A Thermal Analysis for Photovoltaic System at Short Time Interval

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ABSTRACT

However PV array temperature and ambient temperature changes every seconds, previous irradiation and temperature influence the current array temperature. However many paper described the model which estimate PV module temperature is static and hourly value. We have established an experimental equipment and monitor to the temperature on the second time interval scale. This paper presents to estimate fluctuation of PV module temperature using the heat transfer model and demonstrate that PV module temperature influence the output voltage at the short time interval.

1. Introduction

The temperature of PV module, which installed in outdoor is fluctuate at all time, affect to the thermal radiation from the sun, ambient temperature, wind velocity and so on. Generally speaking, output voltage of PV module depends on the variation of PV cells temperature. We had ever presented that maximum power point tracking (MPPT) control capability decreases when the output voltage fluctuates greatly[1]. This paper presents to estimate fluctuation of PV module temperature using the heat transfer model and demonstrate that PV module temperature influence the output voltage at the short time interval.

Many paper describing the estimation method of PV module temperature rise or PV thermal model[2][3]. However, these models analyze 1 minute or more long time period sampling or no consideration about dynamic time movement. Maximum power point tracking (MPPT) of PV inverter is faster control than that of time period. Output voltage of PV module depends on the variation of PV cells temperature. Fluctuation of output voltage exerts a strong influence on MPPT control. So there are needs to demonstrate the heat transfer analysis of short time interval.

2. Experimental setup

Figure 1 shows the measuring system and Table 1 shows measurement parameter. For comparative experiments two identical single-crystalline PV modules (Siemens SP-75) are prepared. Thermocouples are installed on the back surface of both PV modules. Each PV module measured two points of temperature using thermocouples, peeling the back sheet (PV cell temperature) and on the back sheet on the back sheet. The ambient temperature measured in the shade near PV modules using thermocouple. The irradiance is measured the current of reference PV cell. This experiment need to measure the high-speed variation of irradiance, therefore we didn't use thermopile type pyranometer which have long time constant. Wind velocity and wind direction are measured by anemometer and anemoscope.

One-second sampled data have been obtained with the measurement facilities installed on the top of a building in our University (35° 41'N, 139° 31'E).

Table 1 Measurement parameter

Measurement parameter	Measurement place
Cell temperature (peeling the back sheet) (T type thermocouple)	PV module A and B
Module temperature（on the back sheet）(T type thermocouple)	PV module A and B
Open circuit voltage	PV module A and B
Current (for irradiation monitoring)	Reference PV cell
Wind direction	Anemoscope
Wind velocity	Anemometer
Ambient temperature	Near the PV module

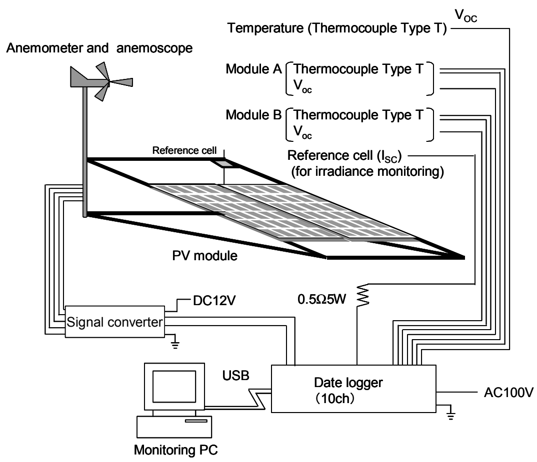

Fig.1 Outline of measuring system

3. Experimental Results

PV module temperature is mainly concerned with irradiance and ambient temperature (wind velocity), i.e. depends on the thermal radiation and heat transfer by convection. Therefore relation between PV module temperature and irradiance or ambient temperature is examined.

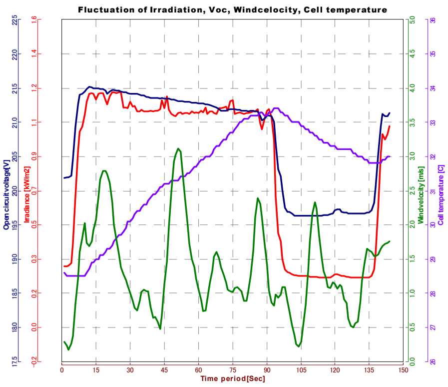

Fig. 2 PV module temperature and V_{oc} response to rapid fluctuation in irradiance (data from Oct. 9 / 2003 10:11)

Figure 2 shows the PV module temperature and open circuit voltage (V_{oc}) response to the case of a very rapid fluctuation in the irradiance level over a short period of time, a increase of about 0.6kW/m^2 in 3sec, and decrease of about 0.6kW/m^2 in 4sec. Open circuit voltage rises coupled with irradiance increase. After that time, open circuit voltage ratchet down with increase of PV cell temperature. Open circuit voltage depends on the fluctuation of irradiance at short time period.

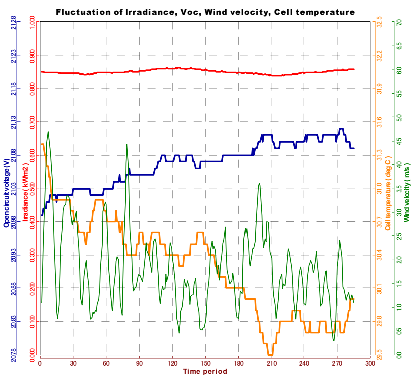

Fig. 2 PV module temperature and Voc response to fluctuation in wind velocity (data from Dec. 17 / 2002 10:11)

Figure 2 shows the PV module temperature response and V_{oc} to fluctuation in wind velocity. The PV module temperature decrease to influence the wind velocity. This case is slower temperature fluctuation than the case of rapid step change in irradiance. But it's difficult to evaluate the effect of wind at outside experiment. Therefore indoor experiment was conducted in parallel.

Energy was provided for the PV module using current power supply, with the object of analyzing heat transfer. Flush bulb was blinked at fixed interval for measurement to the open circuit voltage. PV module temperature was measured using thermo-couple. The heat transfer by forced convection was evoked using air blower. In order to avoid the influence of thermal radiation, indoors experiment conducted in the darkroom. Results of these experiments are shown in Fig. 4 and 5.

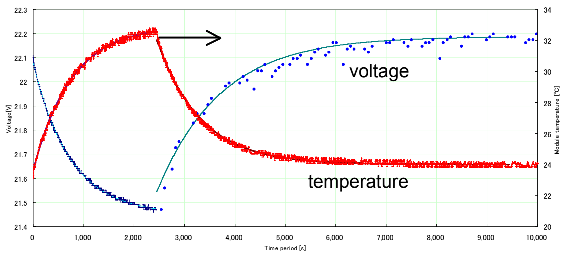

Fig. 4 Result of indoor experiment (no air blower)

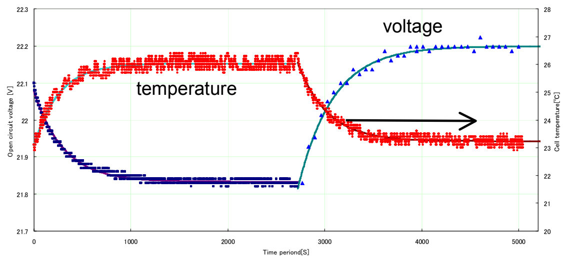

Fig. 5 Result of indoor experiment (with air blower)

Time constant was calculated from results of heat transfer experiment as shown in Table 2. The time constant is apparently short according to the heat transfer by forced convection

Table 2 time constant of PV module

	Time constant [sec]	
	Phase of rise in temperature	Phase of drop in temperature
No air blower	756.82	860.63
With air blower	256.91	304.72

4. Conclusions

Thermal analysis for PV system was become apparent by conducting outdoor or indoor experiment. For the future, simulation will be leverage for more depth evaluation of PV heat transmission.

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