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Photovoltaic (PV) arrays – Earth fault protection equipment – Safety and safety-related functionality

Groupes photovoltaïques (PV) – Matériel de protection contre les défauts à la terre – Sécurité et fonctionnalités relatives à la sécurité

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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CONTENTS

FOREWORD 6
INTRODUCTION 8
1 Scope 9
2 Normative references 9
3 Terms, definitions, symbols and abbreviated terms 10
4 Requirements relating PV-EFP to system topology 12
4.1 General 12
4.2 PV-EFP functions for different system topologies 16
4.3 PV-EFPE control over host system operation 18
4.3.1 General 18
4.3.2 Types of PV-EFPE requiring host system control 18
4.3.3 Methods of control of the host system operation 18
4.4 Disconnection under fault conditions 19
4.4.1 General 19
4.4.2 Disconnecting means 19
4.4.3 High impedance connections 19
4.4.4 Indirect disconnection 19
4.5 Systems with more than one sub-array (informative) 20
4.5.1 General 20
4.5.2 Isolated sub-arrays 20
4.5.3 Non-isolated sub-arrays 20
5 PV array to earth insulation monitoring 20
5.1 General 20
5.2 Array insulation monitoring requirements 21
5.3 Array insulation fault response requirements 21
5.4 Provisions for reset 22
5.5 Insulation monitoring function adjustability 22
6 PV array residual or earth current monitoring 22
6.1 General 22
6.2 Required PV-EFP current monitoring functions 22
6.3 Shock hazard current monitoring 23
6.3.1 General 23
6.3.2 Limits and response 23
6.3.3 Provisions for reset 23
6.3.4 Shock hazard current monitoring – adjustability 24
6.3.5 Fault tolerance of shock hazard current monitoring 24
6.4 Fire hazard (continuous) current monitoring by electronic means 24
6.4.1 Overview 24
6.4.2 General 24
6.4.3 Settings and response 24
6.4.4 Provisions for reset 25
6.4.5 Fire hazard current monitoring function adjustability 25
6.4.6 Fault tolerance of fire hazard current monitoring by electronic means 25
6.5 Fire hazard current monitoring by an overcurrent protective device in the functional earthing conductor 25
6.5.1 Overview 25

6.5.2 General 25
6.5.3 Ratings 26
6.5.4 Response 26
6.5.5 Provisions for reset 26
6.5.6 Overcurrent protective device adjustability and replacement 26
7 Construction 27
7.1 General 27
7.2 Environmental considerations 27
8 PV-EFP Fault Indication 28
8.1 General 28
8.2 Integral fault indication 28
8.3 Remote fault indication 28
8.3.1 General 28
8.3.2 Observability 28
8.3.3 Remote fault indication means 28
8.4 Resetting of the fault indication 28
9 Testing 29
9.1 General requirements for the tests in 9.2 through 9.5 29
9.1.1 Tests required 29
9.1.2 DC sources 29
9.1.3 AC sources 30
9.1.4 Laboratory conditions 30
9.1.5 Monitoring the PV-EFPE means of control of the host system 30
9.1.6 Control of the PV-EFPE state 30
9.1.7 Test setup 31
9.2 Tests for PV array insulation monitoring functions 32
9.2.1 Setup 32
9.2.2 Sequence of tests 33
9.2.3 Test for R_{iso} above setting during system start-up 34
9.2.4 Test for R_{iso} below setting during system start-up 34
9.2.5 Test for R_{iso} dropping below setting during operation 34
9.2.6 Test for short circuit earth fault during system start-up 35
9.2.7 Test for short circuit earth fault during operation – non-earth-referenced PV arrays 35
9.2.8 Tests for PV array mid-point fault detection 36
9.2.9 24 h timer test 36
9.3 Tests for residual or earth current monitoring functions: 36
9.3.1 Setup 36
9.3.2 Sequence of tests 37
9.3.3 Tests for shock hazard current monitoring 37
9.3.4 Tests for fire hazard current monitoring by electronic means 39
9.3.5 Fault-tolerance of shock hazard current monitoring and fire hazard current monitoring by electronic means 41
9.3.6 Tests for fire hazard current monitoring by an overcurrent protective device in the functional earthing conductor 42
9.4 Test for short circuit earth fault during operation 42
9.4.1 General 42
9.4.2 Short circuit earth fault test procedure 42
9.4.3 Short circuit earth fault test pass/fail criteria 42

9.5 Tests for coordination of PV-EFP functions 43
9.6 Product safety tests 44
10 Software or firmware performing safety critical functions 44
10.1 General 44
10.1.1 Overview 44
10.1.2 Risk analysis 44
10.1.3 Integrated PV-EFPE 45
10.2 Evaluation methods 45
10.2.1 General 45
10.2.2 Testing with features disabled 45
10.2.3 Functional safety analysis 45
11 Marking and documentation 46
11.1 Equipment markings 46
11.1.1 General 46
11.1.2 Marking content 46
11.2 Installation and operating instructions 48
11.2.1 General 48
11.2.2 General content 49
11.2.3 Information related to installation 49
11.2.4 Information related to operation 51
11.2.5 Information related to maintenance 52
12 Routine (production) tests 52
12.1 General 52
12.2 Routine dielectric tests 52
12.3 Routine EFP function tests 52
12.3.1 General 52
12.3.2 Shock hazard current monitoring 53
12.3.3 Electronic fire hazard current monitoring 53
12.3.4 Residual current device test function 53
12.3.5 PV array insulation monitoring function 53
Annex A (informative) Examples of system topologies with respect to PV Earth Fault Protection 54
A.1 General 54
A.2 Functionally earthed (FE) system with FE current monitoring 54
A.3 Functionally earthed (FE) system with a functionally earthed conductor fault 55
A.4 Functionally earthed (FE) system with residual current monitoring 56
A.5 Non-separated system with residual current monitoring on PV+/- 57
A.6 Non-separated system with residual current monitoring on the AC side 58
A.7 Non-earth-referenced system with continuous insulation monitoring 59
Annex B (informative) Background and rationale for PV Earth Fault Protection requirements 60
B.1 Purpose 60
B.2 PV earth faults – scope and meaning 60
B.3 PV-EFP goals 61
B.4 PV-EFP challenges 61
B.4.1 Characteristics of PV systems that affect PV-EFP approaches 61
B.4.2 PV-EFP “blind spots” and coordination of protective measures 63
B.4.3 Relation between PV-EFP protection settings and PV system size 65
B.5 Current and historical standards covering PV Earth Fault Protection 68

B.5.1 General 68
B.5.2 NFPA 70 – the US National Electrical Code (NEC) 68
B.5.3 UL1741 and related documents 68
B.5.4 VDE 0126-1-1 69
B.5.5 IEC 62109-2 70
B.5.6 IEC 60364-7-712 71
B.5.7 IEC 62548 71
B.5.8 Conclusions 72
Bibliography 73

Figure 1 – Examples of functionally earthed system topologies 14
Figure 2 – Examples of non-earth-referenced system topologies 15
Figure 3 – Examples of non-separated system topologies 16
Figure 4 – Example setup for PV-EFPE testing 32
Figure 5 – Example setup for PV-EFPE testing of array mid-point faults 33
Figure A.1 – Functionally earthed (FE) system with current monitoring in the FE conductor 54
Figure A.2 – Functionally earthed (FE) system with a functionally earthed conductor fault 55
Figure A.3 – Functionally earthed (FE) system with residual current monitoring 56
Figure A.4 – Non-separated 3-phase system with residual current monitoring on PV+/- 57
Figure A.5 – Non-separated 1-phase system with residual current monitoring on the AC side 58
Figure A.6 – Non-earth-referenced system with continuous insulation monitoring 59

Table 1 – PV-EFP functions based on system topology and earthing 17
Table 2 – Example PV array to earth insulation resistance limits 21
Table 3 – Shock hazard – Sudden current change limits and response times 23
Table 4 – Example continuous current limits and response times 24
Table 5 – Example trip current of overcurrent protection in the functional earthing conductor 26
Table B.1 – Sudden change residual current limits 70

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PHOTOVOLTAIC (PV) ARRAYS – EARTH FAULT PROTECTION EQUIPMENT – SAFETY AND SAFETY-RELATED FUNCTIONALITY

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FDIS	Report on voting
82/1885/FDIS	82/1903/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.

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INTRODUCTION

This document specifies the safety requirements that are applicable to Photovoltaic Earth-Fault Protection (PV-EFP) equipment (PV-EFPE) whose function is to detect, interrupt, and warn PV system operators of earth faults in solar photovoltaic arrays. A stand-alone standard on this topic is deemed necessary and appropriate because PV-EFPE may be designed as stand-alone equipment or may be integrated into other equipment such as PV inverters, charge controllers, combiner boxes, etc. Therefore it is not appropriate to continue the current standardization approach in which the PV-EFPE requirements are located only in an end-product standard specific to inverters: IEC 62109-2:2011. It is intended that in coordination with the publication of this document, IEC 62109-2 will be revised to refer to this document and to remove overlapping and conflicting requirements. With this approach, the PV-EFPE requirements will be more visible and will be usable for PV-EFPE that is not part of an inverter.

It is also desirable that in coordination with the publication of this document, the applicable IEC system and installation standards for PV arrays will be amended to refer to this document, to specify required functions and to remove overlapping and conflicting requirements. This work will be managed by TC82 for IEC 62548 and jointly by TC82 and TC64 through JWG32 for IEC 60364-7-712.

The appropriate functions, settings, responses, and timing for PV-EFP functions are dependent on the size and topology of the overall PV system. These array details are not known at the time the PV-EFPE is being evaluated to this product standard; therefore the required PV-EFP functions and settings need to be provided by local and international system and installation standards. As a result, this document does not require all PV-EFPE to implement all possible functions, and does not generally contain the required settings for the functions. The functions, settings, and ranges of adjustment that are claimed by the equipment manufacturer are tested and evaluated, and the documentation for the installer and user specifies what functions are and are not provided.

As well as requirements for the PV-EFP functions, this document includes product safety requirements covering the construction, environmental suitability, markings, documentation, and testing of the equipment. Since PV-EFPE is related to, and often integral to, PV power conversion equipment, references are made to product safety requirements in IEC 62109-1. However, those requirements may overlap or conflict with existing IEC standards for certain types of equipment related to PV-EFP (for example insulation monitoring devices and residual current monitoring equipment). Therefore, for some aspects, this document provides options for equipment to comply with those standards, where such standards exist.

NOTE Further information on the intent of this document and special aspects of PV earth faults are summarized in the (informative) Annex B.

PHOTOVOLTAIC (PV) ARRAYS – EARTH FAULT PROTECTION EQUIPMENT – SAFETY AND SAFETY-RELATED FUNCTIONALITY

1 Scope

This document is applicable to low voltage Photovoltaic Earth-Fault Protection Equipment (PV-EFPE) whose function is to detect, interrupt, and warn system operators of earth faults in solar photovoltaic arrays.

NOTE 1 In the context of this document, the PV array may include connected wiring and equipment. The required coverage of the monitoring and protection is defined in PV installation codes and standards, including aspects such as whether or not the coverage is required to include battery circuits, the DC outputs of DC-DC converters, etc.

NOTE 2 The IEC definition of low voltage is 1 000 V or less for AC systems and 1 500 V or less for DC systems. PV-EFPE may be stand-alone or integrated into other equipment such as PV power conversion equipment, a PV combiner, etc.

This document specifies:

– the types and levels of the monitoring and protection functions that may be provided;
– the nature and timing of responses to earth faults;
– test methods for validating the monitoring and protection functions provided;
– requirements for functional safety and fault tolerance;
– requirements for product safety including construction, environmental suitability, markings, documentation, and testing.

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 60269-6, *Low-voltage fuses – Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems*

IEC 60417, *Graphical symbols for use on equipment – 12-month subscription to regularly updated online database comprising all graphical symbols published in IEC 60417*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

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

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

IEC 61008-1:2010, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*
IEC 61008-1:2010/AMD1:2012
IEC 61008-1:2010/AMD2:2013

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

IEC 61557-8, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems*

IEC TS 61836, *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*

IEC 62109-3:2020, *Safety of power converters for use in photovoltaic power systems – Part 3: Particular requirements for electronic devices in combination with photovoltaic elements*

IEC TS 63053, *General requirements for residual current operated protective devices for DC system*

ISO 3864 (all parts), *Graphical symbols – Safety colors and safety signs*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC TS 61836 and the following apply.

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

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

3.1
closed electrical operating area
room or location for electrical equipment to which access is restricted to skilled or instructed persons by the opening of a door or the removal of a barrier by the use of a key or tool and which is clearly marked by appropriate warning signs

3.2
DC-only system
PV system where all energy sources and power conversion is DC, with no inverter and no AC connection in the system

3.3
earth fault
ground fault (US)
occurrence of an accidental conductive path between a live conductor and the Earth

Note 1 to entry: The conductive path can pass through a faulty insulation, through structures (e.g. poles, scaffoldings, cranes, ladders), or through vegetation (e.g. trees, bushes) and can have a significant impedance.

[SOURCE: IEC 60050-195:1998,195-04-14]

3.4
host equipment
equipment that integrated PV-EFPE is intended to be used with or installed in (see also 3.7)

3.5
host system
system in which the PV-EFPE is connected, consisting of at least a PV array, the PV-EFPE, and the load(s) for the PV system, such as PCE, energy storage equipment, DC loads, etc.

3.6
indicate <a fault>
annunciate that a fault has occurred in a manner that can be locally and remotely observed

Note 1 to entry: Requirements for fault indication are given in detail in 8.1 through 8.3.

3.7
integrated PV-EFPE
PV-EFPE that is integrated into, intended to be integrated into, or specified to be exclusively used with particular host equipment (see 3.4) that has intended function(s) other than PV earth fault protection, and that the PV-EFPE is evaluated and tested with (for example a PCE, a PV combiner box, etc.)

3.8
***I*SC-PR-MAX**
PV-EFPE rating, applicable to any terminal intended for connection to an external power system, specifying the absolute maximum prospective short circuit fault current allowed to be available at the PV-EFPE terminals if a fault of negligible impedance is applied at the PV-EFPE terminals

Note 1 to entry: This is a general term applicable to all ports connecting to external sources of supply.For the PV port, the specific term is $I_{SC\ PV}$ as defined in 3.9.

3.9
***I*SC PV**

PV-EFPE maximum rated prospective short circuit current (see 3.8) at the PV input terminals; i.e. the absolute maximum current the PV input to the PV-EFPE is designed to withstand or carry under normal and fault conditions

Note 1 to entry: At the system design level, this rating would typically be coordinated with the total I_{sc} of the connected PV strings, adjusted for temperature, excess irradiance, etc., as required by installation standards (i.e. not simply the sum of the marked I_{sc} ratings of the connected PV modules, since those markings are based on short-circuit conditions under standard test conditions (STC), and may be exceeded in actual use).

Note 2 to entry: This is a particular case of the general definition of $I_{sc\text{-}pr\text{-}max}$ in 3.8, and is aligned with IEC 62109-1.

3.10
PV-EFP
photovoltaic earth fault protection

3.11
PV-EFPE
photovoltaic earth fault protection equipment

3.12
power conversion equipment
PCE
electrical device converting one kind of electrical power from a voltage or current source into another kind of electrical power with respect to voltage, current and frequency

Note 1 to entry: Examples include AC-DC converters, DC-AC inverters, DC-DC charge controllers, frequency converters, etc.

[SOURCE: IEC 62109-1:2010, 3.66]

3.13
R_{iso}
symbol representing the insulation resistance (isolation) between the PV array and earth

3.14
routine test
conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.15
safe state
condition which continues to preserve safety

[SOURCE: IEC 60050-821:2017, 821-12-49]

3.16
stand-alone PV-EFPE
PV-EFPE that is self-contained, and therefore not integrated PV-EFPE in accordance with 3.7, is for use in unspecified systems or with unspecified equipment, and is tested independently of any particular host equipment

3.17
system, functionally-earthed
system in which the PV array has one conductor intentionally connected to earth for purposes other than safety, by means not complying with the requirements for protective bonding

Note 1 to entry: Examples of functionally-earthed systems include earthing one conductor of the PV array through an impedance, relay, or overcurrent protective device, or systems in which the array is not permanently earthed (opening the earth connection periodically or under fault conditions).

Note 2 to entry: Examples of design elements that are not functional earthing include the use of varistors or other surge protection devices between a circuit and earth, and the use of a resistive network connected between the array and earth to measure the array insulation resistance (impedance monitoring). Neither of these examples creates a functionally-earthed system, as the impedance of such connections is normally very high.

Note 3 to entry: For examples of the various system types, refer to Figure 1 through Figure 3.

3.18
system, non-earth-referenced
system that has none of its conductors intentionally referenced to earth either directly or through the power conversion equipment (PCE)

3.19
system, non-separated
system in which the PV array is connected to an intentionally earth-referenced system, through a PCE without at least simple separation

4 Requirements relating PV-EFP to system topology

4.1 General

The following aspects of the system topology affect the approaches needed to protect against earth faults in the PV array:

– the PV system may or may not have separation between the PV array and the AC mains or other earthed power system;

– the PV array may or may not be functionally-earthed;

– the AC mains or other power system that the PV system output connects to may or may not be an earthed system.

In consideration of the above aspects, this document uses the following system types, for which examples are given in Figure 1 through Figure 3, to define requirements for protection against earth faults:

- functionally-earthed systems, as per 3.17 and Figure 1
- non-earth-referenced systems, as per 3.18 and Figure 2
- non-separated systems, as per 3.19 and Figure 3

Additional examples are given in Annex A, illustrating and explaining the fault current paths and EFP actions for various system topologies.