Study on Lighting -Heating-Electricity Coupled Energy Saving Potential for STPV Window in Southwest China

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Abstract: Building integrated photovoltaic (BIPV) is an important application of solar cells. In this paper, the experiments were conducted to test the performance of photovoltaic panels installed in buildings. The experiments were carried out in Chengdu, Southwest China which located in climate zone of hot summer and cold winter. The real-time power generation, the simultaneous generation of heat and the impact on indoor lighting are important factors for building energy consumption. Two identical rooms were built up as experimental units, and one of which was fitted with amorphous silicon PV windows, and another was fitted with conventical window. According to the test results, it can be seen that, the PV film windows could save the 30% building load on typical sunny days, and provide additional 0.41 kWh/per day.

Key words: BIPV, PV film window, Power generation, Heating load, Lighting load

1.Introduction

PV used to meet the demand for electricity has been widely recognized. It is a key development direction in the energy field in China's 13th Five-Year Plan. The application of PV technology in the construction field is particularly important. The current building energy consumption accounts around 30% of the total energy consumption [1]-[3]. The research and development of BIPV application could improve living standards with the villages and towns in Southwest China.

In recent years, the attention of many researchers has been attracted by the semi-transparent PV (STPV) windows, and which can not only generate electricity, but also reduce cooling and heating loads. P. W. Wong et al [4] studied STPV as the roof of residential applications. The experimental results show that

PV roof can save indoor energy consumption. Wei Liao et al [5] compares amorphous silicon glass with traditional glass in different buildings. Considered the influence of building conditions, it was showed in the experiment that STPV windows are more advantageous than traditional glass windows.
For the energy consumption of STPV windows, Tin-Tai Chow et al [6] built an experimental system for a typical office environment in Hong Kong. It was showed in the test results that the innovative natural ventilation photovoltaic double glazing can significantly reduce indoor energy consumption by 28%. Wei He et al [7] compared the performance of single-layer PV windows and double-layer PV windows in Hefei, China. Based on the test result, double glaze PV has the better thermal comfort. Peng et al [8-9] set up the experimental units in Hong Kong to test the heating performance of STPV windows in winter. The simulation model set up by Peng [10] for an optimized double- PV window shows that the annual power output can be doubled even with ventilation.
Vartiainen et al. [11] found that the solar panel coverage of solar cells increased, and the annual average DA of buildings increased significantly. For dynamic lighting indicators (UDI), the improvement was not significant. Olivieri et al. [12] studied the relationship between photovoltaic cell transmittance and building interior lighting by establishing an ideal model. The results show that when the transmittance of STPV windows is reduced from 40% to 10%, the indoor lighting coefficient is gradually reduced, but the uniformity of illumination is improved.

According to the previous study, it was shown that STPV windows can reduce building load significantly. However, the comprehensive energy saving potential for STPV window in southwest china has not yet been evaluated. This article is aimed to evaluate the lighting heating-electricity coupled energy saving of film STPV windows. It would contribute to develop clean energy, reduce carbon emissions, promote green building development in
Southwest China.

2 Experimental methods

2.1 Parameters of PV module

The double-layer STPV window was designed and produced by our research team and the Hanergy Company. The film PV module is amorphous silicon. It has the advantages of low light absorption and better performance.

The double-skin STPV window consists of one layer of single STPV windows, and one layer of conventional window with a vacuum air layer. The key characteristics of the PV module are shown in Table 1.

Table 1. Parameters of PV module

PV type scribed semi-transparent module light transmittance	20%
Material	a-SiGe
Maximum power under STC (W)	50

Photoelectric conversion rate	6.7%

2.2Test rig

To test the performance of the double-skin STPV window, a test rig was built in Sichuan University is shown in the Fig.1. The test rig included two identical test units, which is 3m(depth)×3m(width)×3m(height), and the 75 mm thick sandwich rock wool board has been used as the materials of wall and roof to meet the requirement of the thermal insulation. The windows are installed on the south facing wall.

Measurement instruments of the test rig are shown in Fig. 1, the wireless daylighting illuminance sensors were used to measure the daylighting illuminance on the working surface. The experimental data except electrical parameters were collected by wireless Multi-channel data recorder with a sampling interval of 1 min. For the indoor energy consumption, STPV windows not only generate electric, but also have influence on the indoor light environment and thermal environment. To comprehensive analyze the indoor energy consumption, the power consumption of indoor air-conditioner and lighting have been collected by the electric quantity recorder.

Fig 1. Test rig and measurement instruments

3. Experimental results and analysis

Experiments were conducted to test the heating energy consumption and lighting load of two units different working conditions in cloudy and sunny days from March to April.

3.1 Heating Load test

It is showed in the experiment that the power consumption of the test unit is more than that of the comparison unit when it is sunny. Because the shading of solar radiation by the STPV window increase the air conditioning load of the unit. The power consumption of air conditioners in two units is shown in the Fig. 2. On sunny days, the average power consumption of the test unit and contrast unit is 70W and 49W. On cloudy days, the average power consumption of the test unit and contrast unit is 206W and 219W, have almost the same amount of electricity.

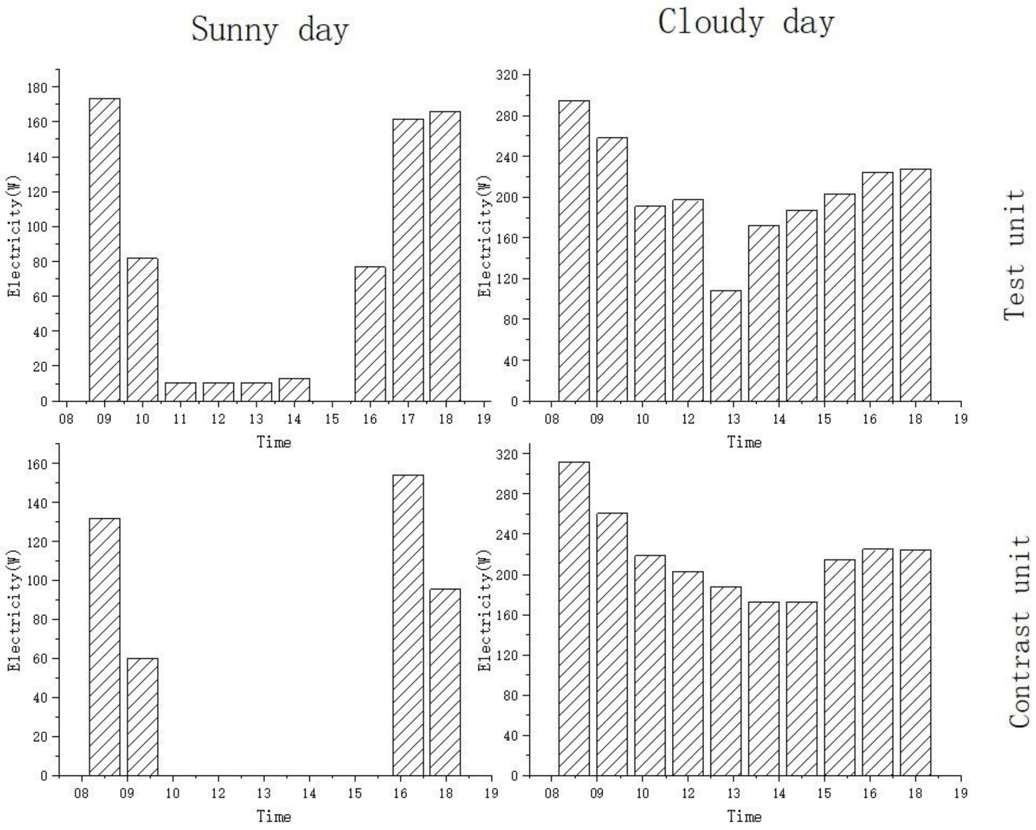

Fig 2 Electricity for air-conditioner

It shows that when the STPV windows were used in winter hot summer and cold winter, the air conditioning energy consumption is more in the experimental unit than that in the comparison unit.

3.2 lighting load test

Compared with the experiment tests of the daily lighting, indoor lighting would be reduced due to the shading of STPV windows. When the illuminance does not meet 300lx, the lighting is turned on automatically, and the electric power meter is used to record the electricity consumption of the lighting. As can be found in the experiment, in the sunny days, STPV windows would not affect indoor lighting, and the average illuminance reaches 1583 lx. In cloudy days, the light intensity is not high, and the average illuminance in the room is only 208 lx. Therefore, when the light intensity is insufficient, electric light lighting needs to be turned on. The Fig. 3 shows the consumption of lighting load in cloudy days.

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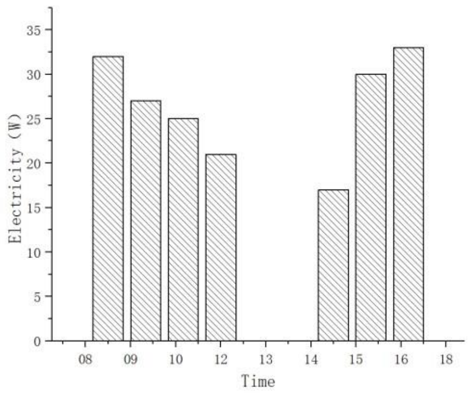

Fig 3 Electricity for lighting

3.3 Building load Analysis

In sunny days, the electricity generation of PV windows can reach 50W, and the power generation can have an income of around 0.41 kWh a day. The energy saving of experimental units will be better than cloudy days. The lighting in the unit will not be affected by PV windows. Natural lighting can fully meet the needs of indoor lighting. In cloudy days, there is little power generation, and the indoor lighting is affected by PV windows. Lighting is required to be turned on throughout the day.

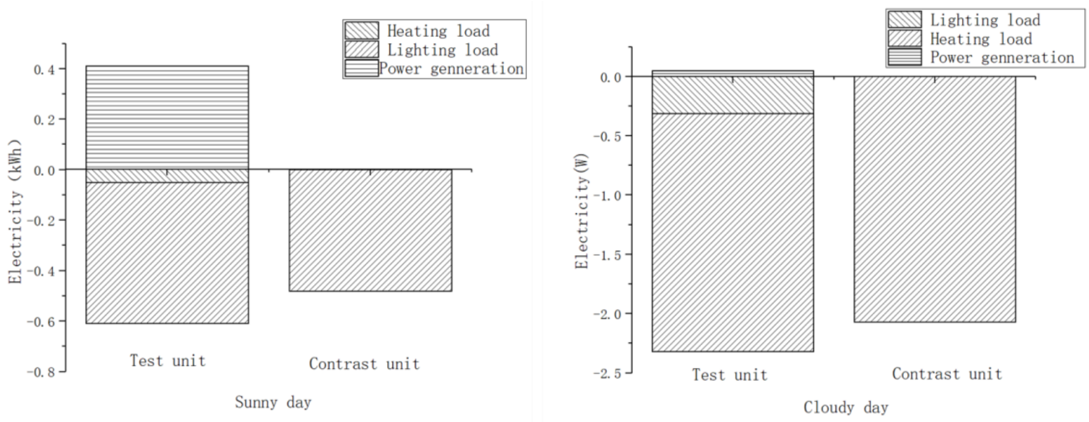

Fig 4 Overall power consumption of two units

4 Conclusion

The current work has studied the application potential of solar film windows in Southwest China, including the impact on daylighting and indoor heating loads. The results show that it has a high potential for application.

In sunny days, the power consumption of the experimental unit is more than that of the comparison unit, and the STPV windows can generate electricity, which can make up for the lighting electricity consumption in the unit. According to the test results, it can be seen that, the PV film windows could save the 30% building load on typical sunny days, and provide additional 0.41 kWh/per day.

In cloudy days, the test unit and the comparison unit have the same power consumption of airconditioner. Due to the sunshade of photovoltaic windows, the test unit needs to turn on the lighting, and the consumption is 0.24 kWh.

In breve, the use of photovoltaic windows can reduce indoor energy consumption by 30%. In cloudy days, indoor lighting will be affected. The a- SiGe is absent on conversion efficiency, and silicon which has higher conversion efficiency could be chosen in the PV windows in the future.

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