PERFORMANCE ASSESSMENT OF BIPV SYSTEMS: RESEARCH ON BIPV CHARACTERIZATION METHODS

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ABSTRACT: The dynamic sector of Building Integrated Photovoltaics (BIPV) is progressively achieving a level of technical maturity and one of the major challenges to address in the coming years will be cost-effectiveness towards a mass-market implementation. Supported by the increasing technological development, by digitization and process innovation, such systems will have to be ready on the next frontier: to be integrated throughout the regular construction market in order to make cities healthier and powered by on-site solar renewables. BIPV products, evolving towards multifunctional products, will need more clear qualification and certification processes as construction products to promote commercialization throughout the EU, based on dedicated standards supporting higher market confidence. The H2020 project "BIPVBOOST" [1] is focused on obtaining a reduction in costs along the entire production chain by pursuing product and process innovation, thus supporting the BIPV implementation in the built environment. As introduced by the authors [2] [3], EN 50583: 2016 Parts 1 & 2 represent the main regulatory framework in Europe for BIPV whereas the IEC Project Team PT 63092 is currently preparing an international BIPV standard. Basically, the product qualification is currently based on standards created for standard PV or, on the other hand, for "non-active" traditional construction products. Starting from this framework, the analysis of the missing gaps and a roadmap to define new reference procedures for BIPV product qualification were set as a first step of the research. The next step of the project which is currently ongoing, is targeted to the development of some reference performance-based schemes, referred to a set of technical requirements and product families, which will aim at combining both PV and construction requirements in a harmonized assessment. The paper will present the basic aspects of the procedures under development: Energy economy; Electrical performance in non-conventional scenarios; Mechanical performance of BIPV elements; Fire reaction of BIPV components/systems.
Keywords: BIPV performance assessment, standards, performance-based approach, quality, BIPV testing

1 INTRODUCTION

The built environment remains a strategic research and innovation domain in view of the goal of full decarbonisation by 2050. As set in the European Green Deal, one of the two major components of this transition is constructing and retrofitting buildings to reduce their embodied emissions and increase their energy efficient operation. On the other hand, the second component is related to produce on-site sustainable, renewable energy technologies, such as electricity, covering their energy needs and contributing to the grid stability of energy positive buildings [4]. The exploitation of building skin surfaces represents a huge potential in turning the built environment into a decentralised renewable energy producer, by saving lands and landscape areas towards a refurbished and improved building stock in the EU, as the building sector is one of the largest energy consumers in Europe. From the origin of BIPV experimentation, along last 3 decades, the process of PV transfer in the building envelope covered various approaches and is still highlighting today its innovation trends, ranging from new concepts and materials, advances in the manufacturing, assembling, construction processes, till the progressive improvement of existing technologies.

In this context, although there are normative efforts focused on BIPV, such as EN 50583 [5] and the future IEC 63092, the two functions (building and electrical) still remain separate in the original normative acts (CPR 305/2011 and LVD 2014/35/EU) and in the consequent harmonized standards, thus not providing concrete specification references supporting a multidisciplinary assessment of BIPV. Laboratory tests consequently remain on separate paths, sectors and qualification logics are usually disconnected (e.g. for CE-marking and market introduction) and today there are no test procedures considering a combination of building and PV functionality as a matter of fact for performance assessment and product qualification. The topic of BIPV products qualification still pays the complexity and contradicting nature of building and PV normative assets, as it’s been already discussed and argued by authors in a report developed within BIPVBOOST project [1].The topic has been also addressed in the report “Proposed Topics for Future International BIPV Standardisation Activities” from Task 15 IEA-PVPS which identified areas where there is still a need for international standardisation on multifunctional characterisation of BIPV modules and systems and to recommend approaches which could be taken to meet this need [6]. Moreover current state-of-art in product qualification and product engineering for BIPV glasses has been further discussed in [7] along with the literature framework of the experimental investigations which attempted to cover the applicability of a performance assessment for BIPV.

However, to date, the building codes do not consider the presence of active parts that produce energy, such as PV cells, while the standards regarding PV modules are mainly do not cover the building requirements especially in the many cases where BIPV is realized as a construction product with a customized approach. All questions discussed so far highlight that the current BIPV standardization framework is not sufficiently developed, so that it arises the technical need, especially for some of the main requirements, to identify new performance levels and test methodologies suited to ensure the quality of solar active building skin systems. A possible path is considered achievable by developing a new approach for the qualification of BIPV products, coherent with the principles of CPR 305/2001, considering BIPV as a construction product and aimed at filling the missing gaps and criticalities previously analyzed. As part of BIPVBOOST project, the authors defined a roadmap describing the principles and basic approaches to define new reference performance-based procedures for BIPV products qualification, as a basic ground for the development of new procedures [8].

Since a prescriptive approach demonstrated all the limits applied to construction sector, a key-aspect is taking some of the advantages of a performance-based regulation based on the reliability-based principles that have to be defined as a number of limit states to be explicitly checked. In the still ongoing part of the project a higher design flexibility based on performance objectives is under investigation in order to constitute a beneficial and competitive concept for BIPV engineering, ensuring a higher reliability level of a design choice, a simplification of the testing procedures and a reduction of the needed time and costs. By focusing on pre-defined requirements and specific product technologies developed within the consortium, new approaches are under experimentation, to test and validate the behaviour of BIPV products, considering the fundamental aspects of multifunctionality and cost reduction.

2 METHODOLOGY

The purpose of the project is to identify and implement some pilot routes aimed at contributing to a BIPV **cost reduction** through an advanced scheme supporting the qualification for a massive and reliable implementation of BIPV in the building sector. After the preliminary investigation, which identified the **state of art** of the regulatory framework, the current **missing gaps** related to the most relevant BIPV features, components and performances and defined the **main routes** for new qualification procedures applicable in the BIPV sector, as already presented in [8], this paper will describe some more details of topical methodologies suitable to identify new procedures to qualify BIPV. Since these multifunctional products are conceived to perform their functions in different fields of application, some products already established on the market will be mainly considered or for which a first real prototype is planned within the project. The proposed procedures will start through the pinpointing of the missing gaps. The new testing procedures will have to meet the regulations in both the building and PV fields. For the electrical performance, the starting point will be the PV normative framework the BIPV product shall comply with. For all the remaining requirements, the reference will be imposed by the building field regulation as set according to CPR 305/2011. In developing a new test procedure, the standard test methods will be the starting point on which modifications, extensions, and combination should be considered according to the electrical function/safety, and to the limit states considering the final product including PV. According to the investigated topic, the procedures will be developed in order to cover the relevant technical requirements either for materials, building skin, and complete systems. In general, the product family will be defined according to the normative in force for the building components, namely from harmonized standards in force based on CPR 305/2011. The combined effect of PV and building performances as well as the coexistence of effects/actions aimed at reproducing representative limit states will be considered.

The thematic areas object of investigation are:

- Energy economy: thermal transmittance (U) value, solar (g) factor and energy performance
- Electrical safety performance in non-conventional scenarios
- Mechanical performance of BIPV elements
- Fire reaction of BIPV components/systems

In developing the new procedures, the following steps are planned.

As a *first step* the cross-comparison of **building and PV standards**, definitions and prescriptions will be done:
- Analysis of relevant technical requirements, object of analysis, in each relevant standard
- Identification of similar/analogue requirements in different standards
- Determination of redundancies, missing requirements in PV or building normative (partially missing)
- Decision on the need of add a new requirement in PV or building assessment
- Identification of missing requirements in both PV and building normative
- Decision on the need of adding a new requirement in PV and/or building assessment

As a *second step*, the definition of **performance assessment goals** for PV and building requirements will be done:
- Finding of building requirements which are significantly affected by PV aspects/materials/uses
- Finding of PV requirements which are significantly affected by building aspects/materials/uses
- Decision on the methodology of requirement re-definition, according to limit states, combined approach, etc.

The *third step*, which will not be discussed in the article, will consist in defining and validating the new test procedures for the identified new performance levels.

3 INPUTS FOR CARACHTERIZATION METHODS IN A PERFORMANCE-BASED APPROACH

3.1 Energy economy

The current assessment of the building energy performance including BIPV solutions is based on common construction standards in which the presence of the solar cells is not properly taken into consideration, even if their influence can be significant. For instance, if the BIPV product is based on laminated glass, the calculation of its thermal transmittance (U factor), its optical properties and its solar heat gain coefficient (g value or SHGC) are based on standards developed for the common architectural glass industry. However, the PV laminated glass has additional characteristics that should be considered for the calculation of their optical and thermal properties. An example is the energy conversion of a part of the incident radiation into electricity due to the PV effect, so this energy will not produce heat and will impact the final performance in terms of SHGC. Moreover, the experimental characterization of the SHGC is not an alternative as normally is a costly and complex matter.

The final purpose of this work is to analyze and determine the new characteristics introduced by the BIPV products, compared to their equivalent non-PV construction product, that may affect the final building energy parameters in real operation. In addition, new calculation methodologies will be proposed in order to get more realistic and comparable values of the BIPV products.

3.1.1 Thermal transmittance (U) value

Specific technical requirement covered by the new procedure (TR):
Determination of thermal transmittance (U value)
Product family (PF):
Laminated PV glass, Insulating PV glass units (PV IGUs), BIPV systems including structure, PV modules based on other materials than glass
Specific reference standards in force in PV and building domain for product qualification/marking:
EN 673 - Glass in building - Determination of thermal transmittance (U value) - Calculation method EN 674 - Glass in building - Determination of thermal transmittance (U value) - Guarded hot plate method EN 675 - Glass in building - Determination of thermal transmittance (U value) - Heat flow meter method EN 12898 - Glass in building - Determination of the emissivity EN ISO 10077-1 - Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General EN ISO 10077-2 - Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames EN 12412-2 - Thermal performance of windows, doors and shutters - Determination of thermal transmittance by hot box method - Part 2: Frames EN ISO 12567-1 - Thermal performance of windows and doors - Determination of thermal transmittance by the hot-box method - Part 1: Complete windows and doors EN ISO 12567-2 - Thermal performance of windows and doors - Determination of thermal transmittance by hot box method - Part 2: Roof windows and other projecting windows EN ISO 6946 - Building components and building elements - Thermal resistance and thermal transmittance - Calculation method EN ISO 12631 - Thermal performance of curtain walling - Calculation of thermal transmittance EN 1279-2 - Glass in building - Insulating glass units - Part 2: Long term test method and requirements for moisture penetration EN 1279-3 - Glass in building - Insulating glass units - Part 3: Long term test method and requirements for gas leakage rate and for gas concentration tolerances EN 1279-4 - Glass in Building - Insulating Glass Units - Part 4: Methods of test for the physical attributes of edge seal components and inserts
Innovation of the new procedure with reference to existing standards:
The average operation temperature is higher for BIPV glass than for conventional glass, mainly due to higher radiation absorption. Some reference temperatures might be increased. This fact affects calculations / measurements related to thermal transmittance of air layers and described in EN 673, EN 674, EN 675, EN ISO 10077-1 and EN ISO 6946. The maximum operation temperature reached by BIPV glazing is higher than conventional glass, mainly due to higher radiation absorption. It can also be higher than conventional PV due to lower heat dissipation. Thus, some experimental serviceable and ageing test should assess the increase of the maximum temperatures. This fact may affect EN 1279-2, EN 1279-3, 1279-4 and ageing tests described in IEC 61215. The heat flux can change from inner to outer glass even in winter due to radiation heat in the PV layer. Thus, the operative U-value might be quite different in these conditions, especially in skylights, where the thermal transmittance of the glass chamber depends strongly on the heat flux sense For the calculation of thermal transmittance of a complete system (including framing), probably the thermal resistance and the area of the junction box should be considered if it is located on the back side of BIPV glass (EN ISO 10077-1, EN ISO 12631). For the calculation of frame thermal transmittance, the effect of the cables within the frame chambers and the holes required for the cables, that can communicate different chambers of the frame, should be assessed (EN ISO 10077-2, EN 12412-2, EN ISO 12631). The final report describing the materials of the samples should include, in general, the type and number of solar cells, their size and position.
Methodology
A review of the state-of-the-art it is required in order to assess the impact of the different factors. If no information available, some calculations/ simulations or experimental measurements might be needed. Once the impact of the new effects has been evaluated; new calculation procedures might be needed to be described in the standards.

3.1.2 Optical properties and solar gain (g value)

Specific technical requirement covered by the new procedure (TR):
Determination of optical properties and solar gain (g value) of BIPV products
Product family (PF):
Laminated PV glass, insulating PV glass units (PV IGUs), PV modules based on other materials than glass

Specific reference standards in force in PV and building domain for product qualification/marking:

EN 410 - Glass in building - Determination of luminous and solar characteristics of glazing

ISO 9050 - Glass in building - Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors

ISO 15099 - Thermal performance of windows, doors and shading devices - Detailed calculations

EN ISO 52022-1 - Energy performance of buildings - Thermal, solar and daylight properties of building components and elements - Part 1: Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing

EN ISO 52022-3 - Energy performance of buildings - Thermal, solar and daylight properties of building components and elements - Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing

ISO 19467:2017 - Thermal performance of windows and doors - Determination of solar heat gain coefficient using solar simulator

Innovation of the new procedure with reference to existing standards:

The final optical properties of the PV glass will be a mixture between the optical properties of the opaque area, occupied by the solar cells, and the non-occupied transparent area (EN 410, ISO 9050, ISO 15099). An area weighed average has been proposed in the literature but should be further investigated.

The radiation converted into electricity should be removed from the system. This is determined by the efficiency of the worse (less efficient) solar cell in the module and its temperature. (EN 410, ISO 9050, ISO 15099). The optical properties of the solar cell should be considered, as there are solar cells that do not absorb all the radiation in the near infrared region. In other words, the solar cells cannot be considered fully opaque without an optical characterization. Although it will not affect significantly to visual properties, it may affect solar transmittance and solar heat gain coefficient. (EN 410, ISO 9050, ISO 15099)

With normal incidence of light (as it is described in the standard) the effect of solar cell backside on the optical properties will be negligible. However, with angular incidence of light the effect of backside reflectance could be significant. This should be further studied. (EN 410, ISO 9050, ISO 15099)

The presence of the junction box on the rear side of the BIPV module will affect the optical properties in this area. The optical and thermal properties of the junction box should be quantified in order to assess its impact on the final optical and thermal properties.

The final test report should include the position of the solar cells, the solar cells type and the glass ratio covered by the solar cells.

Methodology

A review of the state-of-the-art it is required in order to assess the impact of the different factors. If no information available, some calculations/ simulations or experimental measurements might be needed.

Once the impact of the new effects has been evaluated; new calculation procedures might be needed to be described in the standards.

3.1.3 Energy economy (EE): Energy Performance of Buildings (EPB)

Specific technical requirement covered by the new procedure (TR):

Energy performance of BIPV solutions from the building viewpoint and calculation of PV energy production

Product family (PF):

Laminated PV glass, Insulating PV glass units (PV IGUs), BIPV systems including structure, PV modules based on other materials than glass

Specific reference standards in force in PV and building domain for product qualification/marking:

EN ISO 52000-1 - Energy performance of buildings - Overarching EPB assessment - Part 1: General framework and procedures

EN ISO 52016-1 - Energy performance of buildings - Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads - Part 1: Calculation procedures

EN 15316-4-3 - Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-3: Heat generation systems, thermal solar and photovoltaic systems, Module M3-8-3, M8-8-3, M11-8-3

EN ISO 13789 - Thermal performance of buildings - Transmission and ventilation heat transfer coefficients - Calculation method

ISO 10292 - Glass in building -- Calculation of steady-state U values (thermal transmittance) of multiple glazing

EN ISO 10211 - Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations

Innovation of the new procedure with reference to existing standards:

New procedures (described previously) should be applied to the calculation of U and G value before using them in EN ISO 52016-1. In addition, this standard could refer to specific products of BIPV glazing when giving examples or data. The standard considers PV glazing as “dynamic transparent element” because “there may be an interaction between the electric output and the thermal or optical properties”. This fact should be further analyzed.

A simple method to calculate the PV production is described in EN 15316-4-3. Reference performance factors are provided for different ventilation cases. More information can be included in order to perform a more accurate calculation of PV production.

Methodology

A review of the state-of-the-art it is required in order to assess the impact of the different factors. If no information available, some calculations/ simulations or experimental measurements might be needed.

Once the impact of the new effects has been evaluated; new calculation procedures might be needed to be described in the standards.

3.2 Electrical safety in non-conventional scenarios

The BIPV products, as an integral part of the building skin within a urban environment, can be often subjected to unconventional conditions (e.g. variable shading) compared to the traditional PV module leading to long-term and cyclic stresses during operation which can impact its electrical performance and in certain cases, lifespan.

A BIPV product, for example, can have a different heat dissipation due to the integration in a multi-layered product that alters the electrical performance related to temperature. Very often then, a BIPV product undergoes the shading due to the conformation of the building, forcing the operation of the protective devices (diodes) in order to avoid hot spots. The aim of the work is to define new procedures which alongside the existing ones, considering the external factors and defining the limit states of performance assessment and evaluation.

3.2.1 Environmental and Electrical safety: thermal behaviour and performance in non-conventional scenarios due to shading effects

Specific technical requirement covered by the new procedure (TR):
1_Environmental conditions and Electrical safety in Serviceability Limit State (SLS): electrical safety and performance in variable shading scenarios
Product family (PF):
2_All BIPV families
Reference standards in force in PV and building domain for product qualification/marking:
• Directive 2014/35/EU « Low voltage directive » (LVD): EN IEC 61730 series; IEC 61730-2: 2016, Cl. 10.15 "Temperature test – MST21" IEC 61730-2: 2016, Cl. 10.16 "Hot-spot endurance test – MST22" • IEC 61215-2: 2016, Cl. 4.19 «Stabilization – MQT19" • DRAFT IEC TS 61340 "photovoltaic (PV) modules – partial shade endurance testing for monolithically integrated products" • Additional BIPV standards: EN 50583 part1&2. The test sequences according to IEC 61730 will include also the test method from draft IEC TS 61340, while implementing a new indoor testing procedure.
Innovation of the new procedure with reference to existing standards:
The new testing procedure will define, following a performance-based approach and related limit states, the behaviour of BIPV elements in variable shading scenarios. The testing procedure is expected to reduce dramatically the testing time and related cost. In particular, the tests will go beyond the intended use of the PV element as specified by the manufacturer according to the PV standards. The test procedure is not equivalent to, and is not intended to replace, the 'hot-spot endurance test' in IEC 61215-2.
Methodology
The purpose of this procedure will be to define a test methodology/workflow in order to assess the operating temperature of BIPV modules/systems with regard to reference mounting/shading scenarios. According to the performance-based approach, different limit States will be defined. Test methods for quantifying the change in BIPV module's power output resulting from pre-defined partial shade conditions will be developed. The tests are intended to excite similar levels of shading stress during an extended period of outdoor service life.
Application
Light Soak with variable shadowing in combination with controlled environmental conditions

3.2.2 Electrical insulation and durability of insulating materials in non-conventional scenarios

Technical requirement covered by the new procedure (TR):
1_ Electrical safety in Serviceability Limit State (SLS): electrical insulation and durability of insulating materials
Product family (PF):
2_All BIPV families
Reference standards in force in PV and building domain for product qualification/marking:
• CPR 305/2011: applicable harmonized standards • Directive 2014/35/EU « Low voltage directive » (LVD): EN IEC 61730 series; IEC 61730-2: 2016, Cl. 10.31 "UV test MST 54" IEC 61730-2: 2016, Cl. 10.29 "Humidity freeze test - MST 52" IEC 61730-2: 2016, Cl. 10.13 «Insulation test – MST16" IEC 61730-2: 2016, Cl. 10.14 «Wet leakage current test – MST17" Additional BIPV standards: EN 50583 part1&2. IEC61215 (MQT15/MQT18/MQT19…)
Innovation of the new procedure with reference to existing standards:
The new testing procedure will combine thermal cycling and UV exposure with electrical safety tests. Other PV degradation phenomena (i.e. PID and LeTID) can also be investigated with the same set-up.
Methodology
The purpose of this test is to determine whether the BIPV module is sufficiently well insulated between current carrying parts and the frame or other outside accessible components while exposed to extreme environmental conditions, relevant for its mounting application category and temperature range (defined in the previous procedure). The humidity and freeze test according to IEC 61730 will be alternated with the UV exposure test. With both the thermal and UV ageing, the electrical insulation properties will be assessed on a real time basis.
Applications
Insulation test during thermal cycling and in combination with standard Humidity and Freeze test

3.2.3 Electrical safety and suitability of protection devices

Technical requirement covered by the new procedure (TR):
1_Electrical safety in Serviceability Limit State (SLS): suitability of protection devices (bypass diodes) and reverse current overload test
Product family (PF):
2_All BIPV families
Reference standards in force in PV and building domain for product qualification/marking:

- CPR 305/2011: applicable harmonized standards
- Directive 2014/35/EU « Low voltage directive » (LVD): EN IEC 61730 series;
  IEC 61730-2: 2016, Cl. 10.19 «Bypass diodes thermal test – MST25”
  IEC 61730-2: 2016, Cl. 10.20 « Reverse current overload test – MST26”
  IEC 62979:2017, “Photovoltaic modules - Bypass diode - Thermal runaway test”
- Additional BIPV standards: EN 50583 part1&2.

The test method according to IEC 61730 will be integrated with the requirements from IEC 62979. The results will be included in the CPR’s specific technical documentation in addition to the other requirements.

Innovation of the new procedure with reference to existing standards:

The new testing procedure will be based on the performance-based approach and introduce combined new test sequences involving electrical safety in the final product conformity assessment. Observation of diodes stress during thermal cycling

Methodology

According to the performance-based approach, the Serviceability Limit State (SLS) related to the suitability of protection devices (bypass diodes) and reverse current overload test will be defined. Since the expected increase of bypass diodes’ stress in BIPV and in non-conventional scenarios due to increasing shading, the test procedures will be developed to assess the adequacy of the thermal design and relative long-term reliability of the bypass diodes used to limit the detrimental effects of module hot-spot susceptibility.

Application

Development of new equipment suitable to coordinate with the thermal cycling in order to perform a comprehensive diode test.

3.3 Mechanical performance

Differently by standard PV modules, where a prescribed value of mechanical action is considered during the qualification tests, the BIPV component should respond to different actions according to the building skin typology and function. Moreover, the addition of the active PV layer to a building component could alter the mechanical resistance values that the same non-active component would have. In presence of a material that performs the PV function (e.g. solar cells within a laminated glass, or a glass-glass module onto a cladding system), also the different operating temperatures could affect mechanical parameters (e.g. resistance, stiffness, safety). The aim of the work is to define procedures to investigate the compatibility of the active electrical parts in the building component, highlighting the effects in terms of mechanical behaviour, providing limits and methods of use.

3.3.1 Combined mechanical and thermal stress for performance assessment of BIPV components/systems in Serviceability Limit State (SLS)

Technical requirement covered by the new procedure (TR):

- Mechanical rigidity and deflection in the Serviceability Limit State (SLS): construction and electrical parts *;
- Electrical safety during the mechanical test *

*in correlation with temperature

Product family (PF):

2_All families – (for each family different tests ca be applicable)

Reference standards in force in PV and building domain for product qualification/marking:

- *CPR 305/2011: applicable harmonized* standards for the product category
- Directive 2014/35/EU « Low voltage directive » (LVD): EN IEC 61730 series.
  IEC 61730-2: 2016, Cl. 10.23 « Static mechanical load test– MST34”
- Additional BIPV standards: EN 50583 part1&2.

Starting from the mechanical construction requirements set by the CPR for the product type, the mechanical test sequence according to IEC 61730 will be modified and extended.

Innovation of the new procedure with reference to existing standards:

This procedure, for a given product category, will define a test methodology/workflow to assess the construction and electrical levels which describe the product integrity in operation conditions (considering the electrical circuits and materials simultaneously) with the application of a mechanical load at different temperature scenarios.

Methodology

According to the performance-based approach, the Serviceability Limit State (SLS) will be defined for the specific product type to describe the behaviour in conditions when a reliable and functional behaviour is ensured for its intended use without damages. Combining the mechanical load with a thermal stress, correlated measures of electrical parameters will be defined as SLS threshold reached by electrical components and circuits, by considering the interaction with construction materials during the test execution.

Application

Some examples can be mechanical load, bending test, lap shear test upgrading with units for electrical/power measurements/assessment and thermal control

3.3.2 Combined mechanical/thermal stress for structural integrity and safety assessment of BIPV elements/systems in Ultimate Limit State (ULS)

Technical requirement covered by the new procedure (TR):

- Structural integrity (mechanical resistance) for Safeguard/Ultimate limit states concerning construction and electrical aspects* (e.g. adhesion);
- Final deflection defining the Safeguard Limit State (SfLS) until the Ultimate Limit State (ULS)*.

*in correlation with temperature

Product family (PF):

2_All families –focus on Glass-glass modules

Reference standards in force in PV and building domain for product qualification/marking:

- CPR 305/2011: applicable harmonized standards and ETAG 002 series.
- ISO 12543-1:2011 "Glass in building — Laminated glass and laminated safety glass" series.
- ISO 1288-3:2016 "Glass in building — Determination of the bending strength of glass — Part 3: Test with specimen supported at two points (four point bending)".
- EN 12600:2002: "Glass in building - Pendulum test - Impact test method and classification for flat glass"
- Directive 2014/35/EU « Low voltage directive » (LVD): EN IEC 61730 series.
- Additional BIPV standards: EN 50583 part1&2.
- NF EN 12179 « Curtain walling — Resistance to wind load — Test method"

Innovation of the new procedure with reference to existing standards:

In general, also destructive mechanical tests such as impact test can be affected by the temperature, e.g. due to the encapsulant properties. As BIPV modules operate at higher temperatures than normal glass, the new testing procedure will introduce combined test sequences involving measurements for structural and electrical safety in the final product conformity for ULS with relevant temperature scenarios.

Methodology

According to the performance-based approach, Safeguard limit state (SfLS) and Ultimate limit state (ULS) will be defined for the specific product type taking into account construction and electrical thresholds and parameters. Combining the mechanical load with a thermal stress, correlated measures of electrical and structural parameters will indicate SLS threshold reached by components and systems (module + structure), in conditions when the product doesn't maintain the initial functionality and safety conditions are no longer guaranteed.

Application

- Upgrading the mechanical tests with units for electrical/power measurements/assessment and thermal control in post-failure conditions

3.4 Fire reaction

Also in fire safety, the combination of building and electric functionalities involves taking into account a new approach for performance interaction, on possible effects combination (links between electrical hazard and fire ignition or promotion). The purpose of this work is to suggest new procedures, adapted to BIPV components under fire reaction standard test and to support the development of BIPV fire performance assessment.

Technical requirement covered by the new procedure (TR):

1_To assess fire reaction of BIPV components taking into account of technical surrounding, integration mode and interaction with other materials >> Fire Rating respective to BIPV solution

2_Evaluate the gap/difference from standard products (without active layer)

Product family (PF):

1-Balustrade; 2-Floor / ceiling; 3-Wall / ventilated façade / cladding; 4-Roof

Reference standards in force in PV and building domain for product qualification/marking:

CPR 305/2011 : no harmonized technical specification are mandatory for Fire resistance

EN 13501 : Part 2 :2016 - Fire classification of construction products and building elements

EN 1364 : Part 1 : 2012 – Fire resistance tests (general requirements)

EN 13823 : 2020 - Reaction to fire tests for building products

XP CEN/TS 1187 : 2014 -Test methods for external fire exposure to roofs

French technical specification 249 (IT 249) of the safety regulation on fire safety in public buildings, LEPIR 2 testing facility - Propagation of fire outside façades for buildings subject to specific regulations

PV requirements included in EN IEC 61730:2018 and EN IEC 61215:2017 as working bases. Specific standards dedicated to BIPV component to assess (floor or wall or roof …) and all relevant standards according to product BIPV family

Innovation of the new procedure with reference to existing standards:

Test procedures are carried on procedure with active elements (with/without electrical load) focused on a specific fire safety test (e.g. SBI), on a specific product category (e.g. façade system) to investigate current missing gaps for describing BIPV fire behaviour due to BIPV critical parts.

Methodology

Identification of BIPV specific features (e.g. high operating temperature, cablings, electric part interaction, additional elements and building configuration) that could drastically influence fire safety.

Test fire resistance and reaction of BIPV components with and without electrical load to assess effect of BIPV features on possible hazard expansion

Identify necessary fire test and combined tests with Energy/Electricity/Mechanical according to BIPV implementation cases to improve assessment of BIPV impact on fire performance

Feedbacks and key points that could affect Fire results with all additional parts (junction boxes, cables, connectors), including also all electrical systems.

Application

Indoor and outdoor standard devices for fire test (Burning brand, horizontal and vertical Furnace, fire spread façade, SBI …) with all building elements and integration mode according to building type. All deviation results compared to conventional building elements will allow to increase the accuracy of assessment and security..

6 CONCLUSIONS

As of today, the current regulatory framework applicable for BIPV mainly gathers a set of norms coming separately from standard PV and traditional "non-active" construction products. However, an assessment of the features, operation and safety conditions to be fulfilled by BIPV systems evidences that such approach is not valid in some cases. The construction of multifunctional BIPV products that can perform different functions, involves more and more the use of several materials that must coexist in the same construction component. These elements, electrically active and non-active, assembled together, mutually induce and influence changes both in the energy performance and in the construction requirements, such as the energy yield, dissipation of heat, the mechanical and fire behaviour, etc. These performance relations have been only partially investigated at the state of art of BIPV quality assessment. Towards the development of new qualification procedures, a first cornerstone is related to the use of a performance-based approach, as it is necessary to overcome the limits of a prescriptive method and to define limit states (LS) including both the PV and the building requirements. Moreover, the introduction of combined stress factors as they occur in real operation scenarios, is a second key-point to better reproduces the environmental conditions, to discover weaknesses, reduce risk for both construction requirements and PV condition. The implementation of such a new approach in different aspects such as energy economy, electrical safety, mechanical and fire safety, as current research in BIPVBOOST project, it is expected to provide evidence of ensuring a higher product quality, streamline the qualification process in a cost-effective way, and provide a pre-normative reference to revamp the standards allowing a BIPV market pull throughout the EU.

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