A Simplified Estimating Model For In-Plane Irradiation Using Minute Horizontal Irradiation

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ABSTRACT

To develop a new formula for calculating irradiation onto an arbitrary orientation-inclination plane, detailed examinations have been made by using data obtained at every one minute interval with four types of pyranometer, such as horizontal, diffuse, direct normal, and tilt global. Instantaneous irradiance values sampled with 1 min. interval have been verified by clearness index, which is a parameter independent from the lapse of time. Scattered tendencies observed on direct and diffused component ratios have been studied in detail by classifying data to different classes of clearness indices. In our model, moving averages of time-series irradiance data provide the information of weather condition in order to select model parameters prepared for assumed three types of clouds conditions. Only global irradiance data monitored at one minute intervals are used for the input of the model. The result of this work demonstrates that an algorithm associated with Perez model can estimate the in-plane irradiation with a *RMSE* of about 50W/m^2.

1. Introduction

For analyzing the performance of photovoltaic systems accurately, it is essential to obtain the in-plane irradiation onto PV array. However, some systems lack costly pyranometers enough to monitor the in-plane irradiation. For such systems, it is necessary to substitute conversional irradiance data for actually measured data. By the appearance of building integrated module(BIPV) recently, it is considered that these necessity will increase. In order to estimate in-plane irradiation, it is necessary to separate global irradiation into two components, such as diffuse irradiation and direct irradiation. After such separation process, in-plane irradiation is calculated by composing them. Some models for estimating the diffuse fraction of global irradiation using clearness indices, which are defined as the ratio of the global irradiation to horizontal extraterrestrial irradiation , have been already proposed by many authors and are often used. However, almost such models naturally have widespread errors in their estimation in medium irradiation conditions. Japan Weather Association (JWA) have improved their model by adding sunshine duration time data into the model in order to enhance the accuracy of the estimation in the medium irradiation conditions[1]. In this study, the authors propose a simplified model for estimating the diffuse fraction, which uses time series of minutely global irradiation data instead of the sunshine duration time data.

2. Pyranometers

One-minute sampled data have been obtained with the measurement facilities installed on the top of a building at Koganei Campus. Four types of irradiance are obtained at every 1 minute intervals, i.e., horizontal global irradiance, horizontal diffuse irradiation, normal direct irradiance, in-plane irradiation at an incline of 35 degrees.

3. Model for Estimating Diffuse Irradiation

<u>Analysis for distribution of Diffuse Component Ratio</u>

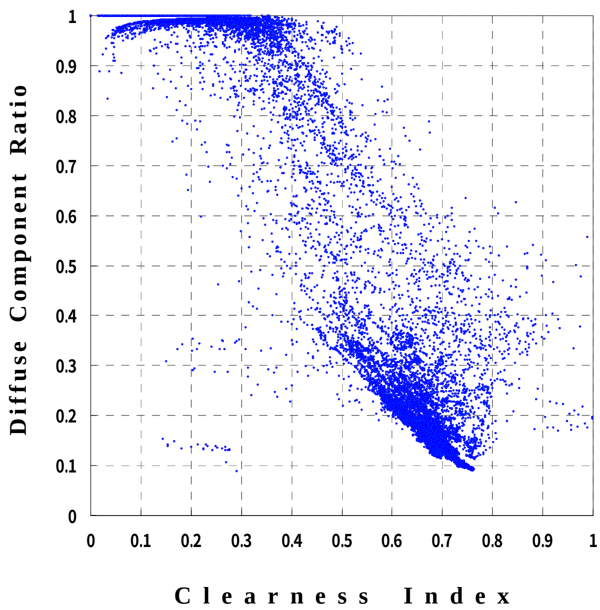

Fig.1 Relationship between diffused component ratio and clearness index (January 1998)

Figure 1 illustrates a relationship between diffuse component ratios and instantaneous clearness indices. In the study, instantaneous time-series data were used. A general tendency of them is classified to 3 typical patterns, i.e., clear day, partially cloudy day and entirely cloudy day. By modeling suitable for each weather condition, the accuracy of an estimation can be improved.

Moving Average

To obtain an information of weather condition, backward moving average was introduced. This parameter is described for instantaneous clearness index *G(s)* as Equation (1). In this work, the evaluating parameter, F_{CI}, was defined as Equation (2).

$$\overline{G(s)_N} = \frac{1}{N}\sum_{i=1}^{N} G(s-i) \quad \textbf{(1)}$$

$$F_{CI}(s) = G(s) - \overline{G(s-1)_N} \quad \textbf{(2)}$$

Algorithm of estimating for diffuse irradiation

When the sky is clear or completely cloudy, the diffuse component ratio can be estimated easily. As the fluctuation of the weather condition becomes larger, the estimation becomes more difficult. As a result of this investigation, a new estimation procedure was developed for calculating diffuse irradiation directly.

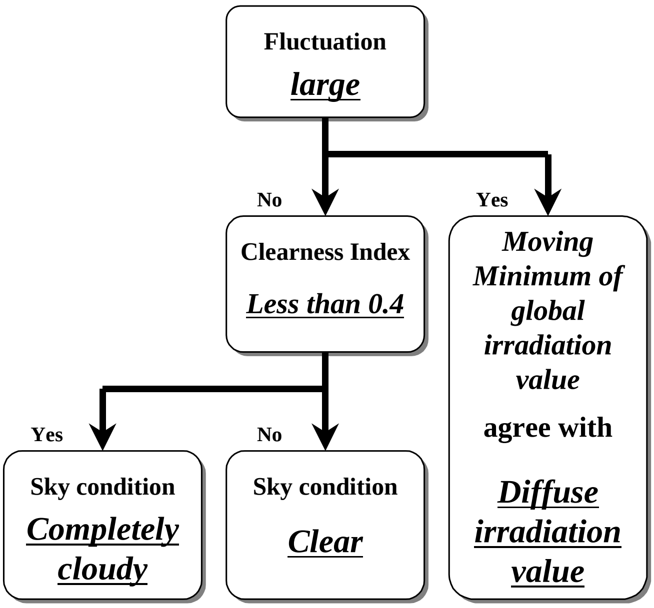

Fig.2 Flow Chart of model for estimating diffuse irradiation

When clouds move across the sun, a dynamic change happens in irradiance. In addition, global irradiation value is the same as diffuse irradiation value when the sun is covered with clouds completely. On the other side, when the sun appears sometimes through scattered clouds, diffuse irradiation value can be considered to change slowly compared with direct component. Thus, while global irradiation fluctuates dynamically, the diffuse irradiation value can be identified with the minimum value of global irradiation. Based on this idea, a new estimating model was developed. The flow chart presenting this algorithm is shown in the Figure 2.

4. Application of a new estimation model

Using the new model, an estimation for separating global irradiation to diffuse and direct irradiation was performed. To show the evaluation of this model, the root mean square error(*RMSE*) and mean bias error(*MBE*) were calculated. These are shown in Table 1.

Table.1 Evaluation of the estimation model for separating global irradiation (January 1998)

	One-minute value		Hourly mean value	
	RMSE [W/m^2]	MBE [W/m^2]	RMSE [W/m^2]	MBE [W/m^2]
Difuse irradiation	33.16	−0.08	21.60	−0.08
Direct irradiation	93.36	33.16	63.14	26.32

5. Evaluation for the model for composing in-plane irradiation

Using diffuse and direct irradiation value estimated by the new model, in-plane irradiation value was estimated. To perform this, Isotropic model, Hay model, and Perez model were examined. The result is shown in Table 2. In this study, the result associated with Perez model showed the highest accuracy of estimation. The values of *RMSE* and *MBE* associated with Isotropic model result in greater relative to associated with the others.

Table.2 Evaluation of the estimation model for in-plane irradiation (January 1998)

	One-minute value		Hourly mean value	
	RMSE [W/m^2]	MBE [W/m^2]	RMSE [W/m^2]	MBE [W/m^2]
Isotropic	238.42	164.68	228.02	163.47
Hay	66.73	54.42	63.02	54.42
Perez	45.50	25.30	37.71	25.30

6. Conclusions

In this work, a new estimation model for in-plane irradiation using only instantaneous global horizontal solar irradiation was proposed. The weather information can be observed from the transition of time-series data. The accuracy of estimation could be improved. In addition, the climate information is included in this model so that the accuracy of estimation is expected to be improved when one-minute data is integrated.

In case of making a observation network, the result of this work can provide a guide that one-minute global horizontal irradiation value should be measured, at least as row data.

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REFERENCES

[1] Study on meteorological data for optimal design of PV systems, NEDO Contract Study Report, March 1998(In Jpn.).