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The Evaluation Method of PV Systems

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ABSTRACT

Data evaluation methods have wide adaptation ranges, such as feedbacks to PV system operation management and design. The authors have improved and established the fundamental model of the SV method that can identify six kinds of system loss rates using basis information and simply four measurable data.

1. Introduction

Japan Quality Assurance Organization (JQA) has arranged operational data from hundreds of PV systems, which were partially funded by New Energy and Industrial Technology Development Organization (NEDO) under the “Field Test (FT) Program”. Data evaluation methods have wide adaptation ranges, such as feedbacks to PV system employment management and design. In this study, Our Sophisticated Verification Method (SV method) of PV systems has been developed as a simple evaluation method. This method estimates loss factors of PV systems by field operational data. Outlines and analysis result of the SV method have been already presented in some papers by authors (e.g. [1]). In this paper, improved and extended algorithms of the SV method in order to produce more reliable and robust estimates and described.

2. Outline of the SV method

The SV method classifies loss factors of PV system operation into six kinds of system losses (shading effect, losses due to incident angle, load mismatch, efficiency decrease by temperature, inverter losses and other losses) using system specifications, such as latitude [deg], longitude [deg], inclination angle [deg], azimuth [deg], system rating: P_{AS} [kW] and temperature coefficient:a_{Pmax} [W/°C], and measured operational data (inclined-plane irradiation: H_A [kWh/m2], array output: E_A[kWh], system output: E_P [kWh] and module temperature: T_C [°C]). Before SV method analysis, diagnosis of quality of irradiation data is carried out, and outlying observations and missing data are compensated by external weather observations.

3. The SV method analysis

3.1 Principle of Loss rate definitions on monthly basis

This method adopts the model by appropriate assumption based from experience. It is the essence of the SV method to make each calculation model of losses for a month using each model and the measured data for every site. The principle of analysis of the SV method is shown in **Fig.1**. The Principle of Incident-angle-dependent rate definition is described as follows.

3.1.1 Principle of Incident-angle-dependent rate definition for a month

A scattered graph as shown in **Fig.2** also gives very important information. An upper straight line corresponds to ideal energy production: E_{AS}. Scattered dots are all the hourly data E_{AT} (it converts into cell temperature: 25[°C] of standard condition). A lower straight line is drawn as the upper envelope of scattered points by changing m_{NM}. The line is called “No mismatch line: E_{NM}” means the most efficient performance and no shading, no mismatch and not incident-angle-dependent.

$$E_{NM} = m_{NM} \cdot P_{AS} \cdot H_A / G_S$$

E_{AT} to H_A does not become a perfect proportionality relation by being due to incidence angle, but becoming the curve fell for a while from the straight line relation in the small range of H_A is known). Therefore a lower curve is drawn as changing m_{NI} of the following formula. The curve is called "Independence incident angle line: E_{NI}" means almost no being due to incidence angle.

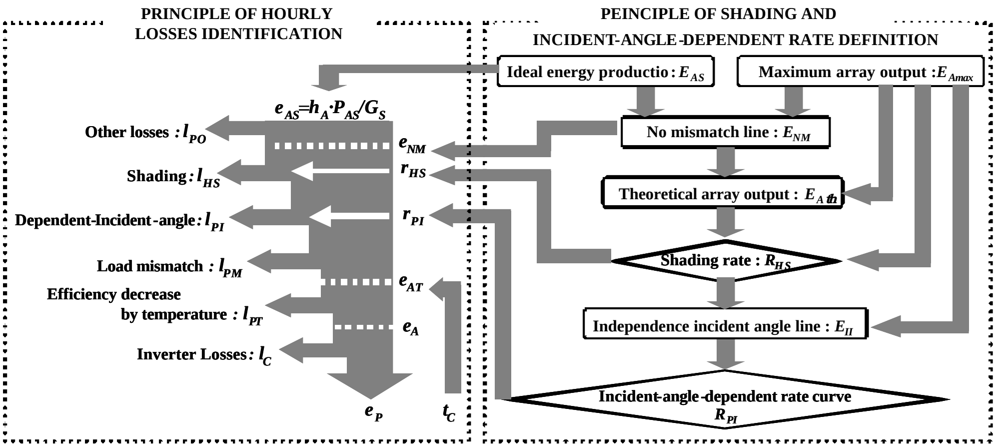

Fig1 Principle of analysis of the SV method

$$E_{NI} = (1+m_{NI})\cdot H_A - m_{NI}\cdot\{1-\exp(-8\cdot H_A)\}$$

E_{II}, E_{NM} and incident angle corresponding to hourly h_A is determine, and the maximum ratio of E_{II} and E_{NM} is extracted for every incident angle (Refer to **Fig.3**). The curve is adjusted to fit scattered points by changing m_{PI} from the following formula. The envelope shows the rate of loss for every incident angle: R_{PI}

$$R_{PI} = m_{PI}\,(1/\cos q - 1)$$

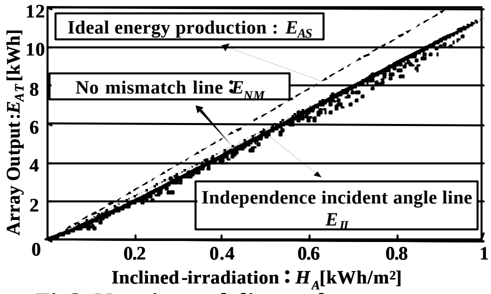

Fig2. No mismatch line and Independence incident angle line

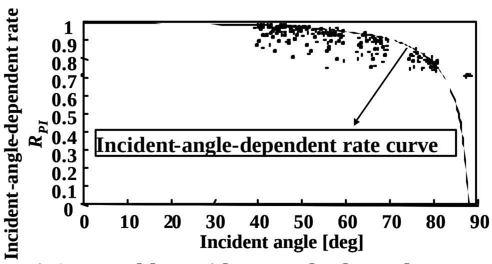

Fig3. Monthly Incident-angle-dependent rate

3.2 Principle of Losses identification on hourly basis

Hourly losses are identified by the following formula. Losses by shading and incident-angle-dependent are separate using each loss rates and a diffused component: r_g.

$$l_{HS} = \{(1-r_g)\cdot h_A\cdot P_{AS}\}\cdot(1-r_{HS})$$

$$l_{PI} = \{(1-r_g)\cdot h_A\cdot P_{AS} - l_{HS}\}\cdot(1-r_{PI})$$

$$l_{PM} = (e_{NM} - l_{HS} - l_{PI}) - e_{AT}$$

$$l_{PT} = \{a_{P\max}\cdot(25-t_C)\}/\{1+a_{P\max}\cdot(t_c-25)\}\cdot e_A$$

$$l_C = e_A - e_P$$

$$l_{PO} = e_{AS} - e_{NM}$$

4. An evaluation result by the SV method

As a part of FT, NEDO has installed around 260 PV systems over Japan since FY1992. The average of parameters was estimated by the SV method for four fiscal years FY1995 to FT 1999, as shown in Fig.3. To valid data out of actually monitored total of 421 sites are chosen in 525 sites.

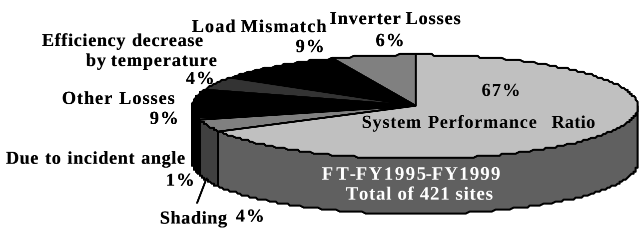

Fig.3 An evaluation result of FT by the SV method

5. Comparison with fisheye photograph analysis

Shading losses analysis using fisheye photographs have been also developed by another group in the authors' organizations in order to identify with shading factor [2]. The comparison with the SV method and the fisheye photograph analysis analyzed the data from a 70 kW PV system in AIST Tsukuba for two years. This result is shown in **Fig.4**. There are differences of the range of values between SV method's estimation and fisheye photograph analysis's estimation, but the tend of the time-series is almost the same. The difference of the range was likely caused by the deference of treat ment diffuse irradiation.

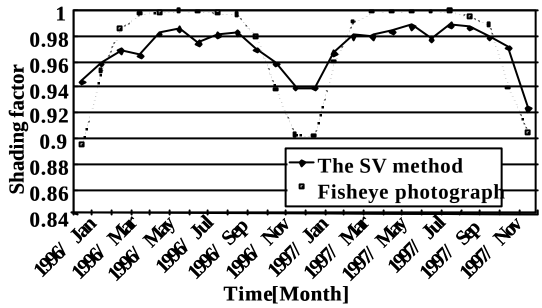

Fig.4 Comparison with fisheye photograph analysis

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6. Conclusions

The SV method developed at this study has established the fundamental model. The measurement errors in field data have been able to be compensated by introducing quality diagnosis, and the algorithm of this method had been improved, therefore evaluation result have become better than the previous model.

Nomenclatures

- P_{AS} [kW]: System rating
- a_{Pmax}[W/°C]: Temperature coefficient
- H_A[kWh/m^2] : Inclined-plane irradiation
- E_A [kWh]: Array output
- E_P [kWh]: System output
- T_C [°C]: Module temperature
- E_{AT} [kWh]: Array output converts into cell temperature 25[°C]
- E_{NM} [kWh: Array output on No mismatch line
- E_{II} [kWh]: Array output on Independence incident angle line
- E_{AS} [kWh]: Ideal energy production:
- L_{HS} [kWh]: Shading losses
- L_{PI} [kWh]: Incident-angle-dependent losses
- L_{PM} [kWh]: Load mismatch losses
- L_{PT} [kWh]: Efficiency decrease by temperature
- L_C [kWh]: Inverter losses
- L_{PO} [kWh]: Other losses
- R_{HS}: Shading ratio
- R_{PI}: Incident-angle-dependent loss ratio
- R_g: Diffused component
- q [deg]: Incident angle

Reference

[1] Kosuke KUROKAWA, " Realistic PV performance values obtained by a number of grid-connected systems in Japan " Energy Congress VI, 2000

[2] Kenji OTANI, *et al.* "Shading loss analysis of PV systems in urban area" PVSEC-12, Jeju, Korea, 2000