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Development of Movable Testing Equipment for Artificial Light Source Photovoltaic Module

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Abstract. The market for photovoltaic power generation system reached a limit recently due to the advancement of technology and excessive supply. Consequently, interest is moving for the development of a management technology to effectively maintain and supervise the system. One of the most important aspects in managing photovoltaic power generation system is to resolve problems causing the deterioration of cumulative photovoltaic power generation. The existing method takes a large amount of manual work, cost, and time such as cleaning photovoltaic modules, measuring ground resistance, etc. This study aims to develop a movable photovoltaic module tester that maintains and manages a photovoltaic power generation system capable of fast and easy maintenance in order to produce a maximum cumulative photovoltaic power generation. We propose a plan to measure the normal operation status of photovoltaic module with the proposed system.

Keywords: photovoltaic power generation system, photovoltaic module tester, measurement of normal operation for photovoltaic module

1 Introduction

Photovoltaic power generation system now reached a limit in further technology development for luminous efficiency and converting efficiency based on insolation thanks to a high degree of technology advancement. The world photovoltaic market shows growth by around 20% year on year from 57GW in 2015. However, due to a surplus of parts or equipment, supply is saturated compared with increases in its demand. Therefore, our interest is moving towards management technology for effective maintenance and management of the system. The most important management aspect for the photovoltaic system is to maintain cumulative photovoltaic power generation level to a maximum. This means that management method to remove various factors that deteriorate photovoltaic power generation system needs to be developed. Existing maintenance and management methods include cleaning the photovoltaic module, checking of fuse and protective device in

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the junction box, measurement of ground resistance and insulation resistance, testing the protective relay, and display and measurement of output by watt-hour meter. However, these methods involve a large amount of manual operation and of time and cost. Therefore, in this study, a low-cost movable photovoltaic module tester for rapid and simple maintenance of the photovoltaic module was developed, and a measurement method for normal operation condition by using this system is proposed for practical application.

2 Research Status

Preceding researches include a construction inspection kit for photovoltaic power generation called ASM-3000 and a portable photovoltaic I-V checker in relation with the management technology of the photovoltaic power generation system. These technologies are being used during regular inspection and diagnosis during and after construction of the photovoltaic power plant. These technologies are optimized for fast measurement speed and breakdown diagnosis, and are technologies meant mainly for large capacity to be used conveniently for mega-solar level photovoltaic power plants. The dispenser, which is being used for the production of the photovoltaic module, is a silicone injection type dispensing device and is an important production technology to raise the efficiency of the photovoltaic module. Existing management technology is either a large-scale, expensive, or fixed system, or is limited as a management technology for pre-production process to raise the efficiency of the equipment. Therefore, in this study, a movable tester for photovoltaic module was developed by using an artificial light source for effective post-maintenance and management for personal or small scale photovoltaic power generation system.

3 Detail of Research

Current-voltage characteristics graph that is implemented for the performance evaluation of the photovoltaic module is generally rectangular-shaped as shown in Figure 1.

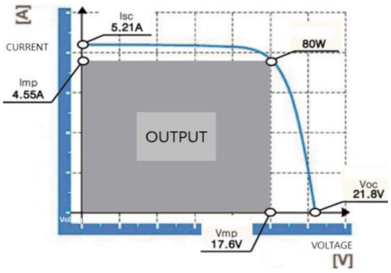

Fig. 1. Output characteristics graph of photovoltaic module

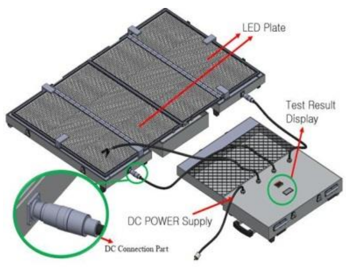

Fig. 2. 3D model of photovoltaic module tester

Major parameters include short-circuit current (Isc) when voltage is zero (0) in the photovoltaic cell, open-circuit volt (Voc) when current is not flowing through, maximum power current (Imp), maximum power volt (Vmp), and maximum power(Pmax) calculated by multiplying maximum current and maximum volt at an optimum operation point. Figure 2 shows the photovoltaic module tester developed in this study. Photovoltaic module tester is composed of power supply device, LED module measurement device, and output device. Table 1 shows its detailed specifications.

Table 1. Parameters for the measurement of photovoltaic module specification for portable photovoltaic module tester using 320W grade artificial light (LED)

INPUT		AC 100-220VAC 50/60Hz, 50A
LED PACKAGE	LED BAR PCB Assembly	320W/1 SET * 16 SET (16Serial 40Parallel 640 CHIP/1 SET)
	PACKAGE	LG-LEMWS51R80XX/XX
	CCT	5,700K (K:Kelbin)
	Luminous flux	19,200lm * 16EA = 307,200 lm over
OUTPUT	SMPS	DC 48V / 6.5A / 312W * 16EA = 5kW
	Exposure Time	0.5 sec-2 sec
Sensing Method		Distribution resistor and design of shunt resistor circuit
Protection		Designing of overcharge and over-discharge protective circuit
Outer dimension of SMPS		W300mm*D200mm*90mm
Value of radiation plate of artificial light		W1600mm*D1040mm
Reflection plate		Model MIR02 from Alanod, Germany
Number indicator		4.1 Inch LED Backlight Display
Others		caster (wheels): 4EA / handle: 8EA / safety lock 2 EA

To implement the criteria to judge the normal operation of the photovoltaic module, Table 2 may be referred to. In Table 2, the analysis data of standard during outgoing in “S” company and measurement data with the photovoltaic module tester developed in this study are arranged. [1]

Table 2. Parameter standard for measurement for photovoltaic module

Parameter	Year 0	1 Year	2 Year ~ 24	25 Year Over
Vmax[V]	30.8	29.9	28.6	24.7
Imax [A]	8.3	8.0	7.7	6.6
Voc [V]	37.9	36.8	35.2	30.4
Isc [A]	8.8	8.6	8.2	7.1

Parameters during outgoing of photovoltaic module

Parameter	Year 0	1 Year	2 Year ~ 24	25 Year Over
Vmax[V]	27.7	26.9	25.8	22.2
Imax [A]	7.5	7.2	6.9	6.0
Voc [V]	34.1	33.1	31.7	27.4
Isc [A]	7.9	7.7	7.4	6.4

Parameters for measuring by photovoltaic module tester

* For “S” Company in Korea: Measurement efficiency at 90% and output measurement error at ±2%

The procedure to measure photovoltaic module in the running photovoltaic power plant is shown in below Figure 3. After cleaning photovoltaic module by using module cleaner, temperature testing is executed using a thermal camera. Based on the management and policy standard of the customer's photovoltaic power plant, the modules showing a temperature difference of more than 10% when measured by the thermal camera are collected. Measurement is performed by setting the measurement value when the measurement efficiency of the photovoltaic module tester is at 90% as standard. The conditions to obtain the same measurement results when several photovoltaic modules are measured are: surface temperature of the photovoltaic module maintained at 25℃, distance between artificial light and photovoltaic module being at a maximum of 150mm, and the irradiation time of artificial light being within two seconds. The moment when the surface temperature of the photovoltaic module exceeds 25℃, the measurement system would be OFF right away [4]. During outgoing of the photovoltaic module from the factory, when the difference from the module tester with artificial light in the measurement values between outgoing is more than 5%, the module can be replaced. Therefore, the basic cause of cumulative deterioration in the power generation can be resolved.

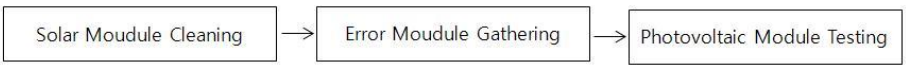

Fig. 3. Measurement procedure of photovoltaic module

The analysis of economic feasibility is as follows. To begin with, the flow of economic effect is as in Figure 4. With this flow, formula (1) can be considered to judge its economic feasibility [8]. This is the method to calculate present value by using annual profit in the state sustaining a regular efficiency. Accordingly, we suppose that the price of tester is I, annual profit A be maintained regularly year after year and salvage value be defied.

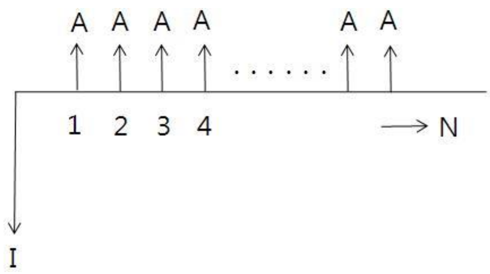

Fig. 4. Flow of economic feasibility by implementing the photovoltaic module tester

$$NPV = -I + A(P/A, i\,\%, n) = -I + A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \quad (1)$$

Here, I: Investment capital, A: annual equal profit series, n: number of years, i: interest rate a year, and NPV: net present value. If NPV is larger than 0, it is beneficial to buy equipment, whilst, if it is smaller than 0, it is advisable not to invest on the equipment.

4 Conclusion

A movable photovoltaic module tester using an artificial light and measurement methods for photovoltaic module parameters are proposed to efficiently maintain and manage a photovoltaic power plant. When photovoltaic module tester system is implemented in the photovoltaic power generation system, problems of cumulative deterioration in the photovoltaic module can be resolved rapidly, conveniently, and fundamentally. The proposed technology can boost the demand and supply for photovoltaic module replacement market and photovoltaic module cleaner market, which are potential niche markets for photovoltaic power plants. Further, it is expected to expand human and material infrastructure in the maintenance and management markets. The parameters such as Isc, Voc, Imp, Vmp and Pmax for the photovoltaic module tester proposed in this study are recommended references based on the customer's management and policy for the photovoltaic power plants. Therefore, it is necessary to carry out additional researches about the setting of standard values in the future for more objective parameters after implementing the developed equipment.

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