

INTERNATIONAL STANDARD

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

**Appareillage à basse tension –
Partie 9-2: Systèmes actifs de limitation des défauts d'arc – Dispositifs optiques
de détection et de limitation d'arcs internes**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 9-2: Active arc-fault mitigation systems –
Optical-based internal arc-detection and mitigation devices**

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IEC 60947-9-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
121A/406/FDIS	121A/417/RVD

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 International Standard 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/standardsdev/publications.

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INTRODUCTION

Low-voltage switchgear and controlgear, as well as complementary protective and measuring devices, are installed in assemblies according to IEC 61439 series standards and/or others, which provide rules and requirements for interface characteristics, service conditions, construction, performance and verification.

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 overvoltage, overload or short-circuit currents.

The case of an arc-fault inside a LV assembly is considered by the following publications:

- IEC TR 61641, which specify tests requirements for assemblies under internal arc-fault;
- IEC TR 61439-0:2013, which identifies arc-fault containment in its Annex C;
- IEC TS 63107, which specifies tests to verify correct integration of internal arc-fault mitigation systems in power switchgear and controlgear assemblies (PSC assemblies) according to IEC 61439-2.

Even in a Class I assembly according to IEC TR 61641, the occurrence of an internal arc cannot be completely excluded. Typically, internal arc-faults result from:

- conducting materials inadvertently left inside equipment during manufacture, installation or maintenance;
- failures in materials or workmanship;
- inadvertent contact with a live conductor;
- entry of small animals such as mice, snakes, ants, etc.;
- use of an incorrect assembly for the application resulting in overheating and subsequently an internal arcing fault;
- inappropriate operating conditions (for example water, fungus, or dust);
- incorrect operation; or,
- lack of maintenance or inappropriate maintenance (loose parts, paint, etc.).

The occurrence of arcs inside enclosed assemblies is associated 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, metals or vapours, which may be discharged outside of the enclosure.

Due to the risk of personal injury, damage and loss of energy supply as consequences of internal arc-faults there is a growing demand for internal arc-fault sensing and mitigation. This is the reason why some standards have been drafted to give specifications including test protocol and acceptance criteria for corresponding devices. Arc-fault effects can be dramatically reduced by active arc-fault mitigation systems, combining fast detection of the internal arc-fault, and related actions on short-circuit protection devices and/or additional quenching devices. Therefore, the application of such devices can result in:

- reduction of incident/released energy;
- shortening of power outage/downtime (by minimizing damage to the enclosed equipment, switchgear and controlgear as well as other measuring and protective devices);
- limitation of side-effects to other systems, due to high and continuously increasing density of installed apparatus.

This document is intended to cover devices and functions dedicated to:

- detect an arc-fault internal to an assembly by processing optical effects of an internal arc-fault, and to signal and trigger devices intended to mitigate the internal arc-fault, and
- detect by processing optical effects of an internal arc-fault and mitigate the impact of the internal arc-fault by its extinction.

NOTE Even when both terms are related to assemblies in which an arc occurs between conductors, arc-flash is terminology mainly used in NFPA 70E, CSA Z462 and IEEE 1584, which usually describes effects of direct exposure of workers to thermal energy emitted, whereas the term "internal arc-fault" as used in this document describes the hot-gas flow phenomena which can injure people in the vicinity of the arcing current.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 9-2: Active arc-fault mitigation systems – Optical-based internal arc-detection and mitigation devices

1 Scope

This document covers internal arc-fault control devices, hereinafter referred to as IACD, which are intended to:

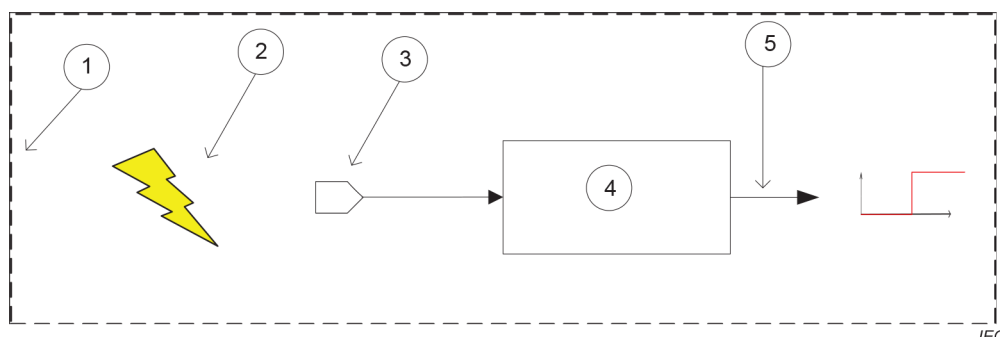
- detect internal arc-faults in low-voltage switchgear and controlgear assemblies, by processing (at a minimum) the optical effect of an internal arc-fault, and
- operate mitigation device (either external or combined)

in order to minimize the effects of the internal arc-fault (see Figure 1).

For the purpose of this document the terms "light" or "optical" covers more than visible spectra. They may cover also, for example, infrared or ultraviolet electromagnetic radiations (see Annex D).

For combined-type IACD, this document is considered in addition to the relevant product standard for internal arc-fault mitigation devices (IARD per IEC TS 63107:2020). Compliance to the relevant product standard is mandatory and cannot be claimed by testing to this document alone.

NOTE 1 Low-voltage switchgear and controlgear assemblies are usually described by IEC 61439 series.



NOTE This figure displays a simplified IACD schematic with only one optical sensor and no other sensing means that can be used for secondary confirmation of an arcing fault, such as current sensing.

Key

- 1 assembly enclosure
- 2 internal arc-fault
- 3 optical sensor
- 4 processing unit
- 5 trigger output used to operate e.g. mitigation device

Figure 1 – Optical-based IACD schematic (stand-alone type and no secondary sensor)

Therefore, this document covers the following:

- internal arc-fault control device (stand-alone, multifunction or combined);
- one or more associated sensor(s) used to detect optical effect of the internal arc-fault;
- sensor(s), sensing another physical effect, to confirm the fault;
- associated or combined mitigation device.

An IACD is not intended to trigger under normal operation of low-voltage switchgear and controlgear (i.e. absence of internal arc-fault), including normal arcing associated with operation of disconnecting and switching devices.

This document only covers the following methods:

- optical detection of the light caused by an internal arc-fault;
- optional confirmation of internal arc-fault by line current measurement.

Many different conductive materials could be used in LV assemblies (e.g. steel, copper, aluminium). Nevertheless, tests specified in this document are deemed to represent the most critical and challenging conditions for arc-detection and cover all combinations of conductive materials.

NOTE 2 Compared to other materials (e.g. steel, aluminium), copper leads to a lower optical radiation energy.

The rated voltage of the assembly in which an IACD is installed does not exceed 1 000 V AC.

Such devices are designed to be operated and maintained by skilled persons only.

This document does not cover:

- DC internal arc-fault detection and control;
- overcurrent relays;
- AFDD (arc-fault detection devices) as defined by IEC 62606;
- guidance on installation within assemblies;

NOTE 3 The integration of an IACD into an assembly is described in IEC TS 63107.

- use with additional measures needed for installation and operation within explosive atmospheres. These are given in IEC 60079 series documents;
- requirements for embedded software and firmware design rules; for this subject, the manufacturer is responsible for taking additional safety measures;

NOTE 4 IEC TR 63201 describes rules for firmware and embedded software development preventing errors in software.

- cybersecurity aspects; for this subject, the manufacturer is responsible for taking additional safety measures;

NOTE 5 See IEC TS 63208.

- mobile applications.

NOTE 6 Even when addressing internal arc-fault mitigation devices, this document does not supersede any other relevant product standard (e.g. IEC 60947-2 or IEC 60947-9-1).

NOTE 7 DC arcing fault phenomena are under consideration. Further investigation is needed to comprehend DC arcing phenomena and required sensing.

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 60068-2-6:2007, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27:2008, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60255-27:2013, *Measuring relays and protection equipment – Part 27: Product safety requirements*

IEC 60695-2-10, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2014, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60695-2-12, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials*

IEC 60715:2017, *Dimensions of low-voltage switchgear and controlgear – Standardized mounting on rails for mechanical support of switchgear, controlgear and accessories*

IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-2:2016, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*
IEC 60947-2:2016/AMD1:2019

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

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 61482-1-2:2014, *Live working – Protective clothing against the thermal hazards of an electric arc – Part 1-2: Test methods – Method 2: Determination of arc protection class of material and clothing by using a constrained and directed arc (box test)*

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016

CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission requirements*

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 3864-2:2016, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

arc

current through air arising from a fault between live parts of different potential and/or between live parts and other conductive parts within an assembly

Note 1 to entry: This phenomenon is accompanied (for example) by thermal, magnetic, radiation and luminescent effects.

[SOURCE: IEC TR 61641:2014, 3.5, modified – "Free-burning short-circuit" replaced with "current", new note 1 to entry inserted.]

3.2

arc-fault

internal arc-fault

<assembly> unintentional arc arising from an accidental conductive path between live parts of different potential and/or between live parts and other conductive parts within an assembly

Note 1 to entry: Within IEEE 1584:2018 and NFPA 70E, there is a different term and definition for the same current phenomenon: arcing fault current, "A fault current flowing through an electrical arc plasma, also called arc current".

3.3

internal arc-fault control device

IACD

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

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

Note 2 to entry: In the United States of America, these devices are commonly named AFR (arc-flash relays).

3.4

internal arc-fault reduction device

IARD

device intended to reduce the energy released by an arc-fault

Note 1 to entry: An IARD can be achieved by a SCPD, AQD or IALD (Internal arc-fault limiting device).

Note 2 to entry: An IALD is an 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.

[SOURCE: IEC TS 63107:2020, 3.3, modified – In the definition, deletion of "internal", insertion of Note 2 to entry based on 3.3.2 of IEC TS 63107:2020.]

3.5

arc-fault detection time

t_{ad}

interval of time between the ignition of the internal arc-fault, and the transition of an IACD output signal to "triggered" state

3.6

arc-fault extinction time

t_{ae}

<IACD> interval of time between the ignition of the internal arc-fault 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.

Note 2 to entry: In case of stand-alone or multifunction IACD, the arc-fault extinction time when installed in assembly is not considered in this document. See IEC TS 63107.

3.7

current sensitivity

<arc-fault> value of prospective fault-current an IACD can detect

Note 1 to entry: This value can be expressed as an absolute value (in RMS A or kA), or as a ratio of current value.

3.8

mitigation device

device intended to reduce the effects of the internal arc-fault

Note 1 to entry: Mitigation devices may be fuses (IEC 60269 (all parts)), circuit-breakers (IEC 60947-2), switches (IEC 60947-3), arc-quenching device (IEC 60947-9-1), or a combination of any of these devices.

3.9

arc quenching device

AQD

device intended to eliminate arc-faults, by creating a lower impedance current path, to cause the arcing current to transfer to the new current path

[SOURCE: IEC 60947-9-1:2019, 3.1]

3.10

prospective short-circuit current

current expected to flow when the arc electrodes are shunted by a conductor of negligible impedance (available short-circuit current of supply)

Note 1 to entry: Prospective short-circuit current is expressed in RMS A.

Note 2 to entry: There is a difference between the arc current and the prospective short-circuit current. The arc current flowing during the arc duration is smaller and fluctuates due to the non-linear arc impedance stochastically varying with time. Reproducible test conditions may only be defined by means of the prospective short-circuit current to be expected in case of short-circuited arc electrodes.

[SOURCE: IEC 61482-1-2:2014, 3.1.26, modified – In Note 1 to entry "kA rms" replaced with "RMS A", and Note 2 to entry reworded.]

3.11

optical sensor

sensor used to detect the optical emission of an internal arc-fault

3.12

secondary sensor

sensor used in addition to optical sensor(s) to confirm indication by sensing another physical effect of the arc, and to support additional function

Note 1 to entry: Secondary sensor(s) are optional.

Note 2 to entry: Current sensors are the only secondary sensor-type considered in this document.

Note 3 to entry: Current sensors are selected according to manufacturer's instructions.

3.13

latching time

steady-state duration value of the operating output signal after detection

Note 1 to entry: Not applicable to combined-type IACD.

3.14

arc-setting current

I_{as}

current pickup value enabling arc-detection

Note 1 to entry: This value can be expressed as an absolute value (in RMS A) or as a ratio of current value.

3.15

arc-setting current range

current setting range between the minimum and maximum values over which the arc-detection current function is enabled

Note 1 to entry: This setting can be expressed as an absolute value (in RMS A) or as a ratio of current value.

3.16

construction break

significant difference in design between IACD of the same type, requiring additional type testing

EXAMPLE: Different arc-detection algorithm, different conditioning of optical sensor signal.

3.17

overvoltage category

OVC

numeral defining a transient overvoltage condition

Note 1 to entry: Overvoltage categories I, II, III and IV are used, see 4.3.3.2 of IEC 60664-1:2020.

Note 2 to entry: OVC is correlated with impulse withstand voltage and earthing system (see Table H.1 of IEC 60947-1:2020).

[SOURCE: IEC 60664-1:2020, 3.1.20, modified – Alternative term "OVC" added, reference in Note 1 to entry modified, Note 2 to entry added.]

3.18

skilled person

person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-826:2004, 826-18-01]

3.19

arc ignition

moment in time at which the ignition wire vaporizes

3.20

arc ignition time

t_0

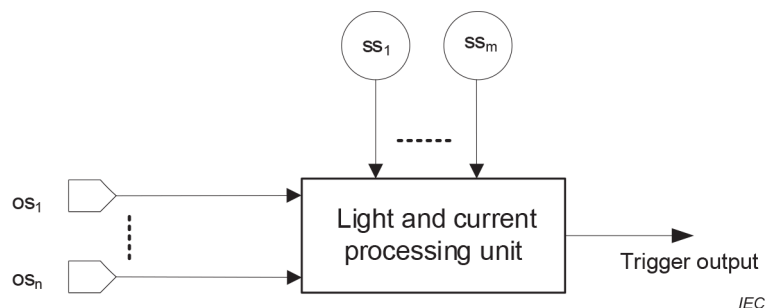
moment in time considered as a reference for the measurement of an IACD time response

4 Classification

4.1 IACD type

4.1.1 Stand-alone type IACD

An IACD with no function other than internal arc-fault detection and signalling (see Figure 2).

**Key**

OS_1 to OS_n optical sensor 1 to n

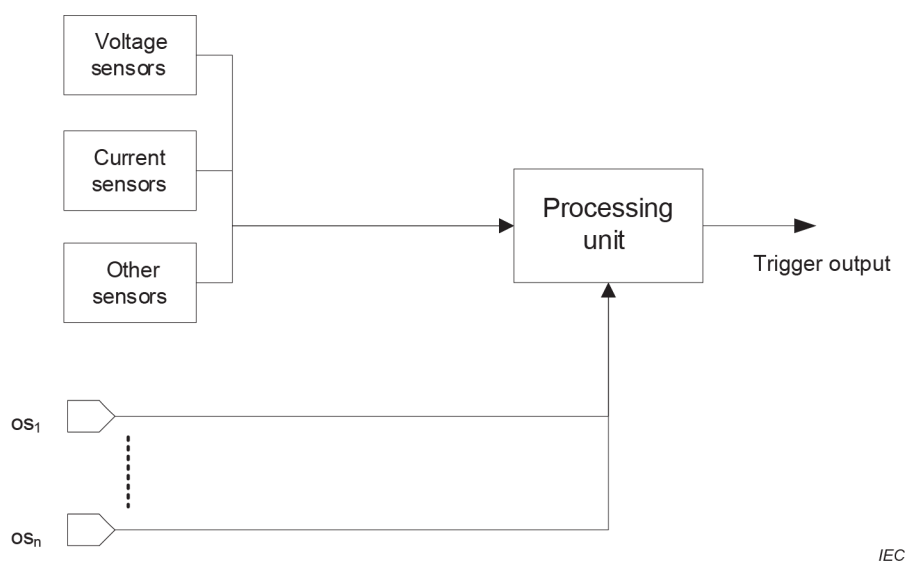
SS_1 to SS_m optional secondary current sensor 1 to m

Figure 2 – Stand-alone type IACD architecture overview

NOTE Essential performance of such type of IACD is arc-fault detection time (t_{ad}).

4.1.2 Multifunction-type IACD

A device in which an IACD is an integrated function of a measurement or protective device or relay (see Figure 3).

**Key**

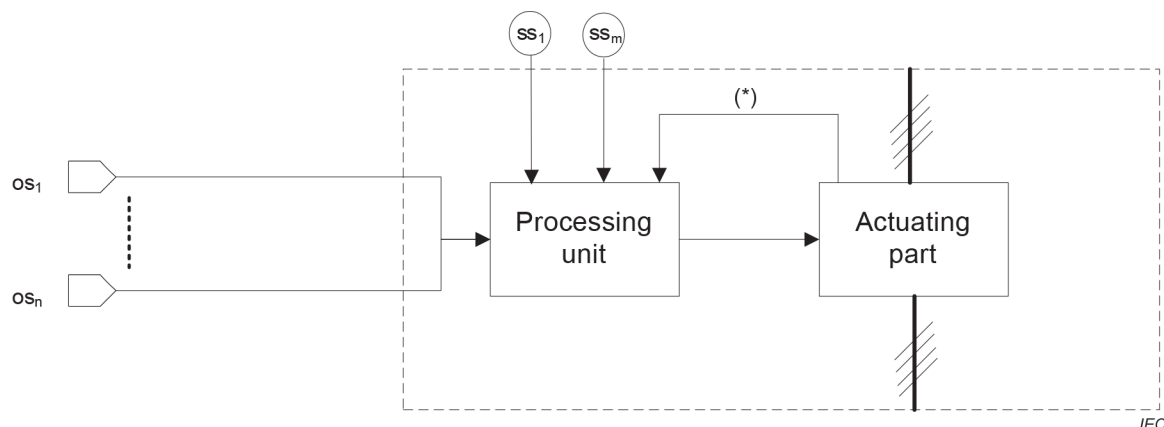
OS_1 to OS_n optical sensor 1 to n

Figure 3 – Multifunction-type IACD architecture overview

NOTE Essential performance of such type of IACD is arc-fault detection time.

4.1.3 Combined-type IACD

Device or combination of devices, including IACD function, designed to detect and mitigate an internal arc-fault (see Figure 4).



Key

- OS₁ to OS_n optical sensor 1 to *n*
- SS₁ to SS_m optional secondary sensor 1 to *m*, or alternatively (*) current data value from embedded sensors
- Actuating part mitigation subset of associated device (suitably rated and capable devices)

Figure 4 – Combined-type IACD architecture overview

Architecture as per Figure 4 is theoretical, and any other combination is acceptable, if the IACD essential functions are fulfilled.

NOTE Arc-fault detection time is not relevant for such type of IACD, because it is a part of the arc-fault extinction time (t_{ae}), manufacturer's claimed performance.

For combined-types IACD:

- this document shall be considered in addition to any other relevant product standard (i.e. IEC 60947-2, IEC 60947-9-1);
- compliance to the relevant product standard is mandatory and cannot be claimed regarding this document only;
- relevant tests of product standard shall have been done with additional features (software and hardware) mandatory for IACD functions (e.g. EMC tests including optical sensors, unless purely fibre-type). If this condition is not fulfilled, additional test sequences apply (see Clause 9).

4.2 Combination of sensors

4.2.1 Optical sensors-only type

An IACD which is designed and intended to operate with optical sensor(s) only.

Optical sensors are considered as part of the product, and therefore provided by the same manufacturer, or approved by the manufacturer.

4.2.2 Optical sensors and secondary sensors type

An IACD which is designed and intended to operate with both optical sensor(s) and secondary sensor(s).

NOTE 1 Secondary sensors can be separated from or integrated into the IACD.

NOTE 2 Secondary sensors can be embedded in the actuating part.

4.3 Binary output types

4.3.1 Operate output

An operate output is directly activated regarding the main function of the IACD.

EXAMPLE "trip" output, "tripped" output, "ATS inhibit" output.

NOTE Operate output is optional for combined-type IACD.

4.3.2 Auxiliary binary output

An auxiliary binary output is not intended to fulfil any protection requirement.

EXAMPLE Buzzer control, indicating lights control.

NOTE Auxiliary binary output is an optional feature.

5 Characteristics

5.1 Maximum arc-fault detection time

The maximum arc-fault detection time (t_{ad}) of an IACD is the maximum time from ignition of the arc-fault to the final steady-state condition of the IACD operate output signal(s).

See Annex C for definition and identification of ignition-time of the arc-fault.

NOTE 1 The manufacturer can express a set of detection time dependent upon rated mains supply voltage or arc-fault prospective current, when relevant.

NOTE 2 This characteristic applies only to stand-alone and multifunction types IACD.

5.2 Maximum arc-fault extinction time

The maximum arc-fault extinction time (t_{ae}) of an IACD is the maximum time from ignition of the arc-fault to its complete extinguishing (see C.3 and C.5).

See Annex C for definition and identification of ignition-time and extinguishing of the arc-fault.

NOTE 1 The manufacturer can express a set of extinction time dependent upon rated mains supply voltage or arc-fault prospective current, when relevant.

NOTE 2 This characteristic applies only to combined-type IACD.

5.3 Minimum arc-fault detection current value

The value declared by the manufacturer, in prospective current, that indicates the minimum level of detection.

All IACDs shall be capable of sensing the arcing current corresponding to a 10 kA prospective current. The preferred lower values that may be offered are: 5 kA or 7 kA.

NOTE 1 Higher sensitivity increases the risk of unintended operation.

NOTE 2 By pickup sensitivity, more than one preferred value can be covered.

NOTE 3 Minimum values of combined-type IACD can be expressed as a ratio of rated or nominal current.

5.4 Maximum prospective short-circuit current value

The maximum prospective short-circuit current value is the value an IACD can successfully sustain for a defined duration and/or interrupts as claimed by the manufacturer.

The preferred value shall be one of the following:

10 kA, 30 kA, 50 kA, 65 kA, 85 kA or 100 kA

NOTE The preferred values above are comparable to the usual short-circuit values of assemblies, and therefore cannot be compared to values stated in IEC TR 61641, which are only used to create maximum stress to the assembly.

6 Product information

6.1 Nature of information

Subclause 6.1 of IEC 60947-1:2020 applies, as far as appropriate.

6.2 Markings

Each IACD shall be marked in a legible and durable manner; data to be provided and corresponding locations are indicated in Table 1 below.

Table 1 – Markings and indications for an IACD ^d

Item	Information	Marking location
1.1	Indication of the status (e.g. READY, TRIP, ERROR...)	Visible ^a
1.2	Explanation of the status indicator(s)	Documentation
1.3	Manufacturer's name or trade mark	Marked
1.4	Type designation or serial number	Marked
1.5	"IEC 60947-9-2", if the manufacturer claims compliance with the document	Marked or Documentation ⁱ
1.6	Need for auxiliary power supply ^e , as well as its characteristics, such as voltage, frequency, current, etc.	Documentation
1.7	Rated characteristics of any output signal (operate or auxiliary binary) ^{b, c}	Documentation
1.8	Characteristics of any input signal ^{b, c}	Documentation
1.9	Maximum detection time (when relevant) ^{f, k}	Documentation
1.10	Maximum extinction time (when relevant) ^{f, k}	Documentation
1.11	For an IACD with no provisions for secondary sensors, the following warning: WARNING This is an IACD with optical sensors Light from other than internal arc-fault may unintentionally trigger the device	Documentation
1.12	Immunity to ambient light (yes/no), and associated ambient-light level max value (in lux), when greater than 2 000 lx	Documentation
1.13	Minimum prospective short-circuit (bolted-fault) and associated sensor distance, according to Annex A	Documentation
1.14	Maximum prospective short-circuit current value	Documentation
1.15	Rated mains operational voltage (when combined-type)	Documentation
1.16	Arc-setting current and arc-setting current range (when relevant)	Documentation
1.17	Optical sensitivity value and range setting (when relevant)	Documentation
1.18	Marking of terminals ^g	Marked
1.19	IP code ^h	Documentation

Item	Information	Marking location
1.20	Overvoltage category (OVC) at connecting point ^{l, j}	Documentation
Key Visible visible from the front when the IACD is installed as in service and the operator controls are accessible Marked marked on the exterior of the product Documentation in the manufacturer documentation NOTE Thermal performance and light sensitivity can be impacted by the installation in an assembly.		
^a Marking can be replaced with display for some operation information. Display shall return to essential information after a short delay. ^b The manufacturer shall define the ratings for each binary input/output. For example, when optical output offered, wavelength, connector type, mode, diameter, optical power shall be specified. ^c The manufacturer shall define the ratings for each analogue input/output, unless proprietary. ^d In addition to upper list, an additional marking of the assembly is required (see 9.3.3.2). ^e Auxiliary power supply shall be reliable relative to the application. ^f When the manufacturer claims for different performances with regards to conditions (e.g. for different auxiliary powering conditions), each-one shall to be tested. ^g In accordance with IEC 60255-27 or alternatively 8.1.8.4 and Annex L of IEC 60947-1:2020. ^h When multiple (e.g. due to different mounting cases), all shall be listed. ⁱ With rated voltage and type of system (see Annex H and Table H.1 of IEC 60947-1:2020). ^j OVC can be replaced by U_{imp} (impulse withstand voltage), in accordance with Table H.1 of IEC 60947-1:2020. ^k When dependent upon mains rated supply voltage or arc-fault prospective current, set of times shall be provided. ^l Reference to standard in documentation accepted for multifunction-type IACD or when required surface is not sufficient.		

The markings defined in Table 1 above shall be considered as mandatory additional markings, when applied to combined-type IACD, for which all other relevant product standards marking requirements also apply.

6.3 Instructions for installation, operation, maintenance, decommissioning and dismantling

Subclause 6.3 of IEC 60947-1:2020 applies with the following addition.

The following information shall be provided by the manufacturer of the IACD system and IACD components including all mounting accessories (such as optical fibre splices, holders, etc.):

- identification of optical sensors to be used;
- maximum distances from sensor(s) to the IACD for proper operation;
- identification of current sensing to be used (when relevant);
- installation rules for the IACD, optical sensors and any guidance required for proper installation;
- ambient-air temperature range.

Rail mounting of an IACD shall be specified according to IEC 60715:2017, when relevant.

Additional information for the maintenance, decommissioning and dismantling of the equipment shall be made available to the user in case of foreseeable hazardous condition of the device, for example due to stored energy, instability or falling of objects, etc.

7 Normal service, mounting and transport conditions

Clause 7 of IEC 60947-1:2020 applies.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 8.1 of IEC 60947-1:2020 applies with the following modifications.

Unless complying with protection class II, stand alone or multifunction-type IACD with metallic touchable parts shall have means of connection for the external protective conductor or earthing rail according to IEC 60715:2017. For such IACD type having a continuous leakage current of more than 3,5 mA AC or 10 mA DC in normal use, the supply input shall be connected as for a permanently connected equipment (see Clause E.2 of IEC 60255-27:2013); this shall be stated in the manufacturer's documentation. The protective conductor terminal (earthing terminal) or the earthing part when a mounting rail is used as earthing conductor shall be corrosion resistant.

Annex O of IEC 60947-1:2020 should be considered carefully especially for substitution or reduction in use of hazardous substances, or if not possible for providing measures to prevent emission and contact with them.

Annex W of IEC 60947-1:2020 should be considered for material declaration in conjunction with IEC 62474.

8.1.2 Creepages and clearances

Creepages and clearances shall fulfil the requirements of Table 13 and Table 15 of IEC 60947-1:2020.

8.1.3 Material requirement

8.1.3.1 General

Subclause 8.1.2.1 of IEC 60947-1:2020 applies with the following addition.

Tests shall be made for parts of insulating materials necessary to retain current-carrying parts in position and parts of insulating materials that are in close proximity to such parts.

The manufacturer shall specify which test method, 8.1.3.2 or 8.1.3.3, is to be used.

8.1.3.2 Glow-wire testing

The suitability of materials used is verified by:

- a) making tests on the equipment; or
- b) making tests on sections taken from the equipment; or
- c) making tests on any parts of identical material having representative thickness; or
- d) providing data from the insulating material supplier fulfilling the requirements according to IEC 60695-2-12.

The suitability shall be determined with respect to resistance to abnormal heat and fire. The manufacturer shall indicate which methods, amongst a), b), c) and d) shall be used.

If an identical material having representative cross-sections has already satisfied the requirements of any of the tests of 9.2.2 of IEC 60947-1:2020, then those tests shall not be repeated.

Tests on equipment shall be made by the glow-wire end-product test of IEC 60695-2-10 and IEC 60695-2-11.

For combined-type IACD, unless new material(s) added, or tests done with lower severity level, glow wire tests are not deemed to be repeated. In the former case, only new materials shall be tested.

Tests shall be made according to 9.2.2.1 of IEC 60947-1:2020 with the conditions given in Table 2 below.

Table 2 – Test conditions for glow-wire test

Part under test	Test condition
Part with a mass lower than 2 g ^a	Test not necessary
Part which is a small part according to 3.1 of IEC 60695-2-11:2014 ^a	Test not necessary
Part which is not in close proximity to current-carrying parts ^b	Test not necessary
Part which is in close proximity to current-carrying parts ^b	Glow-wire test at a temperature of 650 °C
Part which retains current-carrying parts in position	Glow-wire test at a temperature of 850 °C
^a For products containing a plurality of small parts, the total mass of non-tested parts located in close proximity to each other shall not exceed 10 g.	
^b Proximity shall be based on engineering judgment that takes into consideration the risk of propagation of fire.	

8.1.3.3 Test based on flammability category

Subclause 8.1.2.3 of IEC 60947-1:2020 applies.

For combined-type IACD, unless new material(s) added, or tests done with lower severity level, flammability tests are not deemed to be repeated. In the former case, only new materials shall be tested.

8.2 Performance requirements

8.2.1 General

For stand-alone or multifunction type IACD, the maximum arc-fault detection time and the minimum arc-fault sensitivity shall comply with the values as stated by the manufacturer.

For combined-type IACD, the maximum arc-fault extinction time, minimum arc-fault sensitivity and maximum arc-fault extinction capability shall comply with the values as stated by the manufacturer.

8.2.2 Operating conditions

8.2.1 of IEC 60947-1:2020 applies.

8.2.3 Temperature-rise

The temperature-rises of parts of an IACD measured during a test carried out under the conditions specified in 9.3.8 shall not exceed the limiting values stated in Table 2 of IEC 60947-1:2020 and Table 3 of IEC 60947-1:2020.

8.3 Electromagnetic compatibility (EMC)

Subclause 8.3 of IEC 60947-1:2020 applies.

9 Tests

9.1 General – Kind of tests

Subclause 9.1 of IEC 60947-1:2020 applies, with the following additions:

The tests to verify the characteristics of an IACD are:

- type tests (done on representative samples for each construction break) (see 9.3);
- routine tests (on each product) (see 9.4).

Within a sequence, tests shall be performed in order listed in Table 3 and Table 4.

The sample is a combination of one optical sensor and the IACD.

9.2 Compliance with constructional requirements

Subclause 9.2 of IEC 60947-1:2020 applies, with the following additions.

Conditions for glow-wire tests are defined in 8.1.3.2.

Leakage current measurements according to 8.1.1 shall be performed using the measuring circuit in Figure 4 of IEC 60990:2016. The equipment shall be isolated from earth and the measuring circuit connected between the protective conductor terminal and the protective conductor.

9.3 Type tests

9.3.1 General

An IACD shall be subjected to the following type tests:

- temperature-rise tests: to verify that temperature will not exceed some limits considering material performances and operator safety;
- arc-detection tests (for stand-alone or multifunction-type) to ensure that the sensing system can detect the minimum and sustain the maximum arc-fault currents specified by the manufacturer;
- arc-extinction tests (for combined-type) to ensure that an IACD can mitigate minimum and maximum arc-fault current values specified by the manufacturer;
- light-immunity tests: to ensure the sensing is not activated by normal ambient light or light from common artificial sources, when claimed by manufacturer. Immunity to light from nearby arcing devices may need additional measures not addressed in this document;

NOTE 1 Ambient light values as specified in Annex E are considered as a minimum immunity level. Manufacturers can claim for higher immunity levels.

- environmental tests (e.g. EMC, vibration, damp heat).

All operate outputs shall be tested. Test of auxiliary binary outputs is optional and can be done upon agreement between manufacturer and user.

When an IACD has more than one identical output, each one shall be evaluated during the same test sequence, all results being recorded in test report. Normally open outputs may be tested together in series, and normally closed outputs may be tested together in parallel.

When different sets of contacts are functionally different, each set shall be tested independently.

Optical fibre digital output(s), if any, shall be verified as well. When the interface used to convert optical to logical is provided by manufacturer, it shall be recorded in the test report. When belonging to the test laboratory, the additional delay induced by optical to logical conversion shall be given in the test report as well.

Connection of optical sensors and secondary current sensors (when used) shall be in accordance with the manufacturer's instruction.

A stand-alone or multifunction type IACD shall be subjected to the following type tests grouped together in a sequence and shall be run preferably in the order listed in Table 3 below. For practical reasons, order can be changed under agreement between manufacturer and user.

Table 3 – Tests sequences for standalone-type or multifunction-type IACD

Test	Type test sequence	Subclause
1	Light immunity tests	9.3.3
	Arc-detection tests:	9.3.4
	– Reduced energy arcs	9.3.4.3
	– High energy arcs	9.3.4.4
	Dielectric properties	9.3.5
	Functional tests ^a	9.3.9
2	EMC test:	9.3.6
	– Emission	9.3.6.3
	– Immunity	9.3.6.2
	Functional tests ^a	9.3.9
3	Temperature-rise tests	9.3.8
4	Damp heat	9.3.7.2
	Vibration and shock	9.3.7.3, 9.3.7.4
	Dielectric properties	9.3.5
	Functional tests	9.3.9
^a Can be omitted if the same test sample is used for the other following test sequences.		

Upon manufacturer request, each test sequence of Table 3 can be performed with a new sample.

NOTE 2 Optical sensor replacement is not considered as being a new sample.

NOTE 3 Some tests can be not relevant if the device or system does not have a corresponding operational mode.

When a combined-type IACD has already passed all EMC, temperature-rise and environmental tests according to their mitigation device standard and if the requirements of these tests cover the ones described in this document, then the IACD shall be subjected only to the following additional type tests grouped together in one sequence listed in Table 4 below. When not, additional sequences 2, 3 and/or 4 of Table 3 applies as well.

Table 4 – Tests sequences for combined-type IACD

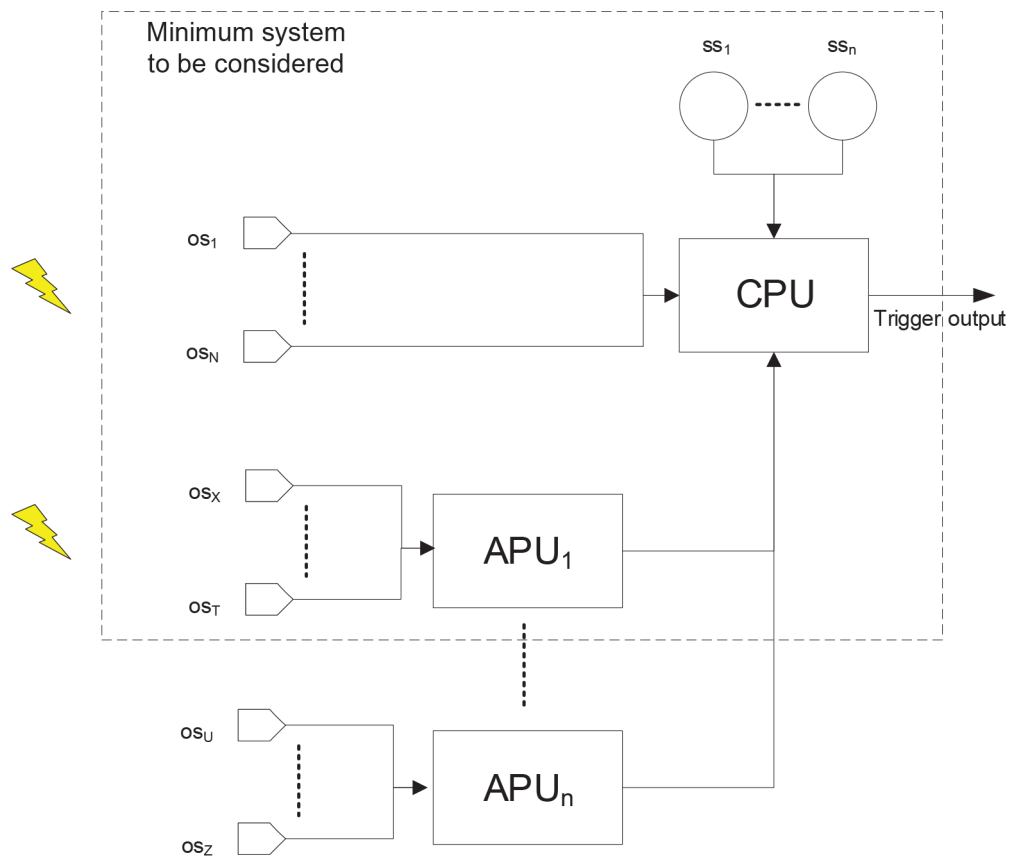
Test	Type test sequence	Subclause
1	Light immunity tests	9.3.3
	Arc extinction tests:	9.3.4
	– Reduced energy arcs	9.3.4.3
	– High energy arcs	9.3.4.4
	Dielectric properties	9.3.5
	Functional tests	9.3.9

Clause 10 specifies data to be recorded in test report.

9.3.2 Guidance on sample selection

As described in Figure 5 and Figure 6 below, an IACD of the same type can demonstrate multiple architectures or structures to perform the main function, at the choice of the manufacturer.

Samples selection shall be driven only by construction breaks, significant difference(s) in terms of hardware and/or firmware selection, algorithms and methods, all of which can result in significant increase of CPU workload, or data transfer, therefore making additional tests mandatory.



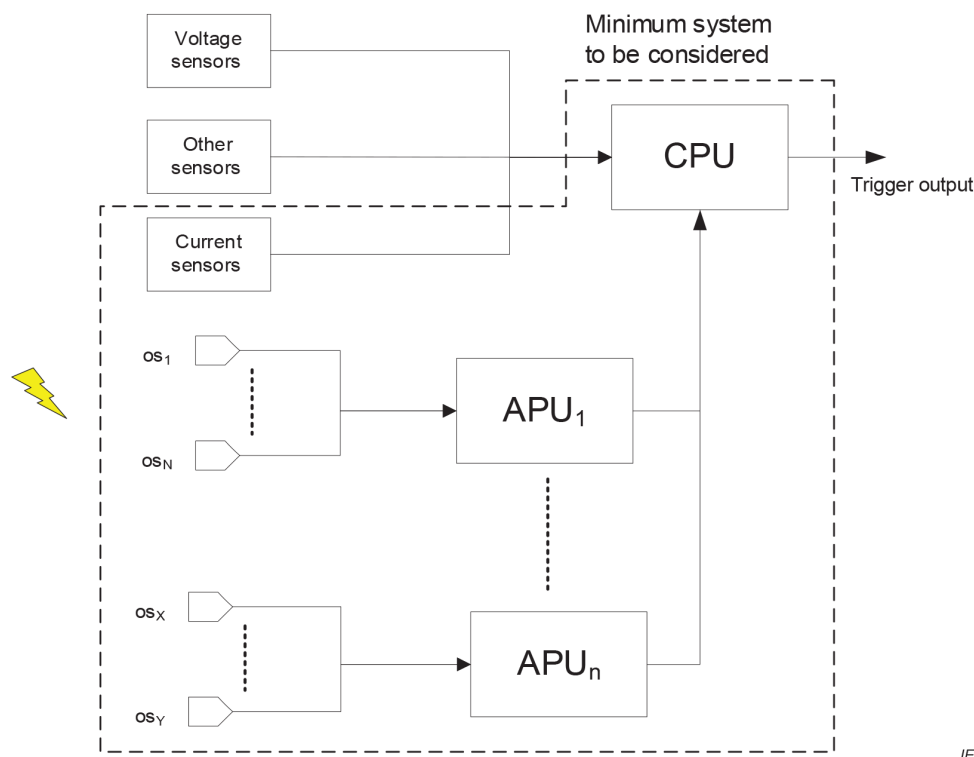
IEC

NOTE In upper figure CPU and APU₁ to APU_n can also be merged in the same component.

Key

os	optical sensor
ss	optional secondary sensor
CPU	central processing unit
APU	auxiliary processing unit
---	minimum system to be considered

Figure 5 – Stand-alone IACD (hardware) architecture



IEC

NOTE In upper figure CPU and APU1 to APUn can also be merged in the same component.

Key

os optical sensor

CPU central processing unit

APU auxiliary processing unit

--- minimum system to be considered

Figure 6 – Multifunction-type IACD (hardware) architecture

Unless supported by engineering judgement, stand-alone and multifunction IACD types are considered to have a construction break if any one of the following features are not the same:

- overall IACD dimensions;
- auxiliary power supply characteristics (when any);
- number of PCBs;
- PCB hardware layout (unless omitted components on the same layout);
- embedded software/firmware for arc-detection function;
- moulding and insulating materials;
- declared IP;
- optical sensor type or manufacturer;
- current sensing device type and characteristics.

In case of no construction break the selection shall be as follows:

- tests of stand-alone type IACD limited to central processing unit and one add-in unit only, when any (see Figure 5);
- tests of multifunction-type IACD limited to central processing unit, current-sensor conditioning (when relevant) and one add-in unit only (see Figure 6).

Combined-type IACD are essentially driven by mitigation device construction breaks, and samples shall be selected accordingly.

NOTE In the case of circuit-breaker combined-type, list of construction breaks can be found in 7.1.6 of IEC 60947-2:2016.

The required equipment shall be one optical sensor per unit (APU and/or CPU). When the manufacturer claims performance for different types of optical sensors (e.g. point-sensor, and optical fibre sensor), each-one shall be tested separately.

9.3.3 Light-immunity tests

9.3.3.1 General

Two cases shall be considered:

- IACD without secondary sensor(s);
- IACD with secondary sensor(s).

9.3.3.2 IACD without secondary sensor(s)

Unless specifically designed, an IACD without secondary sensors is potentially sensible to ambient light. In such cases, no tests are deemed necessary.

However, discrimination between normal ambient light and light arising from internal arcing fault may be an option offered by manufacturer. In such case, tests shall be performed according to Annex E, to validate immunity level claimed by manufacturer.

EXAMPLE A manufacturer can claim immunity up to 2 000 lux ambient light, simulated by a tungsten-halogen lamp, which may occur when opening a door of an assembly that is installed in electrical room.

The following characteristics of the proposed method shall be considered:

- simulation by use of tungsten-halogen lamp (which is not covering all cases);

NOTE 1 It is recognized that there are many other types of light sources, besides tungsten-halogen, which have a different spectra (i.e. wavelength characteristics). One reason, among many, for choosing the tungsten-halogen light source is because it provides a high level of intensity (i.e. irradiance) in the wavelength range (red to IR) in which silicon photodiodes, commonly used in an IACD, have the highest sensitivity resulting in worst case test conditions as compared to other types of light sources.

- specific light sources encountered on site may exceed defined test parameters;
- the proposed method identifies and clarifies one type of light source. The manufacturer may, in addition, perform tests with other sources, which are not covered by this document.

NOTE 2 Light intensity is expressed in lux rather than in W/m^2 due to its measurement with commonly available laboratory test equipment.

Immunity to arcs caused by devices switching current such as air circuit-breakers (ACB), moulded-case circuit-breakers (MCCB) or switches within the assembly shall be considered at system level, for example by containment or shielding. Such tests are specified in IEC TS 63107.

The manufacturer shall provide a label or plate, and instructions for the label or plate to be placed at all relevant locations on the assembly. The label or plate shall be marked with the following English or French text. Additional translations in other languages shall be provided in accordance with national regulations.

Case 1: For an IACD which has been successfully tested according to Annex E, text of label or plate shall read:

WARNING This assembly is fitted with an arc-detection system with optical sensors – Light from other than internal arc-fault may unintentionally trigger the device Tested regarding immunity to ambient-light under 2 000 lx by tungsten-halogen lamp
AVERTISSEMENT Cet ensemble est équipé d'un dispositif détecteur d'arcs avec capteurs optiques – Toute source lumineuse autre qu'un arc de défaut est susceptible de déclencher le dispositif Immunité à une lumière ambiante de 2 000 lx vérifiée sous éclairage tungstène-halogène

Case 2: For an IACD which has not been tested according to Annex E, text of label or plate shall read:

WARNING This assembly is fitted with an arc-detection system with optical sensors – Light from other than internal arc-fault may unintentionally trigger the device
AVERTISSEMENT Cet ensemble est équipé d'un dispositif détecteur d'arcs avec capteurs optiques – Toute source lumineuse autre qu'un arc de défaut est susceptible de déclencher le dispositif

NOTE 3 2 000 lx value in upper text can be modified to any greater value when tested under special agreement between the manufacturer and the user.

NOTE 4 Probability of unwanted operation of IACDs under ambient light can be decreased by adding secondary current sensing. However, secondary current sensing can be insufficient to reliably prevent unintended operation caused by the light from switching devices associated with high fault current, installed within the low voltage assembly. Such immunity is addressed in IEC TS 63107.

The height of the text shall be at least 5 mm. The text shall be marked in a durable and legible manner and the colour of the text shall be different from the colour of the label or plate. Label or plate shall be designed in accordance with ISO 3864-1 and ISO 3864-2 and coloured according to national practice.

9.3.3.3 IACD with secondary sensor(s)

9.3.3.3.1 General

For an IACD having more than one current sensor, each input shall be tested separately. If the inputs are identical, any phase may be tested. The test current shall have no asymmetry.

Immunity to arcs caused by devices switching current such as ACBs, MCCBs or switches within the assembly shall be considered at system level, for example by containment or shielding. Such tests are specified in IEC TS 63107.

9.3.3.3.2 Current threshold considerations

Depending upon the existence of current threshold I_{as} settings (fixed or adjustable), the manufacturer may offer more than one method to measure current to determine if a threshold has been exceeded.

All offered current measurement and threshold comparison methods shall be tested individually.

9.3.3.3.3 Test method

For these tests, optical sensor shall be permanently illuminated (unless not permitted by the manufacturer) by any suitable light source. When not permitted, test laboratory shall synchronize illumination with secondary current.

NOTE Xenon lamp can be used, because of their spectra which is stable, reproducible, and covers the whole visible spectra.

The test shall be performed at 80 % and 120 % of the arc-setting current value:

- at a test current having a value equal to 80 % of the setting, the system shall not operate, the current being maintained for 0,2 s.
- at a test current having a value equal to 120 % of the setting, the IACD shall operate within 0,2 s.

Test shall be repeated for the two extreme settings value of the arc-setting current range (when applicable).

9.3.4 Detection and extinction tests

9.3.4.1 General

The two types of detection and extinction tests for all types of IACD are:

- tests under reduced energy arc (see Annex A);
- tests under high energy arcs (see Annex B).

A manufacturer can state different performances for alternative supply methods for IACD. In such cases each method shall be tested according to the manufacturer's specifications.

Current sensors (CTs), when employed, shall be installed and connected in accordance with the manufacturer's instructions. The overall configuration shall be recorded in test report.

9.3.4.2 Measuring and data tracking system

The measuring system shall be capable to record simultaneously:

- the source voltage and current;
- the arc-current and voltage;

- the output(s) of the IACD (for stand-alone or multifunction-type);
- more signals upon manufacturer's request.

Minimum performances (regarding sampling rate, bandwidth and digitization) shall be in accordance with C.6.

Arc-current and arc-voltage waveforms shall be recorded at each arc test and displayed graphically over the time in the test report.

9.3.4.3 Tests under reduced energy arcs

9.3.4.3.1 General

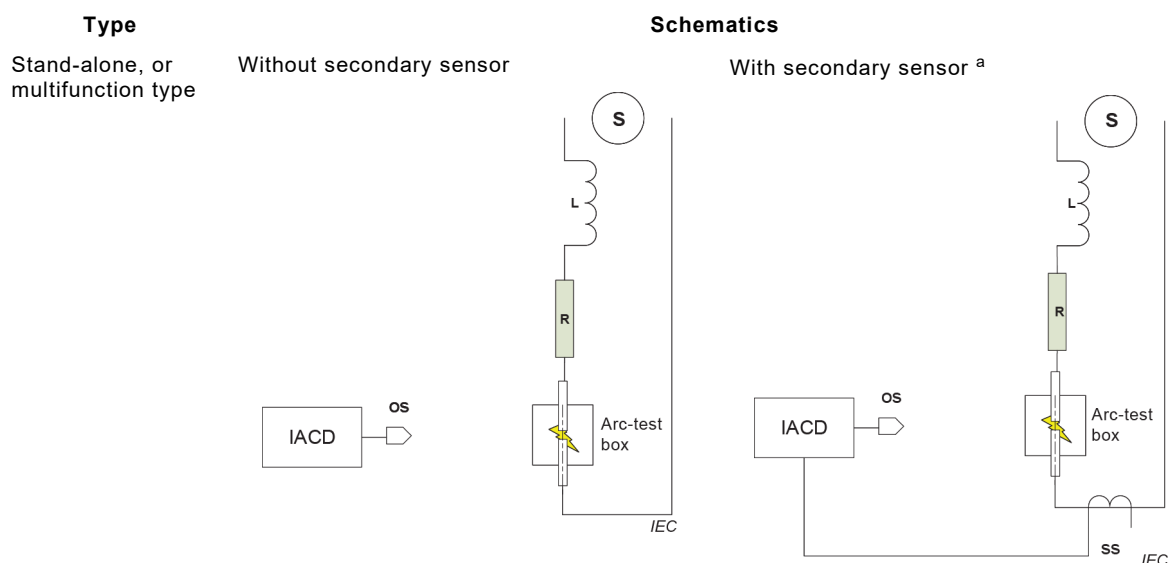
The intent of these tests is to evaluate the detection capability under reduced energy, single-phase, arcing-fault conditions, and when other system conditions may also make it difficult to successfully sense the arc-fault, in order to:

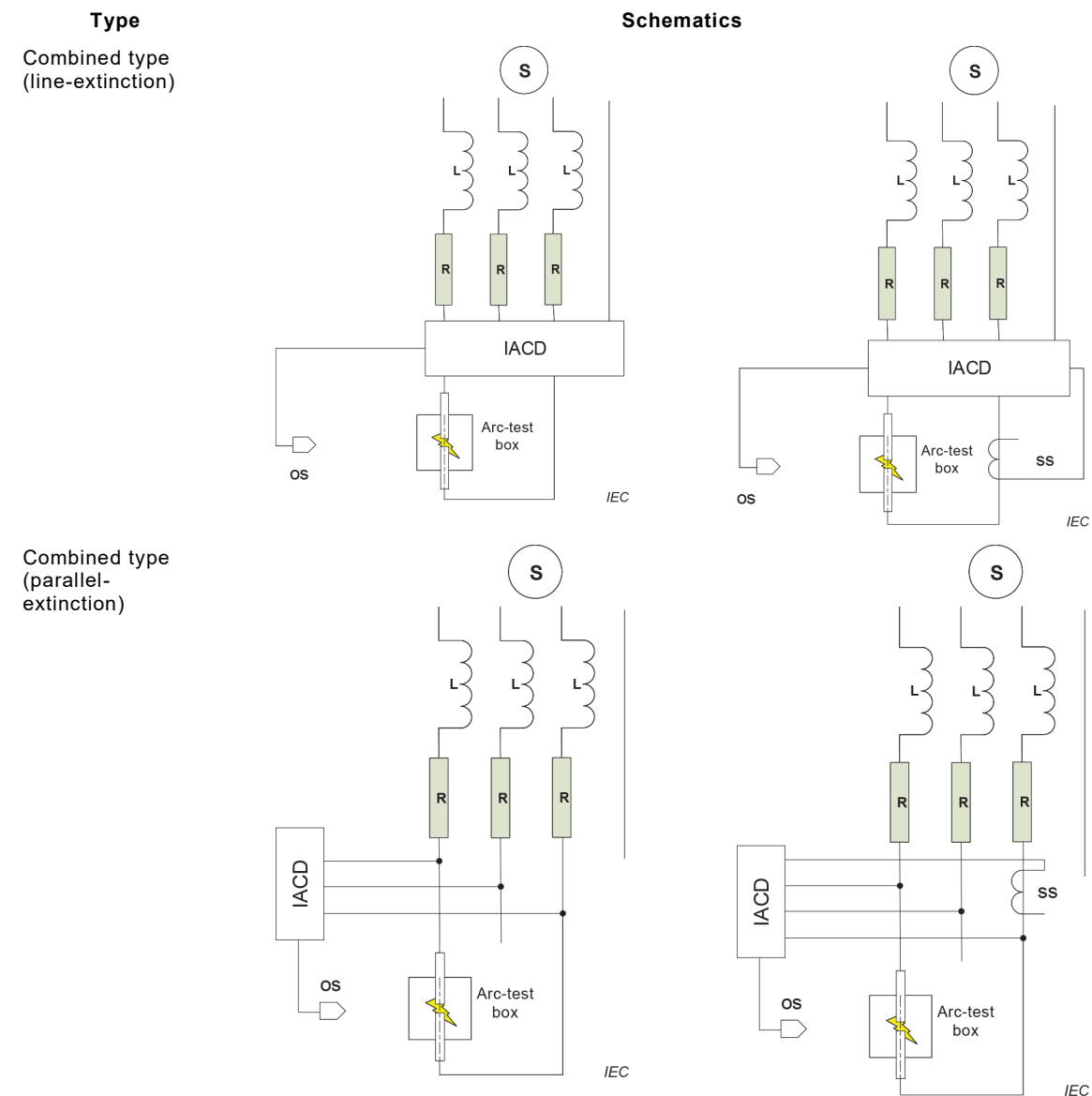
- validate the detection sensitivity to reduced energy arcs;

NOTE Reduced energy arcs can be for example phase to ground arc-faults.

- validate the detection sensitivity under defined sensor-arc distance, sensor direction and similar.

See Figure 7 for test arrangements principle and Annex A for any information regarding such tests.





NOTE Optical sensor (os), even identified as separate component, is part of the IACD.

^a Secondary sensors can be embedded in an IACD or separated from an IACD.

Key

S	source
os	optical sensor
ss	optional secondary sensor
L,R	test circuit additional reactance and resistance

Figure 7 – Reduced energy detection tests – Arrangement principle

9.3.4.3.2 Test conditions

Unless required by the manufacturer (e.g. for accelerated ageing reasons), tests shall be performed on one sample in accordance with Annex A.

These tests are designed to demonstrate the minimum sensitivity (i.e. to lowest-level energy) of an IACD, and therefore, by default, when adjustable, the sensitivity shall be set to the minimum. Alternatively, the manufacturer can request a specific level for light-immunity which shall be adjusted before testing.

9.3.4.3.3 Test acceptance criteria

The following criteria shall be fulfilled:

- each arc shall be detected. If an arc is undetected, test is failed and cannot be repeated without any adjustment;

NOTE 1 When testing an IACD with secondary sensing, lack of detection due to test current being less than I_{as} is not considered a valid test. Test can be repeated with suitable I_{as} setting if possible.

- each operation of the IACD shall be a consequence of arc-fault detection;
- maximum value of detection time value of each output (when relevant), or (alternatively, for combined-type IACD) extinction time value shall be within the manufacturer specifications, for three successive test operations;
- when there are different types of outputs (e.g. NO or NC, solid-state or electromechanical...), performance of each-one shall be evaluated separately when manufacturer's performance specifications are different. When not, all shall be monitored by measuring maximum value for each test;
- after the last test operation, system functionality shall be verified; this verification shall represent a condition at least equal to the previous tests. Arc simulation using a light source is permitted, as well as use of manufacturer's specific tooling;

NOTE 2 This functional test sequence is agreed between the manufacturer and the test laboratory.

- latching time shall be in accordance with the manufacturer's declaration after each test operation (not applicable to combined-type IACD);
- resetting shall be effective after each operation.

NOTE 3 Test laboratories are authorized to reset the device after each test operation, if applicable.

Reference for detection time (respectively extinction time) measurements shall be identified according to C.3.

Due to the selection method of t_0 used in the measurement protocol, it is possible that the sensing systems that are sensitive to light-emission prior to t_0 may result in very short, even negative, detection times (see C.7). This is not necessarily indicative of fast detection, it may be indicative of high sensitivity.

NOTE 4 High sensitivity of an IACD can impact system reliability, such as unintended operation.

9.3.4.4 Tests under high energy arcs

9.3.4.4.1 General

The test's objective is to reproduce the IACD operation (based on three-phase internal arc-faults).

NOTE 1 Three-phase internal arc-faults are not the only possible fault. However, single or two-phase arc-faults can propagate into three-phase faults. This also provides consistency with IEC TR 61641.

The rationale for this test sequence is to:

- ensure that no masking or saturation could impact the performance;
- ensure a three-phase detection and an extinction performance;
- document the detection time or the extinction time;
- confirm the single-phase performance (previously tested under reduced energy).

See Figure 9 for test arrangements principle and Annex B for any information regarding such tests.

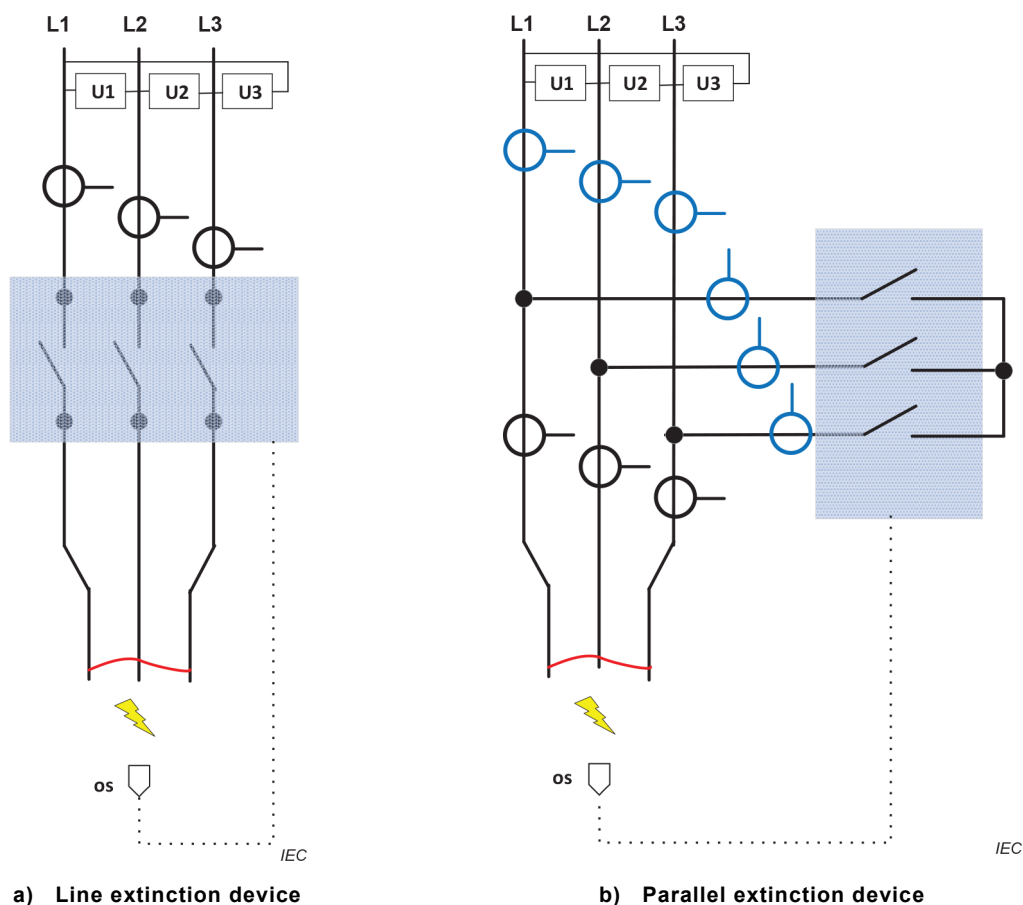
NOTE 2 EMC is covered by other requirements of this document.

9.3.4.4.2 Methods of test

The performance of the combined-type IACD shall be determined by applying the following methods (see Figure 8).

The extinction time of the arc can be determined by measuring:

- either (preferably) upstream line current and IACD current;
- or alternatively downstream line current.



NOTE The position and number of CT is left to the convenience of the test laboratory, assuming the arc mitigation is properly measured.

Key

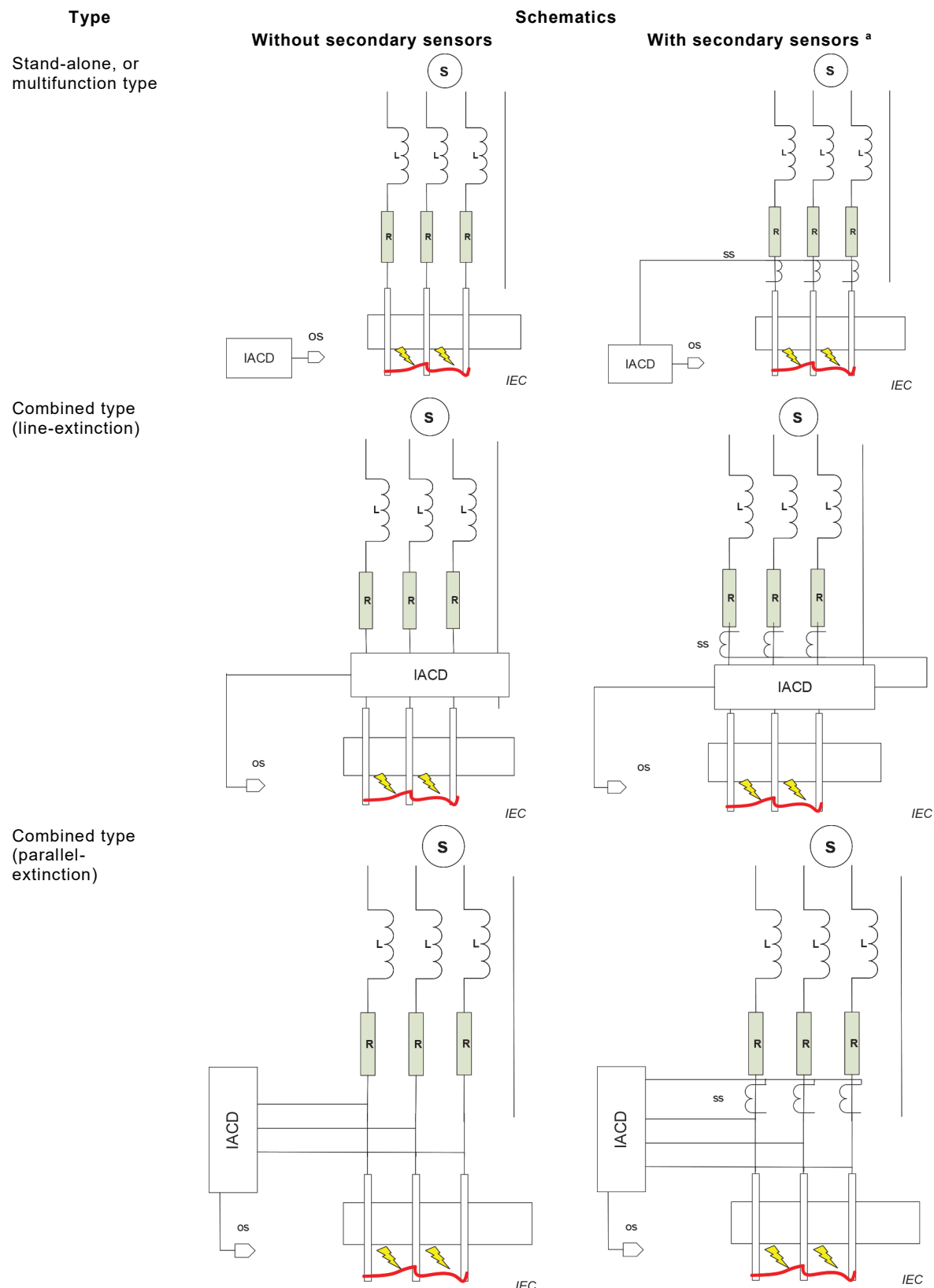
- os optical sensor
- U_1, U_2, U_3 phase-to-phase voltage
- alternative current sensors position (see Note)

Figure 8 – Method of test

The mitigation is achieved when:

- Figure 8 a): line current goes to and remains equal to zero;
- Figure 8 b): difference between upstream current and current flowing through the IACD equals and remains at zero

The reference time for measurements shall be made in accordance with Annex C.



NOTE The optical sensor (os), even identified as separate component, is part of the IACD.

^a Secondary sensors can be embedded in an IACD or separated from an IACD.

Key

- S source
- os optical sensor
- ss secondary sensor
- L,R test circuit additional reactance and resistance

Figure 9 – High energy detection and extinction tests – Arrangement in principle

9.3.4.4.3 Test conditions

Tests shall be performed in accordance with Table 5 below and Annex B.

Table 5 – General conditions of tests under high energy

Parameter	Value	Remark
Number of samples ^a	According to the manufacturer's instructions, 1 by default.	Unless replacement, after each or a definite number of test operation required by the manufacturer's instructions.
Number of test operations	1, unless specific manufacturer's requirements.	
^a To optimize tests, more than one IACD, stand-alone or multifunction type, can be tested during the same test sequence.		

9.3.4.4.4 Test result criteria

When combined with a circuit-breaker, the phase current allows the determination of the extinction time, the source voltage being maintained for sufficient time. See C.5.

When combined with an AQD, the extinction time is the time difference between t_0 and the instant when all phase currents of the AQD become and remain equal to zero, or alternatively the time when the current difference between the source and the AQD becomes and remains equal to zero.

The following criteria shall be fulfilled:

- the detection time value of each output (when relevant), or (alternatively, for combined-type IACD) the extinction time value shall be within the manufacturer specifications;
- when there are different types of outputs (e.g. NO or NC, solid-state or electromechanical...), the performance of each-one shall be evaluated separately when the manufacturer's performance specifications are different. When not, all shall be considered for the measuring maximum value for each test;
- unless clearly excluded by the manufacturer's instructions (e.g. requiring the IACD replacement after an arc-fault event), a functional test (as specified by the manufacturer) shall be conducted after the test and recorded in the test report;

NOTE 1 This functional test sequence is agreed between the manufacturer and the test laboratory.

NOTE 2 The functional test includes the detection of faulty sensor(s), when relevant.

- the latching time is in accordance with the manufacturer's declaration (not applicable to combined-type IACD);
- each operation of the IACD is a consequence of arc-fault detection;
- the resetting shall be effective after operation.

A voltage spike is used to determine t_0 for the detection and the extinction time measurement within this document. It allows an accurate start for an IACD performance measurement. See C.3 for exact method.

9.3.5 Dielectric properties

The IACD shall comply with 9.3.3.4 of IEC 60947-1:2020.

9.3.6 EMC tests

9.3.6.1 General

Subclause 9.4 of IEC 60947-1:2020 applies with the following additions.

The IACD is considered as product relevant for EMC environment A only.

Environment A relates to low-voltage non-public or industrial networks/locations/installations including highly disturbing sources.

NOTE Environment A corresponds to equipment class A in CISPR 11 and CISPR 32.

Combined-type IACD based on circuit-breakers shall be submitted to EMC tests according to F.2.2, F.3.2, F.4.2 to F.4.7, F.5 and Annex J of IEC 60947-2:2016 and of IEC 60947-2:2016/AMD1:2019.

Combined-type IACD based on AQD shall be submitted to EMC tests according to 9.3.2 of IEC 60947-9-1:2019.

Stand-alone and multifunction types IACD shall be submitted to tests according to 9.3.6.2 and 9.3.6.3.

To ensure the EMC compliance of the equipment during its useful life based on this type test, the manufacturer shall consider how to maintain the expected characteristic variations of the equipment within appropriate margins.

9.3.6.2 Electromagnetic disturbances immunity tests

9.3.6.2.1 General

Subclause 9.4.2.1 of IEC 60947-1:2020 applies.

9.3.6.2.2 Electrostatic discharges

Subclause 9.4.2.2 of IEC 60947-1:2020 applies.

9.3.6.2.3 Radiated radio-frequency electromagnetic fields

Subclause 9.4.2.3 of IEC 60947-1:2020 applies.

9.3.6.2.4 Conducted disturbances induced by radio-frequency fields

Subclause 9.4.2.4 of IEC 60947-1:2020 applies.

9.3.6.2.5 Electrical fast transients/bursts (EFT/B)

Subclause 9.4.2.5 of IEC 60947-1:2020 applies.

9.3.6.2.6 Surges

Subclause 9.4.2.6 of IEC 60947-1:2020 applies.

9.3.6.2.7 Power frequency magnetic fields

Subclause 9.4.2.7 of IEC 60947-1:2020 applies.

9.3.6.2.8 Voltage dips and interruptions

Subclause 9.4.2.8 of IEC 60947-1:2020 applies.

9.3.6.3 Electromagnetic disturbances emission tests

Subclause 9.4.3 of IEC 60947-1:2020 applies with the following additions.

Emission tests shall be performed according to Table 6 below.

Table 6 – EMC – Emission tests

Description	Reference standard	Limits	Mounting
Conducted RF disturbances 150 kHz to 30 MHz	CISPR 11 ^c	Class A, group 1 ^b	Free air
	CISPR 32	Class A ^b	
Radiated RF disturbances 30 MHz to 1 000 MHz ^a	CISPR 11 ^c	Class A, group 1 ^b	Free air
	CISPR 32	Class A ^b	
^a Applicable only for equipment under test containing processing devices (e.g. microprocessors) or switched-mode power supplies operating at frequencies greater than 9 kHz.			
^b Equipment class A in CISPR 11 and CISPR 32 corresponds to environment A in IEC 60947-1. Environment A equipment can cause electromagnetic interferences when installed in environment B. The manufacturer of environment A equipment shall declare the risk of electromagnetic interference in the product documentation.			
^c A description of the test, the test method and the test set-up is given in Clause 7 of CISPR 11:2015 and CISPR 11:2015/AMD1:2016.			

9.3.7 Environmental tests

9.3.7.1 General

Q.3.1 of IEC 60947-1:2020 applies, with the following additions:

The IACD under test shall be equipped with at least one optical sensor of each type that is available for the IACD.

The functional test shall be performed in accordance with the manufacturer's specifications. The use of any tooling is permitted.

Vibration tests and shock tests shall be run successively on the same sample, in the order agreeable to the manufacturer.

9.3.7.2 Damp heat test

The test shall be performed according to IEC 60068-2-30 (Test Db) 2 cycles at 55 °C, Variant 2.

A functional test shall be done during the first 2 h of the first cycle at the test temperature and during the last 2 h of the second cycle at the test temperature.

After a recovery period of 24 h in the normal atmospheric conditions, the insulation resistance measurement shall be conducted within 1 h after the recovery time. The insulation resistance shall be measured between each circuit and between each circuit and earth with a testing equipment complying with IEC 61557-2 (certain components, e.g. for transient suppression, may be required to be disconnected for this test). Table 7 below gives the conditions for insulation test.

Table 7 – Insulation test parameters

Maximum of the rated operational voltages	Test voltage DC	Minimum insulation resistance
Up to 65 V	2 × supply voltage (minimum 24 V)	10 MΩ
Over 65 V	500 V	100 MΩ ^a
^a Lower values are accepted for products already previously successfully tested accordingly to 10.6.4.4 of IEC 60255-27:2013.		

The IACD shall be verified after damp heat test by functional test (after minimum recovery time).

9.3.7.3 Vibration test

A vibration test shall be performed according to IEC 60068-2-6, Test Fc under conditions given by following Table 8:

Table 8 – Vibration test parameters

Frequency range	Displacement	Acceleration
2 ₀ ⁺³ Hz to 13,2 Hz	±1 mm	-
13,2 Hz to 100 Hz	-	±0,7 g

Test conditions:

- duration in case of no resonance condition: 90 min at 30 Hz;
- duration at each resonance frequency at which $Q \geq 2$ is recorded: 90 min;
- tests shall be carried out in three mutually perpendicular planes;
- generally an amplification factor $Q \leq 10$ is considered acceptable. Values higher than 10 shall be declared in the manufacturer documentation;
- critical frequencies are range of resonance frequencies where the amplification factor is greater than 2 without interruption;
- in case of several resonance frequencies within a range of 0,8 and 1,2 (sweep) of the critical frequencies, the duration of the test shall be 120 min at acceleration of 0,7 g.

Results obtained by continuous monitoring: during the vibration test, an unintended opening and closing of the contacts of more than 3 ms is considered a failure, unless a longer time is stated by the manufacturer in his documentation.

The defined interruption time (bouncing) may cause problems in some applications (e.g. programmable logic controller-monitoring with high speed inputs), this characteristic shall be considered in the application.

The IACD shall be verified after the vibration test by a functional test (see 9.3.9).

9.3.7.4 Shock test

Shock tests shall be performed according to IEC 60068-2-27, Test Ea under the following conditions:

Three positive and negative shocks, applied in each direction along three mutually perpendicular axes:

- pulse shape: half-sine;

- peak acceleration: 100 m/s²;
- duration of the pulse: 11 ms.

The IACD shall be verified after the shock test by a functional test.

9.3.8 Temperature-rise tests

9.3.3.3 of IEC 60947-1:2020 applies with the following addition.

Current-carrying parts with rated value less than 0,5 A are not deemed to be tested.

9.3.9 Functional tests

The following methods are said acceptable, upon the manufacturer's choice:

- embedded automatic test routine (permanent or on-demand);
- mobile test bench (for light and current simulation);
- any other solution provided by the manufacturer agreed by the laboratory.

The test criteria is the capability of an IACD to operate as intended.

The functional tests results shall be recorded in the test report.

9.4 Routine tests

9.4.1 General

For the definition of routine tests, see 3.8.2 of IEC 60947-1:2020 and 9.1.3 of IEC 60947-1:2020.

Routine tests are deemed to verify the following essential requirements on each product before commissioning:

- functional requirements;
- safety requirements.

They are usually performed at the last manufacturing stage but left to the manufacturer's discretion.

They are not intended to:

- verify the performances stated by the manufacturer;
- demonstrate any sensitivity or immunity level;
- cover all combinations of settings, hardware and software equipment;
- cover all ranges of supply voltage, input currents.

No additional routine tests for safety requirements (9.4.3) are deemed necessary for combined-type IACD compliant with their associated product standard.

When compliance is not demonstrated, safety requirements are covered by processing tests in 8.4 of IEC 60947-2:2016 (for line-type combined IACD) and 9.4 of IEC 60947-9-1:2019 (for parallel-type combined IACD).

9.4.2 Functional requirements

For these tests, the minimum equipment of the IACD can be acceptable as follows:

- one optical sensor;
- auxiliary power supply (when any) powered at nominal rated value;
- one output monitored, selected at random;
- when relevant, one external CT;

NOTE 1 More onerous configurations can be accepted.

In addition, the following is permitted:

- simulation of secondary current (either by Ampere x turn using a CT, secondary injection to simulate CT or full software simulation);
- simulation of arc-light by appropriate method (e.g. permanent light source for example xenon lamp, or arc-light simulation).

The following test applies:

- single verification of the operation of the IACD when all conditions (light and current, when relevant) are satisfied;
- single verification of the non-operation of the IACD when "light" condition is not fulfilled;
- alternatively (and for multifunction-type only) to verify the additional involved hardware components (e.g. CTs, optical inputs, contacts) without testing the operation.

NOTE 2 "Operation of the IACD" to be understood as "change-of-the-state".

9.4.3 Safety requirements

The test conditions shall be in accordance with 9.3.3.4.1, item 1), of IEC 60947-1:2020.

NOTE All input/outputs of stand-alone or multifunction-type IACD are covered by "control and auxiliary circuits" of IEC 60947-1.

The method of test shall be as in a) or b) or c) below at the manufacturer's discretion:

a) Two tests shall be made:

1) Impulse withstand voltage

The test voltage shall not be less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or the peak value corresponding to $2 \times U_i$ whichever is the greater, and

2) Power frequency withstand voltage

The test apparatus shall be as stated in 9.3.3.4.1, item 3) b), of IEC 60947-1:2020, except that the overcurrent trip threshold shall be set to 25 mA. However, at the discretion of the manufacturer, for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the trip setting of the overcurrent relay; for example, for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be $5 \text{ mA} \pm 1 \text{ mA}$.

The value of the test voltage shall be $2 \times U_e \text{ max}$, with a minimum of 1 000 V RMS, applied for not less than 1 s. The overcurrent relay shall not trip.

b) A single power frequency test in accordance with item a) 2) above at a test voltage such that the peak value of the sinusoidal wave corresponds to the highest of the peak values of the following: 30 % of U_{imp} , $2 \times U_i$, $2 \times U_e \text{ max}$ or 1 000 V RMS.

c) An insulation resistance test at 500 V DC. The insulation resistance shall be not less than 1 MΩ at any point.

In addition, an IACD with accessible conductive parts which may become live in the event of a single-fault condition shall be subject to a low current continuity test to verify their bonding to the protective conductor terminal.

10 Test report

With regards to tests performed in accordance with Annex A and Annex B, the following information shall be given in the test report:

- IACD manufacturer's name or trade mark;
- type designation or reference;
- serial number(s);
- all characteristics which are verified by the test(s);
- settings, parameters, configuration for each test(s);
- reference of associated optical sensor and CT(s) (where applicable);
- reference of auxiliary power supply (when any);
- type and number of output(s) tested, and associated configuration (when relevant);
- light sensitivity setting (when relevant);
- for reduced energy tests (see Annex A):
 - environmental conditions;
 - arrangement of the arc-test box connections to power source;
 - description with pictures and/or drawings showing the main dimensions, details relevant to the mechanical and electrical arrangement including optical and current sensors;
 - measured performance for each operation;
 - result of functional tests;
 - tests repeated when deemed void;
 - any replacement of optical fibre or optical sensor;
 - number of samples when greater than 1;
- for high energy tests (see Annex B):
 - environmental conditions;
 - arrangement of the test connections to power source and the point(s) of initiation of the arc(s);
 - description with pictures and/or drawings showing the main dimensions and details relevant to the mechanical and electrical arrangement including optical and current sensors;
 - result of functional tests;
 - any replacement of optical fibre or optical sensor;
 - duration of the arc when different from standard value, and any use of mitigation device provided by the laboratory;
- for calibration, oscillograms showing prospective source-current(s) and source-voltage(s);
- for each test(s), oscillograms showing actual arc-current(s), arc-voltage(s) and any other information relative to the assessed characteristic (e.g. IACD trigger output);
- assessment of the test results.

Annex A (normative)

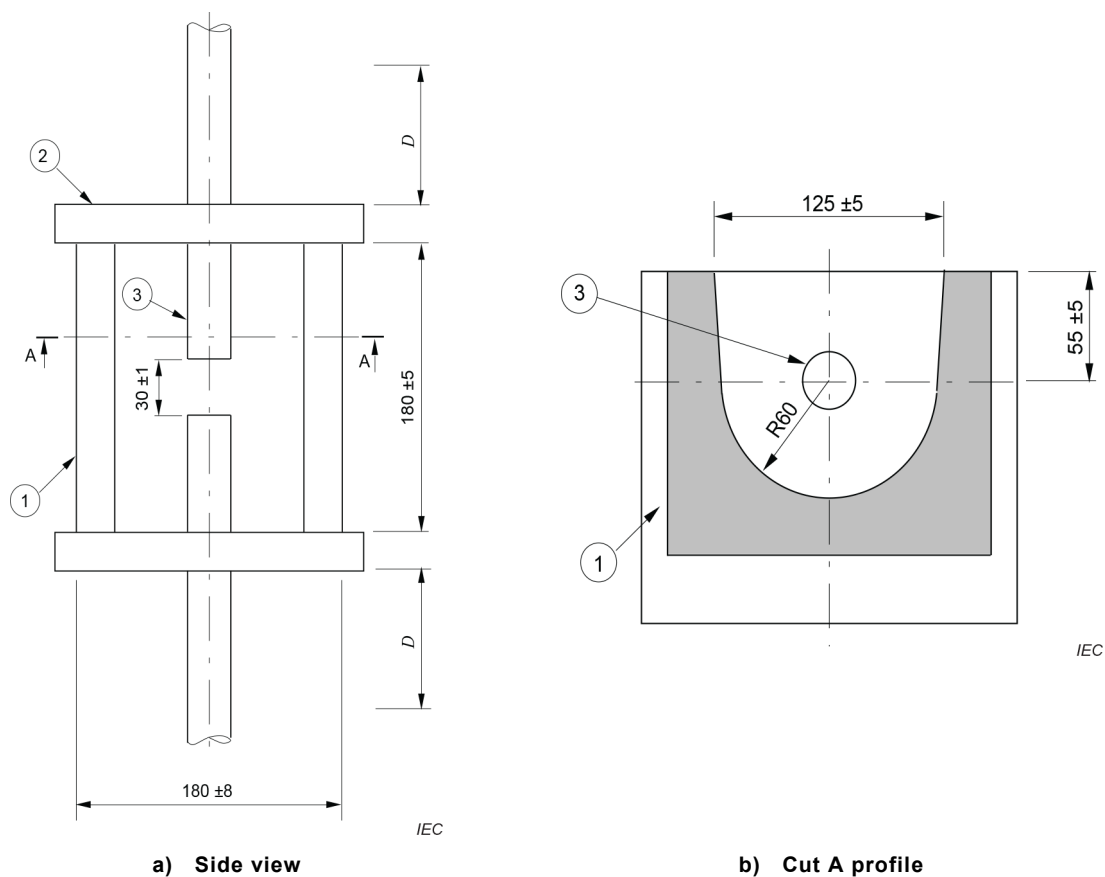
Detection tests under reduced energy arcs

A.1 General

Tests under reduced energy shall be performed using the arc-test box, as defined in IEC 61482-1-2:2014 (see Figure A.1 a) and Figure A.1 b)).

In addition, the following changes applies:

- the electrodes shall be made of copper;
- the cable connection may be simplified (curve radius of connecting cables are not specified as long as arc does not extinguish);
- the material selection may be extended to alternative heat-resistant and non-conductive materials.



NOTE 1 30 mm arcing gap cannot be correlated with final use of the product, which is the scope of IEC TS 63107.

NOTE 2 All distances are in millimetres.

[SOURCE: IEC 61482-1-2:2014, Figure 1 and Figure 2, modified]

Key

- 1 non-conductive heat resistant material (plaster)
- 2 insulating plate, thickness > 15 mm
- 3 electrodes $\varnothing$ 25 mm $\pm$ 1 mm (copper)
- D distance to connection, length > 100 mm

Figure A.1 – Arc-test box outline

A.2 Electrical test circuit, electrodes and arc parameters

A.2.1 Electrical test circuit

Test circuit shall be in accordance with Table A.1 below.

Table A.1 – Test circuit conditions

Parameter	Value
Test voltage and frequency ^{a, b}	45 Hz to 65 Hz 400 V ± 5 %
Cos (Φ)	0,5 _{0,1}
Closing angle of the source	90° $\pm 10^\circ$
^a This document does not cover DC applications or ratings, hence it does not define DC tests. ^b These values are not deemed to reproduce rated voltage or frequency of mains on which IACD is installed.	

A.2.2 Calibration of test circuit

The circuit shall be calibrated by measuring the bolted (prospective) short-circuit current value.

A.2.3 Electrodes

Rod-shaped electrodes shall have a diameter of 25 mm ± 1 mm.

Top and bottom electrodes shall be made from electrolytic copper (purity of at least 99,5 %).

The electrodes shall have flat faces (90° $\pm 5^\circ$ to the centerline axis of the electrode).

A.2.4 Ignition wire

To ignite the arc, an ignition wire defined in Table A.2 shall be used. The wire shall be electrically connected to both electrodes. The wire melts during the test and hence mass shall be kept small to minimize the effects on the tests.

Multiple-stranded twisted ignition wire is not permitted.

Table A.2 – Ignition wire specifications

Parameter	Value
Ignition wire material	Copper ^a
Ignition wire size	Ø 0,4 mm (0,125 mm ²) / AWG 26
NOTE Ignition wire connection on or around electrodes can be done by any convenient way, for example sticking with copper-tape.	
^a Copper is considered to represent other potential materials involved in arcing (e.g. steel, aluminium).	

A.2.5 Arc electrical values

The arc shall be monitored in accordance with Table A.3.

Table A.3 – Arc parameters

Parameter	Value	Remark
Arcing gap	30 mm ± 1 mm	Verification e.g. by use of 3-step caliper.
Arc current value	10 ⁰ ₋₁ kA RMS ^c	Prospective (bolted fault) current value. When adjustable, the test shall be repeated as follows: – I_{as} min – I_{as} max or max permitted setting of I_{as} below 10 ⁰ ₋₁ kA RMS ^c , the greater of.
Orientation of the arc	Vertical	When sensors non-sensitive to arc orientation, horizontal orientation accepted as well.
Duration of the arc ^{a, d} (stand-alone or multifunction)	Half-period of the fundamental	Agreement between user and manufacturer when maintained for longer duration, e.g. when necessary due to any intentional delay or threshold on current.
Duration of the arc ^{a, b} (combined-type)	Twice the maximum extinction time	Agreement between user and manufacturer when maintained for longer duration, e.g. when necessary due to any intentional delay or threshold on current.
^a If the arc extinguishes after detection achieved test is passed. ^b If the arc extinguishes because of mitigation, test is passed. ^c Or any lower value, when claimed by the manufacturer (see 5.2). ^d The arc-continuity shall be checked regarding C.4.		

A.2.6 Environmental conditions

Tests shall be conducted in accordance with Table A.4.

Table A.4 – Environmental conditions

Parameter	Value	Remark
Background light value ^{a, b}	300 lx (max)	No specific "black-box" type enclosure mandatory, upon discretion of test laboratory
Ambient temperature ^c	0 °C to 40 °C	
^a The value shall be recorded in the test report. ^b Any other value may be accepted, provided that no incorrect operation is experienced. ^c The ambient temperature shall be within the limits given by the IACD manufacturer.		
NOTE The atmospheric pressure, the time between test operations and the relative humidity are considered as non-relevant test parameters.		

A.2.7 Conditioning of test objects

No conditioning of sensors is required, unless specified in the manufacturer's documentation.

A.3 Preparation and maintenance

A.3.1 Preparation and conditioning of the test box

The test circuit shall be adjusted to meet the expected test current and the test arcing time values.

The electrodes shall be positioned to get 30 mm arcing gap between each other. The position of the sensor should be in the middle of the 30 mm arcing gap between the electrodes at a distance D . Figure A.2 and Figure A.3 below describe the schematic of point-sensor and optical fibre tests. The ignition wire which connects both electrodes by shortest distance possible shall be tightened and the remaining wire shall be cut off.

NOTE 1 To prevent the consequences of unintended arcs (see C.7), the use of copper tape is an option.

The test box shall be prepared and conditioned prior to the test.

In order to not facilitate the reflection, the U-shape shall be blackened. This could be done by using a black colorant before molding the U-block, or by painting before any use, and periodical re-furbishing. No painting or spraying shall pollute the electrodes. For the former, allow enough time for drying before use.

The test box shall be cleaned after each arc. Metal particles or any other debris shall be removed. If the box does not meet the measuring tolerances given within this document, it shall be replaced.

NOTE 2 The number of maximum test operations per test box are influenced by the box material and the construction of the box.

A.3.2 Care and maintenance of the test equipment

The electrodes shall be cleaned mechanically after each arc test. The surface shall be clean. Melted metal and remains of the ignition wire shall be removed. The cleaning shall ensure a proper electrical contact between electrodes and ignition wire for proper ignition.

The needed 30 mm $\pm$ 1 mm distance between the electrodes shall be ensured after each test.

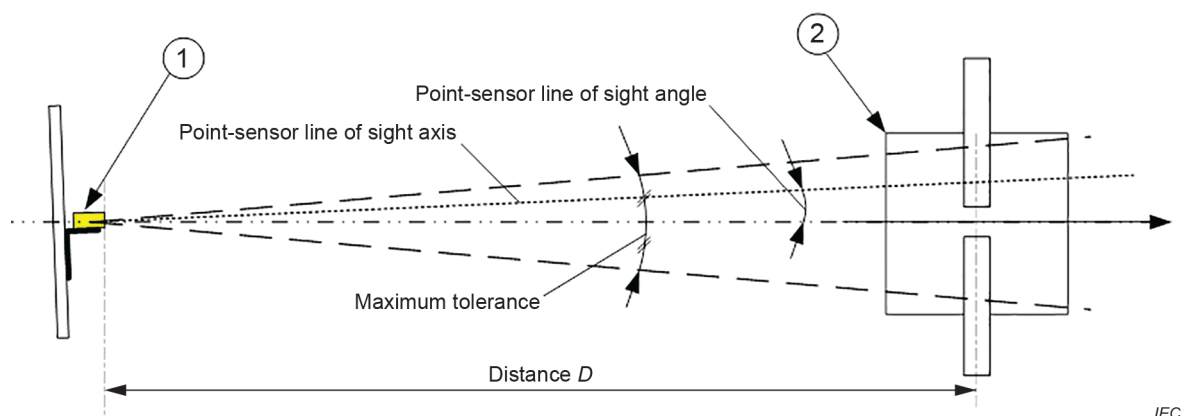
A.4 Optical sensors conditioning and positioning

The conditions for the two existing types of optical sensors (i.e. point-sensors and optical fibre sensors) are described in Table A.5 and Table A.6.

Tests assume that point-sensors have a uniform angle of light acceptance. In any other case, additional tests shall be agreed between the manufacturer and the user.

Table A.5 – Point-sensor positioning values

Parameter	Value	Remark
Point-sensor distance D to the arc	Maximum sensor distance to the arc (according to the manufacturer's specifications), with a maximum distance of 2 000 mm ^a .	Tolerance on distance is $^{+5\%}_0$. When the manufacturer specifies to replace the sensor after each test operation, it shall be recorded in the test report. When light sensitivity ^d is adjustable, the two extreme setting values shall be tested and results recorded in the test report. Additional tests may be required by the manufacturer.
Point-sensor line of sight angle ^b	$0^{+15^\circ}_{-15^\circ}$ ^c	
^a Under agreement between manufacturer and user, this distance may be increased. ^b Point-sensor line of sight angle is the angle between the theoretical mid-distance to the electrodes and the real line of sight axis of the sensor as specified by the manufacturer. ^c Additional tests at greater values may be performed at the option of the manufacturer. ^d "Highest sensitivity" to be understood as the lowest current-value, or the lower setting, when adjustable.		



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Key

- 1 optical point-sensor
- 2 arc-test box

Figure A.2 – Positioning principle (point-sensor test case)

Table A.6 – Optical fibre sensor positioning values

Parameter	Value	Remark
Exposed length of optical fibre sensor	Single section. Unless a different value is required by the manufacturer, expose a length of 0,5 m centred at the mid-point of the arcing gap. This length shall be installed at the longest distance from the IACD's optical input allowed by the manufacturer.	The tolerance on exposed length is $0_{-5\%}$. No reflection is allowed. A tube will protect non-exposed length. The background will be blackened to avoid any reflection.
Distance D from arc to optical fibre sensor exposed length	The fibre exposed mid-length distance to arc shall be set to the maximum value according to the manufacturer's specifications, with a maximum distance of 2 000 mm ^a.	Tolerance on distance is $+5\%_0$. The distance shall be recorded in the test report. When the fibre has been damaged, the replacement is deemed to be done in accordance with the manufacturer's instructions and recorded in the test report.
Shape of exposed length of optical fibre sensor	Vertically straight.	Fixing in open-air or on wooden plate is authorized to keep it straight. Possibility to fix the "upper" part, and to weight the lower when necessary.
^a If agreed between the manufacturer and the user, this distance can be increased.		