MODELING I-V CURVES OF PV MODULES USING LINEAR INTERPOLATION /EXTRAPOLATION

Yuki Tsuno[1, 2], Yoshihiro Hishikawa[1] and Kosuke Kurokawa[2]
[1] National Institute of Advanced Industrial Science and Technology (AIST), Research Center for Photovoltaics, Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki, 305-8568, Japan

[2] Tokyo University of Agriculture and Technology (TUAT), 2-24-16 Naka-cho, Koganei, Tokyo, 184-0012, Japan

ABSTRACT

A translation procedure based on the linear interpolation/extrapolation is proposed, in order to translate the I-V curves to target conditions of irradiance and temperature. The accuracy of the method is investigated, based on the indoor measurements of I-V curves. The calculated I-V curves over a wide range of irradiance and temperature well agree with experimental results. These results indicate that the translation of the I-V curve based on the method is effective for estimating the performance of the PV devices under various climatic conditions.

1. INTRODUCTION

It is useful to understand the effect of the irradiance and temperature on the photovoltaic (PV) cell and module performance, in order to estimate their I-V curves under various climate conditions for power rating and energy rating. Several models for translation of I-V curves or prediction of energy are proposed [1]. However, these models need a lot of measurements in order to determine the parameters, and it takes a long time to determine them.

In this study a practical formation for the linear interpolation / extrapolation which uses no parameters and only four measurements is proposed. The accuracy of the method based on the experimental I-V curves is investigated.

2. LINEAR INTERPOLATION /EXTRAPOLATIO METHOD

The present study demonstrates the new practical formulae [2, 3], which are extension of the equations and do not require adjustment of the reference I-V curves. The procedure of the linear interpolation / extrapolation of the present study is as follows. The measured current-voltage characteristics are corrected to target G and T values by equations (1) and (2).

$$V_3 = V_1 + a \cdot (V_2 - V_1) \qquad (1)$$

$$I_3 = I_1 + a \cdot (I_2 - I_1) \qquad (2)$$

Here, I_1 and V_1 are the current and voltage of the reference I-V curve measured at an irradiance G_1 and temperature T_1. I_2 and V_2 are the current and voltage of the reference I-V curve measured at G_2 and T_2. I_3 and V_3 are current and voltage of the I-V curve at G_3 and T_3. which is the target of the translation. The pair of (I_1,V_1) and (I_2, V_2) should be chosen so that $I_2 = I_1 + (I_{sc2} - I_{sc1})$. Here, I_{sc1} and I_{sc2} are the short circuit current of the reference I-V curves. a is a constant for the interpolation, which has the relation with the irradiance and temperature as shown in equations (3) and (4). When $0< a <1$, the procedure is interpolation, When $a<0$ or $a>1$, the procedure is extrapolation.

$$G_3 = G_1 + a \cdot (G_2 - G_1)\,. \qquad (3)$$

$$T_3 = T_1 + a \cdot (T_2 - T_1)\,. \qquad (4)$$

Equation (5) is also applicable, when the I_{sc} of the device is linear with G. Here, I_{sc3} is the short circuit current of the target I-V curve.

$$I_{sc3} = I_{sc1} + a \cdot (I_{sc2} - I_{sc1}) \qquad (5)$$

The primary advantage of the equations (1), (2) is that there is no restriction for the I_{sc}(or G) and the T of the reference I-V curves. Therefore, any I-V curves can be used as the reference I-V curves without adjustment. Translation of the I-V curves for G at constant T and translation for T at constant G are possible by the same formulae. Furthermore, simultaneous translation for both G and T is possible within the relation of equations (3) and (4).

By utilizing present procedure, I-V cures at wide range of G and T can be calculated from only three or four reference I-V curves measured at indoor or outdoor.

3. EXPERIMENTS

Modeling of the I-V curves was investigated by using the experimental I-V curves of the outdoor poly-Si modules which are located in Tsukuba, Japan. Data were taken for about one year. The total number of the I-V curves used was about 40,000.

The four reference I-V curves for modeling were measured at indoor by using a steady-state solar simulator (Fig. 1). The conditions (G, T_{mod}) of the measurements ware (1SUN, 25°C), (1SUN, 65°C), (Dark, 25°C) and (Dark, 65°C). The module temperature was raised by illumination of the solar simulator light.

Two combinations for input parameter (I_{sc}, T_{mod}), (G, T_{mod}) were used. Then Measured I-V curves and energy were compared to the calculated them.

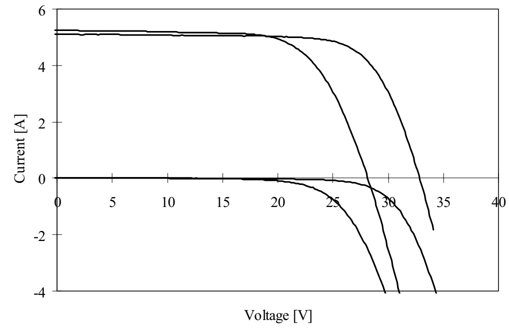

Fig. 1 Reference I-V curves of poly-Si module measured at indoor.

4. COMPARISON OF EXPERIMENTAL RESULTS WITH MODEL PREDICTIONS

The I-V curves calculated by using input parameter (I_{sc}, T_{mod}) showed very good agreement with the experimental data (Fig. 2). For example, the standard deviation and the average between the measured and calculated P_{max} was about 0.68% and -0.45%, respectively (Fig. 3) which demonstrates the accuracy and usefulness of the present procedure of the linear interpolation. On the other hand, the error was observed when (I_{sc}, T_{mod}) were used. This confirms that the G of the device is not linear with I_{sc} caused by spectral irradiance, angle effect etc. The accuracy of energy predictions shows the same tendency (Table I).

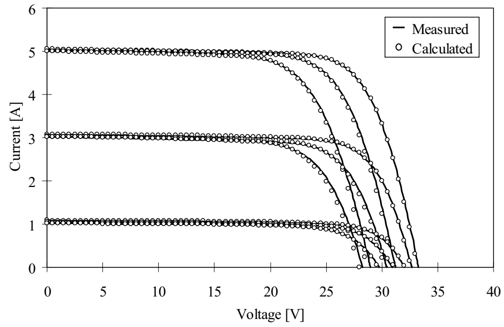

Fig. 2 Examples of measured (lines) and calculated (circles) I-V curves of a polycrystalline Si PV module. Calculated results show very good agreement with the experiment.

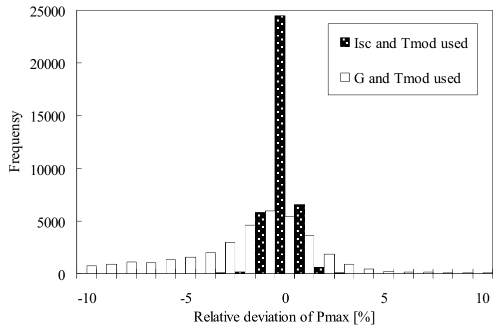

Fig. 3 Deviation of the measured and calculated P_{max} of the outdoor poly-Si module.

Table I. The accuracy of energy predictions by using G or I_{sc}.

	Error
Calculated energy (I_{sc}, T_{mod})	-0.4 %
Calculated energy (G , T_{mod})	-1.5 %

5. CONCLUSIONS

A new practical formulation for the linear interpolation/extrapolation has been investigated, in order to translate the I-V curves and predict the energy of the PV modules for the irradiance G (or I_{sc}) and temperature T. The accuracy of the translation has been investigated based on the experimental outdoor I-V curves of poly-Si modules. Four I-V curves measured at any G (or I_{sc}) and T (also dark conditions) can be used as the reference I-V curves. This makes practical translation procedure and energy prediction much easier than other parametric models. The results well agree with measured maximum power and energy of PV modules. The present method is expected to be very useful for the energy rating and power rating of the PV devices.

This work was supported in part by NEDO under the Ministry of Economy, Trade and Industry.

REFERENCES

[1] S.R. Williams et al., "Accuracy of Energy Prediction Methodologies", Proceedings of the 4th WCPEC (2006) Waikoloa, Hawaii; 2206-2209.

[2] Y. Tsuno, Y. Hishikawa and K. Kurokawa, "Translation Equations for Temperature and Irradiance of the I-V curves of Various PV Cells and Modules" Proceedings of the 4th WCPEC (2006) Waikoloa, Hawaii; 2246-2249.

[3] Y. Hishikawa, Y. Tsuno and K. Kurokawa, "Translation of the I-V curves of various solar cells by improved linear interpolation", Proceedings of the 21st EU PVSEC (2006) Dresden; 2093-2096.