AN EVALUATION RESULT OF PV SYSTEM FIELD TEST PROGRAM FOR INDUSTRY USE BY MEANS OF THE SV METHOD

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ABSTRACT

The authors have been developing an evaluation method, the Sophisticated Verification method (the SV method), for analyzing monitored data, which are observed at PV systems in Field Test sites. This paper is aimed at grasping the standard of a performance and a characteristic for PV systems due to the result evaluated monitored data, "PV system field test program for industry use", by the SV method, and which is compared with examples of field investigation reported by Resources Total System co., Ltd.

1. Introduction

In Japan, new energy sub committee under Agency for Natural Resources and Energy, Ministry of Economy Trade and Industry (METI), formulated the goal to be established the total of photovoltaic systems - 48,200,000 kWp in 2010. Consequently, photovoltaic systems intend to be a main generation of renewable energy, and a large number of PV systems installed in Japan has been the top of the world. Technologies of the PV system, in contract, are considered to be still scant and are deemed necessary to improve more in tandem with penetration of PV. Especially technologies for reliability of operation seem to be the most important because somewhat troubles or effect have been informed from existing PV systems such as a system rate issue, maintenances, and system failures

For the reliability demonstration of PV systems, Field Test project (FT) has become operative since New Energy and Industrial Technology Development Organization (NEDO) commenced the 1st stage of it that promote to install PV systems for public buildings at FY1992. Although this stage was completed supporting the introduction at FY 1997, the 2nd stage of the project, "PV system FT Project for industrial use", commenced again at FY 1998.

2. Object

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; for instance, effect shading around buildings and trees, problem the failure of system rating, the repression of output energy by over voltage control, and the failure of construction, and so on. Moreover, the output energy is more important than PV system rate if environmental issue is focused. As of now, output energy from PV systems is not clear due to that it is difficult to characterize actual performance of PV systems. As a result, an evaluation method for PV systems seems to be necessary because evaluations is useful and helpful for the management of PV systems operation as well as output energy.

The authors have been developing an original evaluation method, the SV method, for analyzing monitored data, which are observed at PV systems in Field Test sites [1][2]. The latest version of the SV method can identify eight kinds of losses in PV systems. The evaluation result affords to determine characteristics of PV and applies to be management technique for operation of PV systems [2].

This paper is aimed at grasping the standard of a performance and a characteristic for PV systems due to the evaluation result of monitoring data in the 2nd FT project, and the result is compared with examples of field investigation reported by Resources Total System co., Ltd (RTS) [3] so that this method can be as management technique for reliability of PV system operating.

2. Field Test program in Japan

Since FY 1992 NEDO (New Energy and Industrial Technology Development Organization) has supported the installation of 186 sites, which are 187 systems – one of theme has two systems – and the total capacity of 4,900 kWp, as of FY 1997 under the scheme for the 1st stage of FT project, "PV system FT Program for Public facilities". Although the 1st stage was completed supporting the introduction at the end of FY 1997 – the project had continued to collect performance data until FY 2001, the 2nd stage of the project, "PV system FT project for industrial use", commenced to install 73 sites (1,940 kWp) at FY 1998, and has already introduced 315 sites, which include 93 sites (2,790 KWp) in FY 1999 and 149 sites (3,680 kWp) in FY 2000. The total capacity has been 8,410 kWp for 3 years. As for this stage, the project has invited public participate of installable systems as a standardization promotion type and a new format utilization type. The objective of the project was originally to introduce PV technology to industrial applications and reducing costs. Additionally, the standardization promotion facilitates to be the simplification of the way to PV systems' application and familiarize for construction of them according to standardizing the PV system as 10 kWp. For the purpose of the new format utilization type, Building Integrate of PV (BIPV) systems and systems composed thin film modules are able to afford diffusion on the market. All of the systems, moreover, carry their monitoring equipments, and those data are obtainable for evaluating the performance. Annual data (from January to December in 1999 and 2000) have been collected for systems which were installed from 1998 to 2000, and the fundamental evaluation was reported the current status installation and operations of the industrial PV systems as well as investigating its characteristics and issues by RTS.

3. The SV method

The SV method has been developed as an evaluation method, which is using monitored data. During converting input energy into output energy, the PV system has numerous kinds of losses, which seem not to be measured. The SV method, however, 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. For 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. **Fig 2** gives the schematic diagram of the SV method, and the principle of the SV method is show in **Fig 1**. The method has two basic models, monthly and hourly, are illustrated in **Fig 1** [2]. As of hourly model, this method adopts ordinary formulas in order to classify those characteristics, performance ratio, power conditioner efficiency, and temperature effect on efficiency. The essence of the method, in addition, is to draw the performance lines which are based on certain assumptions from experience according to real monitored data in the principle of monthly. **Fig 3** is illustrated an example for estimated monthly shading rate on PV systems. In this case, the trend of output power on clear day is not the same as a theoretical pattern by shading effect during a specific month. Shading is expected to be over the PV array at same time every day in specific month, and array output at certain time is dropped from theoretical pattern. As a result, shading loss can estimate due to compare the pattern of monitoring data developed with theoretical pattern. The SV method can identify base on those assumptions and experiment of relation between monitoring data and effect of losses. This kind of pattern is useful for estimating loss power. Other examples, **Fig 4** intends to be correlation diagram between irradiation and output power monitored in the month and performance lines. Three performance lines and one additional line are defined as show in **Fig 4**. Performance line indicates boundary line of performance. Standard Performance line is rated output corresponding with certain irradiation data. Ideal Performance line and Best Performance line is drawn and fit by considering maximum output as much as possible in specific site and month. Those performance every irradiation indicate boundary performances; for example, between Best performance line and array output monitored is consisted of losses, shading, load mismatch, and effect of incident angle. Consequently, losses can be identified by using performance ratio and loss rate models. To develop an individual evaluation model of losses for a specific month and a specific site to improve to identify losses, which are difficult to measure on site; *i.e.,* shading effect, load mismatch, incident-angle optical losses, and DC circuit losses, by using the SV method.

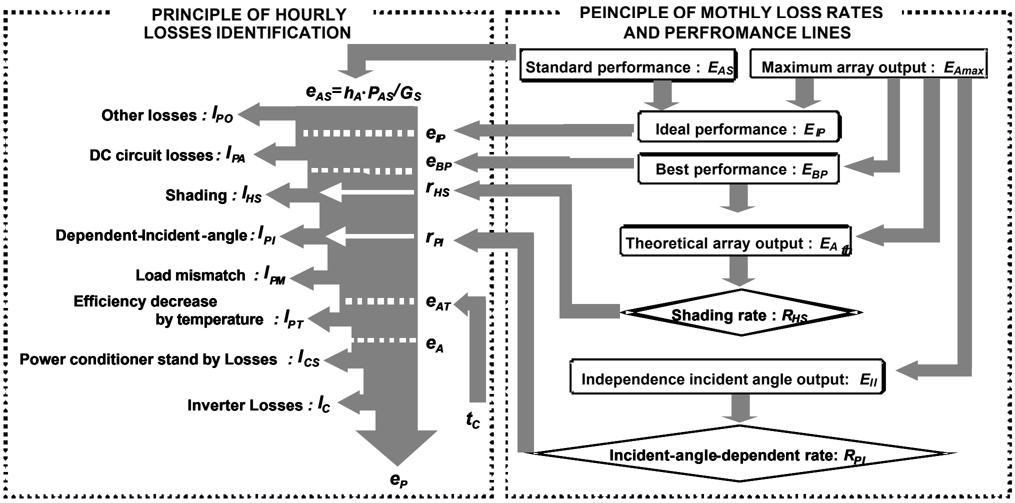

Fig 1. The principle of analysis via the SV method.

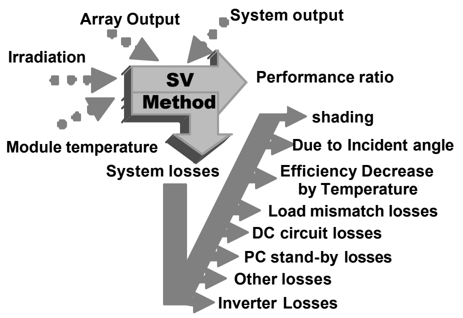

Fig 2. The schematic diagram of the SV method.

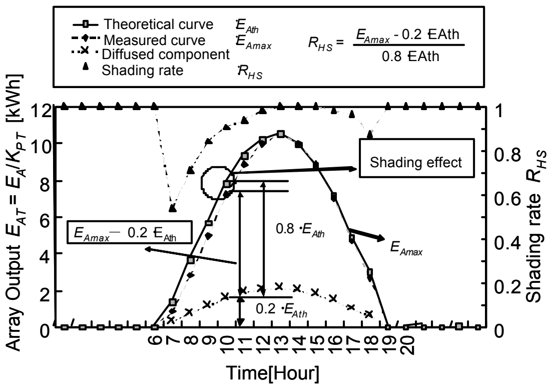

Fig 3. Model of identifying monthly shading rate.

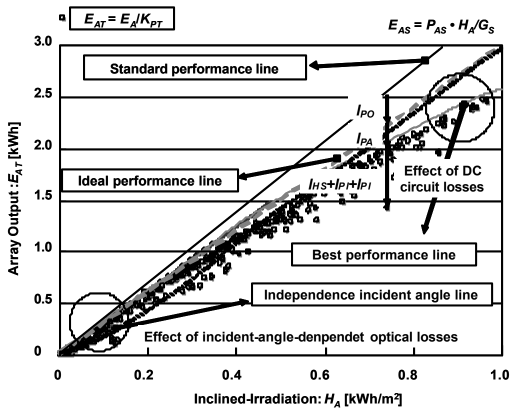

Fig 4. Performance lines of monthly model.

3. An example of report for trouble

According to report by RTS [3], the number of troubles in systems installed in FY 1998 were 244 cases, that of in FY 1999 were 180 cases and that of FY 2000 were 293 cases respectively, 717 cases in total. Out of 717 cases 170 system-related troubles were reported accounting for 23.7 %, unidentified caused troubles were many accounting for 2.2 %, and the rest of the troubles were all measurement-related troubles. Overwhelming majority of system-related troubles was caused by abnormal temperature rise of inverters, and operation of grounding relay. Major causes of measurement-related troubles are computer freeze, wrong operation and missing data measurement due to careless cut-off of computer power source. **Table 1** shows the report of trouble for PV systems in FT. Actual two examples of the trouble are illustrated from **Fig 5** to **Fig 7**. In this specific site and month, two kinds of reported trouble are about the inviter suspended. One of case is caused by abnormal temperature rise of inverters at May 5, 2000 (**case 1**). **Fig 5** shows the scattering plots between system output and irradiation monitored in this case. The inverter was stopped completely in clear day at that time, and it is easy to detect the trouble by means of monitoring only system output. In the other case, one of inverters is suspended on the system, which is consisted of multiple inverters, from 2000 4/20 to 4/26 (**case 2**). **Fig 6** shows the scattering plot under the condition of that. The straight-line illustrates rated system output corresponding to irradiation, and plots of circle illustrated monitoring data. Especially plots of christcross show monitoring data under the condition of reported trouble from 4/20 to 4/26, and plots of triangle are data after repaired automatically from 4/27 to 4/30, 2000. In the figure, the system output under the trouble case is indicated to be in proportion to system output of the faire condition because the data constellation of trouble case is straight-line corresponding to irradiation as well as the faire condition. It makes the detection of system failure be very complicated since system output is not 0 and is not able to compared with irradiation data, which is not correction in normal PV systems such as residential. **Fig 7** shows daily data of system output and performance ratio, and demonstrates that system output in the trouble is same as low output like cloudy day, and performance ratio is decreased in this case. Therefore, the failure is generally detected by monitored performance ratio. Performance ratio, however, cannot identify the reasons of reduced the performance of the system due to the fact that performance ratio is included effect of loss factors, shading, load mismatch, Temperature, and so on.

Table1. The report of trouble for PV systems in FT

Year		1998	1999	2000	Total
system	inverter failure	52	9	43	104
	Operating grounding relay	39	4	22	65
	other	0	0	1	1
total		91	13	66	170
monitoring system	computer freeze	73	9	137	219
	Wrong	15	14	26	55
	other	59	144	54	257
total		147	167	217	531

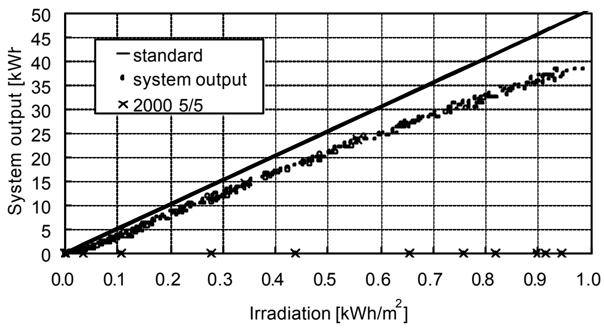

Fig5. The scattering plots between system output and irradiation monitored under the condition of trouble **case 1**.

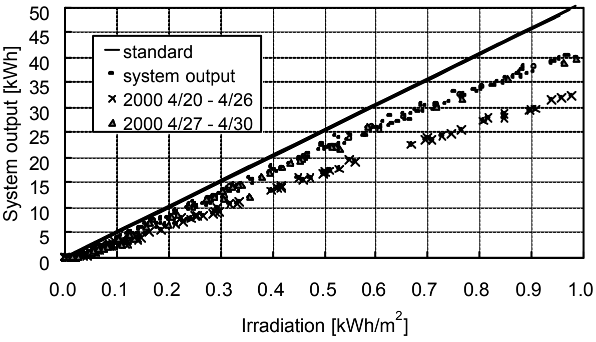

Fig 6. The scattering plots between system output and irradiation monitored under the condition of trouble **case 2**.

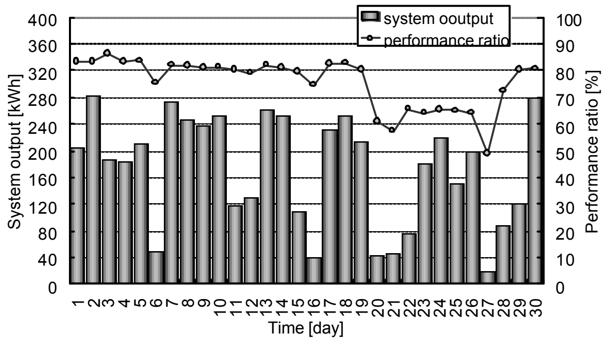

Fig 7. Daily system output and performance ratio under the condition of trouble case 2.

4. Evaluation results by the SV method

Fig 8 shows the evaluation results of **case 2** by the SV method. Legend shows the percentage of losses is referred to **Fig 1**. In this figure, daily losses are identified by the method, and parts of months have load mismatch loss greater than the other days. Those days is corresponding with trouble reported in **case 2**; therefore, the evaluation result is useful to detect the factor of failure and to quantify the loss of its.

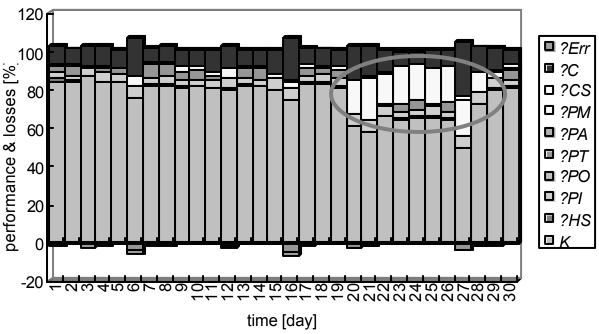

Fig 8. The evaluation result of **case 2** by the SV method

Moreover, **Fig 5** reveals the percentage of losses and shows an example of the evaluation result for 137 PV systems under the 'PV FT program for industrial use" by using the SV method - the total of 166 systems from 1999/1 to 1999/12. 137 systems were allowed to evaluate. Those PV systems are established in FY 1998 and FY 1999 under the project. The result can be the standard performance of PV system and apply to design factors.

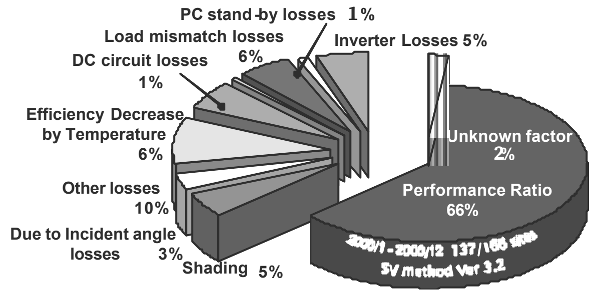

Fig. 9 The evaluation result for "PV FT program for industrial use" systems by using the SV method (2000/1-2000/12)

5. Conclusion

The evaluation method is very useful and helpful for management and operation of PV systems for life because it is usually difficult to clarify the performance of PV systems in the field. In this paper, one of evaluation method, the SV method, is demonstrated to be very available. According to comparison between evaluation results with actual examples, the trouble can be detected with factor, and losses are quantified. As a result, the SV method can be management tool with monitoring data.

We, additionally, intend to determine the standard of a performance and a characteristic for PV systems from average evaluation results of PV systems in field test project. The result should be feed back to design factors, and improve to estimate output energy.

In conclusion, reliability of the system will be secured accordingly by means of the SV method.

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