Accuracy of estimated shading loss ratio by means of the SV method
~ An extraction algorithm of maximum pattern ~

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ABSTRACT

In our laboratory, the sophisticated verification method, which is the evaluation method for PV systems, has been developed. The accuracy of evaluation shading effect by using the SV method was not described because it is difficult to measure the shading effects. The procedure of estimation method is base on certain assumption. Therefore, in this paper, the accuracy of evaluation shading effect was indicated in the way to evince the adequacy of assumptions. As a result, depends of location and the data set up was indicated.

INTRODUCTION

The rapid growth and expansion of grid-connected photovoltaic (PV) systems utilization is significantly beneficial to the mitigation of environmental issues. Even though they are known as the maintenance free generation, PV systems have to be monitored and evaluated their output energy since certain troubles have been reported that PV systems could not generate energy as much as they are expected - shading effect around buildings and trees, the failure of system rating, the repression of output energy by over voltage control, and the failure of construction, and so on. An evaluation method for PV systems seems to be necessary. In our laboratory, the sophisticated verification (SV) method [1], which is the evaluation method for PV systems, has been developed. The SV method can estimate system losses by using a few monitoring data items despite of numerous kinds of losses, which seem not to be measured. Especially shading losses are one of the difficult to identify after established. However, the accuracy of evaluation shading effect by using the SV method was not described because it is difficult to measure the shading effects. The procedure of estimation method is base on certain assumption. Therefore, in this paper, the accuracy of evaluation shading effect was indicated in the way to evince the adequacy of assumptions.

The SV method

The SV method can estimate system losses from irradiation energy (optical energy) to system electricity output power (AC power). Evaluating needs typical four monitored data such as in-plane irradiation data, cell junction temperature - which can be estimable from ambient temperature, array output power, and system output power, so that the system losses are allocated the part of the total system loss. In the latest version of the SV method, classifiable characteristics of PV systems are eight factors: shading losses, optical losses, losses by load mismatching, temperature effect on module efficiency, power conditioner standby losses, power conditioner efficiency, DC circuit losses, and the other losses which reduce the fundamental system performance, for instance; soil on modules, depleted modules, and the erroneous system rate.

Procedures of estimation model for shading losses in the SV method

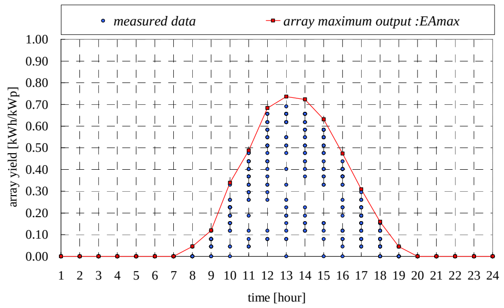
Fig. 1 was illustrated an example for estimated monthly shading rate on PV systems. Fist of all, the maximum of PV output data (E_{Amax}) were obtained each hourly. The curvature was assumed on a clear day condition with shading effect (ref. Fig. 1(a)). Next, a theoretical irradiation pattern was calculated by typical equations, and it was approached to E_{Amax} in the such a way that the curve envelopes the second top of E_{Amax}. The reason of second top is that the error of measured data was considered. As shown Fig. 1 (b), the gap between E_{Amax} and the theoretical output pattern (E_{Ath}) was assumed to be shading effect interrupting a part for direct irradiance in a specific month. Apparently, the effect of shading can be recognized form 8:00 to 11:00 and 16 to 18 as shown in the Fig. 1 (c). If the diffusion component was assumed 20% that is on a standard clear day because E_{Amax} was close to a clear weather day, Eqn. (1) can calculate shading loss factor. In this procedure, two major conditions were assumed based on experiment.

i) Trends of Irradiation is the same on clear day in a month

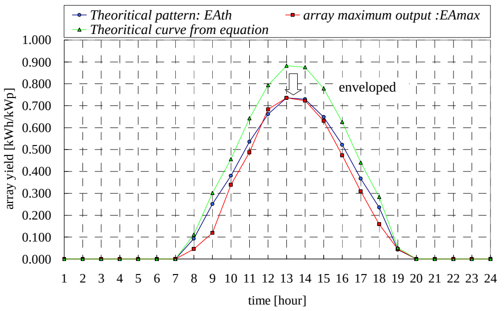
ii) Maximum data is corresponding to clear day pattern.

$$R_{HS} = \frac{(E_{A\max} - 0.2 \cdot E_{Ath})}{0.8 \cdot E_{Ath}} \quad (1)$$

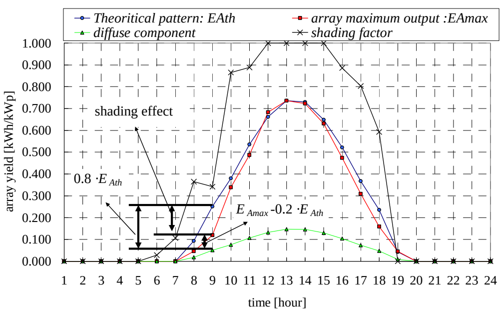
(1.0 is corresponding to no shading)



(a) Measured Irradiation components



(b) Ideal Irradiation components



(c) Shading loss factor

Fig. 1. Schematic of the estimation model for shading loss factor

Evaluation of assumptions

Trends of Irradiation in a month

In order to evidence the trends of irradiation on clear day, estimation models of global irradiance was used (Eqn. (2)). The global irradiance is composed of direct and diffuse irradiance. The direct irradiance is formulated by Eqn. (3). Three model of estimation for diffuse irradiance, Berlage, Matsuo, and Nagata, were selected. As a result of comparing, the accuracy and trend of irradiance were similar with the others on clear day condition. The Berlage model was chosen as estimation model in this paper (Eqn. (3)). The model was assumed the ideal Rayleigh scattering to develop the formula.

$$h_g = h_b + h_d \quad (2)$$

$$h_b = \tau^{AM} \cdot h_{og} \quad (3)$$

$$h_d = 0.5 \cdot h_{og} \cdot \frac{1-\tau^{AM}}{1-1.4\ln\tau} \quad (4)$$

h_g	: Global irradiance	[kW/m^2]
h_b	: direct irradiance	[kW/m^2]
h_d	: Diffuse irradiance	[kW/m^2]
h_{og}	: extra-territorial global irradiance	[kW/m^2]
AM	: airmass	[-]

The atmospheric transmittance and airrmass were primary parameters due to estimate the global irradiance. The dependency of two parameters was demonstrated with Berlage models.

Moreover, Location is one of parameter for irradiance. Varying the latitude and longitude, the irradiance was estimated where the range of those was in Japan (latitude is 20 to 45, and longitude is 120 to 145). The atmospheric transmittance was used the average of monitoring data from 1961 to 2000 at Tateno, Japan (show in Fig.2)

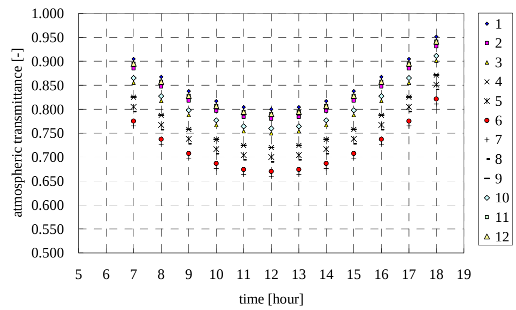


Fig. 2 atmospheric transmittance (base on Tateno data)

Maximum data pattern in a month

Maximum data pattern of PV system data seems to be the trend on clear day condition; for example irradiation and PV output power. Fig.3 was shown as the typical monthly pattern, and measured data was hourly data. In contract, the scattering on edge of cloud cause to increase the diffuse irradiation rather than clear day pattern. The maximum data may deviate from clear day condition as shown in Fig. 4. Basically, the effect is absorbed by averaging of hourly data.

To mean the top of data in the month, the specific circumstance is ignored. However, other errors are intended to exit if numerous data is used by the average. Total losses of shading were the objective function, and the average data was changed from top 1 to 10 data. Measured data was obtained from the acquisition system of Japan meteorological agency. Those are included the global irradiation with direct and diffuse irradiation. The number of site is 13, and location information shows Table 1. Obstructs around monitored sites were checked, and there were no obstructs.

In addition, the shading condition was imitated by using fish-eye photographs analysis [2]. The imitation obstruct was illustrated with sun tracks in Fig. 5. It was assumed to locate from the south west to north. Fig. 6 was indicated the evaluation result of shading loss ration each month on Matsumoto site. Conditions of no obstruct and the obstructs shown in Fig. 5 were calculated by using direct irradiation data. The shading influents on the direct irradiation, and test data were set 13 sites from 1990/1 to 2003/12.

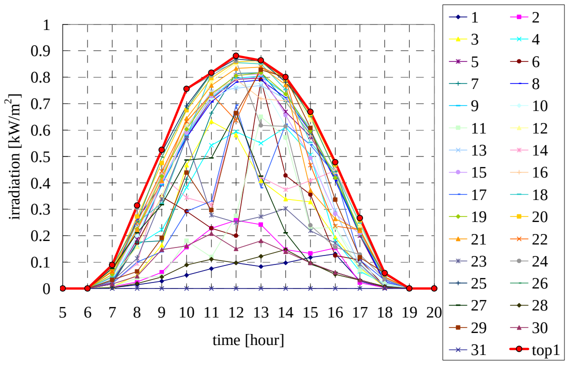


Fig. 3 Trend of irradiance in the month with maximum pattern

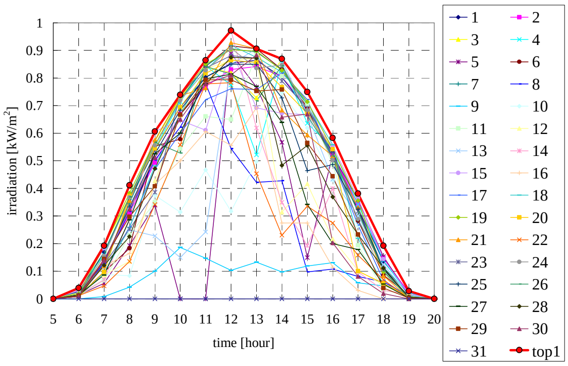


Fig. 4 Trend of irradiance in the month with maximum pattern. (Increased scattering irradiance by cloud)

Table 1. Site information of measured system

location	latitude [deg]	latitude [min]	longitude [deg]	longitude [min]	atitude [m]
Sapporo	43	3.4	141	19.9	17.2
Nemuro	43	19.7	145	35.4	25.2
Akita	39	42.9	140	6.2	6.3
Miyako	39	38.7	141	58.1	42.5
Wajima	37	23.4	136	53.9	5.2
Matsumoto	36	14.6	137	58.4	610
Yonago	35	25.9	133	20.5	6.4
Shionomisaki	33	26.9	135	45.8	73
Fukuoka	33	34.8	130	22.6	2.5
Kagoshima	31	33.1	130	33.1	3.9
Shimizu	32	43.1	133	0.7	31
Ishigaki	24	19.9	124	9.8	5.7
Naha	26	12.2	127	41.3	28.1

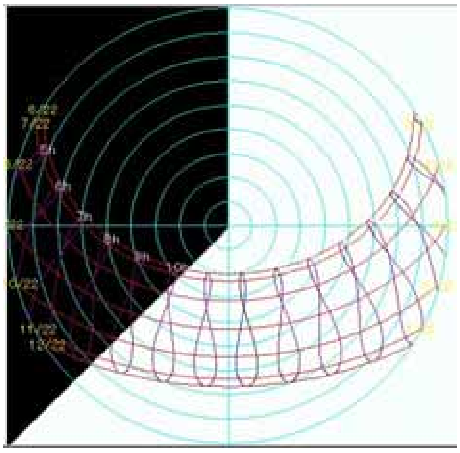


Fig. 5 The imitation obstruct with sun tracks on fish-eye photographs

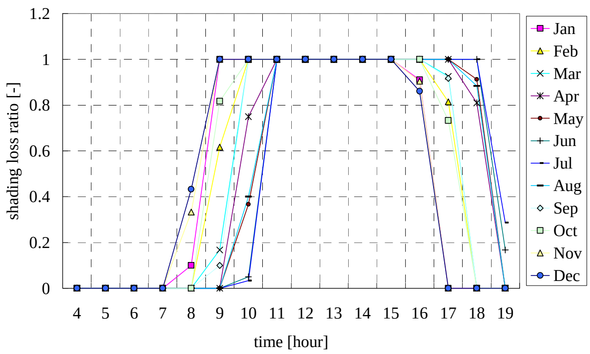


Fig. 6 Evaluated shading loss ratio by fish-eye photographs analysis

Evaluation results

Result of dependency on the atmospheric transmittance and airrmass

Estimated results of global irradiance were shown in Fig. 7. In this figure, extra-terrestrial irradiation was fixed 1.0 which was indicated to be clearness index. Increasing arimass, irradiation was getting low, and the atmospheric transmittance made up irradiation. Typically, the atmospheric transmittance is getting higher with lower of airmass. In other word, the differences of irradiation in month are decreasing.

The accrual condition result was demonstrated in Fig. 8. Evaluate results were calculated using airmass on located and the average of the atmospheric transmittance on sites. The result was the difference of irradiation in the month on the case of Matsumoto site. The gap of irradiation was not realized in June and December. During spring and fall in Japan, the irradiation was increased or decreased in spite of a month. If the maximum data at certain hour are selected in minimum case, and others are chosen n maximum case, the lower irradiation seems to be some trouble or shading effect

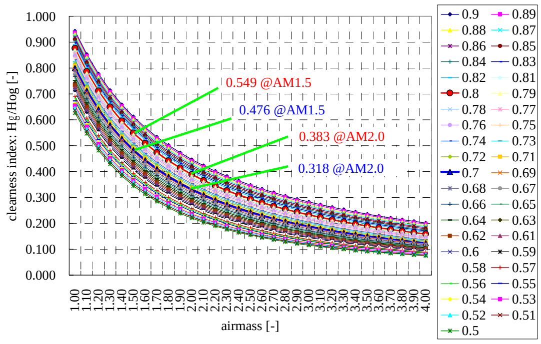


Fig. 7 dependency on the atmospheric transmittance and airrmass

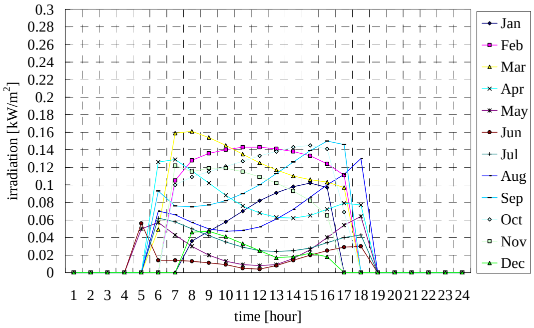


Fig. 8 Actual condition on Matsumoto site

Result of dependency on Location

The dependency of latitude was shown in Fig. 8. Longitude was locked up 135 deg, and the difference of irradiance in the month were 0.2 [kW/m^2] in worst case, March and October at 45 deg. Irradiation was changed in high latitude.

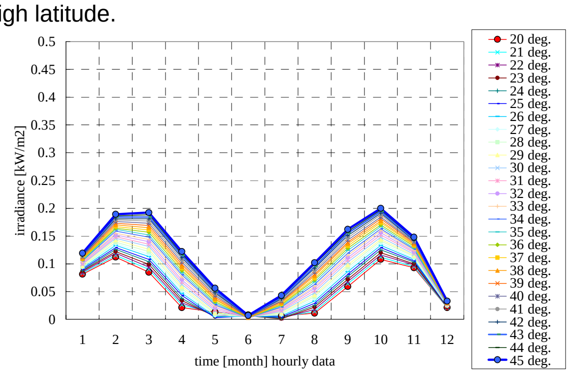


Fig. 9 Dependency of latitude for maximum difference of global irradiance in the month (12:00, longitude 135 deg.)

Evaluated result of average data points

Fig. 10 was illustrated the error of shading loss ratio on no shading condition. Using top of data in maximum data pattern .Error of shading ratio was higher because of maximum data pattern cased as show Fig. 4. However, the case of more than two data points, the error of ratio was lower. In fact, the shading loss ratio was less than 0.012 may ignore in evaluation. The algorithm of the SV method was useful for no obstructs condition.

On the shading condition, the error of shading loss ratio was shown in Fig. 11.In this case, to use top of data was the best way to evaluate the shading. However, the error was high value in the minimum case. The reason is that the shading was changed on time and location in the month, and the condition was specific. The azimuth of sun is intended in the advanced procedure.

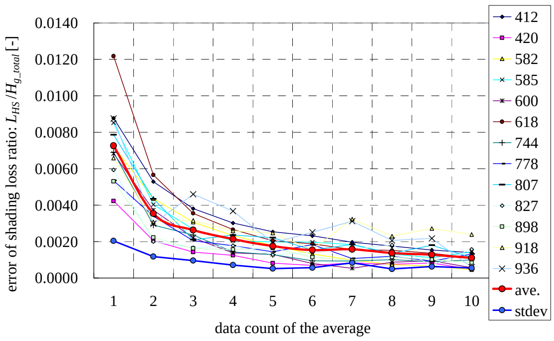


Fig. 10 error of shading ratio every data count of the average on the condition of no obstructs

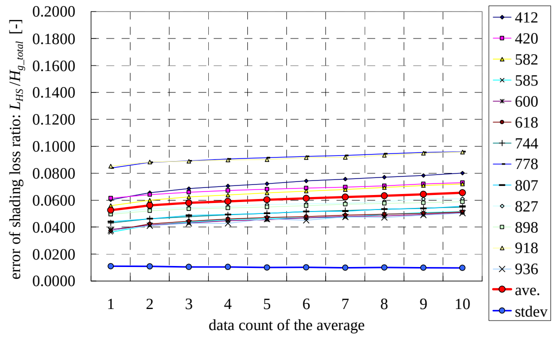


Fig. 11 error of shading ratio every data count of the average with shading condition

Conclusions

Prime factors for estimation of irradiation was evidence, and the difference of irradiance was raveled 0.2 kW\m^2] in the worst case. Estimation accuracy of shading losses were demonstrated less than 0.04. In the future, the azimuth of sun and diffuse ratio of clear day pattern were intended to include in the algorithm.

Acknowledgements

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References

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[2] K. OTANI, et al “A simple monitoring method for estimation of shading loss of photovoltaic systems", EuroSun98, 1998