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An Experimental Study on the Characteristics of Electrical Power Generation Using a-Si Thin-Film PV Module in Self-Shading Buildings

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Abstract

In this study, I have performed a quantitative performance evaluation of the electrical power generation with a-Si thin-film PV module as influenced by self-shading buildings (the length of protrusion from walls) and shadow angle, with a view to applying a-SI thin-film PV windows system in collective housing. The study has found out that when the protruded length increases by 50mm from 0mm to 250mm, power generation efficiency decreases to the range between 97.1% and 88.1%, as compared to power output for the module (with a protruded length of 0mm), which is designed not to throw shadow on the module surface. Also, in case shadow is created so that the angle created by the arrangement of PV cells and the shadow is flat, generation efficiency decreased at a steady rate of about 16% as compared to the power output from the module (with a shadow ratio of 0%), which is designed to obviate shadow as the shadow ratio increases by 10% between 0% and 30%. On the other hand, in case a shadow creates a right angle with the arranged PL cells, generation performance is greatly lowered with generation efficiency diminishing from 88.6% to 12.7% when compared to the power output from the module (with a

shadow ratio of 0%), which is designed to obviate shadow as the shadow ratio increases between 0% and 30%.

Keywords: Photovoltaic Windows System, Amorphous Module, Self-Shading, Shading angle, Generation Characteristic, Apartment

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1 Introduction

a-Si thin-film PV cell (amorphous) has flexibility, which is peculiar to its material, and can be applied to buildings in various forms, and as it has transparency that lets light pass through evenly, can be used for windows system [1]. However, as the structure has a number of cells connected in series in a single module, the shadow that can occur on the surface of a PV module (shadow ratio) and shadow angle (the angle created between the arrangement of a PV cell and shadow) become the factors that can most directly influence the lowering of performance for a photovoltaic system[2][3][4][5]. So, we need a quantitative evaluation that reflects such characteristics.

Thus, in this study, I am going to perform a quantitative evaluation of the influence exerted on the power generation performance from the self-shading that can occur from protrusion of walls from a building and the shadow angle, in case a windows system that adopts a-Si thin-film PV module is applied to collective housing, which is Korea' s major residential building. Also, I will establish basic data to optimize the design of a-Si thin-film PV windows system for collective housing.

2 Methodology

In order to evaluate the influence exerted on power generation performance by the self-shading caused by the length of protrusion from building walls and its characteristics, I chose a location free from sun shadow created by neighboring buildings (E127.63°, N37.27°) to create a mock-up so that windows point to south [6][7][8][9].

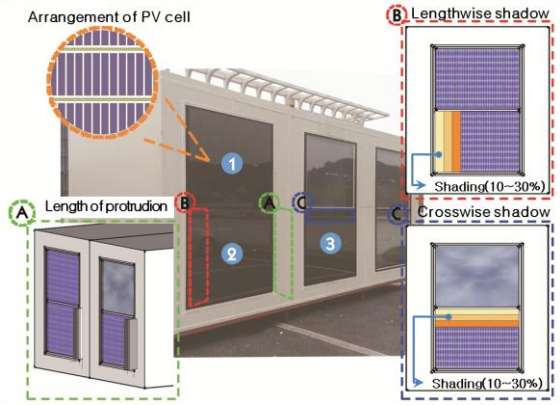
For architectural design for where windows were going to be installed in 22 compounds of collective housing (with total 206 buildings) designed by a public institution (Korea Housing Corporation) that supervises the construction of collective housing in Korea, the length of walls around windows as against the thickness of a structure was figured out as 0mm-250mm. With this, I have collected data for hour-by-hour insolation and power output during winter (Feb. 9 through Feb. 28, 2015), using the following variables.

First, basic characteristics of wintertime power generation were analyzed, using the module (①) that was designed to prevent occurrence of shadow on its surface.

Second, in order to measure changes in power output due to self-shading that can occur from varying length of protrusion from wall, power output was measured by subcategorizing the length of protrusion (0, 50, 100, 150, 200, and 250mm). With the protrusion pointed to south, the power output was analyzed for the time slot from 7 a.m. to noon when self-shading occurs[10].

Third, in order to analyze the characteristics of electric power generation with regard to shadow angle, a sunshade was used to measure the power output under the influence of the shadow (C: crosswise shadow) that is at a right angle to the shadow (B: lengthwise shadow) which is at a flat angle ti PV cells. Power output was analyzed with the ratio of area shaded by a sunshield varying from 10% to 20% and 30%.

Variable conditions and analysis method applied in this study are shown in Figure 1 below.



Applied variables
A. Length of protrusion - 0~250mm(50mm, 100mm, 150mm, 200mm, 250mm) - Installed to east of module
B. Shadow angle (lengthwise shadow) - Shadow abreast with PV Cell C. Shadow angle (crosswise shadow) - Shadow at a right angle to PV Cell => Shaded area ratio(10%, 20%, 30%)
・①: Measurement of basic power output (control group) ・②, ③: Application of variables (experimental group)

Fig 1. Applied variable conditions (length of protrusion and shadow angle) and analysis method

3 Results of Analysis

3.1 Basic Power Output

The ordinary basic power output and insolation for the module (①) that was measured so as to prevent occurrence of shadow on its surface during winter (Feb. 9 through Feb. 28, 2015) are shown in Figure 2.

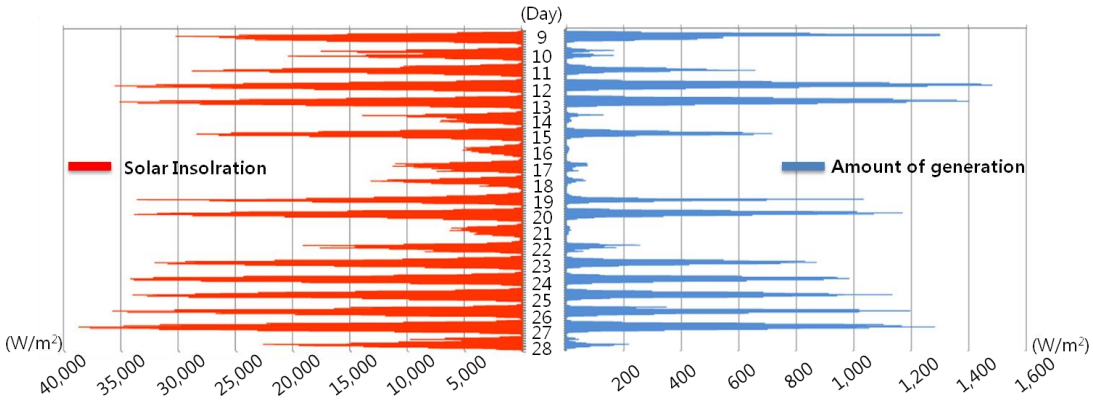


Fig 2. Basic power output and insolation

The measurement of insolation and power output showed that the total power output during the specific period was 61,700.0 W/m^2 and the hourly average was 237.7 W/ m^2. Maximum hourly power output was 1,484.8 W/m2, with wintertime power generation efficiency being 4.2% as compared to insolation (35,597.8 W/ m^2).

The analysis of the hour-by-hour power output showed that the time slot from 10 a.m. to 2 p.m. accounted for minimum 80% of daily power output.

3.2 Characteristics of Electric Power Generation according to Variables (Length of Protrusion, Shadow Angle)

(1) Characteristics of Electric Power Generation with Varying Length of Protrusion

During winter (Feb. 8 through Feb. 17, 2015), length of protrusion was increased by 50mm. Power output A for all five lengths of protrusion (50mm, 100mm, 150mm, 200mm, and 250mm) was compared with basic power output ① which was designed to prevent occurrence of shadow on the module surface, as shown in Figure 3.

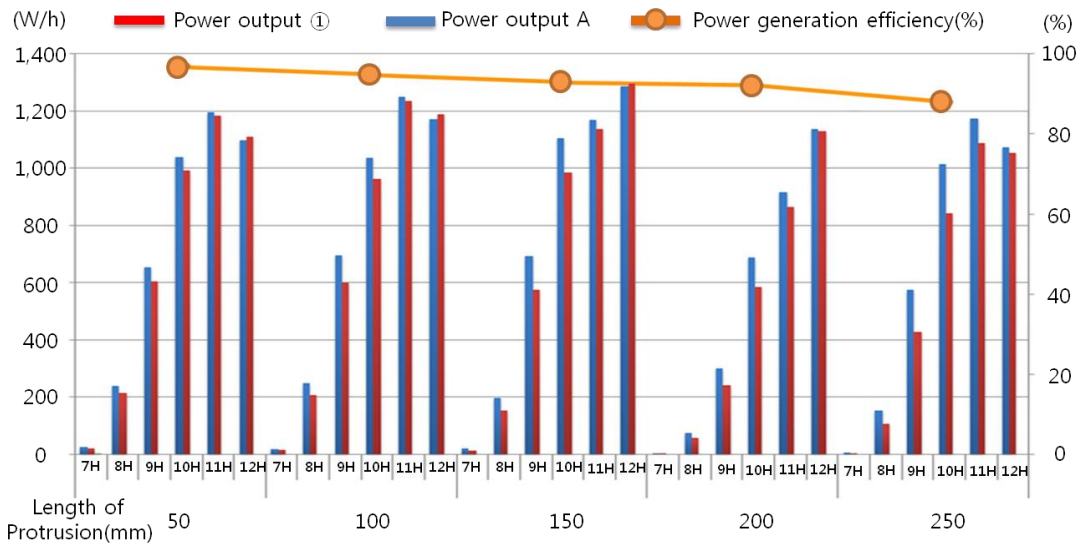


Fig 3. Comparison of power outputs according to varying length of protrusion

The analysis of power output according to varying length of protrusion showed that with length of protrusion increasing from 50mm to 100mm, 150mm, 200mm, and 250mm, power generation efficiency as compared to basic power output ① decreased in the order of 97.1%, 95.1%, 93.1%, 92.4%, and 88.1%. Especially, the analysis showed that power generation decrease according to increasing length of protrusion reached the maximum of 6.3%, as the length of protrusion increased from 200mm to 250mm.

(2) Power output according to shadow angle

In order to measure the power output according to shadow angle during winter (Feb. 18 through 28, 2015), I have measured the power output as affected by the shadow (power output C: crosswise shadow) that comes at a right angle to the shadow (power output B: lengthwise shadow) which comes abreast with PV cell. Here, shaded area ratio as against the module area was varied to 10%, 20%, and 30%. All six measurements of power output were compared with basic power output ① that was designed to prevent occurrence of shadow on the module surface, as shown in Figure 4.

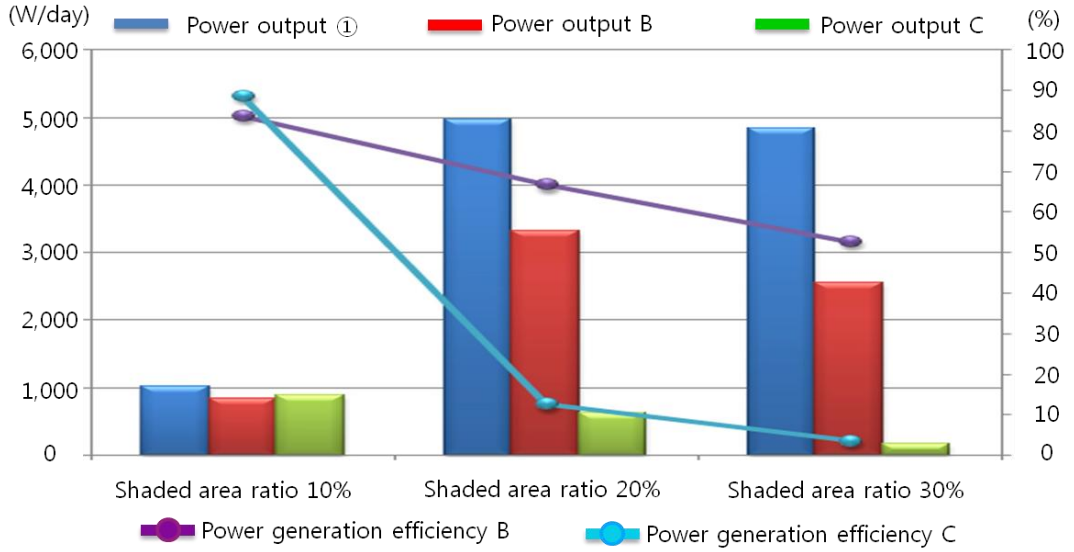


Fig 4. Comparison of power output according to shadow angle

The measurement of power output according to shadow angle showed that in case of a shadow (power output B: lengthwise shadow) that comes abreast with PV cell, an increasing shaded area ratio decreases power generation efficiency (B) as against basic power output ① steadily at about 16%. And at the shaded area ratio of 30%, power generation efficiency (B) registered the maximum decrease of 48.3%.

In case of a shade (power output C: crosswise shadow) that comes at a right angle to PV cell, power generation efficiency (C) for shaded area ratio (10%, 20%, and 30% was respectively 88.6%, 12.7%, and 3.6% as against basic power output ①. Especially, the analysis showed that power generation performance registered the biggest decrease of 76.0% in power generation efficiency (C), when shaded area ratio increased from 10% to 20%.

4 Conclusion

In this study, while considering the characteristics of a-Si thin-film PV module, I have performed a quantitative evaluation of the influence on power generation performance exerted by shadow ratio variation caused by self-shading in buildings (length of protrusion from walls) and shadow angle (the angle created by arrangement of cells and shadow) in collective housing, which is the major residential building in Korea, and the characteristics of the influence, of which key details are as follows.

(1) The measurement of basic power output ① designed to prevent occurrence of shadow on module surface, winter time power generation efficiency was 4.2% as compared to insolation.

(2) The analysis of the power output according to the influence from self-shading of buildings (length of protrusion from walls) showed that a length of protrusion at 250mm brought a maximum decrease of 11.9% in the power generation efficiency as against basic power output ①, and that according to increasing length of protrusion, power generation efficiency brought the biggest decrease of 6.3% in power generation efficiency when the length of protrusion increased from 200mm to 250mm.

(3) The measurement of power output according to shadow angle showed that in case of a shadow (power output B: lengthwise shadow) that comes abreast with PV cell, every 10% increase from 0 to 30% in the shaded area ratio brought a steady decrease of about 16% in the power generation efficiency as against basic power output ①. On the other hand, in case of a shadow (power output C: crosswise shadow) that comes at a right angle to PV cell, power generation performance registered a largest decline with a decrease of 76.0% in power generation efficiency (C) when shaded area ratio increased from 10% to 20%.

The analysis suggests that in applying a-Si thin-film PV module to the windows system of collective housing, consideration should be given to the power generation performance lowered under the influence from self-shading of buildings (length of protrusion from walls) and shadow angle and that if shadow occurs in a-Si Thin-Film PV Windows System, installation that gets shadow abreast with PV cell (power output B: lengthwise shadow) is favorable to power generation performance.

This study presents the results of a quantitative evaluation of the influence exerted on the power generation performance of transparent a-Si thin-film PV module by the self-shading of buildings and shadow angle in collective housing, which represents the Korean residence. With a view to their actual application to collective housing, I expect that further studies will conduct an evaluation of the self-shading of buildings, influence from shadow of neighboring buildings, profitability, and comprehensive evaluation and integrated test comprising heat and view.

Acknowledgements

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