Analysis and Modification in Cooling System Using Solar Photovoltaic Module

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ABSTRACT
Under the project, the effects of fins cooling (passive cooling) and water cooling on performance parameters of solar photovoltaic (PV) module have been done. In the system of fin cooling, an aluminium sink containing fins have been attached to the backside of PV module in order to dissipate efficiently the waste heat from it. In the second method, a water film is created by continuously circulating the water over the surface of solar panel using a pipe distribution system to the top of the panel. After completion the test, 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 3°C to 5°C below the conventional reference module and the percentage increase in electrical efficiency is 2.1% to 5.85%. Whereas the module temperature of water cooling method has maintained at 15°C to 28°C below the conventional and the percentage increase in electrical efficiency is 6.9% to 16.9%.

Keywords: solar panel, cooling, efficiency, thermal analysis, smart cleaning and cooling, dust effect, temperature effect, photovoltaic etc.

I INTRODUCTION

(a) Background - At current condition, most of the world's energy (80%) is produced from fossil fuels. Massive exploitation is leading to the exhaustion of these resources and imposes a real threat to the environment, apparent mainly through global warming and acidification of the water cycle. Keeping the above in mind as well as the lack of fossil fuel present in earth indicates to choose some alternatives to fulfill our requirement of power hence, Renewable energy is one of the most promising alternatives to the above problems. Renewable energy resources have enormous potential and can meet the present world energy demand. The renewable sources of energy derived from the sun are one of the promising options. Solar energy is one of the most important renewable energy technologies, 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 directly into electricity by photovoltaic (PV) cells is a significant and rapidly developing solar energy application. Intensive efforts are made to reduce the cost per peak power obtained from PV cells. These efforts aim at narrowing the gap between PV and conventional power sources. Besides the importance of developing new manufacturing processes related to PV cells, it is quite significant to provide the most appropriate operating conditions for a PV system.

(b) About Photovoltaic - The photovoltaic effect was first discovered by the physicist Edmund Becquerel in 1839. Despite that, this technology is considered to be a very recent one. The first cell which could be considered as PV was constructed in 1941 with an efficiency of 1%. Sunlight is composed of photons, or packets of energy. These photons contain various amount of energy corresponding to the different wavelengths of light. When photons strike a solar cell, a semiconductor P-N junction device, they absorbed the photons. Absorption of a photon in a solar cell results in the generation of electron-hole pair. This EHP, when separated from each other across the P-N junction, results in the generation of a voltage across the junction, who can drive the current in an external circuit and, therefore, power can be extracted from the solar cell, also referred to as photovoltaic device. Present photovoltaic technology has been well developed since 1941. PV panels are used as the primary electricity source in space missions and satellites. The cost of producing electricity for house applications has dropped dramatically and PV panels are becoming more and more economic viable. New materials have been developed and new technology has created PV panels at efficiencies of 20% in many cases. One relative new type of PV panel is the hybrid PV panel. This type of panel converts the sun's radiation to electricity while providing heat to the system for other purposes. This can be done by either air or a fluid coolant. The cooling medium apart from conducting heat is cooling the panel making it more efficient. The most widely used fluid is water.

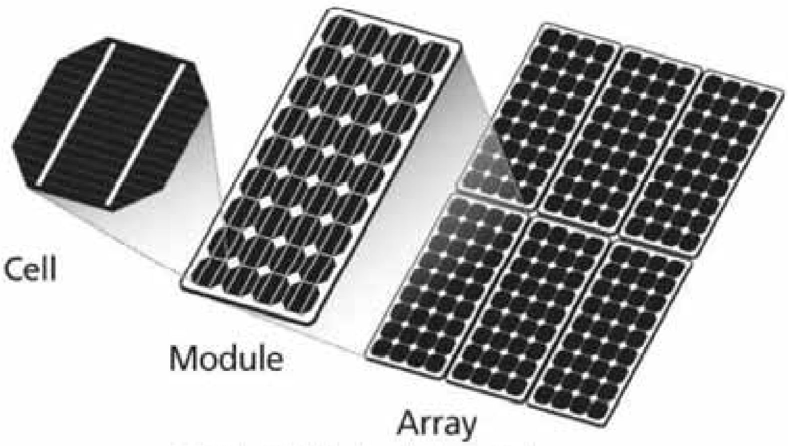


Fig No. 1.1 Photovoltaic module

A solar PV module can be considered as a big solar cell (array of solar cells connected in series and parallel) with larger voltage and current output than a single solar cell (hence large output). The solar PV module is obtained by interconnecting smaller solar cells. In order to protect the module from environmental damage, the PV modules are packaged using glass at the front side and polymer resin for encapsulation and back side protection which provide electrical isolation and protection. Protection from environment is achieved by using two sheets of encapsulant at either side of the electrically connected cells. At the rear side of the module a hard polymer material is used. Normally, it is polyvinyl fluoride (PVF), which is white in color.

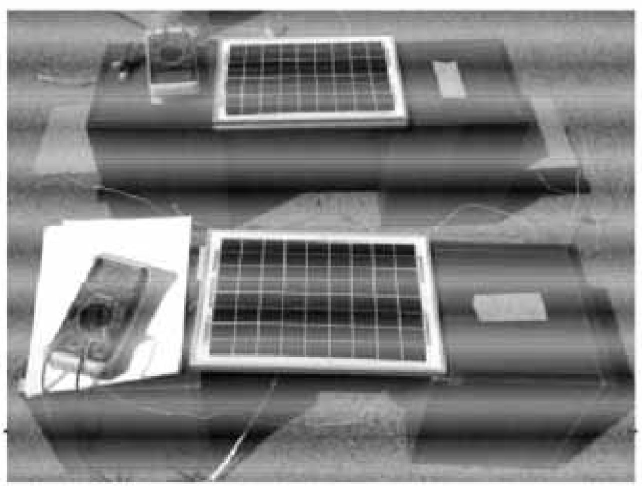


Fig No. 1.2 Component of PV module

II OBJECTIVES OF THE PROJECT

This project is based on the experimental analysis of cooling methods and thermal analysis of photovoltaic module. The objectives of the project are

(a) Apply a passive cooling method by fin cooling method.
(b) Cooling by utilizing a flowing film of water on the module front face (water cooling method). Then, a comparison between these two systems for the most efficient.
(c) Present a thermal mathematical model of photovoltaic module for calculating the PV module temperature.

Passive cooling method means there is no need of energy and in active cooling method energy input is required. In first method, the cooling system is used in which the aluminium fins are attached to the rear side of the PV module. In the Second method a continuously flowing film of water is utilize on the module front.

III LITERATURE

Many studies have been focused on the temperature response of PV performance since operating temperature is one of the biggest factors that affect the conversion efficiency. In order to reduce the impact of temperature on PV cell performance, a cooling system can be implemented to take heat out of them. There are some cooling methods of photovoltaic module.

(a) Previous Work - The problems of the temperature influence on the current-voltage characteristics of silicon photovoltaic system. Physical aspects of deterioration of the output power and the conversion efficiency of solar cell and PV module with increasing temperature are explained by many researchers. Radziemska [1] revealed that the output power declines at -0.65%/°C for crystalline PV cells, which is actually much higher than the theoretical value of -0.4%/°C. Skoplaki and Palyvos [2] presented regarding the operating temperature of commercial grade silicon-based solar cells/modules and its effect upon the electrical performance of photovoltaic installations. The operating temperature plays a central role in the photovoltaic conversion process. Both the electrical efficiency and hence the power output of a PV module depend linearly on the operating temperature. Tonui and Tripanagnostopoulos [3] investigated the performance of two low cost heat extraction improvement modifications in the channel of a PV/T air system to achieve higher thermal output and PV cooling so as to keep the electrical efficiency at acceptable level. PV/T technology allows to produce electrical and thermal 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.3. Shahsavar and Ameri [4] has designed and tested a model of direct-coupled PV/T air collector at a geographic location of Kerman, Iran. In this system, a thin aluminum sheet suspended at the middle of air channel is used to increase the heat exchange surface and consequently improve heat extraction from PV panels. This PV/T system has tested in natural convection and forced convection (with two, four and eight fans operating) and its unsteady results are presented in with and without glass cover cases. Setting glass cover on photovoltaic panels leads to an increase in thermal efficiency and decrease in electrical efficiency of the system.

(b) Outcomes of Literature Review - It is evident from the literatures 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.

IV METHODOLOGY

(a) Experimental Set-Up

(i) Equipment Used For Experimentation

- **Solar PV Module** - Two small solar panel is used for this purpose. One module is left without cooling and the other was cooled by two different cooling method. Two 10 watt rated power photovoltaic module of same specification and manufacturer is used. The second PV module is always used for comparison purpose. The module has 36 cells. The electrical parameters of the module at STC condition are-
- **Infrared Thermometer** - Infrared thermometer is a non-contact type thermometer. The basic design consists of a lens to focus the infrared thermal radiation on to a detector, which converts the radiant power to an electrical signal that can be displayed in units of temperature after being compensated for ambient temperature. The temperature range of the thermometer is -50°C to 550°C with an accuracy of ±2%.

Fig No. 4.1 Infrared thermometer

(c) Complete Experimental View - The output of the photovoltaic module which is kept in the sunlight is connected to the ecosense main controller. The load is changed by rheostat. Other measurements are done by pyranometer, infrared thermometer and anemometer.

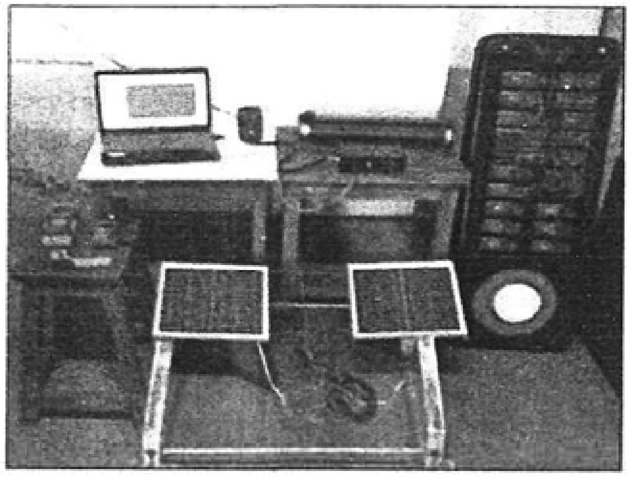
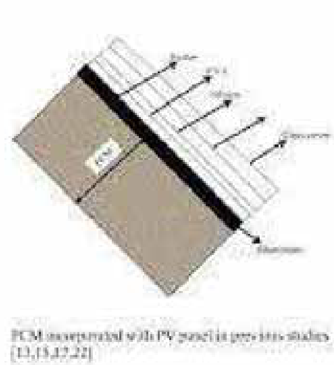
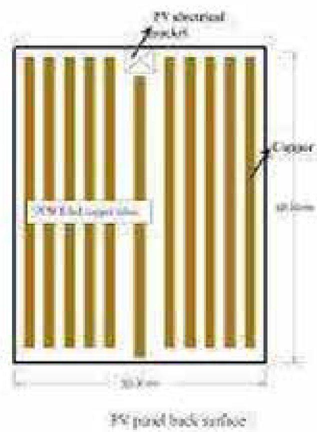


Fig No. 4.2 Complete setup view

(d) 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 of aluminium block with extended surface as shown in figure 4.8. Total number of fins are 21 with 1.5 cm spacing. Thickness of fin material are 2 mm.





V METHODOLOGY

Objective of the project is to compare the performance of the cooled PV module with a conventional module. Two different cooling methods are applied. One is fins cooling method and second is water cooling method. Methodology followed for both cooling methods is same.

(a) Fins Cooling Method - The goal of this study is to investigate passive cooling effects on the performance of PV module and enhancement in the efficiency and power output. In order to evaluate the performance of PV module with fins, experiment has been conducted. Two identical module have analyzed in the experimental study. One of the PV module is equipped with an aluminum heat sink while the other is not. The heat sink is attached at the back of the PV module using adhesive. Experiment has conducted in the month of April 2015 for 4 hour duration.

(i) Before starting the experiments, both PV module maintained at same temperature. Both module are placed at same time in same inclination angle and same weather condition.

(ii) All measurements (module electrical characteristics, module temperature and ambient condition) are taken in the intervals of 1 hour.

(iii) In the intervals of 1 hour, radiation intensity is also measured with the help of pyranometer by keeping it parallel to module surface. The ambient condition like ambient temperature and local wind velocity are measured by Anemometer for every 1 hour.

(b) Water Cooling Method - In the current experiment used two solar PV panel, one is cooled by a continuous film of water on the working surface of the panel while other is not. Besides the cooling of the panel, the other advantages of this system are loss reduction caused by radiation reflectivity (refractive index of water is 1.3, i.e. an intermediate value between 1.5 for glass and air with 1.0) and the possibility of cleaning deposits such as dust or dry leaves on the surface of the panels. Due to the rapid flow of the water there is only a slight increase in water temperature.

VI RESULT AND DISCUSSION

(a) Thermal Analysis - The thermal model which is shown in the work is implemented with the energy balanced equation and heat transfer analysis. Operation of the model is validated simultaneously with experimental measurement. Calculation of a series of module temperature values using the dynamic model requires an initial value of module temperature. So far, all calculations have used the measured value of temperature as the initial estimation.

(b) Fins Cooling Method Result - It is observed that the module temperature decreases using fins cooling system. This causes the panel efficiency to increase.

Table No. 6.1
Result

Time	Conventional PV module Temperature (°C)	Fins Cooled PV Module tempera-ture (°C)	Conventional PV module efficiency (%)	Fins cooled PV module efficiency (%)	Increase In efficiency (%)	Percentage increase in efficiency (%)
10:00	49.1	47.1	7.1	7.43	0.33	4.64
11:00	58	55.8	6.59	6.92	0.33	5
12:00	64.4	60.5	6.2	6.39	0.19	3.06
13:00	62.7	58.9	6.5	6.65	0.15	2.3
14:00	54.5	51.6	6.9	7.12	0.22	3.18

(i) 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 due to fluctuation in radiation and there is a period of low wind speed causing the heating of the modules so ultimately power output reduces, but again with increase in radiation power output increases.

Fins cooled module temperature is 2-3°C cooler than conventional reference PV module.

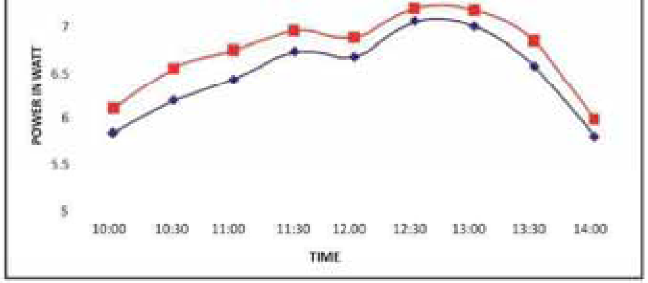


Fig No. 6.1: Graph

(ii) Change In Efficiency with Time - High module temperature decrease the module efficiency, which is shown in the graph below. The increases in efficiency of both modules are 0.13% to 0.41% and percentage increase in efficiency by using the fins cooled module is 2.1% to 5.8%.

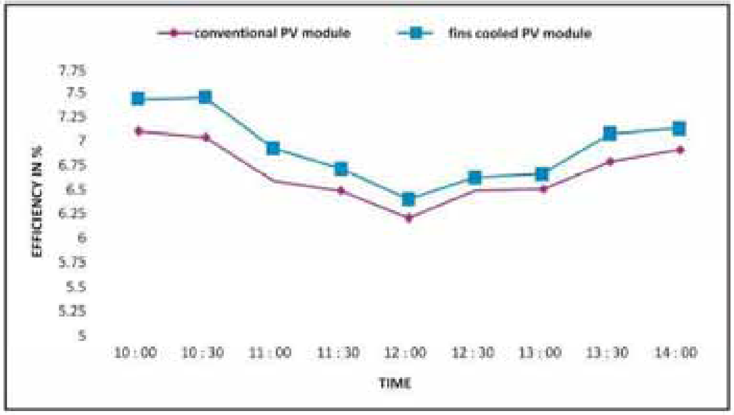


Fig No. 6.2 : Graph of efficiency vs. time

(iii) Change in PV Module Temperature - PV module temperature mainly depend on the sun radiation intensity. It also depends on various climatic variables. In this experiment by using the fins at back of panel, heat transfer is increases due to natural air cooling. This is the reason fins cooled module temperature curve is always below the conventional module.

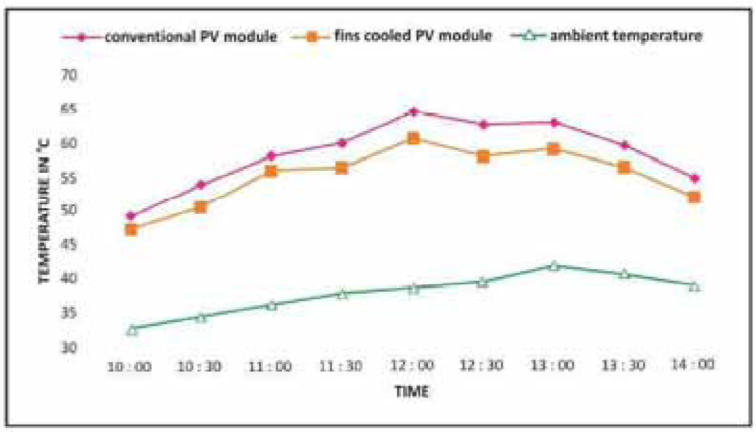


Fig No. 6.3: Graph for module temperature vs. time

(c) Water Cooling Result - Experimental measurements of the power and the module temperature of the PV panel is done during April 2015. Operating temperatures is reducing significantly in comparison to a conventional reference module which is measures simultaneously with water cooled module.

Table No. 6.2
Result

Time	Conventional PV module temperature (°C)	Fins cooled PV module tempera-ture (°C)	Conventional PV Module efficiency (%)	Fins cooled PV module efficiency (%)	Increase in efficiency (%)	Percentage increase in efficiency (%)
10:00	46.6	31.6	7.18	7.68	0.5	6.96
11:00	56.9	34	7.02	7.86	0.84	11.96
12:00	60.7	36	6.99	7.77	0.78	11.15
13:00	65.7	37.3	6.68	7.81	1.13	16.91
14:00	58	36.8	6.84	7.94	1.1	16.08

For this system, the basic requirements are simply a submersible pump that is able to pump a continuous layer of water over panel, water distribution lines, and a tank to collect and recirculate the water. The experiment is carried out using a small, low-cost pump with poor pump efficiency. Using such a pump did not justify the use of the flowing water film in terms of energy gains within an energy balance. The cooling water flowed from 15 holes lined up over the width of modules (354 mm). This configuration utilized very less amount of the pumped water for cooling and the rest directly go into the tank.

After using the water cooling method it gives extra 6.9-16.9% of a normal module power output. !n this experiment, pump is submerged in the tank and height from tank to upper edge of panel is 42 cm. So static head required to pump the water is 42 cm. With the help of pump discharge and pipe dimension, calculated frictional head loss is 0.083 m. So total head becomes 0.5 meter. For a 40% overall efficient pump and 0.5 m total head, energy input require 4-5 watt. In above experiment by using 10 watt small panel, gain in power is 0.4 to 1.243 watt which is not justify the use of the flowing water film in terms of energy gains within an energy balance. But if the higher power module (large scale) will use then with the same percentage increase in efficiency, net gain in power will be more and use of pump can be justify. One more way to justify the use of pump is to arrange PV module in arrays.

VII CONCLUSION AND FUTURE SCOPE

(a) **Conclusion** - The photovoltaic panel efficiency is sensitive to the panel temperature and decreases when the temperature of the panel increases. Results of present work shows that temperature of the panel can be control at a desired temperature level. Temperature of the PV module is also dependent on the ambient temperature. The module surface temperature has a significant effect on the open circuit voltage while it has less effect on short circuit current.

(i) **Fins Cooling** - By using this method, fins cooled module is compared to the usual system as shown in power-voltage curve in chapter 6 results. Efficiency and power output of PV module with and without fins are determined from this curve.

- The temperature difference between the finned module and conventional reference module is only 3°C to 5°C.
- Experimental result shows that increase in efficiency is 0.13% to 0.41%.
- Percentage increase in efficiency is 2.1% to 5.8%. This cooling method is more appropriate when wind velocity is high.

(ii) Water Cooling - A film of water for cooling photovoltaic panel results in decreasing the temperature and reflection loss of the PV panel which increased electrical efficiency. Therefore, total energy output of the system increased significantly compared to the energy output of the conventional photovoltaic panel.

- Temperature difference between the water cooled module and conventional module is 15°C to 28°C. Increase in efficiency in case of water cooling method is 0.5% to 1.13%.
- Percentage increase in efficiency is 6.9% in the morning (low radiation) and it is 16.9% when radiation is maximum. Thus water cooling method is more effective when radiation level is at its peak value.
- The power required by the pump is generally substantially less than the power improvement created by the cooling effect for higher power module.

The water cooling method is significantly higher than the fins cooling method. Due to the quick flow of the water there are only minimal increases in water temperature.

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