Crystalline Silicon Photovoltaic Array – On Site Measurement of I-V Characteristics

N. Chayavanich[1,2,*], T. Chayavanich[1,2], S. Parinyopast[2], Y. Sangpongsanont[2], C.Limsakul[2], and D.Chenvidhya[2]

[1]Department of Electrical Engineering, [2]CES Solar Cell Testing Center(CSSC),
King Mongkut's University of Technology Thonburi, Bangkok, Thailand,
Tel: (662) 4709037, Fax: (662) 8729033
[*]Corresponding author: inatnich@kmutt.ac.th

Abstract: This paper presents a development of testing equipment to measure I-V characteristics of on site crystalline silicon photovoltaic array according to IEC61829 Crystalline silicon photovoltaic (PV) array – On site measurement of I-V characteristics. Prototype of the equipment had been tested with four systems of on-site PV array, single crystalline, poly-crystalline and hybrid thin film, with solar radiation between 128 W/m2 and 1099 W/m2, open circuit voltage of 163.3-316.8V, and short circuit current of 1.7-30.7 A. The equipment was working as design. The purpose of the project is developing a prototype of testing equipment with economical price in order to transfer the technology to private sectors, and can be built as commercial one.

Keywords: Photovoltaic, Solar cell, PV array, Performance, Measurement, Prototype

1. INTRODUCTION

The most of purposes of the PV performance measurement are quality assurance and diagnosis. The performance of the photovoltaic array can be investigated with current and voltage (I-V) characteristics. The I-V measurement can be perform under STC (standard test condition: irradiance of 1000 W/m^2, cell temperature of 25 °C, and AM 1.5) or real operating conditions, which can be extrapolated to STC. I-V characteristic of PV arrays under real operating conditions can compared with contractual specifications agrees between contractors and customers. The shape of the I-V characteristic provides information on the detection of possible unusual PV array, such as disconnected internal circuits, broken cells, shading, mismatch, and so on. The P V measurement can perform with the sun shining on the array while the electrical load sweeps the array voltage from short circuit condition beyond open circuit condition or from open circuit beyond short circuit. The acquisition system gathers the data and then calculates. Making the measuring set for PV array performance on-sites measurement is challenge to developing more conveniently and accurately instrument. This work is about development of the prototype of PV performance on-site measurement set by referring the IEC 61829: On-site photovoltaic array measurement and testing. Energy Policy and Planning Office (EPPO) have support this project in order to transfer the technology to private sectors, and can be built as commercial one.

2. CHARACTERISTICS OF SOLAR CELL

The PV array generates no power in short-circuit (when current I_{SC} is produced) or open-circuit (when cell generates voltage V_{OC}). The cell delivers maximum power P_{MP} when operating at a point on the characteristic where the product IV is maximum. This is shown fig. 1 where the position of the maximum power point represents the largest area of the rectangle shown.
The efficiency of a solar cell is defined as the power P_{MP} supplied by the cell at the maximum power point under standard test conditions, divided by the power of the radiation incident upon it. Most frequent conditions are: irradiance 1000 W/m^2, standard reference spectrum, and temperature 25 ^{o}C. The use of this standard irradiance value is particularly convenient since the cell efficiency in per cent is then numerically equal to the power output from the cell in W/m^2.

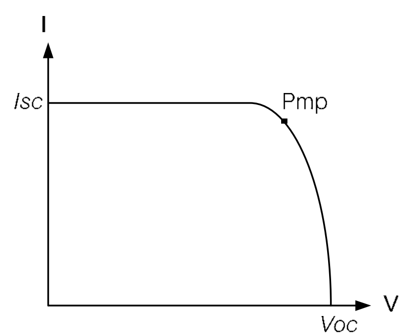

Fig.1 IV characteristic curve of solar cell.

3. DETAILS OF THE PROTOTYPE

3.1 Range of mesurement

We specified the range of measurement of the prototype by considering the rated voltage and current of PV systems which are installed in Thailand. The PV systems are classified into 2 groups which are stand alone systems and grid connected systems. The rated voltage and current of each group are divided as followings:

Stand-alone systems

- Rated power < 2 kW$_P$ (nominal voltage of 48 V)
  Open circuit voltage (V_{OC}) of system: 90 V
  Short circuit current (I_{SC}) of system: 65 A
- 2 kW$_P$ < Rated power < 5 kW$_P$ (nominal voltage of 96 or 120 V)
  Open circuit voltage (V_{OC}) of system: 210 V
  Short circuit current (I_{SC}) of system: 45 A
- 5 kW$_P$ < Rated power < 20 kW$_P$ (nominal voltage of 240 V)
  Open circuit voltage (V_{OC}) of system: 420 V
  Short circuit current (I_{SC}) of system: 90 A

Grid-connected systems

- Rated power < 4 kW$_P$ (nominal voltage of 240 V)

Open circuit voltage (V_{OC}) of system: 420 V
Short circuit current (I_{SC}) of system: 8 A

- 4 kW_P < Rated power < 20 kW_P (nominal voltage of 96 or 120 V)

Open circuit voltage (V_{OC}) of system: 420 V
Short circuit current (I_{SC}) of system: 90 A

The prototype was specified the maximum input voltage for measurement of 450 V and the maximum current of 90 A. The sweeping load for I-V plotting is the capacitive load. The measurement time is not less than 200 ms.

3.2 Diagram

In figure 2 shows that the PV array are connected through the main magnetic connector. The selector switch are used for selection the range of voltage measurement; 100 V, 300V, and 450V. The threes capacitor load are using for sweeping the input voltage. For the voltage measurements, the voltage dividers decrease the input voltage. The analog interface set measure voltage. In the same manner, the current transducers are used for measure the three ranges of input current, 25A, 50A, and 100A. The analog interface set measure current.

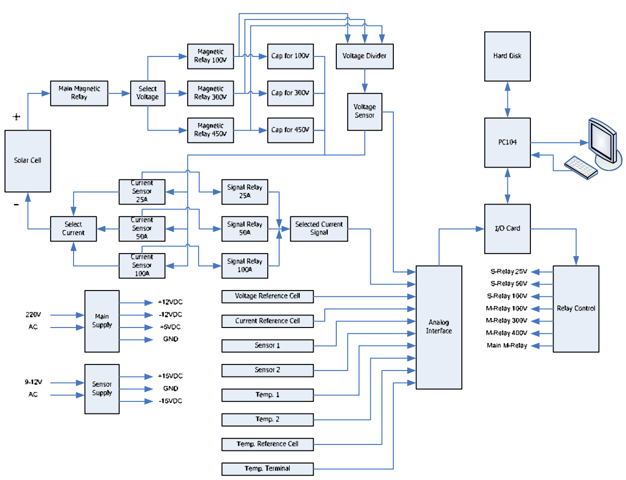

Fig.2 Diagram of the prototype.

In addition, the irradiance is measure by using the reference cell. The reference cell and array temperature, and irradiance are measure by the analog interface set. The microcontroller; PC104, process the measured data from the analog interface set through the I/O card. The data of measurement are kept into the hard disk and displayed on the monitor.

4. EXPERIMENT

The prototype was tested on indoor and on-sites. On indoor testing, to verify the voltage and current measurement the prototype was tested by comparison the results of measurements with the other instruments. We performed the testing with using the dc power supply ; XANTREX XDC 300-40, which was emulated the PV array and measure by the precision power meter; YOKO GAWA WT1600. On outdoor testing, we have tested on three different sites. The first site, we tested on the poly-crystalline silicon PV array 1.2 kW_p. The second site is the hybrid thin-film PV array 6.8 kW_p. The last one is the single crystalline silicon PV array 1.8 kW_p.

5. RESULTS

5.1 Indoor

The results of comparison are shown in Fig 3, for current measurement, and Fig4, for the voltage measurement. The error of current measurement is 3.5% in the range of 1A to 30A. The error of voltage measurement is 2.4% in the range of 10V to 300V . The results of verifying of the measurement show that are acceptance.

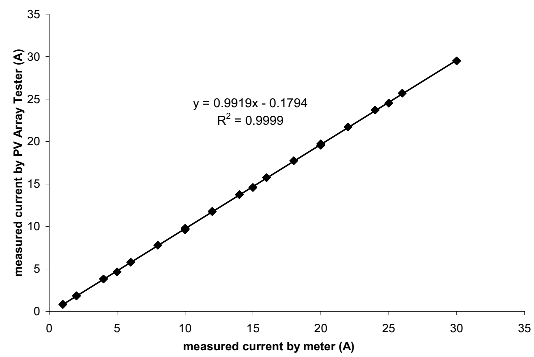

Fig.3 Comparison of current measurement.

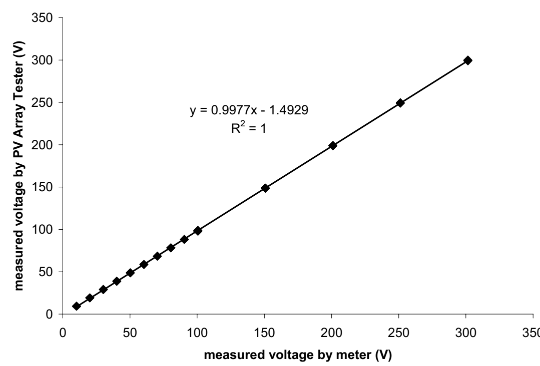

Fig.4 Comparison of voltage measurement

5.2 Outdoor

We have tested the outdoor in three different sites. The first site, we tested on the KMUTT Bangkhuntien campus site that are the poly-crystalline silicon PV array 1.2 kWp. The second site is the DE DE at Rangsit center which are the hybrid thin-film PV array 6.8 kW p. The last one is on the Bangkhuntien campus but are the single crystalline silicon PV array 1.8 kWp. The I-V curves from measuring three sites are shown in Fig 5, 6, and 7 respectively. The numerical results are shown in table 1.

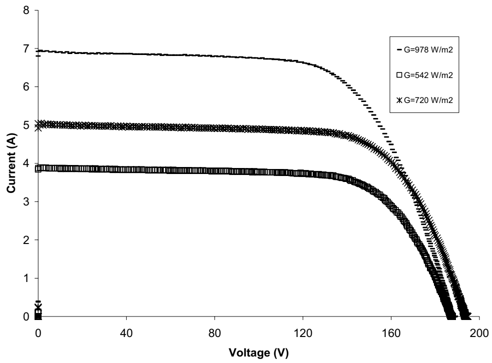

Fig. 5 I-V curve of the poly-crystalline PV array system.

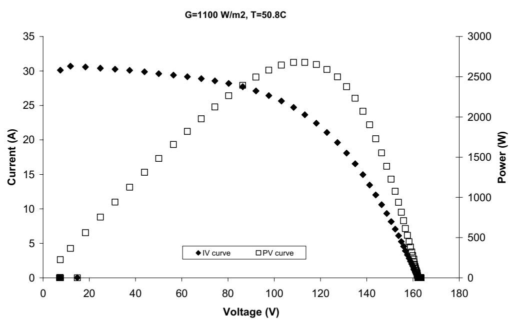

Fig. 6 I-V curve of the Hybrid thin-film PV array system.

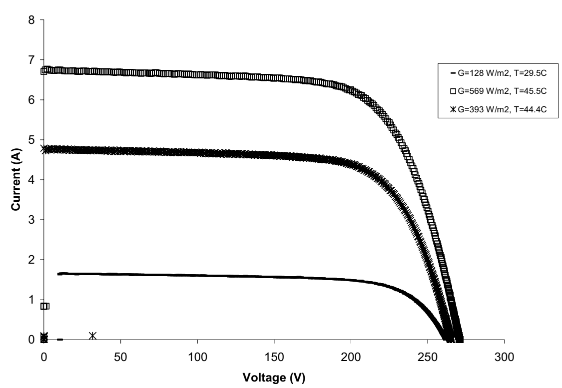

Fig. 7 I-V curve of the single crystalline PV array system.

Table 1 The numerical results of the systems.

PV array System	Si-Crystalline			Hybrid thin-film	P-crystalline		
Irradiance (W/m2)	569	393	128	1,099	978	720	542
Cell temperature (°C)	45.5	44.4	29.5	50.8	46.2	45.6	44.9
Power at maximum point, P_{MP} (W)	1,264	889	306	2,678	849	672	507
Open circuit voltage, V_{OC} (V)	271.1	265.5	262.3	163.3	189	194	188
Short circuit current, I_{SC} (A)	6.77	4.79	1.66	30.69	6.95	5.05	3.89
Voltage at maximum power, V_{MP}(V)	207.1	209.4	214.6	108.4	138.0	150.5	142.6
Current at maximum power, I_{MP}(A)	6.10	4.25	1.43	24.71	6.15	4.47	3.56
Fill factor, FF (%)	68.9	69.9	70.3	53.4	64.7	68.4	69.4

6. CONCLUSION

We have developed the testing equipment to measure I-V characteristics of on site photovoltaic array referring to IEC61829 Crystalline silicon photovoltaic (PV) array – On site measurement of I-V characteristics. Prototype of the equipment had been tested with indoor testing to verifying voltage and current measurement, and tested with three systems of on-site PV array, single crystalline, poly-crystalline and hybrid thin film ,with solar radiation between 128 W/m^2 and 1099 W/m^2, open circuit voltage of 163.3-265.5V, and short circuit current of 1.7-30.7 A . The equipment was working as design.

7. ACKHOWLEDGMENT

This work was supported by the Energy Policy and Planning Office (EPPO).

8. REFERRENCES

[1] IEC 61829 (1995), “Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics”, International Electrotechnical Commission.