

The Analysis of Reduction in Cooling Load by Sun shade BIPV System

- Focusing on the load caused by solar radiation -

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ABSTRACT: As the number of buildings that use the transparent permeation materials as the outer wall increased resulting in coming amount of light rays, the increase in the cooling load and the amount of radiant heat may cause discomfort to the residents. In order to reduce such effect, the installation effects of roof BIPV were to be analyzed. The temperature in the room where sun shade BIPV system was not installed and the temperature in the room where sun shade BIPV system was installed were measured and compared, and the effect of reducing the cooling load by the incoming light rays in the two rooms was compared and analyzed.

The sample space of the third floor of the engineering and science building of S university in which sun shade BIPV system is installed has two rooms of the same condition, and for five sunny days selected in August, we measured the air temperature and the temperature of the fittings by closing the windows to minimize the movement of air without operating the coolers.

In the room where sun shade BIPV system was installed, the maximum cooling load by the incoming light rays was measured as 745.46kcal/h, and it can be attributed as the effect of reducing the cooling load by the incoming rays of the room with sun shade BIPV system installed in it. Even though the effect of cooling load reduction is not that great in a room, the total reduction in cooling room for 32 rooms where sun shade BIPV system is installed was estimated to be 23,854.72kcal/h which will reduce the investment cost significantly due to the reduction in cooling load when initially designing the building and attain the maximum reduction effect of 27.725kW in energy

Keywords: BIPV, sun shade, solar radiation, cooling load, renewable energy

1. INTRODUCTION

1.1 Background and Purpose of this Study
International oil price that was hovering around 20\$ or less per barrel in 2002 has skyrocketed to reach 122\$ in May 2008, and it is expected to reach the range of 150\$ to 200\$ per barrel within two years. Korea imports 97% or more of energy from overseas that it is likely to encounter the troubled time for energy in the future.

For relieving such a difficulty, Korea has implemented the 'Act to Promote New and Recycled Energy Development, Use and Dispersion' for the expansion of use of new and recycled energy and the promotion of technical development. Accordingly, in the construction field, the obligatory use of new and recycled energy on new buildings of public institution has been systemized, and the government has set the goal to expand the ratio of new and reproduced energy supply that had been at 3% of the primary energy in 2006 to 5% by 2011.

Under such a situation, as a part of pilot dispersion project of new and recycled energy, 25.2 kW p-level of sun shade BIPV facilities have been installed on the southern wall of the Engineering building of S University in December 2006, and it has monitored the electric current yield for a year from January to December 2007.

Large glass external wall of the contemporary architecture works not only to increase with excessive cooling load with the excessive solar radiation introduction for each season but also as a cause to stimulate the unpleasant feeling to tenant by the radiant heat of high temperature as well. Accordingly, it offers the strength to generate the electricity while relieving these problems through the sun shade BIPV installed on the southern external wall.

Therefore, under this study, the purpose is to compare and analyze the impact on the savings effect for cooling load in the room by solar radiation and analyze the sun shade effect of the BIPV established.

1.2 Scope and Method of Study

The following is the measurement method to have the basis for measurement and comparison for indoor temperature of same size and condition both areas with BIPV system and without system in third floor in the subject building.

The use of the two rooms was a research room for faculty and an office for faculty, and the window was closed while the air conditioner was not operated to minimize the mobility of air circulation, and the external atmospheric temperature and indoor dry temperature were measured for one hour interval from 10 am to 4 pm. Thereafter, the effect of the sun shade BIPV device was analyzed through the mutual comparison of the measured data.

2. SUBJECT SUN SHADE BIPV SYSTEM

2.1 Summary of Installation

The subject building built with the BIPV is in the "L" -shaped style and there is no question that there is a need of sun-shade device to cut off the sun during the summer for the front side of the building and south side with the lecture hall. The building structure has the steel concrete frame with red block finish. Here, the sun shape is planned and built only on the southern external wall, and the configuration of the installed system-linked BIPV system is shown on Table 1.

Table I: System configuration

sorting	standards	quantity	capacity	remarks
PV modules	135Wp	187EA	25.2kWp	
inverter	32kVA	1EA	32kVA	Grid connected
Junction box	25kVA	1EA	25kVA	
monitoring	-	1 set	-	PC 1 set
construction		1 set		

2.2 Installation Requirement

2.2. 1 Requirement of subject building

The subject building is a building with 5-story on the ground and single underground floor. The building is built on the site with approximately 20m interval and approximately 10m for 5-story dormitory (h=15m) building in the front, and has the distribution of needle trees of 5 ~ 6m in between buildings. The first floor of the subject building has the shade by these two categories that the sun shade BIPV system was installed from the second floor.

The direction of the array is in the southern direction (10 degree of southeast) by the existing directions of the building with the inclined angles of horizontal side and 68°. In general, the incline angle of the array would be the optimal to have 30° for the power generation efficiency, but looking at the size of module, when designing for 30°, it has displayed some problems of lack of harmony for buildings that it extruded too much on the external walls of buildings and have structural difficulty and others.

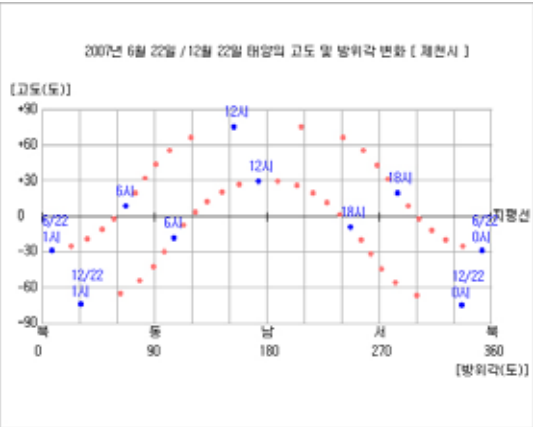


Figure 1: Solar altitude and azimuth of J city

Figure 1 are the graphs showing of solar altitude for each time set of the summer solstice and the winter solstice of the J City region with the solar altitude of the summer solstice for 74.57° and the winter solstice for 29.08° .

Figure 2 displays the location with the shades generated from the elevation of the sun by the sun shade BIPV device installed

in the summer solstice and the winter solstice of the J City region.

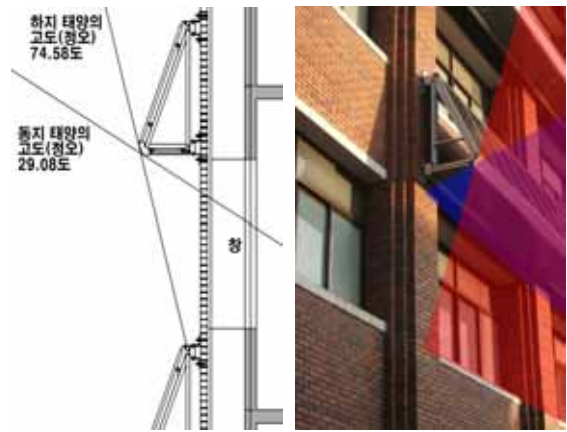


Figure 1: Sunning protection effect by BIPV

2.2.2 Sunning protection effect with that façade fastened system

This is the method of applying the sun shade BIPV on the existing building, not the new building, that the steel support is attached to this building to attach it to the structure. Most of faculty room for faculty and office for department have large cooling load with the influence of summer solar radiation that such an expected effect thereto for installing the sun shade BIPV would be expected, and Table 2 depicts the appearance of the subject building before and after installation.

Table II: overview of the subject building, before and after

before		
after		

When attaching to the wall of the PV module, the cooling load by the solar radiation is considered to shield cut off the impact of solar radiation coming from the

window with the elevation of the sun is cut off in summer while having no problem to attract the solar radiation inside in winter, and the shade in up and down of sun shade module has to be excluded. By considering and designing of such conditions, the solar radiation following the sun elevation at the summer solstice and the winter solstice may be appropriately cut off and adjusted.

As shown on Figure 2, the shade is made from cutting off the light by the sun shade BIPV that the cooling load is reduced by the solar radiation during summer, and it does not interfere in coming of solar radiation inside the room in winter to have the structure without problem in using the passive of solar heat and lighting in the room.

3. ANALYSIS OF VOLUME OF POWER GENERATED FROM SUN SHADE BIPV

The installed sun shade BIPV began its power generation from the middle of December 2006 for electricity production, and after approximately 1 year and 5 months, there are accumulated power generation volumes of approximately 40,000kWp, daily average power generation for approximately 75kWp, and power generation time of approximately 3 hours.

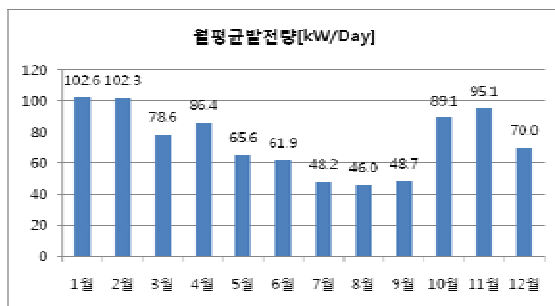


Figure 2: monthly average values of the electric current yield in 2007

Figure 3 is the result of analysis of data generated from January 2007 to December 2007. Looking at the graph, the peak of power generation was shown from

November to February and this is attributable to have the installation angle of the sun shade BIPV for 68° with the solar elevation and module in winter to come close to vertical angle, and the reason for having low power generation in March, July, August, September and December was analyzed as having reduced daily illumination from rainfall and snowfall in the region.

Table 3 is the comparison of the previous global solar radiation for each region, and according to the Table, the global solar radiation was shown to be much higher than other regions, and this would have the positive impact to the volume of generation.

Table III: The comparison of the global solar radiation in different cities

sorting	MJ/m ²
Seoul	11.35
Daejeon	12.85
Kwangju	12.93
Wonju	15.38
Jecheon	20.61
Chungju	21.59

4. MEASUREMENT OF INDOOR TEMPERATURE FOLLOWING THE PRESENCE OF SUN SHADE BIPV

4.1 Summary and Method of Measurement

The measurement was implemented for five days by selecting fine days in August for the room installed with the sun shade BIPV of subject building and un-installed room with the same condition.

Table IV: The excerpt of the measured area

Use	Office
Room size	3,880 mm×7,250 mm×2,750 mm
Ceiling height	3,800 mm
Thickness (external wall)	750 mm
Electrical devices	Fluorescent lamp 32W 6 EA
Window size	3,000 mm×1,870 mm

The measurement method was measured for external temperature and fitting temperature by using the Thermo Recorder TR-71U for one-hour interval from 10 am to 4 pm by minimizing the movement of air by closing the window and not operating the cooling device.

The measurement location was set for 2m (A) and 4m (B) of distance from the window for two rooms as shown on Diagram 6 and 1m height from the floor to install two Thermo Recorder for each room, and the measurement was made when there was no human traffic by using the digital data thermal recorder.

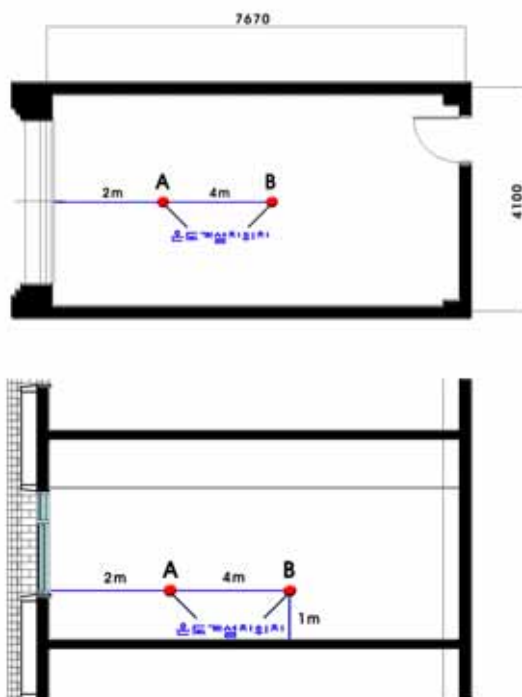


Figure 3: The measurement location, ground plan (above) and section (down)

4.2 Result of measurement

The measurement done with the above-described Thermo Recorder TR-71U for one hour interval from 10 am to 4 pm for five days selected as clear days in August 2007 was shown as follows. The external atmospheric temperature at this time used the data of the regional meteorological office.

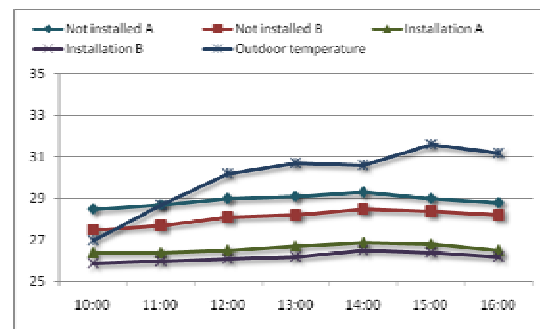


Figure 5: Measuring data of the interior and outside temperature on 16 August

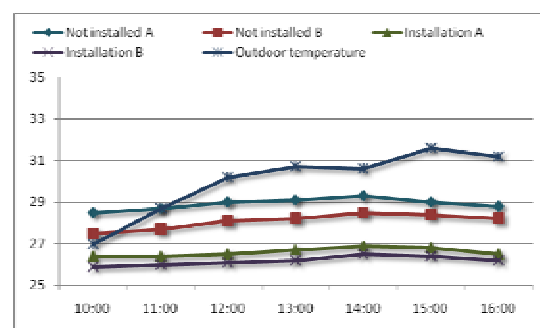


Figure 6: Measuring data of the interior and outside temperature on 17 August

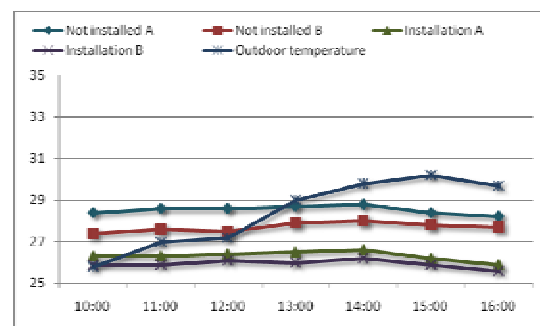


Figure 7: Measuring data of the interior and outside temperature on 23 August

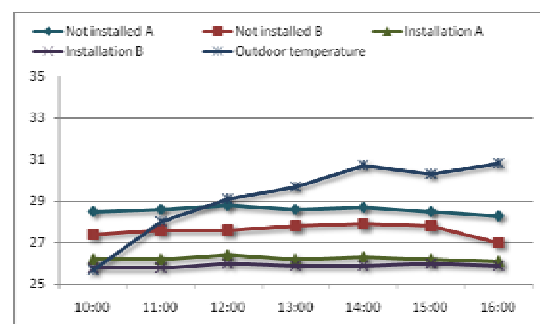


Figure 8: Measuring data of the interior and outside temperature on 24 August

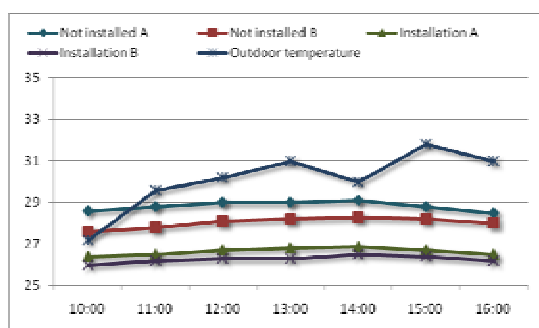


Figure 9: Measuring data of the interior and outside temperature on 25 August

Comparing the two same rooms through measurement, the temperature difference of Location A that was 2m apart from the window displayed approximately 2.3°C in un-installed room than the installed room, and approximately 1.8°C of difference for Location B, respectively, and the temperature difference of Location A and Location B of the un-installed room was approximately 0.85°C, and the installed room with approximately 0.37°C of difference.

The temperature difference for each location of each room may have the impact of the surface temperature and the external temperature of the window for Location A with the close distance to the window, and Location B with some distance thereto would be considered to confirm with the temperature difference for each actual location with the increasing effect by the solar radiation.

5. ANALYSIS OF EFFECT OF SAVING THE COOLING LOAD

The cooling load implicates the energy required to maintain the pleasant condition at the time of cooling in the building. Calculating the cooling load would be most fundamental and important during the process of the air conditioner design. Through the load calculation, the capacity of equipment required in air conditioning

facilities such as, air conditioner, freezer and others.

Such a calculation is referred to as the maximum load calculation for designing and this method is mainly used at this time.

The types of cooling load include the solar radiation load of the window, the heat transmission load of the external building, gap wind load, indoor thermal load, and external atmospheric load. In this experiment, two same rooms were measured with the same load requirements except the window solar radiation load, and the calculation was made through the method of Form 1 and conditions of building with the load differed from the presence of the sun shade device.

The solar radiation volume entered into the room through the window has great difference for each time along with the direction of the room. In the event of the eastern direction, it has the largest around 8 ~ 10 in the morning, and the western direction with 4~6 in the afternoon, and the solar radiation volume following the time period with each room to display differently. The solar radiation load from the window may be calculated with the following formula.

$$q_G = I_G \times A_G \times k_s \quad (1)$$

q_G : Solar radiation load from window (kcal/h)

I_G : Standard acquisition of solar radiation by window (kcal/m² h)

A_G : Window size (m²)

k_s : Shielding coefficient

In theory, the building facing the south would have the greatest detainment of standard solar radiation on the gloss at around one pm with the acquired energy volume of 151 kcal/m² h and screening factor of 0.88 that it calculated the cooling load on the solar radiation of window in the building based on the time with greatest cooling load during a day.

The maximum cooling load by the solar radiation for the room without the sun shade BIPV is calculated with approximately 745.46 kcal/h, however, in the event that the sun shade BIPV is available, there is no impact on load by the solar radiation that it has the reduction effect for that much of cooling load. The reduction effect of the cooling load on a room would not be considered as significant, but when calculating entire 32 rooms with the sun shade BIPV for the subject building, the reduction effect of the cooling load would be 23,854.72 kcal /h, resulting of up to 27.725kW of energy.

6. CONCLUSION

The accumulated power generation data of the sun shade BIPV for one year was analyzed and the indoor fitting temperature and external atmospheric temperature following the presence of the sun-shade device were measured. Based on this measured data, the following outcome was obtained through the analysis of the savings effect of the cooling load.

In analyzing the power generation data for a year, the daily average power generation would be approximately 75kWp, power generation time of approximately 3 hours with relatively fine power generation efficiency. The installation angle of the sun shade BIPV is approximately 68° to display the peak value of power generation during November to February that has the solar incidence angle close to vertical angle. The indoor temperature difference following the installation of the sun shade device was measured with approximately 2.1°C of average temperature difference in the installed room compared to the un-installed of the building, gap wind load, indoor thermal load, and external atmospheric load. This is attributable to have the cooling load difference by the solar radiation, and the difference of the cooling load may be

formulated through Form 1. The solar radiation load for each room was calculated, and the reduced volume of the cooling load for entire 32 rooms with the sun shade BIPV was shown for 27.725kW.

In the meantime, the acquired volume of energy from the sun shade BIPV system of one year was approximately 28,000kWh.

The meaning of reduction in the cooling load for a building is that the operating hour of the machine is reduced, and by using the electricity generated and produced at the peak time, the energy use could be appropriated to save the energy on the existing building, and following the reduction of load in new buildings, it would have the positive effect to have the cost savings of construction with the reduction of energy and equipment volume decline.

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