COMPUTATIONAL STUDY OF COOLING OF PV SOLAR PANEL USING FINNED HEAT PIPE TECHNOLOGY

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ABSTRACT

Various solar energy technologies exist and they have different application techniques in the generation of electrical power. The widespread use of photovoltaic (PV) modules in such technologies has been relatively high costs and low efficiencies. The efficiency of PV panel decreases as the operating temperature increases. This is due to reflection from the top surface, absorption of heat by the parts other than the cell, absorption of heat from the other portion of the spectrum. In some instances, the cell temperature could reach up to 70\textdegree{}C which decreases the output power by up to 0.65%/K and the efficiency to 0.5%/K of the PV module above the operating temperature. Therefore cooling is essential and a reduction by 20\textdegree{}C will give an increase in efficiency by 10%.

In this project, an attempt has been made to reduce the operating temperature of the panel by cooling the panel using finned heat pipe. Computational Fluid Dynamics (CFD) has been used to design the fins and model the solar panel with finned heat pipe assembly. The CFD analysis have shown a maximum decrease of 20K.

Keywords: PV Modules, Finned Heat Pipe, CFD, Heat Pipe.

I. INTRODUCTION

Nowadays, 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. The distribution of fossil fuels around the world is equally uneven. Middle East possesses more than half of the known oil reserves. This fact leads to economical instabilities around the world which affect
the whole geopolitical system. The present system as it is cannot be maintained for more than two generations.

Keeping the above in mind as well as the fact that oil is running out fast, alternatives should be adopted. Renewable energy is one of the most promising alternatives to the above problems. Photovoltaic panels in particular can provide a good source of producing clean electricity. 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%.

The efficiency of photovoltaic cells decreases as temperature increases, therefore cooling is essential at elevated illumination situations for instance concentrating systems, or hot and humid conditions. With the average temperature reaching up to 42 °C in the summer the cell temperature could reach up to 800 °C which decreases the output power.

Hence, a need exists for a passive cooling system for PV modules, which may be fabricated in a cost-effective manner. This paper uses Computational Fluid Dynamics (CFD) to analyze the performance of a finned heat pipe arrangement for cooling of a standard PV module.

II. LITERATURE REVIEW

Qianyan Liu[1] did an experimental Study on the Characteristics of A Novel PV/T System. In this paper, the traditional PV/T system was modified, the hierarchical structure proposed layout, that is, the solar panels and heat-absorbing plate separation, so that cooling water through solar panels on the back before taking the heat, then into the collector absorb more heat. This not only greatly improved the efficiency of solar panels for electricity generation, but also further enhanced the export of refrigerant collector quality. It has been found that the flow rate of water should be in range 10L/hr to 30L/hr for obtaining an increase in power output.

David Meneses-Rodrıguez[8] did a project on photovoltaic solar cells performance at elevated temperatures. The purpose of their study was to investigate the opposite option: to make a cell work at relatively high temperature (around 100–200 °C) and use the excessive heat in a hybrid system of some kind to increase the total efficiency of solar energy utilization. They studied the temperature dependence of the solar cell parameters both theoretically and experimentally, for the basic cells with p–n junction and the Schottky barrier, taking account of the different carrier transport mechanisms and recombination parameters of the cell material. The possibility of usage of the concentrated sunlight was also taken into account. The experiments were conducted in the temperature interval of 25–170 °C and the calculated data showed a real possibility of construction of a two-stage solar-to-electric energy converter with high-temperature second stage, having the overall conversion efficiency of 30–40%.

Xiao Tang [2] did an experiment study on solar panel cooling by a novel micro heat pipe array. Air-cooling and water-cooling methods used were compared in this study. The results indicated that under cooling condition, the temperature can be reduced to effectively increase the photoelectric conversion efficiency of solar panel.

1) Compared with the ordinary solar panel, the temperature of that using air-cooling reduces maximally by 4.7°C, the output power increases maximally by 8.4%, and the efficiency difference is 2.6% (In that day, the maximal air temperature and wind speed are 36°C and 5.32 m/s , the daily global radiation is 26.3 MJ).

2) Compared with the solar panel using air-cooling, the temperature of that using water-cooling reduces maximally by 8°C, the output power increases maximally by 13.9% and the efficiency difference is 3%. The maximum efficiency of 13.5% can be achieved (In that day, the maximal air temperature and wind speed are 35°C and 4.72 m/s, the daily global radiation is 21.9 MJ).
III. OBJECTIVE

The purpose of this research on the finned heat pipe cooling system for PV panels is to decrease the operating temperatures of the PV panels by considering low cost techniques that can decrease the and enhance its power output. The present paper focuses on the performance of a finned heat pipe assembled onto the rear of a PV panel analyzed using CFD.

IV. COMPUTATIONAL STUDY

The 3D Profile of my proposed finned heat Pipe is shown below. The CAD geometry has been drawn in GAMBIT 2.4.

![3D model of finned heat pipe](image)

**Specification of the Solar Panel**

The Specification of the solar panel for which the experiment has to be carried out is listed below:

- Dimension - 33cm x 30cm x 0.3cm
- Number of cells - 36
- Type of cell - Mono crystalline
- Open Circuit Voltage of 1 cell - 0.6V
- Short circuit Current of 1 cell - 0.23A
- Open circuit Voltage of solar panel - 21.6V
- Short circuit current of solar panel - 0.23A
- Maximum Power of the solar panel - 4.968W
Theoretical calculation of the net heat that has to be removed ($Q_{waste}$)

It is assumed that the average heat flux receiving from sun is 500 W/m$^2$ ($Q_{total}$).
Therefore, the heat input to the solar panel is

$$Q_{solar\, panel} = Q_{total} \times A_s$$

$$= 500 \times 33 \times 30$$

$$Q_{solar\, panel} = 49.5W$$

The amount of $Q_{total}$ that is converted to electricity is 5W ($Q_{used}$). The net heat that has to be removed is

$$Q_{waste} = Q_{solar\, panel} - Q_{used}$$

$$= 49.5 - 5$$

$$Q_{waste} = 44.5W$$

Specification of Heat Pipe

Based on the theoretical calculations, the available commercial heat pipe was purchased from 'Global Star Technical Services', Pune.

The specifications of heat pipe are as follows:

- Diameter of the heat pipe - 1.2cm
- Length of the heat pipe - 25cm
- Material - Copper
- Type of Mesh - Sintered screen mesh
- Working Fluid - Water

Design of Fins

The Dimensions of the fins that has to be attached to the heat pipe is decided by conducting a series of CFD analyses in FLUENT 6.3. The geometry of the fins was drawn in GAMBIT 2.4 and is shown below.
The above geometry was meshed in GAMBIT 2.4. The Meshed model is shown below.

![Meshed model of fins](image1)

The mesh details are shown below.

<table>
<thead>
<tr>
<th>Element Type</th>
<th>Spacing(cm)</th>
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<th>Number of Elements</th>
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**Boundary conditions**

The above meshed file was exported to FLUENT 6.3 for doing a 3d, steady state, pressure based analysis. The boundary conditions that were given are.

- Base - Constant Temperature - 308K (because, the wall temperature of heat pipe is constant)
- Tip - Convection - 10W/m²K
- Surface - Convection - 10W/m²K

After doing a series of CFD analysis for different dimensions, the best dimension suiting our requirement was 10cm x 5cm of aluminium material.

The temperature contour of the fin is shown below.

![Temperature contour of fins](image2)
From the analysis, it has been obtained that the heat removed by 1 fin is 1.13W\( (Q_{\text{fin}}) \). The total amount of heat that has to be remove is 44.5W\( (Q_{\text{total}}) \). Therefore, number of fins\( (n) \) required is

\[
n = \frac{Q_{\text{total}}}{Q_{\text{fin}}} \\
n = \frac{44.5}{1.13} \\
n = 39.3
\]

This shows that the number of fins required is 40.

**Computational study of solar panel with Finned Heat Pipe**

The CAD geometry of the solar panel with finned heat pipe was created in GAMBIT 2.4 and is shown below.

![Profile of finned heat pipe](image_url)

The above model was meshed in GAMBIT 2.4 and is shown below.

![Meshed model of finned heat pipe](image_url)
The details of the mesh are given below.

<table>
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<tr>
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<td>7700</td>
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</table>

**Boundary Conditions**

The meshed file was exported and imported in FLUENT 6.3 for doing a 3d, steady state, pressure based analysis. The boundary conditions that were given are.

- Base - Heat Flux - 550W/m²
- Heat Pipe - Constant Temperature - 308K
- Fins - Convection - 15W/m²/K
- Aluminium block except base - Convection - 15W/m²/K

**V. RESULTS AND DISCUSSION**

The temperature contour of the solar panel with finned heat pipe is shown below.

It has been seen in the literature review that the maximum temperature that the solar panel achieves without cooling is 343K. In simulation, we can clearly see that the steady temperature reached with finned heat pipe is 323K. Therefore, the proposed finned heat pipe is able to reduce the temperature of the solar panel by 20K.
VI CONCLUSION

This study confirms the advantages of a finned heat pipe for practical use, especially in the high-temperature region. The temperature of the PV panel for power generation systems set up on a roof may exceed 70°C. The proposed finned heat pipe can be used to passively remove the heat, accepting high heat flux by natural convection. A copper heat pipe with water as the working fluid and fins attached was examined by a series of CFD analyses. The CFD analyses determined the optimum temperature cooled under environmental conditions, which is in the range of solar cells operating temperature of 30°C. It encourages continuing investigations in this direction, with the final goal to create a cooling system to maintaining the cell temperature within the environmental conditions.

REFERENCES