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Heat Recovery from Solar Photovoltaic (PV) Panel

Atharva Saturdekar, Pratham Bhilare,
Pratik Chavan, Rohan Patil,
Student, Mechanical Engineering,
Pillai College of Engineering (Panvel),
Navi Mumbai, India

Meeta Vedpathak,
Professor, Mechanical Engineering,
Pillai College of Engineering (Panvel),
Navi Mumbai, India

***Abstract*: - Although there are many fluctuations in energy prices, they seem like they are rising day by day. Thus, energy recovery systems have an increasing trend. Photovoltaic systems convert solar radiation directly into electrical energy. However, due to the nature of semiconductors, all the solar energy cannot turn into electrical energy and the remaining energy turns into waste heat. While obtaining electricity from a Solar Panel, there is a possibility that the panel may get overheated due to an excess amount of sun radiation falling on it. This leads to a loss in the efficiency of the Solar Panel, so we found a method to improve the efficiency of an overheated solar panel by passing air over the Solar Panel. Further, we have utilized the hot air at the outlet of the Solar Panel to utilize it for some other purposes. This research aims to evaluate this waste heat energy by air cooling system, so our main objective is to improve the efficiency of the Solar Panel and to evaluate this waste heat energy by air cooling system.**

***KeyWords:* - Solar energy, Radiation, Efficiency, Drier**

I. INTRODUCTION:

Renewable energy sources that use photovoltaic (PV) panels are among the most significant. It is employed to directly convert solar radiation that strikes them into electrical power. The operation of solar panels is influenced by a wide range of internal and external elements. It is unable to manage external elements including wind direction, incident radiation rate, room temperature, and dust build up on photovoltaic cells. Certain internal parameters, like the temperature of the PV surface, are controllable. While the remaining incident radiation is absorbed inside the PV cell, some of the radiation that hits its surface is converted into electricity. This raises the temperature of its surface as a result. Unfortunately, worse conversion performance and less dependability over the higher the panel temperature long-term events happen. As a result, a lot of cooling systems have been created and researched with the goal of successfully preventing an excessive temperature rise and improving their effectiveness. Solar cells are cooled using a variety of techniques, including phase-change material (PCM) cooling, active cooling, passive cooling, and PCM cooling with additional additives like nanoparticles or porous metal. This article reviews and analyses typical cooling techniques for photovoltaic panels.

II. LITERATURE SURVEY:

Amelia (2016) [1] Conducted a hands-on attempt to cool the cell by directing several DC fans toward its rear. It was observed that when the number of fans increased, so did the cooling rate and the electricity generated by the cell; nevertheless, the power needed to run these fans also increased. The power generated rose by 12.93% when one fan was used the power grew to 37.17%, 41.28%, and 44.34%, respectively, when the number of fans was increased to 2, 3.

Káiser and Zamora (2013) [2] Carried out an investigation to contrast forced and natural convection in solar cooling. He employed two photovoltaics in their setup; one serves as a reference, and the other has a steel plate beneath it to make an air channel. In the first investigation, natural convection was used to cool the photovoltaic system by allowing air to flow down the channel. In the second investigation, forced convection is used to cool photovoltaic cells by forcing air into the channel using a centrifugal fan. The findings showed that, in comparison to natural convection, induced convection resulted in a 15% gain in electrical power and a 15% decrease in surface temperature.

Kenji Kamide et al. (2018) [3] Introduce the "heat recovery (HERC) solar cell," a novel idea for a solar cell that allows for heat recovery to increase conversion efficiency. The two essential components are carrier-energy selection and an absorber that is hotter than the electrodes. Possible barriers positioned in the way of the electrodes whose band gap is greater than the absorber.

Figure 1: Natural and Forced convection [2]

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When operating out of equilibrium, HERC solar cells can achieve high efficiency levels that beyond the detailed-balance limit. Its feasibility is greatly increased since, in contrast to hot carrier solar cells, it does not call for quick carrier extraction during the Thermalization period. An absorber made of silicon can be used to create HERC solar cells.

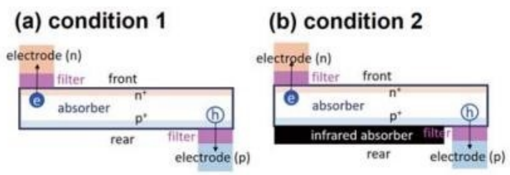

Figure 2: HERC solar cell [3]

Odeh and Behnia (2009) [4] Experimentally cooled the photovoltaic cell by spraying water on its surface, as demonstrated, and documented the outcomes throughout the year's seasons. According to the data, during the hottest part of the summer, cell output might increase by up to 15%. On average, however, cell output can increase by 5% all year long due to the cooling process. Because of the sun rays' refraction in the water layer, the water layer has caused the cell's surface to cool, cleared away collected dust, and increased solar radiation.

Bahaidarah et al. (2013) [5] Used, as demonstrated, water cooling for photovoltaic cells. According to the results, employing active water cooling for PV modules can result in a 20% reduction in module temperature, which translates to a 9% efficiency enhancement. The temperature in the tested modes, including the case with no cooling and the case with water cooling, demonstrated the efficiency of this approach in cooling down the PV. By using this technique, PV energy generation efficiency is increased while also increasing the amount of gathered energy since the extracted heat can be put to diverse uses.

Kabeel et al. (2019) [6] Under Egyptian temperature circumstances, a comparative study of cooling strategies for photovoltaic modules with reflectors has been conducted. The study took into consideration three distinct cooling methods: forced air cooling, water cooling, and forced air/water cooling combined. The outcomes of the experiment demonstrated that, in the environment of Egypt, water cooling was the most effective cooling solution for photovoltaic modules.

Themelis (2010) [7] Completed three modules to use natural air to cool photovoltaic solar panels. In order to speed up the cooling process, a thin metal sheet (TMS) is inserted into the middle of the air duct in the second module, which also has an air duct at the back of the cell. In the third module, metal fins are positioned in the back of the cell to increase the surface area exposed to air and, consequently, speed up the cooling process.

III. COMPONENTS:

In experimental setup, the process of development of heat recovery from solar panel through dryer. Thermocouple wires are used which is K type and the calibration of the same is done to get accurate readings.

1. PV panel

Photovoltaic (PV) are used to capture solar rays and convert it into electricity. Total 9 PV cell are used which are connected together in series connection with the help of tabbing wire. Connected PV panels are mounted on polycarbonate sheet having a thickness of 8 mm transfers heat of the solar panel to the dryer. PV panels are covered with a thin and transparent polycarbonate sheet to avoid dust.

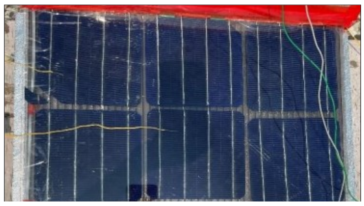

Figure 3: PV Panel

2. Dryer Box

The function of dryer is to suck the air from the polycarbonate sheet and gather it inside. In dryer box any food or other product can be stored for drying process. The dimension of the dryer box is 50 x 50 x 28 cm which was made from ASAWA Smart PIR Panel. A slot was provided on front side of dryer cabinet for insertion of PV Panel. Door is provided on the rear side of the dryer box for insertion and removal of drying trays. Two DC fans were fitted on top of dryer cabinet to incorporate forced convection of air inside dryer cabinet.

3. Other components

Multimeter is used to measure voltage and current produced by solar panel. Dryer and solar panel stand used to keep the dryer and solar panel at an accurate angle of 35º.

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IV. SYSTEM DESIGN AND SETUP:

The above listed components are assembled in the following way, in which polycrystalline sheet (8mm) is placed below solar panel with some extra extension of polycarbonate to insert in the dryer box. And in between both of them there are 3 thermocouples in different places to measure the temperature of solar panel and 2 thermocouples are placed at the start and the end of polycarbonate sheet. Dryer tray is kept inside dryer to hold the object and 1 thermocouple is placed on this tray to measure its temperature.

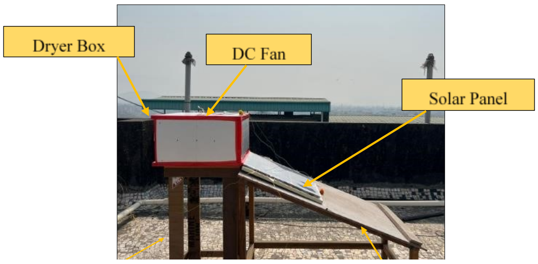


Figure 2: Experimental Setup

Pyranometer is used to measure the radiation of Sun, the data (radiation and temperature from thermocouple) is gathered by a device called as DAQ (Data Acquisition Hardware). This device is connected to the computer in which the LabVIEW software is used so that we can see the data. These readings were coordinated with respective time frame.

V. RESULT:

From the readings obtained we calculated the mass flow rate of air, efficiency of solar panel with and without forced convection, power rating of Dc fans, final moisture content of dried fenugreek, energy required to dry 110g of fenugreek in dryer which we have been calculated from experimental readings.The mass flow rate of air is $3.503*10^{3}$ kg/s by using the formula given below:

$$Q = m*Cp*(T2-T1)$$

Q = Radiation , M = mass, Cp = Specific heat constant, T1 = Temperature of solar panel after cooling, T2 = Temperature of solar panel
The efficiency of solar panel with forced convection is 20.34%.

$$\eta 1= (V*I*100) / Ig*A$$

η = Efficiency of solar panel, V = Voltage generated by solar panel, I = Current generated by solar panel A = Area of solar panel, Ig = Radiation
The efficiency of solar panel without forced convection is 18.22%.

$$\eta 2= (V*I*100) / Ig*As$$

The power rating of DC fans is 2.4 W by using the formula:

$$P_{fan1} = V_{fan1}*I_{fan}$$

$$P_{fan2} = P_{fan1}$$

$$P_{fan} = P_{fan1} + P_{fan2}$$

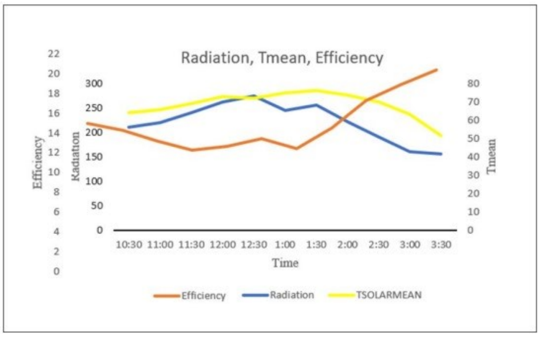
P = Power (Watt)
The initial weight of fenugreek was 0.11kg and the initial moisture of fenugreek was 84%. After experiment was performed, we got the final weight of the fenugreek which is 0.021kg. From this value we got the final moisture content of fenugreek i.e. 16.19% from the formula shown below.

$$W_{Final}= W_{initial}*(100 – M_{initial}) / (100 – M_{final})$$

W = Weight of fenugreek, M = Moisture of Fenugreek
The energy required to dry fenugreek is 342.1 KJ.

Sr. No	Parameter	Value
1	Mass flow rate of air	$3.503*10^{-3}$ kg/s
2	Efficiency of solar panel [forced convection]	20.34%
3	Efficiency of solar panel [without dryer]	18.22%
4	Power rating of DC fans	2.4 W
5	Final moisture content of Fenugreek	16.19%
6	Energy required to dry fenugreek	342.1KJ

VI. GRAPHICAL RESULTS:



Graph 1: Comparison between Radiation, Tmean, Efficiency (With Dryer)

Graph 1: shows the comparison between radiation, T_{mean}, efficiency of solar panel with forced convection. Tsolarmean is the average of all the temperature recorded from the solar panel.

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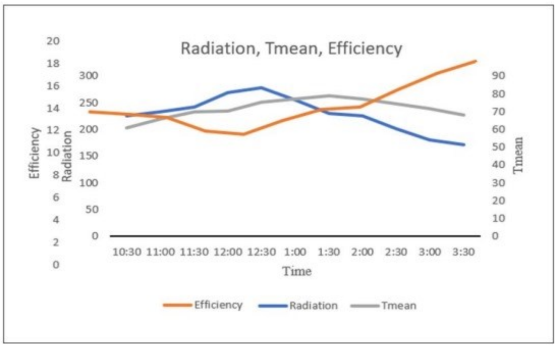

Graph 2: Comparison between Radiation, Tmean, Efficiency (Without Dryer)

Graph 2: shows the comparison between radiation, T_{mean}, efficiency of solar panel without forced convection.

As we noticed from the graph that as the radiation and temperature of the solar panel increases the efficiency of the solar panel decreases.

VII. CONCLUSION:

In this experiment, we reduced the PV panel temperature with the help of forced convection. The by-product of this process was used to dry fenugreek. We concluded from this experiment that:

1. Temperature of PV panel reduced by 3.82ºC when DC fan used for circulating air inside the PV panel.
2. Average Efficiency of solar panel increased from 18.22% to 20.34% in case of forced convection of air. PV panel also generated maximum power in case of forced convection.
3. Good quality dried product as compared to open sun drying was obtained after drying fenugreek in dryer cabinet, the final product having a moisture content of 16.19% retained its green colour.

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