Design and Development of Cooling Device for a Solar Photovoltaic Panel

A DESIGN AND FABRICATION PROJECT REPORT

Submitted by

ADITHYA HARI	**191002005**
ADYANTH MANU	**191002006**
ASHWIN PRABHU	**191002024**
BHAVISH ATHREYA K	**191002028**

in partial fulfillment for the award of degree of

BACHELOR OF ENGINEERING
in
MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Sri Sivasubramaniya Nadar College of Engineering

(An Autonomous Institution, Affiliated to Anna University)

Rajiv Gandhi Salai (OMR), Kalavakkam – 603 110

MAY 2022

Sri Sivasubramaniya Nadar College of Engineering

(An Autonomous Institution, Affiliated to Anna University)

BONAFIDE CERTIFICATE

Certified that this Report titled **"Design and Development of Cooling Device for a Solar Photovoltaic Panel"** is the bonafide work of **ADITHYA HARI (191002005), ADYANTH MANU (191002006), ASHWIN PRABHU (191002024), BHAVISH ATHREYA K (191002028)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

Signature of the HOD
Dr. K.S.Vijay Sekar
Professor and Head
Department of Mechanical Engineering
SSN College of Engineering
Kalvakkam – 603 110

Signature of the Supervisor
Dr. N. Lakshmi Narasimhan
Associate Professor
Department of Mechanical Engineering
SSN College of Engineering
Kalavakkam – 603 110

Submitted for project viva-voce examination held on....................

EXTERNAL EXAMINER

INTERNAL EXAMINER

ACKNOWLEDGEMENT

We are grateful to our Principal **Dr. V. E. Annamalai** for providing us a constructive environment for carrying out our project.

We sincerely thank our Head of the Department, **Dr. K. S. Vijay Sekar** for giving us permission to carry out our Design and Fabrication Project.

We would like to express our gratitude to our guide **Dr.N. Lakshmi Narasimhan** for his valuable guidance and support throughout the period of this project work.

We would also like to thank our project coordinator **Dr. B. Anand Ronald** and **Dr. C. Arun Prakash** for their valuable suggestions in carrying out the project work.

Table of Contents

ABSTRACT

The inevitable growth of solar panel systems depicts the importance of improving its efficiency. The incident solar radiation on Photo Voltaic (PV) panel is partially converted into power, which means other gets converted into heat energy. Since the rise in temperature of PV panel has a negative effect on efficiency, several cooling methods were proposed by researchers so far. Among all the proposals, PV panel with Phase Changing Material (PCM) provides maximum power by reducing the operating temperature of the panel. The low thermal conductivity nature of PCM makes use of thermal enhancers. Researchers found several such Thermal Conductivity Enhancers (TCE) for PCMs. The proposed work focuses on a novel technique for enhancing the efficiency of the solar PV panel with the PCM and the aluminium casing as TCE. This approach has been experimented naturally under direct sun rays for two hours and observed results are attached. The experiment has been conducted using two 5 W panels, and the results of the PV-PCM entrenched with aluminium panel is compared with naturally ventilated panel without PCM and aluminium.

LIST OF FIGURES

LIST OF TABLES AND GRAPHS

LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

PV	-	PhotoVoltaic
TCE	-	Thermal Conductivity Enhancer
PCM	-	Phase Change Material
P_{max}	-	Maximum Power
V_{OC}	-	Open Circuit Voltage
I_{SC}	-	Short Circuit Current
V_m	-	Maximum Power Voltage
I_m	-	Maximum Power Current
V	-	Volts
A	-	Ampere
η	-	Efficiency

CHAPTER 1

INTRODUCTION

PhotoVoltaic (PV) cells are semiconductor materials which convert the solar radiations into electric current. Generally, PV modules have a conversion efficiency of 5%−20%. Therefore, the efficiency of the PV panel depends on the type of solar cells, the weather condition, the temperature of the cell, etc. Only some solar rays falling on the panel are converted into power, and the other few rays are dissipated as heat. Thus, increase in temperature of solar cells causes a decrease in efficiency and damages the panel. The rate of decrease in efficiency ranges from 0.25% to 0.5% per degree Celsius depending on the type of PV material. Therefore, several cooling techniques under active cooling methods and passive cooling methods were proposed. Active methods involve the use of electrical energy to reduce heat. Passive methods are mostly used in industrial applications, which reduce the temperature of solar panel by natural conduction/convection like water passive methods, air passive methods and so on. The main advantages of passive methods over active methods are that, they do not consume energy and they require only less maintenance.

CHAPTER 2

SOLAR PANEL WITH PCM AND ALUMINIUM

A solar cell (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light. Individual solar cells can be combined to form modules commonly known as solar panels.

2.1 Working Principle of Solar Cell

When light reaches the p-n junction, the light photons can easily enter in the junction, through very thin p-type layer. The light energy, in the form of photons, supplies sufficient energy to the junction to create a number of electron-hole pairs. The incident light breaks the thermal equilibrium condition of the junction. The free electrons in the depletion region can quickly come to the n-type side of the junction.

Similarly, the holes in the depletion can quickly come to the p-type side of the junction. Once, the newly created free electrons come to the n-type side, cannot further cross the junction because of barrier potential of the junction.

Similarly, the newly created holes once come to the p-type side cannot further cross the junction became of same barrier potential of the junction. As the concentration of electrons becomes higher in one side, i.e., n-type side of the junction and concentration of holes becomes more in another side, i.e., the p-type side of the junction, the p-n junction will behave like a small battery cell. A voltage is set up which is known as photo voltage. If we connect a small load across the junction, there will be a tiny current flowing through it.

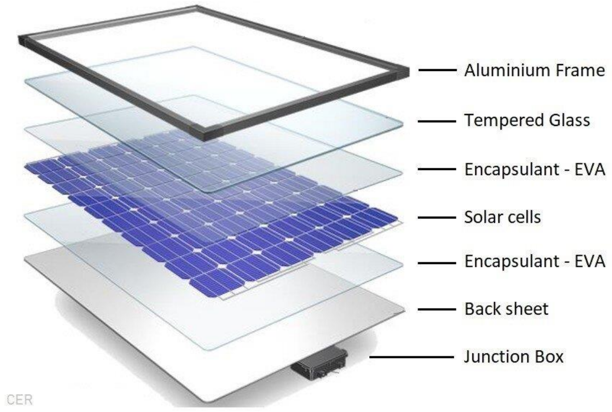


Fig 2.1 PV panel

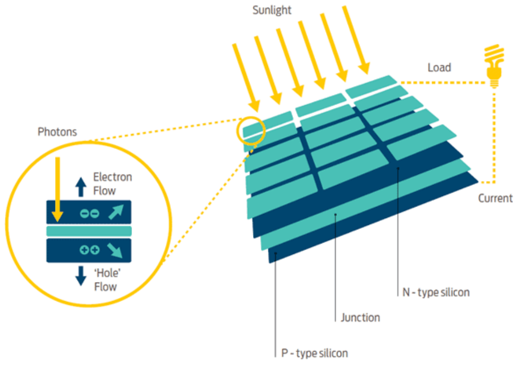


Fig 2.2 Working of PV panel

2.1.1 Specification of the PV panel

Brand	:	WaaRee
Number of cells	:	72
Dimension (in mm)	:	290 x 185 x 22

Solar Cell Type	Poly-Crystalline Silicon
Maximum Power [P_{max}]	5.0 W
Open circuit Volt [V_{OC}]	21.02 V
Short circuit Current [I_{SC}]	0.32 A
Maximum Power Voltage [V_m]	17.00 V
Maximum Power Current [I_m]	0.30 A
Maximum System Voltage	600 V

Table 2.1 Specification of the PV panel

2.2 Phase Change Material (PCM)

Phase Changing Materials (PCM) come under conductive passive cooling techniques. PCM is a material with large heat of fusion and sharp melting point. PCM acts as latent heat storage as it can absorb or release heat when it changes from solid-liquid phase and vice versa.

2.2.1 Types of PCM

There are three types of PCMs such as,

1) Organic PCM - materials are paraffin and non-paraffin
2) Inorganic PCM - materials are hydrated salts
3) Eutectic PCM - material are combination of two or more materials

2.2.2 PCM selection criteria

Choice of material should have the following properties,

1) High latent fusion heat
2) High thermal conductivity
3) Non-toxic elements
4) Non-corrosive elements
5) Minimal sub cooling elements and chemically stable properties

Paraffin is the most commonly used material in electronic thermal management which has above properties.

2.2.3 Limitation of PCM

Although PCM has a high latent heat of fusion per unit volume, organic PCMs have low thermal conductivity. In order to augment this lower thermal conductivity, a high thermal conductivity material should be added to improve heat transfer.

2.2.4 Characteristic of the selected PCM

Type: RT42 Organic PCM (RT - RUBITHERM) (Refer Fig 2.4)

Melting Point	38 - 43 °C
Congealing Point	43 - 37 °C
Heat storage Capacity	165 kJ/kg
Specific heat capacity	2 kJ/kgK
Density (as a solid)	0.88 kg/l
Density (as a liquid)	0.76 kg/l
Maximum Operating Temperature	72 °C

Table 2.2 Characteristic of RT42 organic PCM

2.2.5 Thermal Conductivity Enhancer

Aluminium is chosen as the Thermal Conductivity Enhancer (TCE) for the PCM RT42 because their cheap price, conductivity (239 W/mK) and abundancy. This Aluminium is made into a box type arrangement in order to contain the PCM from sheet metal form.

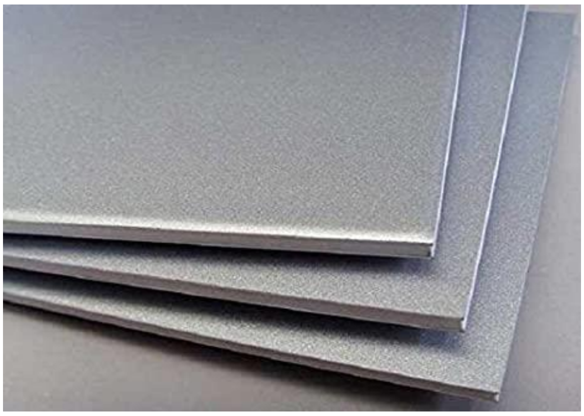


Fig 2.3 Aluminium sheet

Fig 2.4 RT42 PCM

CHAPTER 3

DESIGN CALCULATIONS

1. Dimensions of the panel: 290 x 185 x 22 (mm)

2. Dimensions of the PCM Al framework: 253 x 146 x 14 (mm)

   Volume: Part - A: 253 x 146 x 14 = 5.1508 x 10^-4 m^3

   Part - B: 50 x 50 x 13 = 3.25 x10^-5 m^3

   Net Volume = A - B = 4.8258 x 10^-4 m^3

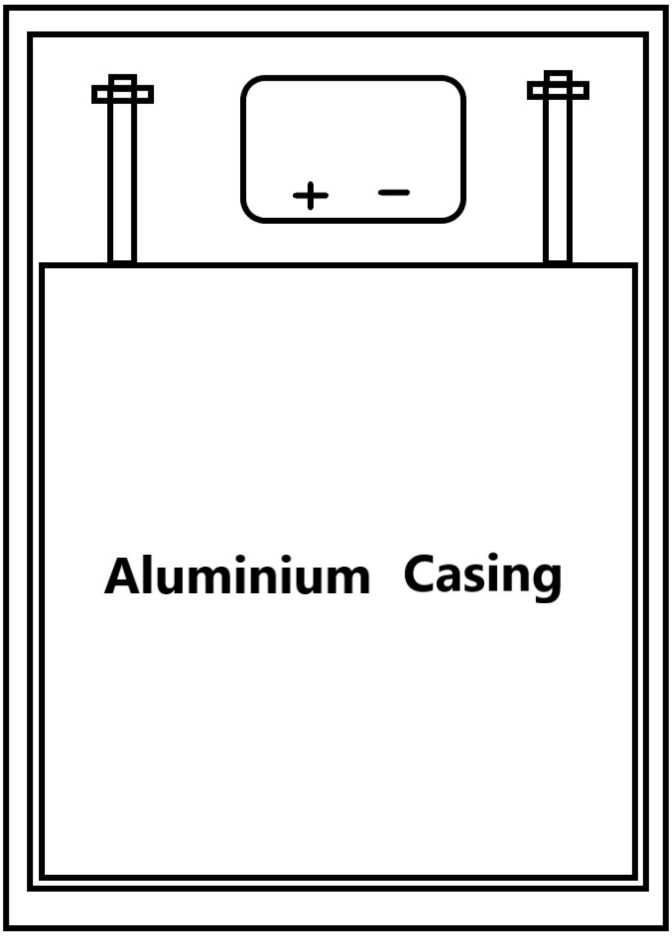


Fig 3.1 Sketch of Aluminium casing

3. Volume of PCM to be filled = 4.8258×10^{-4} m^3

Density of PCM = 0.88×10^3 Kg/m^3

4. Mass of PCM = $4.8258 \times 10^{-4} \times 0.88 \times 10^3$ = 0.4246 Kg

Approximately, the mass of PCM enclosed will be 0.5 Kg

5. Fill factor, $FF = V_m I_m / V_{OC} I_{SC}$

6. Maximum Power, $P_{max} = V_m I_m = (FF) V_{OC} I_{SC}$ (Watts)

7. Efficiency, $\eta = V_m I_m / E A$ (%)

CHAPTER 4

3D MODELLING

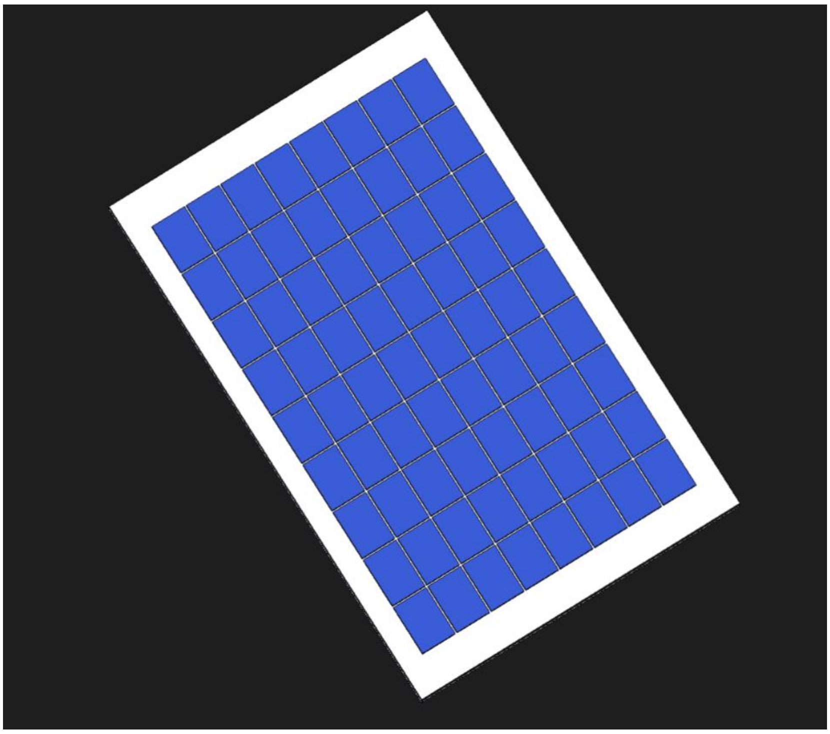


Fig 4.1 Silicon Solar Cells - 8 x 9 - 72 Cells

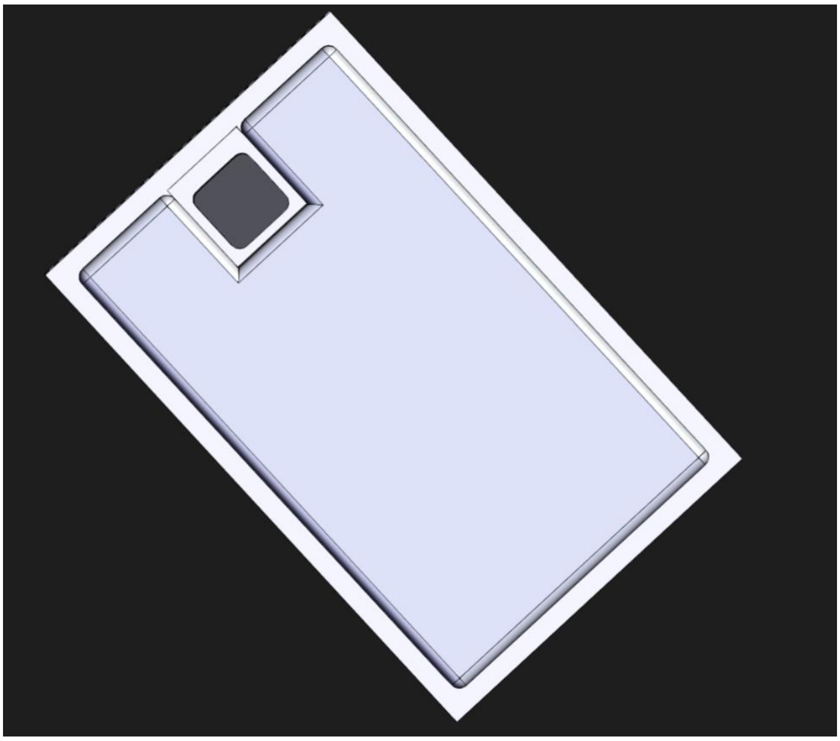


Fig 4.2 PCM Framework made with Aluminium

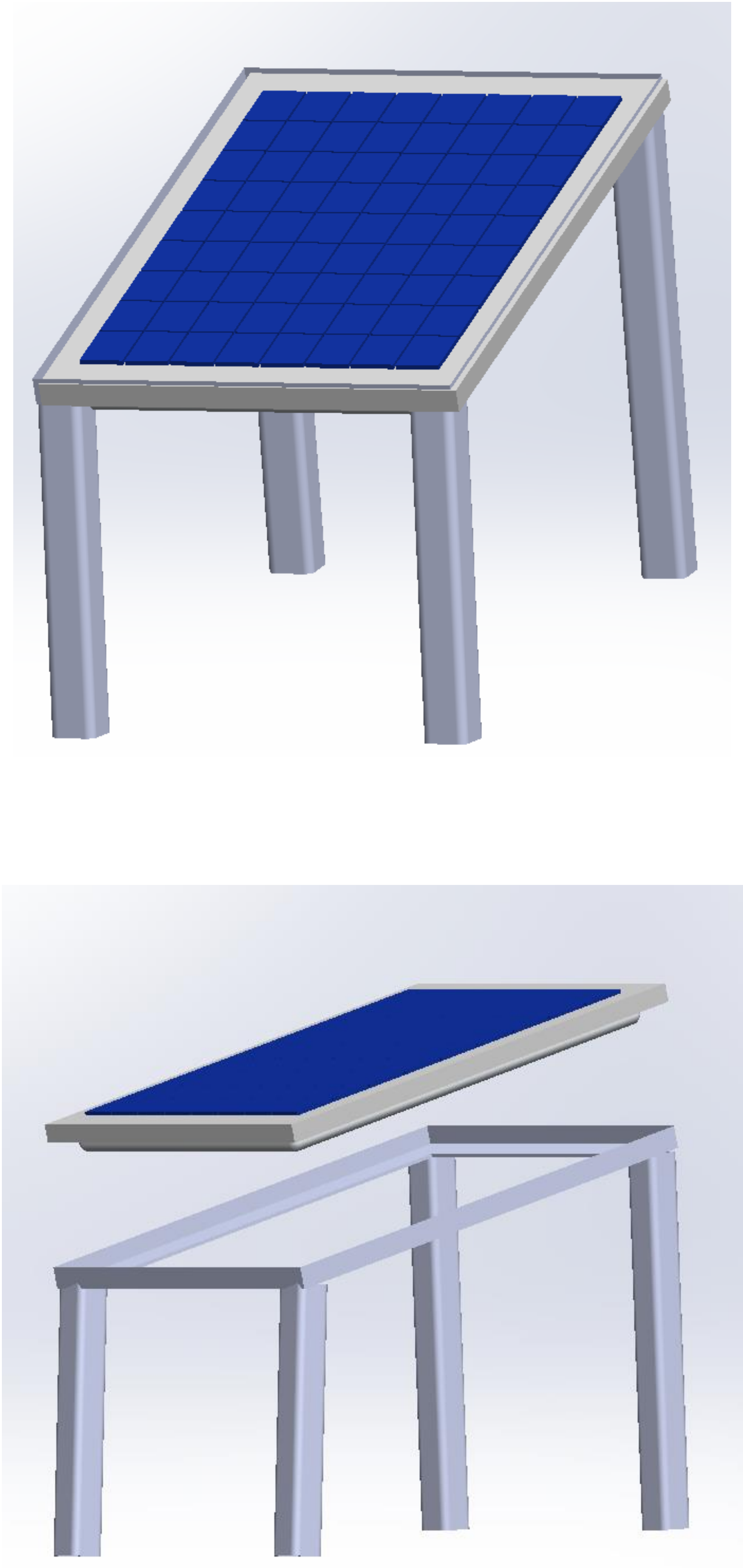


Fig 4.3 (a) and (b) Stand for the Solar Panel made with Mild Steel and welded together with 5W panels placed on top.

CHAPTER 5

FABRICATION

5.1 PCM CASING

5.1.1 Material

Aluminium was used for the fabrication of the PCM casing. Aluminium by nature is light in weight, has good heat conducting properties and cheap in cost.

The thickness of the aluminum sheet used is 2mm.

5.1.2 FABRICATION PROCESSES

5.1.2.1 Cutting

The aluminium sheet metal was cut to the required dimensions using an industrial sheet cutting machine.

	Dimensions in mm
Length	180
Breadth	140
Height	20

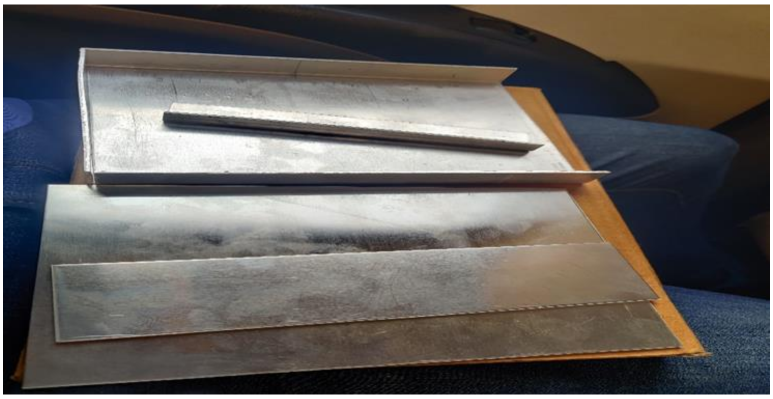


Fig 5.1 Aluminium sheet cut to required dimensions

5.1.2.2 Welding

The aluminium sheets were welded together by DC TIG welding. Tungsten Inert Gas (TIG) welding, also known as Gas Tungsten Arc Welding (GTAW) is an arc welding process that produces the weld with a non-consumable tungsten electrode.

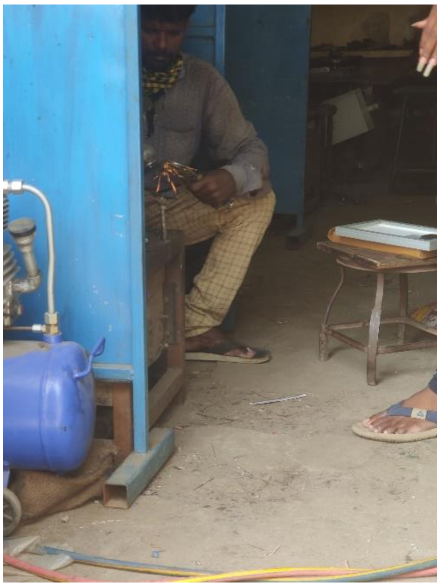
(a)

(b)

Fig 5.2 (a) Welding of PCM casing, (b) welding machine used

5.1.2.3 Grinding

The welded product was grinded to smooth the welds and the edges.



(a)

(b)

(c)

Fig 5.3 (a) and (b) Grinding to ensure smooth edges, (c) Finished PCM casing

5.2 PV PANEL STAND

5.2.1 Material

Mild steel (MS) L-angle - 1x1” cross section with 4 mm thickness

Fig 5.4 L-ANGLE MS steel

5.2.2 FABRICATION PROCESSES

5.2.2.1 Cutting

The MS steel was cut to the required dimensions.

5.1.2.2 Welding

The MS steel was welded using ARC welding. Arc welding is a type of welding process where an electric arc is used to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using alternating (AC) currents.

Fig 5.5 Solar Panel Stand with Angle Adjustment Support

5.1.2.2 Grinding

The edges were grinded to enhance safety.

CHAPTER 6

EXPERIMENT ANALYSIS AND RESULT

6.1 Experiment Methodology

The experiment consists of two solar panels of same ratings and size. The ratings of the solar PV panel is about 12 V and 5 W panel manufactured by WaaRee Pvt. Ltd. . Refer Table 2.1 for the panel specification.

Between the two panels, one panel is neither filled with PCM nor fixed with aluminium case at rear side, where as the other panel is filled by the cooling material PCM of 0.5 Kg, enclosed with the aluminium casing. The thickness of the aluminium is very small in the range of millimetres. The two panels are placed on the stand very near to each other in such a way that the solar radiation incident on both the panel are almost the same. The stand is inclined at an angle of 60° throughout the experiment. The output from the both the panel is fetched through wires which are connected to a Rheostat and multimeters. The current is measured through one multimeter by connecting it in series and the voltage is measured through another multimeter which is connected in parallel to it.

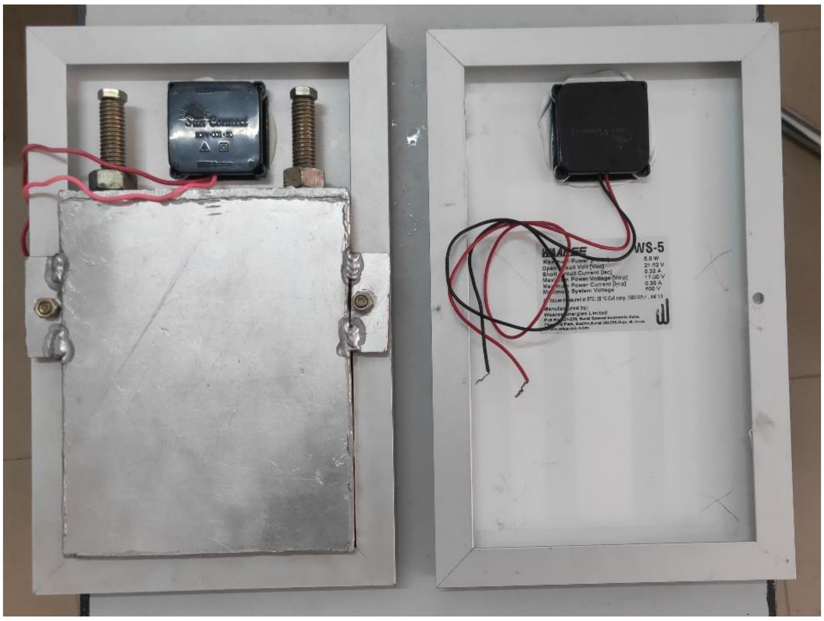


Fig 6.1 Solar panel with (left) and without (right) PCM casing

(a)

(b)

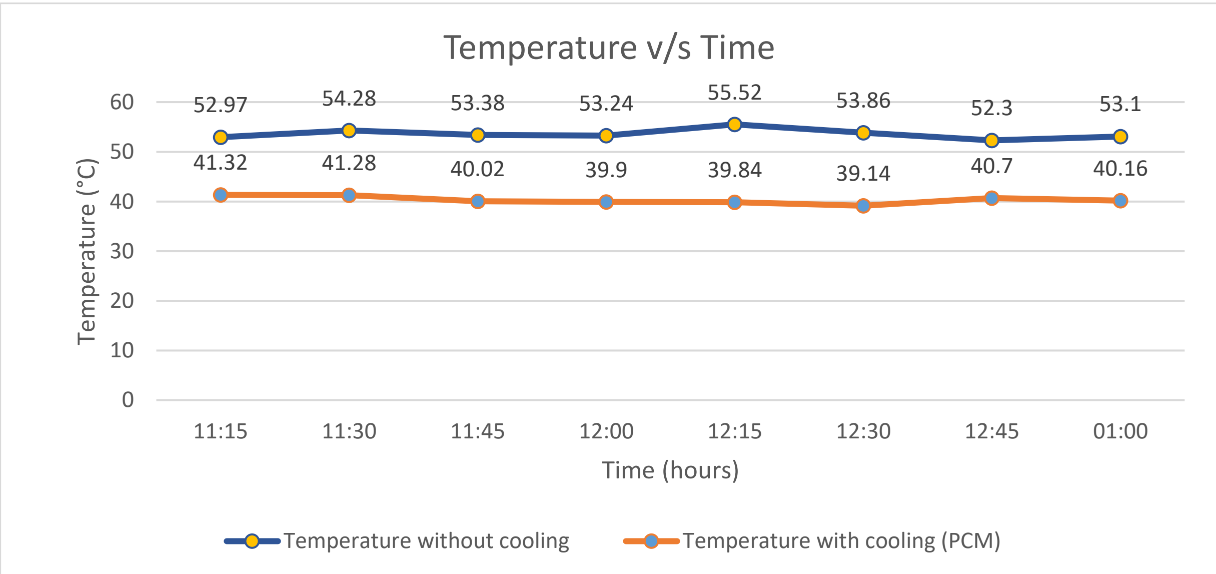
Fig 6.2 (a), (b) Experimental setup

6.2 Experimental results

The experiment was carried out on 31st May 2022, outside Department of EEE, SSN College of Engineering. The first reading was noted after the experimental setup is exposed to sunlight for 20 minutes. The tabulated result are as follows,

Time (hours)	Temperature without cooling (°C)						Temperature with cooling (°C)					
	T1	T2	T3	T4	T5	T(avg)	T1	T2	T3	T4	T5	T(avg)
11:15	54.9	54.2	52.1	50.7	50	52.38	39.6	42	41.6	42.2	41.2	41.32
11:30	54.8	54.1	54.2	54.1	54.2	54.28	39.6	41.3	40.5	43.2	41.8	41.28
11:45	54.6	53.1	53.2	53.8	52.2	53.38	38.8	39.6	39.8	41.3	40.6	40.02
12:00	53.5	53.2	53.7	53.2	52.6	53.24	37.8	40.5	40.3	40.8	40.1	39.9
12:15	56.4	55	55.4	56	54.8	55.52	38.9	39.8	40.3	40	40.2	39.84
12:30	54.5	53.6	53.9	53.8	53.5	53.86	37.2	38.9	40.5	39.9	39.2	39.14
12:45	53.6	51.1	52.1	53.4	51.3	52.3	38.7	40.3	40.3	40.8	43.4	40.7
01:00	53.8	51.2	53.5	54.7	52.3	53.1	38.3	39.7	40.3	40.3	42.2	40.16

Table 6.1 Temperature of PV panel with and without PCM with respect to time



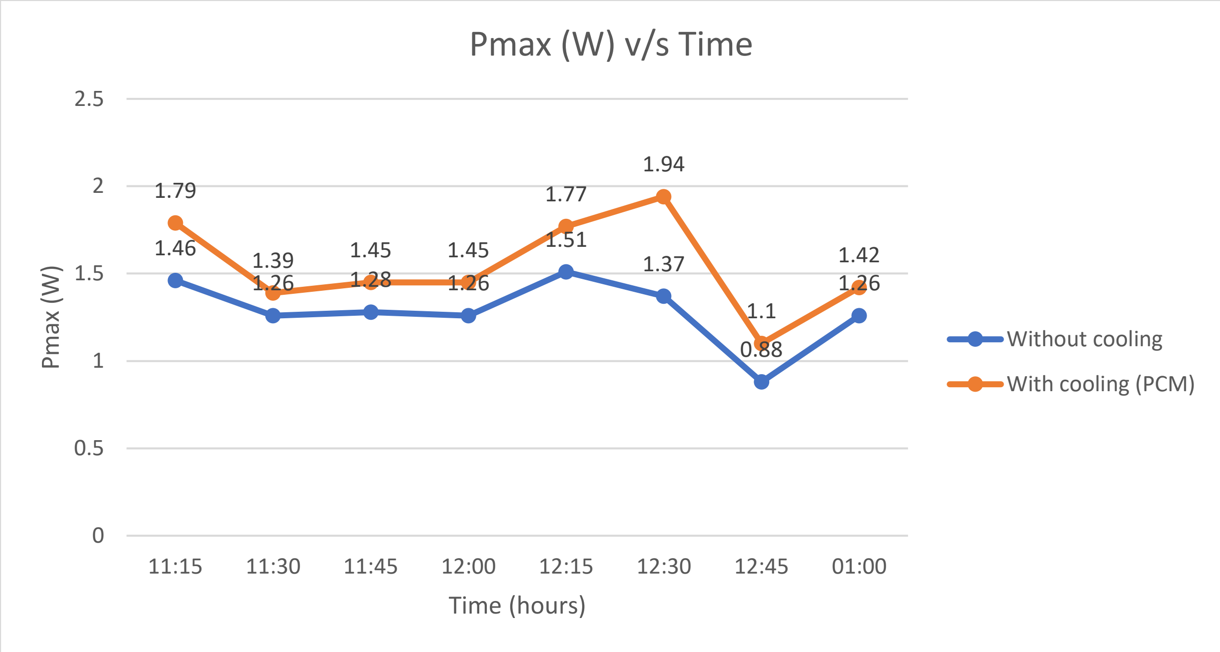
Graph 6.1 Temperature of PV panel with and without PCM with respect to time

Time (hours)	Ambient temperature (°C)	PV Panel without cooling				
		V_{oc} (V)	I_{sc} (A)	P_{max} (W)	Efficiency (%)	T1 (°C)
11:15	35	19.2	0.1	1.46	10.89	52.97
11:30	36	20.8	0.08	1.26	9.39	54.28
11:45	36	21	0.08	1.28	9.54	53.38
12:00	36	20.8	0.08	1.26	9.39	53.24
12:15	37	19.9	0.1	1.51	11.26	55.52
12:30	37	20	0.09	1.37	10.21	53.86
12:45	36	19.3	0.06	0.88	6.56	52.3
01:00	36	20.8	0.08	1.26	9.39	53.1

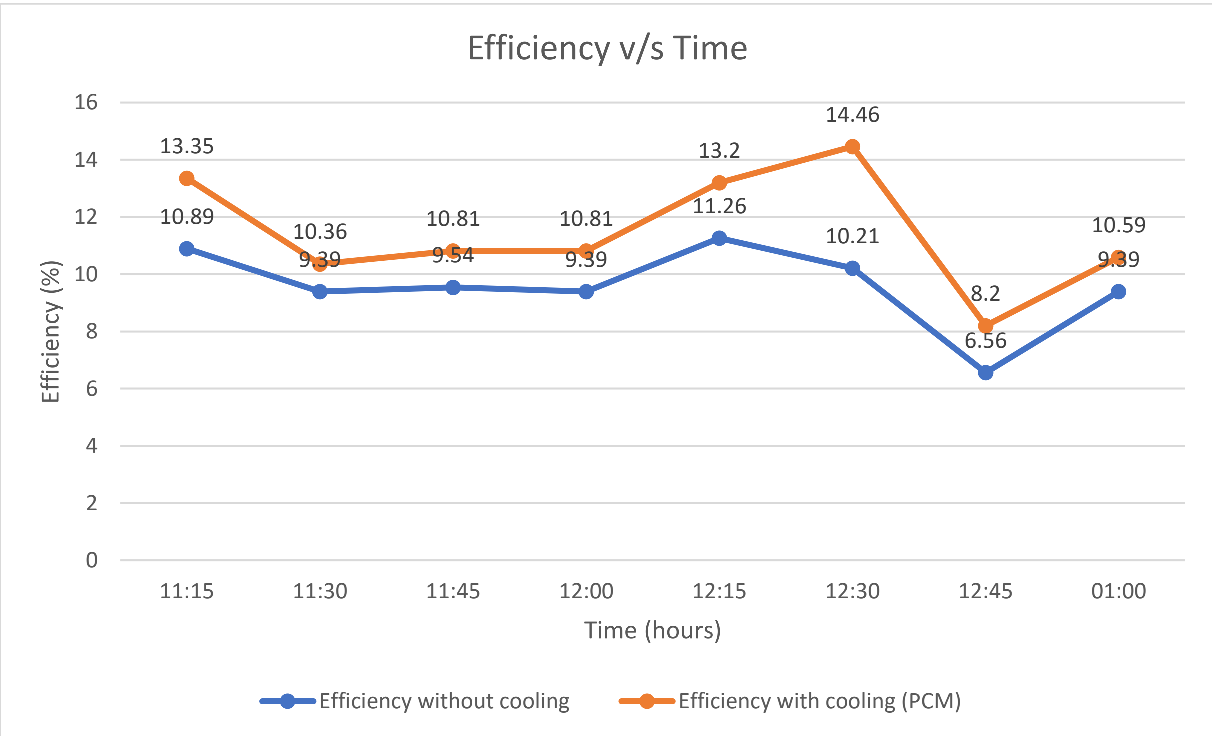
Table 6.2 Measured specification PV panel without cooling

Time (hours)	Ambient temperature (°C)	PV Panel cooled with PCM and aluminium				
		V_{oc} (V)	I_{sc} (A)	P_{max} (W)	Efficiency (%)	T2 (°C)
11:15	35	21.4	0.11	1.79	13.35	41.32
11:30	36	20.3	0.09	1.39	10.36	41.28
11:45	36	21.2	0.09	1.45	10.81	40.02
12:00	36	21.2	0.09	1.45	10.81	39.9
12:15	37	21.2	0.11	1.77	13.2	39.84
12:30	37	21.3	0.12	1.94	14.46	39.14
12:45	36	20.7	0.07	1.1	8.2	40.7
01:00	36	20.7	0.09	1.42	10.59	40.16

Table 6.3 Measured specification of PV panel with PCM and Aluminium cooling



Graph 6.2 Maximum power v/s Time for PV panel with and without cooling



Graph 6.3 Efficiency v/s Time for PV panel with and without cooling

6.3 Result Analysis

The results prove that, PCM enclosed with aluminium casing in the PV panel has improved the conversion efficiency on an average by 16.5%. With the average temperature decrease of 13.22°C, the overall average electrical efficiency has been increased by 2%. Comparing the average output power of the conventional uncooled PV panel, the PV-PCM based panel with aluminium as TCE has an average increase of 20% of electrical power. These technical results can be interpreted as, the PCM material created a shift in temperature on the surface of the PV panel whereas the aluminium was used to accelerate the rate of diffusion of heat to the surroundings, thus reducing the operating temperature of the panel.

6.4 Cost

ITEM	QUANTITY	COST
Solar panel (5W)	2	₹1000
Rheostat	2	-
Multimeter	4	-
Temperature Gun	1	-
Multi-Turn wires	5m	₹200
Panel Stand	2	₹1500
PCM RT42	0.5kg	-
Al Framework	1	₹1500
	Total	₹4200

CONCLUSION

The main objective of this project is reducing the operating temperature of the PV panel thereby increasing its power output and efficiency.

The above stated results in Chapter 6 prove that, when compared to other existing methods of PV panel cooling available in literatures, this PCM entrenched with aluminium based PV panel shows better performance under natural sun's irradiance. Thus, this method can certainly be an effective approach to reduce the operating temperature of the PV panel with minimal cost, less weight along with an increase in efficiency of the PV panel.

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