IMPROVEMENT OF THE ELECTRICAL EFFICIENCY OF A SOLAR PANEL USING ANTI-REFLECTIVE COATING AND COOLING SYSTEM

Nandigam Kalyan Karthik[a*], Vegesna Rishi Eswar Varma[b]

[a]Corresponding author ,UG SCholar, Department of Mechanical Engineering, PSG College of Technology, Coimbatore,*
[b]UG Scholar, Department of Mechanical Engineering, PSG College of Technology, Coimbatore

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Abstract: *A conventional solar photovoltaic cell has a drop in electrical efficiency as the day passes by. This is due to the fact that the efficiency largely depends on the operating temperature. The surface temperature of the photovoltaic cell is inversely proportional to the electrical efficiency. As a consequence of this phenomenon, the efficiency of the solar panel is approximately in the range of 15-16% and it gradually decreases further when the day passes. To eliminate this drawback there are two methodologies employed in this research work:*

Coating a layer of polyethylene terephthalate serves as an anti-reflective material on the surface of the panel. This aids in collecting all possible photons emitted from the sun without much scattering and hence the utilization is improvised.

Another technique is by circulating cooling water all over the panel so as to mitigate the surface temperature. The cooling water is discharged at the rate of 1L/hour. By employing this, the surface of the solar panel is almost maintained at a constant level of temperature and thus the electrical efficiency is also increased.

Key words: **Solar energy, irradiation, antireflective coating, open circuit voltage, surface temperature**

1. INTRODUCTION

Solar energy is abundant in nature and is a clean source of energy. Solar panels are used to convert solar energy in electricity which can use for household purposes. According to many researchers if the amount of solar energy incident on earth is to be collected and converted into electricity it can power the entire earth of more than a decade. The production of electricity from solar energy does no releases any harmful gases. The intensity of solar radiation differs from place to place. According to Indian meteorological department solar energy incident on Chennai, Varanasi, Vishakhapatnam have the highest intensity. So in this place the solar panel work more effectively than compared to other places. But in various other places the solar radiation is incident at a particular angle so in order to obtain maximum efficiency various methods are followed some of them are by place the solar panel at an angle so that the solar radiation falls at 0° with the vertical.

The solar energy conversion efficiency of a standard solar panel is in the range of 15%-17%. This journal paper mainly discusses about how to increase the efficiency of the solar panel. The two methods which we use in this project are increasing efficiency by using an anti-reflective coating and by using a water cooling system. First of all usage of anti-reflective coating made up of material poly ethylene terephthalate (PET). By using anti-reflective coating made up of PET the efficiency is increased by 0.9% to 1.4%. This anti reflective coating reduces the scattering of the solar radiation incident on the solar panel. By absorbing more amount of solar radiation the amount of energy the solar panel collects increases increasing the efficiency.

And other method which we followed to increase the efficiency of solar panel is by using a cooling system. Generally as the temperature of the solar panel increases the efficiency of solar panel decreases so in order to overcome this problem we are using a cooling system to maintain the temperature of the solar panel. There are two types of cooling systems available they are water cooling and air cooling systems. Air cooling system is not as efficient as air is used as a convective medium and it requires more powerful motor to circulate air across the solar panel. So in this case we are using water cooling system in this water is used and the cold fluid. The panel is kept at an inclination and water is released from the top of the panel using a motor so due to the inclination the water can flow over the solar panel cooling it. By using the water cooling system the efficiency of solar panel can be increased by 0.8% - 1.2%.

2. METHODOLOGY

A photovoltaic cell of 12V potential difference is taken as a test sample. The efficiency of that panel is calculated by measuring the amount of power it produces by using a wattmeter. Generally the electrical efficiency ranges from 15-16% on an average. This is cross verified by connecting the circuit across various load elements like bulbs, resistors etc. The total power produced is not completely utilized because of the scattering of the incident radiation.

A pack of polyethylene terephthalate is purchased and coated on the surface of the photovoltaic cell. This particular material acts as an anti-reflective material which in fact traps the radiation from the sun. The coating is made parallel to the surface of the cells such the irradiation is completely absorbed. This is then transmitted through the glass panel and reaches the black surface to collect energy. The black surface has a capacity to absorb all energy given and store them.

For a constant surface temperature on the surface of the panel, it has to be cooled throughout. Water is being pumped by means of a reciprocating installed with the solar panel apparatus. The pump is placed at the bottom of the solar panel and the water is pumped upwards vertically by the action of the pump. The photovoltaic cells are mounted inclined at an angle with respect to the ground. The water is pumped at a discharge of 5L/hour to the top of the panel. Water then flows down as a result of gravity by running through the solar panel without disturbing the coating which was already given. By employing a cooling water setup, the surface temperature remains almost a constant and hence yielding constant electrical efficiency.

3. ANTI-REFLECTIVE COATING

The main property of a solar panel is its capacity to absorb the maximum light possible in order to generate maximum voltage, increasing the power output. But one of the main problems faced by the panel is the reflection loss. This loss is amounting to a very high decrease in the efficiency. This reflective loss mainly occurs at the glass air interface because of the refractive index of the glass. In order to overcome this some material has to be coated over the glass. This coating must play an important role in reducing the reflection and increasing the absorbing capacity. As this coating prevents the reflection of light rays it is known as Anti-Reflective coating. We do have many Anti- Reflective coatings such as solid sheets of optical glass, low-index material silica, titanium nitride, niobium nitrite, polymers etc. Out of all these we have selected polymer as our Anti-Reflective coating because of its physical properties and economics.

3.1 ARC IN THE FORM OF A PLAIN POLYMER LAYER

For a silicon solar panel the main losses occurs at the glass and air interface. Since the refractive index of glass is slightly greater than 1.5, a transparent polymer sheet with a typical refractive index between 1.4 and 1.5 can be placed on the glass layer as an Anti-Reflective Coating for the panel. The polymer used is polyethylene terephthalate for our solar panel. Polyethylene terephthalate is commonly known as PET, is the most common thermoplastic polymer resin of the polyester family. PET consists of polymerized units of the monomer ethylene with repeating units of ($C_{10}H_8O_4$) units.

3.2 PHYSICAL PROPERTIES OF PET

Young's modulus (E)	2800-3100MPa
Tensile strength (σ_t)	55-75MPa
Elastic limit	50-150%
Notch test	3.6 kJ/m^2
Glass transition temperature (T_g)	67-81°C
Vicat B	82°C
Linear expansion coefficient(a)	7 x $10^{-5}K^{-1}$
Water absorption (ASTM)	0.16

PET is hygroscopic, meaning that it absorbs water from its surroundings. However, when this "damp" PET is then heated, the water hydrolyses the PET, decreasing its resilience. We have dried the polymer by exposing it to the sunlight. This process is a slow one and consumes lot of time in drying the coating and adhering it to the panel. But this process does not alter the properties of PET and also economically benefitting. Analysis for the solar panel with and without the coating has been done and the following results are shown in the analysis section of this paper.

3.3 COOLING OF SOLAR PANEL

One of the main disadvantages of a solar panel is its deficiency to work under extreme conditions of heat and cold. The main focus is put the overcoming the effects caused due to overheating of the solar panel. During summer the temperature reaches beyond the limit point. This cross over causes the panels to get heated up in an unusual way. This heating of the panels leads in the decrease of the efficiency. How does this decrease in the efficiency take place? This takes place by decreasing the voltage generated which thereby decreases the power output of the panel. At relatively low temperatures the voltage generated is high there by the power output is high too. Therefore in order to increase the voltage generated a cooling system has to be arranged. We have used water as the coolant as it being a fluid with most suitable physical and chemical properties, with being most abundant and cheap. We have installed an overhead pump on the panel and a temperature sensor in the panel. A specified temperature limit of 50 is given in prior to the temperature sensor. The temperature sensor and the pump system are connected. Therefore whenever the temperature exceeds the limit the sensor alerts the pump system. Then the pump system opens the valve and sprinkles water over the panel. This water is collected by a water collector trough. This water can be reused again which furthermore is economically benefitting.

3.4 DUST REMOVAL USING WATER PUMP SYSTEM

Dust accumulation is one of the problems faced in regions with lot of wind flow. A lot of dust is accumulated and therefore it forms a layer over the panel restricting the amount of light absorbed by the solar panel. This reduces the amount of voltage generated which thereby decreases the power output. Therefore efficiency of the solar panel is reduced to a larger extent if this dust accumulated is not cleaned at regular intervals. We then thought that why we can't use the already existing water pump cooling system to clean the dust. The pump is opened at regular intervals of time to clean off the dust accumulated. This cleans the surface of the solar panel and therefore prevents the blocking of the light rays to reach the solar panel. Now as the panel receives ample amount of light the voltage generated is to the desired level thereby increasing the power output.

4. DESIGN

The solar panel which we used for this experiment is luminous solar panel. It is a 10W and 12V solar panel. It is made of polycrystalline cells type solar panel. The voltage at maximum power V_{max} is 18V and open circuit voltage is 22V. The current at max power i_{max} is 5.56A and short circuit current is 6.06A. It consists of back surface coating to obstruct the sun rays to from escaping the panel. And the panel is encapsulated with advanced ethyl vinyl acetate. And high strength lightweight aluminium frame design for high torsion resistance against winds and snow loads. It has potential induced degradation for safety against substantial power loss due to stray currents triggered by certain climate conditions. It has excellent low light performance in low visibility in clouds, evening and morning. An anti-reflective coating is used to reduce the irradiance of solar radiation. And a water cooling method in which the water is circulated throughout the solar panel to maintain the temperature of the solar panel. The water pump we are using 12V dc pump to pump water at a constant flow rate on to the solar panel. The anti-reflective coating is made up of poly ethylene terephthalate ($C_{27}H_{36}N_2O_{10}$).The fabrication of the solar panel is as follows.

5. FABRICATION

For the experiment we require an anti-reflective coating which is made from polyurethane solution diluted to 40% by volume by using ethyl alcohol and a prepared solution is applied on the solar panel. Generally the thickness of this anti-reflective coating is in order of microns(10^{-6}m). The solar panel is kept on an inclined frame the angle of inclination of the solar panel frame is 90°-θ°. Where θ° is the angle at which the sun rays are falling on the solar panel. And a small water tank is connected to a 12V DC pump which is used in water filters and oxygen tanks in aquarium tanks. The tube is set along the top of the solar panel to facilitate the flow of water over the solar panel to maintain the temperature of the solar panel. The solar panel coated with anti-reflective coating and water cooling system is used for our experiment.

6. EXPERIMENTATION

A total of 2 complete day sessions are required to perform the experiment. The second reading is noted at 7AM. Similarly, every reading has to be noted at an hour interval. The values of voltage keep increasing steadily until the maximum number of photons fall on the panel. In other words, the voltage increases until the time in which the maximum temperature is observed on a day. After this the values of open circuit voltage start to fall gradually.

Open circuit voltage is taken into consideration purpose to show the significant rise in voltage. In practical cases, voltage with loads connected has to be used. On a particular day, the value of maximum open circuit voltage occurs at around 1PM. Hence the experimentation for with coating and without cooling system gets completed. On another day, the experiments for with both coating and cooling system are to be conducted. For this the power supply to the pump is switched on along with the temperature control unit.

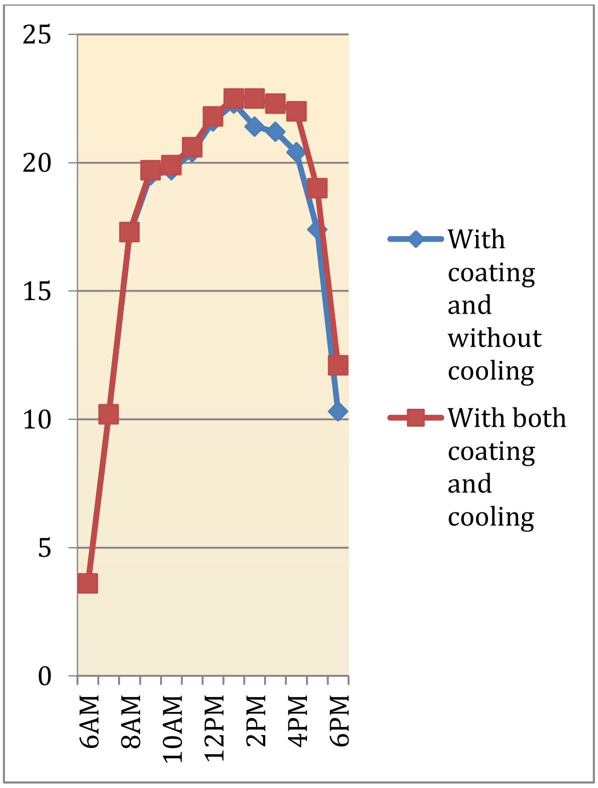
The temperature to be set on the top of the solar panel for cooling system also plays a part in the efficiency of the panel. For the purpose of experimentation in this case, a threshold value of 40^0C is set on the temperature control unit. This means that when the temperature on the surface of the solar panel exceeds the set value in the temperature control unit, the pumps get actuated. The pumps draws water from the mild steel tank stored underneath the solar panel and circulates it. When the temperature again falls back in position, the temperature control unit recognizes this and disconnects the cooling system using a relay. So the cooling system has its effect momentarily. Once again when the temperature exceeds the set value, the same aforementioned process repeats.

6.1 TABLE OF VOLTAGE

TIME OF THE DAY	VOLTAGE VALUE WITH COATING AND WITHOUT COOLING SYSTEM (V)	VOLTAGE VALUE WITH BOTH COATING AND COOLING SYSTEM (V)
6AM	3.6	3.6
7AM	10.2	10.2
8AM	17.2	17.3
9AM	19.5	19.7
10AM	19.7	19.9
11AM	20.4	20.6
12PM	21.6	21.8
1PM	22.3	22.5
2PM	21.4	22.5
3PM	21.2	22.3
4PM	20.4	22
5PM	17.4	19
6PM	10.3	12.1

6.2 TREND LINE PATTERN

The noted values of voltage can be plotted in a trend line graph to see the behaviour of the solar panel in various circumstances and conditions on various times of the day. The graphs for both the conditions are plotted in a single graph such that the maximum voltage can be found to be observed at 1PM in both the cases.



7. ANALYSIS

The analysis done on a polyethylene terephthalate coated solar panel can be performed using ANSYS Mechanical APDL 15.0 and the results are shown below in the images.

7.1 ASSUMPTIONS

1. The cross section of the solar panel is taken for analysis rather than the surface area
2. The solar panel comprises of three materials namely aluminium as the frame, silicon which acts as the PV semi-conductor and glass which transmits photons from the sun.
3. An additional coating of polyethylene terephthalate of 1.5mm is coated on the 25mm thick solar panel
4. Thermal analysis is performed on the composite wall

7.2 VALUES OF CONSTANTS TAKEN

MATERIAL NUMBER	MATERIAL	THERMAL CONDUCTIVITY (W/m K)	THICKNESS (mm)
1	Aluminium	204.2	15
2	Silicon	884	5
3	Glass	1	5
4	Polyethylene Terephthalate	0.19	1.5

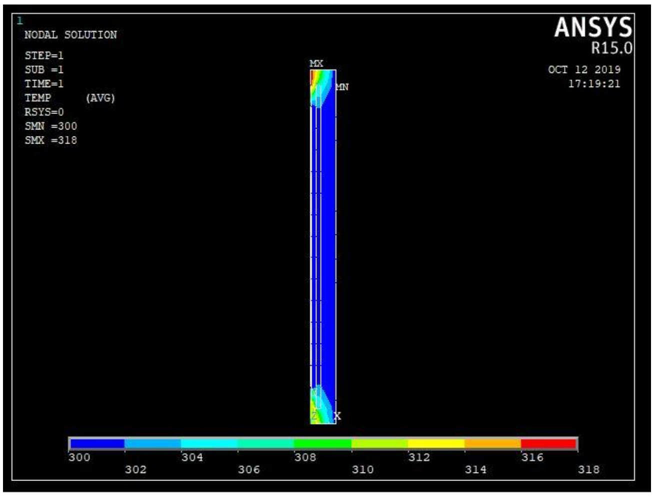
By constructing a solid model in ANSYS Mechanical APDL, the nodal and vector plot can be interpreted.

The total dimensions of the model is found to be 26mm X 356mm

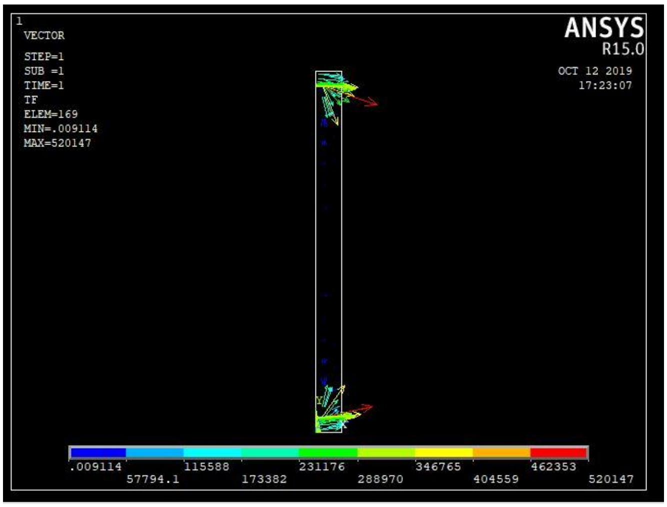
7.3 BOUNDARY CONDITIONS

Assuming the time in which the maximum temperature occurs on a day (say 2pm), the temperature can be recorded as 318K. The same temperature exists on the surface of the solar panel and the temperature underneath is found to be at room temperature 300K. By applying these boundary conditions on the model, the analysis is found to be as follows:

7.4 NODAL SOLUTION



7.5 VECTOR PLOT



8. RESULTS

The coating of polyethylene terephthalate was coated for about 1 to 1.5mm on the surface of the solar panel and a significant rise in the electrical efficiency of the panel was observed. In addition to that cooling water of discharge 1 litre/hour was recirculated by using a vacuum pump. In total an efficiency rise of 2% was found to occur.

9. ACKNOWLEDGEMENT

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10. FURTHER RESEARCH AVENUES

Few other materials like polyurethane and acrylonitrile butadiene styrene can be coated on the surface of the solar panel whose thermal conductivity values are also in the fractions of unity and the power and voltage obtained can be incurred to prove an efficiency boost. The cooling water circulation discharge can be increased by introducing a considerably high power pump and the hike in efficiency can be recorded.

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