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TECHNICAL REPORT

RAPPORT TECHNIQUE

Enclosed low-voltage switchgear and controlgear assemblies – Guide for testing under conditions of arcing due to internal fault

Ensembles d'appareillage à basse tension sous enveloppe – Guide pour l'essai en conditions d'arc dues à un défaut interne

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ENCLOSED LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

GUIDE FOR TESTING UNDER CONDITIONS OF ARCING DUE TO INTERNAL FAULT

FOREWORD

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IEC/TR 61641, which is a technical report, has been prepared by subcommittee SC 121B: Low-voltage switchgear and controlgear assemblies, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage.

This third edition cancels and replaces the second edition published in 2008. It constitutes a technical revision.

This third edition includes the following significant technical changes with respect to the previous edition:

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– arcing classes to define the different forms of protection provided against arcing faults; (i) personnel protection, (ii) damage restricted to part of the ASSEMBLY, and (iii) ASSEMBLY suitable for limited further service.;
– two levels of personnel protection afforded by ASSEMBLIES under arcing fault conditions; (i) for ASSEMBLIES installed in areas where access to the ASSEMBLY is restricted to skilled persons, and (ii) for ASSEMBLIES installed in areas where the area is accessible to ordinary persons;
– option of individually insulating all live conductors to make the complete ASSEMBLY an arc ignition protected zone (referred to as an 'arc free zone' in previous editions of the Technical report);
– arc fault protection front, back and sides of an ASSEMBLY as the normal requirement;
– minimum performance requirements for arc ignition protected zone.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
121B/4/DTR	121B/14/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The reader's attention is drawn to the fact that Annex B lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this Technical Report.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

The IEC 61439 series of standards gives rules and requirements for interface characteristics, service conditions, construction, performance and verification of low-voltage switchgear and controlgear assemblies, hereafter called ASSEMBLIES.

The main objective of these standards is to achieve the safe operation of low-voltage switchgear and controlgear assemblies under normal operating conditions as well as under abnormal operating conditions, e.g. occurrence of overvoltages, overload or short-circuit currents. Therefore no characteristics, design and verification requirements are given dealing with the case of an arc fault inside the ASSEMBLY.

Nevertheless the occurrence of an internal arc cannot completely be excluded. On the rare occasions that they do occur, typically internal arc faults result from:

– conducting materials inadvertently left in ASSEMBLIES during manufacture, installation or maintenance;
– faults in materials or workmanship;
– entry of small animals such as mice, snakes, etc.;
– use of an incorrect ASSEMBLY for the application resulting in overheating and subsequently an internal arcing fault;
– inappropriate operating conditions;
– incorrect operation; or,
– lack of maintenance.

The occurrence of arcs inside enclosed ASSEMBLIES is coupled with various physical phenomena. For example, the arc energy resulting from an arc developed in air at atmospheric pressure within the enclosure will cause an internal overpressure and local overheating which will result in mechanical and thermal stressing of the ASSEMBLY. Moreover, the materials involved may produce hot decomposition products, either gases or vapours, which may be discharged to the outside of the enclosure.

Due to the risk of personal injury, damage and loss of energy supply as consequences of arc faults there is a demand for arc fault tested ASSEMBLIES, even though an arc fault in an ASSEMBLY is considered as an unlikely event. The purpose of this technical report is to give guidance on the method of testing of ASSEMBLIES under conditions of arcing in air due to an internal failure.

The ability of an ASSEMBLY to pass tests according to this technical report is only one aspect when assessing the potential risk due to an arc fault within an ASSEMBLY. The skill of personnel having access to the ASSEMBLY, the personal protective equipment (PPE) used, the working procedures applied and the conditions in the location where the ASSEMBLY is installed, are other aspects that need to be taken into account.

The possibility of an arc fault within an ASSEMBLY can be reduced by the addition of suitable solid insulation of all conductors. Such ASSEMBLIES are categorised as arcing class I. This technical report does not provide any indication of performance in the unlikely event of an arcing fault within an arcing class I ASSEMBLY (see 4.1).

General information about arc fault behaviour and possible protective measures from the perspective of the user of an ASSEMBLY is given in IEC/TR 61439-0:2013, C.3 and Annex A of this technical report.

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ENCLOSED LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

GUIDE FOR TESTING UNDER CONDITIONS OF ARCING DUE TO INTERNAL FAULT

1 Scope

This technical report gives guidance on the method of testing of ASSEMBLIES under conditions of arcing in air due to an internal fault.

The purpose of this test is to assess the ability of the ASSEMBLY to limit the risk of personal injury, damage of ASSEMBLIES and its suitability for further service as a result of an internal arcing fault.

The test procedure given in this technical report applies only:

– to enclosed, floor-standing or wall-mounted low-voltage switchgear and controlgear assemblies according to IEC 61439-2 (power switchgear and controlgear assemblies – PSC ASSEMBLIES);

NOTE This technical report can be used as a reference for arc fault tests of other products, but adaptations of the test procedures and acceptance criteria can apply taking into account the specifics of such other ASSEMBLIES or products.

– to situations when doors and covers of the ASSEMBLY are closed and correctly secured.

When tests under different or more severe conditions are agreed between the user and the manufacturer, this technical report can be used as a guide.

The test procedure given in this technical report takes into consideration:

– the effects of the internal overpressure acting on covers, doors, etc.;
– the thermal effects of the arc or its roots on the enclosures and of ejected hot gases and glowing particles.

The test procedure given in this technical report does not cover:

– other effects which can constitute a risk, such as toxic gases and loud noises;
– conditions during maintenance work, open doors or similar;
– access to the top and bottom of the ASSEMBLY.

This is a voluntary test made at the discretion of the manufacturer.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529:1989/AMD 1:1999
IEC 60529:1989/AMD 2:2013

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IEC 61439-1:2011, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61439-2:2011, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61439-2, as well as the following, apply.

3.1
permissible short-circuit current under self-extinguishing arcing conditions
$I_{\text{ps arc}}$
r.m.s. value of the maximum permissible prospective short circuit current at the incoming terminals of the ASSEMBLY, as declared by the manufacturer, for a given rated operational voltage U_e, for which the ASSEMBLY is able to satisfy the requirements of this technical report by means of a self-extinguishing arc and without the operation of any protection devices

3.2
permissible short-circuit current under arcing conditions
$I_{\text{p arc}}$
r.m.s. value of the maximum permissible prospective short circuit current at the incoming terminals of the ASSEMBLY, as declared by the manufacturer for a given rated operational voltage U_e, and arc duration (see 3.3) for which the ASSEMBLY is able to satisfy the requirements of this technical report

3.3
permissible arc duration
t_{arc}
value of the maximum arc duration which is not self-extinguishing and which is not limited by any current-limiting device, as declared by the manufacturer, for a given prospective short circuit current and rated operational voltage U_e at the incoming terminals of the ASSEMBLY and for which the requirements of this technical report are satisfied

Note 1 to entry: The value can be different for different parts of the ASSEMBLY.

3.4
permissible conditional short-circuit current under arcing conditions
$I_{\text{pc arc}}$
r.m.s value of maximum permissible prospective short circuit current at the incoming terminals of the ASSEMBLY, as declared by the manufacturer, for a given rated operational voltage U_e, for a circuit of an ASSEMBLY which satisfies the requirements of this technical report when the circuit is protected by a current-limiting device or by an arcing fault mitigation device with arc current-limiting function

3.5
arc
free burning short-circuit through air arising from a fault between live parts of different potential and/or between live parts and other conductive parts within an ASSEMBLY

3.6
personnel protection under arcing conditions
ability of an ASSEMBLY to limit the risk of personnel injury caused by the mechanical and thermal effects of an internal arcing fault

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3.7
ASSEMBLY protection under arcing conditions
ability of an ASSEMBLY to limit the effects of an internal arcing fault inside the ASSEMBLY to an area as defined by the manufacturer

3.8
ASSEMBLY protection under arcing conditions with limited operation
ability of an ASSEMBLY to limit the effects of an internal arcing fault inside the ASSEMBLY to an area as defined by the manufacturer and to allow limited continued operation after such a fault

3.9
arc ignition protected zone
part of a circuit within an ASSEMBLY where specific measures are provided to ensure the initiation of an arcing fault is a remote possibility

Note 1 to entry: Arc ignition protected zones were previously referred to as “arc free zones”.

Note 2 to entry: The concept of an arc ignition protected zone takes into account that insulation is an important means to reduce the probability of an arc ignition and the possibility of an arc propagating within the ASSEMBLY. When adopting the concept of arc ignition protected zones it should be recognized that also within an arc ignition protected zone there is a residual risk of an arc ignition, either due to damage of the insulation itself or due to failure of the insulated conductor or its connections. The quality and reliability of the conductor, its connections and its insulation within an arc ignition protected zone is crucial for the additional arc fault protection offered by the so called arc ignition protected zone.

Note 3 to entry: See 6.1 for constructional requirements of an arc ignition protected zone.

3.10
arc tested zone
part of a circuit or compartment where the ignition of an arc is made and all selected criteria for the assessment of the test(s) are fulfilled

3.11
current-limiting device
device that, within a specified range of current, prevents the let-through current reaching the prospective peak value and which limits the let-through energy (I^2t)

3.12
arcing fault mitigation device
device that operates only in case of an arc fault to reduce the duration of burning

Note 1 to entry: Arc mitigation devices use effects of an arc, e.g. light, gas pressure, harmonics in the current or voltage etc, and possibly the magnitude of the current to detect an arc inside the ASSEMBLY. They can comprise special components for reduction, fast interruption or transfer of the fault current to a bolted short circuit link, and/or they can instantaneously trip an upstream circuit breaker irrespective of its settings.

3.13
arcing fault mitigation device with arc current-limiting function
arcing fault mitigation device with an operation time short enough to prevent the arc current reaching its otherwise attainable peak value

Note 1 to entry: The arc current can be limited by fast interruption of the fault current or by transfer of the fault current to another current path. In the first case the arc current-limiting arc mitigation device acts as a current-limiting device, whereas in the latter case the fault current continues to flow, can increase if the impedance of the new current path is lower (e.g. in the case of a bolted short circuit link) and needs to be interrupted by another protection device.

3.14
access (to an ASSEMBLY)
ability of a person to be in close proximity to an ASSEMBLY with all its doors and covers closed and secured as in normal service and to operate devices such as switches and circuit breakers that have external operating handles, buttons etc.

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3.15
restricted access
access to the location of the ASSEMBLY limited to authorized personnel only

Note 1 to entry: Technical measures to restrict access are, for example, placing the ASSEMBLY in dedicated switch rooms, behind walls, fences or obstacles. Organizational measures are for example; safety instructions or marking of walkways at the appropriate distance.

3.16
unrestricted access
access to the location of the ASSEMBLY by any person, including ordinary persons, allowed

3.17
duration of test
t_d
time the power supply is applied to the ASSEMBLY under arc fault test conditions

3.18
solid insulation
suitable non-liquid, non-gaseous, non-conducting material used to insulate conductive parts of the main circuits of an ASSEMBLY that can only be removed by the use of a tool or destruction

3.19
duration of burning
t_b
total burning time of the arc during a single test (comprising in the case of arcs that extinguish and re-strike, the sum of the individual burning durations)

4 Classification of low-voltage switchgear and controlgear assemblies

4.1 Classification with regard to the protection characteristic

According to their characteristics under arcing conditions ASSEMBLIES can be classified by the manufacturer into:

Arcing class A – ASSEMBLY providing personnel protection under arcing condition by arc tested zones conforming to arcing conditions in 8.7, criteria 1 to 5, and by arc ignition protected zones, if any;

Arcing class B – ASSEMBLY providing personnel and ASSEMBLY protection under arcing conditions by arc tested zones conforming to arcing conditions to 8.7, criteria 1 to 6, and by arc ignition protected zones, if any;

Arcing class C – ASSEMBLY providing personnel and ASSEMBLY protection under arcing conditions by arc tested zones conforming to arcing conditions with limited operation in 8.7, criteria 1 to 7, and by arc ignition protected zones, if any;

Arcing class I – ASSEMBLY providing a reduced risk of arcing faults solely by means of arc ignition protected zones.

4.2 Classification with regard to persons who have access

Additionally the ASSEMBLY is classified according to the kind of persons who have access to area where the ASSEMBLY is installed, as follows:

– restricted access (default arrangement);
– unrestricted access (special arrangement).

When considering arc fault protection in respect of ASSEMBLIES the first protective measure should be, whenever practical, to locate the ASSEMBLY in an area where access is restricted to authorised personnel only. Unless specifically agreed between the user and the manufacturer, restricted access is applicable.

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NOTE 1 Operation of ASSEMBLIES according to IEC 61439-2 by ordinary persons is not intended. Nevertheless they can be accessible to ordinary persons, e.g. when they are placed in a general work floor without any complementary safety measures and/or rules.

NOTE 2 Additionally local safety regulations have to be taken into account and can impose additional and/or more stringent requirements with regard to access, personal protective equipment (PPE) to be used and working procedures to be applied.

5 ASSEMBLY characteristics

For ASSEMBLIES with only arc ignition protected zones:

– Classification of the ASSEMBLY – Arcing class I.

The following characteristics should be declared by the manufacturer as appropriate, if the ASSEMBLY was arc fault tested according to this technical report:

– Rated operational voltage (U_e);
– Classification of the ASSEMBLY (arcing class A, arcing class B or arcing class C);
– For arcing class B and arcing class C ASSEMBLIES the defined areas (e.g. section, sub-section) to which the effects of an internal arcing fault are limited.

a) If the arc duration is limited by a non current-limiting device (inside or upstream of the ASSEMBLY) and/or an arc mitigation device which does not limit the arc current, the following additional characteristics should be stated:

– permissible short circuit current under arcing conditions ($I_{p\ arc}$);
– permissible arcing duration (t_{arc});

NOTE 1 The permissible current under arcing conditions can be lower than the rated short time withstand current (I_{cw}).

or

b) If the arc duration and the arc current are limited by a current-limiting protection device (inside or upstream of the ASSEMBLY) and/or an arc current-limiting arc mitigation device:

– permissible conditional short-circuit current under arcing conditions ($I_{p\ arc}$).

The characteristics and settings of the current-limiting devices (e.g. current rating, breaking capacity, cut-off current, I^2t of current-limiting circuit breakers or fuses), or of the arc current-limiting arc mitigation device, necessary for the protection of the circuit should be stated in the test report.

NOTE 2 The permissible conditional short circuit current under arcing conditions can be lower than the rated conditional short circuit current (I_{cc}).

or

c) If the arc duration is limited because the design of the ASSEMBLY is such that the arc is self-extinguishing without operation of any protection device (see 8.6.3):

– permissible short-circuit current under self-extinguishing arcing conditions ($I_{ps\ arc}$).

NOTE 3 Different sets of characteristics a), b) or c) can be stated for different parts of the ASSEMBLY.

6 Requirements and tests for an arc ignition protected zone

6.1 Constructional requirements of an arc ignition protected zone

A part of a circuit within an arc ignition protected zone is considered such a zone if the following conditions are fulfilled:

– all live parts of each main circuit are separately protected by solid insulation or insulating barriers;

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– the insulation complies with the electrical, thermal and mechanical requirements as defined in IEC 61439-2;
– the insulating materials and constructional means of the insulation protected zone meet the dielectric test requirements of 6.2;
– the solid insulation provides ingress protection such that foreign bodies cannot make contact with the live conductors in accordance with IP4X of IEC 60529;
– insulating barriers provide protection against contact with live conductors in accordance with IP3XD of IEC 60529.

6.2 Dielectric test of arc ignition protected zones

Representative samples of arc ignition protected zones should be power frequency dielectric tested by the manufacturer by applying a metal foil laid on the outer surface of insulation covering live conductors and over any joints and openings in the insulation.

For this test the test voltage should be equal to 1,5 times the values given in IEC 61439-1:2011, Table 8. The test voltage should be in accordance with IEC 61439-1:2011, 10.9.2.2. The power frequency voltage at the moment of application should not exceed 50 % of the full test value. It should then be progressively increased to the full value for 5^{+2}_{0} s. Acceptance criteria are in accordance with IEC 61439-1:2011, 10.9.2.4.

6.3 IP test of arc ignition protected zones

IP4X for solid insulation and IP3XD for insulating barriers should to be tested according to IEC 60529.

7 Selection of test specimen and validity of tests for similar designs (possibilities for derivation)

The arc tests should be made on representative ASSEMBLIES. Due to the variety of types, ratings and possible combinations of functional units and components, it is not practicable to make arc tests on all the arrangements. The performance of any particular arrangement can be substantiated by test results of a comparable design. The test should be performed on every representative functional unit in the position deemed most onerous in the ASSEMBLY.

ASSEMBLIES or functional units which are protected by current-limiting devices should be tested with the device having the highest values of the limitation characteristics (I^2t, I_{pk}) at the intended prospective short circuit current and operational voltage.

The validity of the results of a test carried out in a functional unit of a particular design of an ASSEMBLY can be extended to a similar design provided that the original test was equal to or more stressing and this other functional unit can be considered as equal to the tested one in the following aspects:

– dimensions;
– structure and strength of the enclosure;
– architecture of the partitioning;
– performance of the pressure relief device, if any;
– insulation system;
– surface treatment of the inside of the enclosure and internal partitions, e.g. non conducting surface treatment or bare metal.

A test carried out at a particular short circuit current, rated operation voltage and duration covers:

– the same or lower short circuit currents;

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– same or lower rated operational voltage, and;
– the same or lower duration.

An ASSEMBLY intended to be used with d.c. should to be tested with d.c.. A substitution with an a.c. test is not recommended because the behaviour of the arc and any associated protective devices differs considerably.

8 Testing – Arc fault tests

8.1 General

The test is carried out on representative samples.

When conducting arcing fault tests:

a) the test should be carried out on a test specimen not previously subjected to an arcing test or on a refurbished test specimen as appropriate. The specimen and the equipment in it can be repaired or replaced before each test;

NOTE Degradation of insulation due to carbonization or moderate erosion of metal parts is not necessarily considered to render a unit unsuitable for a further test.

b) the mounting conditions should be as close as possible to those of normal service. A mock-up of any room in which the ASSEMBLY could be installed is in general not necessary;

c) the doors and covers are closed and correctly secured as prescribed by the manufacturer;

d) the test specimen should be fully equipped and complete with arc ignition protected zones, if any. Mock-ups of internal components (excluding arc ignition protected zones) are permitted provided that:

   1) they have the same volume and shape, and a similar external material as the original items;

   2) any metallic external material is earthed in a similar manner to normal service;

   3) the main circuit of that functional unit should be replicated by representative conductors which are energized;

e) any outgoing cables normally associated with the functional unit under test should be installed as in service with any cable glands or similar equipment. In addition any cables on adjacent functional units that could influence the results of the tests should be installed;

f) all switching devices are switched on and removable and withdrawable parts are connected to the supply circuit. All other equipment which can be mounted on the enclosure, for example, switching control devices, measuring instruments, and monitoring devices should be installed as in normal service;

g) if the ASSEMBLY contains an arc mitigation device, then this device is allowed to operate, as specified by the manufacturer;

h) the assigned measures for protection against electric shock should be effective (see IEC 61439-2:2011, 8.4);

i) the arcing test is carried out as a single-phase or three-phase test according to the service conditions.

Where tests on an ASSEMBLY have been conducted in accordance with a previous edition of IEC/TR 61641, and the test results fulfil the requirements of this technical report, the tests do not need to be repeated. By agreement between user and manufacturer tests to earlier editions of this Technical Report remain valid.

8.2 Voltage

The applied voltage to the test circuit is (105 ± 5) % of the rated operational voltage U_e of the ASSEMBLY.

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8.3 Current

For the tests, the value of the prospective short-circuit current at a test voltage equal to 1,05 times the rated operational voltage should be determined from a calibration oscillogram which is taken with the supply conductors to the ASSEMBLY short-circuited by a connection of negligible impedance placed as near as possible to the input supply of the ASSEMBLY. The oscillogram should show that there is a constant flow of current such that it is measurable for the specified test duration. The value of current during the calibration is the average of the r.m.s. values of the a.c. component in all phases. The calibration current in each phase should be equal to the permissible short-circuit current within a tolerance of $^{+5}_{0}$ % and the power factor should be within a tolerance of $^{+0,00}_{-0,05}$.

For the relationship between peak value and r.m.s. value of short-circuit currents, see IEC 61439-1:2011, Table 7.

The impedance used to adjust the test supply is the same used during the test.

8.4 Frequency

All tests with a.c. current should be made at the rated frequency of the ASSEMBLY with a tolerance of ±25 %.

NOTE Tests executed on 50 Hz are deemed to cover applications for 60 Hz and vice versa.

8.5 Duration of the test

The power supply should be applied to the ASSEMBLY under test for a duration as given by the manufacturer and should be applied for at least 0,1 s. Normally the duration of test will be between 0,1 s and 0,5 s and is chosen according to the time response of the electrical protection devices.

NOTE When high voltage protection equipment is relied upon to isolate a fault the permissible arc duration of the incoming switching device in general will be 0,3 s to allow for the operation of the equipment.

In the case of a circuit protected by a non current-limiting device the voltage should be applied for the specified duration of the test. Where the circuit is protected by a current-limiting device the voltage should be applied for at least 0,2 s.

8.6 Test procedure

8.6.1 Supply circuit

The test sample is connected and supplied corresponding to the normal service arrangement. This includes the connection of PE, N and PEN conductors, which are connected directly to the neutral point of the test current source. If the supply can be fed from more than one direction, the direction of feed to be chosen is that one likely to result in the highest stress(es).

8.6.2 Arc initiation

The point of initiation should be chosen so that the effects of the resultant arc produce the highest stresses in the ASSEMBLY.

When determining the position of arc ignition the following points along the main circuit should be considered, as applicable:

a) load side of the outgoing functional unit,

b) supply side of the outgoing functional unit and any associated arc ignition protected zone,

c) along the distribution busbar,

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