Faculty of Electrical Technology and Engineering

DESIGN AND DEVELOPMENT OF AN INTEGRATED MOUNTING STRUCTURE WITH COOLING FINS FOR PV TEMPERATURE REDUCTION

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Bachelor of Electrical Engineering Technology with Honours

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in partial fulfillment of the requirements for the degree of
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ABSTRACT

The increasing demand for renewable energy sources has led to a significant rise in the deployment of photovoltaic (PV) systems worldwide. However, the efficiency and performance of PV panels can be adversely affected by excessive heat buildup during operation, which reduces their overall energy output and lifespan. To mitigate this challenge, this project focuses on the design and development of a novel PV cooling system that integrates aluminum fins with the existing mounting structure. The proposed aluminum fins are design in such a way that can be directly attached to the base of the mounting structure. The mounting structure serves a dual purpose by providing structural support to the PV array and facilitating efficient heat transfer through the integrated fins. This project involves several key stages, including mechanical design, and electrical performance evaluationof the proposed system. The mechanical design and fabrication process will consider factors such as material selection, fin dimensions, and attachment methods to ensure seamless integration with the existing mounting structure. Experimental evaluation will be conducted to analyse the performance and effectiveness of the proposed design under outdoor operating conditions. The integration of the cooling system with the mounting structure offers a cost-effective and space-efficient solution for PV installations, eliminating the need for additional support structures or cooling mechanisms.

ABSTRAK

Permintaan yang semakin meningkat untuk sumber tenaga boleh diperbaharui telah membawa kepada peningkatan yang ketara dalam penggunaan sistem fotovoltaik (PV) di seluruh dunia. Walau bagaimanapun, kecekapan dan prestasi panel PV boleh terjejas oleh pengumpulan haba yang berlebihan semasa operasi, yang mengurangkan pengeluaran tenaga dan jangka hayat keseluruhannya. Untuk mengurangkan cabaran ini, projek ini memberi tumpuan kepada reka bentuk dan pembangunan sistem penyejukan PV baru yang menyepadukan sirip aluminium dengan struktur pelekap sedia ada. Sirip aluminium yang dicadangkan adalah reka bentuk sedemikian yang boleh dilekatkan terus pada dasar struktur pelekap. Struktur pelekap berfungsi untuk dua tujuan dengan menyediakan sokongan struktur kepada tatasusunan PV dan memudahkan pemindahan haba yang cekap melalui sirip bersepadu. Projek ini melibatkan beberapa peringkat utama, termasuk reka bentuk mekanikal, dan penilaian prestasi elektrik sistem yang dicadangkan. Reka bentuk mekanikal dan proses fabrikasi akan mempertimbangkan faktor seperti pemilihan bahan, dimensi sirip, dan kaedah lampiran untuk memastikan penyepaduan yang lancar dengan struktur pelekap sedia ada. Penilaian eksperimen akan dijalankan untuk menganalisis prestasi dan keberkesanan reka bentuk yang dicadangkan di bawah keadaan operasi luar. Penyepaduan sistem penyejukan dengan struktur pelekap menawarkan penyelesaian yang kos efektif dan cekap ruang untuk pemasangan PV, menghapuskan keperluan untuk struktur sokongan tambahan atau mekanisme penyejukan.

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CHAPTER 1

INTRODUCTION

1.1 Background

Mounting structures for photovoltaic (PV) modules are typically designed to securely hold the modules in place and optimize their performance by positioning them at the most favorable angle to the sun. The mounting structure must be designed to allow for easy access to the PV modules for maintenance and cleaning. The mounting structure should also be designed to meet local building codes and regulations to ensure that the system is installed safely and meets all applicable standards.

A framework or support system created to install photovoltaic (PV) panels while adding fins that help lower the operating temperature of the panels is referred to as a mounting structure with a fin for temperature reduction. PV panels use sunlight to generate electricity, but when their temperature rises, they may lose efficiency. For better energy output and longer panel life, the mounting structure's fins help drain extra heat and maintain ideal working temperatures. Typically, strong, corrosion-resistant, and heat-dissipating materials like steel or aluminum are used to construct the mounting framework. The fins are typically long, thin structures that are either built into the mounting structure itself or affixed to the back of the PV panel. These fins expand the area that is exposed to outside air, which facilitates greater heat transfer and dissipation.

The underlying idea is that the fins improve PV panel cooling by expanding the surface area and promoting convective airflow. The fins assist in removing the heat produced by the panel as it absorbs sunlight. The heat is removed from the fins by the increased airflow, which keeps it from building up and potentially damaging the panels or reducing efficiency. PV panels can function at lower temperatures by using a mounting system with fins, which raises their general efficiency and output. In hot climes or during times of maximum solar intensity, when PV panels are more susceptible to heat-related performance loss, this can be especially helpful. Lower working temperatures also help the panels last longer and be more reliable, which lengthens their lifespan and requires less maintenance.

i. Characterization of PV modules

A PV is characterized based on current voltage performance of a string of cells in the module. The current-voltage performance is characterized using an I-V curve and power curve as shown in Figure 1 the I-V curve and power curve are valid at a particular irradiance and cell temperature only. Understanding the IV curve characteristics helps in assessing and optimizing the performance of PV modules.

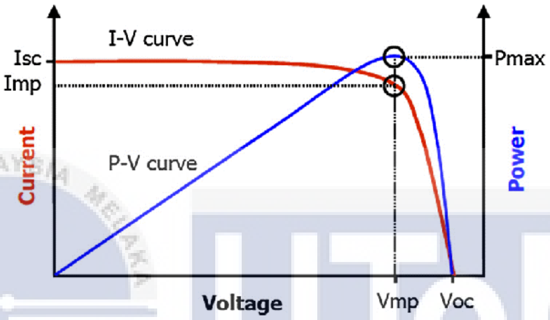


Figure 1.1 Characteristic of a PV module

There are four points on the I-V curve and power curve which are used characterize the electrical performance of the solar cell or PV module,

- P_{mp} is maximum power in W: It is the point on the curve where the product of current and voltage ($I \times V$) is at its highest, indicating the maximum power output the module can achieve.
- V_{oc} is open circuit voltage in V: It is the maximum voltage the module can generate when no current is flowing.
- V_{mp} is voltage at maximum power in V: Vmp refers to the voltage at which the PV module operates to achieve its maximum power output.
- I_{sc} is short circuit current in A: It is the maximum current the module can produce when the output terminals are shorted.
- I_{mp} is current at maximum power in A: Imp represents the current at which the PV module operates at its maximum power point. It is the current value at the MPP on the *IV* curve.

ii. Fill Factor

The fill factor is a measure of how effectively the module utilizes the available voltage and current. It is calculated as the ratio of the maximum power point (Pmax) to the product of Voc and Isc (FF = Pmax / (Voc × Isc)). A higher fill factor indicates a more efficient module.Fill Factor (FF) represent a measure of the “squareness” of the I-V curve is shown in Figure 2.

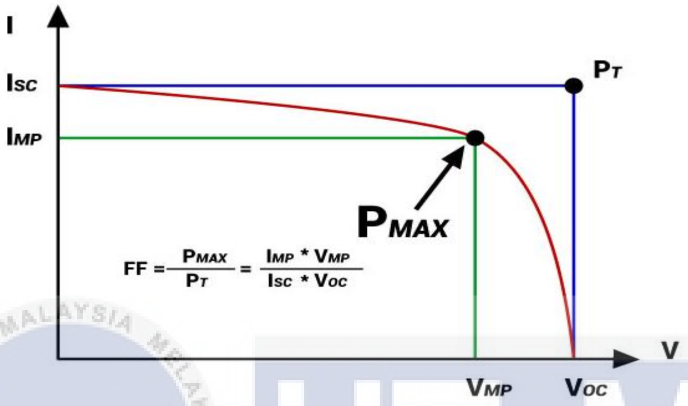


Figure 1.2 Illustration of FF of a PV module.

iii. Effect of irradiance

Irradiance, which refers to the intensity of sunlight, measured in W/m^2 has a significant effect on the *I-V* curve.The effect of irradiance on the *I-V* curve of a PV module is illustrated in Figure 3. As the irradiance level rises, the PV module's output current increases, causing the IV curve to shift upward along the current axis. This is because higher irradiance provides more photons, resulting in increased electron excitation and current flow.

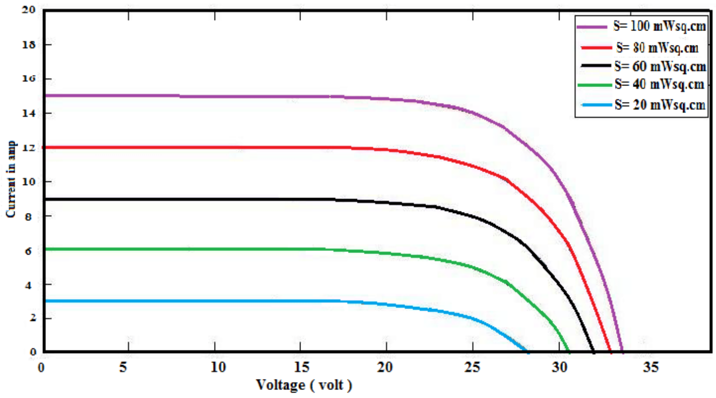


Figure 1.3 The I-V curve of a PV module at different levels of irradiance.

iv. Effect of temperature

Temperature has a significant impact on the IV curve of a photovoltaic (PV) module. As the temperature rises, the open-circuit voltage (Voc) of the module decreases due to the temperature dependence of the semiconductor material. The effect of temperature on the *I-V* curve of a PV module is shown in Figure 4. As a result, the IV curve shifts upward along the current axis. Conversely, as the temperature decreases, the Voc increases, while the output current decreases. Therefore, temperature variations have a significant impact on the performance and power output of PV modules, and it is crucial to consider temperature effects when designing and operating solar energy systems.

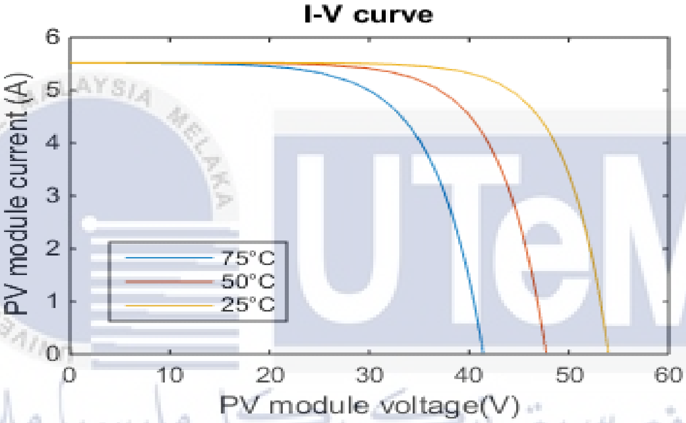


Figure 1.4 The I-V curve of a PV module at different levels of temperature.

1.2 Problem Statement

The problem is that high temperatures can have a severe impact on photovoltaic (PV) module performance, which can reduce the amount of electricity generated by solar panels. The output efficiency of photovoltaic modules can be reduced by 10–25% by heat, depending on where they are installed, during testing at a temperature of 25 ⁰C (STC). The solar panel's output current grows exponentially as its temperature rises, but its voltage output decreases linearly. This means that the efficiency of solar panels typically decreases by 0.3% to 0.5% for every degree Celsius over 25°C. Therefore, in order to optimize energy output, it is important to address the serious issue of the high temperature of PV modules.

1.3 Project Objective

There are two main objectives involved in this study. The following objectives are considered:

a) To design and fabricate a cooling system that integrates aluminum fins with the existing mounting structure of the PV panels. (PSM 1)

b) To conduct experimental testing and validation of the integrated PV cooling system. (PSM 2)

1.4 Scope of Project

The scope of this project are as follows:

a) This project involves design and fabrication of a PV cooling system that integrates aluminum fins with the existing mounting structure. It involves selecting suitable materials for the fin profiles, and determining the fin dimensions and arrangement. The design will consider factors such as structural integrity, ease of installation, and compatibility with different PV panel configurations.

b) Further, the development stage involves installing the fabricated fin structures on a PV panel module and subjecting it to real operating conditions. The performance of the proposed cooling system will be evaluated by monitoring the temperature reduction and assessing the impact on PV panel efficiency and energy output. This project scope aims to validate the effectiveness and reliability of the cooling system design, ensuring its practical applicability and potential for wider adoption in PV installations.

CHAPTER 2

LITERATURE REVIEW

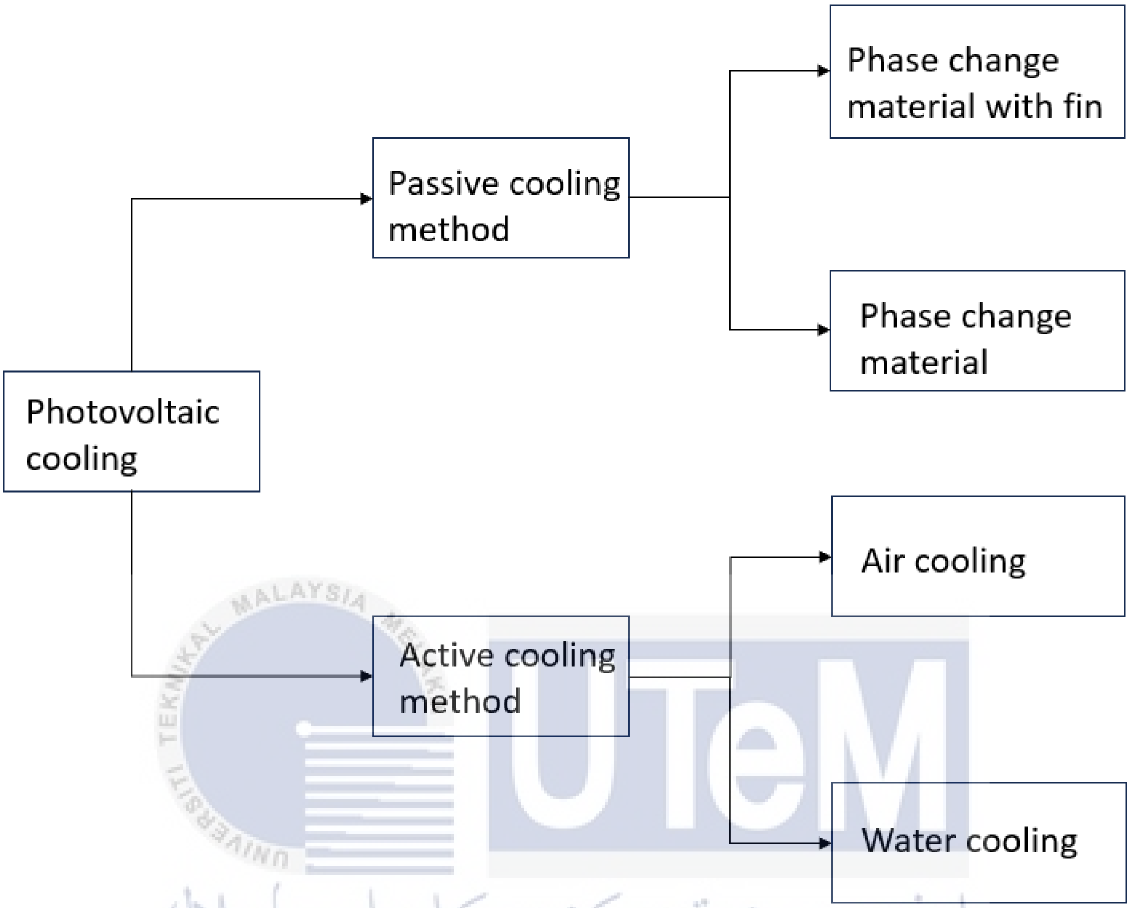
2.1 Introduction

The primary objective of this chapter is to comprehend the existing knowledge regarding the potential of photovoltaics (PV) in temperature reduction. Figure 5 illustrates a comprehensive summary of the key findings in the literature, highlighting their interconnectedness and contribution to advancing the field of knowledge, thus emphasizing the significance of the study. The initial aspect of the literature revolves around gaining an understanding of passive cooling methods, specifically focusing on the implementation of phase change materials (PCMs) in conjunction with fins and PCM technologies. The subsequent section of the literature concentrates on active cooling methods, examining relevant studies and their findings in this area.

2.2 Overview Of Existing Project System

A comprehensive examination of past project designs and implementations that are directly related to the system being studied. Over the years, numerous exceptional researchers have dedicated their time and expertise to uncovering the most efficient and effective methods for optimizing the cooling of photovoltaic (PV) systems, with the primary objective of reducing temperatures. By reviewing and analyzing these previous projects, we aim to build upon the wealth of knowledge that has been accumulated in this field, identifying successful strategies and valuable insights that can contribute to the development and implementation of an optimized cooling system for PV applications.

2.3 Understanding Photovoltaic Cooling Methods



2.4 Passive Cooling Method

2.4.1 PCM with fin

A.Abdulmunem et al.(2018) conducted a study to investigate numerically and experimentally the effect of using PCM with and without fins on the PV cell thermal performance. The author used aluminum[1] fins with PCM led to accelerate melting of PCM by 3.5 min at a depth of 2 cm and about 14 min at a depth of 3 cm compared with using PCM only. The aluminum fins inside the PCM led to good distribution of temperature inside the PCM. PCM with fins and without fins will shown as Figure 6 source by A.Abdulmunem et al (2018). Similar studied was conducted by W. Lu et al.(2018), but a numerical 3D model was developed to predict the temperature distribution of the PCM during the phase change process and the predicted results agreed well with the experimenta measurement. The research get 6 deg c temperature reduction with effiency 10%. PCM container was filled with 9.08kg of paraffin RT27-10% of the container volume remained empty to allow for material expansion during the process of phase transition. The researcher carriout out the simulation to installing horizontal and vertical aluminum fins with different thickness[2] as shown in Figure 7. It is to optimize the heat transfer between PV module and fins.

PCM without fins

PCM with fins

Figure 2.1 PCM with fin and PCM without fin

Source by A.Abdulmunem et al.(2018)

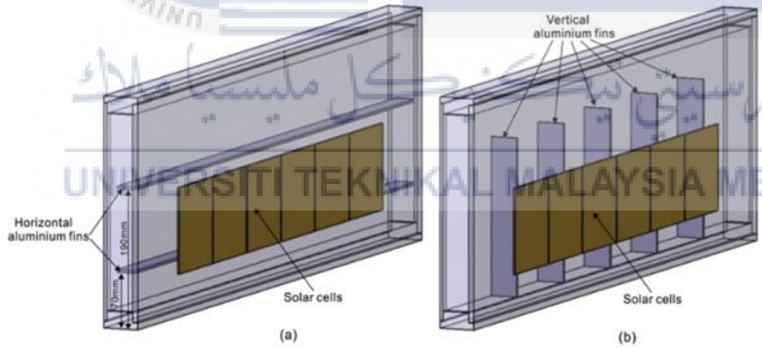


Figure 2.2 horizontal and vertical fins.

Using ANSYS to solve the equations, numerical research was done to determine the depth of the phase change material's container that would keep photovoltaic cooling in the necessary temperature range for varying daily solar radiation (S. Khanna et al (2018)). Verified based on an experimental investigation by Huang et al. The best fin length is the one that touches the bottom of the container. Fin thickness greater than 2 mm does not significantly increase performance[3]. Figure 8 will show PV system without PCM and Figure 9 will show PV with PCM system.

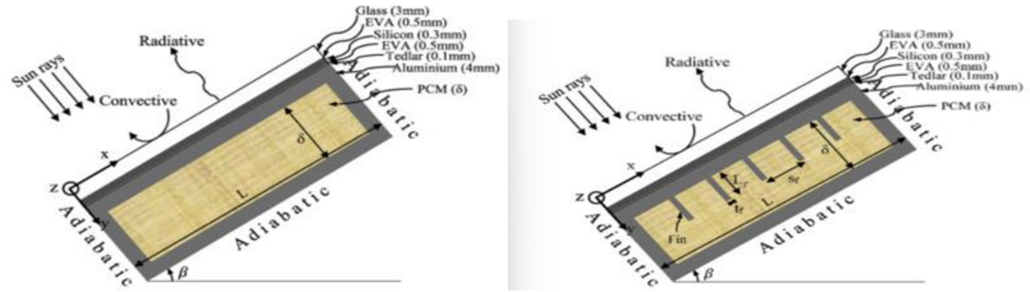


Figure 2.3 PV module with and without PCM system

Source by S. Khanna et al. (2018)

Lipping Tan et al. (2017) study Metallic fins were added to the PCM to speed up melting to improve the PCM's poor thermal conductivity. Similar with previous research or PCM with fins. The experiment was conducted for one hour under the average ambient temperature of 20 deg C, average wind speed of gm/s and average solar irradiance of 1000 w/m2[4]. The result as shown in Figure 10 and the experimental setup as shown in Figure 11

Figure 2.4 experimental setup

Source by Lippong Tan et al. (2017)

2.4.2 Comparison research about PCM with fin

Author	Temperature reduction (°C)	Type of Phase change material (PCM)
A.Abdulmunem et al.(2018)	-	Paraffin (m.p =45)
W. Lu et al. (2018)	6	RT27
S. Khanna et al. (2018)	-	RT25 HC
Lippong Tan et al. (2017)	15	Organic based paraffin wax (m.p = 27 °C

2.4.3 Phase Chane Material

(Yousef et al. 2022) has done a PV study using the PCM technique. The PV temperature drop was 11.9. PCM material is commercial PCM RT42. The place where the experiment is held is in Benha, Egypt and the monitor is for 5 minutes from 8am-4 pm.[5]. Experimental setup from (Yousef et al. (2022) as shown in Figure 12. In the same year, (Ejaz et al. 2022) used PCM type commercial PCM; PT58 and RT44. The location at Taxila, Pakistan and using PCM (PT58, RT44) + Aluminum metallic foam of 2 different thickness (8 and 12mm). The experiment was monitored by researchers every 30 minutes from 8am-4pm. PV temperature drop from these experiments was 9.03.[6]. Figure 13 as shown different image between aluminum foam having 8 mm thickness and aluminum foam having 12 mm thickness.

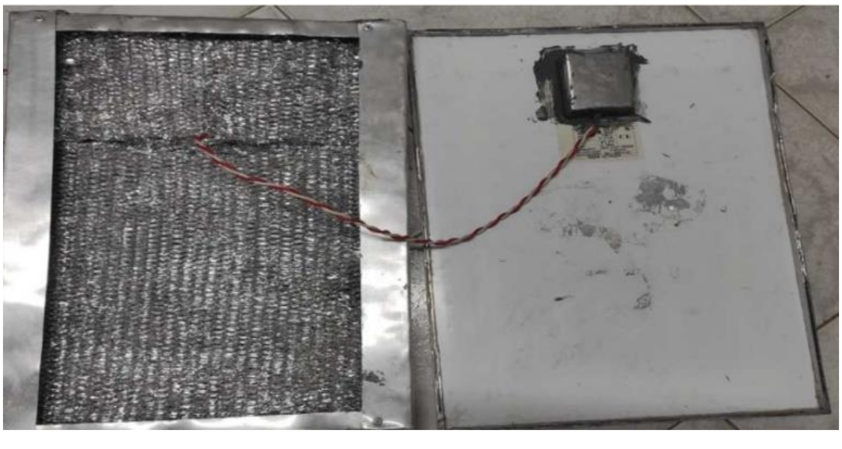


Figure 2.5 experimental setup by (Yousef et al 2022)

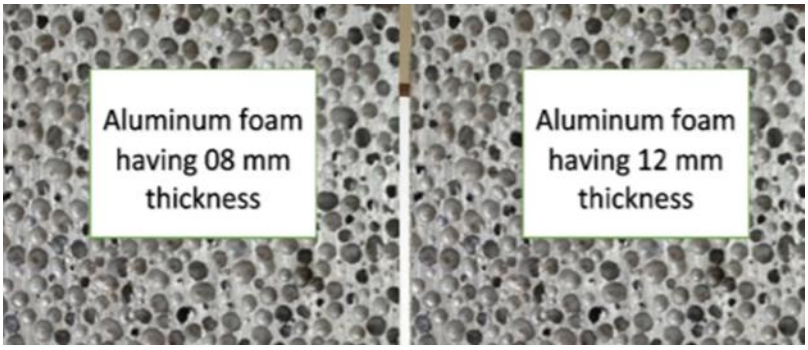


Figure 2.6 shows different thickness for aluminum foam.

(Amin et al. 2021) was conducted of PCM with temperature reduction 4.2 deg C. the material of PCM is salt hydrate PCM. This project used PCM and aluminum shaving. The water will flow into that area.[7] But it is not suitable for large scale PV. This project monitors from 9-5 pm. The location of the project at Tehran, Iran. In the same year, (Sandro Nizetic et al. 2021) used PCM material commercial PCM Rubitherm on phase change at 25 deg C. the temperature reduction only 1 deg C. the location of the research at Split, Croatia. This project used 2 different configurations of Al plate filled with 2 mm thickness of PCM, one with full PCM 1.38kg and other side with half PCM 0.73kg.[8]. The figure of this experiment as shown in Figure 14.

Figure 2.7 experimental setup by (Sandro Nizetic et al. 2021)

2.4.4 Comparison research about PCM

Author	PV temperature drop deg C	PCM material	PV module size
Yousef et al. (2022)	11.9	Commercial PCM RT42	Poly (20W)
Ejaz et al. (2022)	9.03	Commercial PCM : PT%* and RT44	Poly (10W)
Amin et al. (2021)	4.2	Salt hydrate PCM	Mono (25W)
Sandro Nizetic et al. (2021)	1.0	Commercial PCM Rubithern phase change at 25 deg C	Poly (10W)

2.5 Active Cooling Method

Active cooling is a technique for removing heat from a system or device by utilizing outside resources. It entails actively transferring heat away from the object or system to keep its temperature within a desired range using mechanical or electrical components. Electronics, industrial processes, and HVAC (heating, ventilation, and air conditioning) systems are just a few examples of the many areas where active cooling techniques are frequently used. There are several common active cooling methods.

2.5.1 Air-cooled

Air cooling techniques involve the use of fans or blowers to move air over the PV modules' surface. Convective heat transport is aided by this, and cooling is encouraged. Natural convection or induced convection utilizing fans are two ways to cool the air. Compared to water-based systems, it is a more straightforward and affordable cooling technique. A researcher named (Y. Amanlou et al. 2018) once studied active cooling for PV systems in 2018. Y. Amanlou used 12VDC Fan and made a ducting to Fresnel reflector on mounted at 35.7 equal to latitude of Tehran.[9]. Experimental setup as shown in figure 15. In the same year, (S. Golzari et al 2018) used 44 AC FANS and corona wind effect realized through anode/cathode electrodes- mounted on 35 ^{0} according to Tehran climate. The aims for this project for observe effect of corona discharge on thermal performance of PVT.[10] The limitation of this project is highest voltage supply required to establish corona discharge. Figure 16 as shown the project setup by S. Golzari.

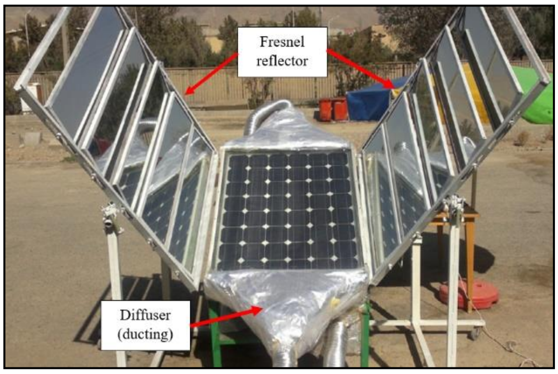


Figure 2.8 Experimental setup by (Y. Amanlou et al. 2018)

Figure 2.9 experimental setup of active air-cooled method

Source by (S. Golzari et al. 2018)

An experiment active air cooling conducted by Shrivastava et al. 2022) to identify optimal arrangement of forced cooling enhancements such as baffles and fins.[11] The project's proposed setup does not require higher fan power due to fin/baffles as shown in figure 17. While (A.H. Shirav et al. 2022) study active air cooled to study effects of both air blowing and emitted radiation are investigated experimentally in the ranges of 7.7 km/h and 360e840 W/mm2.[12]. The results prove that the impact of cooling the module on electrical efficiency strongly depends on the level of irradiation intensity. The operation of this project will show as figure 18.

Figure 2.10 experimental setup

Source by (A. Shrivastava et al. 2022)

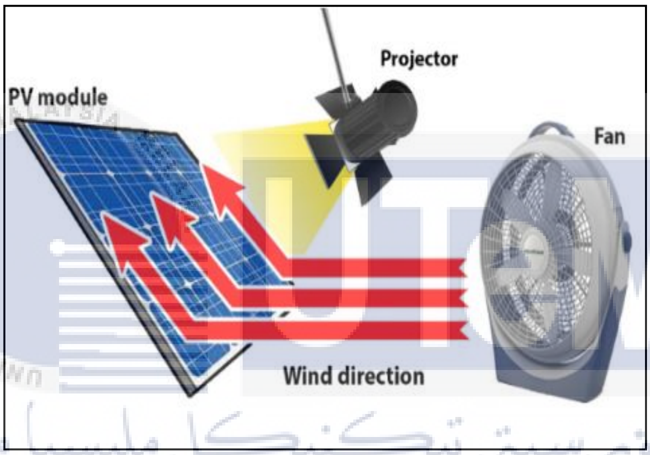


Figure 2.11 operation of project active air cooled

Source by (A. H. Shirav et al. 2022)

2.5.2 Water cooled

By flowing water along the surface of photovoltaic (PV) panels, the active water cooling of PV modules approach lowers the temperature of the panels. This cooling technique's main goal is to raise the PV system's overall effectiveness and performance. (Talebnejad et al. 2022) study of water-cooling system for PV module. The aims of the research are to enhance the PV efficiency and increase the productivity of the conventional RO system.[13] Figure 19 as shown experimental setup of this project. (B. Alberto et al. 2021) also research about active water cooling. The aims of this project are to study different nozzles numbers (2, 6, 9) and its position[14] as shown in Figure 20.

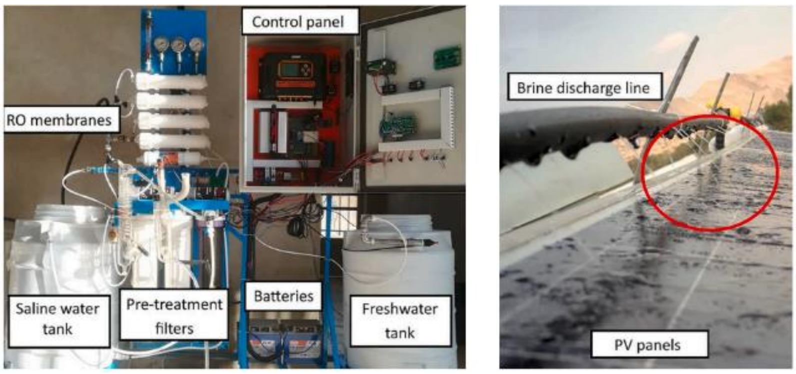


Figure 2.12 experimental setup by (Talebnejad et al. 2022)

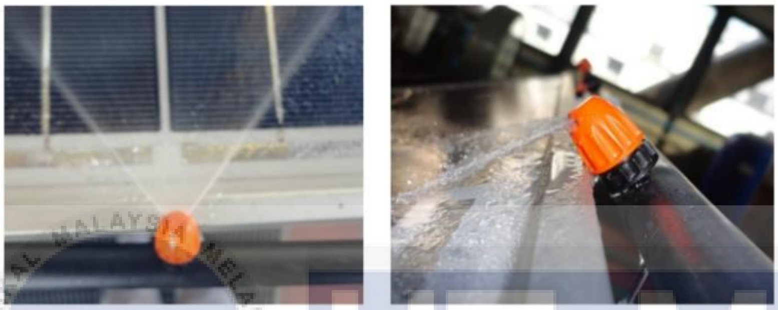


Figure 2.13 different position of nozzles

2.6 Summary

The literature analysis emphasizes the growing need for PV modules that have cooling fins to improve their performance and efficiency. The results imply that different cooling strategies can successfully lower the operating temperature of PV modules, improving power output and system dependability. To address issues with system complexity, cost effectiveness, and long-term performance evaluation, however, more research is required. The optimization tactics suggested in the literature study offer insightful information for upcoming research in this field, assisting in the creation of more effective and environmentally friendly solar energy systems. For my research, I chose PCM with fin for the mounting structure. This method is to ensure that the temperature on the PV module can be transferred from the module to the fin. so, the temperature on the surface of the module will decrease and will increase the power on the PV module. The angle on the mounting structure can also be changed to provide the right angle for some places. The material for the fin and mounting structure is aluminum because aluminum can transfer heat from one place to another.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter focuses on a methodical approach to execute the project. The overall project methodologies are separated into two parts. The first part is conducted through PSM 1, while the second part is carried out in PSM 2.

3.2 Selecting And Evaluating Materials For Stability And Functionality Mounting Structure

The methods and technologies that will be used to gather and analyze data from PV modules must be carefully chosen and evaluated when building and implementing a mounting structure project with an emphasis on sustainability. This requires a variety of methodological considerations, including evaluating the durability and dependability of cooling fin and materials on mounting structures and taking the projects' effects on the environment into consideration. Additionally, a variety of strategies can be employed to support these methodological concerns, such as conducting field tests to compare the temperature reduction between PV on mounting structures with cooling fins and PV on mounting structures without cooling fins. Researchers and practitioners can make sure that their initiatives are efficient, sustainable, and influential by carefully choosing and analyzing tools/materials for a mounting structure and Fin.

3.3 Methodology

Several strategies will be used in this project to meet the goals, including reading materials and the creation of mounting structures with cooling fins to lower the temperature of PV modules. The project is created in stages, starting with a search for the project title, followed by the identification of the problem statements, objectives, project scope, literature search, hardware, and data collecting. In this section, all the applied techniques, tools, and hardware used for this project are described. Figure 21 shows the overall project flowchart.

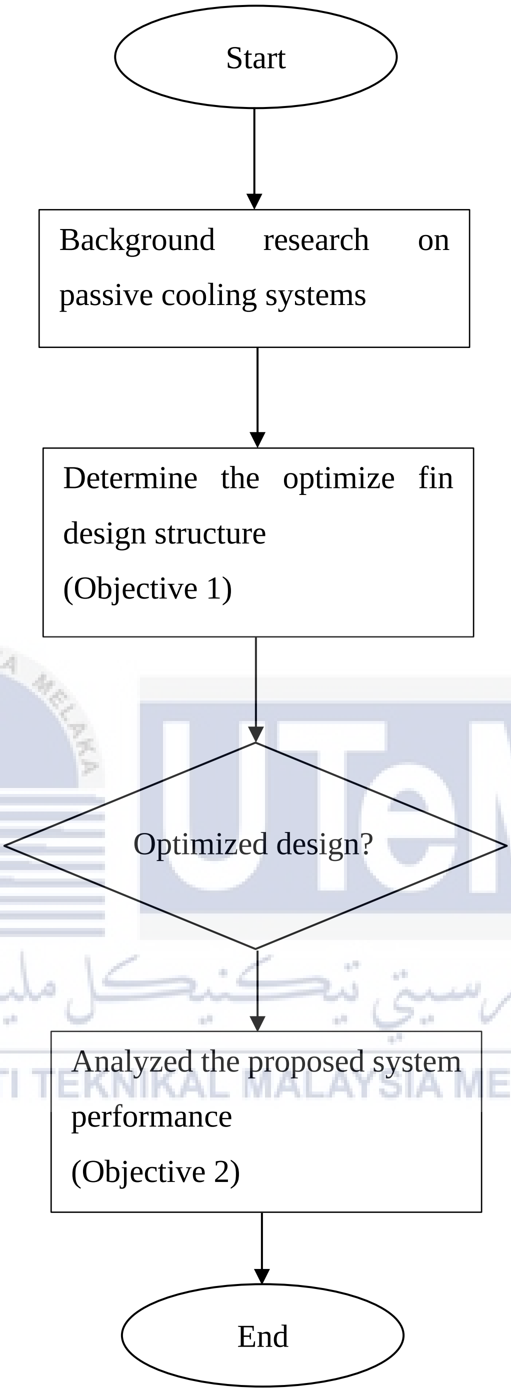


Figure 21 The overall project flowchart

3.4 The Development Of Pv And Integrated Mounting Structure With Fin.

The selection of PV modules, the manufacturing of fin material, and the choice of thermally conductive adhesive are the essential components of the creation of PV and Integrated

Mounting Structure with Fin. Various fin materials are chosen from the published literature based on their working conditions to ensure the materials can survive adverse environmental effects. The flowchart in Figure 22 shows a process to build a mounting structure with fin.

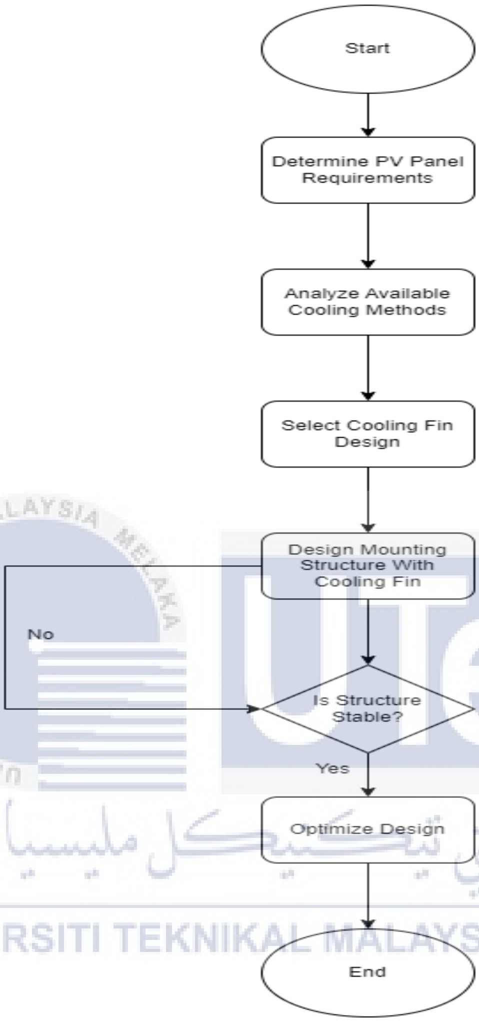


Figure 22 Process flow chart for the prototype development

3.4.1 Selection of Photovoltaic Module (PV)

The overall PV module efficiency drops by 0.3-0.5% for every 1 °C over the Standard Test Condition temperature (STC) (Alami, 2014; Karthikeyan et al., 2020a). Many solutions, such PCM with a fin attached to the mounting structure, are used to reduce this loss in hot climates. However, many cooling approached reported in the literature were tested on small capacity of PV module, as summarized in table 1

Table 1 Hghlights recently tested PV technologies

Authors	Technology	Capacity (W)	Electrical efficiency (%)
(Yousef et al. 2022)	Si-Poly	20	11.9
(Ejaz et al. 2022)	Si-poly	10	11.5
(Hernandez-perez et al. 2021)	Si Poly	15	11.9
(Hooshmandzade et al. 2021)	Si-Poly	35	15.0
(Sandro Nižetić et al. 2021)	Si-Poly	20	11.9
(Shastry & Arunachala 2020)	Si-Poly	20	11.5
(Salem et al. 2019)	Si-Poly	50	13.5
(Grubišić-Čabo et al. 2018)	Si-poly	50	13.8

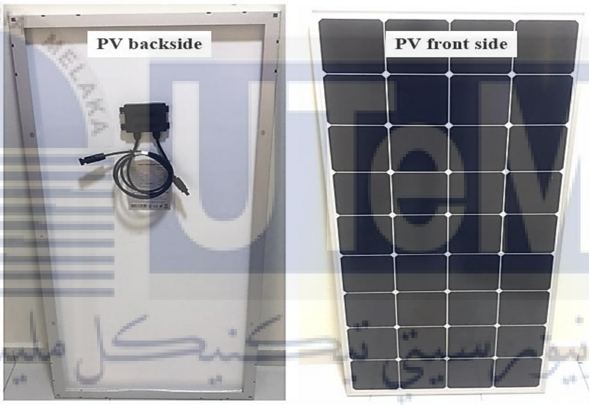


Figure 23 shown the PV module 120Wp monocrystalline silicon.

As shown in Figure 23, the testing scale used in this investigation uses a 120Wp monocrystalline silicon module. Table 2 provides a description of the module specifications.

Table 2 technical specification of the tested PV module

Parameters	Value
Maximum power at STC (P_{max})	120 W
Open-circuit voltage (Voc)	24.64 V
Short-circuit current (I_{sc})	6.21 A
Maximum operating voltage (V_{mp})	20.88 V

Maximum operating current (I_{mp})	5.75 A
Operating temperature	-40 ºC to +85 ºC
Power temperature coefficient (γ)	-0.35 % / ºC
Voltage temperature coefficient (β)	-0.27 % / ºC
Current temperature coefficient (α)	0.05 % / ºC
Module dimensions (mm)	540 x 1190 x 35
Module efficiency	22.6 %
Weight	18.0 kg

3.4.2 Integrated Fin Material Selection

The most common integrated fin materials are aluminum alloys subdivided into wrought aluminum alloy and cast aluminium alloy. Another significant factor affecting cooling performance is the arrangement of the pin fins. Copper and aluminium are frequently utilised as fin materials in heat sink cooling applications. However, the comparative examination of raw materials and alloys still receives a lesser amount of attention.

Conductivity, price, and availability are taken considerations while choosing materials. Aluminium, beryllium, copper, gold, lithium, magnesium, nickel, silver, titanium, tungsten, 356 alloys, 6061 alloys, and 7075 alloys were the materials chosen for the analysis. Finding the ideal heat sink design that can satisfy the performance and cost requirements at the same time is one of the main reasons for this study. In order to ensure that the total mass of materials required in the heat sink design does not change, a comparison analysis for a set of specified materials is carried out for an airfoil fin configuration. Table 4 presents the findings for the materials that were chosen.

Table 3 Material characteristics

Material	Dissipated Power (W)	Pressure Lose (Pa)
Silver	37.33	18.52
Copper	37.27	18.52
Gold	37.03	18.52
Aluminium	36.68	18.52

7075 alloy	36.44	18.52
Berylium	36.34	18.52
356 alloy	36.32	18.52
Tungsten	36.15	18.51
6061 alloy	36.02	18.51
Magnesium	35.98	18.51
Nickel	34.60	18.51
Lithium	34.46	18.51
Titanium	28.67	18.53

Table 3.7's findings show that the pressure loss values are about equivalent to one another and that all values are less than 20 Pa, which is designated as the upper limit for PC cooling applications. Silver exhibits the best performance in terms of heat dissipation. However, when cost is considered, 356 Alloys and aluminium are preferred over other materials.

3.4.3 Determination of Fin Geometry

Different analyses are performed in the COMSOL environment to establish the fin geometry of the proposed heat sink model. Five distinct fin configurations pin-square, rectangular, airfoil, pin-hexagonal, and pin-circular were chosen as candidates for the analysis. Figure 24 shows type of fin Geometry.

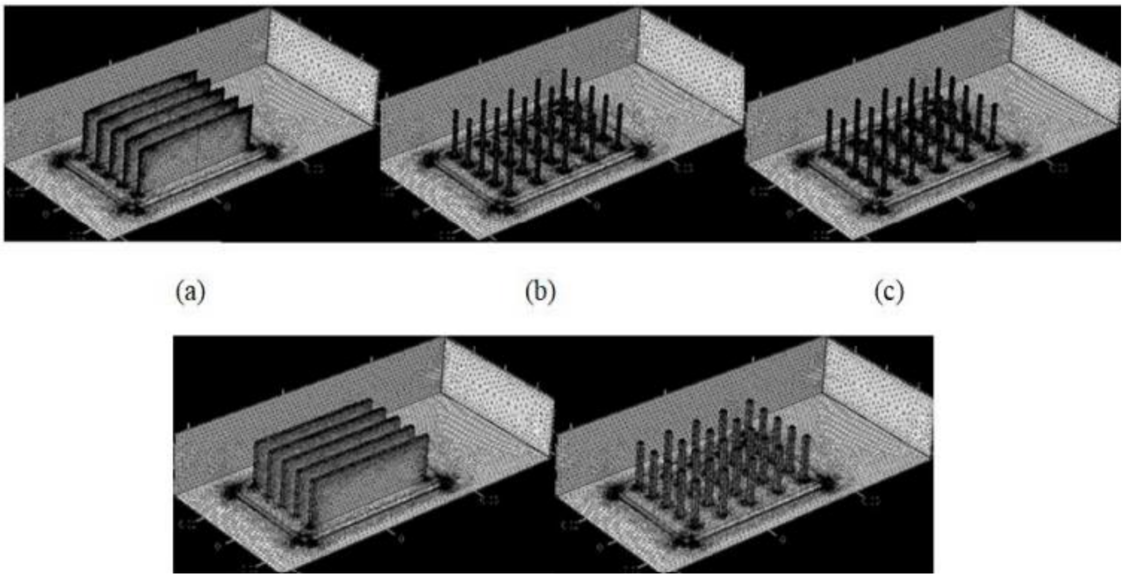


Figure 24 type of Fin Geometry

3.4.4 Thermal Interface Material (TIM)

The mounting structure's attachment of the heatsinks is the fabrication's most crucially vital feature. When the PV module is attached to the mounting structure with a fin, it always has a small amount of micro-roughness and is never completely smooth. Only at isolated places with voids in between can two surfaces make physical touch with one another. Therefore, it can be fixed by enhancing the heat flow by filling the air spaces with a thermal interface material. By filling in the air spaces, the thermal interface material in Figure 25 improves heat flow.

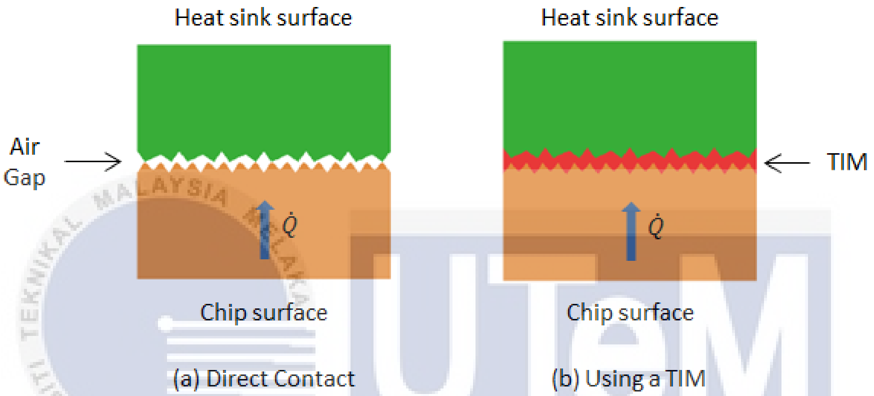


Figure 25 Thermal Interface Material

3.5 Development Of Experimental Setup

The experiment setup consists of two identical PV module, placed side by side. The data will be recorded using weather monitoring unit. The data acquisition includes temperature and irradiance profiles.

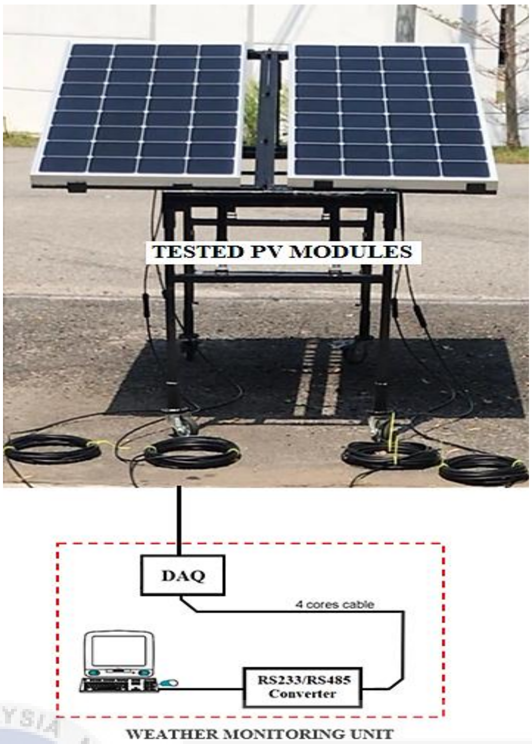
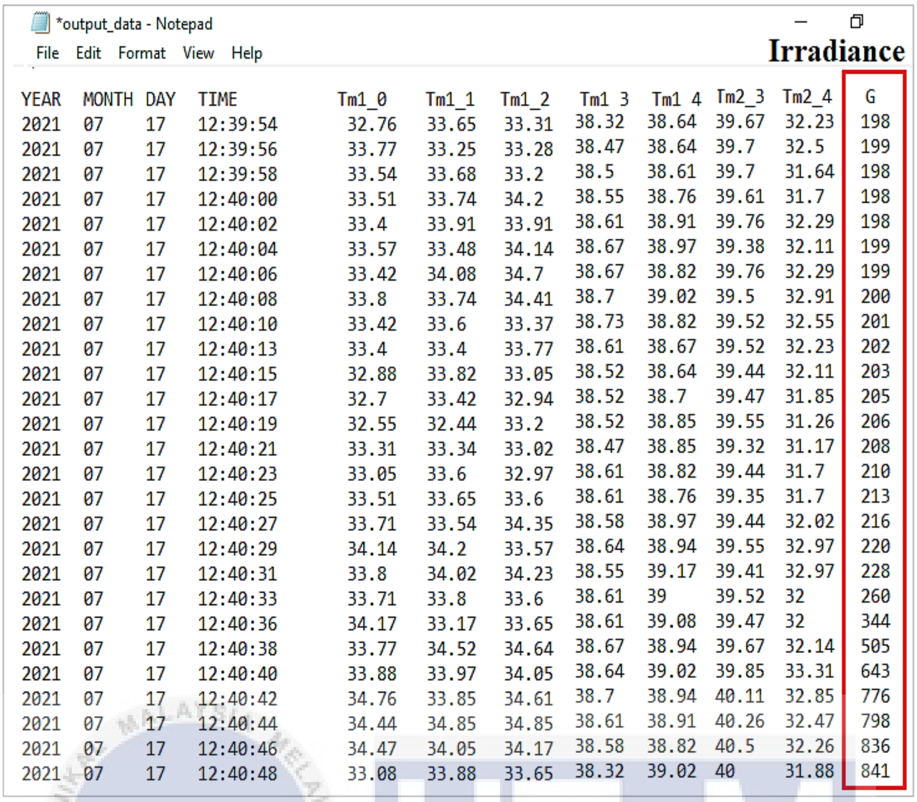


Figure 26 tested PV module without Integrated Mounting Structure with Fin

3.5.1 Solar Irradiance Measurement

Thermopile-based equipment (pyranometers) or calibrated PV reference cells can be used to measure the irradiance. However, their responses to the incoming radiation were inverse, and their relative uncertainties for the pyranometer and the PV reference cell were +/-5% and +/-2.4% (Dunn et al. 2012). Researchers came to the conclusion that the PV reference cell offers superior irradiance measurements as a result. The voltage across a resistor serves as the foundation for the PV reference cell's basic operation. It produces a current that is influenced by the distribution of photons. As shown in table 5 depicts a sample of data that was recorded at the test site.



```
YEAR  MONTH DAY  TIME         Tm1_0    Tm1_1   Tm1_2   Tm1 3  Tm1 4  Tm2_3  Tm2_4   G
2021  07    17   12:39:54      32.76   33.65   33.31  38.32  38.64  39.67  32.23  198
2021  07    17   12:39:56      33.77   33.25   33.28  38.47  38.64  39.7   32.5   199
2021  07    17   12:39:58      33.54   33.68   33.2   38.5   38.61  39.7   31.64  198
2021  07    17   12:40:00      33.51   33.74   34.2   38.55  38.76  39.61  31.7   198
2021  07    17   12:40:02      33.4    33.91   33.91  38.61  38.91  39.76  32.29  198
2021  07    17   12:40:04      33.57   33.48   34.14  38.67  38.97  39.38  32.11  199
2021  07    17   12:40:06      33.42   34.08   34.7   38.67  38.82  39.76  32.29  199
2021  07    17   12:40:08      33.8    33.74   34.41  38.7   39.02  39.5   32.91  200
2021  07    17   12:40:10      33.42   33.6    33.37  38.73  38.82  39.52  32.55  201
2021  07    17   12:40:13      33.4    33.4    33.77  38.61  38.67  39.52  32.23  202
2021  07    17   12:40:15      32.88   33.82   33.05  38.52  38.64  39.44  32.11  203
2021  07    17   12:40:17      32.7    33.42   32.94  38.52  38.7   39.47  31.85  205
2021  07    17   12:40:19      32.55   32.44   33.2   38.52  38.85  39.55  31.26  206
2021  07    17   12:40:21      33.31   33.34   33.02  38.47  38.85  39.32  31.17  208
2021  07    17   12:40:23      33.05   33.6    32.97  38.61  38.82  39.44  31.7   210
2021  07    17   12:40:25      33.51   33.65   33.6   38.61  38.76  39.35  31.7   213
2021  07    17   12:40:27      33.71   33.54   34.35  38.58  38.97  39.44  32.02  216
2021  07    17   12:40:29      34.14   34.2    33.57  38.64  38.94  39.55  32.97  220
2021  07    17   12:40:31      33.8    34.02   34.23  38.55  39.17  39.41  32.97  228
2021  07    17   12:40:33      33.71   33.8    33.6   38.61  39     39.52  32     260
2021  07    17   12:40:36      34.17   33.17   33.65  38.61  39.08  39.47  32     344
2021  07    17   12:40:38      33.77   34.52   34.64  38.67  38.94  39.67  32.14  505
2021  07    17   12:40:40      33.88   33.97   34.05  38.64  39.02  39.85  33.31  643
2021  07    17   12:40:42      34.76   33.85   34.61  38.7   38.94  40.11  32.85  776
2021  07    17   12:40:44      34.44   34.85   34.85  38.61  38.91  40.26  32.47  798
2021  07    17   12:40:46      34.47   34.05   34.17  38.58  38.82  40.5   32.26  836
2021  07    17   12:40:48      33.08   33.88   33.65  38.32  39.02  40     31.88  841
```

Table 4 Sample of data that was recorded at the test site

3.5.2 Temperature Measurement

Many factors, including solar radiation, air temperature, wind direction and speed, panel material composition, and mounting structure, affect the operating temperature of PV panels. A typical commercial PV panel converts between 13 and 20 percent of the sun's energy into electricity, with the other portion becoming heat. It has been well established that the working temperature of PV panels has an impact on their output efficiency with higher temperatures resulting in a reduction in the quantity of electricity available. Figure 27 a typical error in temperature measurements is the positioning of thermocouples at the front side of PV modules. It is important to ensure the thermocouples are not placed directly on the solar cell to avoid shading.

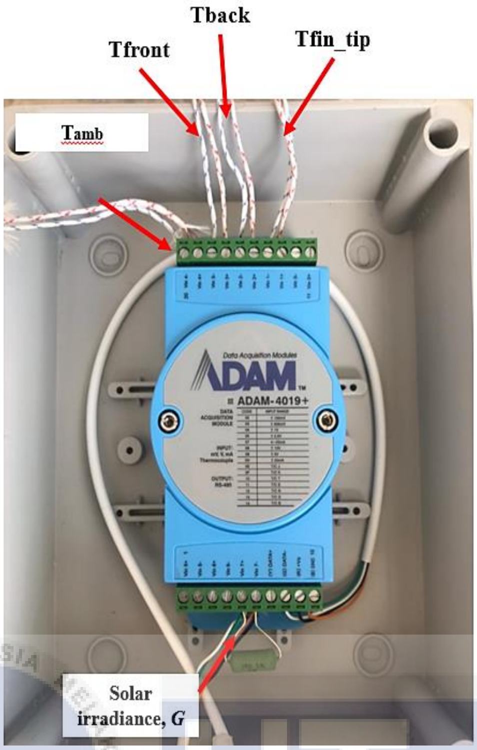


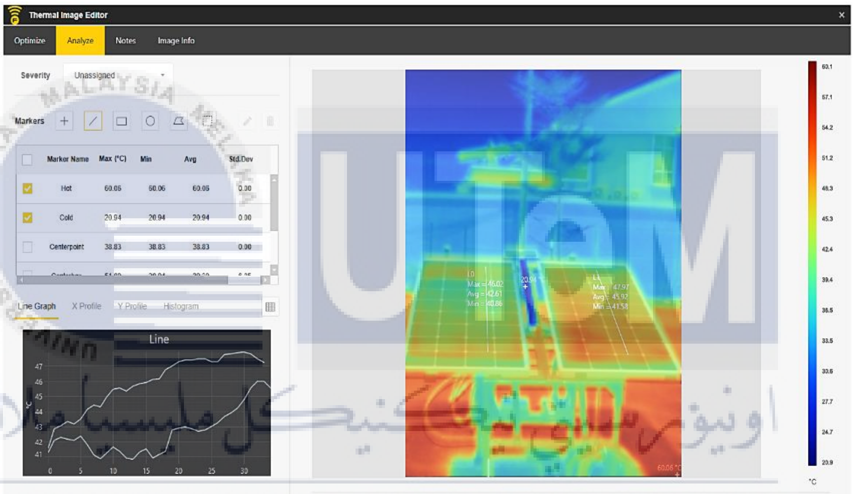
Figure 27 The temperature sensors used is K-type thermocouple

Figure 28 shows a flowchart for analyzing a suitable mounting structure with cooling fins for heat dissipation of PV module.

3.5.3 Infrared Thermal Imager

An infrared camera, also called a thermal imager, detects and quantifies an object's infrared energy. The camera transforms the infrared data into an electronic image that displays the measured object's apparent surface temperature. Figure 29. can easily spot and record hotspots using the image-capture technology. The FLUKE Connect Software can be used to further investigate the captured images, as seen in Figure 30.

Figure 29 Infrared Thermal Imager



☐	Marker Name	Max (°C)	Min	Avg	Std.Dev
☑	Hot	60.06	60.06	60.06	0.00
☑	Cold	20.94	20.94	20.94	0.00
☐	Centerpoint	38.83	38.83	38.83	0.00

Figure 30 Results from Infrared Thermal Imager

3.5.4 Sustainable development

Solar power takes the A practical source of clean and environmentally beneficial renewable energy is a PV system. The use of solar energy presents several options for addressing global issues like climate change, energy consumption, and environmental degradation. Solar technology creates an active sustainable future for many generations by utilising the power of the sun. It is a fantastic advancement that will help everyone live in a better future by utilising solar energy to its fullest capacity. The project's mounting system was designed to work with solar energy's enhancing benefits. Because it boosts solar PV efficiency, this project also benefits solar energy.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter summarizes the expected result based on the analysis of the output of this project. The expected result will focus on two parts which are the temperature reduction on PV module and the power efficiency on the PV module. The preliminary result is based on the theories applied and hardware on the frame mounting structure with cooling fin.

4.2 Preliminary Results and Analysis

The integrated mounting structure with Fin is proposed to reduce temperature from PV module and release unnecessary heat to airflow. The preliminary mounting structure has been built using aluminum material. The mounting structure has been built to get a preliminary result of power efficiency and reading of temperature on PV module.

In this hardware, the length and width of every reading were recorded. Every size of mounting structure was needed because the space, thickness, and area of fin at mounting structure influence the dissipation of heat. Figure 31 shows the preliminary frame of mounting structure without fin and figure 32 preliminary mounting structure with frame.

Figure 4.1 Frame Mounting Structure without Fins

Figure 4.2 Frame mounting Structure with Fins

4.2.1 The Influence Of Varying Fin Spacing On The Pv Module Temperature

Determining how closely spaced or widely spread fins are for a certain issue is a frequent query in the fin heat sink design. According to Kraus et al. (2001), tightly packed fins will have more surface area for heat transfer but more thermal resistance. This is so because the amount of heat dissipated by a heatsink is directly inversely proportional to the area that is wetted. Reviewing the pertinent literature shows that, even though much research has considered various fin spacings, they are still mostly restricted to experimental evaluations. Table 6 lists the ideal fin spacing that has been discovered in earlier research.

Table 5 The optimum fin spacing for passive cooling in recent literature.

Authors	**Optimum fin spacing, *s* (mm)**	**Type of study**
[24] Idoko	31.2	Experimental
[25] Bayrak	20.0	Experimental
[26] Arifin	30.0	Experimental
[27] Hernandez-Perez	20.0	Experimental
[28] Hasan	10.0	Experimental
[29] Elbreki	30.0	Experimental
[30] Johnston	15.0	Experimental &numerical

[31] Waleed Hammad	10.0	Experimental
[32] Raina	5.5	Experimental

Therefore, a parametric study was carried out to investigate the effects of fin spacing on the temperature and thermal resistance of PV modules. Fin spacing was 50mm for which the numerical modelling was done.

4.2.2 The Influence Of Varying Fin Height On The Pv Module Temperature

Table 7 shows the highlight optimum fin heights reported by recent literature.

Table 6 Highlights Highlights the optimum

fin heights reported by recent literature.

Authors	Optimum fin height, *h* (mm)	Fins geometry
(Idoko et al. 2018)	100	Rectangular
(Bayrak et al. 2019)	40	Staggered-Rectangular
(Arifin et al. 2020)	30	Perforated-Rectangular
(Hernandez-perez et al. 2020)	40	Staggered-Rectangular
(Hasan & Farhan 2020)	25	Rectangular
(Elbreki et al. 2020)	100	Lapping
(Johnston et al. 2021)	180	Rectangular
(Waleed Hammad et al. 2021)	25	U-shape-Rectangular
(Raina et al. 2022)	20	Rectangular

In this study, the effect of variable fin heights impacted by natural convection was taken into consideration. The primary and secondary multi-level fin height variants were quantitatively examined.

4.3 PV Module Specification

Figure 4.3 illustration for front and back side of PV module

Geometric Parameter	Value	Unit
Maximum Power (Pmax)	150	WP
Voltage at Pmax (Vmp)	18	V
Current at Pmax (Imp)	8.33	A
Open-circuit voltage (Voc)	21.6	V
Short-circuit current (Isc)	9.16	A

4.4 Solar Irradiance and Ambient Temperature Measurements

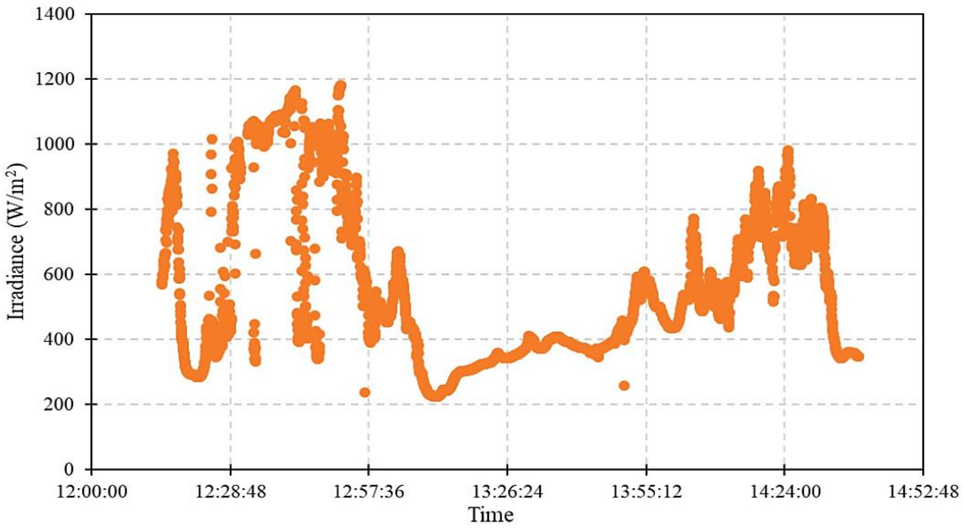


Figure 4.4 The irradiance profile during measurement

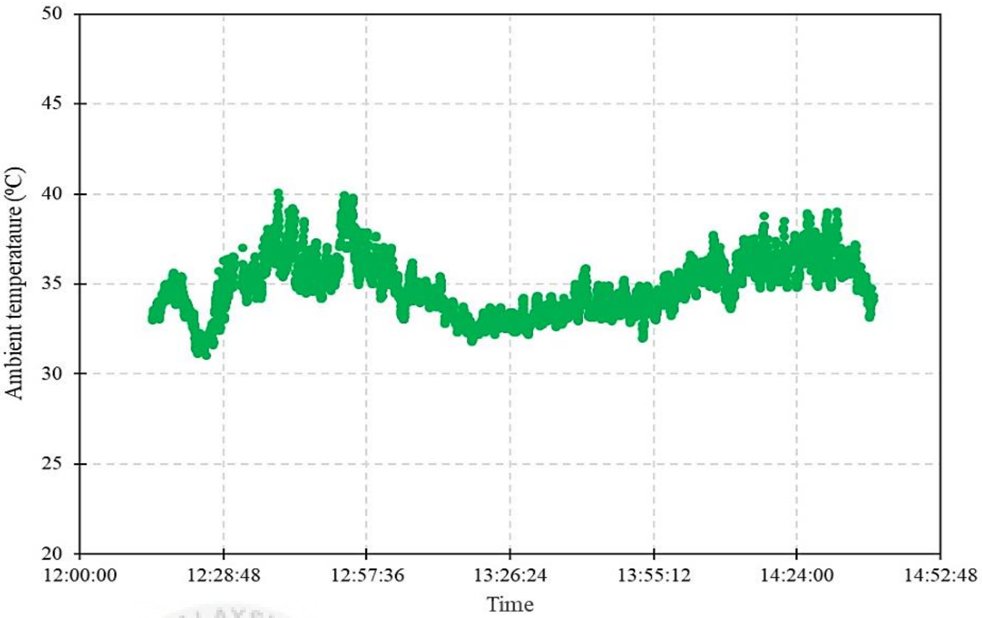


Figure 4.5 The ambient temperature recorded during measurement

Irradiance is a measure of the solar power incident on a surface per unit area. In the context of PV modules, it specifically refers to the amount of sunlight energy that reaches the solar cells. Based on figure 4.4 and figure 4.5 show irradiance and ambient temperature against time. At noon, when the irradiance reaches its peak value of 1000-1200W/m2, the elevated ambient temperature results in an increased temperature of the PV module. The rise in temperature adversely affects the power output of the PV module, as power is inversely proportional to temperature according to the temperature coefficient specified for the module. Consequently, the module's efficiency decreases, contributing to a lower actual power output compared to its rated power output at Standard Test Conditions (STC).

4.5 PV Temperature Profiling Via Infrared Thermal Imager

Figure 4.6 references of PV temperature

Figure 4.7 PV module with cooling fin

The disparity between the PV module reference model and the PV module with the fin model is quantified through measurement. In Figure 4.6, the reference PV temperature serves as a benchmark for models equipped with cooling fins. Figure 4.7 depicts the framework of the fin integrated into the mounting structure, providing an observational perspective of the temperature module differential. This measurement employs a Infrared Thermal Imager device to detect and quantify the temperature variations present on the PV module under investigation

4.6 PV temperature difference between reference PV module and PV module with cooling fin

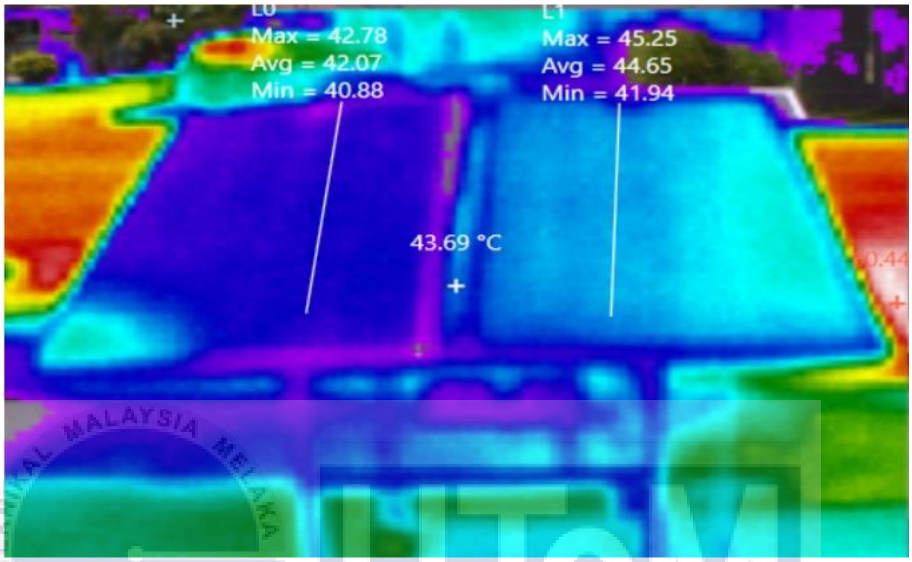


Figure 4.8 image using thermal imager

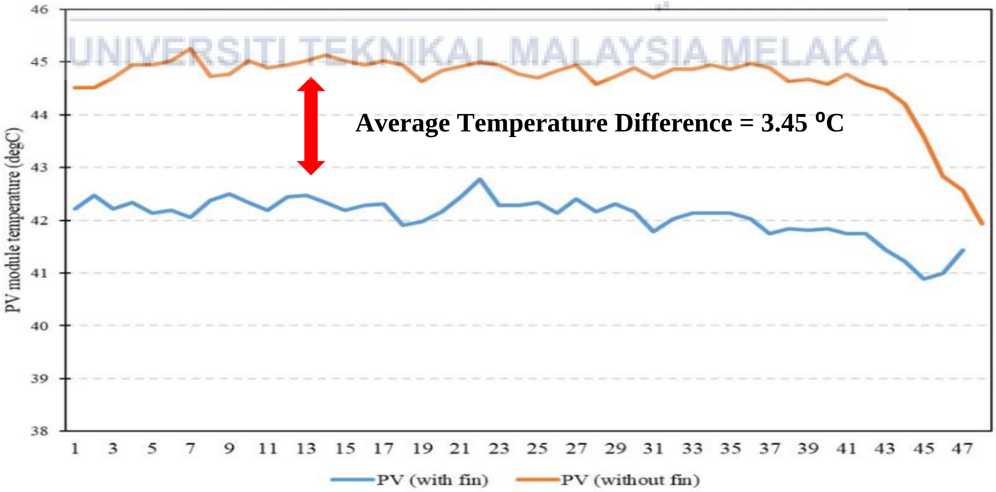


Figure 4.9 PV module temperature against time

4.7 Difference IV-Curve Between Reference PV Module and PV Module With Cooling Fin

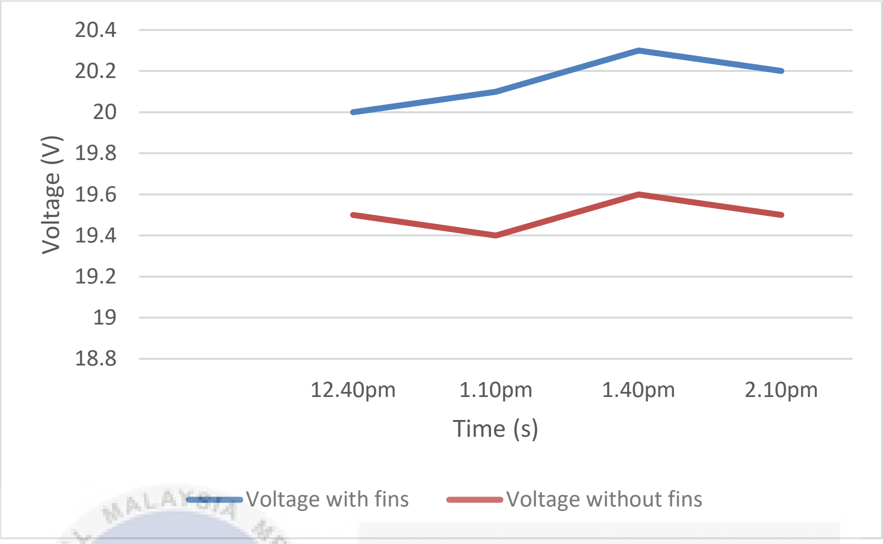


Figure 4.10 the voltage performance between reference PV and PV module with cooling fin

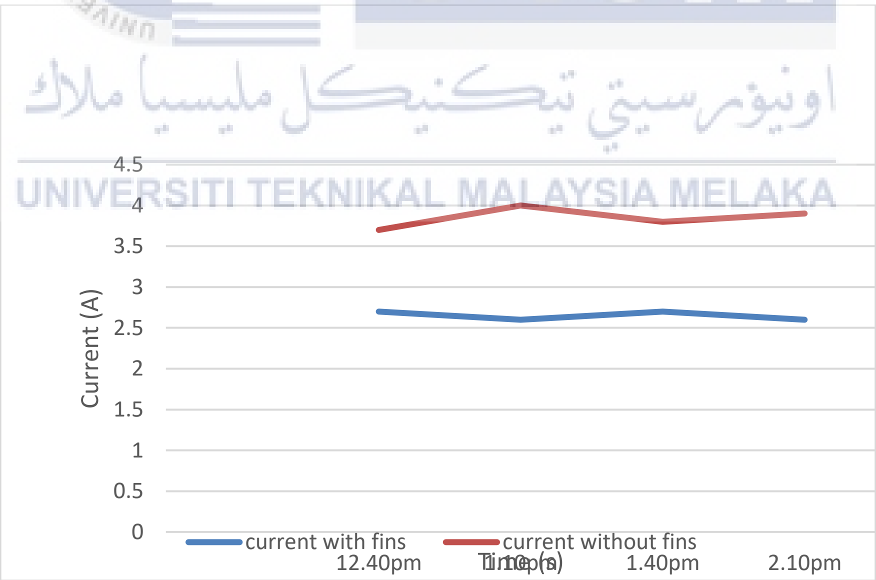


Figure 4.11 the current performance between reference PV and PV module with cooling fin

The different of two graph illustrates voltage and current variations over time under two distinct conditions, namely the reference PV module and the PV module equipped with a cooling fin. In Figure 4.10, it is evident that the voltage of the PV module with the cooling fin lower than that of the reference PV module, implying a discernible impact of temperature on PV module efficiency. In Figure 4.11, the current-versus-time plot reveals that the current in the reference PV module exceeds that in the PV module with the cooling fin. This observation can be attributed to the inverse relationship between voltage and current.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The objective of this research is to introduce a novel approach for estimating the Design and Development of an Integrated Mounting Structure with Fins to achieve temperature reduction. The proposed methodology is not only effective but also resilient, as it yields favorable outcomes by relying on reasonably accurate information and minimal network measurement data. The system is divided into two primary components: the PV module and the Integrated Mounting Structure with Fins. The key function of the fins integrated into the mounting structure is to facilitate the dissipation of excess heat from the PV module into the surrounding airflow. By reducing the temperature of the PV module, the overall power efficiency is enhanced, enabling optimal power generation from the PV module.

5.2 Recommendations

Mitigating temperature is imperative for enhancing power efficiency in photovoltaic (PV) modules. Various recommendations warrant consideration to augment the efficiency of the PV module. Primarily, affixing aluminum tape to the fin, ensuring attachment to the PV module body, facilitates the heat transfer process between the module and the fin. Direct contact facilitates effective heat dissipation, leading to a subsequent reduction in module temperature. The resultant decrease in temperature correlates with an increase in power efficiency.

Furthermore, optimizing the surface area of the fin is integral for enhancing heat transfer from the PV module to the cooling fin. An expansive surface area accelerates the heat transfer process, thereby inducing a significant reduction in module temperature and positively influencing the overall power efficiency. This recommendation aims to render the fin-mounted structure more efficient and suitable for prospective applications.

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