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Comparative Thermal Analysis of Different Solar Panel Materials using ANSYS

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***Abstract*— Solar photovoltaic has already emerged as a convincing renewable energy technology. Solar Photovoltaic (PV) modules are one of the most effective, sustainable, and eco-friendly systems in recent world. Different types of PV solar technologies like Mono crystalline silicon, poly crystalline silicon, amorphous silicon, thin film are the most popular technologies to produce electricity. Their module performance and efficiency depend on the electrical and environmental parameters of the PV materials. This paper presents some theoretical evaluations for variation in the efficiency of energy for different types of photovoltaic (PV) module under standardized environmental parameters. A proper comparison is developed between Amorphous Silicon, Crystalline Silicon, Gallium Arsenide and Soluble Platinum using the model parameters. This work also illustrates the variation in temperature distribution and efficiency of a specific photovoltaic module under real operating conditions.**

Keywords—Solar Energy; Thermal analysis; Ansys; Energy.

I. INTRODUCTION

Energy plays a very important role in development of industries and human society. Need of energy is rising as the various engineering sectors are advancing with time. While the alarming greenhouse situation compels that this rising energy demand be met with renewable sources which cause no pollution instead of fossil fuels etc. [1] which currently dominate the energy market, these have 2 main issues i.e., they will perish soon and cause a lot of CO2 and other polluting emissions [2]. Many countries all around the world are now focused their goal on renewable energy production by eliminating use of conventional fuels to achieve goal of net-zero carbon emissions by 2050. To achieve these goals, it is very essential that efficiency of renewable energy equipments and processes must be increased by lessening their drawbacks [3]. Numerous research studies are expected to study and find solution about the factors which are contributing to decreasing efficiency of renewable energy production [4][5].

As sun is the constant and reliable source of energy on earth. Solar energy can be utilized to fulfil need of rising energy demand. As solar energy is non-vanishing, non-polluting and noise free energy method, more studies are concentrated on this field [6][7]. In this study we aim to find materials used for making solar panels, and select the best amongst them via conducing a thermal analysis and evaluating the characteristics of the selected materials under specified environmental conditions. We plan to choose a solar panel of standard dimensions. While these dimensions would be used for all materials, hence coping with the concerns of varied data.

Solar is one of the best energy sources available due to its properties as it's a renewable resource with the ability to compensate for all the other resources combined. The main objective behind choosing this project was to achieve better efficiency of solar panels, which is one of the major concerns in the growth of this renewable industry. As a material with optimum properties would lead to lesser hotspots, micro-cracks and hence provide a better power output.

Mallikarjun G. et al. [8] studied that the effect of temperature on the solar cell plays an important role as the rise in temperature increases the band gap of cells and in turn decrease the output power of the cell. The shading or cloud cover, dust and proper installation also play a major role and hence can lead to inefficiency if left unattended. Various experiments conducted to find out the effects of partial or full shading have shown the poor performance of solar systems. In case of Mono crystalline silicon solar cells Czochralski process is used for manufacturing cells having efficiency of 20-21%, usually life span of these solar panels is about 25 years. Mono crystalline solar panels tend to be more efficient in warm weather and deteriorate in performance as temperature goes up. On the other hand, Polycrystalline silicon solar cells are Less heat tolerant, have lower space-efficiency than mono crystalline solar panels resulting into 13-16% efficiency and reduced lifespan. In case of Thin-film solar cells (TFSC) the performance degrades faster than mono- and polycrystalline solar panels. Amorphous silicon solar cells have a good efficiency ranging between 6-8%. Cadmium telluride thin-film solar panel exhibits a very good efficiency in the range 9-11% and they are also cost-efficient as compared to crystalline silicon. Copper indium gallium selenide solar cells have efficiency in the range of 10-12%.

Shruti Sharma et al. [9] In their study found the radiation efficiency of solar panel to be up-to 22%. In case of traditional solar panels, silicon crystalline wafer modules are usually used which are heavier and hence are very difficult to transport. Mono-crystalline Si cells are expensive and multi-process and provide an efficiency of 17-18%. Poly-Si cells provide an efficiency of 12-14%. Thin Film Solar Cells have light absorbing layer of the size of 1micrometer. Amorphous Si is an indefinite arrangement of atoms in lattice, it has cheaper Efficiency of 4-8%. While CdTe is low cost, and has an efficiency of 9-11%. CIGS has an efficiency of 10-12%. Third Gen solar cells are not yet commercially investigated.

Author M. Senthil Kumar et al. [10] investigate how the heat energy received from solar radiation in the form of temperature affects the solar panel efficiency in this study by conducting an experiment with a 50W solar PV panel in a real-world outdoor environment. The experiment was carried out in Chennai, and current, voltage, and temperature readings were taken. Based on the results of this experiment, we discovered that the voltage, current, power, and efficiency of solar PV panels decreased as a result of solar radiation, and that the temperature of the solar PV panels, as well as the increase in temperature, was the main factor in the efficiency decrease. According to the research, the main cause of efficiency loss is rising temperatures of solar panels.

The effect of irradiance and increased temperature on the back surface of the PV module, according to the author Mohsin Ali Koondhar et.al [11] would reduce the PV module's standardized efficiency. This study proposes using the observed results of the solar module (ORSM) and Newton Raphson's (iterative) methods to solve this problem. To calculate irradiance and various operating conditions, this article compares ORSM and iterative methods of changing the specifications of a single diode model (SDM) extracted from a PV module under standard test conditions (STC). For this study, two models were chosen: one was used for the ORSM method, and the other was used for the Newton-Raphson method (iterative) method. This article covers a variety of methods for modifying the model's SDM parameters for various radiation intensities and temperatures. Newton Raphson's technique has been proven to be the most precise method for finding these specifications in STC, according to this study.

II. EXPERIMENTAL STUDY

The main objective of this study is selection of panel material with least hotspots and hence better efficiency for solar panels which would lead to enhancement in solar energy usage. To achieve this, the literature survey is carried in details, wherein the materials suitable for the panel and the properties that make them suitable were studied. This study led us to a few material choices and after selecting four optimal materials from the studied materials, the CAD model was designed via SOLIDWORKS which is a solid modelling CAD and CAE computer program. After this the thermal analysis of these material was conducted via the use of ANSYS software, which is a Multiphysics engineering simulation software which aids in product design, its testing and its operation.

As our research involves study of heat transfer and temperature distribution, the energy equation in Ansys FLUENT for the fluid domain in solved in the form given below:

$$\partial/\partial t(\rho E) + \nabla.(\nu(\rho E + p)) = \nabla.(k_{eff}\nabla T - \sum h_j j_j + (\tau_{elf} . \nu)) + S_h.$$

In the equation mentioned above Jj is the diffusion flux of the species J and Keff represent effective thermal conductivity of the fluid. Furthermore, the initial three terms on the right-hand side of the equation represent conduction transfer, species diffusion and viscous dissipations, respectively, while the last term Sh indicate the volumetric source of heat generation.

The energy equation for solid region utilized by ANSYS FLUENT is modelled as mentioned below,

$$\partial/\partial t(\rho h) + \nabla.(\nu\text{-}\rho h) = \nabla.(k\nabla T) + Sh.$$

Where the term ρ, h, k, T and Sh represents density, sensible enthalpy, thermal conductivity of the solid, temperature and volumetric heat source, respectively. The terms given on right side of the equation are representing the heat flux due to conduction and volumetric heat generation.

The analysis was conducted to assess the thermal characteristics of the four different materials, while the best material was picked out from the list by evaluating results from ANSYS software, this evaluation was based on hot spot generation characteristics of the materials regarding the irradiance received from the sun. The evaluation shows effect of material used on the heating characteristics and hotspot formation of the panel, as these high temperature zones lead to decrease in the efficiency of panel as it operates at higher temperature with respect to the highest power output temperature.

III. CAD DESIGN OF SOLAR PANEL

The CAD model of solar panel was designed using three-dimensional modelling software SOLIDWORKS 2021-2022, as it can be observed the model was designed in layers where each layer serves its purpose. Aluminium frame has high strength and is light in weight and hence is employed, tempered glass serves the purpose of shielding the cells from dirt etc., Eva is used as adhesive for bonding of silicon cells to the back sheet and the tempered glass, while the back sheet provides electrical insulation and the solar cells serve the purpose of electricity generation. For the scope of this study all the other materials are kept the same while the solar cell material is changed for thermal analysis in Ansys, hence providing us with the change in temperature values with change in material. Exploded view of the solar panel which designed specifically for this study is shown below in figure 1.

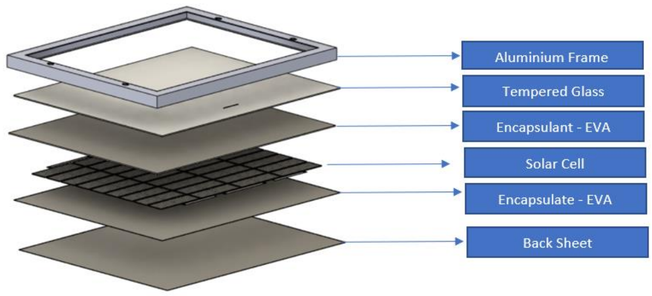

Fig. 1. Exploded view of Solar Panel Designed for the study

IV. SELECTION OF DIFFERENT MATERIALS

The most recent and fastest-growing trend is solar photovoltaic in renewable energy sector. One of the reasons for this has been attributed its ability of green and clean energy. Environmental benefits are numerous and significant. The efficiency of a PV cell is simply the amount of electrical power produced by the cell in comparison to the energy emitted by the light shining on it, indicating how efficient the cell is at converting energy from one form to another. The amount of electricity generated by PV cells is determined by the characteristics of the materials. So, it is essential to select the

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materials with great research. Solar Panel materials should have best suitable properties to increase their overall efficiency and sustainability while also being cost effective. The materials were chosen by conducting literature survey of many reputed research articles.

The material properties of selected materials are mentioned below in Table

TABLE 1. THERMOSTATIC PROPERTIES OF MATERIALS SELECTED

Properties	**Materials**			
	Soluble Platinum	Amorphous Silicon	Gallium Arsenide	Crystalline Silicon
Density (kg/m^3)	21450	2330	5317	2.3290
Melting Point (k)	2042	1683	1511	1687
Thermal Conductivity (W/m k)	69.1	148	55	160
Specific Heat (J/kg k)	133	710	330	690

V. RESULT AND DISCUSSION

In the performed study of thermal analysis, solar panel was designed in details and analyzed its thermal properties. Solar panel dimensions were chosen by conducting literature survey. The 3-dimensional model of solar panel was designed into Solidworks 2021-2022 software. The designed CAD model was exported in IGES format to ANSYS Workbench software, and the layers were assigned their materials, and their corresponding material properties. Thermal analysis was conducted on the different materials selected and the high temperature zones and their temperature values were evaluated. The higher the temperature lower is the efficiency, and thus the better material for panels was determined. Also, these results were comprehended via a cost analysis of the chosen materials, hence determining the economic feasibility with respect to the efficiencies obtained above.

For the scope of this paper the location for the solar panel was chosen to be Katpadi, Vellore a town in Tamil Nādu, India. It corresponds to latitude of 12.97256 and longitude of 79.13819, while the month of April was seen to have the highest realistic average daily solar insolation values historically and hence was chosen for this study. The observed insolation value was 5.575 kWh/m^2/day and considering 6 hours of peak sunlight daily we can evaluate the insolation to be:

$5.575/6 * 1000 = 929.16\ W/m^2$

This is the input value for heat flux used in analysis of every material in ANSYS.

In case of the amorphous silicon, it was observed that the maximum temperature reached by a cell was 188.01 degree Celsius, and the minimum temperature observed was 146.23 degree Celsius, while the average temperature came out to be 173.73 degree Celsius. The temperature distribution analysis of solar panel of amorphous silicon material is shown below in figure 2.

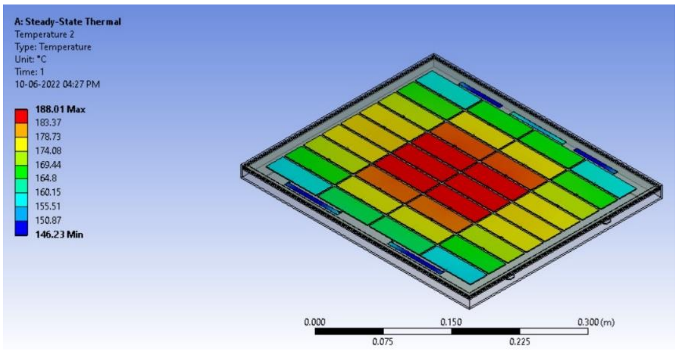

Fig. 2. Temperature distribution of solar panel of Amorphous Silicon

In case of Soluble platinum, it was observed that the maximum temperature reached by a cell was 190.77 degree Celsius, and the minimum temperature observed was 139.43 degree Celsius, while the average temperature came out to be 174.15 degree Celsius. The temperature distribution analysis of solar panel of Soluble Platinum material is shown below in figure 3.

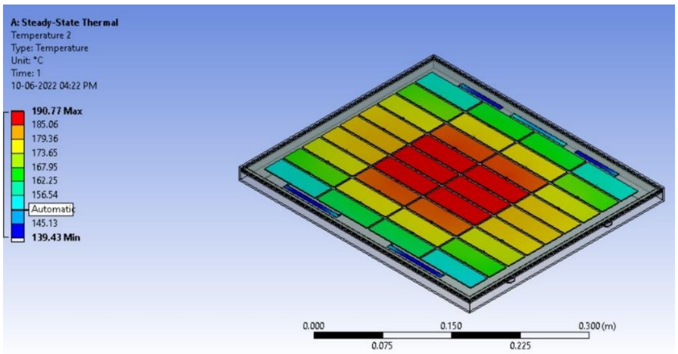

Fig. 3. Temperature distribution of solar panel of Soluble Platinum

In case of crystalline silicon, it was observed that the maximum temperature reached by a cell was 187.69 degree Celsius, and the minimum temperature observed was 146.72 degree Celsius, while the average temperature came out to be 173.68 degree Celsius. The temperature distribution analysis of solar panel of Crystalline Silicon material is shown below in figure 4.

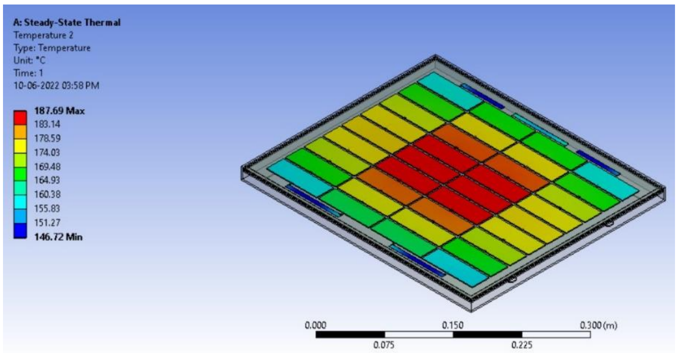

Fig. 4. Temperature distribution of solar panel of Crystalline Silicon

In case of Gallium Arsenide, it was observed that the maximum temperature reached by a cell was 191.46 degree Celsius, and the minimum temperature observed was 138.64 degree Celsius, while the average temperature came out to be 174.24 degree Celsius. The temperature distribution analysis of solar panel of Gallium Arsenide material is shown below in figure 5.

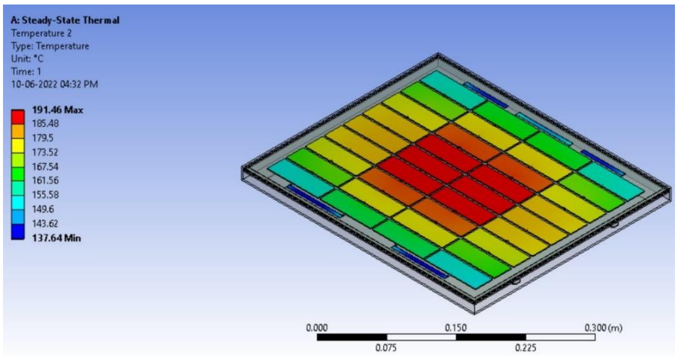

Fig. 5. Temperature distribution of solar panel of Gallium Arsenide

VI. CONCLUSION

After conducting thermal analysis of solar panel by varying four materials, from our observations we can evaluate that the least high temperature value was observed in the case of crystalline silicon, i.e., 187.69 degree Celsius hence would have the highest efficiency as we know from literature reviews that the higher the temperature lower is the efficiency. While the highest maximum temperature value was observed in the case of gallium arsenide which was 191.46, hence gallium arsenide would show the least efficiency amongst the materials chosen. We can also observe that there is not much difference in the readings of maximum, minimum and average temperature of amorphous and crystalline silicon, this can be attributed to their similar physical and chemical properties thus the decision between the usage of amorphous silicon or crystalline silicon can also be subjected to economic feasibility which is again subjected to location, in places where amorphous silicon is considerably cheaper it can be considered as primary material for solar cells. To facilitate our conclusions further we can also see that the average temperature is also the lowest in case of crystalline silicon i.e., 173.68 degree Celsius and hence greater efficiency.

These conclusions are drawn with keeping all other parameters except cell material constant, the environmental conditions are set corresponding to Katpadi in the month of April and hence the insolation value was determined.

The study attempts to contribute to the research regarding selection of best material for solar panels as it is one of the most promising aspect in terms of dealing with the rise in energy demand and does so via a renewable path, a lot more research in this field needs to be conducted in aspects of finding new and better material which fulfils all the required characteristics i.e., they must be easily available, cheap, must not cause a lot of pollution while mining and should provide efficient solar cells.

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