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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Photovoltaic power systems – DC arc detection and interruption

Systèmes photovoltaïques – Détection et interruption d'arc en courant continu

IEC 63027:2023-05(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOVOLTAIC POWER SYSTEMS – DC ARC DETECTION AND INTERRUPTION

FOREWORD

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

Draft	Report on voting
82/2112/FDIS	82/2133/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/publications.

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

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- withdrawn,
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INTRODUCTION

This document provides requirements and testing procedures for arc-fault protection devices used in PV systems to reduce the risk of igniting an electrical fire.

A PV system contains a number of distributed DC sources (PV modules) and circuits. In AC systems series arc durations are limited by the alternating current crossing through zero ampere twice per cycle. In DC systems the arcing current may be constant and longer arc durations are expected. In contrast to a centralized power supply, where in case of a fault the circuit is disconnected at the connection to the supply, a PV system is made up of distributed power supplies which cannot disconnect circuits in a single location. For extinguishing series arcs, however, the location of the arc within the circuit is irrelevant as long as the current is interrupted. This arc fault protection may be located inside the inverter, on array circuits, subarray circuits, string circuits, or at the module level. Therefore, this document provides a range of test setups to cover the expected system topologies.

In PV systems earth fault protection is required according to the IEC installation standards. Moreover, single core cables with double or reinforced insulation are required (except ELV systems). Consequently, the risk of parallel arcs is quite low because in most cases an earth fault occurs first. As such, this document does not address requirements or testing for parallel arc detection. The larger risk for PV systems comes from series arcs, therefore the focus of this document is to provide requirements and tests for arc fault protection equipment to ensure that most series arcs in a PV system will be detected.

Many arc fault detectors detect arcs by analyzing and comparing the arc's HF signal emission. These devices may trip due to external disturbances from other equipment connected to the PV array, e.g. the inverter. Therefore, interoperability needs to be evaluated. Other external influences such as radio signals, sparks from trams, and load switching, among others, may also cause nuisance tripping. These causes are a performance issue and therefore not addressed by this document.

Arc fault detectors for PV systems have been introduced as a requirement in the USA since the 2011 U.S. National Electrical Code was published. This led to the development of a PV arc-fault protection product standard, UL 1699B. Experience derived from these documents and their application in the USA has been used as a basis for this document. This document was written in parallel to the maintenance of UL 1699B. Both writing teams considered the work of each other and aligned requirements as much as possible, including the dimensions of the electrodes.

Arc fault detectors have been mandatory for many years in the USA for certain AC installations. Within the IEC, arc fault detectors required according to IEC 62606 have been introduced for certain locations for AC circuits. For PV circuits there was no IEC product standard available. This document therefore now provides test procedures for PV system arc fault detectors, where required by installation standards.

This document was written for the special needs and characteristics of PV systems. The unique aspects of PV DC sources (group of distributed sources, current behavior, dependency to irradiance, system impedance, etc.) differ considerably from other DC sources and applications. Therefore, this PV specific standard was necessary, and equipment compliant to this document is not suitable for other DC sources and applications.

PHOTOVOLTAIC POWER SYSTEMS – DC ARC DETECTION AND INTERRUPTION

1 Scope

This document applies to equipment used for the detection and optionally the interruption of electric DC arcs in photovoltaic (PV) system circuits. The document covers test procedures for the detection of series arcs within PV circuits, and the response times of equipment employed to interrupt the arcs.

The document defines reference scenarios according to which the testing is conducted. This document covers equipment connected to systems not exceeding a maximum PV source circuit voltage of 1 500 V DC.

The detection of parallel circuit arcs is not covered in this document. This document is not applicable to DC sources or applications other than PV DC sources.

NOTE Parallel arc detection may be considered for a future edition.

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 60730-1:2013, *Automatic electrical controls – Part 1: General requirements*
IEC 60730-1:2013/AMD1:2015
IEC 60730-1:2013/AMD2:2020

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

IEC 60947-3:2020, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC TS 61836:2016, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 62109-1:2010, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions in IEC TS 61836 apply, as well as the following:

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
arc
arcing
self-maintained gas conduction for which most of the charge carriers are electrons supplied by primary-electron emission

[SOURCE: IEC 60050-121:1998, 121-13-12]

3.2
arc fault
arcing fault
dangerous unintentional parallel or series arc between conductors

[SOURCE: IEC 62606:2013, 3.2, modified – "parallel or series" and "between conductors" has been added]

3.3
arc fault detector
AFD
device or group of devices to detect arcs

3.4
arc fault interrupter
AFI
device triggered by an AFD and able to interrupt an arc

3.5
arc fault protection equipment
AFPE
combination of AFD and AFI to detect and interrupt arc faults

3.6
arc detection
function of sensing the presence of an arc fault

[SOURCE: IEC 62606:2013,3.5, modified – "consisting in" has been replaced by "of"]

3.7
arc interruption
function of extinguishing the arc by de-energizing it, achieved by e.g. opening the circuit using a mechanical contact set with an air gap or a solid state switching device

3.8
series arc fault
arcing that is in series with the load and is the result of a failure in the intended continuity of a conductor, connection, module or other system components in the direct current PV circuit

3.9
open-circuit voltage
V_{oc}
voltage at the output terminals of a PV device at a particular temperature and irradiance when the output electric current of the PV device is zero, defining a voltage input parameter of the AFPE or AFD

[SOURCE: IEC TS 61836:2016, 3.4.56, modified – "defining a voltage input parameter of the AFPE or AFD" has been added]

3.10
current at maximum power point
I_{mpp}
current at the output terminals of a PV device at a particular temperature and irradiance at the conditions of maximum power of the PV device, defining a current input parameter of the AFPE or AFD

3.11
voltage at maximum power point
V_{mpp}
voltage at the output terminals of a PV device at a particular temperature and irradiance at the conditions of maximum power of the PV device, defining a voltage input parameter of the AFPE or AFD

3.12
rated channel current
current the AFPE or AFD channel can carry. This corresponds to the sum of all currents carried by a channel

3.13
rated interruption current
current the AFI or AFPE can interrupt

3.14
maximum rated current per input port
I_{pA}
current that one input port of an AFD or AFPE is limited to

Note 1 to entry: The maximum current per input port is typically identical to the maximum arc current.

3.15
power conversion equipment
PCE
device or equipment able to convert electric power from one form to another

3.16
string
circuit of one or more series-connected PV modules

3.17
PCE integrated device
AFD or AFI or AFPE which are integrated into the PCE

3.18
stand-alone device
AFD or AFI or AFPE which are separated and independent from the PCE

3.19
distributed detection system
AFPE which is distributed within the PV system

3.20
single channel device
device which has one sensor circuit for arc detection

3.21
multi channel device
device which has two or more independent sensor circuits for arc detection

3.22
device under test
DUT
particular sample that is being measured or observed

3.23
photovoltaic
PV
relating to the conversion of light directly into electrical energy

[SOURCE: IEC 62109-1:2010, 3.55]

3.24
short-circuit current
I_{sc}
electric current at the output terminals of a PV device at a particular temperature and irradiance when the device output voltage is equal to or close to zero

[SOURCE: IEC 61836:2016, 3.4.80, modified – Note 1 has been deleted]

4 Classification

4.1 General

This clause gives an overview of the classifications used for AFD and AFPEs in this document. The classification scheme describes the equipment type and considers the important aspects relevant for testing and installation. Installation standards can refer to this classification to specify requirements for arc fault protection.

Protection coverage: Defines which parts of a PV system or installation are covered by the AFD or AFPE.

Method of implementation: Defines the type and design of the AFD or AFPE. The method of implementation especially impacts construction requirements and testing.

Functionality: Indicates whether an equipment or device is an AFD or AFPE.

Number of monitored strings, inputs and channels: The maximum number of connected PV strings, inputs and measurement channels that can be supported by the AFD or AFPE, and for which it is tested.

Reconnection method: Defines which reconnection methods are supported by the product.

Annex B provides additional information and introduces measures to group the following classifications into various use cases.

AFPE may have more than one classification, and different ratings may apply for each classification. In this case the manufacturer shall document the installation and connection requirements for each classification.

NOTE One example is an inverter that allows for the direct connection of PV strings or the connection of one DC main cable. For direct string connections the classification could be F-I-AFPE-1-4-1 and for the main cable connection the classification could be P-I-AFPE-6-1-1.

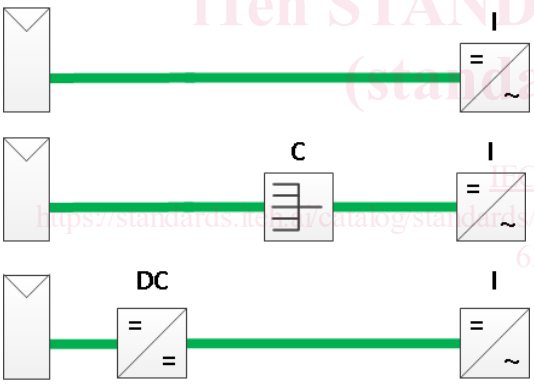
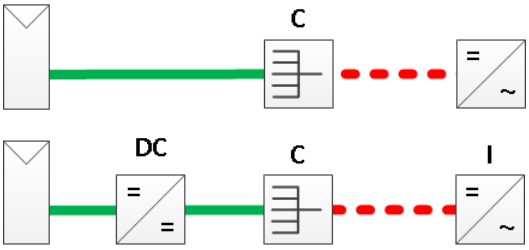
AFPE may provide input ports with different ratings (e.g. number of strings per input port, current rating). In this case the tests shall be performed in the worst-case configuration.

4.2 Protection coverage

The protection coverage defines which circuits and components of the PV system are covered by the AFD or AFPE.

Two types of classifications are defined, see Table 1.

Table 1 – Classification of protection coverage

System	Code	Description
	F	Arc fault protection is provided from the PV modules up to the inverter input terminals. (Full coverage)
	P	Arc fault protection is provided from the PV modules up to the parallel connection of the strings. No arc fault protection is provided for wiring between the parallel connection and the inverter input terminals. (Partial coverage)

NOTE Typically full coverage (F) is hard to achieve for high currents in DC main cables. Also, the 750 J protection threshold may be difficult to achieve because of the high currents and the physical limits in interruption times. Fire hazard protection may be provided by means of installation.

4.3 Method of implementation

4.3.1 PCE integrated device (I)

The AFPE is implemented within a PCE connected to the PV array and makes use of the housing and terminals of the PCE.