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Low-voltage switchgear and controlgear assemblies - Internal arc-fault protection of low-voltage switchgear and controlgear assemblies in accordance with the IEC 61439 series

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Low-voltage switchgear and controlgear assemblies - Internal arc-fault protection of low-voltage switchgear and controlgear assemblies in accordance with the IEC 61439 series

FOREWORD

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IEC TS 61641 has been prepared by subcommittee SC 121B: Low-voltage switchgear and controlgear assemblies, of IEC technical committee TC 121: Switchgear and controlgear and their assemblies for low voltage. It is a Technical Specification.

This edition cancels and replaces IEC TR 61641:2014 and IEC TS 63107:2020. This edition constitutes a technical revision.

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

a) Introduction of the term "arcing class zone", using the term "arcing classes" from the previous document IEC TR 61641:2014.

b) Structured using of the terms "zone" and "area". "Area" is used to describe the place of installation and the accessibility of the assembly (macro-environment). "Zone" is used in this document to describe a defined space within the assembly (micro-environment).

c) Assembly protection is classified into two levels.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
121B/228/DTS	121B/232/RVDTS

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

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document is to be used in conjunction with the IEC 61439 series.

It supplements or modifies the corresponding clauses in the IEC 61439 series.

The following numbering system is used:

– subclauses, tables and figures that are numbered starting from 101 are additional to those in the IEC 61439 series;

– unless notes are in a new subclause or involve notes in the IEC 61439 series, they are numbered starting from 101, including those in a replaced clause or subclause;

– additional annexes are lettered AA, BB, etc.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

INTRODUCTION

This document deals with the internal arc-fault protection of low-voltage switchgear and controlgear assemblies.

The IEC 61439 series of documents identifies rules and requirements for the interface characteristics, service conditions, construction, performance and verification of low-voltage switchgear and controlgear assemblies, hereafter called an assembly. The main objective of the IEC 61439 series of documents is to provide assemblies that operate safely under normal operating conditions. An internal arc-fault is not considered as a normal operating condition. Therefore, no characteristics, design and verification requirements are given dealing with an internal arc-fault within an assembly.

Assemblies built, operated and maintained according to the IEC 61439 series cannot exclude the risk of occurrence of an internal arc-fault. On the rare occasions that they do occur, internal arc-faults result from circumstances including:

– foreign objects inadvertently left in the assembly during manufacture, installation or maintenance operations, e.g. a tool;
– faults in construction materials and components;
– entry of small animals like mice, snakes, etc.;
– use of an inappropriate assembly for the application resulting in incorrect operation, overheating, accelerated ageing of insulation;
– unforeseen operating conditions or lack of maintenance;
– human error, poor or faulty workmanship whether under energized or de-energized conditions.

Avoiding all of the above and similar circumstances results in a remote possibility of an internal arc-fault. Any of these circumstances creates a higher possibility of an internal arc-fault, which should be considered in a risk assessment.

The ignition of an internal arc-fault within an assembly generates various phenomena, such as extreme overheating resulting in high overpressure inside the assembly and emission of hot materials, gases and flame which may endanger people in close proximity to the assembly causing burns from the potential projection of these hot materials and/or gases from the assembly as well as impacts from suddenly opening doors, and damage to the assembly.

Due to the risk of personal injury, damage and loss of power availability because of an arc-fault there is a demand for internal arc-fault verified assemblies.

There are various methods of mitigating the effects of internal arc-faults. Assemblies often use several methods for protection against the risk of injury, damage and loss of power availability as a consequence of an arc-fault.

This document describes the verification of an assembly under conditions of arcing in air due to an internal failure where the mechanical construction of the assembly provides arc-fault resistance, commonly called "passive" arc-fault protection, and an assembly which is fitted with an internal arc-fault mitigation system (IAMS), commonly called "active" arc-fault protection.

The aim of the integration of the IAMS into assemblies is to reduce the released energy in case of an internal arc-fault by using the activation of an internal arc-fault reduction device (IARD) in order to:

– improve the ability of assemblies to reduce the risk of injury to personnel;
– reduce the consequential damage to assemblies;
– improve the power availability from assemblies for further service after an internal arc-fault.

The above-mentioned improvements are related only to an assembly complying with certain parts of the IEC 61439 series.

The ability of an assembly to pass tests according to this document is only one aspect when assessing the potential risk due to an internal arc-fault within an assembly. Risk assessments should be carried out considering for example, the skill of personnel having access to the assembly, any protective measures required, the working procedures applied and the conditions in the location where the assembly is installed.

General information about internal arc-fault considerations and possible protective measures from the perspective of the user of an assembly is given in IEC TR 61439-0:2022, Clause D.2 and Annex AA and Annex BB of this document.

1 Scope

This document identifies methods used to verify the ability of the assembly:

– to limit the risk of injury to personnel during an internal arc-fault;
– to limit the damage to an acceptable level as a result of an internal arc-fault;
– to improve the power availability following an internal arc-fault.

This document takes into consideration:

– the effects of the internal overpressure acting on covers, doors, etc.;
– the thermal effects of the internal arc-fault or its roots on the enclosures and of ejected hot gases and glowing particles.
– the correct function of the IAMS within the assembly;
– the prevention of unintended operation of the IAMS within the assembly, for example caused by switching arcs;
– the functioning behaviour of the IAMS immediately after the assembly is energized.

This document describes different methods to assess the performance of an assembly or zones of an assembly in respect of arcing in air due to an internal failure:

– with "passive" arc-fault protection (provided by mechanical construction, e.g. suitable door locks, hinges, pressure relief devices, barriers);

NOTE 1 This approach corresponds to the method according to IEC TR 61641:2014.

– with "active" arc-fault protection (with the integration of IAMS);

NOTE 2 This approach corresponds to the method according to IEC TS 63107:2020.

– with the use of an arc ignition protected zone (to make the ignition of an arc-fault an extremely remote possibility).

NOTE 3 This approach corresponds to the method according to IEC TR 61641:2014.

IAMS consist of internal arc-fault control devices (IACD), e.g. optical-based IACD's in accordance with IEC 60947-9-2 and internal arc-fault reduction devices (IARD), e.g. arc quenching devices (AQDs) in accordance with IEC 60947-9-1 and short-circuit protection devices SCPD's in accordance with IEC 60947-2 (see Figure EE.1). IAMS can be provided by a combined-type device according to IEC 60947-9-2.

IEC 60364-4-42:2024 (Clause 427) provides guidance on the need for internal arc-fault protection.

This document does not supersede any individual product standard. Individual devices are required to comply with their relevant standard.

This document does not apply to integration of arc fault detection devices (AFDD) according to IEC 62606.

Informative Annex AA gives guidance for the user (see IEC 61439-1:2020, 3.11) on internal arc-fault mitigation.

Informative Annex BB gives guidance for the user (see IEC 61439-1:2020, 3.11) of assemblies with "active" arc-fault protection (with the integration of IAMS).

Informative Annex CC gives guidance for the original manufacturer of an assembly when incorporating an integrated IAMS.

This document does not consider other effects which can constitute a risk, such as emission of toxic gases, loud noises and/or intense light. Furthermore, this document does not consider conditions during maintenance work and the personal protective equipment used.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60947-9-1:2019, *Low-voltage switchgear and controlgear - Part 9-1: Active arc-fault mitigation systems - Arc quenching devices*

IEC 60947-9-2:2021, *Low-voltage switchgear and controlgear - Active arc-fault mitigation systems - Part 9-2: Optical-based internal arc-detection and mitigation devices*

IEC 61439-1:2020, *Low-voltage switchgear and controlgear assemblies - Part 1: General rules*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61439 series of document and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

3.1 General terms

Additional terms and definitions:

3.1.101
internal arc-fault
free burning fault current through air arising from a fault between live parts of different potential and/or between live parts and other conductive parts within an enclosed assembly

3.1.102
arcing class
protection level to differentiate the various methods of protection provided against effects of arc-faults

3.1.103
access (to an assembly)
ability of a person to be in close proximity to an assembly to operate devices such as switches and circuit-breakers that have external operating handles, buttons, etc. where all doors, covers are closed and secured as in normal service

3.1.104
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 switchgear rooms, behind walls, fences or obstacles. Organizational measures are for example safety instructions or marking of gangways at the appropriate distance.

3.1.105
unrestricted access
access to the location of the assembly by any person, including ordinary persons

3.6 Insulation characteristics

Additional term and definition:

3.6.101
solid insulation
suitable non-liquid, non-gaseous, non-conducting material used to insulate conductive parts of the electrical circuits of an assembly that can only be removed by the use of a tool or destruction

3.8 Characteristics

Additional terms and definitions:

3.8.101
current characteristics

3.8.101.1
prospective short-circuit current under arcing conditions
$I_{cp\ arc}$
value of the I_{cp} (see IEC 61439-1:2020, 3.8.7 prospective short-circuit current) for which the assembly is able to meet the requirements of this document

Note 1 to entry: Former terms of the current(s) and compatibility to this term are mentioned in EE.2.3.

3.8.101.2
internal arc-fault current
I_{arc}
average RMS value for AC or mean value for DC of the short-circuit current under arcing conditions over the duration of burning t_b

Note 1 to entry: Former terms of the current(s) and compatibility to this term are mentioned in EE.2.3.

3.8.101.3
peak internal arc-fault current
$I_{pk\ arc}$
highest peak value of short-circuit current under arcing conditions

Note 1 to entry: Former terms of the current(s) and compatibility to this term are mentioned in EE.2.3.

3.8.102
time characteristics

3.8.102.1
prospective internal arc-fault duration
$t_{cp\ arc}$
duration the power supply is applied to the assembly under internal arc-fault conditions for a given prospective short-circuit current under arcing conditions $I_{cp\ arc}$

Note 1 to entry: Former terms of the time(s) and compatibility to this term are mentioned in EE.2.3.

3.8.102.2
duration of burning
t_b
total burning time of the internal arc-fault during a single test (comprising in the case of arcs that extinguish and re-strike, the sum of the individual burning durations) expressed for each phase individually in the case of a multi-phase system

3.8.102.3
arc ignition time
t_0
moment in time at which the ignition wire has vaporized, considered as a reference for the measurement of an IACD time response

Note 1 to entry: See for clarification t_0 is shown in Figure DD.7.

[SOURCE: IEC 60947-9-2:2021, 3.20, modified – Addition of "at which the ignition wire has vaporized" and addition of the Note to entry.]

3.8.102.4
arc-fault mitigation time in an assembly
t_{mtA}
interval of time between the ignition t_0 of the internal arc-fault and the effective commutation of currents into the AQD

Note 1 to entry: Arc-fault mitigation time in an assembly is as described in Figure DD.5 between points c) and g).

Note 2 to entry: For applications without AQD(s), the arc-fault extinction time t_{ae} of IEC 60947-9-2 can be used as an alternative to t_{mtA}.

3.8.102.5
arc-fault extinction time
t_{ae}
<IACD> interval of time between the ignition of the internal arc-fault t_0 and the complete extinction of the same

Note 1 to entry: Extinction time can be determined by measuring upstream line current and IACD current, alternatively downstream line current.

[SOURCE: IEC 60947-9-2:2021, 3.6. modified – Addition of t_0 internal arc-fault, deletion of Note 2 to entry.]

3.8.103
other characteristics

3.8.103.1
arc-fault energy
E_{arc}
energy released by the arc during the internal arc-fault

Note 1 to entry: In this document, the arc-fault energy is the value determined by the measured voltages at the incoming terminals of the assembly, the measured currents and durations. The formulas can be found in 10.101.6.6.1 and 10.101.6.6.2.

Additional terms and definitions:

3.101 Types of protection under arcing conditions

3.101.1
personnel protection under arcing conditions
ability to limit personal injury caused by the mechanical and thermal effects of an internal arc-fault, other effects which can constitute a risk such as toxic gases or other risks as radiated light flashes and noise not being considered

3.101.2
assembly protection under arcing conditions
ability of an assembly to limit the effects of an internal arc-fault inside the assembly to a zone as defined by the manufacturer

3.101.3
assembly protection under arcing conditions with limited operation
ability to limit the effects of an internal arc-fault inside the assembly as defined by the manufacturer and to allow conditional limited continued operation after such a fault

3.101.4
enhanced protection under arcing conditions
assembly protection considering faster power availability from the assembly by reducing recommissioning time and improving personnel protection with further reduction of the risk of personal injury caused by the mechanical and thermal effects of an internal arc-fault due to the reduction of internal arc-fault energy

3.102 Zones classification

3.102.1
arcing class zone
space within an assembly defined by the original manufacturer that fulfils the requirements of a given protection level against effects of internal arc-faults

Note 1 to entry: An arcing class zone can be defined for the complete assembly or part of the assembly (see Table 102).

3.102.1.1
IAMS protected zone
arcing class zone monitored by an IAMS where an internal arc-fault is detected and then mitigated and finally extinguished

3.102.1.2
arc ignition protected zone
arcing class zone where specific measures are provided to ensure the initiation of an arc-fault is an extremely remote possibility

Note 1 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 internal arc-fault ignition and the possibility of an internal arc-fault 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 internal arc-fault 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 and effectiveness of maintenance of the assembly are crucial for the additional internal arc-fault protection offered by the arc ignition protected zone.

Note 2 to entry: See 8.101 for constructional requirements of an arc ignition protected zone.

Note 3 to entry: Arcing class I zone(s) is an alternative way to achieve risk reduction related to the protection of personnel and the assembly by reducing the probability of an internal arc-fault.

3.103 Types of devices

3.103.1
internal arc-fault mitigation system
IAMS
system consisting of an internal arc-fault control device (IACD) and an internal arc-fault reduction device (IARD) that operates in the case of an internal arc-fault

Note 1 to entry: An IAMS can include a "combined-type" single device which combines the functions of an IACD and an IARD as defined in IEC 60947-9-2.

3.103.2
internal arc-fault control device
IACD
device intended to detect an internal arc-fault, which provides a signal for operation of a separate IARD, or automatically mitigates the internal arc-fault

Note 1 to entry: An IACD with mitigation capability combines in the same device internal arc-fault detection and breaking or making capabilities.

[SOURCE: IEC 60947-9-2:2021, 3.3, modified – Substitution of "mitigation device" with "IARD" and deletion of Note 2 to entry.]

3.103.3
internal arc-fault reduction device
IARD
device intended to reduce the energy released by an internal arc-fault, which receives a signal for operation from an IACD

Note 1 to entry: An IARD can be achieved by a SCPD, AQD with its associated SCPD(s), or an IALD (internal arc-fault limiting device) with its associated SCPD(s).

3.103.4
internal arc-fault limiting device
IALD
IARD intended to reduce the arc-fault current below a particular level other than a SCPD with current limiting functionality e.g. fuse or circuit-breaker

Note 1 to entry: See Figure EE.1.

3.103.5
arc quenching device
AQD
IARD intended to eliminate internal arc-faults by creating a lower impedance current path in order to cause the arcing current to transfer to the new current path

[SOURCE: IEC 60947-9-1:2019, 3.1, modified – In the definition, replacement of "device" with "IARD" and deletion of Note 1 to entry.]

3.103.6
automatic transfer switching equipment
ATSE
self-acting transfer switching equipment

Note 1 to entry: An ATSE normally includes all necessary devices for monitoring and transferring operations.

Note 2 to entry: An ATSE can have an optional feature for manual operation.

[SOURCE: IEC 60947-6-1:2021, 3.3.4, modified – In the definition, deletion of "including all necessary sensing inputs, monitoring, and control logic for transferring operations", addition of a Note to entry, modification of the text of the existing Note to entry.]