

Dynamic Evaluation of Maximum Power Point Tracking Operation with PV Array Simulator

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ABSTRACT

This paper presents a quite new proposal how to measure the dynamic control ability of Maximum Power Point Tracking (MPPT) for PV inverters under the condition of fluctuating irradiance. It is a kind of indoor testing facility and easy to be adopted by industries. Basic functions are given by a specially designed PV array I-V curve simulator composed of the active power load (APL). Most of parameters are controllable by sophisticated software within very short time and for very long period of time. In this paper detailed structure of the equipment is described and test examples are also given by using a commercial PV inverter.

1. Introduction

It is effective for test of PV inverter using PV array I-V curve simulator which is able to reproduce variable conditions. Tokyo University of Agriculture and Technology (TUAT) and Myway Labs Co., Ltd have developed a PV array I-V curve simulator. The simulator is based on the active power load (APL) of Myway and software for I-V curve simulation of TUAT. Using this simulator, the I-V curve studied by Matukawa et al. [1] can be simulated. So, irregular pattern caused by shading etc. are also able to be simulated. PV array structure is arranged freely. Furthermore, when an I-V curve data set is formed, irradiance fluctuation is easily able to be treated. In this paper, detailed structure of the equipment is described. Then, results of tests are also introduced. Effectiveness of the dynamic evaluation of MPPT operation with this simulator has been cleared.

2. PV array I-V curve simulator

A basic structure of PV array I-V curve simulator including APL [2] is shown in Fig. 1. The PC and the APL are connected by optical fiber with RS232C. At first, an I-V curve is generated in the PC. Then the data of the I-V curve is transmitted to APL. Following the data, the APL performs as a PV simulator. While its operation, parameters of APL are transmitted to PC and monitored every one

second. The I-V, P-V characteristics, value of P_{MAX} and output power are also indicated. Characteristics of the PV array I-V curve simulator are summarized as follows.

1. Simulating irradiance every one second for 9-hour operation
2. Preinstalled standard patterns of irradiance fluctuation (Additional files are able to be installed.)
3. Faithfully simulated output characteristics of PV array (Parameters are able to be set.)
4. Size, weight, and cost reduction
5. Operation by a PC with convenient handling
6. Simulating an enough scale of PV array for a standard residence
7. Further utilization as constant voltage and/or current power supply

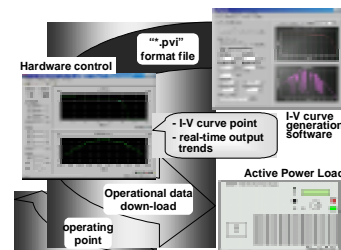


Fig.1 Basic structure of PV array I-V curve simulator

3. Tests of PV inverter response time

A commercial PV inverter was tested with the PV array I-V curve simulator using an experimental circuit model shown in Fig. 2.

3.1 Tests for sudden irradiance fluctuating

Figure 3 shows observed output waveforms of the simulator and the inverter. In this test, irradiance was stepped down from 1.0 kW/m^2 to 0.5 kW/m^2 . The measured voltage control response time of the inverter was approximately 0.5 s in this test.

3.2 Tests for sudden temperature variation

The temperature of PV module was suddenly stepped up from 40 deg to 60 deg, in this case it took approximately 200 s to 240 s tracking the P_{MAX} point. When the temperature changed from 60 deg to 40 deg, it was about 200 s.

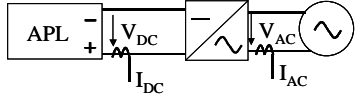


Fig. 2 Circuit model for measurement

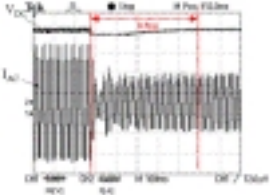


Fig. 3 Observed waveforms of the inverter output current I_{AC} and the simulator output voltage V_{DC} .

4. Tests of PV inverter for MPPT control with the simulator

4.1 Default data of irradiance fluctuating

The commercial PV inverter was tested with the simulator for MPPT control. Figure 4 shows the default data sets prepared for a typical clear sky pattern “Clear” and 3 kinds of fluctuating patterns “Vary-1”, “Vary-2” and “Vary-3”. These are chosen from actual observation with 1 second sampling at Tsukuba around 4 years since 1996.

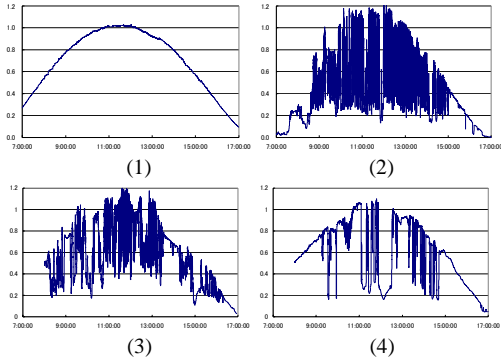


Fig. 4 Default irradiance patterns: (1) Clear; (2) Vary-1; (3) Vary-2; (4) Vary-3

We define a factor K_{PM} for evaluating the inverter’s MPPT control capability.

$$K_{PM} = \frac{\sum PV \text{ array Output Power}}{\sum P_{MAX}} \times 100[\%] \quad (1)$$

4.2 Calculation of array temperature variation

Presumption of array temperature usually requires many parameters. However we can easily calculate the temperature by the following equations,

$$T_{CR} = T_A + \Delta T, \quad (2)$$

$$\Delta T = (-6.036 + 0.274 \cdot V + 0.071 \cdot V^2) + H_{AE} \cdot (45.63 - 5.91 \cdot V + 0.333 \cdot V^2),$$

where, T_{CR} , T_A , V , and H_{AE} , are array temperature, air temperature, wind velocity, and irradiance. $T_A = 25$ deg and $V = 1.0$ m/s are assumed. The developed simulator allows an operational mode of high speed fluctuation of irradiance and followed temperature variation.

4.3 Experimental results

Using the irradiance data of array temperature, a commercial inverter has been tested. The results are shown in Fig. 5. The power P_{max} and voltage V_{pmax}

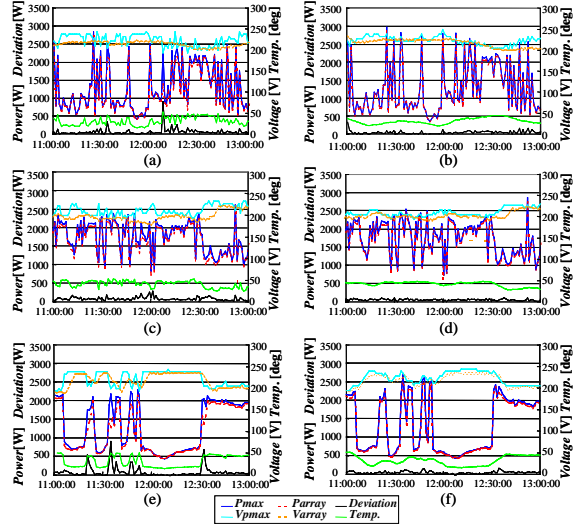


Fig. 5. Measured and calculated parameters of the tests as functions of time, for the irradiance data: (a),(b) Vary-1 with 1min. and 10min., (c),(d) Vary-2 with 1min. and 10min. and (e),(f) Vary-3 with 1min. and 10min.

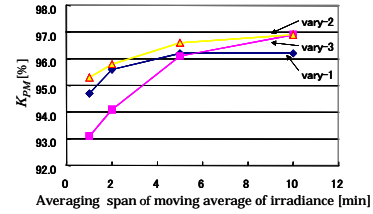


Fig. 6 MPPT control capability

P_{MAX} point, the output power P_{array} and voltage V_{array} of PV array, deviation of P_{array} from P_{max} , and temperature are shown as functions of time for the irradiance data, Vary-1, Vary-2, and Vary-3. For each case, two sets of data are shown by moving average of irradiance data with 1 min and 10 min averaging spans. All the data are stored in the monitoring PC. From results of these tests, using eq.(1), K_{PM} for evaluating the inverter’s MPPT control capability of the inverter is calculated and shown in Fig. 6. Transient control mismatch can be clearly observed by the PV array I-V curve simulator. These results show that MPPT control capability decreases as irradiance of temperature increases.

5. Conclusions

The detailed structure of the PV array I-V curve simulator including APL has been described. The results of tests have been shown. The dynamic evaluation of MPPT operation has become possible by means of using this simulator. That is very effective for testing commercial inverters with MPPT control function.

References

- [1] H. Matsukawa, M. Shioya, T. Yamada, T. Sugiura and K. Kurokawa, “Investigation of photovoltaic array simulation method for architecture”, Proc.JSES/JWEA Joint Conf.’99, pp.57-60, Nov. 1999 (in Japanese)
- [2] K. Koshiishi, H. Matsukawa, K. Kurokawa, M. Hamada, Liu bo, “Evaluation of maximum power point tracking operation with PV array I-V curve simulator”, National Convention Record IEEJ, p. 3042, March 2001