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Standard Test Methods for Insulation Integrity and Ground Path Continuity of Photovoltaic Modules[1]

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1. Scope

1.1 These test methods cover procedures for (*1*) testing for current leakage between the electrical circuit of a photovoltaic module and its external components while a user-specified voltage is applied and (*2*) for testing for possible module insulation breakdown (dielectric voltage withstand test).

1.2 A procedure is described for measuring the insulation resistance between the electrical circuit of a photovoltaic module and its external components (insulation resistance test).

1.3 A procedure is provided for verifying that electrical continuity exists between the exposed external conductive surfaces of the module, such as the frame, structural members, or edge closures, and its grounding point (ground path continuity test).

1.4 This test method does not establish pass or fail levels. The determination of acceptable or unacceptable results is beyond the scope of this test method.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
E772 Terminology of Solar Energy Conversion

2.2 *Underwriters Laboratories Standard:*[3]
ANSI/UL 1703 Standard for Safety for Flat-Plate Photovoltaic Modules and Panels

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method may be found in Terminologies E772.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *ground path continuity, n*—the electrical continuity between the external and conductive surfaces of a photovoltaic module and the intended grounding point of the module.

3.2.2 *insulation resistance, n*—the electrical resistance of a photovoltaic module insulation, measured at a specified applied voltage between the module internal circuitry and its grounding point or mounting structure.

4. Summary of Test Method

4.1 *Insulation Integrity*—Two procedures are provided for testing the isolation of the electrically active parts of the module from the accessible conductive parts and the exposed nonconductive surfaces. This isolation is necessary to provide for safe insulation, use, and service of a photovoltaic module or system.

4.1.1 *Dielectric Voltage Withstand Procedure*—A ramped voltage is applied between the photovoltaic circuit and the accessible parts and surfaces of the module outside of the photovoltaic circuit while monitoring the current, or by determining whether the leakage current exceeds a predetermined limit. The module is then inspected for evidence of possible arcing.

4.1.2 *Insulation Resistance Procedure*—The insulation resistance is measured between the photovoltaic circuit and the accessible parts and surfaces of the module outside of the photovoltaic circuit, using a high-impedance ohmmeter.

4.2 *Ground Path Continuity Procedure*—This procedure is intended for verification that electrical continuity exists between all of the external conductive components and the module grounding point specified by the manufacturer. This is accomplished by passing a current between the grounding

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Underwriters Laboratories Incorporated, Publication Stock, 333 Pfingsten Road, Northbrook, IL 60062.

terminal or lead and the conductive part in question and calculating the resistance between these two points.

5. Significance and Use

5.1 The design of a photovoltaic module or system intended to provide safe conversion of the sun's radiant energy into useful electricity must take into consideration the possibility of hazard should the user come into contact with the electrical potential of the module. These test methods describe procedures for verifying that the design and construction of the module or system are capable of providing protection from shock through normal installation and use. At no location on the module should this electrical potential be accessible, with the obvious exception of the intended output leads.

5.2 These test methods describe procedures for determining the ability of the module to provide protection from electrical hazards.

5.3 These procedures may be specified as part of a series of qualification tests involving environmental exposure, mechanical stress, electrical overload, or accelerated life testing.

5.4 These procedures are normally intended for use on dry modules; however, the test modules may be either wet or dry, as indicated by the appropriate protocol.

5.5 These procedures may be used to verify module assembly on a production line.

5.6 Insulation resistance and leakage current are strong functions of module dimensions, ambient relative humidity and absorbed water vapor, and the ground path continuity procedure is strongly affected by the location of contacts and test leads to the module frame and grounding points.

5.6.1 For these reasons, it is the responsibility of the user of these test methods to specify the maximum acceptable leakage current for the dielectric voltage withstand test, and the maximum acceptable resistance for the ground path continuity procedure.

5.6.2 Fifty µA has been commonly used as the maximum acceptable leakage current (see ANSI/UL 1703, Section 26.1), and 0.1 Ω has been commonly used as the maximum acceptable resistance.

5.7 Some module designs may not use any external metallic components and thus lack a ground point designated by the module manufacturer. In these cases, the ground path continuity test is not applicable.

6. Apparatus

6.1 *Variable d-c Voltage Power Supply*—For the dielectric voltage withstand test, a d-c voltage power supply capable of providing the specified test voltage (see 5.6) in a gradual and smooth manner is required. The application of voltage must not allow transients that may cause the instantaneous voltage to exceed the specified test voltage; nor may the flow of capacitive current, due to charging, cause the test to indicate an erroneous leakage current.

6.1.1 The power supply must include a means of indicating the test voltage that is applied to the module.

6.1.2 The output voltage of the power supply must be continuously adjustable and may have an automatically controlled ramp rate.

6.1.3 The power supply must be capable, as a minimum, of detecting a leakage current of 1 µA.

6.1.4 The power supply may, as an option, include a leakage current limit set-point that will shut down the power supply when the leakage current exceeds the set-point. Audible or visual alarms which indicate that the leakage current has exceeded the set-point are also acceptable.

6.2 *Ground Path Continuity Tester,* for measuring the resistance between any accessible conductive frame or support element and the module grounding point, with a minimum resolution of 0.01 Ω.

6.2.1 The tester must be capable of passing a current of twice the module short-circuit current through the module ground path being tested.

6.2.2 The tester must be able to limit the power applied to a module ground path to 500 W.

6.3 *Ohmmeter*—A high-impedance ohmmeter, or similar device, capable of measuring a minimum of 1000 MΩ, and can provide a voltage suitable for measuring high-resistances.

6.4 *Metallic Contact(s),* aluminum or other metallic foil, or a rigid metallic plate, placed on the surfaces of modules lacking a metallic frame. The metallic contact(s) function as a substitute for a metallic frame.

6.5 *Test Stand,* for holding modules during testing.

7. Procedures

7.1 *Procedure A—Insulation Integrity, Dielectric Voltage Withstand:*

7.1.1 Mount the module to be tested on the test stand and ensure that the module is not illuminated. This may be accomplished by placing it face down on the test stand or by shading the face of the module with an appropriately sized opaque material.

7.1.2 Short the output leads of the module together.

7.1.3 Ensure that the power supply is turned off before any electrical connections are made.

7.1.4 Connect the high potential output of the power supply to the module output leads.

7.1.5 Connect the grounded output of the power supply to the module grounding point or specific component being tested.

7.1.5.1 The module may contain separate and unconnected metallic components; if so, the procedure must be repeated for each metallic component. For example, a junction box not connected to the frame must be tested separately.

7.1.5.2 Any connections to metallic components must be made to uninsulated points for the procedure to be valid. For example, an anodized aluminum frame would not qualify unless the anodization was removed at the test point.

7.1.5.3 If the module lacks any exterior metallic components, the leakage current connection must be made to an insulating surface such as a nonmetallic module frame. A metallic contact (see 6.4) must be placed in contact with the surface, and connection is then made to the metallic contact.

The contact must be at least the same size as the surface being tested. The sponsor or user of this procedure must specify acceptable connections in these cases.

7.1.6 Determine the test voltage for the dielectric voltage withstand test. The maximum system voltage (see Terminology E772) for which a module is suitable must be specified by the module manufacturer. The test voltage shall be twice the maximum system voltage plus 1000 V. For a module with a maximum system voltage of 30 volts or less, the test voltage shall be 500 volts.

7.1.7 Increase the voltage, not to exceed a rate of 200 V/s, until the test voltage is achieved.

NOTE 1—The capacitance of modules may be large enough to cause large currents to flow while the insulation capacitance is charging. The operator must be aware of such conditions and allow time for the current to stabilize.

7.1.8 Hold the power supply voltage at the test voltage for 1 min.

7.1.9 Record the maximum leakage current, or the voltage at which the leakage current set-point was exceeded.

7.1.9.1 If the equipment has the current limit set-point capability described in 6.1.4 and the power supply shuts down or the alarms are triggered, the maximum current leakage has been exceeded.

7.1.10 Observe and listen to the module during the test for evidence of arcing or flash-over.

7.1.11 Turn off the power supply.

7.1.12 Reverse the power supply-to-module connection polarity (see 7.1.4 and 7.1.5) and repeat 7.1.7 through 7.1.11.

7.1.13 Disconnect the test module.

7.1.14 Inspect the module for any visual evidence of arcing or flash-over.

7.2 *Procedure B—Insulation Integrity, Insulation Resistance:*

7.2.1 Mount the module as specified in 7.1.1 and 7.1.2.

7.2.2 Connect the ohmmeter to the module as specified in 7.1.3-7.1.5 with references to the power supply replaced with the ohmmeter.

7.2.3 Measure and record the insulation resistance indicated by the ohmmeter.

7.3 *Procedure C—Ground Path Continuity:*

7.3.1 Determine the necessary current to pass through any module ground paths. This current is equal to twice the module short-circuit current.

7.3.2 Determine the location of the grounding point and all accessible conductive parts of the module. Establish the contact size, location, and attachment method necessary to perform the ground path continuity test.

7.3.2.1 A conductive part is considered accessible unless it is insulated with a material that has been evaluated for its insulation properties in the intended application or it is physically inaccessible according to the definition in ANSI/UL 1703, Section 14.

7.3.2.2 If the module has more than one accessible conductive part, each must be tested separately.

7.3.3 Connect the grounded lead of the continuity tester to the module grounding point identified by the module manufacturer.

7.3.4 Connect the the high potential lead of the continuity tester to an accessible conductive part of the module.

7.3.5 Increase the voltage applied by the continuity tester from zero until a current of twice the module short-circuit current is passing through the grounding path under test, or until the maximum wattage indicated in 6.2.2 is reached.

7.3.6 Compute and record the resistance from the voltage drop across the continuity tester leads at the points at which they connect to the module.

7.3.7 Repeat 7.3.4-7.3.6 for each ground path identified in 7.3.2.

8. Report

8.1 Report the following items at the minimum:

8.1.1 The manufacturer and a complete test specimen identification,

8.1.2 A description of the module construction,

8.1.3 A description of the measurement equipment and measurement conditions or parameters,

8.1.4 A description of any apparent changes due to testing, with any sketches or photographs providing clarification,

8.1.5 The actual maximum leakage current observed (7.1.9) or the applied voltage at which the maximum current leakage was exceeded (7.1.9.1),

8.1.6 Observations or indications of arcing or flash-over,

8.1.7 The insulation resistance recorded in 7.2.3,

8.1.8 Results of the ground path continuity procedure from 7.3.6, and

8.1.9 Any deviation from the procedures.

9. Precision and Bias

9.1 Several factors make a determination of the precision and bias from results of an interlaboratory study not practicable for these procedures.

9.1.1 Insulation resistance and insulation current leakage are strong functions of ambient relative humidity and absorbed water vapor.

9.1.2 The ground path continuity procedure is affected strongly by the location, size, shape, and attachment methods of contacts and test leads to the module frame and grounding points.

9.1.3 For these reasons, the user of this test method specifies acceptable threshold levels for the dielectric voltage withstand and ground path continuity procedures (see 5.6.1).

9.2 Precision and bias will be a function of the precision and bias limits of the electrical instruments. Therefore, these electrical measurements should be made in accordance with sound engineering practices using instruments that have recent calibrations traceable to national and international standards.

10. Keywords

10.1 dielectric voltage withstand; electrical testing; ground path continuity; insulation integrity; insulation resistance; modules; photovoltaics; solar energy