NEW TEST METHODS FOR BIPV: RESULTS FROM IP PERFORMANCE

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ABSTRACT: Within the Performance project new test procedures for PV building products and the building performance as a whole when PV is applied in buildings have been drafted. It has resulted in a first draft of new test procedures for PV building products and proposals for tests for novel BIPV technology like thin film. The test proposed are a module breakage test for BIPV products, a fire safety test for BIPV products and a dynamic load test for BIPV products. Furthermore first proposals of how flexible PV modules could be tested in an appropriate way to ensure long time quality and safety of these new products are presented.
Keywords: Building Integrated PV (BIPV), PV Market, Thin Film

1 INTRODUCTION

PV on buildings is in Europe the application giving the most value to a PV system. It is this application of PV that will first reach grid parity. PV is successful as a building product in Germany, Switzerland and the Netherlands. In most European countries, including those with a favourable irradiation, a BIPV market has not really developed yet. To achieve a sustainable market it is crucial that developed PV products are compatible with the existing building codes and practices. The lack of standardisation hinders the creation of a European market. Therefore, within the framework of the European project IP Performance [1] focus has been on developing Europe-wide accepted test procedures and standards for PV building products and PV systems meant for building integration.

2 EC DIRECTIVES FOR PV IN BUILDINGS

PV as a building element should fulfil the requirements of the EC directives. Due to its nature PV as building element can be regarded as an electronic device and as a building product. The relevant EC directives for PV in buildings are therefore:

- Low Voltage Directive (LVD, 2006/95/EC);
- Electromagnetic Compatibility Directive (EMCD, 2004/108/EC).
- Construction Products Directive (CPD, 89/106/EEC);
- Energy Performance of Buildings Directive (EPBD, 2002/91/EC).

In this paper focus will be on the Construction Products Directive.

3 CE MARKING

3.1 CE marking

The CE-marking is a mandatory European marking for certain product groups to indicate conformity with the essential health and safety requirements set out in the European directives. In the near future only building products that carry a CE-mark are allowed to be traded in Europe. So building products carrying a CE-mark can be brought to all European markets without major restrictions.

Figure 1: The CE logo

3.1 Declaration of Conformity

The CE-marking is a declaration of conformity made by the manufacturer, which documents that the product in question adheres to the protection requirements of the relevant EC directives. By affixing the CE-mark the manufacturer declares his personal responsibility for ensuring that the marked product meets the requirements of all pertinent EC directives. The declaration of conformity is bound to the CE-marking. The manufacturer must keep it and the necessary technical documentation for at least 10 years after production of the last product, and, if required, shall inform the control authorities accordingly as requested.

4 CONSTRUCTION PRODUCTS DIRECTIVE

4.1 Fit for intended use

According to the Construction Products Directive CDP, 89/106/EEC, all building products should carry the CE-mark, showing that the product is fit for intended use. One of the goals of the CPD is the removal of technical barriers to trade in the construction products sector. PV as building element should fulfil the requirements of the directives. This is the case if the product complies with:

- A harmonised European standard, or
- A European technical approval (ETA), or
- A non-harmonised technical specification recognised at Community level.

For BIPV products and also for a lot of other building products these specifications are not yet completely determined and the required produce is established and implemented.

4.2 Essential requirements

The essential requirements for building products, as formulated in the Construction Products Directive are classified in the following categories:

1 Mechanical resistance and stability
2 Safety in case of fire
3 Hygiene, health and the environment
4 Safety in use
5 Protection against noise
6 Energy, economy and heat retention

The essential requirements applicable to works which may influence the technical characteristics of a product are set out in terms of objectives as follows.

4.3 Mechanical resistance and stability

The construction works must be designed and built in such a way that the loadings that are liable to act on it during its constructions and use will not lead to any of the following:

- Collapse of the whole or part of the work
- Major deformations to an inadmissible degree
- Damage to other parts of the works or to fittings or installed equipment as a result of major deformation of the load-bearing construction
- Damage by an event to an extent disproportionate to the original cause

4.4 Safety in case of fire

The construction works must be designed and built in such a way that in the event of an outbreak of fire:

- The load-bearing capacity of the construction can be assumed for a specific period of time
- The generation and spread of fire and smoke within the works are limited
- The spread of the fire to neighbouring construction works is limited
- Occupants can leave the works or be rescued by other means
- The safety of rescue teams is taken into consideration

4.4 Safety in use

The construction work must be designed and built in such a way that it does not present unacceptable risks of accidents in service or in operation such as slipping, falling, collision, burns, electric shock or injury from explosion.

5 PROPOSED TEST PROCEDURES FOR BIPV PRODUCTS

The following tests were identified as relevant and a first test proposal has been worked out.

- Module breakage test
- Fire safety test (PV as a source of fire)
- Dynamic load test

For a water tightness test reference is made to other work by the EurActiveRoofer project [2]. With respect to the effects of arcing a separate paper has been presented.

6 MODULE BREAKAGE TEST BIPV PRODUCTS

6.1 Purpose

The purpose of the module breakage test for BIPV products is to provide confidence that a BIPV module remains its mechanical and electrical safety characteristics at the mounting system and glass surface. Weak junctions, materials and components form a risk by releasing parts such as glass fractions under the influence of a mechanical impact. Openings on the front or back of the modules surface shall have no influence on the outer electrical insulation.

6.2 Procedure

The modules intended for building integrated use shall be installed using the mounting system supplied and prescribed by the manufacturer with a combination of at least four modules. The test set-up has to be established as implemented in practice. As a result, also junctions of modules such as sealing’s or connectors need to be installed. Test results may just be valid for the one system tested. An ‘impactor bag’ shall be filled with lead shot and to be applied to the third drop height (1220mm) according to IEC/EN 61730-2.

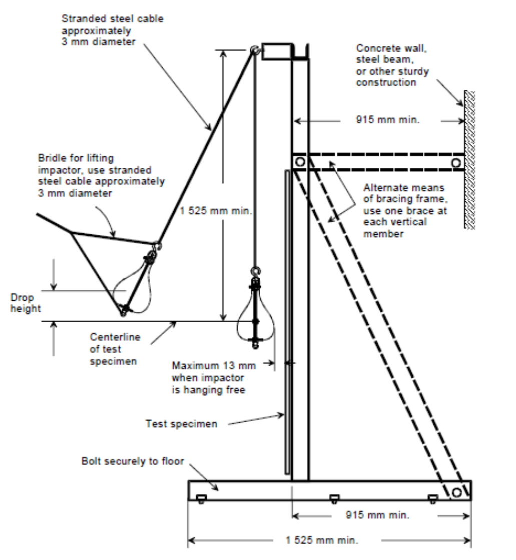

Figure 2 Construction and test set-up module breakage test (IEC 61730)

The ‘impactor bag’ shall be struck into the centre of the PV module as described in IEC/EN 61730 at a drop height of 300mm. The test is conducted only once. The test criteria below shall characterize the test results. After the evaluation, the test has to be repeated at a drop height of 450 and 1220mm, where each experimental series (300, 450 and 1220mm) imply new samples. However this is still under discussion.

6.3 Pass criteria

The module breakage test is failed if any of the requirements and sub items defined in the following assessment criteria is not fulfilled.

a) If openings at the front or back of the module reveal electrical life parts, an accessibility test according to MST 11 of IEC/EN 61730-2 shall be conducted. This test determines if non-insulated electrical connections represent a shock hazard to personnel. A cylindrical test fixture 'Type 11' (of IEC 61032) and an ohmmeter or continuity tester (attached to the module electric circuit) shall be used to determine the electric resistance. Pass criterion: At not time during the test shall be less than 1Mohm resistance between the test fixture and the module electric circuit.

b) When disintegration of particles occur at the front and / or the back of the module, the dimensions for the released fractions and the remained hole on the glass front is characterized by EN 12600. Pass criteria:

1) Numerous cracks occur but no shearing or opening occurs through which a sphere 76mm in diameter can pass when a maximum force of 25 N is applied.

2) 3 minutes after the impact particles detached from the test piece weigh no more than a mass equivalent of 10,000 mm² of the original test piece and the largest single particle weighs less than the mass equivalent of 4,400 mm² of the original test piece.

3) The 10 largest crack-free disintegrated particles collected within 3 minutes after impact and weighed together within 5 minutes of impact do not weigh more than the mass equivalent of 6,500 mm² of the original test piece (according to EN 12600).

c) When the mounting system and framing of the module and PV system is affected, the damage shall be characterized by the following pass criteria.

1) There shall be no screws and clamps of the mounting system neither be ripped and torn nor detached or released from the module or the sub construction. The tested system needs to remain rigid after the impact.

2) A bent frame of the module revealing electric life parts shall be evaluated with the accessibility test in a).

7 FIRE SAFETY TESTS BIPV PRODUCTS

7.1 Purpose

The fire safety test for BIPV products integrated in pitched and flat roofs shall be conducted following the demands of the classification standard for roofs EN 13501-5 and the fire test with burning brands and radiant heat according to ENV 1187. Furthermore BIPV products need to fulfil the requirements of EN 13501-1 which classifies in general the building material to class E. The aforementioned standards are listed in the Construction Products Directive. The purpose of the classification is to proof that the BIPV system, replacing the outer roofing layer, provides the confidence to withstand an external fire with burning brands and radiant heat. The characterization of the BIPV-system shall be named by BRoof t1…t4 according to the different fire tests that were conducted. As long as there are different tests demanded by different countries in Europe and no harmonized and ultimate test is defined, the intended region of application and economic interest should decide which test or how many of the ENV1187-tests should be carried out by the manufacturer. Differences in the tests are for instance the composition of the burning brands. The most common use burning brand can be seen in figure 3.

Figure 3 Wired basket filled with wood wool (source: [TÜV Rheinland 2009)

7.2 Procedure

The BIPV system shall be represented by a combination of at least four modules at each testing angle (depending on the adapted ENV 1187-test). The set-up shall be constructed and mounted close to reality and fixed with the sub-construction and mounting system of the manufacturer. The incendiary compositions or radiant panels or general fire and heat sources shall be applied on the system as prescribed in the adequate fire test method (ENV 1187-1, -2, -3 or -4). It shall be mandatory that the whole system is taken into account. This means that sealing's and joints of the modules also need to be regarded. The burning brands should at least be positioned on a vertical and horizontal joint between modules.

7.3 Pass criteria

The pass criteria shall by characterized by EN 13501-5 to approve the system being according to the requirements of the roofing classification. According to EN 13501-5 many different classification criteria are named. Basically the classification relates to the burning behaviour of the fire depending on fire spread (directions and distances) and burn through (the material). Besides that, the released material which is released at the front or back of the module due to combustion is brought into focus. For instance a fire spread upwards has to be smaller than 0.7m and downwards smaller than 0.6m. A burn through is not allowed because the sub-construction could be affected. To protect covered layers underneath the tested roofing layer, burning or glowing materials are not allowed to be released and drop off the backing, in this particular case the back sheet of the module.

8 DYNAMIC LOAD TEST BIPV PRODUCTS

8.1 Purpose

The purpose of the dynamic load test is to apply mechanical loads with pressure and tensile forces on a building integrated PV system and proofing the resistivity against the influences of alternating wind forces. The test sequences and used pressure amplitudes depend on a parameterization of values from dynamic load tests of EN standards from the building sector and PV specific requirements, defined in IEC/EN 61215.

8.2 Procedure

The testing set-up is similar to the described mechanical load test in IEC/EN 61215. The PV module, meant for building integration, shall be installed front-side up and interconnected with the mounting technique, prescribed by the manufacturer, on a rigid construction as implemented in practice. Possible sealing's being used at the junctions between the modules (in reality) may be installed as well, depending on the mounting technique. The rigid construction shall allow a freely bending of the system. The mechanical loads shall be applied as follows:

- Application of 500 load cycles at ±2400Pa spread uniformly over the test surface
- Each load cycle shall last 30 s but at least 21 seconds
- The maximums of the mechanical loads on the module and mounting technique (+ and -2400 Pa) shall last on its surface between 7 seconds and 10 seconds.
- The electrical continuity of the module's internal circuit shall be monitored continuously during the test. After the mechanical loads, the BIPV module and mounting technique shall be tested (interconnected as a system) under thermal loads following the test method of IEC/EN 61215/61646 ('thermal cycling test').

8.3 Pass criteria

After the test, the requirements for the mounting system and tested module are:

- No macro cracking or major visual defects are detectable
- Power determination shall not exceed ±5% of PMpp in comparison to the values measured before the test
- No visual lasting bending of the mounting system
- Electrical insulation measurements (test 10.3 and 10.15 of IEC 61215) shall meet the same requirements as defined in IEC/EN 61215 (e.g. initial measurements)
- No intermittent open-circuit fault detected during the test.

9 PROPOSED TESTS FOR NOVEL PV TECHNOLOGY

9.1 Deformations of flexible modules

Flexible PV materials such amorphous silicon on a flexible layer might experience other problems than rigid glass products. For example, forces on the flexible modules are to be expected during installation. Flexible modules show a different construction compared with conventional glass/glass or glass/foil modules. In conventional stiff modules the c-Si cells are embedded between two layers of lamination material (e. g. EVA) that allows dilatation between the cells. The contact stripes serve as a buffer if they are placed correctly, this means without mechanical stress on the stripe itself but with a slight bow that allows deformation if thermal or mechanical stress is applied on the PV module.

Contrary to that, thin-film modules, especially if they are monolithically integrated, consist of one big layer in the final module size. The structuring of the whole format into single cells does not mean that there are intermediate spaces between the cells, which could buffer the shifting of the single layers. Stress on flexible PV modules can be caused by stretching and deformation.

Stretching as well as deformation in two or three dimensions causes mechanical stress on the different layers of a flexible PV module. The cell layer can be regarded as the mechanically most sensitive one. These forces do not at all occur in stiff modules where the glass panes form a stable basis for the solar cells both of crystalline Silicon or thin film cells which are deposited on metal foils and used like c-Si cells in a conventional PV module. These points show that a definition of testing procedures for the elasticity and flexibility of flexible thin-film modules becomes necessary.

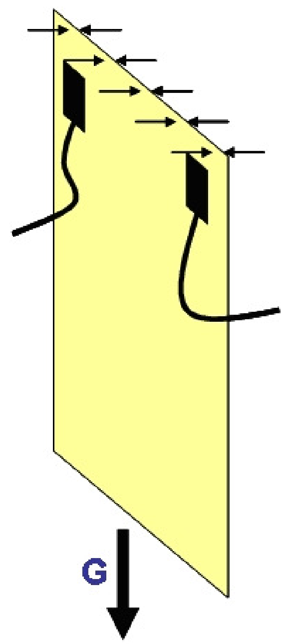

Figure 4: Design for a stretching test

Stretching and bending of modules laminated on building products with considerable sizes by simply carrying and pulling them into the final mounting position will not be completely avoidable. Stretching as well as deformation in two or three dimensions causes mechanical stress on the different layers of a flexible PV module. Distinguished are:

- Stress by stretching (deformation in 1 dimension)
- Deformation in 2 dimensions (bending)
- Deformation is 3 dimensions (punching)

For each of these effects a test method is proposed.

9.2 Stress test

The following test method is proposed. A flexible module is gripped between wide clamps fixed on that short edge where the cables leave the module in a rack of sufficient height in such a way that the module can hang down. The forces are defined by the weight G of the module respectively the PV building product itself. The test shall last 1 hour.

9.3 Bending test

A typical deformation in two dimensions is caused by bending. This can occur both during installation as it can be hardly realized to keep the module absolutely flat and in mounted position, e. g. on a curved roof.

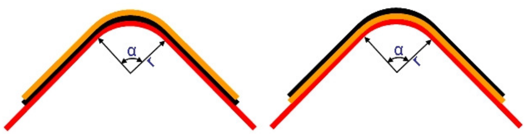

Figure 5: Test bench with a given shape (red) around which the module is to be bended in the convex way (left) and in the concave way (right):

The following test procedure is proposed. A flexible PV module will be bended over the whole width around a given shape both in the convex and the concave shape.

9.4 Stress caused by punching

A probable way of stressing a flexible module especially if placed on a flexible roofing membrane is a three dimensional deformation due to a stone that is pressed into the module (e. g. by a footstep). Depending on the position of the stone (below or above the module) the deformation can again be both concave or convex. The semiconductor is stretched in all directions, expanding forces are not constant over the distance from the centre of the deformation. Radial cracks around the maximum of deformation are expected.

9.5 Ball intrusion test

A simulation of the stone push situation can be implemented as following (fig. 6). A ball of given diameter is pressed into the module which lays on a compressible material (e.g. polystyrene). The following parameters are proposed:

- As standard stone a steel ball is used.
- The diameter is proposed with 5mm. Bigger stones will hardly be transported under shoes.
- As pressure force 1000 N is suggested. This force is applied with a moveable punch of 100 cm² area. These figures can occur if a person is walking on the module with elastic shoe soles.
- The compressible counterpart is suggested to be polystyrene with a density of 30 kg/m³. For isolation materials from mineral wool with the same density the behaviour against point loads can be regarded as similar.
- The intrusion shall be carried out both in concave and convex position and at 10 locations over the whole module to increase possible effects for easier detection.

A destruction of the PV cell layer or parts of it should be detectable by IV-curve measurement before and after the test (and visual inspection for damage) if qualification is the main interest as in EN 61646. If the risk of hazards is dominating it would make sense to make an insulation test after the stress. In this case the test should be better included to EN 61730.

9.6 Checks

In order to determine the effect of the testing a visual inspection is carried out and IV-curve measurements before and after the tests. Passing criteria have to be defined. The final assessment of the foil will consist of inspection for visual damage (delamination, cracks etc.) of the foil after the various bending tests and the IV-curve measurements before and after the tests. Visual damages during the various tests should be recorded at once.

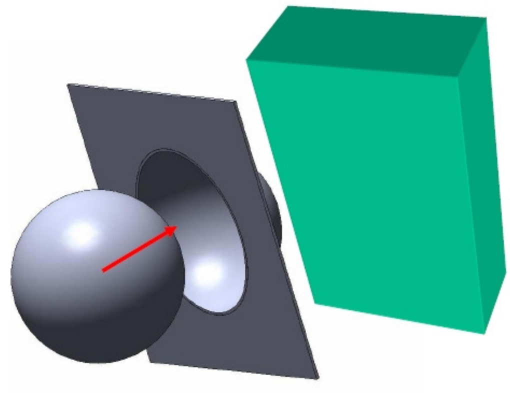

Figure 6: Schematic arrangement of a ball intrusion test

10 CONCLUSIONS

BIPV can play an important role in realising the targets for renewable energy in Europe in 2020 and beyond. To ensure the safety and quality of PV systems in buildings it is necessary to have a framework of Europe-wide accepted test procedures for PV building products. These test procedures will be the basis for a CE mark, as that ensures conformity of a product throughout the European Union.

First proposals for BIPV tests and additional test for flexible PV modules have been presented. Eventually new tests can be taken up as additional tests in existing standards or a new BIPV standard.

The results will be disseminated to the European standardisation committees CEN and CENELEC.

11 ACKNOWLEDGEMENTS

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