# TEMPERATURES PROFILES OF PV MODULE AT GERC

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**ABSTRACT---Temperatures of PV module has known to be one of the parameter than varies the performance of photovoltaic. *The output current and voltage of photovoltaic* module are correlated with the module's temperature. This research is specialized to examine the temperatures profiles of PV module for open circuit and close circuit condition with and without air ventilations at the bottom of the PV modules at standalone structures. The thermocouples are placed at the back of the PV module at 8 different locations. Temperatures are taken for every 5 minutes for one week for each 4 difference condition at the same 8 thermocouples location. Besides that, the temperatures of metal deck PV modules structure are taken at close circuit condition and to be compared with stand-alone PV modules temperatures. The results recorded are analyzed based on the variables.**

## I. INTRODUCTION

Module temperature is a parameter that has great influence in the behaviour of a PV system, as it modifies system efficiency and output energy [1].It depends on the module encapsulating material, its thermal dissipation and absorption properties, the working point of the module, the atmospheric parameters such as irradiance level, ambient temperature and wind speed [2] and the particular installing conditions [3].

These research are to obtained the characteristic of the temperatures profiles which effected by the variables. The variables involved in these experiments are the level of irradiance, location of the thermocouples, structure of the PV modules, the air flow at the back of the PV modules, the position of the PV module and the current flowing in the PV module. This variable are analysed as the possibilities of the change of the PV module temperature. As the variables are varied, the temperatures are recorded.

It is well known that the conversion efficiency decreases when the temperature of the solar cell rises [4]. Thus it is very important to consider the temperature characteristics of the PV system [4]. The temperatures profiles obtained could be analysed to reduce temperatures increase by preventing the courses or proposing solution for temperature rises.

The analysis of eighteen grid connected PV systems showed the importance of the optimal mounting and in the case building integration a well-designed layout to achieve an efficient cooling of the PV-modules [5]. Thus the analyses of the temperatures profiles of differences PV modules structure are important.

## II. METHODOLOGY

The temperatures are measured using J type thermocouple with temperature range of −40 to +750 °C. The PV module is located at Green Energy Research Centre (GERC) Latitude: 3.068385° Longitude: 101.495564 standalone structure. This PV module is standalone structure at 20 cm height 15° slop facing east at cement floor foundation.

ADAM VIEW 4018 software is used to capture the temperature every 5 minutes for 1 week for every condition. There are 8 thermocouple are used at different location under the PV module. The locations of the thermocouple are shown in figure 1.1. The location of the thermocouples are located on the left of PV modules array are to compare the effect to the temperature are related to the location of the examined PV module where there are five other PV modules beside it.

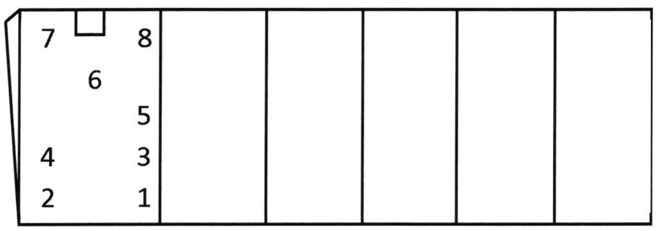


Figure 1.1 top view of thermocouples location under the PV module

There are four conditions of PV module temperatures are taken at Stand-alone structure. The first condition is when the PV module is no load (open circuits) condition which the PV module is disconnected to the inverter and there is no output current from the PV module. Second condition is on load (close circuit) which PV module is connected from the inverter and there is output current from the PV modules. The third condition is when the PV module is no load (open circuit) with non-air ventilation under the modules. The air ventilation is blocked by the plastics wrapping around the PV modules from edge of the PV module to the ground. The fourth is on load (close circuit) condition with non-air ventilation below the PV modules.

The comparisons of PV modules temperatures profiles based on structure are where the temperatures are taken from metal deck structure PV module then compared with standalone temperatures structure. The temperatures of metal deck structure are taken at the bottom of PV module situated at the canter of 3 by 7 PV modules array facing the same direction with Stand-alone structures at less than 10° slop. The foundation of the metal deck structure is the roof of GERC building which made of Zink and steel structure. The temperatures are taken during on load (close circuit) condition where the PV modules are connected to inverter for every 5 minute for one week.

The location of the data logger is inside the GERC building and the thermocouples are located about 20 meters from the data logger. This data logger are using RS 485 interface to reduced error and this type of interface only using 2 wires between the thermocouple and the data logger.

The purposes of the thermocouples been located at difference location are to recognise the variation of the temperature at each location at difference level irradiance at difference conditions. It is to analyse the reasonable reasons of the temperature variation for each location. The graphs of the temperatures are in shape of temperature versus irradiances. The Temperatures variations are representing by polynomial regression order 2. As the temperatures data captured every condition is taken for every 5 minutes for one week, it is difficult to plot on the same graph and to differentiate the temperature of difference thermocouples location.

The graph of polynomial regression line order 2 are compared in the same graph for 8 difference location under the PV module for no load (open circuit) in figure 2.1, on load (close circuit) in figure 2.2, no load (open circuit) with no air ventilation in figure 2.3 and on load (close circuit) with no air ventilation in figure 2.4.

This four condition are compared the variation of the temperatures in the same graph in figure 2.5. The comparison of temperatures profiles for metal deck and stand-alone structure of PV modules at on load condition (close circuit) are plotted at the same graph for comparison in figure 2.6.

## III. RESULT AND DISCUSSION

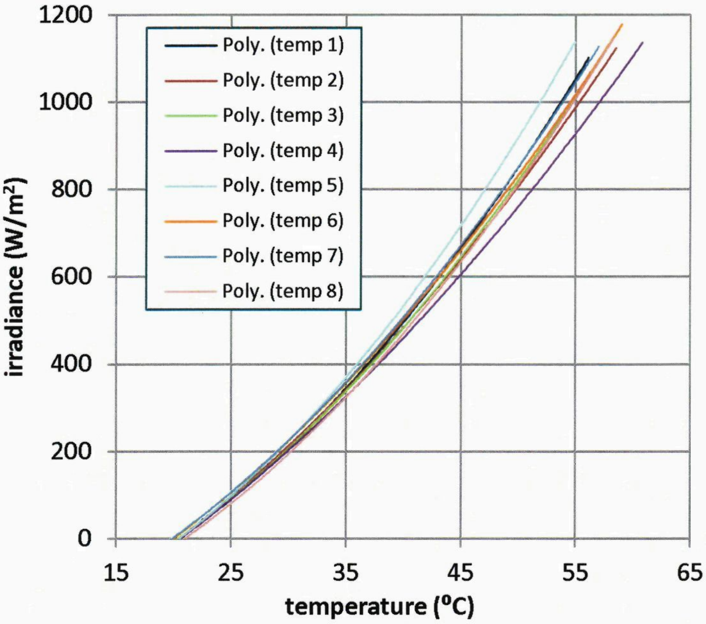


Fig. 2.1 No load temperature profile of a PV module.

Fig. 2.1 shows the graph of temperature profile of PV module for no load (open circuit) condition. These conditions are when the PV modules are not connected to the inverter and there no current flow in the PV modules.

Thermocouples 4 has the highest temperatures at irradiance is more then 300 W/m$^2$. Thermocouple 2, 4 and 7 are located at the left of the module which the heat are reflected from the floor of the PV modules structure. However, heat reflection to thermocouple 2 and 7 are blocked since the cement structure is at the bottoms of each thermocouple. It make thermocouple 2 has second highest temperature at irradiance more than 900 W/m$^2$ and thermocouple 7 is lesser because of the distance between the floor with the thermocouple are higher. At irradiance lest then 300 W/m$^2$, thermocouple 8 has the highest temperature, since irradiance at less than 300 W/m$^2$ captured usually at the morning and evening which are sunrise and sunset. Thermocouples 7 and 8 are located at the highest point of the PV module that make this thermocouples will exposed to the irradiance longer than other thermocouples. Thermocouple 8 has the highest temperature since there are 5 other PV modules at the right of the monitored PV module which make air flow from the right is less than the left of the PV module.

When irradiance is more than 250 W/m$^2$, thermocouples 5 has the lowest temperature. The location of thermocouples 5 is at the canter right of the PV module which the lowest location of irradiance reflection from the bottom of the PV module.

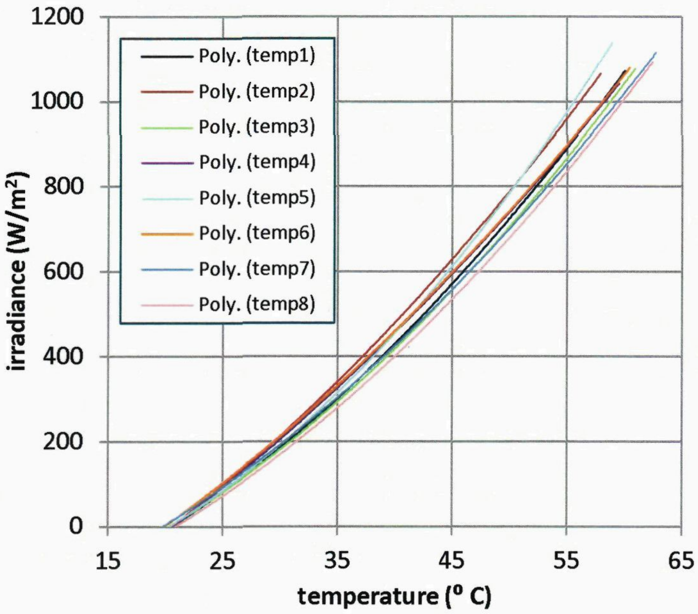


Fig. 2.2 On load temperature profile of a PV module.

Fig. 2.2 shows the graph of temperature profile of PV module for on load (close circuit) condition. This condition is when PV module is connected to the inverter and there is current flowing in the PV module.

From the graph, thermocouple 8 has the highest temperature from the zero irradiance to the highest irradiance. Thermocouple 8 located at the highest point at the PV module with thermocouple 7. At irradiance more than 600 $W/m^2$, thermocouple 7 is the second highest thermocouple. The highest point at the PV module is the highest temperature at PV module when irradiance is more than 600 $W/m^2$. This could be caused by the current flowing in the PV module which increases the temperatures of the PV module. The heat will rise to the highest point of the PV modules in order to balance with ambiance temperatures.

At irradiance at 200$W/m^2$ to 800$W/m^2$, thermocouple 2 has the lowest temperature. This thermocouple is located at the lowest point of the PV module. When irradiance is more than 800 $W/m^2$, thermocouple 5 has the lowest temperature. The location of the thermocouple is at the canter right of the PV module which has the lowest irradiance reflection from the floor of the structure.

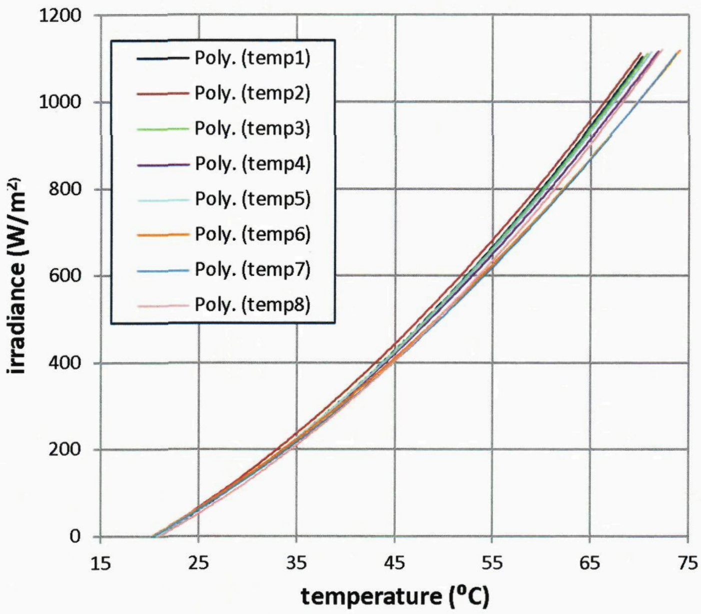


Fig. 2.3 No load temperature profile of A PV module with no air ventilation.

Fig. 2.3 shows the graph of temperature profile of PV module for no load (open circuit) with no air ventilation condition. This condition is when the PV module is not connected to the inverter, there no current flow in the PV module and the PV modules are wrapped at the edge of the PV modules to the floor of the structure to make sure there is no air flow at the bottom of the PV modules.

Based on the graph, when irradiance is less than 400 $W/m^2$, thermocouple 8 has the highest temperature. This could be caused by the hot air that traps in the wrapping. Hot air will rise to the highest point at the PV module. When irradiance is more than 400 W/m2, thermocouples 6 and 7 have the highest temperature. The irradiance from the left of the PV module is affecting the temperature when irradiance is more than 400 $W/m^2$.

Thermocouple 2 has the lowest temperature at any irradiance. Thermocouple 2 is located at the lowest point of the PV module with thermocouple 1. But thermocouple 1 is located at the right of the PV module which there are 5 other PV modules beside it which make the temperature higher than thermocouple 2.

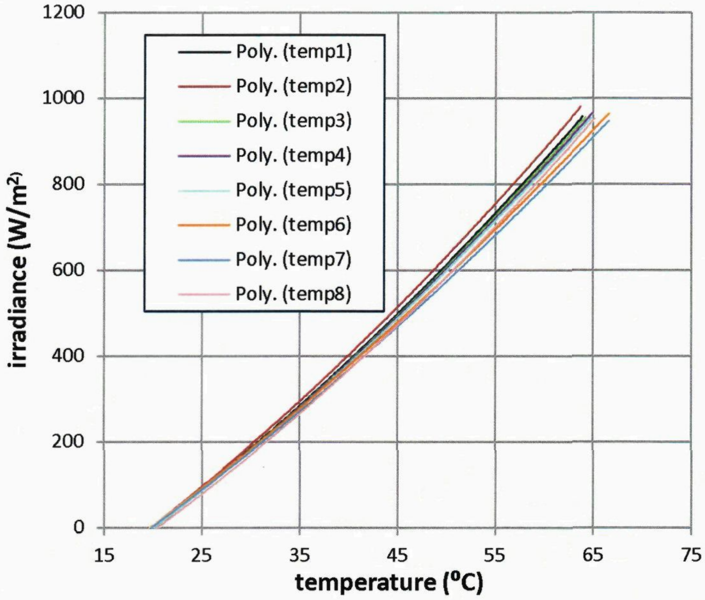


Fig. 2.4 On load temperature profile of A PV module with no air ventilation.

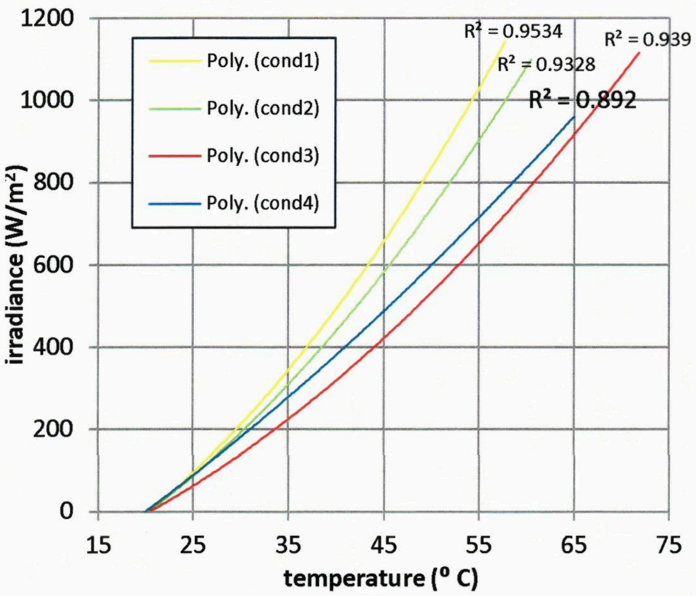


Fig. 2.5 Temperature profiles of four difference condition of module.

Fig. 2.4 shows the graph of temperature profile of PV module for on load (close circuit) with no air ventilation condition. This condition is when the PV module is connected to the inverter. There are current flows in the PV module to the inverter and the PV module is wrapped at the edge of the PV modules to the floor of the structure to make sure there is no air flow at the bottom of the PV modules.

When irradiance are less than 400 W/m$^2$, Thermocouple 7 has the highest temperatures. However, thermocouple 8 is the highest temperature when the irradiance is more than 400 W/m$^2$. These thermocouples 7 and 8 are located at the highest point of the PV module. The highest temperature is changing from the top left to the top right of the PV module. This could be caused by thermocouple 7 temperature are affected by the ambiance temperature outside the wrapping. When PV module's temperature are below ambience temperature, thermocouple 7 temperature will be increased to balance with ambience temperature. When PV module temperature are more than ambience temperature, Thermocouple 8 temperature will increase caused by the increase of irradiance and thermocouple 7 increase in temperature will not the same as thermocouple 8 caused by the effect of ambiance temperature left side of the rapping.

Thermocouple 2 has the lowest temperature at any irradiance. Thermocouple 2 is located at the lowest point of the PV module with thermocouple 1. But thermocouple 1 is located at the right of the PV module which there are 5 other PV modules beside it which make the temperature higher than thermocouple 2.

Fig 2.5 shows the graph of 4 different conditions. The first graph is no load (open circuits), second is on load (close circuits, third is no load (open circuits) with no air ventilation and fourth is on load (close circuit) with no air ventilation.

From above graph, the no load (open circuit) condition has the lowest temperature at irradiance more than 100 W/m$^2$. The air flow below the PV modules does reduce the temperature of the PV module. The current flowing in the PV modules was increase the PV module temperature when there is air flow below the PV modules.

When the air flow below the PV module was blocked, the PV module temperature increased. The current flows in the PV modules to the inverter were reducing the temperature when there is no air ventilation below the PV modules. This could cause by the temperatures of the PV rise to the highest point when there are no air ventilation. When the PV module produced the current, it will reduce the temperature until curtain level where the PV module temperature balances with ambience temperature at current equal to square of current.

The condition when PV module are on load (close circuit) with no air ventilation, the temperature are more scattered compared to other condition. This makes the accuracy of the Polynomial regression line are less accurate compared to other condition. This condition might be affected by the current flowing in the PV module.

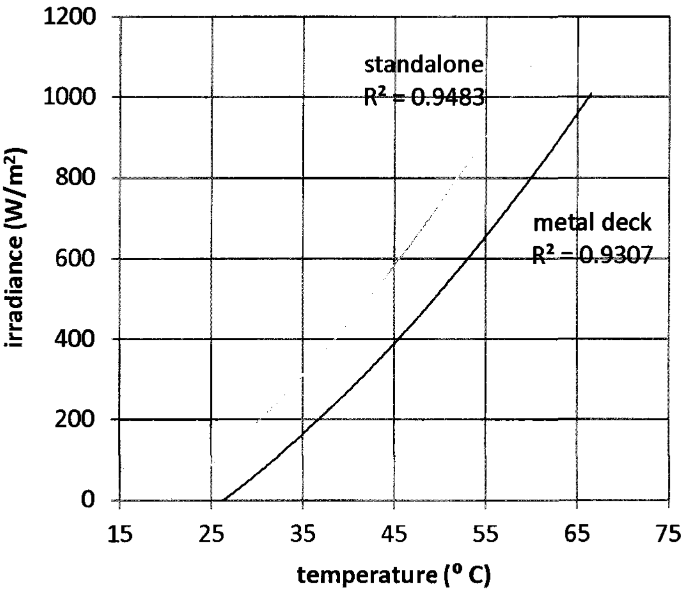


Fig. 2.6 On load Temperature profile of two difference structure.

Fig. 2.6 shows the graph of temperatures profiles of two different structures of PV modules. These two structures have the different at the position of installation.

From the graph, the metal deck structure has higher temperature than standalone structure about 5 ° C. Metal deck structures has less gap between the PV module and the roof where the structure been set. As these metal deck structures are situated at building roof, the temperature of the zinc roof will obviously increase the temperature. The Stand-alone structure has more air flow below the PV modules since the slop of the PV modules are higher than metal deck structure. Besides that, the arrangement of the PV module array of metal deck structure is reducing the air flow below the PV which there is no gap between the PV modules.

## IV. CONCLUSION

The reflected irradiance from the floor of the PV modules structures will increase the PV modules temperatures and the lowest exposed to the reflection will has the lowest temperatures. The current flowing in the PV modules will increase the temperature since current is equal to square of resistance when there are air flow below the PV module. The air flow below the PV modules reduces the PV modules temperature. When there is no air ventilation below the PV module, the current flow in the PV modules reduces the PV modules temperatures because of the hot air trapped below the PV module increase the temperature to the highest point that makes the current flowing makes the PV module temperature reduced. The current flowing in the PV module increase temperature, but no air ventilation is rising the PV modules temperature to higher temperature. The Stand-alone PV modules structure has lower temperature profile compared to metal deck because of the gap between the PV modules and the floor of the structure. In addition, the arrangement of metal deck PV modules array is reducing the air flow below the PV modules

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