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EFFECT OF COOLING ON PERFORMANCE OF SOLAR PHOTO-VOLTAIC MODULE

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Abstract

In this project, the effects of fins cooling (passive cooling) and water cooling on performance parameters of solar photovoltaic (PV) module have discussed. In fin cooling method, an aluminum heat sink with fins have attached to the backside of PV module in order to dissipate waste heat from it. In the second method, a water film has created by recalculating the water with the help of water pump over the surface of solar panel using a pipe distribution system to the top of the panel. From the experiment, it have been concluded that the power and the electrical efficiency of the cooling PV system are higher than the traditional one. It have also been found that the module temperature of the fins cooling method has maintained it 3ºC to 5ºC below the conventional reference module and the percentage increase in electrical efficiency is 2% to 5.82%. Whereas the module temperature of water cooling method has maintained at 15ºC to 28ºC below the conventional and the percentage increase in electrical efficiency is 6.91% to 16.94%.

Keywords: *Solar Photovoltaic Module; Water Cooling; Fin Cooling; Electrical Efficiency*.

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1. Introduction

Renewable energy resources have huge potential and it can meet the present world energy demand. The renewable energy sources which are derived from the sun are one of the best options. Among of all renewable energy technologies Solar energy is one of the most important technology, since it provides an unlimited, clean and environmentally friendly energy. PV cell is one of the most popular renewable energy sources. It can directly convert the solar energy into electricity through the photovoltaic effect. Conversion of sunlight into electricity by using photovoltaic (PV) cells is a consequential and rapidly developing solar energy application. Intensive efforts are made to lower the cost per peak power getting from PV cells. These efforts are aim at decreasing the gap between PV and conventional power sources. Apart from importance of developing a new manufacturing processes related to PV cells, it is very significant to provide the most appropriate operating conditions for a PV cells system.

1.1 About Photovoltaic

The photovoltaic effect was firstly find out by the physicist Edmund Becquerel in 1839. Apart from, this technology is considered to as very recent one. In 1941 first cell which could be considered as PV cell was invented with an efficiency of 1%. Sunlight is composed with photons, which can be called packets of energy. These photons having various amount of energy depending to the wavelengths of light. When photons strike on a solar cell, a semiconductor P-N junction device, they absorbed the photons. Due to absorption of photons in a solar cell this results in the generation of electron-hole pair. This EHP, when separated from each other from the P-N junction, this results in the generation of a voltage across the junction, which can be drive current in an external circuit and, after that, the power can be get from the solar cell, also called as photovoltaic device.

1.2 Rating of PV Modules

According to peak power output, rating are done for the solar PV modules. The peak power output is specified under standard test conditions (STC). The following condition are refers as STC condition:

- Irradiation: 1000 w/$m2$.
- Cell or module temperature: 25ºC.
- Wind speed: 1m/s.

Most of the time and location STC condition is not occur. So in order to have a better realistic figure for the possible power output from a PV module, the performance of the modules should be described in two other test conditions: standard operating conditions (SOC) and nominal operating conditions (NOC). Both of these use a different concept temperature, called nominal operating cell temperature (NOCT).

1.3 Effect of Temperature on Power Output

The output power of a solar PV modules depend on the temperature at which the module is operating. The module temperature could be up to 20ºC to 30ºC higher than the ambient temperature, depending on the conditions such as radiation intensity, wind speed, etc.

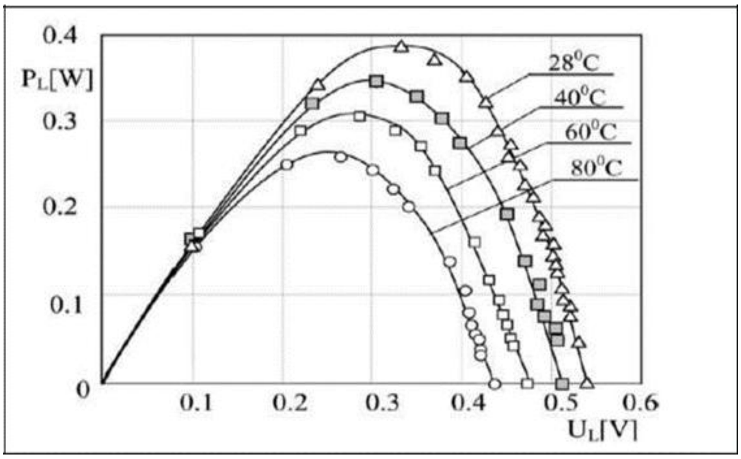

Figure 1: Effect of Temperature on Power.

The increased cell temperature result in an increase in short circuit current and decrease in the open circuit voltage. Decrease in the open circuit voltage is more prominent than the increase in short circuit current. Therefore, as shown in figure 1, the power output and efficiency of solar cell and module decreases with increase in its operating temperature [1]. The current increase with temperature is due to the decrease in the band gap of Si and voltage decrease with temperature due to the increase in the carrier recombination.

2. Literature Review

Palyvos and Skoplaki invented the operating temperature of commercial grade which is based on solar cells/modules and its effect over the electrical performance of photovoltaic installations. The operating temperature plays important role in process of the photovoltaic conversion. So the power output for PV module depends linearly on the operating temperature.

Tripanagnostopoulos and Tonuidoes investigation on the performance of two low cost heat extraction improvement modifications in a PV/T air system to getting higher thermal output and PV cooling so that it keep the electrical efficiency at acceptable level. PV/T technology allows producing thermal and electrical energy at the same time, through the direct conversion of solar radiation. They present a theoretical model and validated against experimental data and used to study the usual and modified configurations applied to the PV/T test models. The use of thin (flat) metal sheet suspended at the middle or a finned back wall of an air channel in a PV/T air.

Moharram et al. minimized the amount of water and electrical energy needed for cooling of the solar panels, a heating rate model is used to get how long it takes to heat the panels to the maximum permissible temperature limit that can be lead to the maximum energy yield. On the basis of this model, it can be determined that when we have to start cooling of the PV panels. A model was developed to have idea how long it will take to cool the PV panels to the normal operating temperature. The rate of cooling is 2 ^{o}C /min, which means that the cooling system is operated for 5 min each time, for decrease the module temperature by 10^{o}C.

Jones and Underwood model a thermal analysis of PV module based on climate variables. The changes in module temperature are shown to be in a non-steady state with respect to time. Combined model is got to agree with the response of the measured model temperature for transient changes in irradiance.

Hyung Do et al. presented a resistance correlation for design tool of a natural convective heat with plate-fins for concentrating photovoltaic (CPV) module cooling is suggested. So, extensive experimental investigations are performed for different heat sink geometries and input power, as well as inclination angle. The thermo physical properties of water confirm that it as a good cooling medium. It transforms radiation to electrical energy and absorbs the heat from the panel. According to this, the panel is working in lower temperatures.

2.1 Outcomes of Literature Review

It is evident from the literature studied by various investigators that the influence on the efficiency of PV module of its operating temperature is significant. There are a lot of work has been done in various cooling method. Some of cooling techniques are- natural or forced convection by air, use of heat pipe, heat sink at the back side of panel, water cooling etc.

3. Problem Identification

Photovoltaic (PV) cells utilize a small fraction, only around 15% of the incident solar radiation to produce electricity and the remainder is turned mainly into waste heat in the cells and substrate raising the PV temperature hence the efficiency of the module drops. That's why, decreasing the temperature of PV module results in boost the electrical efficiency. The cooling of photovoltaic (PV) module is a big problem under great practical significance. Commonly, fue techniques, like water cooling and air cooling, are used to cool the PV module to obtain lower operating temperature.

But, the higher cost of solar cells is an clog to expansion of their use. PV cooling have the potential to overcome the cost of solar energy in following ways. First one is, the electrical efficiency of PV cells decreases with temperature increase. So that Cooling can be improved the electrical production of standard flat panel PV modules. Second one is, cooling makes easy the use of PV systems. Cooling keeps the PV cells from reaching temperatures at which irreversible damage occurs

4. Thermal Analysis

4.1 Energy Balance Equation

Thermal model considering the thermal energy exchange between module and environment. The three modes of heat transfer are conduction, convection and radiation. Energy is also taken from the module in the form of the electrical energy generated. Convection and radiation heat transfer from the front and back surfaces of the module are considered significant, whilst heat conducted from the module to structural framework is considered negligible due to small area of contact points.

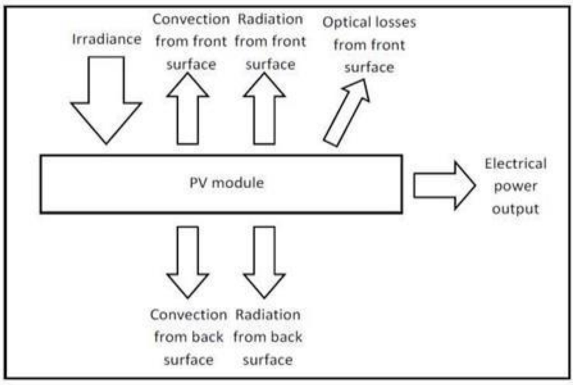

Figure 2: Heat losses from PV module

The resulting rate of temperature change with time may be expressed as the sum of these contributions:

qin - $Pout$ - $qloss$ – $Cmod\ dTmod/dt$= 0, Where qin is the incoming solar radiation reaching the front surface of the PV module, $Pout$ is the electric power produced by the module, includes the heat transfer from the PV module to the environment and vice versa, $Cmod$ is the heat capacity of the PV module, $Tmod$ is the module temperature, and t is time.

The effective incoming solar radiation reaching the front surface of the PV module can be calculated as

qin = αGA,

Where G is the incoming solar irradiation on the tilted PV module, α the absorptivity is taken 0.85 and A the area of the PV module.

The output power can be extracted directly from the electrical current-voltage characteristic of the PV module

$Pout$ = VI

Where I is the produced current and V the voltage.

The main mechanisms of heat transfer from the PV module to the environment are conduction, convection and radiation. However, the contact area between the PV module and its mounting rack is small and the conduction transfer can be neglected leading to

$qloss = qconv + qrad$

Heat capacity refers to the energy transfer required to change the temperature of an object. In the case of the PV panel, which is a multi-layer laminate, the module heat capacity can be calculated traditionally as a composite of the heat capacities of layers in the laminate:

$Cmod = \Sigma\ Adn\ \rho nCp,n$

Where dn is the thickness, ρn the density and , Cp,n the specific heat of layer n. The value of these parameter are taken from the literature. The total value of $Cmod$ is 1614.964 J/k.

4.2 Fin Cooling Arrangement

In fin cooling a heat sink of fins are attached on the rear side of one photovoltaic module with the help of adhesive. The materials of fins are aluminum because of higher thermal conductivity (207w/mk) and light in weight. Fins are made by block of aluminum with extended surface as shown in figure 4.8. Total numbers of fins are 21 with 1.5 cm spacing. Thickness of fin material is 2 mm.

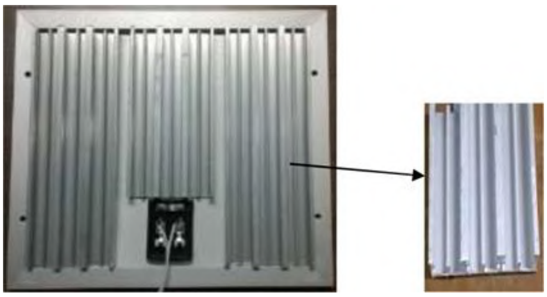

Figure 3: Fins heat sink at the back of PV module

5. Methodology

The objective of this study is to research passive cooling effects on performance of PV module and change in the efficiency and maximum power output is calculated. So as to calculate the performance by natural convective heat sinks with fins, experiment are conducted. Two different type of silicon PV module were examined in the experimental study. One PV module was outfitted with aluminum heat sink and other PV module was not. The heat sink has been attached at the back side of the PV module using adhesive. Temperatures of PV module are calculated by an infrared high-temperature thermometer.

- Before starting the experiments, both PV module are maintain at same temperature..
- All measurements (module electrical characteristics, change in module temperature and ambient condition) are done after each 30 minutes.
- Both module are placed at same time in same inclination angle and same weather condition.
- In every 30 minutes duration radiation intensity is measured with the help of pyrometer by keep it parallel to the parallel of PV module surface.
- The other ambient condition like ambient temperature and local wind velocity is measured by Anemometer for every 30 minutes.
- Temperature of both PV module is measured using high accurate infrared thermometer.
- For calculating the power and efficiency of the module, PV module electrical characteristic i.e. voltage and current should be known. Voltage and current are measured with the help of main controller. Resistance is vary from zero to maximum with the help of rheostat. Thus value of voltage and current are obtained at different condition

6. Result and Discussion

The thermal model implement in this work is based on the energy balance equation and heat transfer analysis. Operation of the model is validated simultaneously with experimental measurement. Calculation of a progression of module temperature values utilizing the dynamic model requires an underlying estimation of module temperature. Up until this point, all calculations have utilized the measured value of temperature as the underlying estimation.

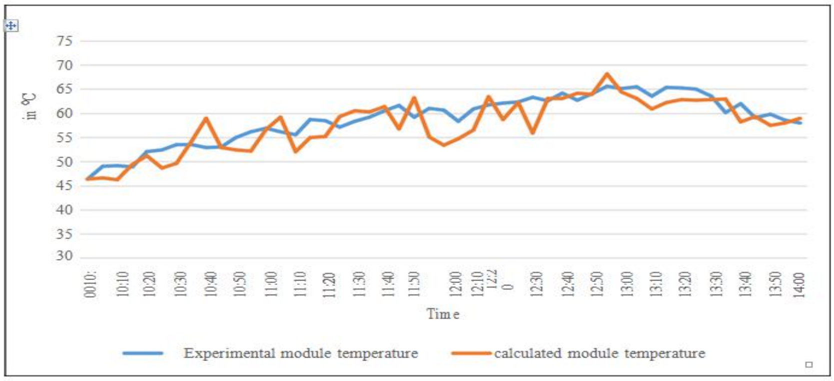

Figure 4: Graph for module temperature variation

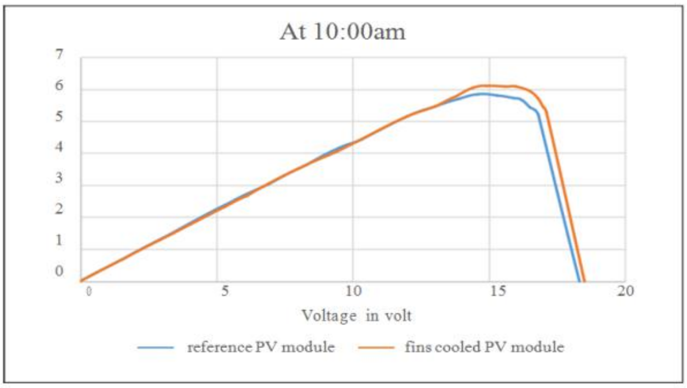

Figure 5: Graph for PV characteristic

6.1 Change In Power With Time

In the morning the radiation level is low, so initially the power output is low. Changes in temperature primarily follow changes in irradiance. At around 12 pm because of change in fluctuation in radiation and there is a time of low wind speed causing the warming of the modules so eventually power output decreases, but again with increase in radiation power output increases. Fins cooled module temperature is 2-3ºC cooler than conventional reference PV module.

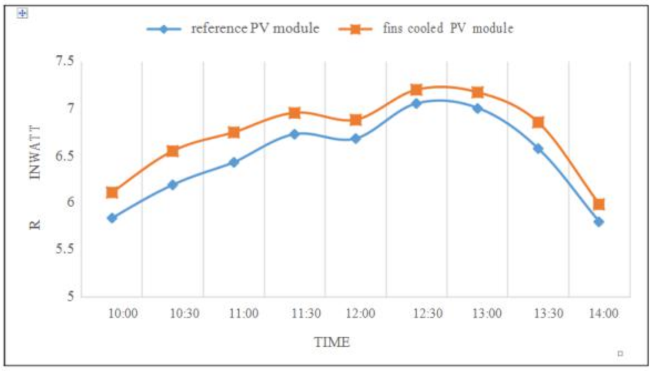

Figure 6: Graph for power vs. time

6.2 Change In Efficiency With Time

High module temperature decrease the module efficiency, which is shown in the graph below. The difference in efficiency of both module are 0.2-0.3%. So fins cooled module gives 2-3 %, percentage increase in efficiency of reference module

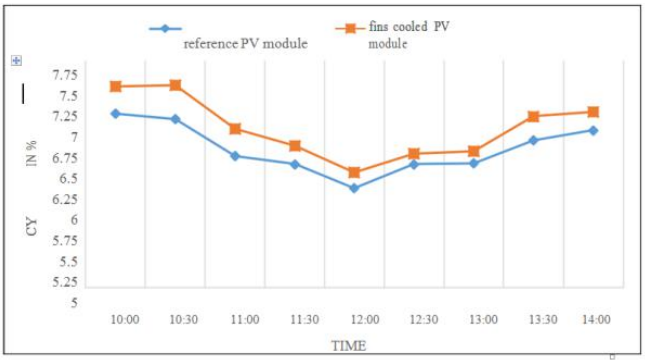

Figure 7: Graph for efficiency vs. time

6.3 Change In PV Module Temperature

PV module temperature follows the radiation changes relying upon different heat transfer processes. It additionally relies upon different climatic factors . In this experiment due to use of fins at back of panel, heat transfer is increases due to natural air cooling.

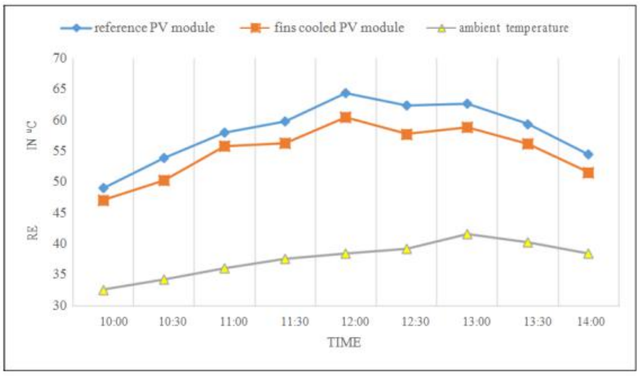

Figure 8: Graph for module temperature vs. time

7. Conclusion

The photovoltaic panel efficiency is dedicated to the panel temperature and decreases when the temperature of the panel increases. Consequences of present work show that temperature of the panel can be control at a ideal temperature level. Temperature of the PV module is additionally subjected to the atm temperature. The module surface temperature significant affects the open circuit voltage, while it has less effect on short circuit current.

Natural convective heat sink with fins arrangements at the back side of the panel's electrical performance compared to the usual system as shown in power-voltage curve in chapter 6 results. We can determine Efficiency and maximum power output of PV cells with and without fins from the curve.

- Difference in temperature between the conventional reference module and finned module is only 3^{0}C to 5^{0}C.
- Experimental outcome justify that increase in efficiency is 0.13% to 0.41%.
- Percentage increase in efficiency is 2% to 5.82%. This cooling method is more appropriate when wind velocity is high.

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