# THERMAL ANALYSIS OF SOLAR PHOTOVOLTAIC MODULE

**[1]Atharv Sangale, [2]Kajal Sargar, [3]Sarthak Balel, [4]Siddhesh Rithe, [5]Zaki Sange**

Vishwakarma Institute of Technology, Pune.
Department of Mechanical Engineering
Vishwakarma Institute of Technology
Pune, 411037, Maharashtra, India.

***Abstract-* The utilization of solar photovoltaic (PV) technology for clean and renewable energy generation has witnessed remarkable growth in recent years. Solar PV modules are at the forefront of this revolution, converting sunlight into electricity efficiently and sustainably. However, the performance and longevity of these PV modules are intimately linked to their operating temperature. Temperature variations can significantly impact the efficiency, reliability, and overall effectiveness of PV systems. This research paper presents a comprehensive study on the thermal analysis of solar PV module.**

***Keywords* - Solar module, Finite Element Analysis, Thermal Analysis, Heat Transfer**

## INTRODUCTION

In an era defined by environmental awareness and the urgent need for sustainable energy solutions, solar photovoltaic (PV) technology stands as a beacon of hope. Solar PV modules, designed to harness the inexhaustible power of the sun, have emerged as a pivotal player in the global shift toward clean and renewable energy sources. However, as the adoption of solar PV systems continues to grow, so does the demand for improved performance and reliability.

The thermal behavior of solar PV modules represents a critical aspect of their operational efficiency and longevity. Temperature fluctuations, a hallmark of real-world environmental conditions, exert a profound influence on the performance of these modules. Elevated temperatures, in particular, can lead to reduced energy conversion efficiency, accelerated material degradation, and a diminished operational lifespan. Thus, understanding and effectively managing temperature dynamics within PV modules have become essential pursuits for advancing the viability of solar energy as a sustainable power source. This research paper embarks on a comprehensive exploration of the thermal analysis of solar PV modules. By delving into the intricacies of temperature regulation within these modules under varying environmental conditions, solar radiation intensities, and module configurations, this study seeks to unravel the complex relationship between temperature and PV module performance. Through a combination of experimental investigations and sophisticated simulation techniques, the aim is to illuminate the mechanisms underlying temperature-induced effects and to propose strategies for optimizing PV module

## LITERATURE REVIEW

In the study titled "Finite Element Thermal Analysis of a Solar Photovoltaic Module" by Yixian Lee and Andrew A. O. Tay, the authors conducted a finite element thermal analysis on a representative photovoltaic (PV) module. The primary focus of this research was to investigate the temperature distribution within various layers of the PV module. Through this analysis, the authors aimed to gain insights into the impact of convection heat loss coefficients at the module surfaces on the temperature levels of the solar cells and, consequently, their overall efficiency. This study contributes to our understanding of thermal management in PV modules, which is crucial for optimizing their performance and ensuring their long-term reliability in real-world operating conditions.

The research paper titled "Numerical Analysis on the Thermal Characteristics of a Photovoltaic Module with Ambient Temperature Variation" authored by Jong Pil Kim, Ho Lim, Ju Hun Song, Young June Chang, and Chung Hwan Jeon focuses on a comprehensive examination of the thermal behavior of a photovoltaic (PV) module under varying ambient temperatures, ranging from a minimum of 25°C to a maximum of 50°C. The investigation is carried out through the utilization of a thermal analysis simulation program, shedding light on how temperature fluctuations impact the module's performance. Furthermore, the study delves into a simulation method for the attachment of fins to the backside of the PV module, thereby enhancing thermal management. Through a comparative analysis, the paper provides valuable insights into the thermal characteristics of PV modules, drawing distinctions between modules with and without fins. These findings hold significance for optimizing the efficiency and reliability of PV systems in diverse environmental conditions.

In the paper titled "Comparative Thermal Analysis of Different Solar Panel Materials using ANSYS" authored by Dishant Bhor, Rushikesh Pote, and Nihal Chavan, a thorough investigation into the thermal performance of various photovoltaic (PV) module materials is presented. The study provides theoretical assessments of energy efficiency variations for different PV module types, all under standardized environmental conditions. Through meticulous modeling and analysis, a comprehensive comparison is drawn between Amorphous Silicon, Crystalline Silicon, Gallium Arsenide, and Soluble Platinum materials. Additionally, the research explores the temperature distribution and efficiency characteristics of a specific photovoltaic module when subjected to real-world operating conditions. These findings contribute valuable insights into material selection and performance optimization for solar panel applications, thus advancing our understanding of PV technology.

In the research paper titled "Behavior of Four Solar PV Modules with Temperature Variation" authored by Akram Abdulameer Abbood Al-Khazzar, a comprehensive study is presented involving the behavior and performance comparison of four distinct photovoltaic (PV) modules. The investigation centers on the experimental exploration of how temperature fluctuations influence the electrical output parameters of these solar modules. The findings of this study reveal that, particularly in high operating temperatures, the amorphous silicon and CIGS (Copper Indium Gallium Selenide) modules exhibit superior performance compared to the crystalline modules. These insights provide valuable information for optimizing PV system design and material selection, ultimately contributing to the efficient utilization of solar energy in varying environmental conditions.

In the research paper titled "Thermal Analysis of PV Module and the Effect on its Efficiency" authored by Rivan Muhfidin and Ing-Song Yu, a comprehensive investigation is presented regarding the temperature dynamics of a photovoltaic (PV) module. The study leverages ANSYS software to calculate and analyze the temperatures within the PV module. This analysis considers the transfer of energy through various mechanisms, including radiation, convection, and conduction, all under different solar irradiation levels and convective heat coefficients. The findings shed light on the intricate interplay between thermal factors and PV module efficiency, providing valuable insights into optimizing the performance of solar photovoltaic systems under varying environmental conditions.

In the research paper titled "A Comparative Study on Thermal Performance of a 3-D Model-Based Solar Photovoltaic Panel through Finite Element Analysis" authored by Suman Kumar Laha, Pradip Kumar Sadhu, and Ankur Ganguly, a comprehensive examination of the thermal performance of a three-dimensional (3-D) model-based solar photovoltaic (PV) panel is presented. The study delves into the methodology of finite element analysis (FEM) applied to the solar PV module, elucidating the intricate processes involved in this analysis. Through this research, the authors contribute to our understanding of how FEM can be employed to assess the thermal behavior of solar PV panels, offering valuable insights for optimizing their performance and efficiency.

In the study titled "Thermal Behavior of Monocrystalline Silicon Solar Cells: A Numerical and Experimental Investigation on the Module Encapsulation Materials" conducted by Ana Pavlovic, Cristiano Fragassa, Marco Bertoldi, and Vladyslav Mikhnych, a comprehensive exploration is presented. The research encompasses both numerical predictions and empirical validations regarding the heat distribution within solar cells. This multifaceted analysis not only provides insights into the temperature dynamics within the solar cell but also highlights the critical influence of design choices on the efficiency of these cells. By bridging the gap between theoretical predictions and real-world experimentation, this study contributes valuable knowledge for enhancing the thermal performance and overall effectiveness of monocrystalline silicon solar cells.

## I. METHODOLOGY/EXPERIMENTAL

### *A. Design of PV module: -*

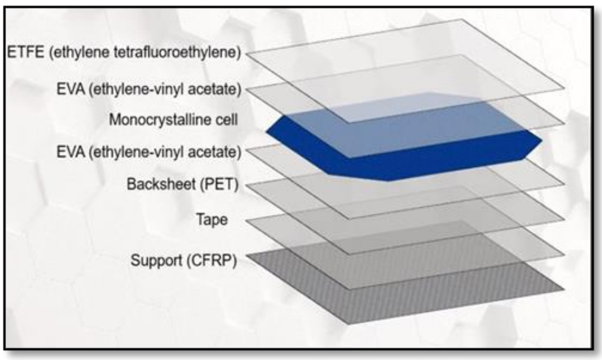


**Fig 1. Different layers of solar panel**

The following model was designed in the design modeler of ANSYS 2023R1 student's version. Generally, A solar panel using silicon cells is commonly made by following layers - Glass (or ETFE),EVA, Mono (or polycrystalline) silicon cells, EVA, PET (or Glass). Mono-crystalline solar cells (125x125mm, pseudo-square with rounded corners) were considered. The glass is used as a protecting base on which a thin ethylene-vinyl acetate (EVA) sheet is spread. This glass has a special content to ensure the highest transparency. Then, a first EVA sheet is positioned facing with the photosensitive side down, before another EVA sheet is placed on the back of the cell and then there is a sheet of insulating plastic material as Polyethylene Terephthalate (PET). Ethylene tetrafluoroethylene (ETFE) is for frontsheet instead of glass with the scope to reduce weight and to have higher transparency. ETFE is a plastic polymer containing fluorine atoms with extraordinary properties which make it exceptionally suitable as frontsheet in solar cells: it is self-cleaning, stable, with very high resistance to corrosion, thermal excursion and atmospheric agents. Moreover, its chemical structure makes the material extremely good at allowing light radiation to pass through, almost eliminating the phenomenon of reflection.

**Table 1. Layers and its thickness**

| Layer | Function | Material | Thickness(mm) |
|---|---|---|---|
| I | Front sheet | ETFE | 0.28 |
| II | Encapsula nt | EVA | 0.20 |
| III | Solar cell | Silicon | 0.15 |
| IV | Encapsula nt | EVA | 0.20 |
| V | Back sheet | PET | 0.20 |
| VI | Adhesive | Tape | 0.13 |
| VII | Support | CFRP | 2.00 |

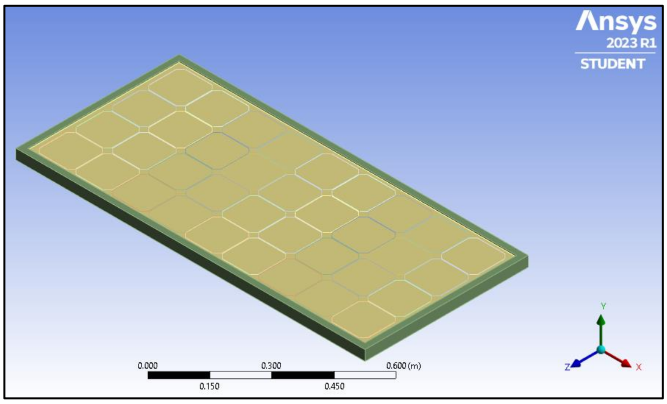


**Fig 2. Model of solar panel**

*B.* ***Experimentation:***

In this project, the thermal analysis of solar module is conducted by which we will find temperatures profiles of the layers of the solar panel. Energy, from solar radiation incident on the PV panel, is generally leaves the system as generated power, optical loss and thermal losses. Heat transfer processes including convection, and radiation from the top and bottom layers to the surrounding environment all contribute to the overall thermal loss. Reflective radiation by the glass (or ETFE) layer represent the major optical loss. In addition, the generated power is also included in the energy balance of PV module. (Qsource) and the environmental temperature (Tenv), in our case is 1000 W/m^2 and 25°C respectively. Boundary conditions like heat flux, radiation and convection were given to the layers of solar panel. Bonded type of connection wasused and multizone mesh with the size of 20mm was considered. Table 2 refers to the different properties required for performing the analysis. Following were the assumptions made for the analysis:

- All material properties used are assumed to be isotropic and independent of temperature.
- The transmissivity of EVA is taken to be unity
- The reflections between layers is considered as negligible.
- The ambient temperature is equal on every area exposed to the environment.

**Table 2. Properties for solar panel**

| Material | Thermal conductivity (W/mK) | Density (Kg/m^3) | Specific heat (J/KgK) |
|---|---|---|---|
| **ETFE** | 0.24 | 1730 | 1172 |
| **EVA** | 0.35 | 945 | 2090 |
| **Silicon** | 148 | 2330 | 700 |
| **PET** | 0.275 | 1350 | 1275 |
| **CFRP** | 6.83 | 1490 | 1130 |
| **Tape** | 0.19 | 1012 | 2000 |

## II. RESULT AND DISCUSSUIONS.

In Figures 3-7, a detailed depiction of temperature distribution across various layers is presented. The analysis reveals distinct temperature profiles within the solar module components. Notably, the ETFE layer displayed a relatively moderate temperature of approximately 25.16°C, suggesting effective thermal management. In contrast, the EVA layer exhibited a slightly higher temperature, measured at 25.55°C. The monocrystalline solar cells, which are integral to the energy conversion process, reached a peak temperature of 25.77°C. These findings offer valuable insights into the thermal behavior of the solar PV module, with implications for system design and efficiency optimization. The temperature variations among the different layers underscore the importance of considering heat dissipation strategies to maintain and enhance overall solar module performance.

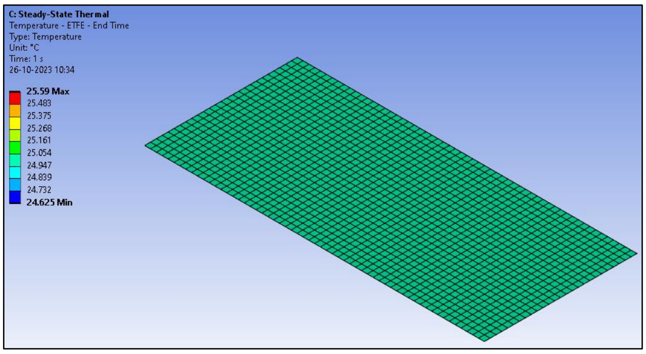


**Fig 3. ETFE Layer**

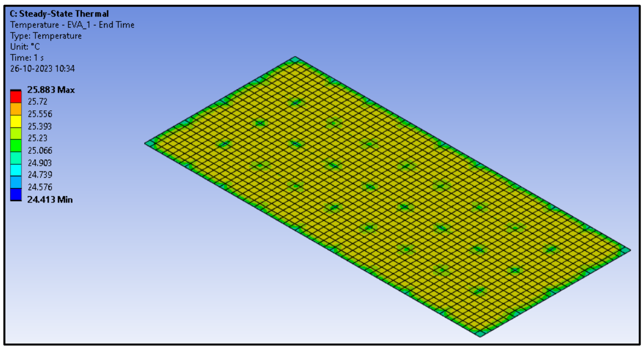


**Fig 4. EVA Layer**

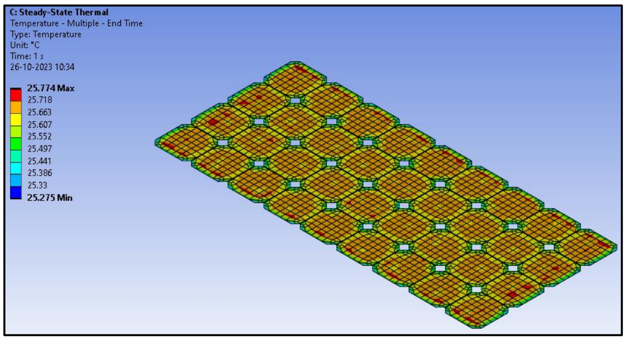


**Fig 5. Solar cells**

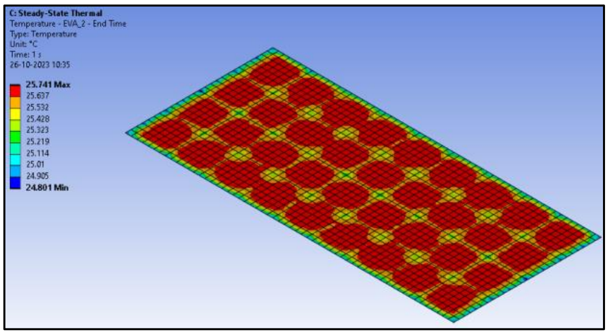


**Fig 6. EVA Layer (below)**

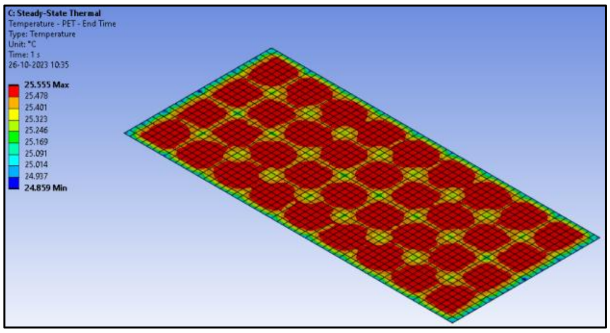


**Fig 7. PET Layer**

## III. CONCLUSION

The analysis focused on the solar panel, utilizing ANSYS. Initial steps involved creating the solar panel in the Design Modeler. Subsequent analysis was conducted on the redesigned model. The analysis results were obtained for the different layers of solar panel under given conditions. It is clear that controlling and reducing the operating temperature of the solar cells is essential for maintaining efficiency and maximizing energy generation.

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