UL 1699B

STANDARD FOR SAFETY

Photovoltaic (PV) DC Arc-Fault Circuit Protection

UL Standard for Safety for Photovoltaic (PV) DC Arc-Fault Circuit Protection, UL 1699B

First Edition, Dated August 22, 2018

SUMMARY OF TOPICS

This revision of ANSI/UL 1699B dated May 18, 2021 includes the following changes in requirements:

– Revision to requirements for the self-testing of circuits; 23.1, 23.2, 23.7, 25.2, 27.2.2, 53.1, 53.2 and 53.7

– Additional set-up figure for the arc-fault detection test; Table 29.1, Figure 29.14, Figure 30.2, Figure 30.3, Figure 30.6B, 30.4.3 and 30.4.4

– Revision for additional single/dual module test configurations; 29.1.1, Table 29.1, Figures 29.7 and 29.8, Figure 29.8A, 29.7.1, Figure 29.17, Figure 29.17A.1 – Figure 29.17A.4, Figure 29.18, 30.1.1 and Figure 30.5A.1 – Figure 30.5A.4

– Clarification of miscellaneous requirements; 29.1.11, 29.1.12, Table 29.3 and Table 30.1

– Revision to annunciation and test methods; 22.1 and 52.1

– Clarification when using array simulators; 24.4, 29.1.3, Table 29.3 and Table 30.1

– Test conditions for single and dual module for electronic devices; Table 29.2

– Clarification for determining most adverse condition and brute force method for series arc-fault detection tests; 29.1.3 and 29.1.4

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated November 27, 2020 and March 12, 2021.

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Standard for Photovoltaic (PV) DC Arc-Fault Circuit Protection

First Edition

August 22, 2018

This ANSI/UL Standard for Safety consists of the First Edition including revisions through May 18, 2021.

The most recent designation of ANSI/UL 1699B as an American National Standard (ANSI) occurred on May 18, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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PART 1 – ALL DEVICES

INTRODUCTION

1 Scope

1.1 These requirements cover DC photovoltaic arc-fault circuit protection devices intended for use in solar photovoltaic electrical energy systems as described in Article 690 of the National Electrical Code, NFPA 70. This protection is intended to mitigate the effects of arcing faults that may pose a risk of fire ignition under certain conditions if the arcing persists.

1.2 These requirements cover devices including photovoltaic (PV) dc arc-fault circuit-interrupters (AFCI), arc-fault detectors (AFD), interrupting devices (ID) and inverters, converters, and charge controllers with integral arc-fault circuit-interrupter protection.

1.3 These requirements cover devices rated 1500 volts or less. They are intended for use in dc electrical systems that are supplied by a photovoltaic source, such as a module with solar cells designed to generate dc power when exposed to sunlight.

1.4 These devices are not intended to detect glowing connections.

1.5 In Part 1 of these requirements the term "device" is used generically to apply to all of the devices covered by these requirements and is modified when the requirement does not apply to all types. In Part 2 and Part 3 of these requirements the term "device" is used generically to apply to all devices covered by the particular part of this Standard, and is modified when the requirement does not apply to all types.

1.6 A device that is also intended to perform other functions, such as overcurrent protection, disconnects, combiner boxes, inverters, or other PV system functions or any combination thereof, shall additionally comply with the requirements of the applicable Standard or Standards that cover devices that provide those functions as intended for use in PV systems.

2 Glossary

2.1 For the purposes of this standard the following definitions apply.

2.2 ANNUNCIATOR – A feature of a device that gives an indication upon the functioning of a protective device.

2.3 ARCING – A luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.

2.4 ARCING FAULT – An unintentional arcing condition in a circuit.

2.5 CELL – The basic photovoltaic device that generates electricity when exposed to sunlight.

2.6 CHARGE CONTROLLER – A device intended to control the charging process of storage batteries used in photovoltaic power systems.

2.7 CONVERTER (DC) – A device that accepts dc power input and converts it to another form of dc power.

2.8 DUT – Device under test.

2.9 FUNCTIONAL INSULATION – Insulation that is necessary only for the functioning of the equipment.

2.10 INVERTER – An electronic device that changes dc power to ac power.

2.11 INTERRUPTING CONTACT – A contact device inserted in series with the source and/or load. It is intended to stop the flow of arcing current by opening the circuit and may be a mechanical contact set with an air gap or a solid state switching device.

2.12 MICROELECTRONICS – Monolithic, hybrid, or module circuits, where the internal circuit connections are not accessible exclusive of provided external connection pins or pads. The circuits are capable of functioning in the analogue mode, digital mode, or a combination of the two modes. Examples of microelectronics include: ASICs, ROMs, RAMs, PROMs, EPROMs, PALs, and PLDs. See 2.18.

2.13 OPERATION INHIBITION – Denotes the concealment of an arcing fault by the normal operation of certain circuit components.

2.14 PARALLEL ARCING – Arcing that is in parallel with the load, such as between the positive and negative conductors, or between any two conductors or, any single conductor and ground.

2.15 PHOTOVOLTAIC (PV) DC ARC-FAULT CIRCUIT-INTERRUPTER (PV AFCI) – A device that is intended to be installed in a photovoltaic energy system to interrupt power delivered to an arcing fault when an arcing fault is detected by the AFCI. It is intended to provide protection to the PV system from unwanted effects of arcing.

2.16 PHOTOVOLTAIC (PV) DC ARC-FAULT DETECTOR (PV AFD) – A device that is intended to provide protection to the PV system from unwanted effects of arcing by enabling an interruption or shorting device to interrupt power delivered to an arcing fault.

2.17 PHOTOVOLTAIC (PV) DC INTERRUPTING DEVICE (PV ID) – A device that is intended for installation in a photovoltaic energy system to interrupt a detected arcing fault. The device is generally enabled by another device which detects arcing, such an arc-fault detector. The device can perform an interruption or shorting function as appropriate to interrupt power delivered to an arcing fault.

2.18 PROGRAMMABLE COMPONENT – Any microelectronic hardware that can be programmed in the design center, the factory, or in the field. Here the term "programmable" is taken to be "any manner in which one can alter the software wherein the behavior of the component can be altered." The microelectronics defined in 2.12 are examples of programmable components.

2.19 PV MODULE – The smallest environmentally protected assembly of solar cells and ancillary parts, such as interconnects and terminals, intended to generate dc power under sunlight.

2.20 SERIES ARCING – 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 source and output circuits.

2.21 SHUNTING CONTACT – A contact device inserted in parallel with the source and/or load. It is intended to stop the flow of arcing current by short circuiting the supply or shunting current around the arcing fault location. It may be a mechanical contact set with an air gap or a solid state switching device.

2.22 TYPE 1 DEVICE – A photovoltaic device that is intended to detect or interrupt series arcing faults.

2.23 UNWANTED TRIP – A tripping function in response to a condition that is not an arcing fault but a condition that occurs as part of the normal or anticipated operation of circuit components.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

3.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

3.3 A component shall be used in accordance with its rating established for the intended conditions of use.

3.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

4 Units of Measurement

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

5 Undated References

5.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

6 General

6.1 All devices shall comply with the construction requirements in Sections 7 – 14 of this standard.

7 Corrosion Protection

7.1 Parts, in addition to enclosures, shall be protected against corrosion if failure of such parts would be likely to result in a hazardous condition such as the inability of the device to perform its intended function. Compliance is determined by the Corrosion Test, Section 38.

8 Current Carrying Parts

8.1 Current-carrying parts shall be of silver, a silver alloy, copper, a copper alloy or other metal acceptable for the application. Screws, nuts, or wire binding screws made of iron or steel and corrosion protected, shall be permitted to be used to secure live parts, but shall not be depended upon to carry current.

9 Internal Wiring

9.1 The gauge and insulation of wires shall withstand the mechanical and electrical stresses of service. Wires smaller than 24 AWG (0.21 mm^2) shall be investigated for the application.

10 Insulation

10.1 A device shall have at least functional insulation throughout. Materials shall be suitable for the temperature, voltage and conditions of service.

11 Power Supply

11.1 The power supply of a device shall be a commercial light and power source available in a building, dc power from a photovoltaic source, or both. The power supply shall be capable of allowing the device to function and provide protection at all times when the danger of an arcing fault is present.

11.2 When conducting tests in accordance with Part 2 or Part 3 of this standard, tests applicable to each intended power supply type as mentioned in 11.1 shall be conducted.

12 Operating Mechanism

12.1 Compliance with the provisions of arcing fault interruption shall not be prevented by manipulation or restraint of accessible levers, knobs, and the like of a device.

13 Programmable Circuit Components

13.1 If a device employs a programmable circuit component such as a microprocessor in its arc fault detection or interruption system, or in its test circuits, that portion of the device shall be investigated in accordance with the Standard for Software in Programmable Components, UL 1998, as defined in 13.2 – 13.9. As an alternative to UL 1998 and the requirements as defined in 13.2 – 13.9, the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, Annex H, or Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems, IEC 61508, may be used to evaluate functional safety. IEC 61508 evaluations shall be SIL2 or higher.

13.2 All of the requirements of the Standard for Software in Programmable Components, UL 1998, apply to programmable components employed in a device as mentioned in 13.1, except as modified by 13.3 – 13.9.

13.3 The risks to be considered for the Risk Analysis portion of UL 1998 include the following scenarios:

a) Unwanted tripping;

b) Failure to trip under conditions where tripping should occur; and

c) Failure of a test circuit to complete evaluation.

13.4 The Tool Qualification requirements from UL 1998 are modified in 13.5 and 13.6.

13.5 All tools used in the design, implementation, and verification of software shall be documented. The documentation shall include:

a) The name of the tool supplier or developer;

b) The model, application, or trade name of the tool;

c) The tool version identification;

d) A description of the purpose for which the tool is used; and

e) A list of known errors, faults or failures of the tool performance, such as a "bug list".

13.6 Software tools are defined as software or hardware used in the development, testing, analysis, or maintenance of a program or its documentation. Examples include compilers, assemblers, timing analyzers, logic analyzers, test case generators, simulators, emulators, and similar tools.

13.7 Means shall be employed to address all microelectronic hardware failure modes identified in the Risk Analysis of 13.3. The analysis shall consider all possible combinations of microelectronic hardware failures, software faults, and other events that are capable of resulting in a risk. This includes, for example, microelectronic hardware failures that cause software faults that are capable of resulting in a risk. Detection of failure modes shall be at a frequency and adequacy suitable for the application.

13.8 One approach to comply with 13.7 is for the manufacturer to:

a) Identify failure modes;

b) Determine safety impact of failure modes;

c) Design and provide means to detect the failure modes that have an impact on safety;

d) Demonstrate that coverage provided by detection means is at a frequency and effective level suitable for the application; and

e) Provide evidence that the failure rate of microelectronic components is suitable for the application.

13.9 The requirements in UL 1998 addressing user interfaces do not apply.

14 Electronic Interruption

14.1 General

14.1.1 Solid state components used in place of air gap contacts to interrupt or shunt an arc fault shall comply with 14.2 – 14.4 as applicable.

14.2 "Off" state or stand-by mode current

14.2.1 When arcing is interrupted by an interrupting contact using electronic means, the available current with the system in the "off" state or stand-by mode after interruption shall not exceed 250 mA with the DC system at maximum rated voltage.

14.3 Reliability

14.3.1 Except as indicated in 14.3.2, solid-state components that function as an interrupting contact or shunting contact to terminate an arc fault shall be investigated in accordance with the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. This UL 991 investigation shall include the failure of any components between the interrupting or shunting components and the product's input and or output wiring connections that may prevent the interrupting or shunting devices from clearing an arc fault.

14.3.2 If degradation and/or failure of these components is detected and indicated by the test circuit, then only the test circuit shall be investigated in accordance with UL 991.

14.3.3 When the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1, Annex H, or Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems, IEC 61508, are used as an alternative to UL 1998 in order to determine compliance with the

requirements as defined in Programmable Circuit Components, Section 13, these standards may be used to evaluate the hardware requirements of UL 991.

14.4 Programmable circuit components

14.4.1 If a device employs a programmable circuit component such as a microprocessor to implement the test circuit function mentioned above in 14.3.2, that portion of the circuit shall be investigated in accordance with Programmable Circuit Components, Section 13.

MANUFACTURING AND PRODUCTION LINE TESTS

15 General

15.1 Each device shall be subjected to the manufacturing and production-line tests described in Appendix B.

PART 2 – PV AFCI, PV AFD, AND PV ID DEVICES

CONSTRUCTION

16 General

16.1 A PV AFCI, PV AFD, or PV ID device shall comply with the construction requirements of Part 1 of this Standard as well as Sections 17 – 23.

17 Accessibility of Energized Parts

17.1 Parts of a device shall not be accessible when they are installed as intended and energized.

17.2 Parts are considered to be accessible if they can be touched using the articulated probe shown in Figure 17.1.

17.3 Access to the trip mechanism shall not be attainable with ordinary tools.