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Optimization Of Cooling Of Solar PV Panel By Attached Trapezoidal Fins Using Simulation On ANSYS Software

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Abstract: The growing need for effective cooling results in solar energy systems is driving exploration on the cooling impact of connected fins with varying shapes on photovoltaic(PV) panels using Computational Fluid Dynamics(CFD) modelling. This paper offers a thorough examination of parametric exploration on fins. Aimed at perfecting the thermal performance and effectiveness of photovoltaic(PV) solar panels. One pivotal area of study to lessen the negative impacts of temperature rise on solar panel performance is the use of fins in PV systems. This study investigates the goods of several fin figure, similar as blockish, trapezoidal, and triangular fins, on the temperature control of photovoltaic panels. The growing need for effective cooling results in solar energy systems is driving exploration on the cooling impact of connected fins with varying shapes on photovoltaic(PV) panels using Computational Fluid Dynamics(CFD) modelling. This paper offers a thorough examination of parametric exploration on fins. Aimed at perfecting the thermal performance and effectiveness of photovoltaic(PV) solar panels. One pivotal area of study to lessen the negative impacts of temperature rise on solar panel performance is the use of fins in PV systems. This study investigates the goods of several fin figure, similar as blockish, trapezoidal, and triangular fins, on the temperature control of photovoltaic panels.
Index Terms **- CFD, ANSYS, PV solar panel, fins**

I. Introduction

Motivated by the growing need for effective cooling solutions in solar energy systems, researchers are utilizing Computational Fluid Dynamics (CFD) modeling to investigate the cooling impact of connected fins of various shapes on photovoltaic (PV) panels. As PV panels are used more and more globally, it is essential to maintain ideal operating temperatures for their longevity and performance.

In order to increase the PV panels' efficiency and dependability, the study intends to explore how different fin shapes and configurations might improve heat dissipation from the panels. The study aims to give important information for the design and optimization of cooling systems for PV installations by utilizing CFD simulations to shed light on the thermal behavior of various fin geometry under various climatic conditions. This study explores temperature control, a crucial component of photovoltaic (PV) system performance. Heat is produced by solar panels when they transform sunlight into energy, which can negatively, impact their longevity and efficiency if improperly controlled.

A potential method for removing extra heat and preserving ideal operating temperatures is the placement of attached fins on the panels. However, depending on its geometry—which includes elements like size, shape, and orientation—fins' efficacy can differ greatly. This study intends to investigate the complex interactions between various fin arrangements and their cooling capacities using extensive Computational Fluid Dynamics (CFD) simulations. To find the most effective cooling methods for PV systems, the study systematically examines several fin geometries under a range of environmental factors, including airflow patterns and solar irradiation levels.

In the end, the results of this study have important relevance for the development of solar energy technology, Improving the performance, dependability, and sustainability of PV systems globally. This study intends to explore the performance of various fin designs and improve our understanding of fluid dynamics in the cooling process. By Simulating airflow over PV panels with attached fins allows researchers to observe how heat is carried away by convective cooling. Understanding flow patterns is critical for optimizing fin design and increasing heat transfer efficiency. The project will examine how environmental elements like wind speed and temperature affect the efficiency of fin cooling.

This detailed investigation will give insights into the thermal characteristics of PV panels and inform the development of refined cooling solutions for specific operating situations. The findings might lead to innovation in renewable energy technology, making solar power more affordable and sustainable for mass use throughout the transition Toward an improved future.

II. RESEARCH METHODOLOGY

2.1 Physical Model

Figure 1 depicts the schematic model for the current study, which uses fins fastened to the rear of the PV module to examine a passive cooling technique. Additionally, this study took into account three fin sizes.

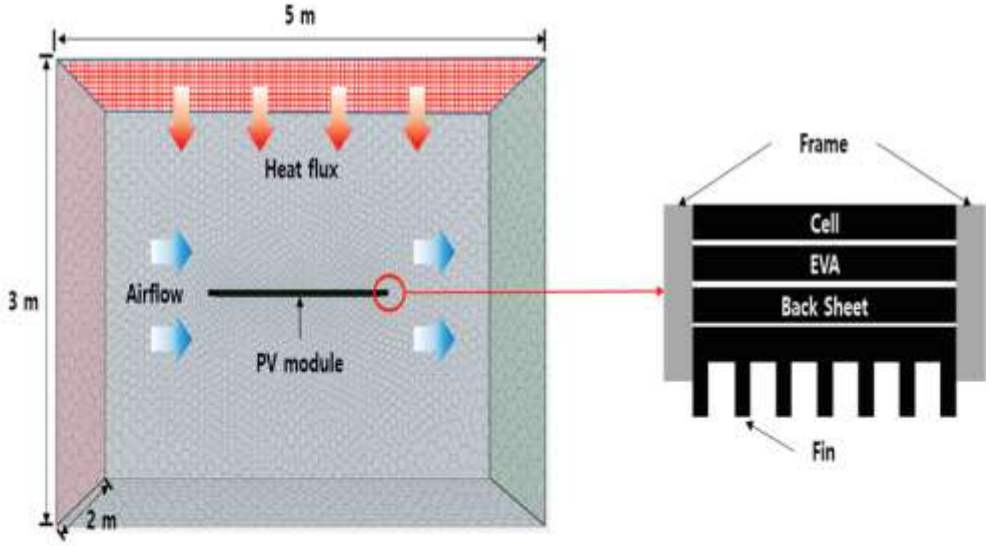


Fig. 2.1: Schematic diagram of the simulation model (Kim and Nam, 2019)

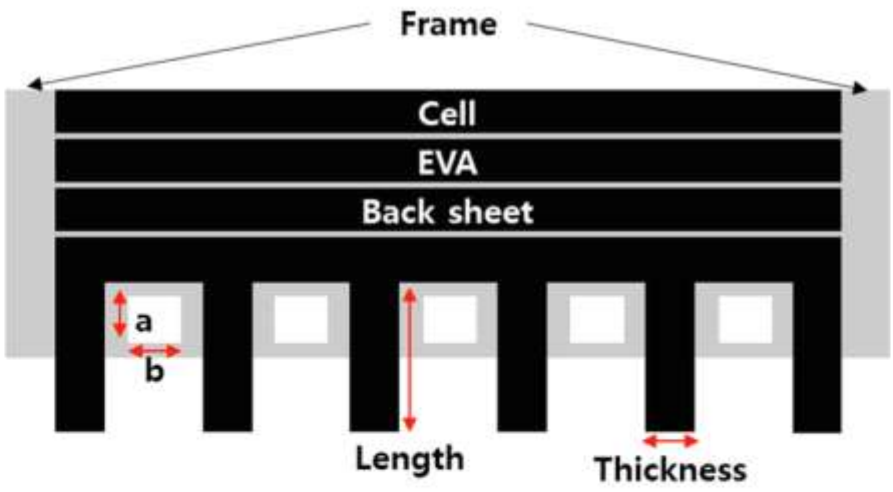


Fig. 2.2: The configuration of fins and slits (Kim and Nam, 2019)

With reference to the indoor test that employed a solar simulator, the simulation model was built to examine the impact of the airflow surrounding the PV module. The PV module was placed inside a 2 m × 3 m × 5 m domain (air) (Figure 2). Furthermore, the spatial grid utilized was a polyhedral masher with multi-region conformal meshing capabilities, and the environmental parameters were based on the three-dimensional steady state.

2.2 Governing Equation

The following governing incompressible fluid flow equations can be used to characterize the steady-state fluid flow characteristic in the three-dimensional computational domain.

Continuity equation:

$$\frac{\partial u_i}{\partial x_i} = 0$$

Momentum balance without gravity force:

$$\rho_{u_i} \frac{\partial u_i}{\partial x_i} = - \frac{\partial P}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j}$$

Energy equation:

$$\rho C_p \frac{\partial (u_i T)}{\partial x_i} = \frac{\partial}{\partial x} \left(\lambda_{eff} \frac{\partial T}{\partial x_i} \right)$$

In conservative form, the partial differential equations for the RNG $k{-}\varepsilon$ model are

Turbulent kinetic equation:

$$\rho u_j \frac{\partial k}{\partial x_i} = \frac{\partial}{\partial x_i}\left[\mu_{eff}\alpha_k \frac{\partial k}{\partial x_j}\right] + \tau_{ij}\frac{\partial u_i}{\partial x_j} - \rho\varepsilon + G_K + G_b$$

Turbulent kinetic dissipation equation

$$\rho u_j \frac{\partial \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\mu_{eff}\alpha_\varepsilon \frac{\partial \epsilon}{\partial x_j}\right] + C_{1\varepsilon}\frac{\partial \varepsilon}{\partial x_j} + C_{1\varepsilon}\frac{\varepsilon}{K}(G_K + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{K}$$

The most cost-effective method for calculating complicated turbulent flow is to use the Reynolds Averaged Navier-Stokes (RANS) turbulence models mentioned above. Stream of industry. The turbulent flow's motion is often described using the Navier-Stokes equations. However, solving these equations for intricate flow problems is too expensive and time-consuming. Instead, two techniques have been proposed: (i) massive Eddy Simulation (LES), in which minor eddies are taken into account via averaging, whereas massive energy-containing eddies are explicitly simulated. The process of (ii) Reynolds averaging (RANS), in which all eddies are taken into account by Reynolds stresses derived by averaging the Navier-Stokes equations (time averaging for statistically stable flows, ensemble averaging for unsteady flows), is necessary to separate big and small eddies.

2.3 Boundary Conditions

The current study uses the SIMPLE algorithm to discover a solution for the coupling between the pressure and velocity, and the commercial CFD program FLUENT 6.3, which is based on the finite volume approach, is utilized for the numerical computation. The cooling performance of the fins affixed to the bottom of the PV module was examined in this study using a parametric analysis based on the fins' shape. Furthermore, a simulation model with slits was taken into consideration. This model can enhance the cooling performance of the fins by creating an active airflow distribution at the bottom of the fins and module. All residual norms for the continuity, momentum, and energy equations must be smaller than 10-6 in order to meet the convergence requirement.

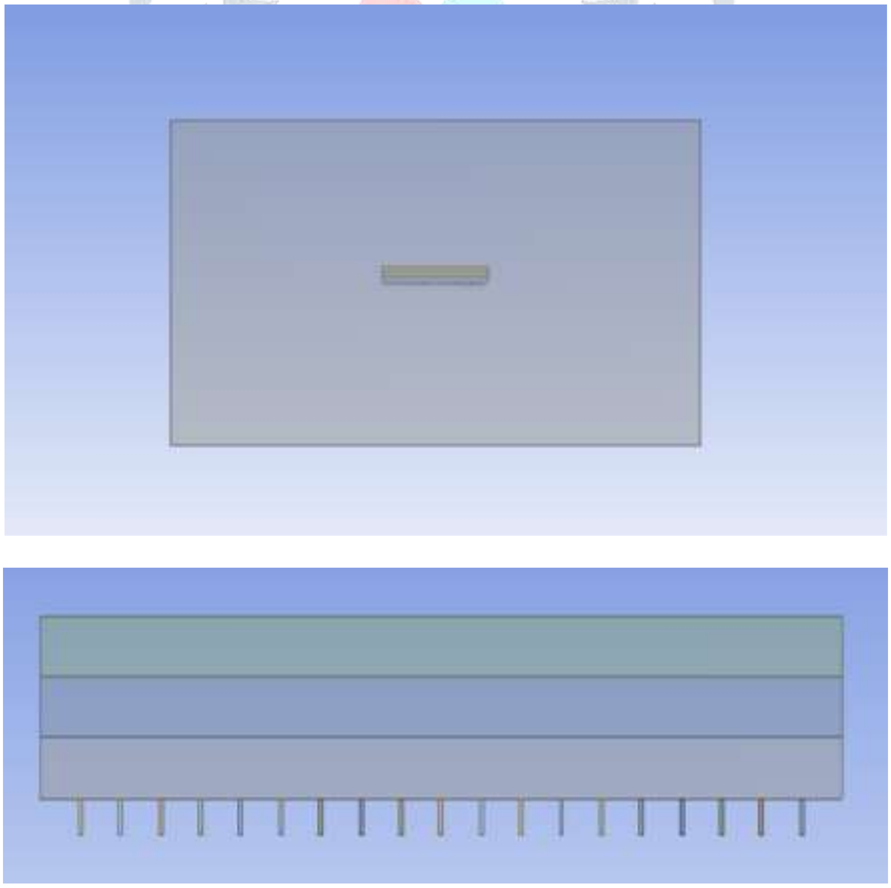


Fig. 2.3: CFD model

The program Gambit is used to construct and mesh the finite-element model, and unstructured grids are employed. The highly refined grid in the area close to the tube wall is regarded as the boundary layer, and the tetrahedral grid is used to mesh the models. The meshing grid is displayed in Fig. 2.4.

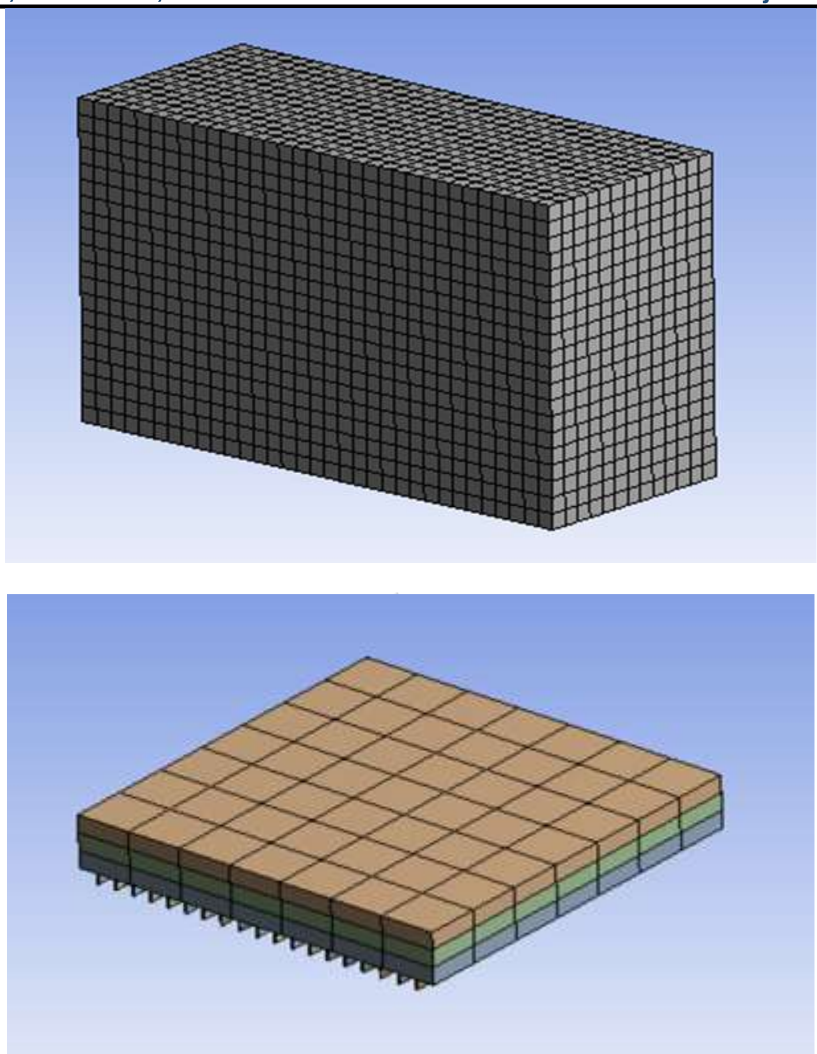


Fig. 2.4: Mesh model

2.4 Choosing the Physical Properties

Setting up the model requires defining the physical characteristics of fluids and solids, such as density, viscosity, specific heat, and thermal conductivity. A back sheet, cells, EVA (ethylene vinyl acetate), and fins—aside from glass—made up the PV module that was simulated. Stated differently, the impact of transmission bodies, such glass and EVA, on the solar irradiance's transmissivity was disregarded. The airflow's velocity entrance and pressure exit were placed on each side of the domain. The boundary condition on the upper surface was the heat flow (Table 1). The velocity and heat flux were set at 0.5 m/s and 600 W/m2, respectively, which fell within the NOCT condition's effective range. Furthermore, the contact resistance was adjusted to 0 m2K/W and it was believed that every layer's interface was in complete contact. The thermal characteristics of every component used in the PV module simulation are displayed in Table 2.

Table 2.1: Simulation conditions

Heat flux, W/m^2	Velocity inlet (m/s)	Ambient temperature, ^oC	Initial temperature, ^oC	Contact Resistance, m^2K/W
600	0.5	26.84	26.84	0

Table 2.2: Thermophysical properties

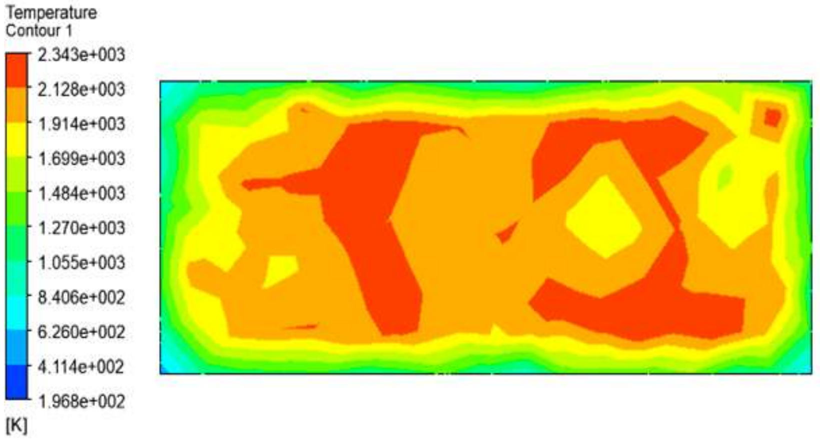
Components	Density (Kg/m^3)	Thickness, mm	Specific heat (J/Kg^oC)	Thermal conductivity, (W/mk)
Cell (Si)	2330	10	677	148
EVA	960	10	2090	0.35
Frame (Al)	2702	60	903	237
Back sheet	1200	1	1250	0.2
Fin (Cu)	8900	5	385	400

III. RESULTS AND DISCUSSION

3.1 Temperature Contour

The temperature distribution in a chamber with a rectangular fin fixed to a surface changes at a speed of 0.5 m/s in a complicated but predictable manner that is impacted by several variables.
Initially, convective heat transfer causes the air to absorb heat from the fin's surface as it passes over it.

Results, the temperature drops close to the fin's surface. This heat is carried away by the air as it passes along the fin's length, gradationally raising the temperature downstream.
Nonetheless, the chamber's temperature distribution is not constant. Because of the direct exposure to the colder incoming airflow, the temperature reduction is more noticeable close to the leading edge of the fin, where the airflow first meets the surface. On the other hand, the temperature increase is more noticeable near the fin's trailing edge, where the airflow has already absorbed heat along its course.



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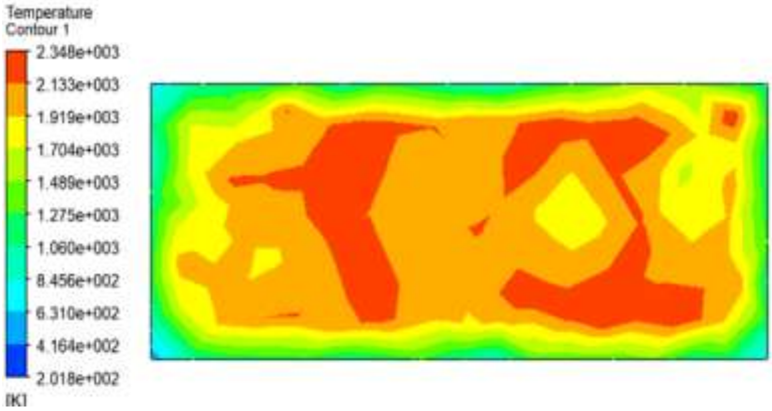
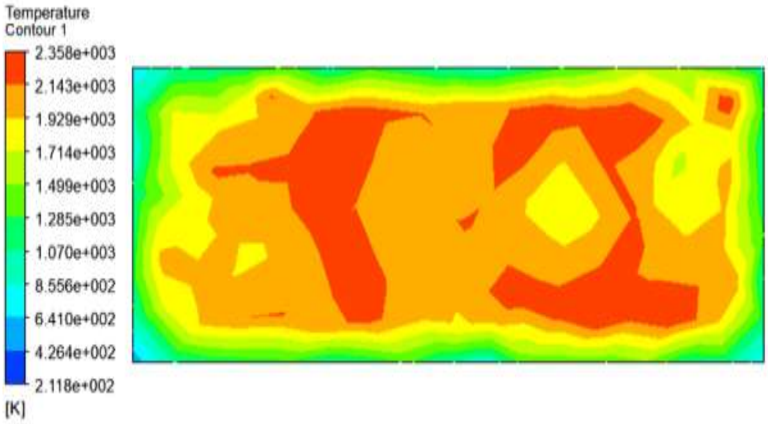
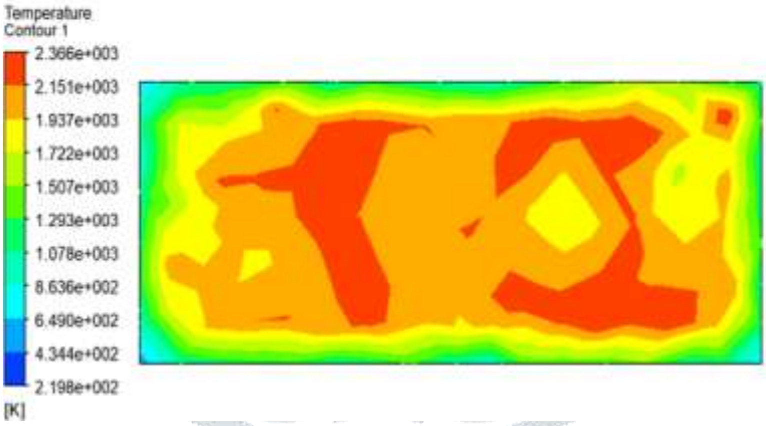
(a) Temperature distribution in chamber for rectangular fin at velocity of 0.5m/s



(b) Temperature distribution in chamber for trapezoidal fin at velocity of 0.5m/s



(c) Temperature distribution in chamber for rectangular fin at velocity of 1 m/s



(d) Temperature distribution in chamber for trapezoidal fin at velocity of 1 m/s

3.2 Analysis of Average Temperature

In this study, two types of fins were considered viz. rectangular, trapezoidal Furthermore, by altering the number, thickness, and length of fins, parametric research was carried out for each fin.

Table 3.1: Average Temperature in Fins

Type of fins	Average temperature from Kim and Nam (2019) (ºC)	Average temperature from Present study (ºC)	Percentage improvement, %
Rectangular	48.71	49.52	1.66%
Trapezoidal		52.67	8.13%

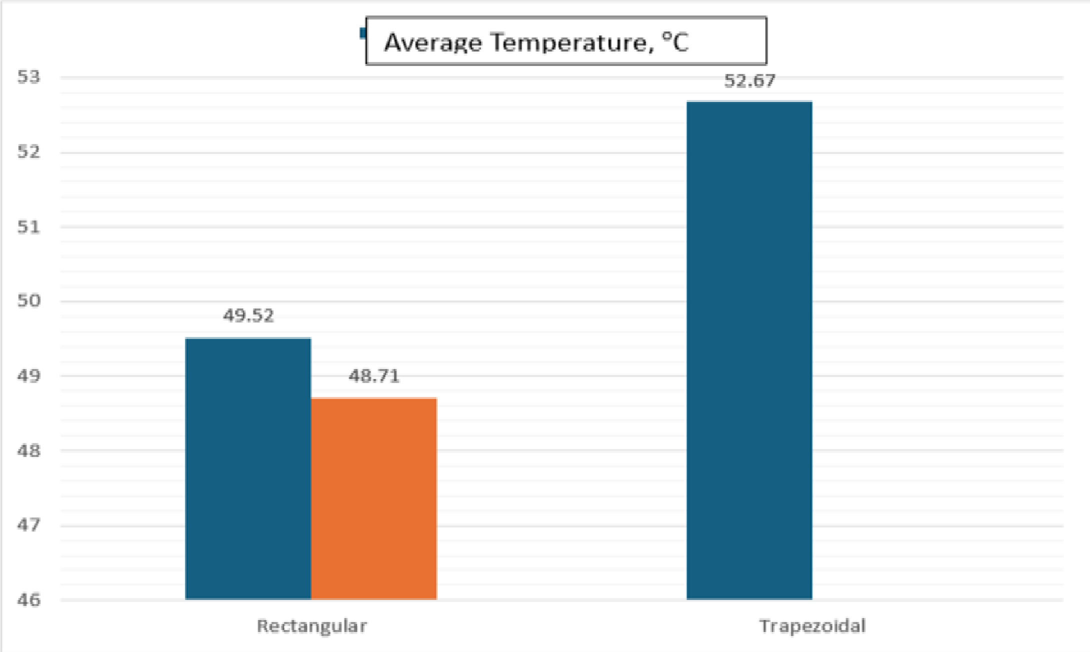


Fig. 3.1 : Comparison of average temperature

3.3 Parametric Study

A parametric study was performed for each fins by varying number of fins. Other comparison like width and length will not be appropriate because width of trapezoidal shape varies throughout its length.

Variation of number fins:

Table 3.2: Variation of no. of fins (rectangular)

No. of fins	Average temperature from Kim and Nam (2019) (ºC)	Average temperature from Present study (ºC)
10	48.71	49.52
20	48.11	49.44

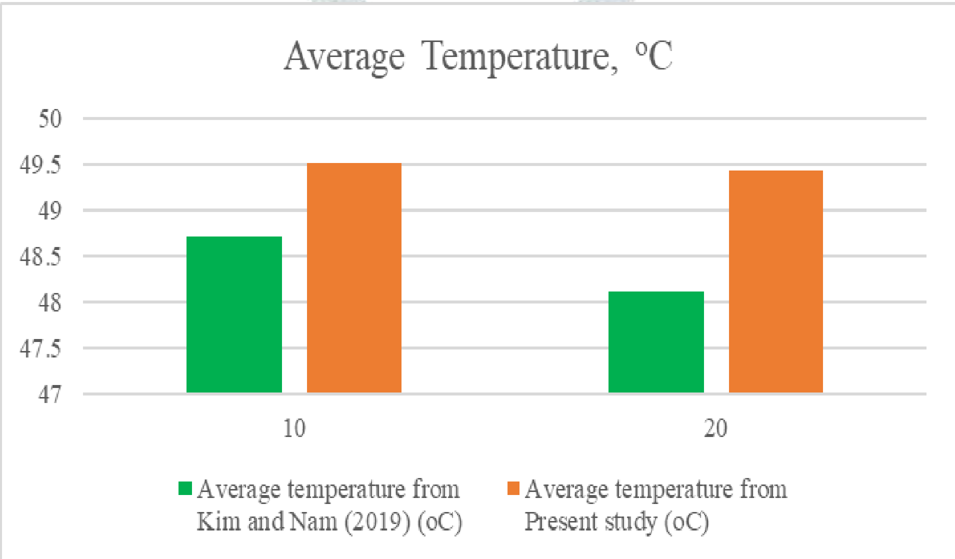


Fig. 3.2: Variation of Average temperature with no. of fins (rectangular)

Table 3.3: Variation of no. of fins (trapezoidal)

No. of fins	Average temperature from Kim and Nam (2019) (°C) for rectangular fin	Average temperature from Present study (°C)	Percentage improvement, %
10	48.71	52.69	8.17
20	48.11	55.24	14.8

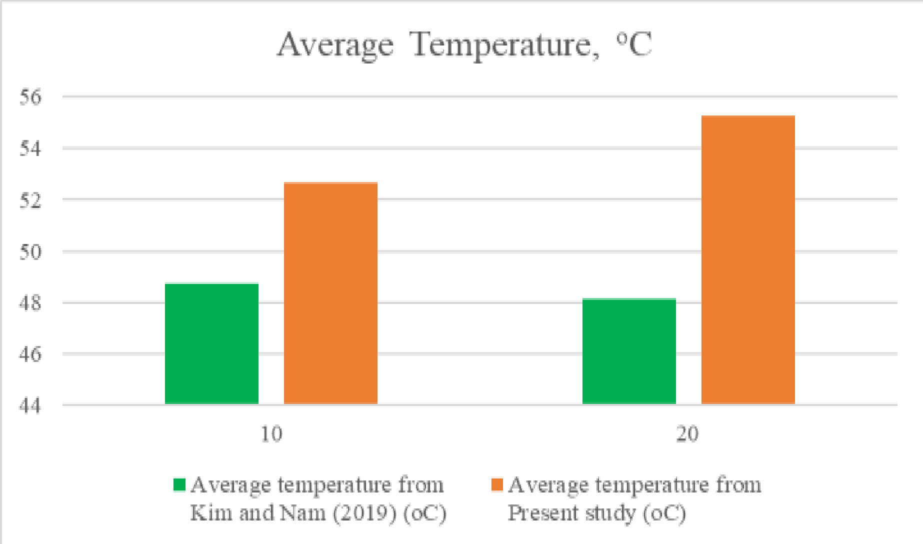


Fig. 3.3: Variation of Average temperature with no. of fins (trapezoidal)

IV. CONCLUSION

1. Both simulation models one with trapezoidal fins attachment and other with rectangular fins attachment were created by altering the fin attachment to the PV. Two fin types — rectangular fin and trapezoidal fin — were taken into consideration in this disquisition. also, a parametric analysis was conducted for every fin. Kim and Nam(2019) reported an average temperature of 48.71 °C for the blockish fin, but the current disquisition set up an average temperature of 49.52 °C. This indicates a little enhancement in thermal performance, with a chance enhancement of 1.66 percentage. This little enhancement in temperature effectiveness was presumably caused by variations made to the blockish fin's design or by the experimental setup used in this disquisition. The current study's average temperature for the trapezoidal fin, for which no previous data from Kim and Nam(2019) is available, is 52.67°C. The chance enhancement is determined to be 8.13 percentage.

2. For fins numbering 10, the average temperature noted by Kim and Nam was 48.71°C, while the present study recorded temperature of 49.52°C. When the number of fins was increased to 20, the average temperature from Kim and Nam's study slightly decreased to 48.11°C, and the present study showed a small decrease as well, with a recorded temperature of 49.44°C.

3. For 10 fins, Kim and Nam recorded an average temperature of 48.71°C, whereas the present study noted a higher temperature of 52.69°C. Similarly, for 20 fins, Kim and Nam's study reported an average temperature of 48.11°C, while the present study recorded 55.24°C.

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