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Pseudo-BIPV Style Rooftop-Solar-Plant Implementation for Small Warehouse Case

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Abstract

In this paper, we propose an example of designing and constructing a roof-type solar power plant structure equipped with a Pseudo-BIPV (Building-Integrated Photovoltaic) shape suitable for use as a roof of a small warehouse with a sandwich-type panel structure.

As the characteristics of the roof-type solar power generation facility to be installed in the small warehouse proposed in this study, the shape of the roof is not a general A type, but a right-angled triangle shape with the slope is designed to face south. We chose a structure in which an inverter for one power plant and a control facility are linked by grouping several roofs of buildings. In addition, the height of the roof structure is less than 20 cm from the floor, and it has a shape similar to that of the BIPV, so it is building-friendly because it is almost in close contact with the roof. At the same time, the roof creates a reflective light source due to the white color. By linking this roof with a double-sided solar panel, we designed it to obtain both the advantage of the roof-friendliness and the advantage of efficiency improvement for the electric power generation based on the double-sided panel. Compared to the existing solar power generation facilities using A-shaped cross-sectional modules, the power generation efficiency of roofs in this case is increased by more than 11%, which we can confirm, through the comparison analysis of monitoring data between power plants in the same area. Therefore, if the roof-type solar structure suitable for the small warehouse we have presented in this paper is used, the facilities of electric power generation is eco-friendly. Further it is easier to obtain facility certification compared to the BIPV, and improved capacity of the power generation can be secured at low material cost. It is believed that the roof-type solar power generation facility we proposed can be usefully used for warehouse or factory-based smart housing. Sensor devices for monitoring, CCTV monitoring, or safety and environment management, operating in connection with the solar power generation facilities, are linked with the Internet of Things (IoT) solution, so they can be monitored and controlled remotely.

Keywords: *Solar, BIPV, IoT, Power Generation*

1. Introduction

As the United States is showing a movement [1] in order to increase the proportion of renewable energy

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generation, including solar power, to about 42 percent by 2050 [1], the demand for photovoltaic power generation facilities with excellent low-carbon effect is increasing internationally, in line with the recent global trend [2] of the development of RE100 and Net-zero technology. Therefore, the Republic of Korea, which is an export-oriented trading country, is also at a point where it is necessary to steadily expand the capacity of solar power generation facilities in line with the global trend. In particular, the recent global energy crisis as a result of the recent war between Russia and Ukraine requires the expansion of various electric power generation facilities. Therefore, the facilities for solar power generation that do not require fuel costs can be a new solution of power generation that should be gradually expanded.

Power plant facilities installed in the mountains have a high risk of collapse. In the case of installing power plant facilities on flat land such as agricultural flat land, it is not easy to build new power plants due to government policies encouraging agriculture and regulatory policies in the region. In the case of installing power plant facilities on general land other than farmland, it is difficult to use them as power plant sites due to high prices of land. Recently, many facilities of power plant have been installed on the roofs of buildings because it is encouraged to construct solar power plants by utilizing the spaces in the existing buildings.

However, in Korea, most of the structures of the facilities for generating solar power have been installed on the roof of the A-shaped building, regardless of the shape of the roof, so that it spoils the beauty of the buildings in the city. BIPV technologies [3-7] that utilize building materials as solar panels have the advantage that buildings are eco-friendly because the building and the solar panel are integrated. When using BIPV materials for the roof of a building, the panel material price is about 2 to 3 times higher than that of the existing panels, the process for obtaining a power plant license is too complicated, and the profit effect from electricity sales cannot be expected at all due to excessive expenses; it can be said that the companies of power generation using the BIPV materials are still being ignored by users. Therefore, in this paper, we present the Pseudo-BIPV style rooftop-solar-plant implementation as a structure of solar power plant, with a building-friendly roof-type, that can be installed on a warehouse.

In particular, in this paper, we show a special design of roof structure, which has a right-angled triangle shape with a slope facing south, as a roof structure for Pseudo-BIPV. By grouping several roofs, we present a structure that links inverter and control facilities for one electric power plant. In addition, the height of the roof structure is less than 20 cm from the floor, and the roof structure has a shape similar to that of the BIPV and has a building-friendly shape, since it is installed almost in close contact with the roof. At the same time, the roof creates a reflective light source because the color is white. By linking this roof with a double-sided solar panel, we designed it to obtain both the advantage of the roof-friendliness and the advantage of efficiency improvement for the electric power generation based on the double-sided panel.

In addition, the generation facilities of solar power we have presented in this paper has the characteristics of being operated in conjunction with data monitoring and sensor-based Internet of Thing (IoT) solutions using smart housing technology.

2. Pseudo-BIPV Style Rooftop-Solar-Plant Structure

The design of the structure we propose, with inverter and control panel to be used in Pseudo-BIPV shown in Figure 1 to Figure 4 of this section, was supported by our partner company [8] based on our opinions, and the electrical design was supported by electrical design company [9]. As shown in Figure 1, in order to install the facilities for solar power generation, the roof of the building was designed to have a right triangle shape, not an A type; and the slope part was designed to face the south.

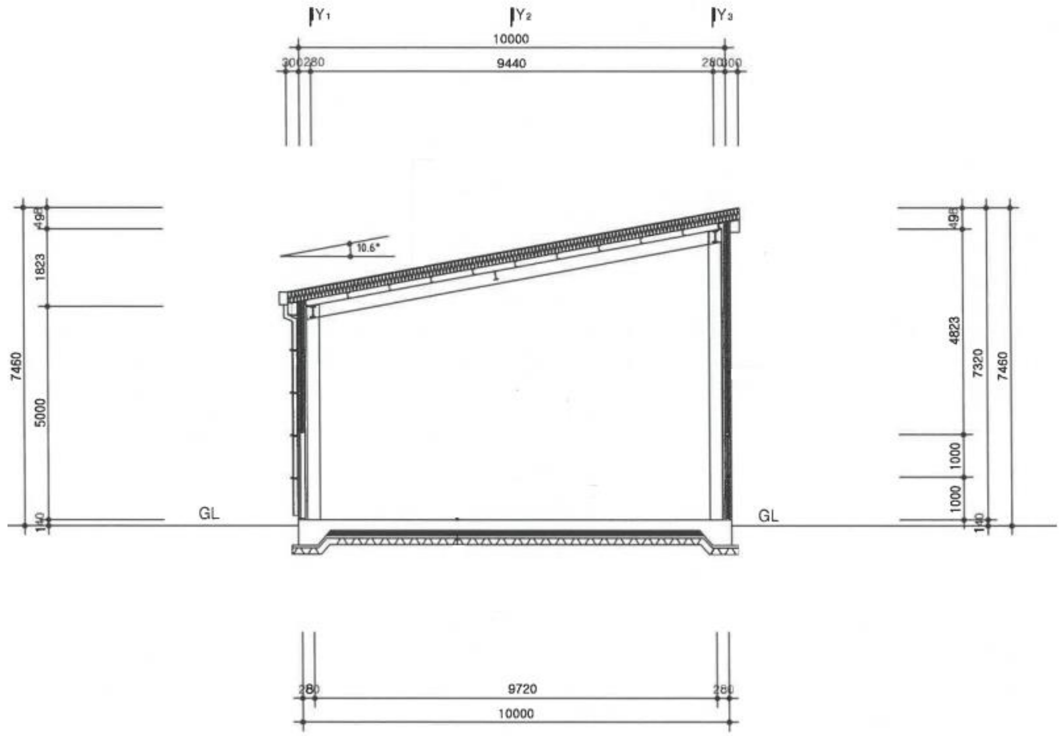

Figure 1. Roof type & Pseudo-BIPV structure (Side view)

In addition, as shown in Figure 2, the facility for solar power generation was designed to have a distance of about 20 centimeters from the bottom of the roof, and the roof of the building was designed in a right-angled triangle shape, not an A type, with the slope facing south. In addition, the height of the roof structure is less than 20 cm from the floor, and it has a shape similar to that of the BIPV, so the structure is a building-friendly one because it is almost in close contact with the roof. At the same time, the roof plays a role of reflecting light source because the color is white. By linking this roof with a double-sided solar panel, we have designed it in order to obtain both the advantage of the roof-friendliness and the advantage of efficiency improvement for the electric power generation based on the double-sided panel.

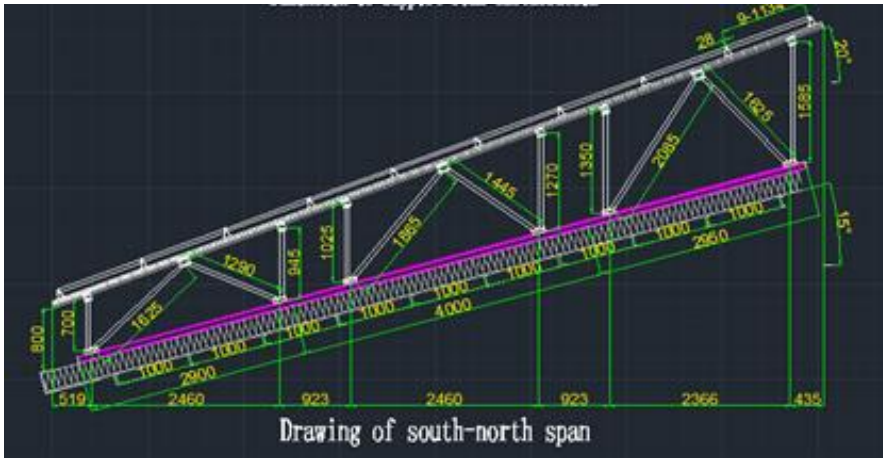

Figure 2. Pseudo-BIPV structure (Enlarged view of roof side)

3. Roof-Top Solar Panel Grouping and IoT Monitoring Equipment Structure

In this section, we present a roof-top solar panel grouping and IoT monitoring equipment structure, and we implement some drawings of the structure with the help of co-work companies [8,9]. Figure 3 shows a structure in which solar panels are mounted on the roofs of two buildings, with a structure in which the roofs of the two buildings are grouped together and linked to an inverter and a control facility, being selected for one electric power plant.

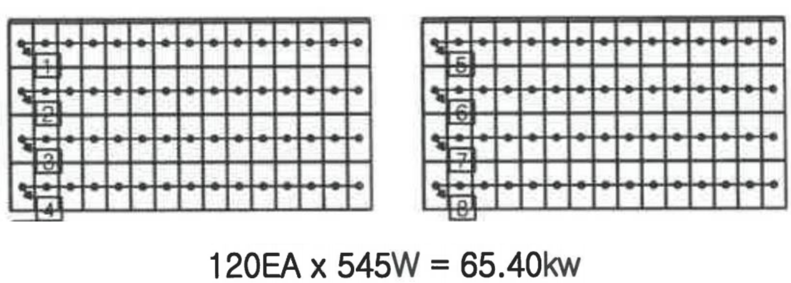

Figure 3. 65.4 kW scale Solar panel's Grouping mode (top view)

At this time, the capacity of electric power for one solar module installed on the roof is 545 W. Since the number of modules is 120 in total, we obtain as equation (1)

$$\text{Generation capacity} = \text{Module capacity } (545\ W) * 120 = 65.4\ kW \qquad (1)$$

as the corresponding resulting power.

Also, as shown in Figure 4, the solar modules installed on the roof in groups are connected to the inverter block by a DC cable. These inverter blocks are connected to the control panels in the field, and the control panels are linked to the IoT MODEM, which has the function to monitor IP-based solar facilities.

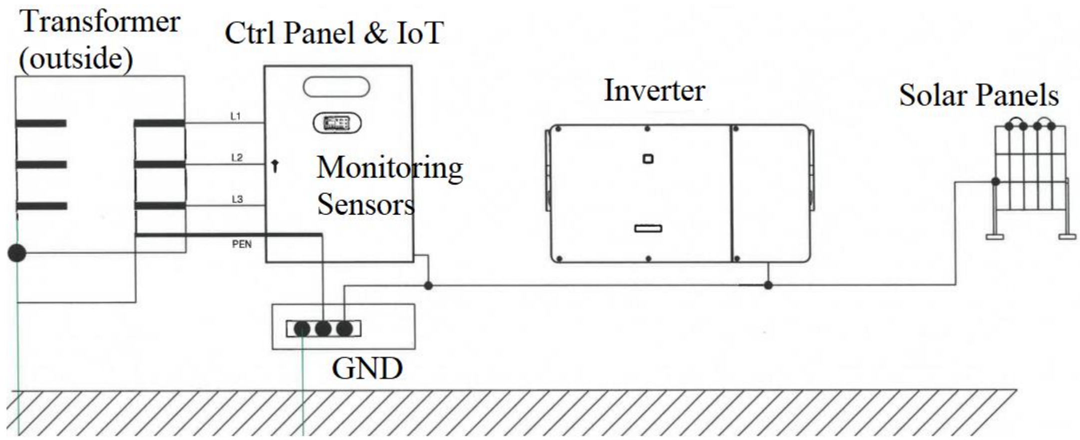

Figure 4. Inverter block with control panel & IoT equipment

4. Implementation Result and Analysis

Figure 5(a) and Figure 5(b) show a field photo of implementing a Pseudo-BIPV style looptop-solar-plant for a small warehouse case, by adopting the structure we have presented in this paper. As shown in the picture, it can be seen that the solar power plant is integrated with the roof and can be implemented in a building-friendly form, almost like a BIPV.

(a) Enlarged view of roof side

(b) Top view

Figure 5. Implementation of solar panel's grouping mode (65.4 kW scale)

Figure 6 shows the inverter block installed on the outer wall of the building.

These inverter blocks function to convert DC voltages to AC voltages, for producing electricity with the facilities of solar power generation.

Figure 6. Implementation of inverter block

As shown in Figure 7, a control panel is installed next to the inverter block, and the panel is linked to the IoT solution in order to provide a function that monitors the working conditions of electric power plant remotely.

Figure 7. Implementation of IoT-based pseudo-BIPV monitoring block

Figure 8 shows the IoT monitoring platform software supported by SMART REMP[10] that supports the IoT monitoring functions. This monitoring software has a version of WEB & APP. The software monitors the status of the power plant, provides the function of alarming the manager when a specific event occurs, and at the same time, provides the function of storing and analyzing the data of power production from the electric power plant over a specific period of time. Please be noted that the first line of the paragraph indent is 0.5cm.

Figure 8. IoT monitoring software supported by SMART REMP

Figure 9 shows the Pseudo BIPV type power plant and the A type power plant, as proposed in this paper, installed in the same area. In the figure, the upper power plant is a conventional type, and the building has an A type. It can be seen that the power plant installed at a location more than 1 meter from the roof is not in eco-friendly manner with the appearance of the roof of the building.

Figure 9. Implementation structure comparison between proposed type (65.4 kW) & conventional A type roof-top plant (78.3 scale)

Table 1 shows a comparison of the values for power generation capacity, over one month (August 2022), obtained by extracting and storing power generation capacity data from the power plant of Pseudo BIPV type (capacity 65.4 kW) and a power plant of conventional A type, with both plants installed in the same test-bed area through SMART REMP, which is an IoT monitoring platform software. As a result, when comparing the data presented in Table1 and Figure 10, the power generation capacity of the solar module of the proposed power plant is 65.4 kW, which is only 83.524904 %, compared to 78.3 kW of the existing plant. However, when calculating and comparing the data of the power generation capacity for one month, one is 6864.9 kW and the other is 7454.98 kW. Therefore, it was found that the power generation capacity of the power plant with the structure we have proposed in this paper is about 92.085% of the power generation capacity of the existing A type power plant. Therefore, when comparing the capacities of the solar modules with the same capacity, it was confirmed that the power generation efficiency was increased by about 11.025% by using the structure we have proposed, compared to the conventional power generation capacity.

Table 1. Comparison of power generation capacity between proposed type(65.4 kW) & conventional A type (78.3 kW)

Generation Capacity		
Roof-top Solar Plant [2022-08-01 ~ 2022-08-31]		
DATE	65.4 (kWh)	78.3 (kWh)
	#Pseduo BIPV	#conventional
08-01	248.9	270.68
08-02	199.8	216.71
08-03	211.7	227.11
08-04	365.6	401.68
08-05	306.3	331.21
08-06	304.6	332
08-07	225.7	246.5
08-08	56.9	58.4
08-09	107.5	114.71
08-10	76.1	80.18
08-11	47	48.41
08-12	393.4	434.5
08-13	86	90.59
08-14	104.4	110.82
08-15	224.5	243.89
08-16	327.7	352.7
08-17	266.2	284.3
08-18	318.8	348.9
08-19	161.6	174.39
08-20	352.9	379
08-21	348.6	379.89
08-22	277.8	303.61
08-23	95.2	99.6
08-24	224.5	240.5
08-25	119.7	128.4
08-26	333.9	362.89
08-27	425.4	466
08-28	423	463.82
08-29	90.4	95.89
08-30	38.4	38.9
08-31	102.4	108.8
	6864.9	7434.98

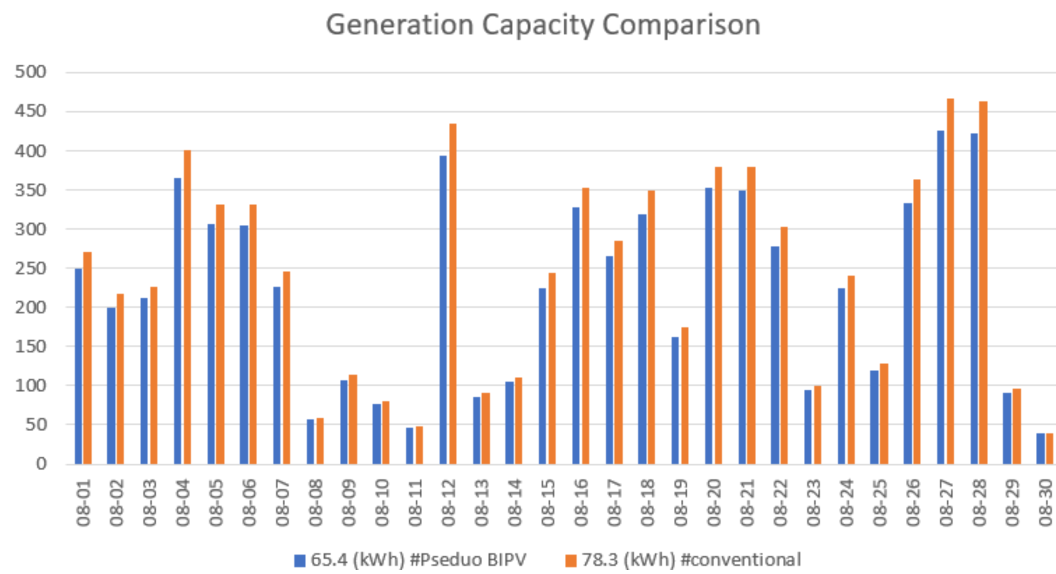

Figure 10. Comparison of power generation capacity between proposed type (65.4 kW) & conventional A type (78.3 kW)

5. Conclusion

In this paper, we have proposed an example of designing and constructing a roof-type solar power plant structure equipped with a Pseudo-BIPV (Building-Integrated Photovoltaic) form suitable for use as a roof of a small warehouse with a sandwich-type panel structure. In this paper, we show a design of roof structure, which has a right-angled triangle shape with a slope facing south. By grouping several roofs, we present a structure that links inverter and control facilities for one power plant. In addition, the height of the roof structure is less than 20cm from the floor, and it has a shape similar to that of the BIPV, so it is building-friendly because it is almost in close contact with the roof. At the same time, the roof creates a reflective light source because the color is white. By linking this roof with a double-sided solar panel, we designed it to obtain both the advantage of the roof-friendliness and the advantage of efficiency improvement for the electric power generation based on the double-sided panel. In this paper, by utilizing the commercially available Smart Remp monitoring platform, we have compared the power generation efficiency of the roof-type solar power generation facilities and the power plant facilities we proposed, both installed in the same area. As a result, based on the same installation area, we could confirmed that the power generation efficiency by the method presented in this paper is increased by more than 11%. In addition, when the pseudo-BIPV technology presented in this paper is used, it can be confirmed that both the building-friendly aspect and the cost-effective aspect are improved; since the pseudo-BIPV technology is eco-friendly, and it is easy for us to obtain facility certification compared to BIPV, and it is possible for us to build a power plant using about 30% of the material cost. In addition, by linking the pseudo-BIPV technology presented in this paper with IoT solutions, we have also partially confirmed the possibility of interworking with smart housing in part by establishing safety management and monitoring functions for power facilities.

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