МУИС, Эрдэм Шинжилгээний бичиг, Физик № 362(17), 2012, хууд. 130-134

Long Term Performance Analysis of Photovoltaic Modules in the Sainshand of Dornogobi Province

Amarbayar Adiyabat[1*], Bat-Erdene Ganbaatar[1], Kenji Otani[2], Naruush Enkhmaa[3]

[1]*Department of Applied Physics, School of Physics and Electronics, National University of Mongolia*
[2]*National Institute of Advanced Industrial Science and Technology (AIST), Japan*
[3]*Sainshand Meteorological Observation Center of Dornogobi province, Mongolia*
[*]*E-mail: Amarbayar@gmail.com*

This paper presents the evaluation results of a long-term performance of 2 type PV module from actual data measured over a period of more than 6 years in the Gobi Desert of Mongolia. For the purpose of estimating solar energy potentials and durability of PV systems in the Gobi desert area, a data acquisition system, which includes crystalline silicon (c-Si), polycrystalline silicon (p-Si) modules and precision pyranometer, thermometer and anemometer, have been installed at the Sainshand city in October, 2002. This system has been measuring 23 parameters including solar irradiation and meteorological parameters in every 10 minutes. It has been observed that the high output gain due to the operating condition in an extreme low ambient temperature and the PV module degradation rate indicated over -1.5[%/yr] after 6 years exposure test.

I.INTRODUCTION

The Gobi Desert, Mongolia, is one of the most promising candidate sites for introduction of the 100MW class Very Large Scale Photovoltaic Systems (VLS-PV) specified by Task 8 “Very Large Scale Photovoltaic Power Generation Systems” conducted as part of the IEA Photovoltaic Power Systems Program (IEA PVPS) [1]. Within the framework of the IEA PVPS Task 8 activity, a conceptual design has been developed and a trial calculation of the costs associated with power generation and construction of a VLS-PV system in the Gobi Desert area has been performed [2].

The meteorological environmental characteristics of the Gobi Desert may affect the PV system performance and design specifications. Therefore, it is necessary to clarify the factors that will affect the system design, operation, and maintenance. However, no useful reference data are available and there have been no case studies analyzing solar energy resources or performance for PV system installation in the Gobi Desert area.

In the Gobi Desert, Mongolia, we set up two types of photovoltaic modules and checking devices (e.g., I-V Curve Tracer, etc.) as well as meteorological devices to study the characteristics of photovoltaic system operation under such severe environmental conditions. The present study was performed to verify the output simulation technique for the VLS-PV to confirm the efficiency of using a large-scale concentrated photovoltaic system in this area, and to clarify the specific requirements for system design. To clarify the actual environmental capabilities (loss analysis) in the Gobi Desert, we measured meteorological data, such as the amount of solar irradiation and temperature, and the I-V characteristics of the photovoltaic modules.

II.EXPERIMENTAL SETUP

In order to determine the potential of VLS-PV in Gobi desert area it has been installed two types of the crystalline silicon PV modules and checking devices (e.g. I-V curve tracer, etc.) as well as a new data acquisition system in the Sainshand (44°54' N and 110°07'E) - the field site (see Figure 1, 2), which is located in the south eastern part of Mongolia. The data acquisition system (see figure 2) automatically will be switched on at every 10 min and records the total solar irradiation received on the horizontal and 45degree tilted surfaces, site meteorological data and measures PV module current-voltage (I-V) curves.

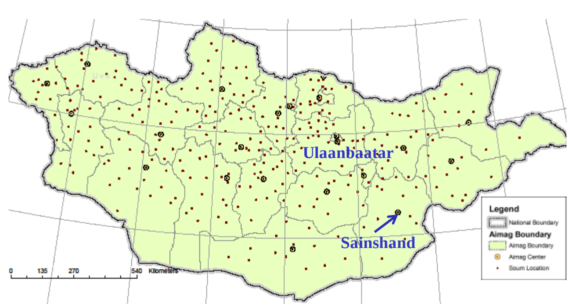


Figure 1. Location of the exposure test site

Measurement items listed below line:

1. Global Irradiance in horizon
2. In-plane Irradiance, in 45 degree
3. Wind Speed & Direction
4. Air Temperature
5. Humidity
6. Albedo
7. Short - circuit current I_{sc}
8. Open - circuit voltage V_{oc}
9. Current at maximum power I_{pm}
10. Voltage at maximum power V_{pm}
11. Temperature of modules T_1,T_2

Figure 2. Overview of the experimental set-up

Table 1 Electrical characteristics of PV modules on the STC

PV module name and Type		PV module-1 p-Si	PV module-2 c-Si
Parameters	Unit		
Short-circuit current (I_{sc})	A	5.3	4.8
Open-circuit voltage (V_{oc})	V	21.3	21.7
Current at max. power (I_{pm})	A	4.7	4.4
Voltage at max. power (V_{pm})	V	17.1	17.0
Maximum power rating (P_{max})	W	80	75
Temperature coefficient	W/°C	0.373	0.321

III.ANALYSIS METHOD

The field data analysis is divided into 3 parts regarding environmental conditions, solar energy resource evaluation, and photovoltaic (PV) performance. The environmental condition indices include ambient and module temperatures, average wind speed, humidity, and albedo. For evaluation of the solar energy resource, we use sunshine duration time, monthly average irradiation, and irradiation variable ratio. The PV Module performance indices include reference yield, array (module) yield, and performance ratio [3].

In this analysis, we used 6 years of data collected from March 2003 to February 2009. First, raw data obtained from the test site were checked and correctable noise was filtered.

A.Environmental condition indices

The average values of the ambient temperature, module backside temperature, wind speed/direction, humidity and albedo will be indicated to Figure out the real environmental situations of PV modules. We will compare measured meteorological data to an average year data of local weather station, in order to evaluate the environmental conditions during the measurement period to a normal year.

B.Solar Energy Resource Indices

The horizontal and in-plane irradiation [kWh/m^2/day], the time of sunshine duration $T_{Meas.Duration}$ [hour/month] and fraction F_{SD} to possible sunshine duration time were used for the indices of solar energy resource. In here, possible sunshine duration time is mean for fine day's duration time. We will compare monthly irradiance and sunshine duration time to local weather station data, in order to evaluate the irradiance situation during the measurement period.

$$F_{SD}=T_{Meas.Duration}/T_{Possible\ Duration} \qquad (1)$$

C.PV Module performance indices

All system performance data have been evaluated in terms of operational performance and reliability. The evaluation procedures are based on the IEC Standard 61724 [7].

$$Y_r = H_A / G_S \ \ (2) \quad Y_A = E_{A,d} / P_{max} \ \ (3)$$
$$PR = Y_A / Y_r \ \ (4)$$

The <u>*reference yield Y_r*</u> is based on the in-plane irradiation H_A and represents the theoretically available energy G_S per day and kW_p. The <u>*array yield Y_A*</u> is the daily array energy output $E_{A,d}$ per kW and represents the number of hours per day that the array would need to operate at its rated output power P_{max} to contribute the same daily array energy to the system as it was monitored. The <u>*array performance ratio PR*</u> is the ratio of actual array output energy to the energy theoretically available (i.e. Y_A/ Y_r). It is independent of location and array size and indicates the overall losses on the array's rated output due to module temperature and incomplete utilization of irradiation. /Array is mean test module in our case/

IV.RESULTS

Environmental condition: The PV module, frame, and cable were working over a wide range of temperatures and were subjected to severe thermal stress. The monthly ambient temperature (average, minimum, maximum) value ranged from –30°C to +40°C (see Figure 4). The monthly average wind speed (6 years) indicated 3.0[m/s] at a height of 3 m, and wind in spring was strong (over 4[m/s]) than other season (see Figure 5).

The daily transition of ambient and module temperature is shown in Figure 3 by the monthly average hour values. The difference between daytime and nighttime air temperature was around 10°C. The rise in module temperature was from 15 to 20°C relative to ambient temperature, and module temperature was kept below the standard conditions of 25°C in April and January.

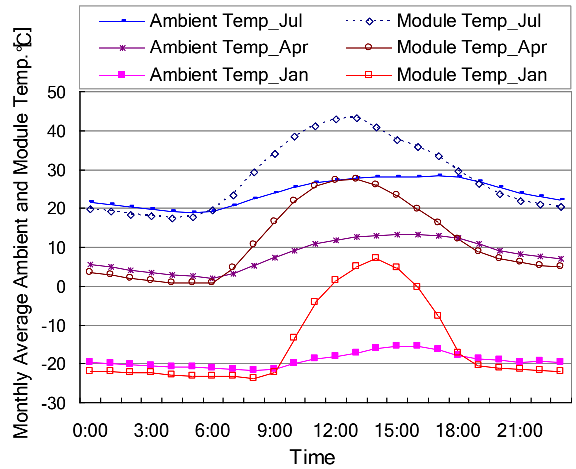


Figure 3 Daily transition of ambient and module temperature by monthly average value

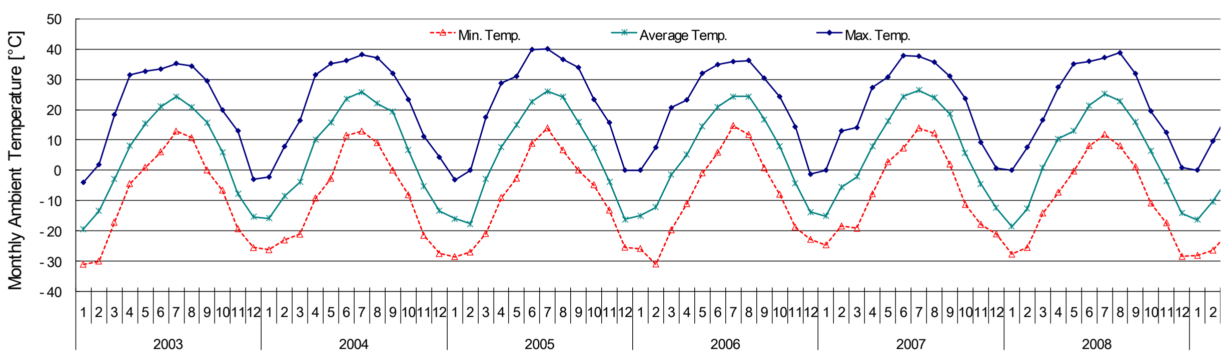


Figure 4 Monthly Ambient Temperature (Average, Min, Max) [°C]

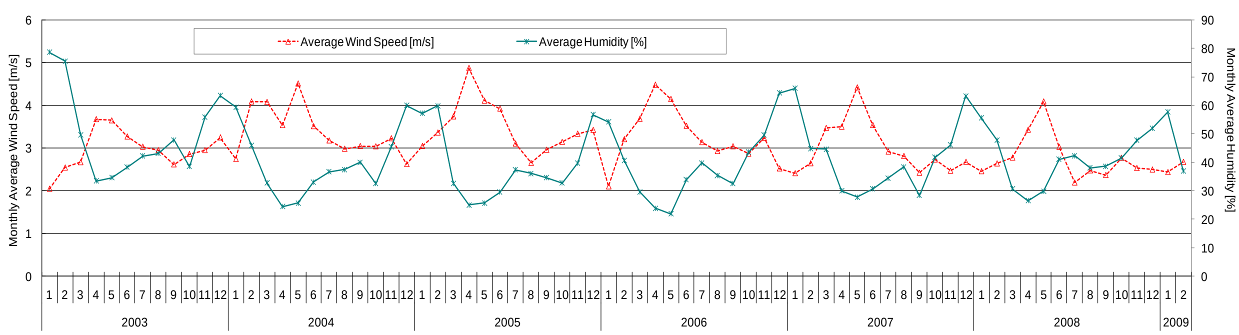


Figure 5 Monthly Average Wind Speed and Humidity

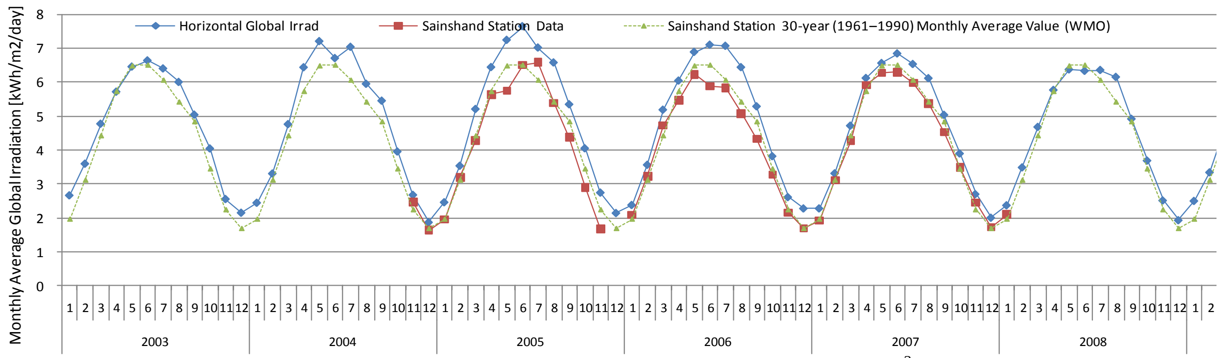


Figure 6 Monthly Average Horizontal Global Irradiation [kWh/m²/day]

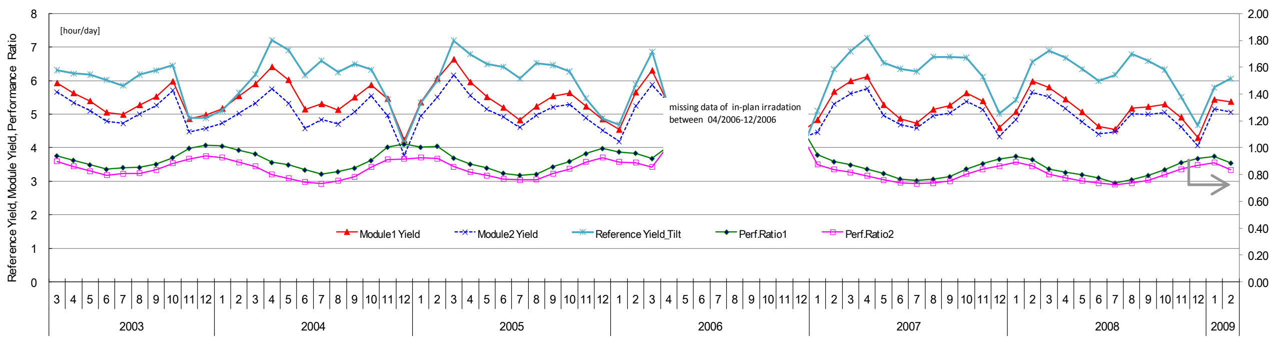


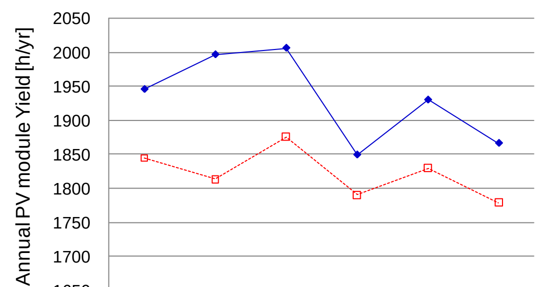
Figure 7 Reference Yield Y_r, Array Yield Y_A, Performance Ratio by monthly average value

A.Solar Energy Resource

Figure 6 shows the monthly average values of horizontal global irradiation with comparison of normal year (1961-1990, 30-year statistic values of Sainshand Weather Station by the WMO). Solar irradiations of 2003, 2007, and 2008 were similar to those in a normal year. The mean of horizontal irradiation was 4.77 [kWh/m²/day], which was 1.5-fold greater than that in Sapporo, Japan. The annual average of in-plane irradiation was 5.95 [kW/m²/day] (6 year average). The tilted irradiation data showed relatively small variation within a year, as precipitation is concentrated in the summer.

B.PV Module performance

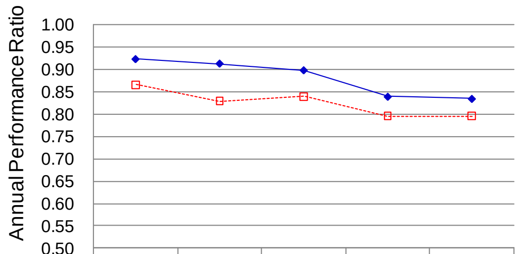
Figure 8 shows the annual PV module yields. The mean of 6 year annual PV module yields were Y_{A1}=1932 and Y_{A2}=1822 [h/yr], indicating that each module worked for 1932 h and 1822 h by rated power, P_{max}, in the year.



	2003	2004	2005	2006	2007	2008
Module-1	1946	1997	2006	1849	1930	1866
Module-2	1844	1813	1876	1790	1830	1779

Figure 8 Annual PV module Yield [h/yr]

It has been observed that the high output gain (see Figure 7, 9) due to the operating condition in an extreme low ambient temperature. Strong seasonal variations were apparent in the performance of both modules. The PR of module 1 showed very high values of >1.0 in winter and around 0.85 in the warm season due to the effect of module temperature. The PV module degradation rate indicated over -1.5[%/yr] after 6 years exposure test.



	2003	2004	2005	2007	2008
Module-1	0.923	0.913	0.898	0.839	0.835
Module-2	0.865	0.828	0.839	0.795	0.795

Figure 9 Annual Average Performance Ratio (NA 2006)

V.CONCLUSION

In this paper, outdoor performance tests of two types of PV module were conducted in Sainshand City, Mongolia. The results described here indicated high output gain due to the extremely low ambient temperature and the module performance ratio showed high values in winter. In summary, the results of the present study show that PV modules with high temperature coefficients, such as crystalline silicon, are advantageous for use in the Gobi Desert area.

REFERENCES

[1] IEA, Photovoltaic Power Systems Program, Task 8: Very large scale photovoltaic power generation systems, http://www.iea-pvps.org/tasks/task8.htm

[2] K. Kurokawa, editor: Energy from the Desert, Feasibility of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems, James & James Ltd: United Kingdom, May, 2003, 195 pages

[3] Amarbayar Adiyabat, Kenji Otani, et al., Evaluation of Solar Energy Potential and PV module Performance in the Gobi Desert of Mongolia, Progress in Photovoltaics, May 2006, pp.553–566, DOI: 10.1002/pip.692