Electrical Efficiency Improvement of PV Cells

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***Abstract*—Photovoltaic solar cell generates electricity by receiving solar irradiance. solar energy is becoming one of the most important energies in the future. Recently, there has been an enormous increase in the understanding of the operational principle of photovoltaic devices, which led to a rapid increase in the electrical efficiencies of such devices. The temperature of photovoltaic modules increases when it absorbs solar radiation, causing a decrease in efficiency. This undesirable effect can be partially avoided by applying a heat recovery unit with liquid circulation with the photovoltaic module. Such unit is called photovoltaic/thermal collector (PV/T) or hybrid (PV/T). The objective of the present work is to design a system for cooling the solar cell in order to increase its electrical efficiency and also to extract the heat energy. A hybrid solar system which generates both electricity and heat energy simultaneously is studied. This hybrid system consists of PV cells attached to an absorber plate with fins attached at the other side of the absorber surface.**

***Index Terms*—Flat Plate PV/T Collector, Solar Irradiance, Electrical Efficiency, Electrical Power**

I. INTRODUCTION

Photovoltaics (PV) comprise the technology to convert sunlight directly into electricity. The term Photo means light and Voltaic means electricity. A photovoltaic (PV) cell, also known as Solar Cell, is a semiconductor device that generates electricity when light falls on it. When sunlight strikes a PV cell, the photons of the absorbed sunlight dislodge the electrons from the atoms of the cell. The free electrons then move through the cell, creating and filling the holes in the cell. It is this movement of electrons and holes that generates electric current. The physical process in which a PV cell or Solar cell converts sunlight into electricity is known as the Photovoltaic Effect. The energy consumption in the world, particularly in the industrialized countries, has been growing at an alarming rate [3]. Recently, the massive consumption and exhaustion of fossil fuel resulted in enormous interest to utilize renewable sources of energy such as solar energy. Photovoltaic power is an established technology and has recently experienced rapid growth over the last ten years. A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated. PVs offer several advantages such as: high reliability, low maintenance cost, no environmental pollution, and absence of noise [5]
The equivalent circuit of the PV cell is shown in Fig 1.

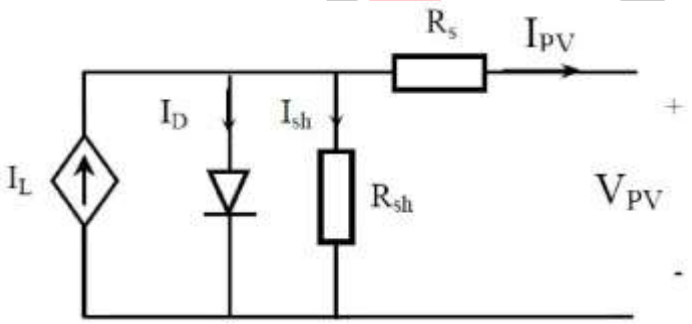

Figure 1: Equivalent circuit of the PV cell

Moreover, the pollution hazard arising out of fossil fuel burning has become quite significant in recent years. About 86 % of the world's energy supply comes from the fossil fuels [3]. According to Deffeyes [13], oil has already started to its peak. This process will push energy prices higher, until sustainable sources replace dependency on fossil fuels as major source of energy. The sustainable energy such as solar energy in the form of solar radiation has been identified as one of the promising source of energy to replace the dependency on other energy resources. The global need for energy savings requires the usage of renewable sources in many applications. One of the renewable sources of energy is the photovoltaic solar energy (PV). As revealed by Hoffmann [14], the photovoltaic (PV) solar market has shown an impressive 33 % growth per year since 1997 till date.

PV Cell is a semiconductor device that generates electricity when light falls on it [7]. A PV cell converts only a small fraction (approximately less than 20 %) of the irradiance into electrical energy [7]. The balance is converted into heating of the cell. As a result, cell can be expected to operate above ambient temperature. If the temperature is increased, there ismarked reduction in the cell voltage. Cell voltage decreases by approximately 2.2 mV per $_0$C rise in operating temperature [7]. Ebrahim Ali [15], in an experiment, investigated single pass solar air heater with photovoltaic cell with compound parabolic collector (CPC) and fins as shown in the "Fig. 1". He discovered that the electrical power of the collector increases with the radiation intensity. Goh li Jin concluded that the solar collector can be changed to double pass collector to improve its performance.

Sopian [11] designed and tested double pass photovoltaic thermal solar collector. He found that because of the turbulence, the heat transfer coefficient increases, which improves performance of the system. designed a double-pass photovoltaic-thermal solar air heater. In this system the fins are introduced in the second channel flow passage, parallel to the length of the collector, . The fins on the back of the photovoltaic panel increase the heat transfer with the air and enhance the efficiency of the system. The double pass PV/T solar air collector with fins and compound parabolic concentrator (CPC) gives very good electrical and thermal energy output [8]. But, the low thermal conductivity of air results in poor heat transfer between the panel and the flowing air. Hence, the air heater efficiency is low. So, in this study, the comparative study is done to improve the electrical output of the PV system, by passing different gases over a finned, single duct & single pass solar collector, the design of which is simple as compared to double pass system

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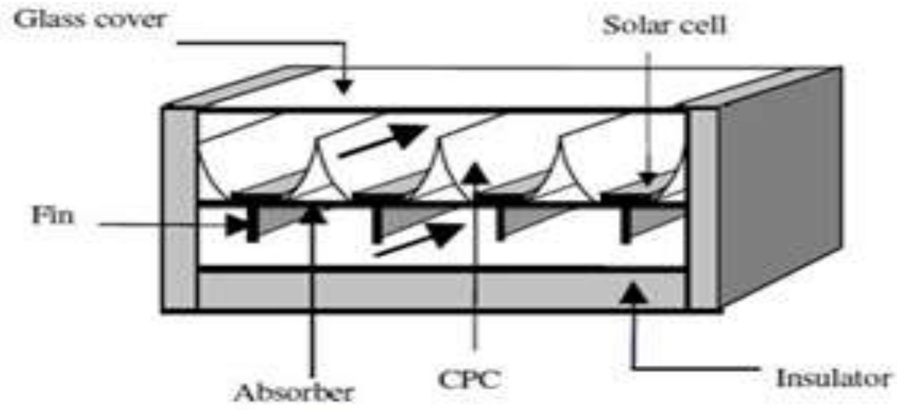

Figure 2. The Schematic Model of Single Pass, Double Duct (PV/T) Solar Collector with CPC and Fins [15]

II. EFFECT OF TEMPERATURE ON PV PERFORMANCE

Solar cells vary under temperature changes. The change in temperature will affect the power outputfrom the cells. The voltage is highly dependent on the temperature and an increase in temperature will decrease the voltage. A PV cell converts only a small fraction (approximately less than20%)oftheirradianceintoelectricalenergy[7]. Thebalanceisconvertedintoheatingofthecell.Asa result, cell can be expected to operate above ambient temperature. If the temperature is increased, there ismarked reduction in the cell voltage. Cell voltage decreases by approximately 2.2 mV per ^{0}C rise in operating temperature [7].

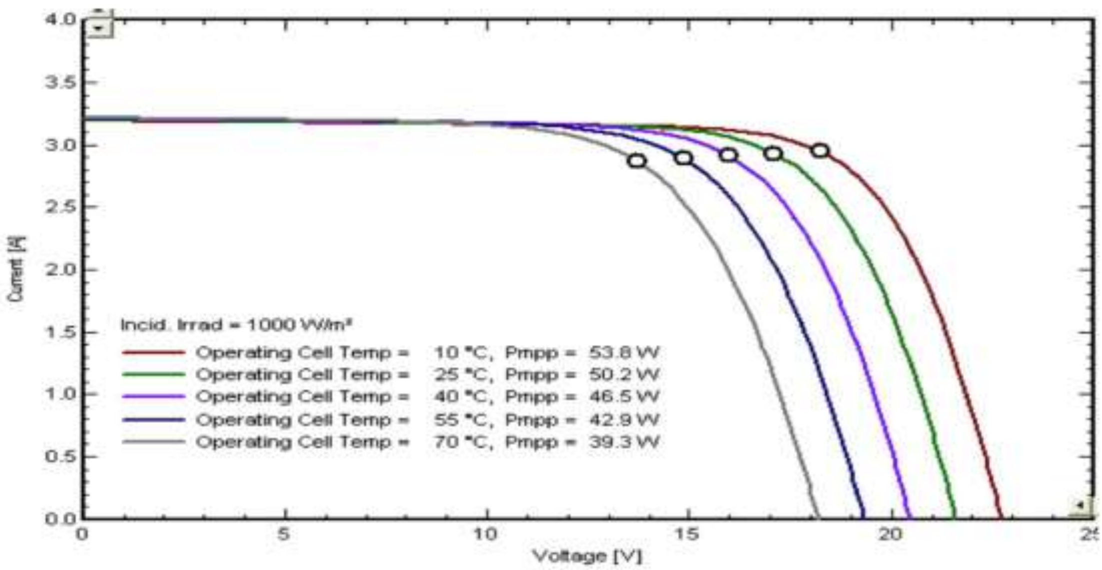

Figure 3: Output I-V characteristics of the PV module with different temperatures

III. DESIGN CONCEPTS

In the present work, fins are attached to the rear face of the panel as shown in the "Fig. 4".The rearsurface of the panel is a substrate such as aluminium. Thefins are modelled as being an extension of this substrate. The substrate material is soldered or attached with adhesive to the rear surface of the cells. In addition,a rectangular duct is attached to the rear surface of the panel, for which the heat transfer parameters are basedontheassumptionofforcedconvection.

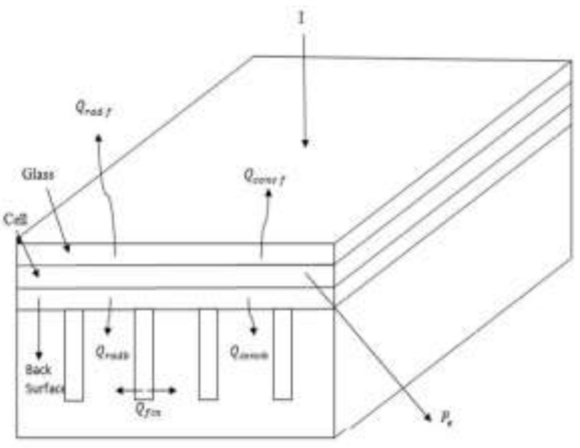

*Figure 4. Fin*Schematic Representation of the Model *Heater*

The duct allows the gas to be blown across the rear surface of the panel. Parameters of the system which are required to be fed in the MAT LAB software are solar irradiation, fin thickness, fin height, fin width, flow velocity, and thermal conductivity of the fin material. Outputs of the model are cell temperature, electrical efficiency, electrical power output, number of fins required for cooling, fin efficiency & mass flow rate of the gas used. Constants of the system are emissivity's, thermal conductivities, convective thermal resistances, Stefan-Boltzmann constant and the ambient temperature.

Boundaryconditions

The input to the system is the solar irradiance. The boundary conditions are the heat losses due to the radiation and convection on the front and back (Q*rad*, Q*conv*) of the panel, as well astheelectricalpower output. The thermodynamic properties of the panel, thermodynamic properties of the fin, and physical dimensions of the panel layers are held constant throughout thestudy.

Assumptions

To simplify the analysis, the following assumptions are made:

1. Steadystateofenergytransferisachieved.
2. No heat generation within thefin.
3. Uniform heat transfer coefficient (h) over the entire surface of thefin.
4. Homogeneousandisotropicfinmaterial.
5. Negligiblecontactthermalresistance.
6. Heatconductionisonedimensional.
7. Capacity effects of the glass cover, solar cells and back plate isneglected.
8. The temperatures of the glass cover, solar cells and plates vary only in the direction of working fluidflow.
9. Thesidelossesfromthesystemarenegligible.

The system can be segregated into twoparts

1. The photovoltaic technology which is derived from solar cell technology which converts solar energy into electricity.
2. Thermal solar technology which derived from the thermal collector and convert the solar energy into heat. A combined PV-thermal collector consisting of a photovoltaic laminate (a PV-laminate) that functions as the absorber of a thermal collector is shown in "Fig. 5". In this way, a device is created that converts solar energy into both electrical and thermalenergy.

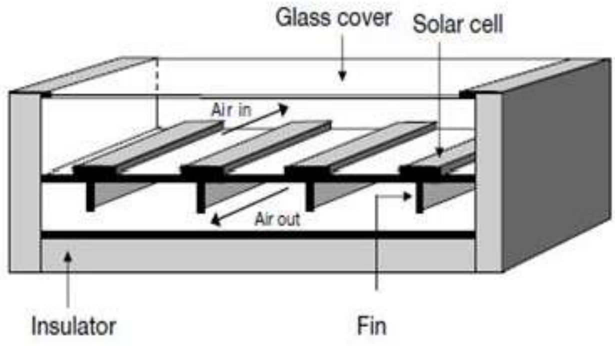

Figure 5. Finned Double-Pass Photovoltaic-Thermal Solar Air Heater

The Advantages of PVTTechnology

1. An area covered with combi-panels produces more electrical and thermal energy than a corresponding area covered half with conventional PV-panels and half with conventional thermal collectors. This is particularly useful when the amount of space on a roof is limited.
2. Combi-panels provide architectural uniformity on a roof, in contrast to a combination of separate PV- and thermalsystems.
3. Depending on the system configuration, the average PV temperature in a PV-thermal collector might be lower than for a conventional PV-laminate, thereby increasing its electrical performance
4. It works on noiselessenvironment.
5. Do not produce any unwanted waste such as radioactivematerials.
6. High performance and reliablesystem.
7. Highly credible system with life span expectation is between 20and 30years

IV. Results and Analysis

The validation of the present model is carried out with two references. "Fig. 6" shows the relationship between electrical efficiency and celltemperature

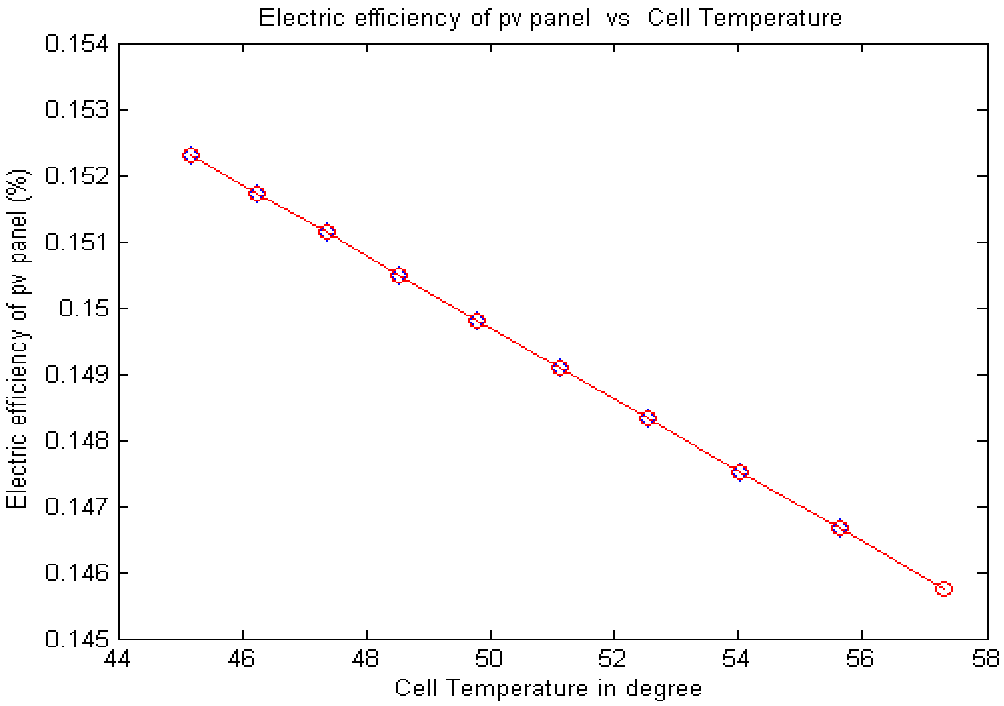

Figure 6. Relationship between the Electrical Efficiency and Cell Temperature at reference temperature of 25^0

It can be observed from the graph that the increase in temperature of the panel results in decreasing its electrical efficiency.

The results from the theoretical model developed are found to be in better agreement with those mentioned in the reference. The discrepancy between the two values is attributed to the unaccounted losses occurring in practice. Also, the relative efficiency and cell efficiency temperature coefficient values of both the papers are different. The reference efficiency of12% and cell efficiency temperature coefficient of 0.0063 is used in the reference [12], whereas in the present work the relative efficiency of 15 % and cell efficiency temperature coefficient 0.0045 are used. Figure 7 show relation between electrical efficiency of PV cell and mass flow rate of fluid used for cooling the PV cell. It can be observed from the graph that there is much better agreement between the predicted values from the theoretical model developed and those mentioned in the reference. The electrical efficiency of PVcell increases with the increase in mass flow rate of fluid.

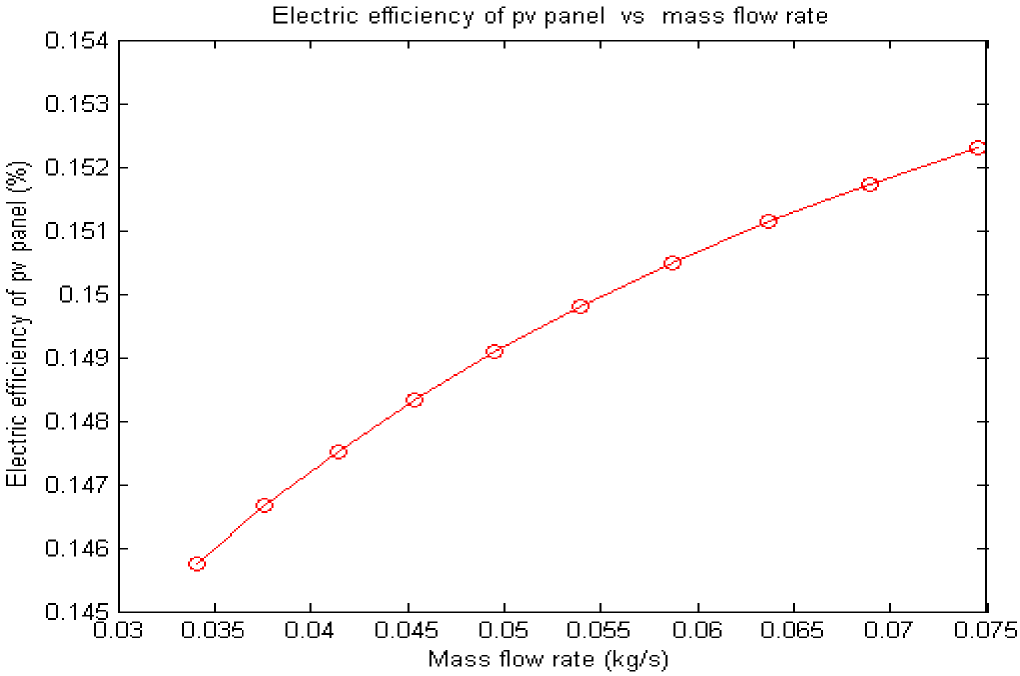

Figure 7. Relationship between the Electrical Efficiency and mass flow rate of fluid

Figure 8. show the relation between Mass flow rate of fluid and PV Cell temperature, If Mass flow rate of fluid is increases Cell temperature is decreases. Thus, efficiency of cell is increases by decrease in cell temperature.

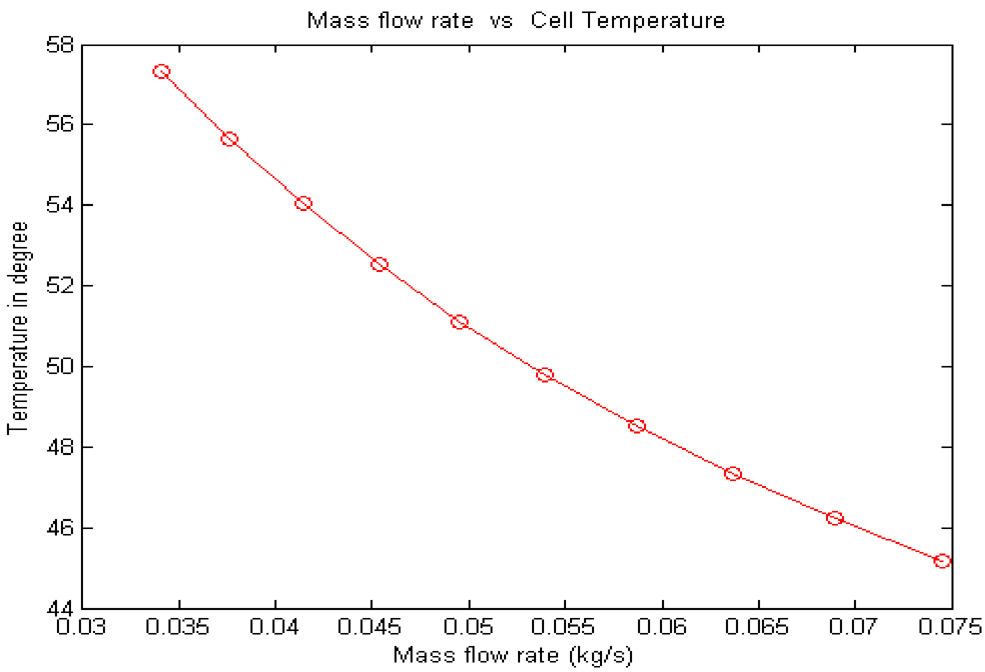

Figure 8. Relationship between the Mass flow rate of fluid and Cell temperature

V. CONCLUSION

PV/T solar system can be categorized based on the type of fluid (air or water). The flat plate PV/T collector system can be classified based on type of the absorber, which is placed below the PV panel. For flat plate PVT air type, it can be categorized as per the air flow pattern and can be glued above, below or on sides of the absorber. The flat plate PV/T air type can also be combined with water type. PVT collector use depends upon the geographical location and the application. At locations where solar radiation is less, space heating is almost required all the year and PVT can be useful and cost effective. At locations where solar irradiation is high as well as ambient temperature, PVT can be useful for water pre-heating purpose, space heating inwinter

Solar cells generate more electricity when receive more solar radiation but the efficiency drops when temperature of solar cells increases. Hybrid photovoltaic and thermal collector is the solution to this problem. Simulation model for single pass, single duct solar collector with fins is developed and performance curves are analysed. The simultaneous use of hybrid PV/T and fins have a potential to significantly increase in power production and reduce the cost of photovoltaic electricity. the system requires a mass flow rate of 0.074501 kg/s, which is the least of all other mass flow rate values & Number of fins required are7.915937.When the collector is operating at high mass flow rate, the cell temperature is reduces and efficiencies of PV cell is increase

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