STUDY ON SIMPLE ASSESSMENT METHOD OF BIPV POWER GENERATION FOR ARCHITECTS

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ABSTRACT

The inhomogeneity of photovoltaic (PV) arrays such as partial shadowing due to architectural design is a critical issue for PV power generation. However, losses due to the inhomogeneity have not been sufficiently analyzed quantitatively. The authors developed a simple experimental method using miniature PV array for annualizing the relation between power output and shading patterns. The method for simplified I-V curve interpolation was improved and verified. The simulation using this new method provided I-V curves with considerable accuracy, and the estimation errors of the maximum power of the array were within 3%. Yearly calculation was used for this simulation method and revealed that the results can guide the design of PV system for architects.

INTRODUCTION

The number of PV systems integrated with buildings is increasing. However, inhomogeneity due to architectural design causes a remarkable deterioration in the total PV power generation. In this paper, power generation characteristic was described, under inhomogeneous building conditions evaluated by experiments with a miniature PV array. The experiments were verified by simulation model of simplified I-V curve interpolation method. Moreover, yearly calculation was used for this simulation method and found that complex array performance index could guide architectural designs of PV system.

OUTLINE OF THE SIMULATION

Experiments were carried out for validity check of simplified I-V curve interpolation method. The experiments perform to use miniature model, which will be described afterward. The flowchart of the simplified I-V curve interpolation method is set out in Fig.1.

![Fig. 1. The flowchart of the simulation model for simplified I-V curve interpolation method.](image)

In this paper we performed simulation of the simplified I-V curve interpolation method. The input parameters are module rating, irradiance and module temperature. This method can also be calculated by plotted I-V data, but in case that I-V data cannot be obtained, it can be generated from module parameters. Each I-V curve calculated is composed according to the electrical wiring. It was simulated taking into consideration bypass diode and blocking diode. The simulation method, diagrammatical compounding according to circuit structure, is very simple, so that the characteristic can be calculated accurately and quickly.
VERIFICATION OF THE SIMULATION

Experiments with a miniature PV array

It is often a difficult issue to measure the real PV systems, especially in terms of the influence of partial shadows and wiring. In this paper, we conducted experiments with a miniature PV array composed of mini-module consisting of 2 cells electrically equivalent to large-scale systems.

![Miniature PV array model](image1)

Fig. 2. Miniature PV array model

![Mini-module consisting of two-cells](image2)

Fig. 3. Mini-module consisting of two-cells

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short circuit current</td>
<td>1.2 [V]</td>
</tr>
<tr>
<td>Open circuit voltage</td>
<td>1.95 [A]</td>
</tr>
<tr>
<td>Peak Power</td>
<td>1.65 [W]</td>
</tr>
<tr>
<td>Maximum power voltage</td>
<td>0.95 [V]</td>
</tr>
<tr>
<td>Maximum power current</td>
<td>1.75 [A]</td>
</tr>
<tr>
<td>Curve correction factor</td>
<td>0.001 [Ω/A]</td>
</tr>
<tr>
<td>Current temperature coefficient</td>
<td>0.001 [V/°C]</td>
</tr>
<tr>
<td>Voltage temperature coefficient</td>
<td>-0.004[W/°C]</td>
</tr>
</tbody>
</table>

Table 1. Rated values of PV module

The outline of each miniature PV array is composed of two-parallel strings of four-series connected modules. Miniature PV array model is set out in Fig.2. Each module is composed of a 10cm × 10cm Mini-module consisting of two-cells(Fig.3). Each cell is connected in series ensuring a higher voltage. Table 1 shows rated values of the PV module.

![I-V curve tracer](image3)

Fig. 4. Measuring system

Influence of diodes

As shown in Fig.5, array output is influenced by blocking and bypass diodes because of module low output. Therefore, experiment deduced a range by the diode not affected. It was found that diode influence could be neglected if more than four two-cell modules were connected in series and schottky barrier diodes which low forward voltage drop were used.

![Diagram of influence on diodes](image4)

Fig. 5. The influence on diodes for 2cell module
Power generation characteristics of PV array in partial shadows

The power generation is greatly influenced by shadows on the PV array. In these experiments, PV characteristics for various shadow patterns were measured using the miniature PV array. The ratio of the area covered with aluminum sheets to the array surface is defined as "shadow cover ratio". Fig.5 shows the relationship between the shadow cover ratio and the output ratio of the PV arrays. The plots under diagonal line mean that output power is smaller than those in proportion to the shadow covered area.

Fig. 6 Relationship between partial shadow patterns and PV power ratio

Output ratio = \frac{\text{Maximum power in each case}}{\text{Maximum power in standard case}} \tag{1}

Fig. 7. Comparison of PV array power generation for experimental cases

Fig. 8. Miniature model with differently inclined array coupling and experimental cases

Validation of the simulation accuracy

Fig. 10 shows a comparison between measured and simulated data. Measured circuits are composed of 8 two-cell module. Two modules in the circuit are covered with aluminum sheets. The error ratio at the maximum power point is approximately 0.3%. So that it is concluded this method has high accuracy.
ATTEMPT OF SYSTEM DESIGN INDEX

Yearly calculation was carried out, using this simplified I-V curve interpolation method. Since the results of the calculation, PV system design index of architects have been revealed. In case those modules of different inclination are connected in series, it is possible that the output power decreases as mentioned. However, there are also some cases that the modules have to be connected in series due to architectural design and to obtain output voltage. In such case, it is desirable to determine quantitatively the decreases of the output power due to module inclination.

Meteorological database

We used METPV\[1\](Meteorological Test data for PhotoVoltaic system) which is a kind of TMY(Typical Meteorological Year) in Japan for yearly calculation. METPV consists of basic metrological elements on horizontal surface and irradiation on inclined surface.

Table 2. Condition of the calculation

<table>
<thead>
<tr>
<th>Meteorological data</th>
<th>METPV '98-edition, average year data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place</td>
<td>Tokyo 35°42.2'N 139°45.9'E</td>
</tr>
<tr>
<td>Used data</td>
<td>Hourly average in-plane irradiance, Wind velocity, Ambient temperature</td>
</tr>
<tr>
<td>Modules</td>
<td>110W monocrystal module</td>
</tr>
</tbody>
</table>

Module temperature was estimated by ambient temperature and wind velocity.

Requirement and results of calculation

As shown in Fig.11, we compared multi-inclinated array and average angle array. The angle of these modules can be calculated as follows.

\[
\alpha = \text{angle of module A} \quad (2)
\]

\[
\beta = \text{angle of module B} \quad (3)
\]

\[
\gamma = \text{angle of average angle array} \quad (4)
\]

\[
\text{difference angle of modules} = |\alpha - \beta| \quad (5)
\]

Complex array performance coefficient was calculated as follows.

\[
\text{complex array performance coefficient} = \frac{\text{power generation of average array}}{\text{power generation of polycline array}} \cdot \frac{\text{power generation of polycline array}}{\text{power generation of average array}}
\]

(6)

Fig. 12 shows the amount that output power of complex array decreases against the output of average angle array.

CONCLUSION

We suggested that experiments with a miniature PV array and the simulation method for simplified I-V curve interpolation. Moreover we have obtained guidelines for the wiring design of PV arrays under inhomogeneous building condition.

REFERENCES