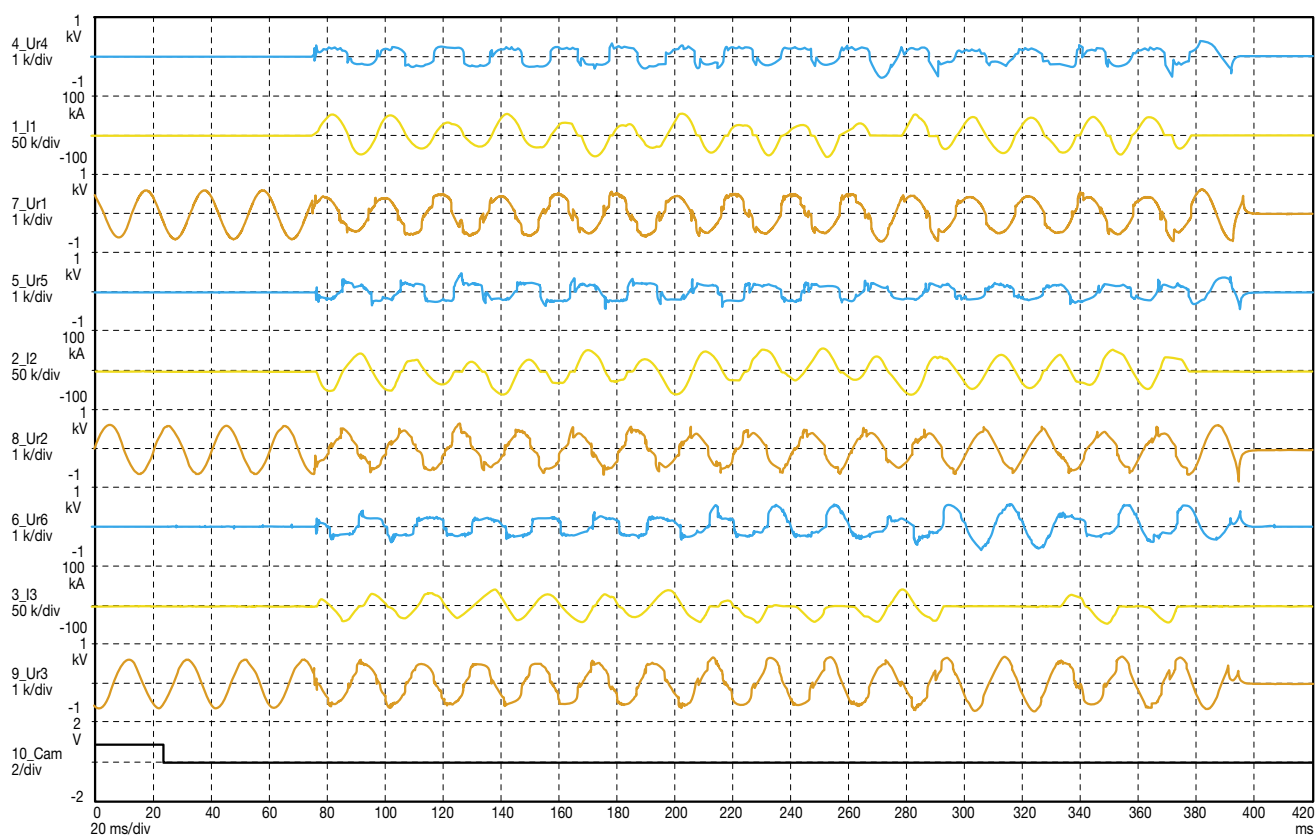




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Due to possible developments of standards as well as of materials, the characteristics and dimensions specified in this document may only be considered binding after confirmation by ABB SACE.

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