BIPV TEMP

BUILDING INTEGRATED PHOTOVOLTAICS THERMAL ASPECTS

Annual Report 2009

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ABSTRACT

The influence of temperatures on the electrical characteristics of PV modules and the heat exchange of BiPV modules with the building are not well-known, in fact very few studies have been carried out in order to assess the relation between the PV product and the building element into which it is integrated (insulated, ventilated, materials, colors, etc). Nowadays, there are some standards from the *International Electrotechnical Commission* (IEC) for the tests of the performance of the PV modules in relation to the technology used (crystalline or thin film). However, due to the physical characteristics of the BiPV systems, some thermal and architectural aspects are not considered, particularly when proceedings and measurements deal with complete BiPV elements (PV and building element). To fill this gap, the BIPVTEMP project aims to analyze the thermal and electrical behavior of PV modules and systems suitable for the architectural integration.

Different kind of BiPV modules were selected: insulated PV glass, laminated PV modules for ventilated façades, waterproofing PV membranes, metal sheets with PV modules. In exchange of providing the BiPV modules free of charge, the PV industry will be updated with the analysis effectuated and will profit of all the results achieved. An agreement between ISAAC and the industries will regulate the confidentiality of the results.

A dedicated outdoor stand is now under construction at *ISAAC*. More than half of the structure is reproducing the ambient conditions of a *MINERGIE®* house with insulated PV glass integrated in the façade and roof. These transparent BiPV modules respect the new Swiss energy policy named *MuKEn* (*Mustervorschriften der Kantone im Energiebereich*) and the building law. The other part of the stand will be equipped with BiPV modules installed in a way to reproduce a ventilated façade and with PV modules combined with waterproofing membranes and metal sheets. The modules will be installed on the stand at the beginning of January and will be analyzed throughout the year. The solar gain and heat transfer coefficient of some modules will be analyzed by the *Swiss laboratories for materials testing and research EMPA* in 2011.

Aims of the project

Project importance

PV industries proponing products that can be integrated as building materials represent so far a niche but promising market. In Switzerland, referring to a study of the International Energy Agency (IEA), the potential of PV installed in well-oriented roof and facade in Switzerland represents the 35% of the annual electricity needs [1].

At the moment only a few studies have been carried out in order to assess the interaction between the fastening systems or the building component and the PV modules [2][3][4]. This fact may represent a barrier for the PV industry but also for the building industry who have to gain confidence in these new materials.

Considering that in the near future PV integrated in façades will become financially interesting, this project analyzes several PV elements used as façade components.

Project particularities

The outdoor testing stand is under construction with the indoor conditions of a *MINERGIE®* house. Hence, it has been necessary to implement the standard semi-transparent PV glass integrated vertically and at an angle of about 30°. The PV laminates had to be transformed into a double insulated glasses in order to respect the heat transfer coefficient (U-value) defined by the *MuKEn* [5].

Consequently, the U-value requested for the thermal envelope of the stand are:

- Glass elements: 1.1 W/m^2K
- Windows (glass + frame): 1.3 W/m^2K
- Opaque elements (walls, roof) versus outside: 0.20 W/m^2K
- Opaque elements (floor) versus non heated zone: 0.28 W/m^2K

Taking into consideration that the U value and the solar gain (g-Value) are often unknown and not specified in the datasheet of PV modules, these characteristics will be measured by the *Swiss laboratories for materials testing and research EMPA*.

Considering that the stand will be air-conditioned it was not necessary to plan such an insulated envelope, but the aim of this operation was to highlight the importance of a correct constructive approach when planning or renovating a building. In fact energy efficiency has to be obtained not only with the technical installations but especially with a high performance building envelope.

Objectives of the project

The objectives of this project are:

- **Acquisition of knowledge regarding the temperature effect on the electrical proprieties of BiPV modules;**
- **Estimation of the influence of the different layers (glass, insulating material, metal sheet) and of the inclination (façade, pitch and flat roof);**
- **Measurements of semi-transparent PV module thermal characteristics: g + U value;**
- **Evaluation of standard measurement processes for PV modules and indication of the problems encountered for BiPV products.**
- **Advises for implementing BiPV module the datasheets;**
- **Knowledge sharing with the industry sector;**
- **Knowledge and results diffusion.**

Objectives for 2009

The quantitative objectives for 2009 are:

- **Choice and obtainment of the BiPV modules/systems (negotiation with PV industries)**
- **Design and building of the testing outdoor stand**
- **Definition of the measurements**
- **Adaptation of the outdoor stand from EMPA**
- **Inspection and actuation of the outdoor stand**
- **Installation of the modules on the outdoor stand**

All the objectives should be reached before January 2010. PV industries delivery of BiPV modules and weather conditions (snow fall) can delay the actuation of the stand.
The measurements within EMPA will be postponed at the beginning of 2011 because of:

- Number of shipment between Lugano and Dübendorf
- Cost of the shipments
- Continuance of the measurements on the outdoor stand

Works carried out and results achieved

Choice and obtainment of the BiPV modules/systems

About twenty BiPV Modules/systems were selected considering the technologies and typologies more adapted for building integration (see Table 1). For the insulated systems, mainly amorphous silicon modules where chosen because of their prospective good electrical behavior in conditions of high temperature (see annealing effect). For the see-through applications, opaque crystalline silicon cells with an adjustable spacing or amorphous silicon modules partially transparent where selected. For flat roof applications, flexible amorphous silicon PV modules were preferred in combination with different roofing membrane types or metal sheets.

The main issue was to find PV producers able to provide not only PV laminates but also insulated PV double glass.

In order to transform the modules into insulated double glass, a collaboration with the company *Verres Industriels* (VIM) in Moutier were initiated. To provide PV modules able to be transformed in double glass, it was asked (dedicated meeting) the PV industry to produce special PV modules with the junction box located on the edge of the panel. A meeting and visit at the *VIM* company was arranged to organize and define the PV module transformation. It was the company *Galvolux* from Ticino that suggested to contact VIM.

Micromorph PV modules, commonly opaque, were expressly made transparent for this project.

It was decided that the project partner of this project would be *Galvolux* and *Verres industriels*.

The only modules that were bought where those of Sunpower, all the other companies agreed to freely collaborate in exchange of a certain extent of confidentiality in case of bad results.

Technologies	Transparency	Position	Typologies and composition
Micromorph	Transparent	Façade	Laminated insulating safety glass module VSG Ug = 1.1W/(m²K)
Micromorph	Transparent	Pitched Roof	Laminated insulating safety glass module for overhead glazing VSG Ug = 1.1W/(m²K)
a-Si, 1j	Transparent	Façade	Laminated insulating safety glass module VSG Ug = 1.1W/(m²K)
a-Si, 1j	Transparent	Pitched Roof	Laminated insulating safety glass module for overhead glazing VSG Ug = 1.1W/(m²K)
mc-Si	Opaque	Ventilated Facade	VSG Laminated safety glass module
mc-Si	Partially	Façade	Laminated insulating safety glass module VSG Ug = 1.1W/(m²K)
mc-Si	Partially	Pitched Roof	Laminated insulating safety glass module for overhead glazing VSG Ug = 1.1W/(m²K)
a-Si, 2j	Transparent	Facade	Laminated insulating safety glass module VSG Ug = 1.1W/(m²K)
a-Si, 2j	Transparent	Pitched Roof	Laminated insulating safety glass module for overhead glazing VSG Ug = 1.1W/(m²K)
a-Si, 2j	Opaque	Ventilated Facade	VSG Laminated safety glass module
a-Si, 2j	Transparent	Facade	Laminated insulating safety glass module VSG Ug = 1.1W/(m²K)
a-Si, 2j	Transparent	Pitched roof	Laminated insulating safety glass module for overhead glazing VSG Ug = 1.1W/(m²K)
a-Si, 2j	Opaque	Ventilated Facade	VSG Laminated safety glass module
sc-Si, back contact design, black sheet	Opaque	Pitched roof	Tedlar-backsheet module
sc-Si back contact design, white sheet	Opaque	Pitched roof	Tedlar-backsheet module
a-Si, 1j	Opaque	Flat Roof	Black Waterproofing membrane
a-Si, 1j	Opaque	Flat Roof	White Waterproofing membrane
a-Si, 1j	Opaque	Flat Roof	Black galvanized steel plate
a-Si, 1j	Opaque	Flat Roof	White galvanized steel plate
a-Si, 1j	Opaque	Flat Roof	Copper sheet
a-Si, 1j	Opaque	Flat Roof	Aluminum sheet

a-Si, 1j	Opaque	Flat Roof	To be defined
a-Si, 1j	Opaque	Flat Roof	To be defined

a-Si: amorphous silicon technologies
1j: single junction
2j: double junction
mc-Si: multicrystalline
sc-Si: monocrystalline
VSG module: Laminated insulating safety glass module

Table 1: list of bipv modules and systems

Design and realization of the testing outdoor stand

The outdoor stand was designed in order to encompass different inclinations (vertical, tilted and horizontal). More than half of the stand was planned as a *MINERGIE®* structure. The other part of the structure represents a ventilated façade and roof. To simulate the conditions found in this kind of "ventilated stratigraphy", a OSB board will be placed at 6 cm distance from the PV laminates. While the flexible thin-film modules will be horizontally installed and laid down onto different kind of waterproofing membranes and metal sheets. See Fig.1 and 2

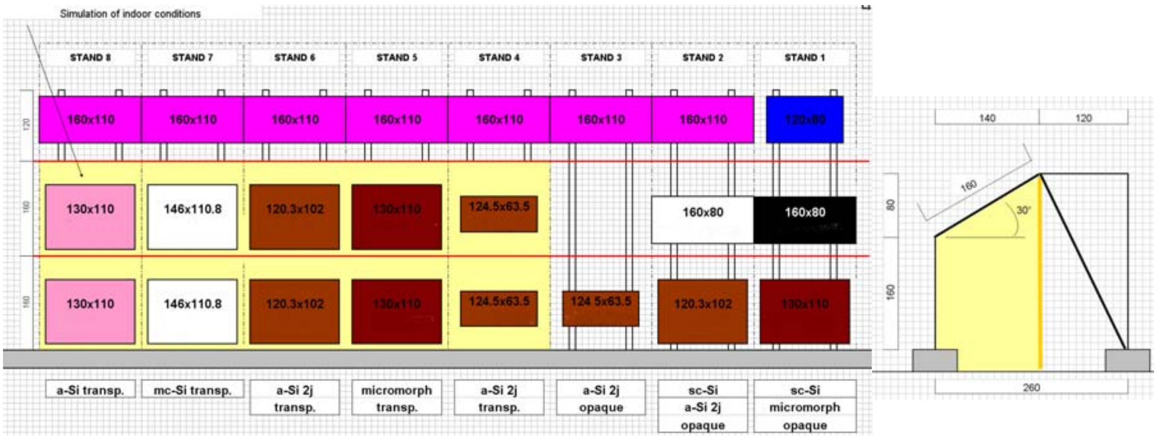

Fig. 1: Scheme of the outdoor stand of the BIPVTEMP project and section

Fig. 2: Work in progress: exterior

Fig.3: Work in progress: interior

Definition of the measurements

The data that will be measured and studied during next year (2010) will be the maximum and minimum temperatures, daily and monthly temperature, final yield, power losses. The annealing effect of amorphous silicon modules will also be studied.

24 MPPT (maximum power point tracker) were realized by ISAAC especially for this project.

Adaptation of the outdoor stand from *EMPA*

During a meeting at *EMPA* with Mr. Manz, Mr. Binder, Mr. Vonbank and Mr. Carl, the project was presented and the requests measurements explained. After this meeting, for practical and economical reason (see chapter objectives for 2009), it was planned to postpone the measurements to 2011.

Installation of the modules on the outdoor stand & Inspection and actuation of the outdoor stand

Planned between December 2009 and the beginning of January 2010.

National and international collaborations

- Verres industriels, Moutier
  Danilo Pirotta director, Bernard Cuttat R&D engineer, Pierre Stettler sales manager
- Galvolux, Bioggio
  Marco Jelmini director
- Swiss laboratories for materials testing and research EMPA, Dübendorf
  Heinrich Manz Head of solar energy group, Bruno Binder, Mr. Vonbank and Stephan Carl
- Various PV producers

2009 Evaluation and future prospects for 2010

The collaborations were really fruitful. An highlight was the interaction between PV industries and the glass industry, a crucial point when producing insulating double PV glass. The interest in finding possibilities of collaboration between the industries was significant.

The PV industries were really keen to collaborate in this project providing PV modules. In fact hey consider really interesting and useful the innovative outdoor stand.

The main problem was that not all PV producers could provide insulated double glass, it was consequently necessary to request the collaboration of a glass transformer industry.

The delay of about one month will not affect the project as the measurement will be from January 2010 to January 2011. Afterwards, some PV modules will be sent to EMPA in order to make the measurement of the g and U value from February 2011 to May-June 2011 (depending of the sun conditions). The end of the project is planned for the 1st July 2011.

References

[1] M. Gutschner: **Potential for building integrated photovoltaics**, IEA, PVPS, Task7 – 04, 2002, http://www.iea-pvps.org.

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[3] T. Nordmann: **Understanding temperature effects on PV system performance**, IEA, PVPS, Task 2 – 03, 2003, http://www.iea-pvps.org.

[4] J.J. Bloem: **The new JRC installation for outdoor testing of BiPV systems**, 16EUPVSEC, 2000.

[5] **Mustervorschriften der Kantone im Energiebereich MuKEn**, Konferenz Kantonaler Energiedirektoren, Lindenquai/Hinterm Bach 6, 7002 Chur, http://www.endk.ch/muken.html