

STANDARD INFORMATION

Standard Number: UL 1699B

Standard Name: Photovoltaic (PV) DC Arc-Fault Circuit Protection

Standard Edition and Issue Date: 1st Edition Dated August 22, 2018

Date of Revision: August 22, 2018

Date of Previous Revision of Standard: Outline of Investigation Issue Number 2 Dated January 14, 2013

EFFECTIVE DATE OF NEW/REVISED REQUIREMENTS

Effective Date: **August 22, 2020**

IMPACT, OVERVIEW, AND ACTION REQUIRED

Impact Statement: A review of all Listing Reports is necessary to determine which products comply with new/revised requirements and which products will require re-evaluation. **NOTE:** Effective immediately, this revised standard will be exclusively used for evaluation of new products unless the Applicant requests in writing that current requirements be used along with their understanding that their listings will be withdrawn on Effective Date noted above, unless the product is found to comply with new/revised requirements.

Overview of Changes:

- Improve test setup
- Revision to use cases
- Improve the series arc gap fixture
- Pass/Fail and automatic reset

Specific details of new/revised requirements are found in table below.

If the applicable requirements noted in the table are not described in your report(s), these requirements will need to be confirmed as met and added to your report(s) such as markings, instructions, test results, etc. (as required).

Client Action:

Information – To assist our Engineer with review of your Listing Reports, please submit technical information in response to the new/revised paragraphs noted in the attached or explain why these new/revised requirements do not apply to your product (s).

Current Listings Not Active? – Please immediately identify any current Listing Reports or products that are no longer active and should be removed from our records. We will do this at no charge as long as Intertek is notified in writing prior to the review of your reports.



STANDARD INFORMATION

CLAUSE	VERDICT	COMMENT
		<i>Additions to existing requirements are <u>underlined</u> and deletions are shown lined out below.</i>
	Info	MANUFACTURING AND PRODUCTION LINE TESTS
15	Info	General
		<i>New clause added;</i>
15.1		Each device shall be subjected to the manufacturing and production-line tests described in Appendix B.
18	Info	Spacings
		A PV AFCI, PV AFD, or PV ID shall comply with the requirements shown in Table 18.1 except that at field-wiring terminals the spacings shall be not less than 1/4 inch (6.4 mm) for devices rated 400 V and less, and not less than 1/2 inch (12.7 mm) for devices rated greater than 400 V between terminals not operating at the same potential.
18.2		<u>At field-wiring terminals, the spacings between terminals with a potential difference between them shall be not less than 6.4 mm (1/4 inch) for devices rated 200 V and less, not less than 9.5 mm (3/8 inch) for devices rated 201 – 400 V, not less than 12.7 mm (1/2 inch) for devices rated 401 – 1000 V, and not less than 30.5 mm (1.20 inch) for devices rated over 1000V.</u>
		<i>New section added;</i>
		Terminals
19		A device shall have terminals suitable for the application. Terminals that are intended to be wired in the field shall be in the form of terminal leads, wire binding screws or pressure-wire terminals (see standard for details).
20	Info	Enclosure
20.1		When a device is provided with its own enclosure, the enclosure shall comply with the requirements in the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50, <u>and the applicable enclosure requirements for the intended environment in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.</u>
23	Info	Test Circuits
		<i>New clause added;</i>
23.4		Failure of a manual or automatic test shall cause the inverter, converter, or charge controller to turn off or go to a stand-by state. The results of the test shall be made



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		known to the user by a positive visual indication. This visual indication is not required when the PV power source is inactive but must be present when PV power is sufficient to activate the inverter or charge controller in an "off" or stand-by state.
23.6		<i>New clause added;</i> An automatic self-test feature shall test the device each time prior to supplying current from the PVDC circuit.
23.7		<i>New clause added;</i> Any test circuit that employs a programmable circuit component shall comply with Section 13, Programmable Circuit Components.
	Info	PERFORMANCE
24	Info	General
24.4		<i>New clause added;</i> For tests requiring a source of PV power, the source shall consist of an array of PV modules connected in a series or series/parallel, or a simulated PV DC power source (or Solar Array/PV Simulator) having characteristics similar to a PV array. Since a simulated PV DC power source may produce unwanted tripping, or may inhibit the PV AFCI from detecting arcing, when deemed necessary, referee tests shall be made using a suitable array of PV modules. When using an actual PV array or Solar Array/PV simulator, the values of Array + Line Impedance shall be used according to Table 29.3. If an actual PV array or Solar Array/PV simulator is used for the DC source, R1 and R2 of the decoupling network are not required.
24.5		<i>New clause added;</i> Where tests are specified to be conducted at maximum power, the PV power source shall be adjusted for its Maximum Power Point (MPP) as follows: a) The open circuit voltage of the PV supply shall be within 10 percent of the rated voltage of the device being tested but less than the rating of the device, and b) The total current capability of the PV supplies shall be at least 125 percent of the maximum DC source short circuit current rating of the DUT. Note: If actual PV modules are used, it may be necessary to parallel two or more strings. c) Power may be limited by the DC source or the inverter.
25		<i>New section added;</i> Humidity Conditioning
25.1		A representative device is to be exposed for 168 hours to air at a relative humidity of 93 ±2 percent at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F). The device is to be exposed to ambient air at a temperature of at least 30°C (86°F) until thermal equilibrium is attained before being placed in the test chamber.



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25.2		Following the conditioning, while still in the chamber or within 60 s after removal from the chamber, the representative device shall be connected to an appropriate source of power. Operation of the representative device shall be verified by actuating the test circuit.
<i>New section added;</i>		
26		<p>Leakage Current Measurement</p> <p>The leakage current of a device with a built-in power supply deriving its power from a commercial light or power source (device with an AC input), shall not be more than 0.5 mA (see standard for details).</p>
27	Info	Voltage Surge Test
27.1	Info	General
27.1.1		Devices deriving their power from a commercial light or power source shall be subjected to Voltage Surge Test of UL 1699 tests described in 27.2 and 27.3. The surges shall be applied to the AC input of the device.
27.1.2		In addition to the tests of 27.1.1, devices deriving their power from a commercial light or power source shall also be subjected to the test of Section 25.3 tests described in 27.2 and 27.3 with the surges applied to the PV DC input of the device.
27.1.3		Devices deriving their power from a photovoltaic DC source shall be subjected to the Voltage Surge Test of UL 1699 tests described in 27.2 and 27.3 with the surges applied to the PV DC input of the device.
<u>When applying the surges to the PV DC input of a device, the following shall apply:</u>		
27.1.4		<p>a) <u>Surges shall be applied to the PV DC input of the device</u> with no PV DC power applied.</p> <p>b) If the device employs a contactor or other air gap device in its DC supply circuitry, it shall be placed in the "on" position or bypassed prior to the application of the surges.</p>
<i>New section added;</i>		
27.2		<p>Unwanted tripping test (Ring wave)</p> <p>A representative device shall not trip when subjected to the surges described in 27.2.2 – 27.2.5 (see standard for details).</p>
<i>New section added;</i>		
27.3		<p>Surge immunity test (Combination wave)</p> <p>The same device subjected to the Unwanted Tripping Test shall be subjected to the Surge Immunity Test (see standard for details).</p>



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28	Info	Environmental Test Sequence <i>New clause added;</i>
28.3		All tests in step 1 of Table 24.1 shall be performed at 25°C ambient. For all other temperatures (steps) in the environmental sequence, it is permissible to choose only that test condition from Table 29.2 that dissipated the most arcing energy before the AFCI tripped at ambient temperature. <i>New section added;</i>
29		Arc Fault Detection Tests The use cases described in Table 29.1 shall be identified and the DUT shall be tested per each use case as applicable (see standard for details).
30	Info	Unwanted Tripping Tests
30.1	Info	General
30.1.1		A representative device shall <u>be tested in accordance with Figures 30.1 – 30.5, using the values in Table 30.1 and the legend in Figure 29.1.</u> The device shall not trip after being tested under each of the loading and sourcing conditions as described in this Section. When tripping occurs, an additional five representative devices of the rating under test shall be tested and shall not trip.
30.2	Info	Loading condition I – Inverters, converters, and charge controllers <i>New clause added;</i>
30.2.3		The DUT shall NOT indicate an arc fault.
30.3	Info	Loading condition II – DC switch operation <i>New clause added;</i>
30.3.1		The DUT shall be installed in a test circuit with a PV power source and an inverter, converter, or charge controller. A disconnect switch external to the inverter shall be installed two feet from the device under test. With the PV power source set up to supply the rated power of the device under test, the disconnect switch shall be operated “on” and then after the inverter has been exporting power for 30 seconds, moved to the “off” position. This sequence shall be repeated three times, with five minutes “off” time between each sequence. <i>New clause added;</i>
30.3.2		The DUT shall NOT indicate an arc fault.
30.4	Info	Loading condition III – Irradiance step changes <i>New clause added;</i>
30.4.1		The DUT shall be installed in a test circuit with a PV power source and an inverter as shown in Figures 30.6A and 30.6B. A mechanical disconnect switch shall be



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		installed on one half of the PV strings connected to the inverter. With the PV power source operating in a manner to supply the rated power of the device under test, the disconnect switch attached to half the PV source circuits shall be operated “on” and then after 30 seconds, “off”. This sequence shall be repeated three times, with five minutes “off” time between each sequence. If a single power source is used this test must be performed by rapidly decreasing the supplied current to at least ½ of the test current in less than 5 seconds. After 30 seconds return to full initial current in less than 5 seconds. If using a module or array this may be achieved with a cover over the array or module. See Figure 30.1.
30.4.2		<i>New clause added;</i> The DUT shall NOT indicate an arc fault.
31		<i>New section added;</i> Normal Temperature Test This section contains requirements for the normal operation test (see standard for details).
32	Info	Overvoltage Test <i>New clause added;</i>
32.1		A device shall operate continuously while connected to a supply set at 110 percent of rated voltage. The test shall continue for 4 hours or until thermal equilibrium is reached. During the 4 hours, the device shall not trip or become inoperative, and shall be in condition to continue the sequence at the end of the 4 hours. <i>New section added;</i>
33		Overload Test This section contains requirements for the overload test (see standard for details).
34	Info	Endurance Test <i>New clause added;</i>
34.2		An interrupting or shunting device that complies with the requirements of the Outline of Investigation for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures for Use with Photovoltaic (PV) Systems, UL 489B, need not be subjected to this test.
34.4		In performing the test described in 34.3, the supply circuit shall have the capacity to provide a closed-circuit voltage not less than 97.5 percent of the rated voltage of the device. <u>Except as indicated in 34.5, the dc supply circuit shall have an inductive time constant of 1.0 – 3.0 ms.</u> Except when a higher value is agreed to by those concerned, the open-circuit voltage is to be in the range of 100 – 105 percent of the rated voltage of the device. A 1-A fuse is to be connected between the grounded conductor of a grounded supply circuit and accessible conductive parts of the device.



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35	Info	Dielectric Voltage-Withstand Test
35.1		<p>The insulation and spacings shall withstand the application of a test voltage equal to two times the maximum rated voltage plus 1000 V between:</p> <p>a) Line and load with the device open for a device that includes a circuit interrupting contact;</p> <p>b) Line and load with the device tripped for a device that includes a circuit interrupting contact;</p> <p>c) Live parts and parts that are grounded, including a ground terminal;</p> <p>d) <u>Live parts and accessible metal parts including an enclosure of insulating material wrapped in metal foil. See 35.7.</u></p>
36		<p><i>New section added;</i></p> <p>Abnormal Operations Test</p> <p>A device shall not become a risk of fire, shock or injury when operating while in an abnormal condition, such as with a short-circuited or open-circuited component (see standard for details).</p>
37	Info	Short Circuit Current Test
37.2		<p>In order to determine compliance with the provisions of 37.1, the supply circuit shall have an open-circuit voltage in the range of 100 – 105 percent of the rating of the device. <u>Except as indicated in 37.3, the dc supply circuit shall have an inductive time constant of 1.0 – 3.0 ms.</u> The impedance of the supply is to be such as to provide a prospective current that shall be any of the following values as required for the application: 50, 100, 400, 800, 1200, 1600, 2000, 3000, 5000, 7500, 10000, 14000, 18000, 20000, 22000, 25000, 30000, 35000, 42000, or 50000 amps.</p>
37.4		<p>Each line terminal of a device is to be connected to the supply mentioned in 37.2 using 4 ft (1.2 m) of insulated wire, sized for the rating of the device. <u>A PV fuse complying with the Outline of Investigation for Low-Voltage Fuses – Fuses For Photovoltaic Systems, UL 2579, rated at the current rating of the PV DC arc-fault circuit-interrupter is to be connected in series with the ungrounded conductor. If the required fuse rating is not a standard fuse rating, the next higher standard value shall be used.</u> The fuse shall have an interrupting rating equal to or greater than the test current. A 508-mm (20-inch) conductor is to be connected between the load terminals or for a single pole device, between the load terminal and the return terminal of the supply. The device is to be in any position considered to be normal in service. A 1-A fuse is to be connected between the supply terminal representing the grounded circuit conductor and accessible conductive parts of the device. Surgical cotton is to cover openings of the device where flame may be emitted.</p>
37.8		<p>After the short circuit current tests, each representative device shall be tested in accordance with 27.3 <u>the Series Connection Arcing Test of 29.1.</u> The device shall interrupt the arcing as described in Table 29.2 for the conditions of Test no. 2 and 3 at room ambient.</p>



CLAUSE	VERDICT	COMMENT
		<i>New section added;</i>
		Surge Current Test
39		All devices with built-in power supplies deriving their power from a commercial light and power source (devices with AC input) shall be subjected to the Surge Current Test in 39.2.1 – 39.4.1, and shall comply with the requirements in 39.1.2 (see standard for details).
		<i>New section added;</i>
		Abnormal Overvoltage Tests
40		All devices with built-in power supplies deriving their power from a commercial light and power source (devices with AC input) shall be subjected to the Full Phase Voltage-High Current Abnormal Overvoltage Test, 40.2, and Limited Current Abnormal Overvoltage Test, 40.3 (see standard for details).
		<i>New section added;</i>
		Surge immunity test (combination wave)
41		All devices with built-in power supplies deriving their power from a commercial light and power source (devices with AC input) shall be subjected to this test (see standard for details)
		<i>New section added;</i>
		Resistance to Environmental Noise Test
42		A device shall demonstrate immunity from false operation when exposed to the conditions described in this Section (see standard for details).
		<i>New section added;</i>
		Strain-Relief Tests
43		A device that is provided with terminal leads intended to be connected in the field shall be subjected to the test described in 43.1.2. Following the test there shall be no indication that either the device or the lead has sustained damage as a result of the test, or that the force would have been transmitted to the terminations (see standard for details).
		<i>New section added;</i>
		Mechanical Tests
44		An interrupting device that is provided with pressure wire connectors or wire binding screw terminals intended for field wiring shall be subjected to the tests described in 44.2 or 44.3 as applicable (see standard for details).



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		<i>New section added;</i>
		Dust Test
45		To determine compliance with 18.7(b)(2), each of six devices, each mounted in a different mounting orientation, is to be placed, deenergized, in an air tight chamber having an internal volume of at least 0.09 m ³ (3 cubic feet) (see standard for details).
	Info	RATINGS
		<i>New section added;</i>
		General
46		A device shall be rated in maximum volts DC and maximum short circuit current of the DC source. See Table 46.1 (see standard for details).
	Info	MARKINGS
47	Info	General
		<i>New clause added;</i>
47.13		A device that automatically resets shall be marked, "This AFCI device automatically resets and may only be used when allowed by NFPA 70."
		<i>New clause added;</i>
47.14		The product shall be marked with the ratings as required by Table 46.1.
		<i>New section added;</i>
		Annunciator
52		An inverter, converter, or charge controller shall be provided with an annunciator (local or remote) that provides a visual indication that the inverter, converter, or charge controller has detected an arc fault (see standard for details).
		<i>New section added;</i>
		Test Circuits
53		A device shall be provided with a manual or automatic test circuit complying with 53.2 – 53.7 (see standard for details).
		<i>New section added;</i>
		Overvoltage, Overload, Endurance, Abnormal Operations, and Short Circuit Tests
56		Switching devices in the power conversion circuits of inverters, converters, and charge controllers that are subjected to the Abnormal Tests, as applicable, of UL 1741 (see standard for details).



CLAUSE	VERDICT	COMMENT
	Info	MARKINGS <i>New section added;</i>
57		General An inverter, converter, or charge controller shall comply with the marking requirements of UL 1741 (see standard for details).
	Info	INSTRUCTIONS <i>New section added;</i>
58		Operating and Installation Instructions An inverter, converter, or charge controller shall comply with the operating and installation instruction requirements of UL 1741 (see standard for details). <i>New section added;</i>
Appendix B		Manufacturing and Production Line Tests Manufacturing and production line tests shall be performed on the products covered by this Standard in accordance with Sections B2 and B3 (see standard for details).
CUSTOMERS PLEASE NOTE: This Table and column "Verdict" can be used in determining how your current or future production is or will be in compliance with new/revised requirements.		