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 afferward. The flowchart of the simplified I-V curve interpolation method is set out in Fig.1.

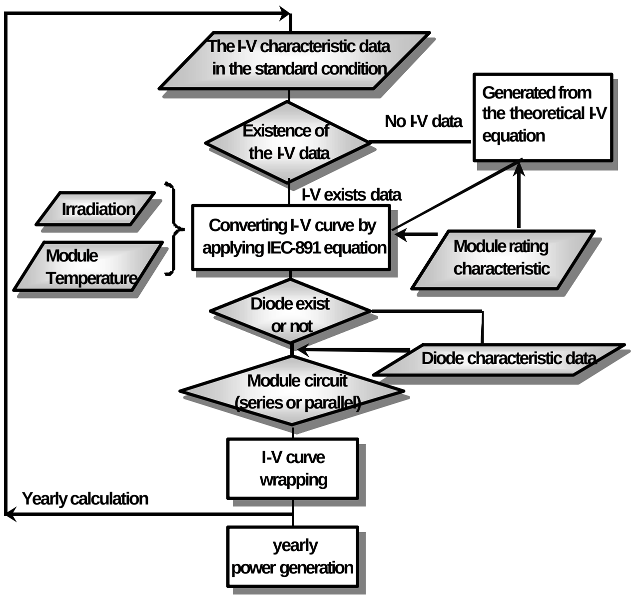


Fig. 1. The flowchart of the simulation model for simplified I-V curve interpolation method**.**

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.

Fig. 2. Miniature PV array model

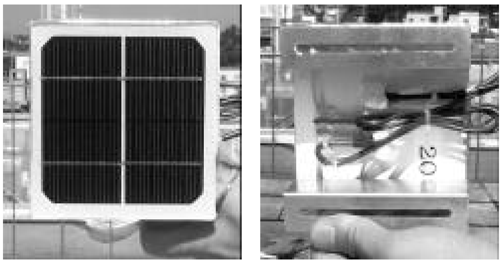


Fig. 3. Mini-module consisting of two-cells

Table 1. Rated values of PV module

Parameters	Rated Value
Short circuit current	1.2 [V]
Open circuit voltage	1.95 [A]
Peak Power	1.65 [W]
Maximum power voltage	0.95 [V]
Maximum power current	1.75 [A]
Curve correction factor	0.001 [Ω/℃]
Current temperature coefficient a	0.001 [A/℃]
Voltage temperature coefficient b	-0.004[V/℃]

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 sell is connected in series ensuring a higher voltage. Table 1 shows rated values of the PV module.

Fig.4 shows the measuring system, in which a change of electric wiring and insertion of bypass and blocking diodes can be performed easily. Thermo-couples are installed for each module. All the modules and ambient temperature are recorded by a multi-data recorder. The current-voltage characteristic of each module is measured with an I-V curve tracer. Irradiance is measured by a pyranometer type EKO MS-801. Covering module surfaces with aluminum sheets simulates various shadow patterns.

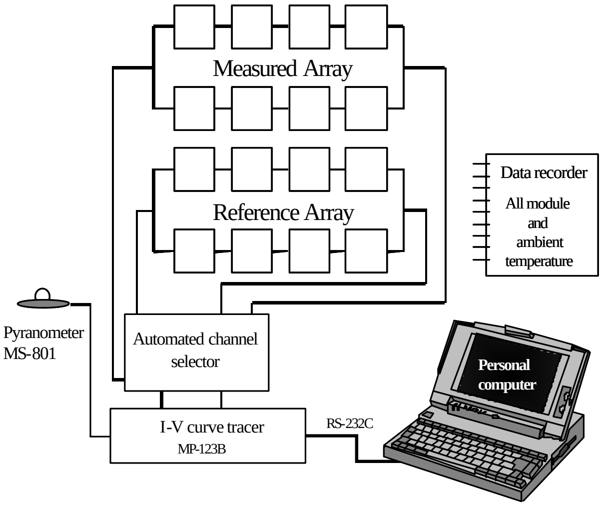


Fig. 4. Measuring system

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.

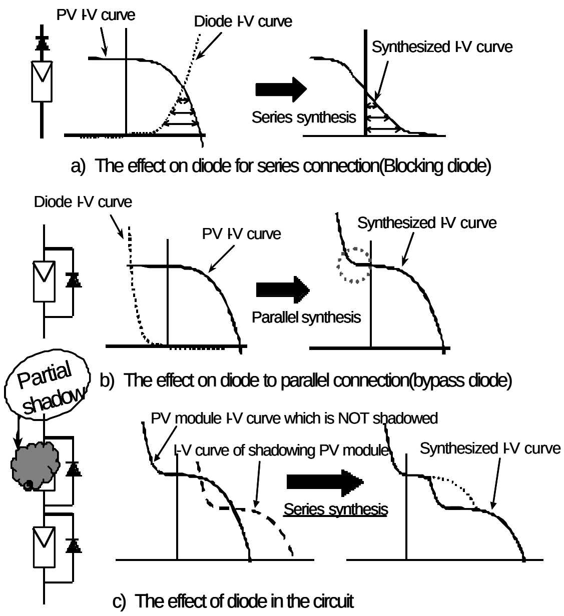


Fig. 5. The influence on diodes for 2cell module

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.

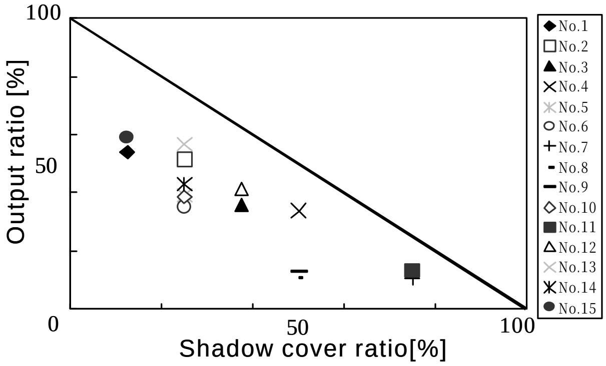


Fig. 6 Relationship between partial shadow patterns and PV power ratio

$$\text{Output ratio} = \frac{\text{Maximum power in each case}}{\text{Maximum power in standard case}} \quad (1)$$

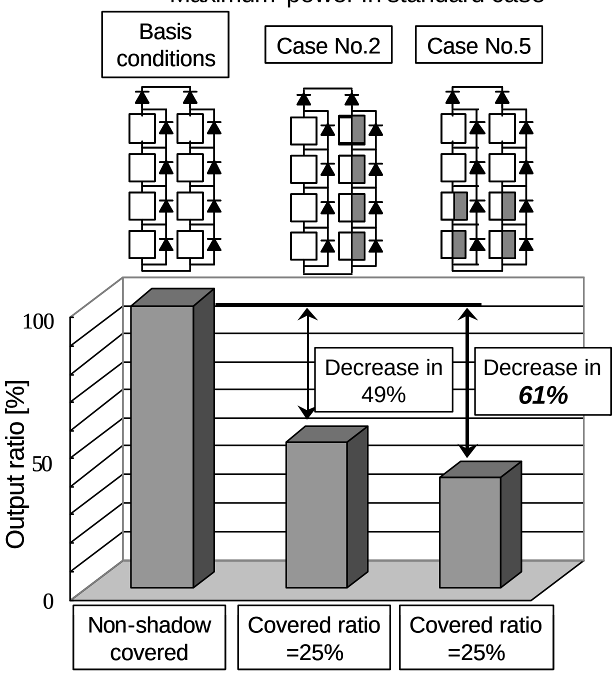


Fig. 7. Comparison of PV array power generation for experimental cases

Fig.7 shows the results of comparison of PV array power generation for experimental cases. The shadow-covered ratio is identical value, but the position of shadows is different. Partial shadows in a same series string decreased the power in proportion to the covered area of each PV module, and the shadow across series strings cause a remarkable deterioration of PV characteristics. These results indicate that the wiring configuration should be designed carefully.

Power generation characteristics in differently oriented PV array couplings

Fig.8 shows the experimental device and the experimental cases. Irradiance was measured for each inclination and orientation. In the measurement of differently inclined array couplings and the arrays connected, series or parallel, the orientation was 0 ° (south). One of the array is fixation in the inclination of 90 ° .

(a) PV array

Differently inclined PV array coupling	
Array #1 inclination	Array #2 inclination
90°(Vertical)	0°(horizontal)
90	30
90	60
90	90°(Vertical)

Orientation =0°

(b) Experimental cases

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

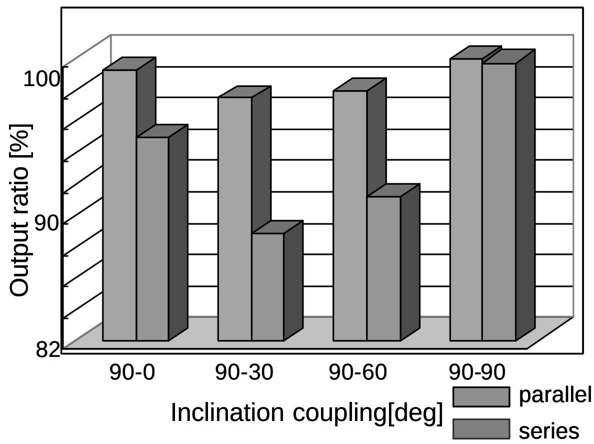
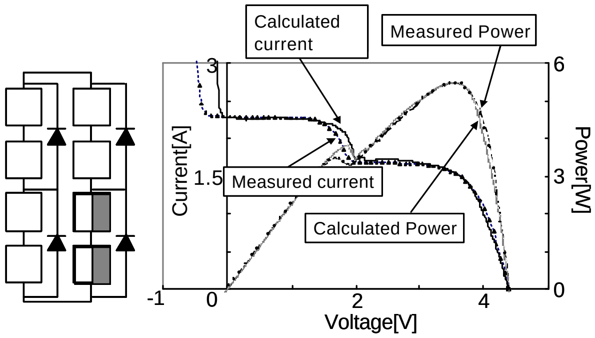


Fig. 9. Influence of differently inclined PV array coupling

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.



(a)Measured circuit (b)Comparison between measured and calculated values

Fig. 10. Comparison between measured and simulated data

ATTEMPT OF SYSTEM DESIGN INDEX

Yearly calculation was carried out, using this simplified I-V carve 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

Meteorological data	METPV '98-edition, average year data
Place	Tokyo 35 ° 42.2'N 139 ° 45.9'E
Used data	Hourly average in-plane irradiance, Wind velocity, Ambient temperature
Modules	110W monocrystal module

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.

a =angle of module A (2)

b =angle of module B (3)

g =angel of average angle array (4)

difference angle of modules = |a − b| (5)

Complex array performance coefficient was calculated as follows.

$$\text{complex array performance coefficient} = 1 - \left(\frac{\text{power generation of average array} - \text{power generation of polycline array}}{\text{power generation of polycline array}} \right) \quad (6)$$

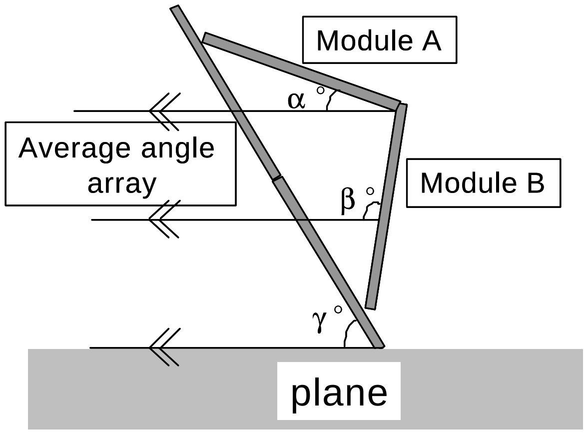


Fig. 11. Image of array configuration used in calculation

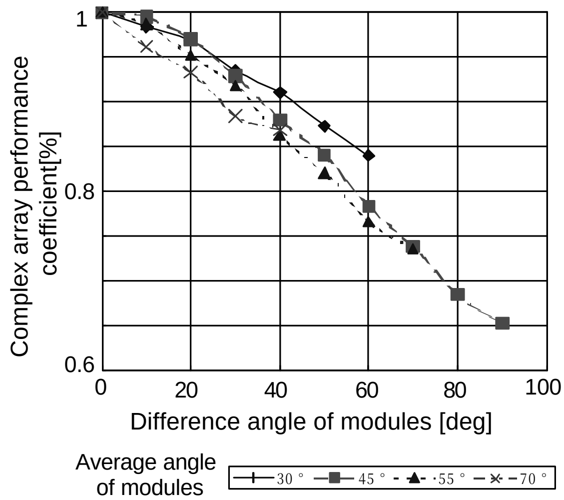


Fig. 12. Yearly calculation of complex array performance coefficient

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

[1] A. Itagaki, H. Iida, and H. Okumura: Meteorological Analysis for Suitable Design of Photovoltaic Power Generation Systems: Preparation of Meteorological data (METPV) which is useful to simulate output from PV systems", 2nd *WCPEC*, Vienna, 1998, pp. 2032-2035.