Actual Temperatures of Building Integrated PV Modules

Study in the framework of the EU IP Performance project
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Introduction

During the Cross Fertilization Workshop on the 24th of June 2008 the question came up which level of temperatures can be expected in the practice of building integrated PV (BIPV) modules integrated or retrofitted to the building. This information is needed to define the set points for the temperatures during ageing tests of the modules. Because SP6 concerns the building integration aspect of PV systems, the sub project group is asked to make a short literary study of measurements that are performed in practice to gain insight in the occurring temperature of the various building assembly methods. This short study gives an overview of the available figures found on this aspect and gives a indication of PV module temperatures occurring in practical situations.

Various methods of assembly

For the study the following most occurring building assembly methods are taken in account:

1) **PV modules directly fixed on an insulated underground.**
   The PV modules are not ventilated at all at the backside e.g. flex PV directly fixed on roof covering or to the façade.

Figure: Flex PV on the flat roof of a building in Lugano/Switzerland [1]

2) **PV modules installed above or between roof tiles of pitched roofs**
   The PV modules are installed above or instead of the tiles with a small air gap in between. In this way the backside of the modules can be low or moderately ventilated.

Figure: PV modules installed between the tiles (left) and above the tiles (right)

3) **PV modules free mounted on a open rack**
PV modules are installed on an open rack construction on a flat roof or to a façade

Figure: PV modules mounted on an open rack contruction on a flat roof

A quick scan research

In order to gather the needed information in a practical way, a quick scan has been made under various experts and available conference papers of suitable projects *(see References*). As a result of this research some useful information came available. Especially the IEA/Task 2 paper *"Understanding temperature effects on PV System Performance"* [2] turned out to be very informative.

Results

The results of this study are laid down in the table *'Overview of Actual Temperatures of BIPV'*. In this table the annual (day) average temperatures and the maximum temperatures of the PV modules can be found.

It is clear that the way of installing the PV modules on the building has a large influence on the occurring temperatures in practice. The main reason for this is that the level of ventilation of backside of the PV modules largely determines the module temperature.

Here a short summary is given of the results for the various assembly groups:

PV modules directly fixed on an insulated underground: In this situation (mostly flexible) modules are directly fixed on the (insulated) roof covering underneath. The ventilation beneath the roof covering is nearly zero. The maximum measured temperature is 85^{o}C at a surrounding temperature of 30^{o}C (Stadelhofen). In case the ambient temperature would have been higher (like at the CPT plant of SUPSI), the module temperature could be even 90^{o}C or more. The average (daytime) temperature of the module is circa 45-50^{o}C.

PV modules installed above or between roof tiles of pitched roofs: In this installation method the temperatures are substantial lower than in the previous situation because the modules are low till moderately ventilated. The maximum measured temperature is 70^{o}C (Hiroshima) at a surrounding temperature of 39^{o}C. The average (daytime) temperature lies between 30 and 40^{o}C (excluding 1 extreme low temperature of 20^{o}C, measured at the Wildkogelbahn project).

PV modules free mounted on a open rack on the roof: In a free standing and open rack construction on a flat roof the PV modules are nearly maximally ventilated. So, this results in the lowest module temperatures of the various mounting systems. The maximal measured temperature is 64°C. The average temperature (daylight) temperature lies between 30 and 35°C.

Table: Overview Actual Temperature of BIPV

Country	Location	Assembly method	Tilt	Module temperature		
				average	maximum	max. 40°C ambient
			°	°C	°C	°C 1)
Not Ventilated *(direct fixed on the roof of façade)*						
Switzerland	Lugano	Fixed on roof material	3	45	80	85
Switzerland	Stadelhofen	Fixed on roof material	5	51	85	95
Netherlands	Petten	add-on to façade	38	-	2)	80
Low-Moderately Ventilated *(PV module installed in or add-on the roof)*						
Austria	Becker	Fixed on/in the roof	30	37	64	74
Italy	Bologna	Fixed on/in the roof	24	38	61	63
Austria	Buchinger	Fixed on/in the roof	26	29	57	60
Japan	Hiroshima	Fixed on/in the roof	19	41	70	71
Austria	Wildkogelbahn	Fixed on/in the roof	26	20	48	62
Netherlands	Petten	Fixed on/in the roof	10	-	2)	63
Maximum Ventilated *(PV module installed with open rack support on a flat roof or facade)*						
Italy	Bolzano	Open rack on flat roof	40	34	58	67
Austria	Laus	Open rack on flat roof	39	35	64	65
Switzerland	Marzil	Open rack on flat roof	35	34	55	65
Switzerland	Muttenz	Open rack on flat roof	45	31	58	65
Switzerland	Stadtmuehle	Open rack on flat roof	25	31	61	68
Netherlands	Petten	Open rack to façade	18	-	2)	52
Note:	1) Measured maximum temperature linear converted to 40 °C ambient temperature					

Besides the ventilation level the real temperature of the PV module depends also on the ambient temperature. The relation between this parameters and the module temperature is nearly linear [4]. In order to get a real maximum temperature in the practice the maximum temperature levels are therefore linear converted to an ambient temperature of 40°C (which could be reached during summer months in some parts of Southern Europe). It is clear that in the tropics, especially arid zones as deserts (e.g. Sahara), the ambient temperatures can even be higher than 40°C, thus also the maximum temperatures.

The actual temperature levels that can occur in practice are summarized in the following table *General Overview of the BIPV temperature levels.*

Table: General Overview of the BIPV temperature levels

Ventilation level	***PV module temperatures (^{o}C)***	
	Maximum [1)]	Average
Not ventilated	80-95	45-50
Low-Moderately ventilated	60-75	35-40
Free ventilated	50-65	30-35

1) Based on a maximum ambient temperature of 40 ^{o}C

The temperature level influences not only the ageing of the used material of the module but also the yield of the PV-systems: depending on the level of ventilation, yield losses of a PV system can vary from 2% (free standing) till 11% (no ventilation).

Conclusion

In general it can be concluded that the used building mounting method of BIPV largely determines the amount of back ventilation and thus largely affects the occurring average and maximum temperatures of BIPV modules.
Maximum occurring temperatures, found in this study and based on a maximum ambient temperature of 40 ^{o}C, range from 50^{o}C to 65^{o}C for free installed systems, from 60^{o}C to 75^{o}C for add-on or building integrated systems and from 80^{o}C to 95^{o}C for directly fixed to the roof modules. These temperatures could be reached in some parts of Southern Europe. In areas with ambient temperatures higher than 40^{o}C, like in tropical areas, the maximum temperatures can even be higher.

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References

[1] Losses and gains of thermally insulated horizontal a-Si PV modules, I. Pola etc., ISAAC-TISO/SUPSI, Lugano, Switzerland

[2] Understanding temperature effects on PV systems performance, Thomas Nordman Consulting AG, Erlenbach, Switzerland

[3] Performance of the PV-systems of ECN Building 31, N. van der Borg, M. Jansen, ECN, Petten

[4] Based on measurements of CREST during the IP-Performance project