Jurnal POLI-TEKNOLOGI
ISSN 1412-2782 eISSN 2407-9103
**Vol 22. No. 3 September 2023**

# Initial Design of Dual Axis Solar Tracking System with the Addition of Camera and Cooling System

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***Abstract***

*Solar panels have been widely used to determine solar energy as an electrical energy generator. However, the installation of solar panels is still static, so it cannot follow the sun's movement optimally. Solar panels with dual-axis tracking have a wide range in the tracking process. The range that can be tracked by dual-axis tracking is azimuth angle and altitude, while single-axis tracking can only choose one side of the angle. In this study, the initial design of the dual-axis solar tracking system was made with cameras and cooling systems combined with heatsinks and tubular pipes. The design made is in the form of a CAD design using SolidWorks software, and the design made will be used for subsequent research, In this solar panel, the fill factor results are 0.634, and the efficiency of solar panels is 17.53% with the addition of a cooling system which can reduce the temperature of solar panels is expected to be higher efficiency. The study results were obtained in the design of a solar tracker with the addition of a cooling system that will later reduce the temperature and increase the efficiency of solar panel about 0.38% every 1℃ decreases of temperature.*

**Article History**
Submitted: 03/07/2023
Revised : 29/07/2023
Accepted : 29/09/2023
Published: 29/09/2023

**Keywords:**
*Design, Dual-Axis Solar Tracking System, Solar Panel, Cooling System, Camera*

## Introduction

Energy is the primary energy source for human progress and prosperity, with the continuous development of times and civilizations. Energy use is also becoming steadily increasing at a fast time. It requires a massive amount of energy and energy reserves to prevent the instability of human society. The thing to do is to process and process more fossil fuels to get a lot of energy [1]. But along with the use of fossil fuels that have been too much, making these fossil fuels also depleted. This results in fossil fuels becoming scarce and prices increasing, and their products' effects cause pollution and depleted fossil fuels. These developments in fossil fuels are becoming scarce, costs are increasing, and the impact of their products causes pollution [2]. Therefore, it is vital to source new environmentally friendly energy that can continue to be renewable to replace conventional energy. Renewable energy is an appropriate substitute for conventional energy because it is produced by utilizing energy sources from nature that can be renewable continuously and unlimitedly. Solar energy, wind energy, and hydropower energy are part of renewable energy [3].

Solar panels have been widely used to determine solar energy as an electrical energy generator. However, the installation of solar panels is still static, so it cannot follow the sun's movement optimally [4]. Compared to static panels, panels with solar trackers can overcome the solution of solar panels that cannot follow the movement of the sun optimally [5]. This solar tracker can be divided into two types, namely single-axis tracking and dual-axis tracking. Solar panels with dual-axis tracking have a wide range in the tracking process. The range that can be tracked by dual-axis tracking is azimuth angle and altitude, while single-axis tracking can only choose one side of the angle [6].

Not only the use of solar trackers that can increase the power efficiency of panel output, but the emission of solar radiation that hits the surface of solar panels is only about 20% converted into electrical energy. In contrast, the rest is converted into heat. Also, the increase in temperature on the surface of solar panels has an impact on decreasing the efficiency of output power [7].

Various studies have been conducted on optimizing solar tracker design and adding cooling systems. The focus of the study is the influence of the movement of solar panels and the addition of cooling systems to be the essential factor in maximizing the potential power output of solar panels [2]–[8].

In line with the information obtained from the study, research that designs solar trackers, and the addition of cooling systems, some methods have never been done before. In addition, the information obtained from this research can be the basis for development that can be further researched to increase the efficiency of solar panels. Therefore, this study aims to design a solar tracker by adding a cooling system, which drains the water in tubular pipes and adds heatsinks on the bottom surface of solar panels.

## Theory

### *A. Solar Tracker*

Solar tracking systems are generally classified into two groups, namely by tilting and rotating, included in the classification of single-axis solar tracking systems and dual-axis solar tracking systems.

The single-axis solar tracking system only uses one axis to move the solar panel against the angle of inclination of the sun. In contrast, the dual-axis solar tracking system uses two axes of rotation to capture the sun's movement. These two axes can use horizontal and vertical axes, including moving solar panels in the east/west and north/south directions [9].

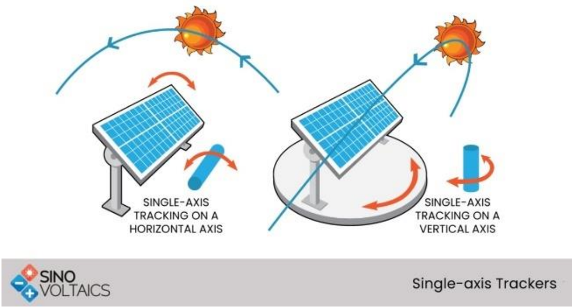


**Figure 1. Single-Axis Trackers**

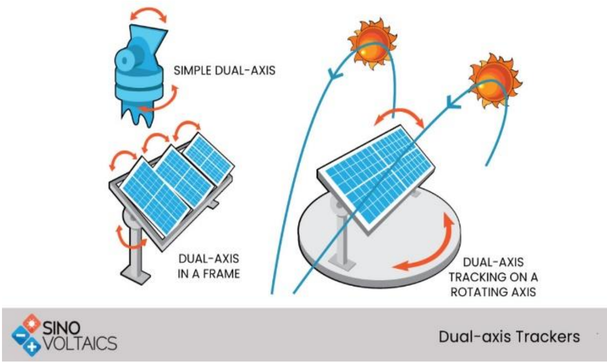


**Figure 2. Dual-Axis Trackers**

### *B. Camera Use*

The use of the camera is to track the sun's position, while the method used is tracking by finding the lowest pixel point. A microcomputer will process image capture, which will later be carried out in several stages, namely the Gaussian Blur process, to reduce noise in the image results. After that, coordinate point data are obtained, which will later be instructed to move the Linear Actuator so that the position of the solar panel is proper in the direction of the coming sun so that the results of solar panel output will be maximized [5]

### *C. Cooling System*

Heatsink is a device made of conductive metal that can absorb heat from high-temperature parts and dissipate it into the surrounding environment. There are two methods for heat transfer, namely the active method and the passive method [10].

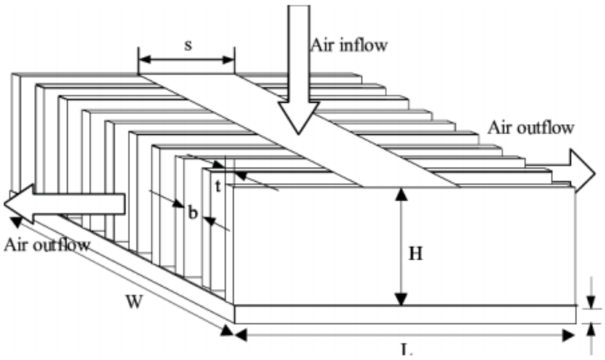


**Figure 3. Heatsink Work System**

The use of water as an active cooling system on solar panels is also one of the widely used methods because, in addition to lowering the temperature on the surface of solar panels, it can also clean the surface of solar panels from dirt and dust, which is one of the factors that are not optimal solar panel power output [11].

As for the calculations for the cooling rate model.

$$Q_{gained\ by\ cooling\ water} = Q_{dissipated\ from\ PV\ panels} \quad (1)$$

$$m_w \times t \times c_w \times \Delta T_w = m_g \times c_g \times \Delta T_g \quad (2)$$

$$t = \frac{m_g \times c_g \times \Delta T_g}{m_w \times c_w \times \Delta T_w} \quad (3)$$

Where:

$m_w$ = Water mass flow column (kg/s)
$c_w$ = Water heat capacity (J/kg°C)
$\Delta T_w$ = Water temperature difference before and after cooling (°C)
$t$ = Solar panel cooling time (s)
$m_g$ = Solar panel glass mass (kg)
$c_g$ = Glass heat capacity (J/kg°C)
$\Delta T_g$ = Temperature difference of solar panels before and after cooling (°C)

## Method

In the research conducted, there are several methodologies carried out, namely:

- Conduct literature studies.
  As an initial stage, literature on solar power generation, the development of solar panels, and the parameters used in research derived from books and journal.
- Observe system design.
  After studying the parameters and design, the parameters and structure of the system are observed.
- Design 3D models on SolidWorks.
  The experimental designs are implemented as 3D models in SolidWorks software.

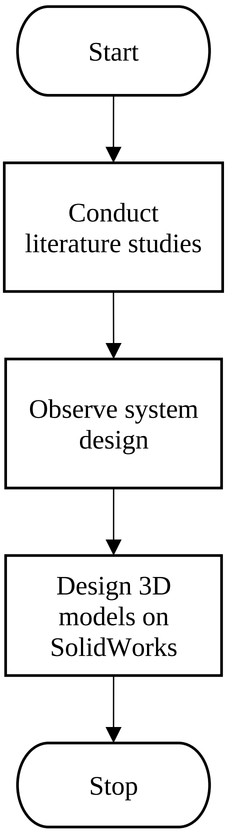


**Figure 4. Flowchart of Method**

## Result and Discussion

System design consists of system design, design details, system design, solar panel requirement calculation formula, battery requirement calculation formula, fill factor formula, efficiency formula, and dual-axis tracking integrated with the camera and cooling system.

### *A. System Design*

The system designed this time consists of solar panels, cameras, two linear actuators, and a cooling system. The camera will be placed on the long side of the solar panel, pointing north or south. The first linear actuator moves the solar panel to the east and west, while the second is used to move the solar panel to the north and south. Later, each linear actuator will receive commands from the camera capture through the image processing process. The cooling system method used is to add a heatsink on the bottom surface of the solar panel, which will be drained by water through a tubular pipe.


**Figure 6. Isometric View of Design**

**Figure 5. Side of View of Design**

## *B. Design Details*

**Solar Panel**

The type of solar panel used in this study is a model MS200M-60 Monocrystalline type with a maximum power of 200 Wp. The comparison between Monocrystalline and Polycrystalline types is very significant, and this monocrystalline type shows an efficiency of 14% compared to the polycrystalline type [12]. Details of specifications will be shown in Table 1.

TABLE 1. SPECIFICATION OF SOLAR PANEL

| | |
|---|---|
| **Model** | MS200M-60 |
| **Rated Maximum Power (Pm)** | 200W |
| **Tolerance** | 0-+5% |
| **Voltage at Pmax (Vmp)** | 16V |
| **Current at Pmax (Imp)** | 12.5A |
| **Open-Circuit Voltage (Voc)** | 24V |
| **Short-Circuit Current (Isc)** | 13.13A |
| **Normal Operating Cell Temp (NOCT)** | 47±2℃ |
| **Maximum System Voltage** | 1000V DC |
| **Maximum Series Fuse Rating** | 10A |
| **Operating Temperature** | -40℃ to +85℃ |
| **Application Class** | Class A |
| **Fire Safety Class** | Class C |
| **Cell Technology** | Mono-Si |
| **Weight** | 16.08kg |
| **Dimension(mm)** | 1480*770*35mm |

### Camera
Cameras or webcams are used to track the presence of the sun, which will later be input for microcomputers.

### DS18B20 Sensor
This DS18B20 sensor is used to read the temperature on the surface of the solar panel, which will later be sent the readings to drive the DC 12 V water pump.

### Solar Charge Controller
This Solar Charge Controller serves to optimize charging on the battery. This study uses the MPPT type because it can maximize battery charging based on the power absorbed by solar panels. This Solar Charge Controller serves to optimize charging on the battery. In this study, using the MPPT type because it can maximize battery charging based on the power absorbed by solar panels [13].

### DC Water Pump 12V
DC water pumps with 12V specifications are used to drain water to the surface of solar panels as a cooling system.

### Linear Actuator
The linear actuator is specifically used to create movement in a straight-line using inputs provided by the system. This linear actuator can provide movement in one or two directions, i.e., pushing, pulling, or both. The number of linear actuators used in this study is two pieces, which will move in the north/south and east/west directions. Details of the specifications will be shown in Table 2

TABLE 2. SPECIFICATION OF LINEAR ACTUATOR

| **Model** | **Linear Actuator 1** | **Linear Actuator 2** |
|---|---|---|
| | KG-TGA | KG-TGA |
| **Motor Type** | Permanent Magnet DC Motor Drive | Permanent Magnet DC Motor Drive |
| **Rated Voltage** | 12VDC | 12VDC |
| **Maximum thrust/pull** | 1500N (50cm=1000N) | 1500N (50cm=1000N) |
| **Self-locking force** | 200KG | 200KG |
| **Speed** | 7 mm/s | 7 mm/s |
| **Effective Stroke** | 500mm | 100mm |
| **Standard protection level** | IP54 | IP54 |
| **Base noise design, noise level below** | 42dB | 42dB |
| **Ambient Temperature** | -26℃ to 50℃ | -26℃ to 50℃ |

**DC Battery 12V**
The 12V DC battery is lead-acid because it has a constant voltage character. It affects the voltage drop on solar panels during cloudy weather conditions [14]. The type of lead acid battery used is a VRLA battery specifically designed so that the electrolyte liquid does not spill or leak.

## *C. Initial System Design*

In the system design, we will discuss the flow diagram of how the dual-axis solar tracker works integrated with the camera and the addition of a cooling system.

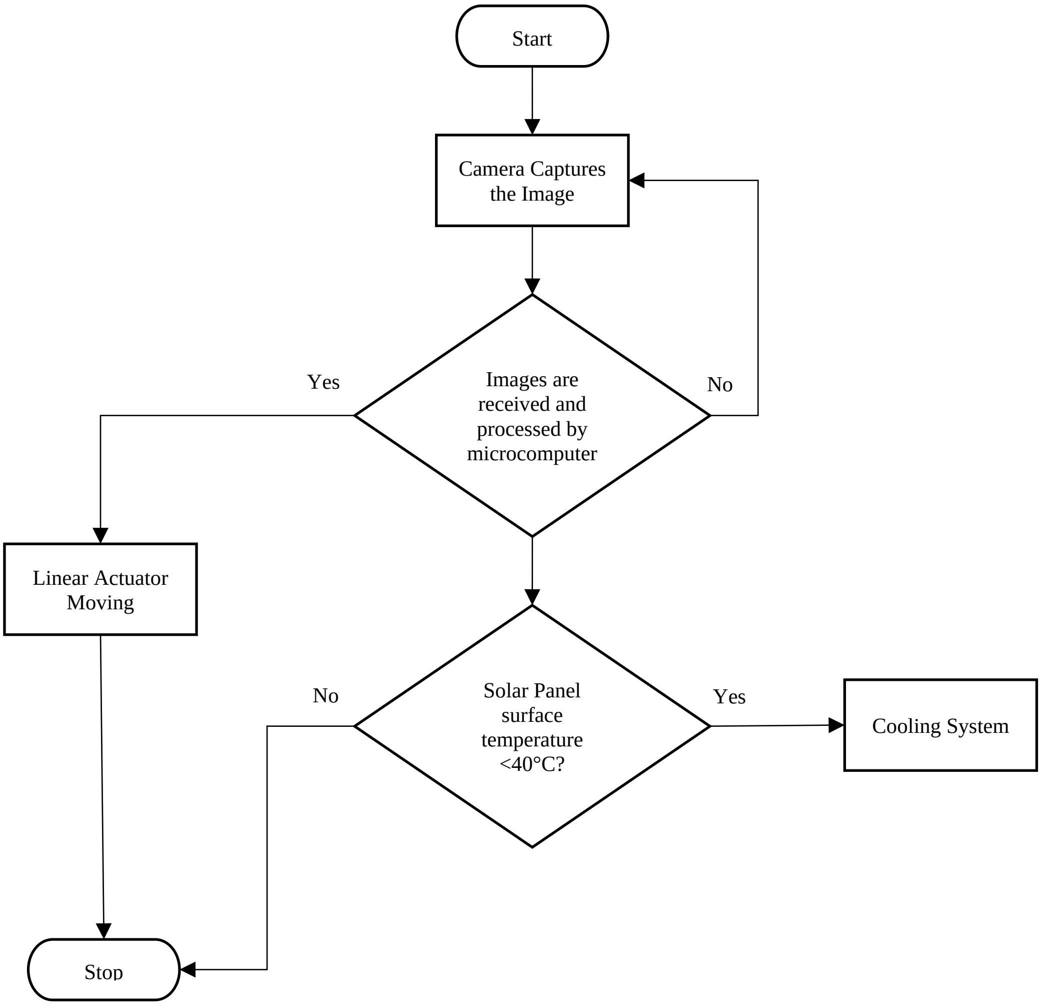


**Figure 7. Flowchart of Design System**

**Solar Panel Requirement Calculation**
Calculations are needed to match energy consumption to get the number of solar panels that needs to be used.

$$Power\ Module\ (Wp) = \frac{24\% \times Energy\ Requirement\ (kwh)}{Radiant\ Energy\ \left(4{,}5\frac{kwh}{m^2}\right) \times \frac{1}{Radiant}\left(\frac{1kw}{m^2}\right) \times powerloss} \quad (4)$$

**Battery Requirement Calculation**

It is very necessary to calculate the required battery requirements of this system so as not to be mistaken in use battery requirement calculation.

$$Battery\ Capacity\ (Ah) = \frac{Energy\ Requirement - (24\% \times Energy\ Requirement)}{Battery\ Voltage \times Charging\ Efficiency\ (0{,}8) \times D.O.D\ (0{,}8)} \tag{5}$$

**Fill Factor**

The fill factor is one of the quantities that become the performance parameter of solar cells, namely the ratio of the maximum power produced to the multiplication between Voc and Isc.

$$Fill\ Factor = \frac{V_{mp} I_{mp}}{V_{sc} I_{sc}} \tag{6}$$

Where:

$V_{mp}$ : Voltage at Pmax (V)
$I_{mp}$ : Current at Pmax (A)
$V_{oc}$ : Open-circuit voltage (V)
$I_{sc}$ : Short-circuit current (A)

In the specifications of the solar panel used, the fill factor value can be found:

$$Fill\ Factor = \frac{16V\ 12.5A}{24V\ 13.13A} \tag{7}$$

$$Fill\ Factor = 0.634 \tag{8}$$

**Efficiency**

The efficiency of solar panels can be interpreted as a comparison between energy output and input energy from the sun. The efficiency of these solar panels is also highly dependent on the spectrum and intensity of sunlight. Therefore, paying attention to purchasing components is necessary to get a good efficiency value.

$$\eta = \frac{V_{oc} I_{sc} FF}{SIA} \tag{9}$$

Where:

$V_{oc}$ : Open-circuit voltage (V)
$I_{sc}$ : Short-circuit current (A)
$FF$ : Fill factor
$SI$ : Solar radiation ($W/m^2$)
$A$ : Surface area of solar panel ($m^2$)

After getting a fill factor value of 0.634. The efficiency value can be found as follows:

$$\eta = \frac{24V\ 13.13A\ 0.634}{1000W/m^2\ 11{,}396m^2} \times 100\% \tag{10}$$

$$\eta = 17.53\% \tag{11}$$

A fill factor value of 0.634 indicates how much sunlight can be absorbed by solar panels with STC (Standard Test Condition). The efficiency value of 17.53% shows how much solar energy can be converted into electrical energy with STC (Standard Test Condition) where the optimum solar panel temperature is 25°C, solar radiation is 1000W/m2 and water mass is 1.5. STC is a standard used by solar panel companies to determine the efficiency of solar panels.

**Dual-Axis Tracking System Integrated with Camera**

The design of this system uses dual-axis tracking integrated with the camera, where this tracking will be driven by the image captured by the camera and processed by a microcomputer to produce output to move the linear actuator.

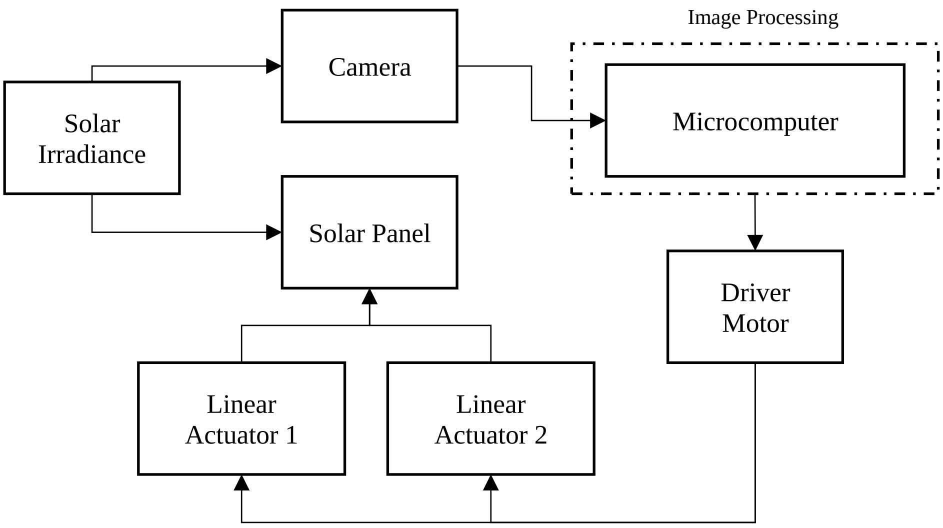


**Figure 8. Block Diagram of Dual-Axis Tracking System Integrated with Camera**

**Figure 9. Camera Placement Position**

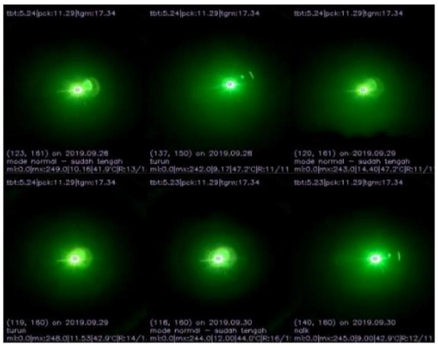

**Figure 10. Solar Tracker Captured Image**

**Cooling System**

The cooling system is a combination of heatsinks and pipes fed by water. This heatsink is useful as a passive cooling system that, without using energy input to work, only relies on fins to dissipate absorbed heat. Then added, a pipe that is flowed by water, by inserting a tube in each gap of the heatsink fin, which is useful for speeding up the heat dissipation process. By using this heatsink cooling system can reduce the surface temperature of solar panels by 15.9 C, and the efficiency achieved is around 28.65% [10]. The use of capillary pipes is also able to reduce the temperature of solar panels is also very good because they can absorb and transfer heat from solar panels through the flow of water in pipes can reduce the temperature of solar panels with a difference of 6.5 °C [15].

The general description of the absorption, dispersion, and heat release process that occurs in solar panels can then be mathematically calculated for the rate of heat absorption and heat distribution through conduction and convection from heat sources.

$$\dot{Q} = m \,.\, C_p \,.\frac{dT}{dt} + k \,.\, A_{cond} \,.\frac{dT}{dx} + h \,.\, A_{conv} \,.\, (T_2 - T_\infty) \quad (12)$$

Where:

$\dot{Q}$ = Heat flow rate
$m$ = Mass
$C_p$ = Heat type
$T$ = Temperature
$t$ = Time
$k$ = Thermal conductivity
$A$ = Surface Area
$x$ = Thickness
$h$ = Convection coefficient

By combining the cooling model using a tubular cooler mounted on the gap of the heatsink fin, heat absorption on the solar panel will be maximized.

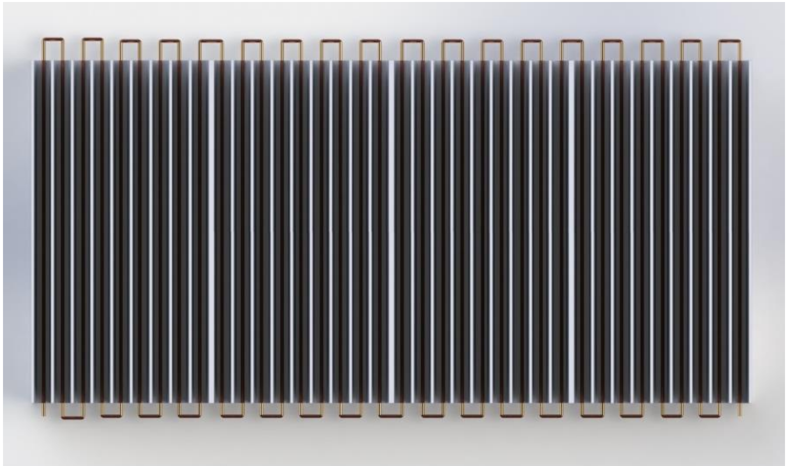

**Figure 11. Heatsink Design and Tubular Pipe Use**

The results of heat reception on solar panels assuming the radiation value per day in 5 hours is 872,060 W/m$^{2,}$ can be seen in Figure 12.

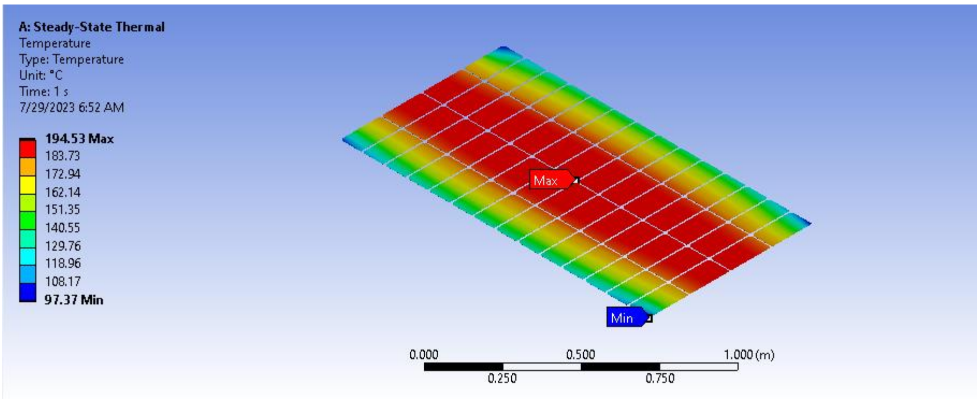


**Figure 12. Simulation results of receiving solar radiation from solar panels**

The highest value at temperature is 194.53°C, and the lowest is 97.37°C. Therefore, using a cooling system that has been designed is expected to reduce the hottest temperature on solar panels.

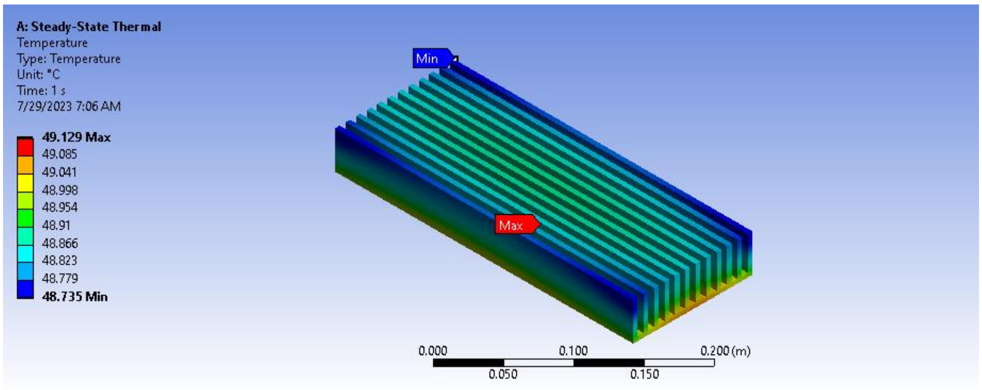


**Figure 13. Results of heatsink heat distribution simulation**

The heatsink simulation results show that the highest value at the accepted temperature is 49.129°C and the lowest at the accepted temperature is 48.735°C. Thus, using this heatsink can reduce the temperature of solar panels so that the efficiency of solar panels can increase, along with the addition of temperature.

With the results of simulations on heatsinks and radiation simulations on solar panels, it can be concluded that assuming the highest temperature on the heatsink is the highest heat from the solar panel and at the lowest temperature on the heatsink is the absorption and spread of heat so that a decrease in temperature can occur by 0.80%.

## Conclusions

The conclusion that can be drawn in the form of a description of the initial design of a dual-axis solar tracker by adding a camera and cooling system with observations from research that has been done is expected to get appropriate results, namely with a decrease every 1°C will increase efficiency by about 0.38%. So that the efficiency of solar panels that have been calculated without cooling is 17.53%, and based on the results of the solar tracker design and the addition of a cooling system is expected to increase the efficiency. Then further research will be carried out related to the design that has been done and will analyse the results that will be produced.

## Acknowledgement

The author would like to thank the parties who have helped during this research process.

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