Junction boxes for photovoltaic modules – qualification and tests

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ABSTRACT
Photovoltaic (PV) modules and components are products which have to withstand the diverse effects of extreme conditions during their lifetime. The wide range of climatic conditions and possible mechanical stresses must be taken into account when designing a PV component. To assess whether the quality of a product is sufficient to withstand such influences, some international standards have been developed. TÜV Rheinland operates several ISO 17025-accredited laboratories worldwide for type approval testing of PV components – such as junction boxes, connectors and cables – as well as concentrating PV modules, flat-plate modules and solar thermal systems. Experience of testing PV components has been gained over the last 12 years, and even over the last 20 years in the case of PV modules. New developments in photovoltaics mean that continuous development and review of standards is necessary.

Introduction

Several national and international type approval standards have been released for PV modules and components, and more recently for concentrating PV modules and assemblies. Third-party testing and certification to these standards is not required by law in most cases. Certificates, however, document the maintenance of a certain level of quality and form the basis for PV project financing. Several test marks have been established to indicate to a buyer the fulfilment of standard requirements. A certificate or quality mark alone, however, does not guarantee the high quality of a PV product. Testing is usually limited to a small number of samples, which in many cases are not even taken from the batch production, but are prototypes of a new series instead. Additional quality assurance measures are therefore needed.

Important standards for PV junction boxes

The type approval test of a PV junction box can be performed according to European standard EN 50548 and to national documents such as DIN V VDE V 0126-5 or UL-subject 3703. Additionally, TÜV Rheinland has created an internal test programme – 2 PfG 1798/11.10 – for PV junction boxes for use with modules qualified to ANSI/UL 1703, which covers requirements drawn from ANSI/UL 1703, complete with the bypass diode test of EN 50548.

Since EN 50548 is currently the only existing and valid international standard for PV junction boxes, and because it is based on DIN V VDE V 0126-5, the following explanations will mainly cover requirements specified in that standard. Working Group 2 of IEC/TC82 is currently creating a proposal for an IEC standard for PV junction boxes.

Type approval tests for PV junction boxes

EN 50548 is interbalanced with current existing and valid PV module IEC standards, such as IEC 61215, IEC 61646 and IEC 61730. It covers most of the safety and qualification tests of these standards.

It is not required that the tests be carried out on complete PV modules. Of course, if a PV junction box is to be tested in combination with a PV module, the tests can be performed on the complete sample. However, in most projects, the junction box will be tested separately because the junction box manufacturer wants to sell his product to different module manufacturers.

The type approval test is divided into nine test groups. Four of these groups (E–H) contain test sequences in which the tests have to be performed consecutively in the specified order. The other five test groups contain single tests.

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If the intention is to test the junction box separately, it must be ensured that the specimen is mounted on the same surface – which may be glass or backsheet foil – with the same adhesive material and under the same conditions as those in an expected installation on the PV module. For example, if the junction box is intended to be potted, the specimen must be prepared in a similar way.

Usually the manufacturer wants to supply its PV junction box to as many PV module manufacturers as possible, so the box has to operate under several combinations of adhesives and backsheet foils. Also different potting materials are often used. In these cases the tests are to be performed in all possible combinations with the relevant number of specimens.

The plates on which the specimens are mounted will be made of glass or similar material. The size of the plates depends on the size of the test chambers. In the case of junction boxes intended to be mounted on

Test group	Description
A	Marking, information and documentation
B	Material tests
C	Constructional requirements
D	Mechanical tests
E	Test sequence I – thermal cycle test (tc200)
F	Test sequence II – damp heat test
G	Test sequence III – thermal cycle test (tc50) and humidity freeze test
H	Test sequence IV – bypass diode thermal test
I	Reverse current test

Table 1. Test groups for type approval tests.

Figure 1. Ball pressure test: material test for resistance to heat.

modules having a backsheet foil, the specimen will be mounted on the same type of backsheet foil, which is bonded to the plate.

Considering that some of the tests are long-term, it is recommended to perform these tests in as many simultaneous combinations of specimens as possible. The number of specimens and their preparation for a type approval test is described in detail in EN 50548 (see table 2 in EN 50548 for an overview).

Test group A: Marking, information and documentation

It must be possible to identify a PV junction box even after it has spent a number of years in the field. This is useful for the replacement of components, such as bypass diodes. Therefore, to allow the identification, a minimum marking on the PV junction box will show the manufacturer's name (this can be a trademark or mark of origin), the type identification (a key code might be helpful for a PV junction box used in several combinations of backsheet foil and/or adhesives, fitted with several types of component, having different ratings, etc.) and, if applicable, the polarity of built-in or integrated connectors (in which case a warning label as shown in annex A of EN 50548 must also be identified near the connector).

The manufacturer must also be able to provide all important data listed in paragraph 4.2.1 of EN 50548 in a data sheet or other technical documentation. Additionally, all other information which is necessary to ensure safe installation and function must be listed in the technical documentation. This can be, for example, information about the termination of cable and/or cell connections, information regarding the connector system, and, of course, all information relating to the mounting, such as the type of backsheet, type and parameters of the adhesive and type of sealing. Installation specifications, such as the pressure needed for fixing the box and the drying time of the adhesive, are also required to be documented.

For the type approval test the applicant must present data sheets or certificates of approval for all components, such as fitted cables, connectors, cable glands or similar. Experience has shown that a lot of delays in projects are caused by missing or incorrect documentation, but this test group would seem to be the easiest one to pass.

Test group B: Material test

In this test group all relevant tests for all materials used are listed. These materials are polymers forming an enclosure or serving as a support for live, current-carrying and other metal parts, and also polymers used in gaskets, if applicable. Testing the durability of labels for markings (if the marking is not performed by impression) and warning labels also forms part of this group. The tests will not be performed on a mounted specimen but on a separate one, or even on a part of one. It is possible that some tests in this group will be modified in future editions or amendments of the standard – the

Figure 2. Glow-wire test: test for resistance to ignition.

reasons for this will be explained later. The wet test for durability of marking will be performed with a test apparatus as described in EN 60068-2-70 and with water as the test liquid. A similar test apparatus may produce the same results.

For polymers forming an enclosure, the flammability test according to EN 60695-11-10 will be performed on a sample, unless the applicant can present the manufacturer's approval of the material. Irrespective of this, TÜV Rheinland has decided to always perform the flammability test since the material properties also depend on the parameters during the injection process. If the wall thickness of the enclosure is less than 3mm, the flammability test must be performed according to EN 60695-11-20.

The weather resistance test with a xenon lamp according to ISO 4892-2 or a fluorescent lamp according to ISO 4892-3 will be performed on another sample of the material. The duration of this test is actually 500 hours. Several technical committees are currently discussing an extension to 1500 hours. After the weather resistance test, a glow-wire test with a temperature of 650°C will be carried out on the conditioned sample.

The ball pressure test will be done on an additional sample of the material. For this test the temperature used will be either 90°C or *the temperature evaluated during the bypass test (see test group H) + 20°C*, whichever is higher.

Important note: The requirement indicated in italics is different from that specified in DIN V VDE V 0126-5. During the first test projects conducted by others in the TÜV Rheinland lab, it was found that these parameters are not realistic requirements. Since the resistance to heat was also evaluated in the bypass diode thermal test, the German committee decided to apply for an amendment to EN 50548 in which the test temperature will be 90°C for polymers serving as an enclosure. Until the amendment has been agreed and decided on by the European committee (CENELEC), the requirement in paragraph 5.3.13 of EN 50548 must be respected as described, unless DIN V VDE V 0126-5 is to be applied as the test standard.

The same test will be performed on polymers serving as a support for live metal parts, but the test temperature used will be either 125°C or *the temperature evaluated during the bypass test (see test group H) + 20°C*, whichever is higher. The important note mentioned above is also applicable for these materials. In addition, the flammability test according to EN 60695-11-10 will be performed on a sample. The glow-wire test will also be performed, but the test temperature for these materials is 750°C. The glow-wire test also applies to potting material (if applicable) which is in contact with live metal parts. For the testing of potting materials, separate test plates can be used as specimens.

Current-carrying and other metal parts must show no sign of corrosion after storing in a 10% solution of ammonium chloride in water and drying in air with a relative humidity of 91–95% at a temperature of 20°C ± 5°C.

Gaskets will be conditioned by accelerated ageing in a heating cabinet at a temperature of 100°C ± 5°C for 240 hours. After conditioning, the gasket will be used for the specimen for the ingress protection (IP) test described in test group E. A modification of the conditioning is planned for future versions of the test, and there are currently discussions about performing in addition a compression test after ageing. This could be realized by closing and opening the lid ten times after reinstallation of the gasket. If the gasket cannot be separated from the lid or the base of the enclosure, the complete part will be inserted into the heating cabinet.

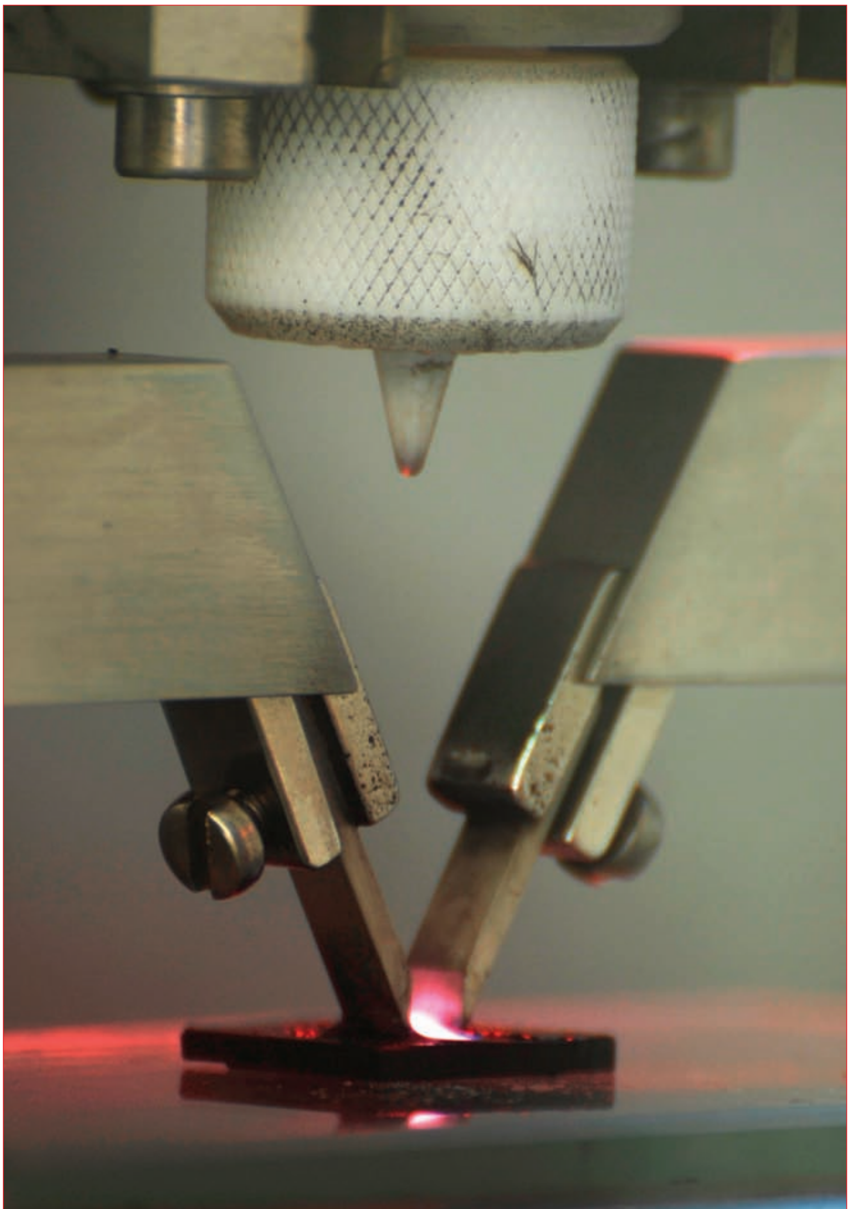

Figure 3. CTI test: proof tracking index (PTI) test for evaluating the CTI value.

Rated voltage [V DC]	Rated impulse voltage for basic insulation [kV (1.2/50µs)]	Rated impulse voltage for reinforced insulation [kV (1.2/50µs)]
100	1.5	2.5
150	2.5	4
300	4	6
600	6	8
1000	8	12
1500	10	16

Note: values are derived from IEC 60664-1 and IEC TR 60664-2-1 for overvoltage category III.

Table 2. Rated impulse voltage for PV junction boxes.

Required impulse voltage [kV (1.2/50µs)]	Minimum clearance for inhomogeneous field [mm]		
	Pollution degree 1	Pollution degree 2	Pollution degree 3
1.5	0.5	0.5	0.8
2.5	1.5	1.5	1.5
4.0	3	3	3
6.0	5.5	5.5	5.5
8.0	8	8	8
12.0	14	14	14
16.0*	19.4	19.4	19.4

* Values for 16.0kV are evaluated by interpolation.

Table 3. Minimum clearances for PV junction boxes.

Rated voltage [V DC]	Minimum creepage distance for basic insulation [mm]					
	Pollution degree 2			Pollution degree 3		
	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
100	0.71	1	1.4	1.8	2	2.2
150	0.78	1.08	1.57	1.97	2.17	2.47
300	1.5	2.08	3	3.77	4.24	4.71
600	3.03	4.29	6	7.6	8.56	9.53
1000	5	7.1	10	12.5	14	16
1500	7.51	10.42	15	18.86	20.86	23.57

Table 4. Minimum creepage distances for basic insulation.

Test group C: Constructional requirements

Group C consists of single tests involving visual inspections. Most of the tests can be done on separate, non-fixed specimens, but it is recommended to have at least one specimen mounted on a test plate.

A visual inspection and application of test probe 11 in accordance with IEC 61032 (applying a force of 20N) must show that, after mounting, the live parts are not accessible, even if any deformation of the housing and/or cover occurs as a result of mechanical and thermal stress, which may be possible during normal use.

Lids or other parts intended to be removed must only be detachable with the aid of tools. If they are attached without screws, there must be one or several detectable facilities, for example recesses, which enable tools to be deployed in order to remove the lids or other parts. Precautions must be taken for preventing the lid being lost from a PV junction box that is intended to be re-opened. To this effect, the lid must be fixed to the base enclosure by hinges, or by other means that will ensure that the lid cannot be misplaced after opening the junction box in the field.

If barriers are used to provide insulation they must be of an insulating material appropriate for the application. Also an 'adequate thickness' of the barrier is required, but there is no definition of this value. The barrier must only be able to be removed by the use of a tool. In the majority of existing PV junction boxes there is no such barrier, so usually this requirement does not apply.

For rewirable connections of the conductors in the relevant terminals, sufficient volume inside the PV junction box must be provided to avoid any damage to the cable and to ensure adequate termination of the cable. In contrast to UL standards or specifications, no particular volume depending on the cross-section of the cables is stipulated. Sharp edges must also be avoided.

Adequate terminations and connection methods must be used inside the PV junction box. The applicant must provide evidence of approval that the terminals comply with the requirements of their relevant IEC or EN standards, and that they are suitable for the type and range of cross-sectional areas of conductor and cell connections. If no approvals exist for the terminals, perhaps due to the fact that they are special constructions for use in that PV junction box, the terminals can be tested during the PV junction box test. Taking account of the relevant standards, the main aspects of the terminal tests are that:

- adequate material is used;
- there is sufficient retention;
- the contact pressure is not transmitted through the insulating material.

Electrical and thermal properties of terminals are also considered during several tests of the PV junction box; mechanical properties are checked by tests in test group D. It must be ensured that terminals are held in position when the conductor or cell connections are attached, and that soldered, welded or similar connections are effected so that they are not held in position by just the connections themselves. For a soldered connection, hooking in an eyelet before soldering, for example, is considered to be a suitable means of retaining the conductor in position.

One important and critical issue is the assessment of the clearances and creepage distances. The description of how to evaluate and measure these distances is quite involved, so only the following brief explanation of these procedures will be given. In general the distances have to be evaluated and assessed according to the requirements of IEC 60664-1 and IEC TR 60664-2-1 (for rated voltages above 1000V DC and up to 15,000V DC). Overvoltage category III and pollution degree 3 (inside the enclosure, the distances must be dimensioned for at least pollution degree

2) must be considered. If additional and special tests according to IEC 60664-3 are met, the pollution degree inside a potted or sealed PV junction box can be considered to be 1.

> "One important and critical issue is the assessment of the clearances and creepage distances."

PV Modules

For an evaluation of creepage distances it is important to know the material group. Materials are classified into four groups according to their comparative tracking index (CTI) values. These values are determined in accordance with IEC 60112 using solution A for every insulating material that could form part of the creepage pathway.

Clearances as well as creepage distances have to be dimensioned for reinforced or double insulation between live parts and accessible surfaces. This also applies to the distances between the terminals for rewirable connections. All other clearances and creepage distances must meet the requirements of basic insulation in relation to the maximum working voltage as specified by the manufacturer.

The adhesive area between a module and a junction box is considered to be a cemented insulated joint provided that all relevant tests, especially those according to test groups E and F, have been passed. Since it is difficult to evaluate the minimum distances in IEC 60664-1, the distances have been calculated and listed in Tables 2–6.

Of course, other constructional requirements must be considered too. It is very important that fitted components such as PV connectors and PV cables are suitable for use in photovoltaic systems and have at least the rated values of the PV junction box. All PV connectors must comply with the requirements of EN 50521; the PV cable must comply with the requirements of 2 PfG 1169/08.2007.

Rated voltage [V DC]	Minimum creepage distance for reinforced insulation [mm]					
	Pollution degree 2			Pollution degree 3		
	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
100	1.42	2	2.8	3.6	4	4.4
150	1.56	2.16	3.14	3.94	4.34	4.94
300	3	4.16	6	7.54	8.48	9.42
600	6.06	8.58	12	15.2	17.12	19.06
1000	10	14.2	20	25	28	32
1500	15.02	20.84	30	37.72	41.72	47.14

Table 5. Minimum creepage distances for reinforced insulation.

Rated voltage [V DC]	Minimum creepage distance for basic insulation [mm]	Minimum creepage distance for reinforced insulation [mm]
100	0.25	0.5
150	0.30	0.6
300	0.7	1.4
600	1.68	3.36
1000	3.2	6.4
1500	5.2	10.4

Table 6. Minimum creepage distances for basic and reinforced insulation (pollution degree 1 and all material groups).

Test group D: Mechanical test

For the single tests of test group D, separate, non-fixed samples could be used, but it is recommended to check a specimen mounted on a test plate. Some of the tests that consider the mechanical properties of terminations and connections are described in paragraph 5.3.19 (of EN 50548), which refers to requirements of other relevant test standards for terminals, depending on the type of connection.

If the junction box has knock-outs (which is usually not the case for most existing types of PV junction box), the retention and the removal of the knock-outs will be tested. It must be ensured that the knock-outs still remain in place without degradation of the IP protection after applying a specified force under special conditions. It must also be ensured that, after removal of the knock-outs with a tool, no sharp edges remain that could cause damage to the cable or other parts.

Another mechanical test concerns cord anchorage. The relevant paragraph 5.3.21 of EN 50548 is divided into two sections: one for a junction box intended to be used with specified cables, and the other for a box intended to be used with generic cables. If the cables are specified, the PV junction box will be tested with these types of cable in all possible combinations to take account of the worst case – this is usually the smallest diameter of the cross-

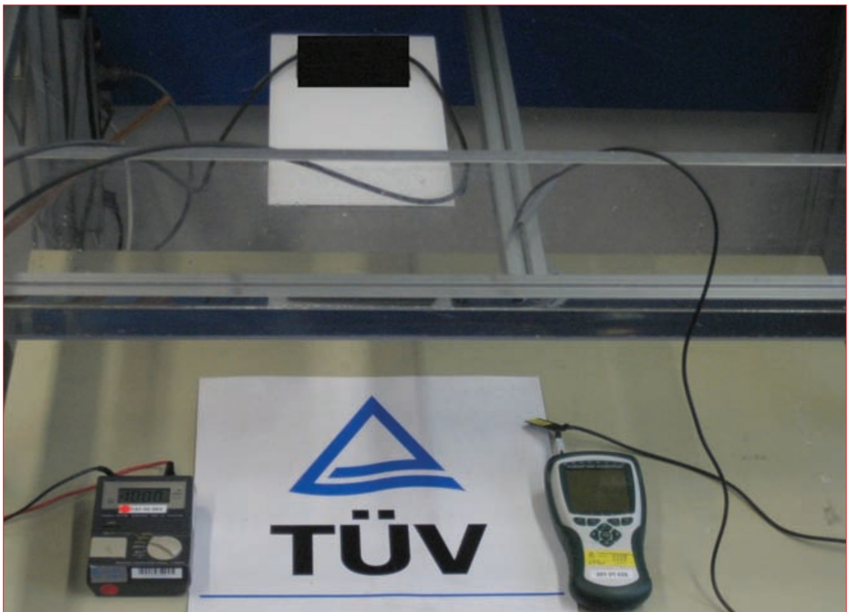

Figure 4. Wet leakage current test: with the junction box lying in the liquid solution, the resistance is measured between the solution and the current-carrying parts.

sectional area. Sometimes cable glands with different inlets are used to cover a wide range of different cable diameters. In this case the cable gland has to be tested with every inlet to consider the worst-case condition. The difference in testing a PV junction box without already mounted or specified cables is the use of a test mandrel, but again all combinations must be considered to check the worst-case scenario.

The cord anchorage is tested by pull and torsion tests. After these tests the cables or mandrels fixed in the PV junction box must not show a displacement exceeding 2mm or a torsion exceeding 45°. In general, potting material must not be considered to be adequate chord anchorage.

To check if the PV junction box is suitable to be mounted or operated at lower temperatures, a cold impact test has to be performed. After storing the PV junction box for a minimum of 5 hours in a test chamber having a temperature of –40°C, four impacts, each having an energy of 1J, will be administered to the box in different positions. No damage that may impair safety or function of the PV junction box should be evident.

The other tests of test group D must be performed on pre-aged specimens of groups E and F, so they will be described in the corresponding test groups. The following test sequences E–H and test group I refer to tests according to module standards and is the reason why they are very similar.

Figure 5. Bypass diode test stand: test equipment for measuring temperatures at bypass diodes of junction boxes mounted on PV modules.

Test group E: Test sequence I – thermal cycle test (tc200)

For this test sequence a specimen will be used that has been prepared as described in paragraph 5.2.5 of EN 50548. The specimen must be mounted on the mounting surface and completely assembled according to the instructions of the manufacturer. At the beginning of the manufacturer's guidelines there will be a description of which mounting surfaces, adhesives, etc. should be used, especially for the case of a PV junction box that is intended to be installed on several backsheet foils. Additionally, the tests must be carried out with the maximum specified number of bypass diodes in an arrangement that covers the worst-case condition.

The cell connections must be bent down and fixed so that they have a conductive connection to the mounting surface. For the thermal cycle test sequence, cell connections will be electrically connected in order to find out if the adhesive material used to fix the PV junction box to the mounting surface meets the requirements of both the IP protection test and the wet leakage current test before and after the thermal cycles.

The first part of the sequence is the IP protection test. According to the specification of the applicant, the tests have to be carried out as described in EN 60529. The IP code consists of two characteristic numerals: the first describes protection against solid objects (5 or 6 in the case of dust); the second describes protection against the ingress of water.

For the first numeral, 5 or 6, the test of tightness against the ingress of dust will be carried out with a low-pressure method in a special dust chamber. No dust must enter the PV junction box for numeral 6. For numeral 5, however, a small amount of dust entering the PV junction box is allowed, but it must be ensured that the dust does not decrease creepage distances or come into contact with live parts.

For the second numeral, a water test, depending on the degree of protection, must be performed. The specimen can be splattered with water from a hose having specified nozzles (IPX5 or IPX6), or it can be submersed in water at a specified pressure and under other conditions (IPX7 or higher). Due to the fact that every IP degree higher than IPX6 does not cover any lower degree, and that minimum IPX5 is required, two different tests have to be performed in the case of IPX7 or higher.

No water must enter the PV junction box. This requirement will be checked by the r.m.s. withstand voltage test using a voltage of 2000V + 4 × rated voltage, applied between a metal foil covering the enclosure and the connected cables of both polarities.

After the IP test, a wet leakage current test has to be performed. This test is very similar to the one described in IEC 61215, with the difference that the connectors must not be immersed in the water/wetting agent solution but must be sprayed instead. This difference is also under discussion by the IEC TC82 Working Group 2 for the next edition of IEC 61215.

The specimen is immersed in the solution to a depth sufficient to cover all surfaces between the mounting surface and the box, but not the cable entries. The cable entries, along with the connectors and the other surfaces of the PV junction box, are sprayed with the solution. A test voltage having a value equal to the rated voltage (but at least 500V) is applied between the connected output cables and the liquid test solution. The measured insulation resistance should not be less than 400MΩ.

Next, the thermal cycle test for 200 cycles (also referred to as the tc200 test) has to be performed with temperatures of –40°C (or lower, if specified by the manufacturer) and +85°C (or higher, if specified by the manufacturer). The rate of change of the temperature must not exceed 100°C/hour. This is followed once again by the r.m.s. withstand voltage test as described above and the impulse voltage withstand test, depending on rated voltage.

As indicated in test group D, the pre-aged specimen of test sequence E must be checked by a mechanical test in which the retention of the PV junction box on the mounting surface is considered. To do this, a force of 40N will be applied for 30 minutes in each direction parallel to the mounting surface and after that for 30 minutes (without jerks) in a direction perpendicular to the mounting surface. During the tests no displacement of the PV junction box must occur, and the subsequent wet leakage current test as described earlier must be passed.

The fixing of the lid must also be checked: a test probe 11 according to IEC 61032 has to be applied with a force of 75N for 1 minute to all areas where this could cause a loosening of the lid. During the test, the lid must not come off.

Test group F: Test sequence II – damp heat test

This sequence is very similar to test sequence I and the specimen must be prepared in the same way. If several combinations are used, this sequence must also be performed for each of them. Test sequence II starts with the wet leakage current test, followed by the damp heat ageing test, using a test temperature of +85°C (or higher, if specified by the manufacturer), a relative humidity of 85% ± 5% and a test duration of 1000 hours.

After the damp heat conditioning, the r.m.s. withstand voltage test as described earlier must be performed. This is followed by the test sequence of test group D, to check retention of the PV junction box on the mounting surface, and then the wet leakage current test. The fixing of the lid is also tested after the damp heat pre-treatment.

Test group G: Test sequence III – thermal cycle test (tc50) and humidity freeze test

The specimen has to be prepared in the same manner as in test sequences I and II. Test sequence III begins with the thermal cycle test as described in test sequence E, but only for 50 cycles (thus referred to as the tc50 test).

Immediately after the tc50 test, the humidity freeze test must be performed. For this test, temperatures of –40°C (or lower, if specified by the manufacturer) and +85°C (or higher, if specified by the manufacturer) also have to be applied, but each dwell time is different from that in the thermal cycle. In addition, a relative humidity of 85% ± 5% (controlled at the dwell time of the highest temperature, not at the cooling and heating phases and dwell time of the lowest temperature) has to be applied. Ten such cycles are to be carried out on the specimen. After this, the r.m.s. withstand voltage test as described above must be performed, followed by the wet leakage current test.

Test group H: Test sequence IV – bypass diode thermal test

The specimen has to be prepared in the same manner as in test sequences I, II and III, but the cell connections must not be short-circuited. If the PV junction box is intended to be used with several types and/or combinations of bypass diode and/or with several rated currents of the PV junction box, the tests must be performed in all possible combinations with the relevant number of specimens.

Another consideration is whether or not the PV junction box is potted. If the PV junction box is intended to be potted so that the bypass diodes are not accessible, the thermal couples must be fixed before potting upon consultation with the testing lab. It is important to read the data sheet of the diode supplier since the placement of the thermal couple depends on the value of the related junction temperature. Some diode suppliers specify the junction temperature with reference to the case temperature, while others specify it with reference to the lead temperature.

Additionally, thermal couples must be fixed near the bypass diode on the insulation materials serving as support for live parts and the enclosure. In the current official edition of EN 50548, the evaluated temperatures of the insulation material are reference temperatures for the ball pressure test (see the important note in test group B).

The specimen must be installed in a heating chamber which has been pre-heated to a temperature of 75°C ± 5°C. It is recommended to store the specimen for a dwell time of 30 minutes before starting the test. After this resting period a current equal to the rated current ± 2% has to be applied for 1 hour, and the temperatures of each bypass diode are then measured. These temperature values are then used in the formula given in paragraph 5.3.18.3 of EN 50548 to calculate the junction temperature. The value obtained must not exceed the specified limit temperature.

The current is then increased to 1.25 × rated current and maintained for 1 hour. Temperatures should be measured, but this is not necessary. The diodes must still be operational and a visual inspection must show no major defects such as:

- current-carrying parts not being kept in position;

- deformation of insulation parts that serve as protection against electric shock;
- other deformation of insulation parts that may pose a safety issue or impair the function of the junction box.

Finally, the specimen must meet the requirements of a wet leakage current test.

Test group I: Reverse current test

The specimen has to be prepared as described in test sequences I to III, but for the reverse current test the cell connection is specified. The connection must have the maximum cross-section as specified by the manufacturer and must be installed in such a way that the test current can flow through all current-carrying parts of the PV junction box. Additionally, it is required that all blocking diodes be short-circuited.

The specimen must be placed with its back on a pinewood board in a horizontal position, covered by a single layer of cheesecloth specified in the relevant part of IEC 60695. A single layer of cheesecloth is laid on the surface of the junction box so that the outer surface of the junction box is completely covered. The specimen is then heated to the upper rated ambient temperature. Once this temperature has been reached, a current equal to the reverse current of the junction ± 2% must be applied to the specimen for 2 hours. The PV junction box passes the test if there is no flaming of the junction box, and no flaming or charring of the cheesecloth in contact with the junction box.

Tests during production

An important part of the procedure for type approval certification is ensuring the quality and compliance of the PV components. To achieve this, a frequent factory surveillance of PV components by TÜV Rheinland experts is necessary. Of even greater importance are the type and frequency of the quality measures performed in the production process. Routine tests need to be carried out, but also a product verification test (PVT) which is frequently performed by the manufacturer must be approved. A list of required routine and product verification tests is available from the relevant department of TÜV Rheinland. Hopefully these measures will someday be standardized.

> "If a manufacturer changes materials, construction, rated values, etc. then the conformance of a PV junction box to a standard must be reassessed."

Retesting guideline

If a manufacturer changes materials, construction, rated values, etc. then the conformance of a PV junction box to a standard must be reassessed. Although a retest does not always have to be carried out, most modifications will require it. To avoid having the PV junction box undergo all type approval tests, only partial tests, depending on the kind of modification, have to be performed. Since TÜV Rheinland has many laboratories worldwide, it is important that the requirements for the type tests as well as for the retests be precisely the same. In order to achieve this, retesting guidelines for all PV components have been issued, but have not yet been standardized.

About the Author

Guido Volberg is the director of the Technical Competence Center PV Components at Cologne-based TÜV Rheinland. He began work at TÜV Rheinland in 1995 as an engineer in electrical components and created the first TÜV internal standards for PV components in 2001. Today, collaborating internationally with the other TÜV Rheinland laboratories, he coordinates a team for testing PV components. Guido is also responsible for developing test programmes for innovative products within the PV business sector. He is currently participating in standardization work through the IEC working groups for flat-plate photovoltaic modules (IEC TC 82 WG2) and balance of systems (IEC TC 82 WG3/WG6).

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