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Available remodeling simulation for a BIPV as a shading device

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ABSTRACT

A building integrated photovoltaic system as a shading device is used as an application and remodeling model. This study applies the simulation program SOLCEL and the computational fluid dynamics method to cases with solar irradiance components analysis and a ventilated double façade remodeling of the BIPV. For the validation of the theoretical work, experimental results of the Samsung Institute of Engineering and Construction Company building are used with a wind velocity of the weather data of Suwon area, Korea, where the real building is located. A photovoltaic system can be used only to generate electricity, but if a photovoltaic module can be used as an element of a double envelope, it could be more useful at the point of view of renewable energy usage and night insulation. Increase of PV module surface temperature is negative for power generation by installing PV module as an element of double envelope. A reasonable combination between renewable energy usage and power generation should be well analyzed for better usage of natural energy to design a BIPV.

1. Introduction

Many different arts of solar cells and application methods for photovoltaic system have been developed, such as crystalline solar cells, thin-film solar cells and Building Integrated Photovoltaic (BIPV) as a window, shading systems, double facade, etc. Important points are not only the efficiency of the solar cell panel itself but also effective applications under different conditions of buildings to reduce heating and cooling load. In this work a BIPV of Samsung Institute of Engineering and Construction Company (SIECT) as a shading device is used as an application and remodeling model. This study applies the simulation program SOLCEL [1] and the computational fluid dynamics (CFD) method [2,4] to cases with solar irradiance components analysis of the BIPV and a ventilated double façade remodeling of the BIPV.

2. Solar components and remodeling simulation for the BIPV

2.1. Solar components

The influence of the angle of the solar cell panel, albedo and building azimuth, and solar cell panels under shading on the power generation is mainly theoretically studied in an earlier paper [1]. For the validation of the theoretical work, experimental results of the Samsung Institute of Engineering and Construction Company (SIECT) building are used with a wind velocity of the weather data of Suwon area, Korea, where the real building is located. The simulation tool SOLCEL is used to simulate solar components and power generation analysis of the BIPV.

Fig. 1 shows an overview (left one of Fig.1) of the SIECT building and solar radiation incidence processes (right one of Fig.1) reaching the solar cell panel of the building façade.

The BIPV cells have been mounted with an inclination of 35° to the vertical wall on each floor (South façade) of a building with 6 floors near Suwon city (latitude: 37.28 N, longitude: 126.58 E), South Korea [5]. Characteristic of the solar cell panel is semi-transparent. The detailed data for PV cells are shown in Table 1.

For the relevant analysis of remodeling of BIPV, one day was selected. The day is a typical winter day (February 17). The global solar irradiances on a horizontal surface, air temperature and surface temperature of PV modules were measured. From the global solar irradiance, beam and diffuse components of solar radiation were derived according to the diffuse ratio as a function of hourly clearness index [3]. For the simulation, the weather data of Suwon, where the building is located, were used for wind speed for convection heat transfer coefficient calculation, because wind speed had not been measured, but the measured global solar irradiance and air temperature were used for comparison of experiment and simulation. The total area of the solar cell panels is 342 m^2 (Sum of 6 Floor, TPA). Fig. 2 shows the experimental and simulation results of the cell surface temperature and the power generation for February 17.

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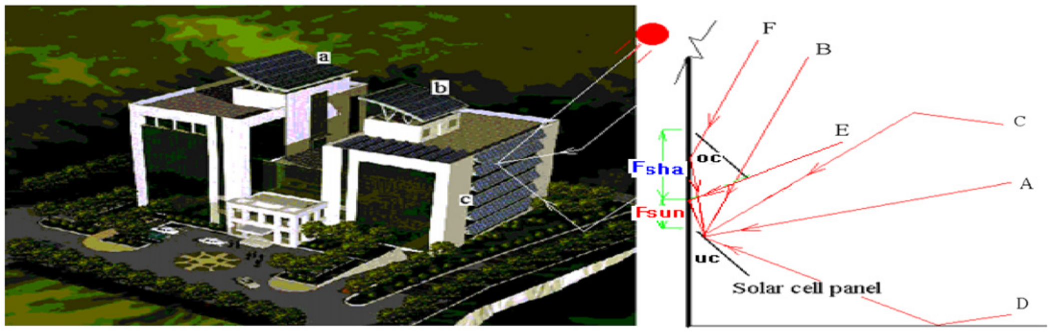

Fig. 1. Overview and solar radiation incidence processes reaching the solar cell panel.

Table 1
Technical data of PV cell unit for the simulation.

Unit dimension	2.47 × 1.17 m	Mpp current	3.04 A
Weight	93 kg	No. of cells per unit	230
STC power (STCWP)	345 W	Cell type	Mono
Standard efficiency	14.4%	No. of total units	114
Coverage ratio of cell	85%	Transmittance of glass area in solar cell panel (2 panes of glass)	0.75 (0.92 × 0.82)
Length × width(PV panel)	2.47m × 22.98 m	Absorption coefficient of PV cell	0.9

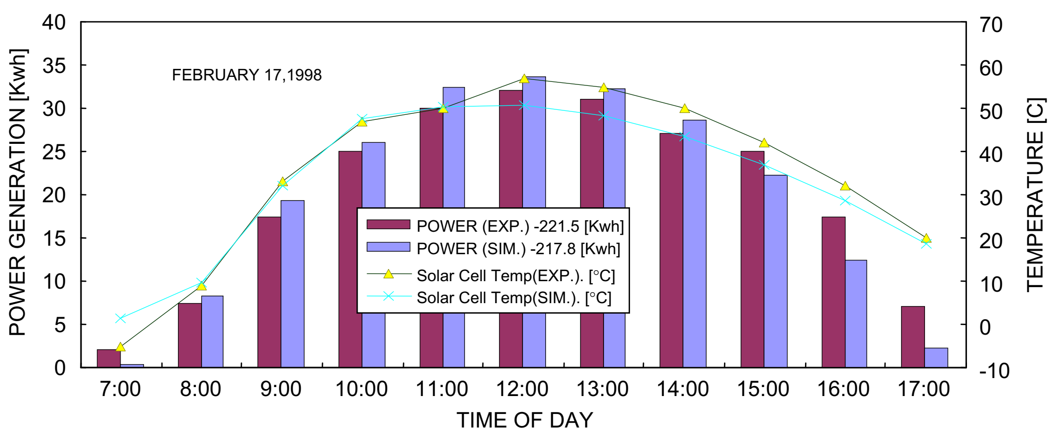

Fig. 2. Power generation and surface temperature on a winter day (February 17, experiment+simulation)

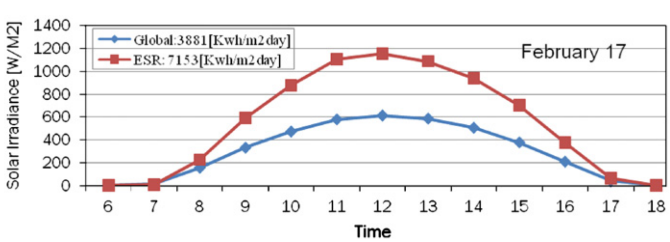

Fig. 3. ESR and global solar irradiance on a winter sunny day (February 17).

The simulation results for power generation have a good agreement of 98% with the experimental results, but the simulation and experimental results for over surface temperature of solar cell panel is a little bit different, as the solar irradiances become higher. This derives from the fact that the measurement point for the cell surface is directly exposed to the sun, but the simulation was made under the condition where the average value of solar radiation for the whole solar cell panel is used. Fig. 3 shows the simulation results of effective solar irradiance (ESR) for the BIPV (simulation) and global solar irradiance (experiment) on a horizontal surface for February 17.

The effective solar irradiance (ESR) is much more than the global irradiance on a winter sunny day. This is caused by various reflected components (*A*–*F* in Fig. 1). Fig. 4 shows the simulation results of arts of solar radiation incidence components.

Each component of solar irradiance on PV module is very different from *A* to *G*. The largest two components are *A* (55%) and *F* (22.5%) on February 17. The other components are as follows: *C* (13%), *D* (7.3%), *G* (1.1%), *E* (0.5%), and *B* (0%)

2.2. Remodeling simulation for the BIPV as a shading device

A BIPV system of the SIECT building was theoretically remodeled by glass cover, which could be used as a ventilated double envelope system with a passive solar concept. The remodeled double envelope BIPV system is simulated by CFD. In the commercial CFD code used [4], the LVEL k–ε turbulence model [6] was chosen for all simulations and the default turbulence model constants applied. Simulation time for boundary condition

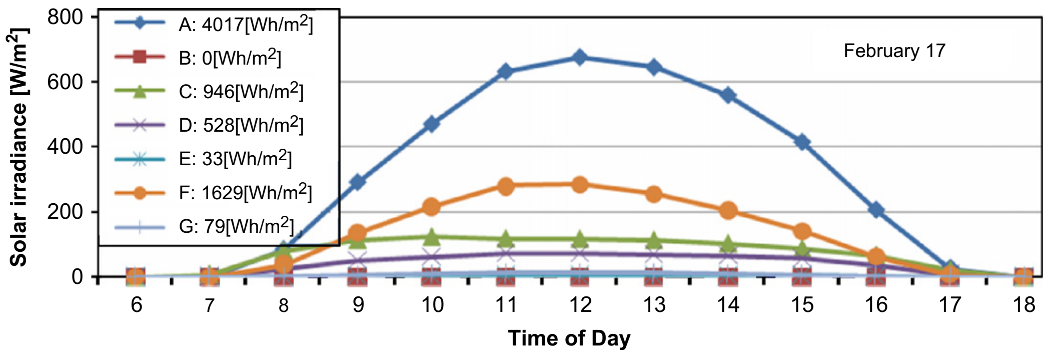

Fig. 4. Amount of solar radiation incidence components on module.

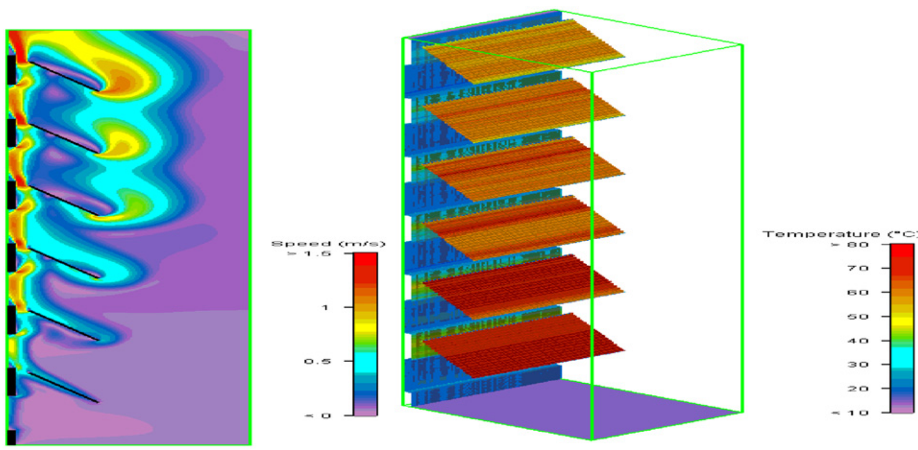

Fig. 5. CFD simulation result for BIPV of the SIECT (air velocity and surface temperature around BIPV).

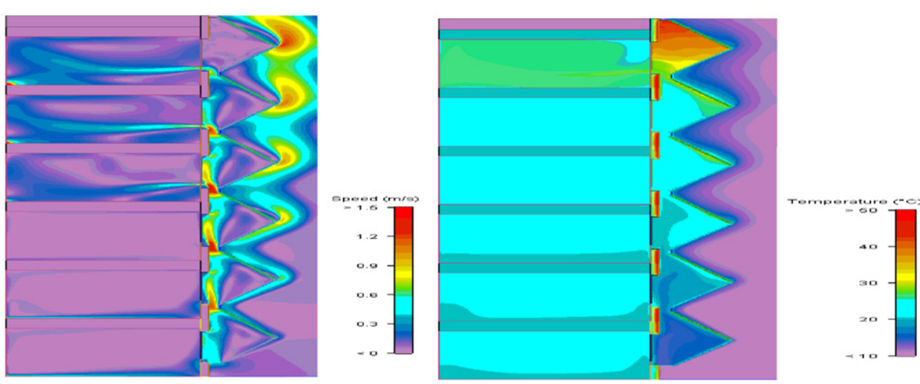

Fig. 6. CFD simulation result remodeled by glass double envelope (air velocity and air temperature).

is 12:00 on February 17. Effective solar irradiance is 825 W/m^2. Outdoor air temperature is 10 °C. A heat source for wall, window and panel is 59.4, 9.9 and 643.5 W/m^2, respectively. The CFD model has the solution domain of double envelope BIPV with glass cover, including an empty room ($3.9 \times 4 \times 5$ m^3). There is an opening of 0.3 m height on 1 m from floor. Over surface temperatures of room and earth are 21 and 13 °C, respectively. Fig. 5 shows the sketch of the CFD model for solution domain. The distance between wall and PV module is 0.3 m for good ventilation. Fig. 5 shows the CFD simulation result (air velocity and surface temperature) for BIPV of the SIECT.

Air velocity increases and the surface temperature of PV module decreases as they go to higher floor. This is caused by a cold radiation (difference of view factor between lower module and higher one) between sky and PV module. Fig. 6 shows the CFD simulation result (air velocity and air temperature) for BIPV, which is remodeled by a glass cover. A heat source is the same as the original building of Fig.6 on February 17, 12:00.

Air velocity increases as it goes to higher floor. It enters the adjacent room of PV double envelope. A fast air velocity for a use of heated air to room appears apparently from the fourth floor. The air temperature of the remodeled double façade increases as it goes higher too. This tendency could decrease power generation, but it could give more energy conservation effect.

3. Conclusion

A BIPV as a shading device was analyzed to review the power generation in one day of winter. Many reflected components of solar irradiance give a big influence on the power generation of this kind of BIPV. There are many possibilities to generate electricity by PV modules. A photovoltaic system can be used only to generate electricity, but if a photovoltaic module can be used as an element of a double envelope, it could be more useful at the point of view of renewable energy usage and night insulation. Increase of PV module surface temperature is negative for power generation by installing PV module as an element of double envelope. A reasonable combination between renewable energy usage and power generation or efficiency should be well analyzed for better usage of natural energy to design a BIPV.

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