FIELD TEST OF A 500X CONCENTRATOR PV SYSTEM WITH DOME FRESNEL LENS

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ABSTRACT : In order to evaluate the performance of a concentrator PV system, a field test of a 500X concentrator PV system with dome Fresnel lens was carried out at Toyohashi, Japan, from June, 2004. PV module output, open-circuit voltage, short-circuit current, direct solar radiation and module temperature were measured every 20 seconds. The measurement result of the concentrator PV system is compared with the flat-plate PV system. It is found that (1) the maximum efficiency of the 500X PV system is 27.0%, (2) daily generated energy per area of the 500X PV system is 1.59 times larger than the flat-plate PV system, while daily global solar insolation on sloping surface is 1.22 times larger than daily direct solar insolation.
Keywords : Concentrator PV system, Dome Fresnel lens, Filed test, Efficiency, Daily generated energy

1. INTRODUCTION

In order to reduce the generation cost of a PV system, a concentrator PV system which has high efficiency has been developed. From November, 2002, field tests of a 300X concentrator PV system with flat Fresnel lens have been carried out at Toyohashi University of Technology (Toyohashi, Japan), and generation power and module temperature have been measured [1][2]. From October, 2003, a 300X concentrator PV system with dome Fresnel lens (300X PV system) has been tested [3].

A dome Fresnel lens with 550X geometrical concentration ratio was developed in order to improve the efficiency of the concentrator PV system, and field tests of a 500X concentrator PV system with dome Fresnel lens (500X PV system) have been carried out at Toyohashi since June, 2004.

In this study, daily global and direct insolation, and daily generated energy per area of the 500X PV system are shown from the results of field tests. And, monthly average values of daily insolation and daily generated energy are also shown. These results are compared with the 300X PV system and the flat-plate PV system (Si poly-crystal) installed in the same place.

2. OUTLINE OF THE SYSTEM

Figure 1 shows the appearance of the concentrator PV system with dome Fresnel lens. This system has two modules and a 2-axis solar tracking system. Right side module is the 300X PV module which was installed in October, 2003. Left side module is the 500X PV module. This module consists of 20 dome Fresnel lenses – solar cell pairs, and 20 cells are connected in series. Total area of the 500X module is 0.545 m^2. The solar cell is the InGaP/InGaAs/Ge 3 junction cell.

The 2-axis solar tracking system controls azimuth angle and elevation angle with high accuracy. Sun tracking error (RMS) of azimuth angle and elevation angle are 0.045° and 0.027°, respectively [4].

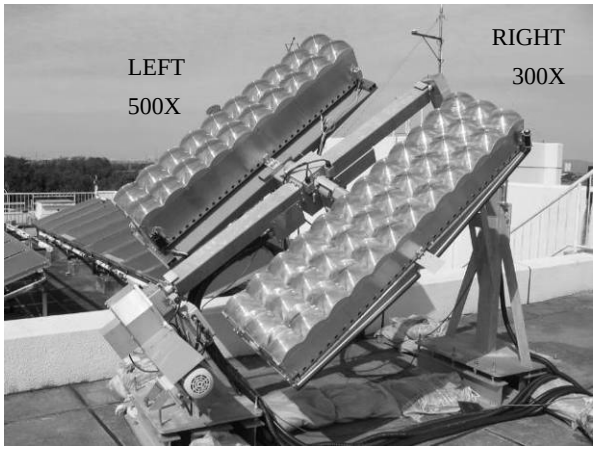

Figure 1: The concentrator PV system with dome Fresnel lens

3. OUTLINE OF FIELD TEST

Field tests of the 500X PV system were carried out at Toyohashi University of Technology (Toyohashi, Japan). Figure 2 shows the measurement system. PV module output at maximum power point, open-circuit

voltage and short-circuit current were measured by an IV tracer every 20 seconds. Module temperatures were measured by thermocouples and a data logger. Direct solar radiation was measured by a pyrheliometer fixed to the module. Weather data such as wind speed and direction, ambient temperature, humidity, horizontal global solar radiation, and global solar radiation on sloping surface (angle : 35°) were also measured.

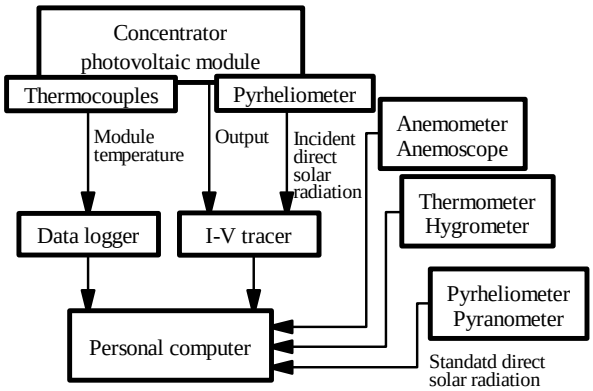

Fig.2 Arrangement of the measurement system

The output of a flat-plate PV system (Si poly-crystal, rated output : 4.8 kWp, efficiency at 25 °C : 12.5%) installed on same place was measured, in order to evaluate the performance of the concentrator PV system.

4. DAILY CURVE OF PV MODULE OUTPUT

Figure 3 shows daily curves for the direct and global solar radiation, module output, efficiency, FF, and module temperature of the 500X PV system on a fine day (20/08/2004). Module output of the flat-plate PV system are also shown in this figure.

In summer season, peak value of global solar radiation is larger than direct solar radiation, because Japan is in the Northern Hemisphere. However, daily direct insolation is larger than daily global insolation on a fine day, because the direct pyrheliometer tracks the sun. In this figure, daily direct and global solar insolation are 8.37 and 7.20 kWh/m^2, respectively.

Module output in figure 3 is divided by the module area, not solar cell area. Module output of the 500X PV system greatly exceeds output of the flat-plate PV system. In this figure, daily generated energy per area of the 500X PV system is 2.05kWh/m^2, and it is 2.9 times larger than the flat-plate PV system.

Maximum efficiency of the 500X PV system reaches 27% (uncorrected to 25 °C). Daily average efficiency (daily generated energy divided by daily direct solar insolation) is 24.4%.

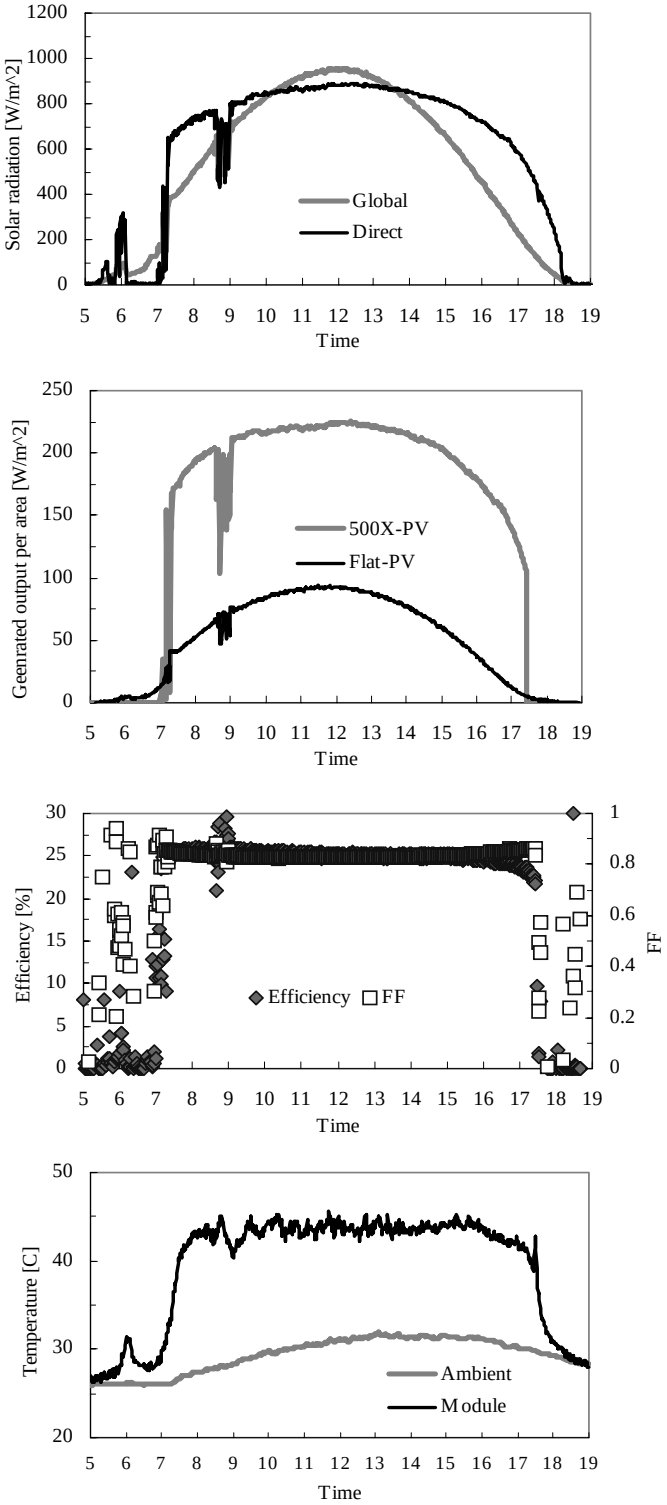

Figure 3 : Daily curve of solar radiation, module output, efficiency, FF and module temperature of the 500X PV system on a fine day
(20/08/2004)

5. DAILY GENERATED ENERGY

Figure 4 shows the daily global, sloping surface (angle : 35°) and direct insolation, and figure 5 shows the daily generated energy per area of the flat-plate PV system and the 300X and the 500X PV system over 10 days in summer.

On a fine day, daily generated energy of the 500X PV system is larger than the flat-plate PV system. On the other hand, direct insolation becomes very small on a cloudy and rainy day, so that the 300X and 500X PV system produce little energy.

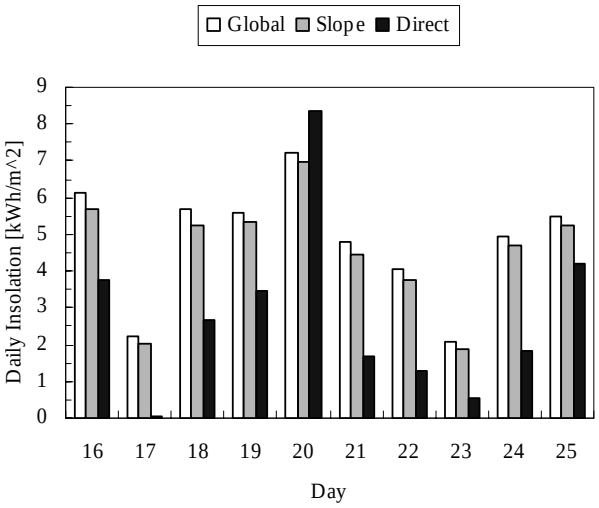

Figure 4 : Daily global, sloping surface and direct insolation
(16/08/2004 – 25/08/2004)

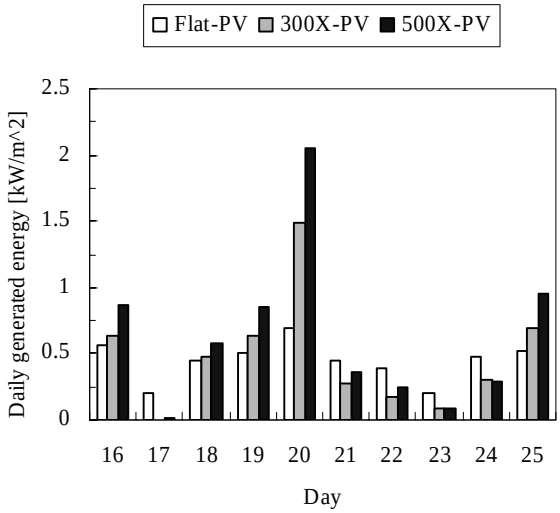

Figure 5 : Daily generated energy of the PV system
(16/08/2004 – 25/08/2004)

Figure 6 shows average daily global, sloping surface and direct insolation for each month. In the summer season, global insolation is the largest of the three for every month. And, direct insolation is the lowest, because the humidity exceeds 80% even on a fine day so that the diffused solar radiation increase.

In opposition, global insolation is the lowest of the three in winter season. And direct insolation is as same as insolation on sloping surface, because the humidity decreases in less than 50% on a fine day.

The reason why the global insolation is high in summer but low in winter is because of the position of the sun. The direct pyrheliometer always faces the sun, so the position of the sun does not affect in greatly, only scattering in the atmosphere. However, in winter when the sun is low in the sky, the sloped pyrheliometer will almost be facing the sun and will receive more radiation than the horizontal global pyrheliometer. In summer, the sun is high in the sky, so the horizontal global pyrheliometer is almost facing the sun and will receive more radiation than the sloped pyrheliometer.

Average daily insolation on sloping surface for 11 months is 1.22 times larger than direct.

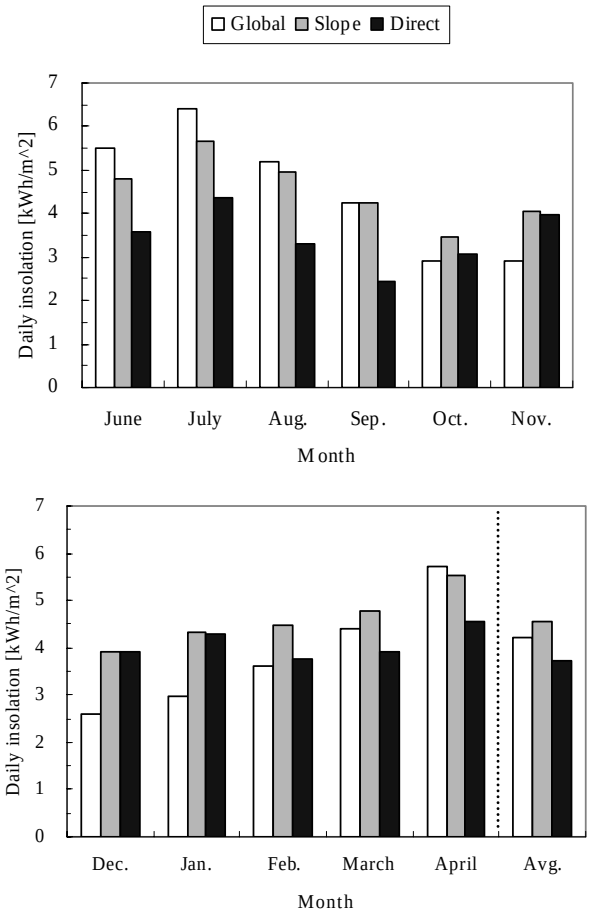

Figure 6 : Average daily insolation of each month
(June, 2004 – April, 2004)

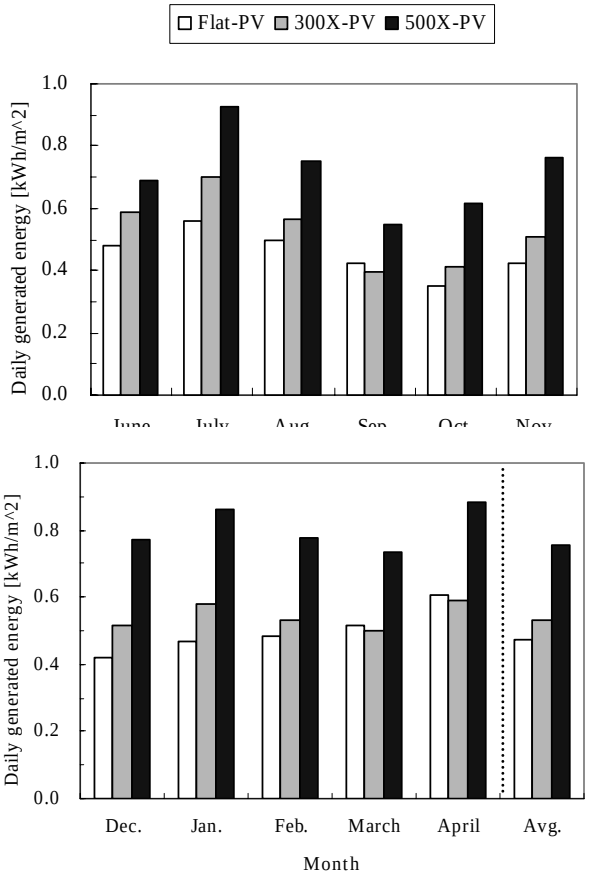

Figure 7 : Average daily generated energy of each month (June, 2004 – April, 2005)

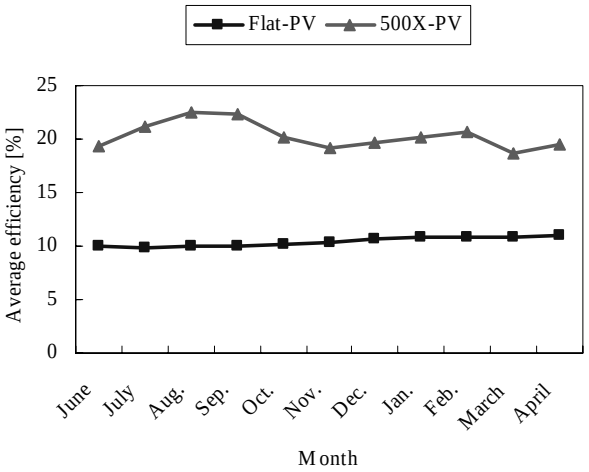

Figure 8 : Monthly average efficiency of each month

Figure 7 shows average daily generated energy per area for each month. Daily generated energy for the 500X PV system is the largest of the three for every month, while daily direct insolation is lower than global insolation on sloping surface. Average daily generated energy for 11 months of the 500X PV system is 1.59 times larger than the flat-plate PV system.

Figure 8 shows monthly average efficiency of each month for the flat-plate PV and the 500X PV system. The efficiency for the 500X PV system is calculated by average daily generated energy divided by average daily direct insolation, while the efficiency of the flat-plate PV is calculated by insolation on sloping surface.

The efficiencies of the flat-plate PV system decrease in the summer season because of increase of the module temperature. On the other hand, the efficiencies of the 500X PV system increase in the summer, and decrease in winter. One of the reason is the influence of seasonal change of the spectrum in direct solar radiation and the humidity. However, detailed analysis has not been done yet.

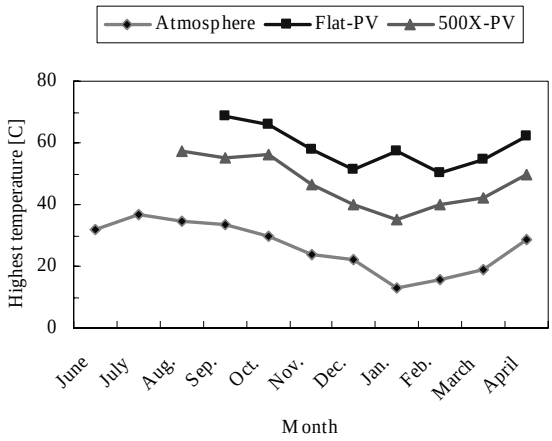

Figure 9 : Highest temperature of atmosphere, and flat PV and 500X PV modules of each month

Figure 9 shows the highest temperature of atmosphere, and flat PV and 500X PV modules of each month. The difference between the highest temperature of the 500X PV module and atmosphere is restrained with in 25 °C, while the highest temperature of the flat-plate PV system is 35 °C higher than the atmospheric temperature.

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