PV System Integrated Evaluation Software

Paulo Sergio Pimentel* Hiroshi Matsukawa** Takashi Oozeki* Toshiyuki Tomori* Kosuke Kurokawa*
*Tokyo University of Agriculture and Technology (TUAT)
2-24-16 Naka-cho, Koganei, Tokyo, 184-8588 Japan
**Resources Total System Co., Ltd.
2-3-11 Shinkawa, Chuo-ku, Tokyo, 104-0033 Japan

ABSTRACT

This paper presents the features of the PV system integrated evaluation software (PVI) developed by Kosuke Kurokawa Lab. team at Tokyo University of Agriculture and Technology (TUAT). PVI was created to assist in the design of grid-connected PV system applications, and mainly consists of a basic design tool and optional tools. The basic design tool is used to determine the PV system annual output energy and system losses percentage based on a detailed parametric analysis on an hourly basis. The optional tools are used for PV applications under complex conditions, including a shading evaluation tool from fish-eye lens pictures for systems facing shading problems, array simulation tool for systems with arrays installed due to different orientations or technologies, and interface to Sophisticated Verification (SV) method statistical data. The last one allows the user to feedback existing systems performance and loss pattern information to new PV system design projects. Future developments involve validation of the outputs against measured values from actual worldwide systems.

BACKGROUND

The popularization of PV systems has led to the development of tools to estimate the output energy characteristics of new systems, and models based on parametric analysis have been widely used for this purpose, especially because of its simplicity. However, according to the complexity of PV system's characteristics, and the increasing of arrays facing shading problems and various installation modes, a detailed and integrated analysis of the design parameters involved in the analysis is necessary. Therefore, there is a need to develop computerized tools able to determine the potential energy output characteristics and operating performance of PV systems under such complex conditions.

PVI SOFTWARE FEATURES

Software General Features

The PV system integrated evaluation software is a unique tool developed by Kosuke Kurokawa Lab. team at Tokyo University of Agriculture and Technology (TUAT) to assist in the design of grid-connected PV system applications. The software mainly consists of a basic design tool and optional tools, representing the laboratory know-how on evaluation and design of PV systems. Basic design tool allows the user to determine system output energy and system losses percentage based on a detailed parametric analysis [1]. PVI also provides the user optional tools for PV applications under complex conditions, such as shading problems, and arrays installed due to different orientations or technologies. Optional tools include one to determine shading correction factor from fisheye lens pictures [2], array simulation tool [3], and interface to statistical data from Sophisticated Verification Method [4].
PVI also have the following features:

- It is a Windows Multiple Document Interface (MDI) that permits the use of six projects at once, making possible the comparison between different installation modes, weather conditions and electrical configurations

- Covers wide range of geographical areas all over the world. Japanese MEteorological Test data for PhotoVoltaic system (METPV), and the worldwide Meteonorm V4.0 hourly weather data can be imported to PVI. User actual data also can be used in PVI simulations

- Includes models to determine cell temperature, and in-plane radiation onto fixed and tracking (1 or 2 axis) arrays
- Includes approximate curves for important parameters such as inverter efficiency and incident angle dependence, allowing the user to adjust the expression parameters
- Report function is available to preview, save, and print the analysis results
- SV Method Database table with sorting function is available to give the user a feedback of existing PV system loss parameters characteristics to new PVI projects
- Includes a PV module database to determine arrays I-V curve used in the array simulation tool
- Includes help function
- Japanese and English versions are available

In this paper, an example system in China is used to illustrate the software use.

Basic Design Tool

The basic design tool is the core of PVI software. Grid-connected system annual output energy and loss pattern can be determined from few input parameters, by using a detailed parametric analysis.
Important design parameters, such as temperature correction coefficient, and shading correction factor are calculated in an hourly basis. Inverter efficiency (see Fig.1), and incident angle dependence are calculated from approximate curves, and the expression parameters can be adjusted to fit the user needs.
For systems under complex conditions, detailed values for the parameters involved in the analysis can be integrated to the basic design tool by using the optional tools. For example, shading loss data can be acquired from the shading analysis tool, and other system parameters can be acquired from SV Method database.
Annual system yield simulation result for a site in China is shown in Fig.2. System performance and loss pattern for the same system is shown in Fig.3. Hourly data from Meteonorm V4.0 was used in the analysis.

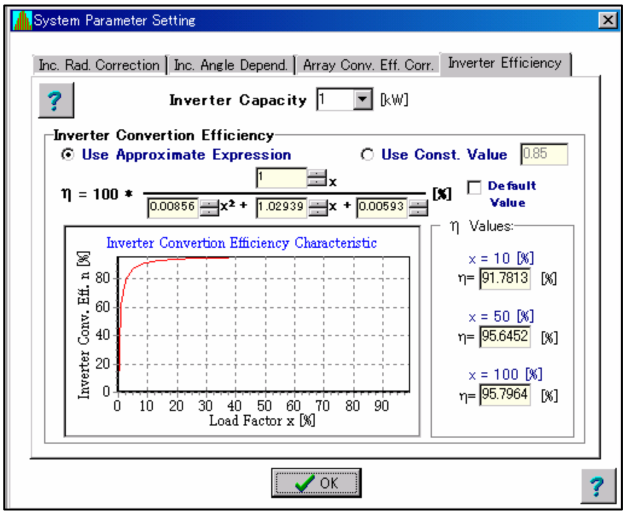


Fig.1. System parameter setting (inverter conversion efficiency).

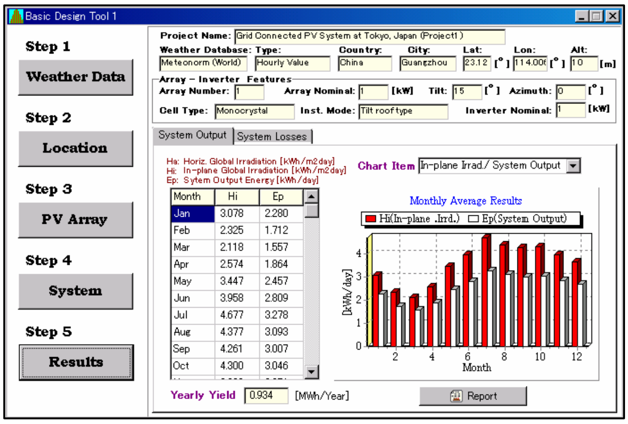


Fig.2. Basic design tool results for a site in China (annual output energy against in-plane irradiation).

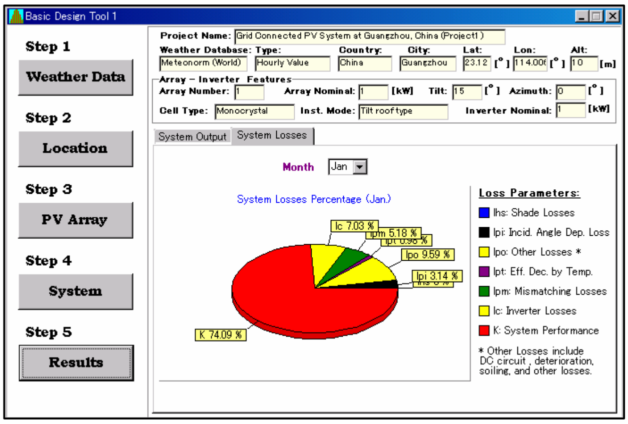


Fig.3. Basic design tool results for a site in China (monthly system performance and system loss pattern).

Optional Tools

- Array shading evaluation tool using fisheye lens pictures:

A detailed analysis for PV systems facing shading problems can be performed by using the array shading evaluation tool from fisheye lens pictures (see Fig.4). The shading correction factor is calculated from on-site pictures, giving an important feedback of the system shading losses. The shading factor derived from the shading coverage area is integrated to the parametric analysis, giving accurate and realistic estimates of system output energy. The yearly shading losses analysis for the system in China is shown in Fig.5.

Fig.4. Image of the shading analysis tool.

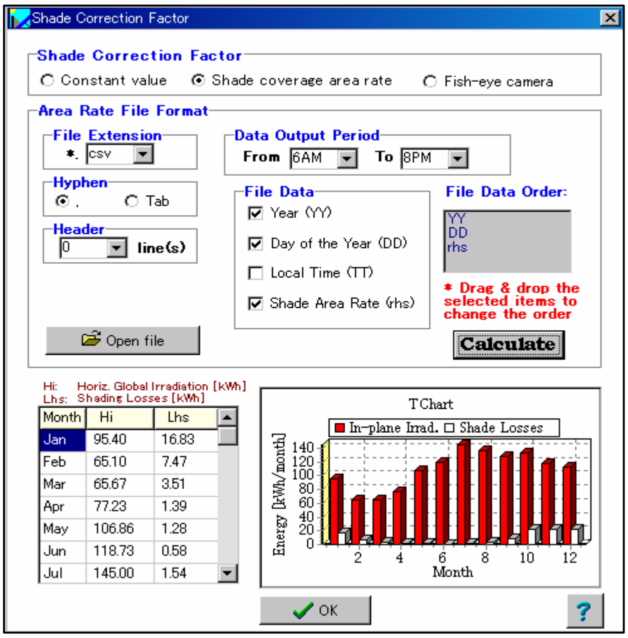


Fig.5. Shading analysis results for a site in China (monthly shading losses against in-plane irradiation).

- Array simulation tool:

Array simulation tool is used for systems with modules of different technologies, installed due to different orientations, or having partial shadowing problems.

Here, a detailed data setting is required. After determining the module I-V curve (see Fig.6) from the PVI modules database, the user set the array orientation and wiring configuration data for until four arrays (if the arrays are connected in series or parallel, and if they include bypass, blocking diodes or not).

The analysis is based on simplified I-V curve interpolation considering the characteristics of each module in the array.

Excellent results for this simulation method have been already confirmed [3]. Fig.7 shows the results of annual yield for a PV system in Tokyo containing two modules connected in parallel, and facing different orientations.

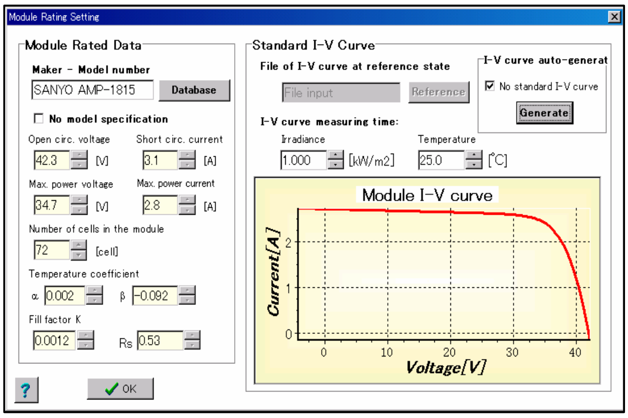


Fig.6. Module I-V curve determined from PV module database values.

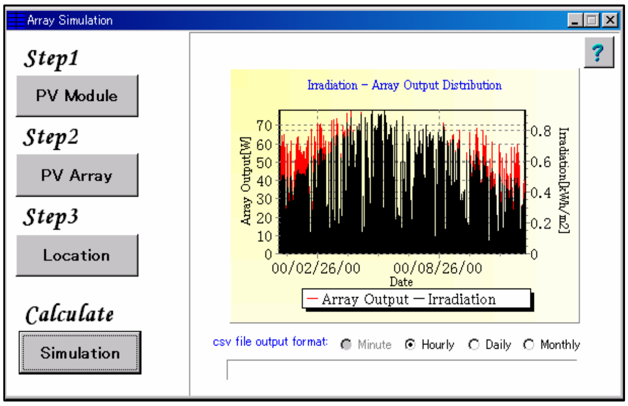
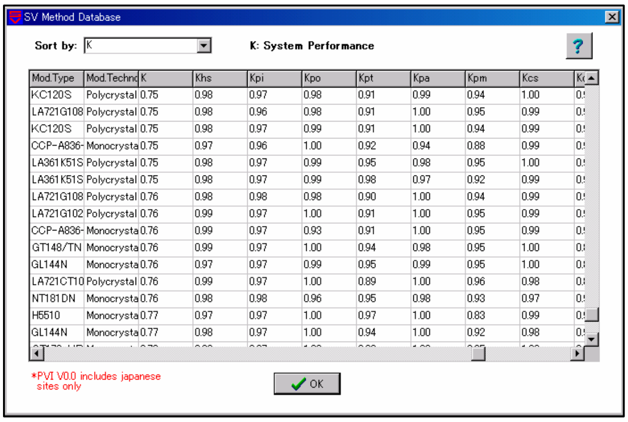


Fig.7. Array simulation result for a site in Tokyo (annual energy output).

- Sophisticated Verification (SV) Method feed-back:

The SV Method, which was also developed in this laboratory, is a simple evaluation method to identify eight kinds of system loss rates by using the existing system basic information: latitude, longitude, rated system power, etc. and simple four monitored data: in-plane irradiation, array output energy, system output energy, and module temperature.
The results obtained from SV method evaluation can be grouped considering regional aspects, makers, and so on, providing the PVI user an important feed-back of the existing PV system loss parameters characteristics to the design of new systems.
Fig. 4 shows the PVI interface for SV Method statistical data from 1995 to 2000 for sites in Japan.



Mod.Type	Mod.Techno	K	Khs	Kpi	Kpo	Kpt	Kpa	Kpm	Kcs	Kc
KC120S	Polycrystal	0.75	0.98	0.97	0.98	0.91	0.99	0.94	1.00	0.
LA721G108	Polycrystal	0.75	0.98	0.96	0.98	0.91	1.00	0.95	0.99	0.
KC120S	Polycrystal	0.75	0.98	0.97	0.99	0.91	1.00	0.94	0.99	0.
CCP-A836-	Monocrysta	0.75	0.97	0.96	1.00	0.92	0.94	0.88	0.99	0.
LA361K51S	Polycrystal	0.75	0.98	0.97	0.99	0.95	0.98	0.95	1.00	0.
LA361K51S	Polycrystal	0.75	0.98	0.97	0.99	0.98	0.97	0.92	0.99	0.
LA721G108	Polycrystal	0.76	0.98	0.98	0.98	0.90	1.00	0.94	0.99	0.
LA721G102	Polycrystal	0.76	0.99	0.97	1.00	0.91	1.00	0.95	0.99	0.
CCP-A836-	Monocrysta	0.76	0.99	0.97	0.93	0.91	1.00	0.95	0.99	0.
GT148/TN	Monocrysta	0.76	0.99	0.97	1.00	0.94	0.98	0.95	1.00	0.
GL144N	Monocrysta	0.76	0.97	0.97	0.99	0.95	0.99	0.95	1.00	0.
LA721CT10	Polycrystal	0.76	0.99	0.97	1.00	0.89	1.00	0.96	0.98	0.
NT181DN	Monocrysta	0.76	0.98	0.98	0.96	0.95	0.98	0.93	0.97	0.
H5510	Monocrysta	0.77	0.97	0.97	1.00	0.97	1.00	0.83	0.99	0.
GL144N	Monocrysta	0.77	0.98	0.97	1.00	0.94	1.00	0.92	0.98	0.

Fig.8. SV Method statistical data table.

Design parameters which can be acquired from SV Method:

K : System performance ratio
K_{HS}: Shading correction factor
K_{PI} : Incident-angle-dependent correction factor
K_{PO}: Other losses factor (include deterioration, and soiling on module surface)
K_{PT} : Temperature correction factor (efficiency decrease by temperature)
K_{PA} : Array circuit correction factor (array circuit losses)
K_{PM} : Load mismatch correction factor
K_{CS} : Inverter stand-by correction factor
K_{C} : Inverter correction factor

RESULTS AND FUTURE TASKS

The main structure of the PV System Integrated Software described in this paper is completed, and future developments of this project involve the validation of output results against measured values from actual worldwide systems.

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REFERENCES

[1] T. Sugiura, T. Yamada, H. Nakamura, M. Umeya, K. Sakuta, and K. Kurokawa, "Measurements, Analysis and Evaluation of Residential PV Systems By Japanese Monitoring Program", *12th International PVSEC*, Jeju, Korea, 2001, p.771

[2] T. Tomori, K. Otani, K. Sakuta, and K. Kurokawa, "On-Site BIPV Array Shading Evaluation Tool Using Stereo-Fisheye Photographs", *28th IEEE Photovoltaic Specialists Conference*, 2000, Anchorage, AK, p.1599

[3] H. Matsukawa, M. Shioya, K. Kurokawa, "Study on Simple Assesment Method of BIPV Power Generation for Architects", *28th IEEE Photovoltaic Specialists Conference*, 2000, Anchorage, AK, p.1648

[4] T. Oozeki, T. Izawa, K. Otani, and K. Kurokawa, "The Evaluation Method of PV Systems", *12th International PVSEC*, Jeju, Korea, 2001, p.741