

Temperature Effect on the Power Drop in Building-Integrated Photovoltaic Module

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ABSTRACT: The market for building-integrated photovoltaic (BIPV) system is growing rapidly because PV system offers considerable scope for energy demand offsets and reduction of greenhouse gas emissions. The mounting technique of sloped roof PV is that an air gap exists between the rear of the module and the roof, providing a cooling effect. On the other hand, the integration technique of sloped roof PV is that additional cost of building material can cut down but no air gap exists. Therefore cooling device need to reduce the heat build-up behind the PV module. The aim of this paper is performance analysis of building-integrated photovoltaic module according to temperature by computer simulation and experiment. The module temperature of no free ventilated PV system is higher than free ventilated PV system about 13.4°C. By the results on simulation, the reduction of electrical power loss is 9.57% into cold facade according to free ventilation. The annual averaged PR of BIPV system into free ventilated is about 73.1%.

Keywords: BIPV (Building-integrated photovoltaic), performance analysis

1. INTRODUCTION

It is well-known that most of the solar radiation absorbed by photovoltaic (PV) module is not converted to electricity but contributes to increase the temperature of the module, thus reducing the electrical efficiency. PV can be used today in different ways on both existing and new buildings. The integration of PV technology into roofs of houses is an approach that is being championed in Germany, Japan and Korea

etc. In the Korea, PV roofing systems already are given the large number of houses which are projected to be built by 2012. It is also important to consider building integrated PV (BIPV) as an integral part of the environmental systems of a building if the application of BIPV is to be successful, because just applying PV onto already designed building envelope, and treating the PV system as an element as if independent from the building, will not enable optimum performance.

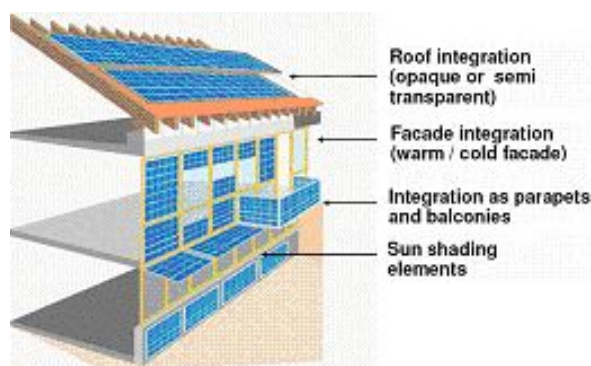


Figure 1: BIPV integration.

The situation is not improving, despite the fact that improved technologies and stricter building codes are making buildings more energy efficient. Their total number is increasing, and they use more equipment and have higher comfort requirements than they ever did before.

BIPV is the only high quality (electricity) renewable energy source possible in an urban environment, where an ever-increasing share of our total energy consumption is taking place. However many PV systems are not installed in suitable part that is concerned about geometrical factor. It is generally recognized that the actual output of PV system in field is a function of orientation, tilt angle, irradiance, wind speed, air temperature, soiling and various system-related losses. Especially BIPV system must consider increasing the temperature of the PV module during generation because of efficiency loss and thermal environment of indoors.

2. EFFECT OF TEMPERATUR

Measurement of NOCT for PV modules applied as BIPV components are of most interest as the negative temperature effect on the maximum power is about $0.5\%/^{\circ}\text{C}$ (referred to conditions at 25°C).

Fig. 2 shows the effects of temperature on the I-V curve of a PV cell. Short circuit current (I_{SC}) increases slightly with temperature, this is so small that it is

normally ignored. However, a more significant effect is the temperature dependence of voltage which decreases with increasing temperature.

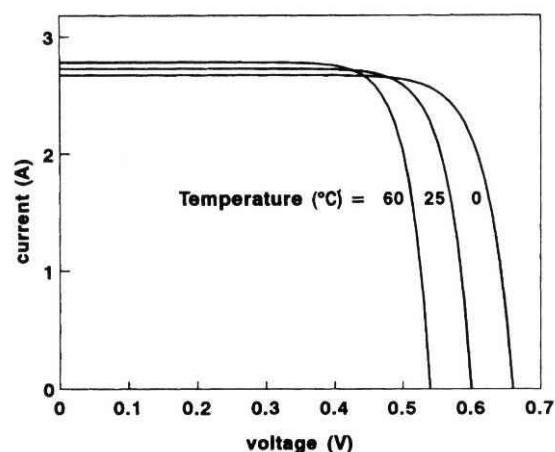


Figure 2: Temperature effects on the I-V curve of a PV cell.

The Building designer are interested in performance under operating conditions for a typical climate, season and specific location taking into account the energy use of their design. Integration of PV in the building envelope implies that they not only have to take into account electrical energy production, but also thermal and comfort aspects. Extreme temperature can also damage PV modules. Since the PV arrays are exposed to direct sunlight, there is a natural tendency to create heat. A well-designed PV array installation should include provisions for venting the array back surface to remove this heat. PV cell temperatures should ideally be kept below 70°C . As a European rule of thumb, the following losses (%) may occur with façade-mounted systems:

- No air gap: 10% loss
- 5cm air gap: 5% loss
- 15cm air gap: minimal loss from temperature effects.

3. PERFORMANC ANALYSIS

3.1 Experimental method

The slop angle and azimuth angle of Experimental building of Korea institute of energy research (KIER) is each 90 degree and 15 degree. T-type thermal sensors have been attached on module because sensors could not integrate into the module during its manufacturing. The temperature data and Electrical power are collected and recorded every minute. The specification of PV module and Power condition system (PCS) is shown in Table I , II .

Table I: module spec. and array component

Module spec		Array component	
Pmax [W]	50.0	Cell type	Mono c-Si
Voc [V]	21.6	Cell size [mm]	103*103
Isc [A]	3.2	Module size[mm]	617*1075*9.5
Vmp [V]	16.95	Modules	22
Imp [A]	2.95	Module connection	11(s)*2(p)

Table II : PCS spec.

DC	
Max operating voltage	300V
Operating voltage range	150~300V
Nominal operating voltage	180V
Max input current	6.7A
Max temperature range	-25~+60°C
AC	
Nominal operating voltage	230V
Nominal operating frequency	60 Hz
Nominal output power	850W
Max output power	900W
Max output current	4.5A RMS

3.2 Estimated method

The electrical power available from a PV device can be modeled with the well known equivalent circuit shown Fig.3. This circuit includes a series resistance and diode in parallel with a shunt resistance. This circuit can be used either for an individual cell, for a module consisting of several cells, or for an array consisting of several modules.

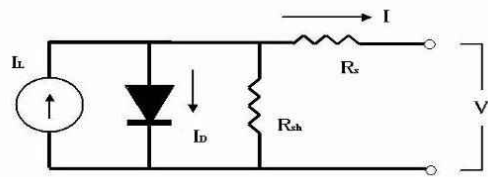


Figure 3: Equivalent circuit representing the five-parameter model

The current-voltage relationship at a fixed cell temperature and solar radiation for the circuit in Fig 3 is expressed in Eq. (1).

$$I = I_L - I_O \left(\exp \frac{V + IR_s}{V_t} - 1 \right) - \frac{V + IR_s}{R_p} \quad (1)$$

where, I_L , I_O , R_s and R_p are the photon-generated current, the dark current, the series resistance and the parallel resistance, respectively. The voltage V_t equals mkT/e ($m=1$, $V_t \approx 25\text{mV}$ at 300K).

$$I = I_{SC} \left[1 - \exp \left(\frac{V - V_{OC} + IR_s}{V_t} \right) \right] \quad (2)$$

The Eq. (2) is expressed in Eq.(2) by the following assumptions:

-the effect of parallel resistance is negligible.

-the photo-generated current and the short-circuit current are equal.

- $\exp(V + IR_s)/V_t) \gg 1$ under all working condition.

3.2 Result

To compare the difference between measured and estimated temperature is shown in Fig. 4. The pattern of estimated

temperature is similar to measured temperature during a day. The averaged temperature difference is about 2.4 °C. BIPV module is influenced by indoor temperature as well as ambient temperature. Fig. 5 shows temperature of PV module according to outdoor and indoor temperature. The averaged temperature difference is about 13.4 °C.

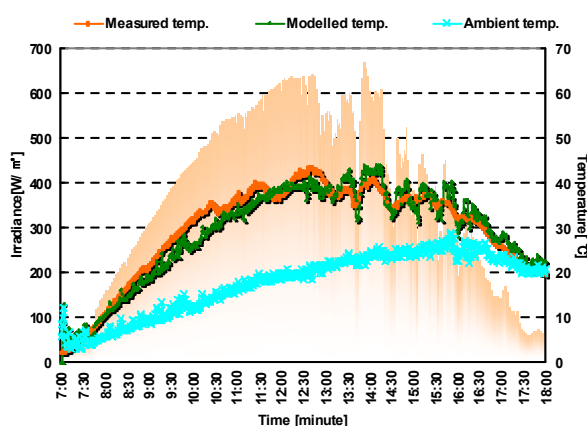


Figure 4: Comparison of measured and estimated PV module temperature

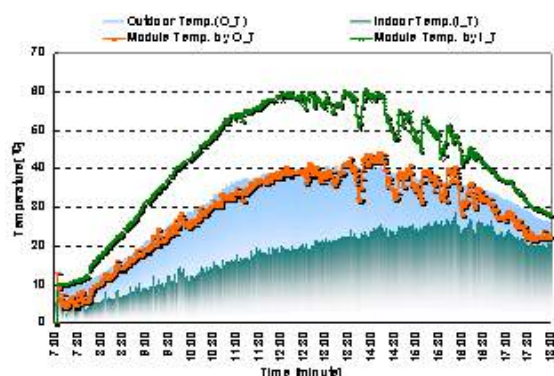


Figure 5: Comparison of PV module temperature according to thermal stress

To compare the difference between measured and estimated PV array electrical power (DC) is shown in Fig. 6. The pattern of estimated electrical power is similar to measured electrical power according to solar radiation level. The averaged difference of power which influence by ambient temperature is about 21 watt. The averaged difference of estimated power which

influence by each ambient and indoor temperature is about 35.1 watt.

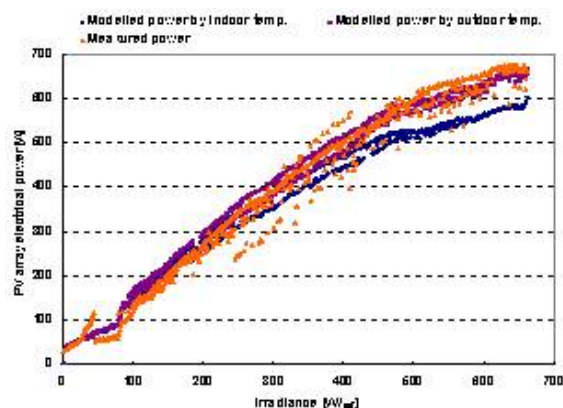


Figure 6: Comparison of PV array electrical power according to solar radiation

5. CONCLUSION

Photovoltaic modules must withstand high and low temperature, rain, ice and UV-light. PV module need to be resistant enough to these stress factors to maintain their electrical power at a steady level for at least 20~30 years. Thus this study presents the drop of PV electrical power in BIPV module according thermal stress. By the result, the module temperature of no free ventilated PV system is higher than free ventilated PV system about 13.4°C. By the results on simulation, the reduction of electrical power loss is 9.57% into cold facade according to free ventilation. The annual averaged PR of BIPV system into free ventilated is about 73.1%.

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