Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 61 (2014) 2387 – 2390

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Performance Test Conditions for Direct Temperature Elements of Multiple PV Array configurations in Malaysia

M. Effendy Ya'acob[1,*], H. Hizam[1,2], M. Bakri A[3], M. Amran M. Radzi[1,2], Tamer Khatib[4], A.H.M.A. Rahim[5]

[1] Department of Electrical & Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, 43400, Selangor, Malaysia

[2] Centre of Advanced Power and Energy Research (CAPER), Universiti Putra Malaysia, Serdang, 43400, Selangor, Malaysia

[3] Institute of Mathematical Research, Universiti Putra Malaysia

[4] Institute of Networked & Embedded Systems, Alpen-Adria Universitat Klagenfurt, Lakeside laps, 9020 Klagenfurt, Austria,

[5] Department of Electrical Engineering, King Fahd University of Petroleum & Minerals, P.O Box 349, Dhahran 31261, Saudi Arabia

Abstract

Solar PV technology and application has been given the highest priority in Malaysia Feed-in-Tariff (FiT) program based on the per kWh electricity rate achieving huge cumulative quota of 18,000 MW. The high enthusiasm and green culture is based on the fact that solar energy source is free, abundance, clean and Malaysia receive approximately 6 hours of sunlight every day the whole year round. This study explores the performance test conditions (PTC) for PV arrays in the tropics based on the direct temperature effect whereby surface temperature (Ts) is implied to the Flat (FF) PV and Tracking Flat (TF) PV array while the concentrating PV (CPV) array implies bottom temperature (Tb) of the Monocrystalline PV module. The field measurement for 10 months results in array efficiency of 3.04 % for CPV, 10.04 % for FF and the highest conversion efficiency of 10.78 % from TF array. Recent studies have proven such significant reduction of 0.5 % in energy generation based on 1 ^{0}C increase in PV array temperature. Based on this critical value and field validation, contrarily, it is found that an increase of 1 ^{0}C of direct temperature element results in 3.3 % of array efficiency increase for CPV, 6.7 % for TF array and the highest increment of 8.2 % for FF array.

Keywords: Tracking PV, Field Monitoring, Performance Test Conditions, Temperature Effect

* Corresponding Author: Tel 603-89466258; Fax: 603-86567099; E-mail: fendyupm@gmail.com

doi:10.1016/j.egypro.2014.12.011

1. Introduction

Malaysia as the net oil (9th world ranking) and gas (14th world ranking) exporter is moving fast in the adaptation of renewable energy. The issue revolves on the reserve life of 33 years for gas and the remaining of 19 years for oil as of 2005 benchmark [1, 2]. Under the Tenth Malaysia Plan (RM-10), Malaysia introduced the Renewable Energy (RE) Action Plan with Feed-in-Tariff (FiT) schemes which spelled out in detail the way forward to increase the market share of RE in the generation mix. The decreasing trend fluctuates at the rate of more than 25% over the past ten years with advance technology in developing PV cells and cheaper pricing in the world market. Solar PV technology and application has been given the highest priority in Malaysia Feed-in-Tariff (FiT) program based on the kWh electricity rate and targeted Renewable Energy (RE) generation with cumulative quota of 18,000 MW [1, 2]. Solar PV received the highest FiT rate compared to the other RE resources with the rates of RM1.23 to RM1.78 for the duration of 21 years with 8% degradation.

Nomenclature	
P_{pv}	PV grid power
$T_{b,FF}$	Bottom temperature for fixed flat PV generator
$T_{b,TF}$	Bottom temperature for tracking flat PV generator
$T_{s,CPV}$	Surface temperature for concentrating PV generator
R^2	Coefficient of Determination

The Performance test condition or commonly known the Standard Testing Condition (STC) for the Photovoltaic technology refers to the reference values of the in-plane irradiance (G_{ref}) of 1000 W/m^2, PV cell junction temperature, T_c of 25 ^{0}C and air mass (AM) of 1.5 value to be used during the quality testing of any PV device. A high quality, safe and durable PV module delivers the expected rated power (W_p) withstanding extremely wide range of environmental conditions and is reputedly capable of delivering high energy yield over a period of time. The environmental test for both the module qualification and reliability testing is set at extreme conditions, compared to normal ones to accelerate any degradation especially at the PV surface. Most PV manufacturers provide the temperature elements for their crystalline PV modules based on the NOCT as the cell temperature (T_c) [3, 4, 5].

$$T_c = T_a + G / 800 \ (NOCT - 20^0C) \qquad (1)$$

where T_c is the cell temperature, T_a is the ambient temperature, G is the instant solar radiation, NOCT is the nominal operation cell temperature. Koelh et al. in [6, 7] highlights that the NOCT value should characterize the temperature dependence of the PV module which allows the estimation of the performance and the energy yield for a specific time duration and proposed Realistic Nominal Operating Cell Temperature (ROMT) as in equation (2).

$$ROMT = 20\ ^0C + 800\ W/m^2 / (U_0 + U_1 * 1\ m/s), \qquad (2)$$

where U_0 ,U_1 refers to the seasonal variation of model parameters. Good estimation for the cell temperature for a PV system installed at a specific site is very important as it affects its size and performance [8]. This study explores the performance test conditions (PTC) for PV arrays based on the effect of direct temperature increase for the given PV array configurations.

2. Methodology

Field setup of 10 kWp Solar PV Pilot Plant has been successfully installed at Universiti Putra Malaysia comprising multiple PV array configurations as shown in Figure 1. The monitoring system applied for the site is based on real-time data acquisition system with embedded Compact Reconfigurable Input Output (cRIO) platform for data synchronization. The K-type thermocouple sensors are connected directly to the surface and bottom side of each PV array configuration as to analyze the temperature difference and the impact towards green energy generation.

Figure 1: Site setup of multiple PV array configurations with thermocouple sensor

3. Results and Discussion

Systems' array efficiency values are shown in Figure 2 where the average efficiency value for the FF array is 10.04 % while the TF valued at 10.78 % which is the highest and the CPV only achieves 3.04 %. These values are much lower than the claimed efficiency of 17 % (95 W CEEG PV module). This is obviously and realistically true because of the stochastic condition at site and the series configuration of an array. Figure 2 shows the field data for PV array efficiency for all system and typical CPV surface temperature versus grid power in Figure 3.

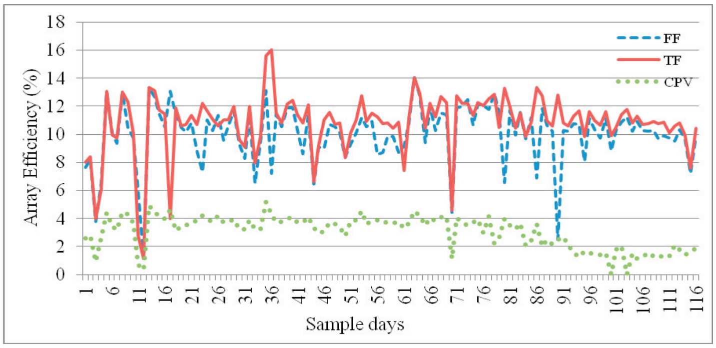

Figure 2: PV array efficiency for multiple PV array configurations

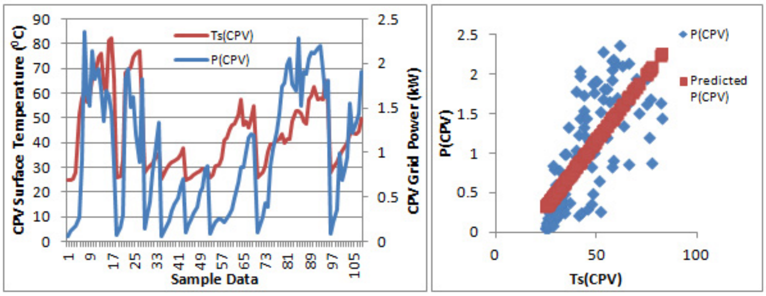

Figure 3: Typical sample for CPV surface temperature versus the grid power generated with Line Fit Plot

From site measurements and regression analysis, the following Linear Regression equations are observed.

$P\ (CPV) = 28.2 + 16.2\ T_{s,CPV}$, $R^2 = 0.54$ (3)

$P\ (TF) = 30.3 + 14.5\ T_{b,TF}$, $R^2 = 0.5$ (4)

$P\ (FF) = 28.6 + 14.6\ T_{b,FF}$, $R^2 = 0.61$ (5)

$\eta_{cpv} = 3.3\ \ln(x) - 8$, $R^2 = 0.47$ (6)

$\eta_{tf} = 6.7\ \ln(x) - 15.7$, $R^2 = 0.34$ (7)

$\eta_{ff} = 8.2\ \ln(x) - 21.2$, $R^2 = 0.42$ (8)

It is found that an increase of 1 ^{0}C of direct temperature element of PV array results in power increase of 16.2 W, 14.6 W and 14.5 W for CPV, TF and FF array respectively. For the array efficiency, the increase of 1 ^{0}C of direct temperature element results in 3.3 % increase for CPV, 6.7 % for TF array and the highest increment of 8.2 % for FF array. The findings may be due to the module tested at site is a combination of PV module in an array configuration and refers to specific sample location of direct temperature effect (surface temperature for CPV and bottom temperature for TF and FF PV array); degradation effect of silicon-based material for the PV arrays is not considered in this study and the sampling duration is within 15 minutes intervals with 108 observations.

4. Conclusion

The tropical field evaluation of temperature effect on multiple PV array efficiency is presented. Based on regression analysis on the sampled data, the result clarifies contradiction to the 0.5% energy decrease on 1 ^{0}C of temperature hike. Each PV array efficiency shows significant increase with respect to the increasing direct array temperature; 3.3 % increase for CPV, 6.7 % for TF array and the highest increment of 8.2 % for FF array.

References

[1] Effendy Ya'acob, M., Hizam, H., Htay, M. T., Radzi, M. A. M., Khatib, T., & Bakri A, M. (2013). Calculating electrical and thermal characteristics of multiple PV array configurations installed in the tropics. *Energy Conversion and Management, 75*(0), 418-424.

[2] Haris, A. (2008). MBIPV project: Catalyzing local PV market. *Finance & Investment Forum on PV Technology, Kuala Lumpur, Malaysia,*

[3] Mekhilef, S., Saidur, R., & Kamalisarvestani, M. (2012). Effect of dust, humidity and air velocity on efficiency of photovoltaic cells. *Renewable and Sustainable Energy Reviews, 16*(5), 2920-2925.

[4] Mattei, M., Notton, G., Cristofari, C., Muselli, M., & Poggi, P. (2006). Calculation of the polycrystalline PV module temperature using a simple method of energy balance. *Renewable Energy, 31*(4), 553-567.

[5] Huang, B. J., Yang, P. E., Lin, Y. P., Lin, B. Y., Chen, H. J., Lai, R. C., et al. (2011). Solar cell junction temperature measurement of PV module. *Solar Energy, 85*(2), 388-392.

[6] Koehl, M., Heck, M., & Wiesmeier, S. (2012). Modelling of conditions for accelerated lifetime testing of humidity impact on PV-modules based on monitoring of climatic data. *Solar Energy Materials and Solar Cells, 99*(0), 282-291.

[7] Koehl, M., Heck, M., Wiesmeier, S., & Wirth, J. (2011). Modeling of the nominal operating cell temperature based on outdoor weathering. *Solar Energy Materials and Solar Cells, 95*(7), 1638-1646.

[8] Khatib, T., Sopian, K., & Kazem, H. A. (2013). Actual performance and characteristic of a grid connected photovoltaic power system in the tropics: A short term evaluation. *Energy Conversion and Management, 71*(0), 115-119.