Experimental Study of Solar PV Panel Enhanced with Phase Changing Material

Ganesh Kumar. K V
Assistant Professor,
Department of Mechanical Engineering
Hindusthan Institute of Technology,
Coimbatore-641 032.

C.Lokanath Reddy, K.Chandra Mouli Naidu,
N.V.Sainath Reddy
UG Students,
Department of Mechanical Engineering,
Hindusthan Institute of Technology, Coimbatore-641 032.

***Abstract*:- Solar PV panels are the most widely used to convert renewable energy i.e., solar energy into electric energy. In solar PV panel large part of absorbed solar radiation is converted into heat, which causes heating of PV cells and therefore leads to decrease PV efficiency. The conversion efficiency of photovoltaic (PV) panels is reduced while the PV temperature rises. It is revealed that that every Celsius degree rise in PV temperature can result in as large as a 0.65% drop in the efficiency. This phenomenon attracts substantial scholar attentions in mitigating and controlling the PV temperature. Among those applied techniques, phase change material (PCM) is considered as a potential candidate to hold the PV temperature at a low degree because of its latent heat storage.**

Keywords: Solar energy, PV Panel, Phase Change Material, Battery.

INTRODUCTION:

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is 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 cell devices are often the electrical building blocks of photovoltaic modules, known colloquially as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 volts to 0.6 volts.

Solar cells are described as being photovoltaic, irrespective of whether the source is sunlight or an artificial light. In addition to producing energy, they can be used as a photo detector (for example infrared detectors), detecting light or other Electromagnetic radiation near the visible range, or measuring light intensity.

The most commonly known solar cell is configured as a large area p–n junction made from silicon. Other possible solar cell types are organic solar cells, dye sensitized solar cells, perovskite solar cells, quantum dot solar cells etc.. . The illuminated side of a solar cell generally has a transparent conducting film for allowing light to enter into the active material and to collect the generated charge carriers.

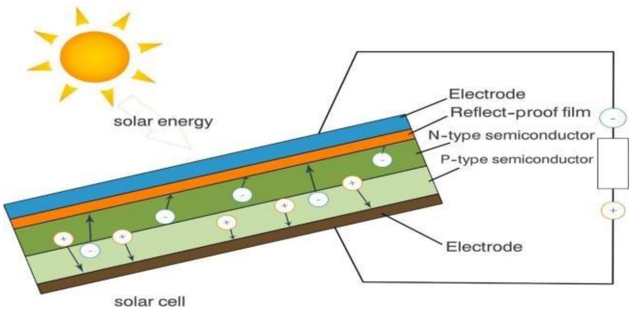
LITERATURE SURVEY:

Huanget al., have proved PCMs have previously been used to control the temperature of PV systems. Huang et al. (2004) conducted experiments using PCM for cooling building integrated photovoltaic. They achieved some success, with the results indicating that a 40 mm thick PCM slab attached to the rear of the PV panel could delay the rise in temperature for about 150 min under 750 W/m^2 insolation, before the temperature continued to rise (Huang et al., 2006). In order to achieve this reasonable cooling effect, internal Aluminium fins were used in the PCM in order to overcome its inherently low thermal conductivity.. Interestingly they found that fin cooling without PCM was significantly less effective at reducing PV temperature rise than the PV/PCM systems).

PROBLEM STATEMENT :

As we know solar energy is most commonly used Renewable energy. In this solar panels are used. These panels when subjected to rays gets heated. Due to this heat the efficiency of solar panels decreases. There are various methods available for increasing efficiency by cooling the solar panel such as water spraying etc., But in th is method large amount of water is required as we want to spray water continuously.

METHODOLOGY:



A photovoltaic cell is made of semiconductor materials that absorb the photons emitted by the sun and generate a flow of electrons. Photons are elementary particles that carry solar radiation at a speed of 300,000 kilo meters per second. In the 1920s, Albert Einstein referred to them as “grains of light”. When the photons strike a semiconductor material like silicon , they release the electrons from its atoms, leaving behind a vacant space. The stray electrons move around randomly looking for another “hole” to fill. When the electrons are excited by the photons, they are swept to the n-side by an electric field, while the holes drift to the p-side. The electrons and holes are directed to the electrical contacts applied to both sides before flowing to the external circuit in the form of electrical energy. This produces direct current. An anti-reflective coating is added to the top of the cell to minimize photon loss due to surface reflection (see diagram).

COOLING METHODS OF PV CELLS:

An effective way of improving efficiency and reducing the rate of thermal degradation of a photovoltaic module is by reducing the operating temperature of its surface. This can be achieved by cooling the module and reducing the heat stored inside a PV cell during operation. Crystalline silicon currently offers a yield of 15-16%. And some studies consider that its limits would be reached approximately 25% under laboratory conditions. Overheating of a PV module decreases performance of output power by 0.4-0.5% per rise of 1oC over its Standard Test Conditions (STC). This is way the concept "cooling of PV" has become so important.

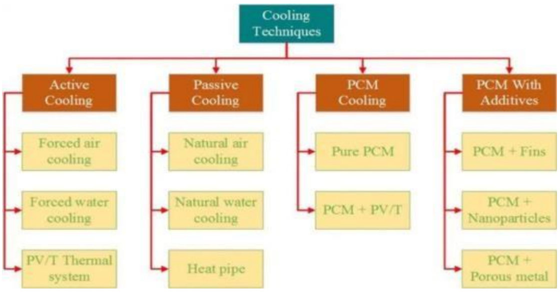


Fig: cooling methods

EXSISTING METHOD:

Water Spraying:

Water is sprayed through the sprinklers on the front of the P.V. modules in this system, with the pump and the connected pipes (Figure). Previous research on water spraying has obtained interesting results, showing an electrical efficiency increase of up to 15% in extreme weather environments. While this system uses and wastes a large amount of water installed on the overland P.V. plant, it can be a suitable and cost- effective solution for floating solar systems.

The results indicated that the front side cooling gives improved results than the back-side cooling. The electrical power improvement achieved was approximately 14.6%. The device comprises of P.V. modules, a storage tank, a pump, spray nozzles and recycling system. With the use of water spray, the solar panel temperature reduces to 35°C.

Fig: Water Spraying

The major disadvantage of this model is the water is to be sprayed continuously. So, it required lot of water and that water cannot be used again.

Cooling by Phase Changing Material (PCM) :

Phase change materials (PCM) cooling is a distinct form of passive conductive cooling. PCM are substances capable of retaining thermal energy, allowing temperature stabilization. These will absorb or release significant quantities of so-called 'latent' heat when these experiences a change in their physical state, such as during the melting and freezing cycle.

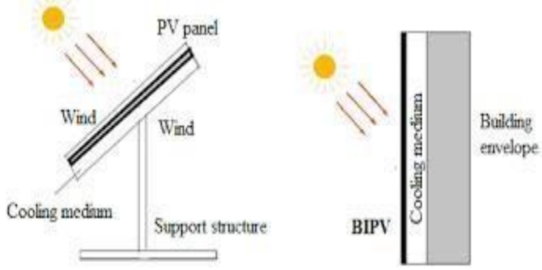


Fig: Cooling by phase changing method

EXPERIMENTAL SETUP: Apparatus:

PV Panels

PCM

Battery

Thermocouples

Multi meter

Design for test rig

PV PANELS:

In this work, outdoor experiments were conducted to examine the impact of PCM addition to PV modules on its performance. In this setup, two different configurations of PV modules each of 50 W were designed and constructed i.e. convectional PV system and PV integrated with enhanced PCM using aluminium foam matrix PV-PCM.

Two aluminium container having dimensions of 75.7cm × 33.4 cm × 2.5 cm and 50cm × 33.8 × 2.5 cm as conventional and PV PCM modules.

Fig: Solar cells

One incorporated underside the PV module in which paraffin wax as PCM was stored for passive cooling purposes. Initially, paraffin wax granules were melted at 85 °C in a bowl with the heater. then, the melted wax was poured into the enclosure thought the rear side of panel which also served as a breather to avoid the pressure building up. About 4.56 kg of paraffin wax was required to fill the enclosure after considering the potential volume expansion during phase change processes. To avoid leakage of liquid PCM, a wooden card-board was provided between the PV rear and PCM enclosure followed by compressing with the help of screws. One multi meter is connected to the PV cell to note down the various readings like current, voltage. And also thermocouple is connected to measure the temperature. Here we used modern thermocouple which will be same as multi meter.

SPECIFICATIONS OF PV MODULE:

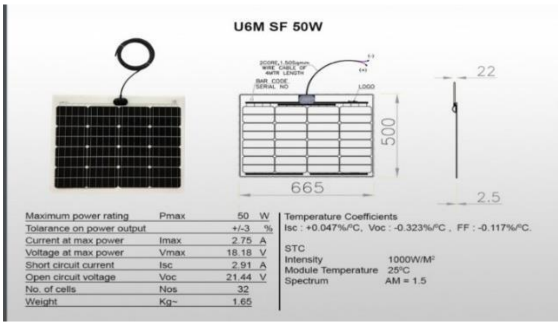


Fig: PV reference

Materials for PV Modules:

Solar cells are arguably the most important feature of a solar panel. It is the solar cell that is responsible for converting sunlight into electricity through the photovoltaic effect**.**

PHASE CHANGE MATERIAL (PCM):

Paraffin wax as phase change material (PCM) **Paraffin preparation:**

Paraffin wax (or petroleum wax) is a soft color less solid derived from petroleum, coal or oil shale that consists of a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37°C (99°F),[2] and its boiling point is above 370°C (698°F).Common application paraffin wax include lubrication, electrical insulation, and candles, dyed paraffin wax can be made into crayons. It is distinct from kerosene and other petroleum products that are sometimes called paraffin.

Properties:

➢Paraffin wax is mostly found as a white, odourless, tasteless, waxy solid.

➢Melting point between about 46 and 68°C (115 and 154°F)

➢ Density of around 900 kg/m3.

Fig: PCM Granules

Paraffin wax was first created in 1830 by the German chemist Karl von Reichenbach when he tried to develop the means to efficiently separate and refine the waxy substances naturally occurring in petroleum. Paraffin represented a major advance in the candle making industry because it burned cleanly and reliably and was cheaper to manufacture than any other candle fuel.

The first step in making paraffin wax is to remove the oil (de-oiling or de-waxing) from the slack wax. The oil is separated crystallization.

Fig: Molten Wax

Fig: PV-PCM

About 4.56 kg of paraffin wax was required to fill the enclosure after considering the potential volume expansion during phase change processes. To avoid leakage of liquid PCM, a wooden card-board was provided between the PV rear and PCM enclosure followed by compressing with the help of screws.

And the setup for the analysis have been made as per below figure and the setup for the analysis have been made as per below figure

Fig: PV-PCM

BATTERY:

• A standard battery 12v each is used to store the produced electricity from the PV cells

• And, to measure the variations in voltage batteries were connected to it on both PV modules at the output. Arduino

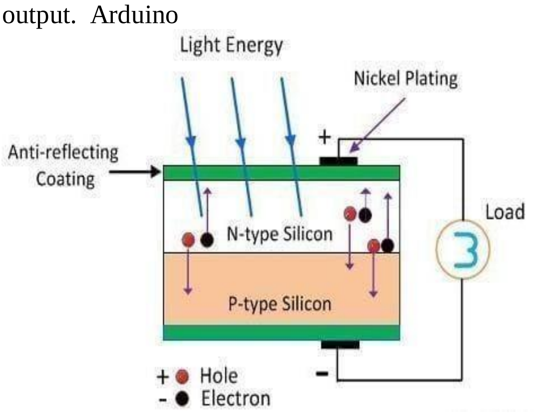


Fig: Battery

THERMOCOUPLES:

• In this setup we use modern type of thermocouples which is same as Multi meter. It is having a cable same as multi meter. Unlike multi meter it is having a single wire.

• One end is having 2 pins which is used to connect to multi meter same as multi meter pins. This end is fixed to the multi meter where as another end is the main end by which we are going to measure temperature. This end is placed on the panel font end it will show the temperature of the body.

• We used this type of thermocouple to reduce the cost as it required one meter for both. The temperature is measured at various places of a solar front end.

• These temperatures are noted clearly in the table because we are doing project to reduce the temperature of the panel. The temperatures are measured to a panel without using PCM and noted separately and on other hand temperature of the panel with PCM is noted separately because these are important for comparing the temperatures.

Fig: PV Solar cell with Thermocouples

MULIMETER:

- A digital multimeter is a measuring instrument that can measure multiple electrical properties.
- A typical multi meter can measure voltage, resistance.
- current, in which case it is also known as a volt-ohm-milliammeter (VOM), as the unit is equipped with voltmeter, ammeter, and ohmmeter functionality. Some feature the measurement of additional properties such as temperature and volume.
- Modern multimeter is often digital due to their accuracy, durability and extra features. In a digital multimeter the signal under test is converted to a voltage and an amplifier with electronically controlled gain preconditions the signal. A digital multimeter displays the quantity measured as a number, which eliminates parallax errors. Modern digital multimeter may have an embedded computer, which provides a wealth of convenience features.

Fig: Digital Multi meter

DESIGN FOR TEST RIG:

Fig: structure for PV Module

To receive maximum solar radiation, both panels are fixed on a stand at a south-facing 16-degree inclination angle, according to the location latitude & longitude. The structure is made by iron material to keep them in the better stability.

EXPERIMENTAL PROCEDURE:

- During the experimentation, the PV cell with the structure is placed in open place or top of the building for a long period of 4-6 hours on a sunny day
- Based on the maximum solar intensity the design for PV cell is inclined at 16˚ angle as per latitude and longitudes of the building.
- Two thermocouples are used to give the average PV temperature.
- Besides, another two thermocouples were used to measure the temperature of the rear surface of PV modules.
- Also, to monitor the transient temperature variation inside the PCM enclosure, two thermocouples were used which are positioned at depths of 2 cm and 2 cm from the top surface of the container, and noted as PCM1 (upper point) and PCM2 (lower point),respectively.
- A battery is connected to the both PV cells to store the produced energy.
- Battery worked as open circuit and closed circuit.
- As the temperature goes on increasing (550c-600c) the variation in the state of pcm and temperature are to be noted for every 30 minutes and for two days.
- When the PV PCM is reached for a maximum temperature the PCM will gets into molten state Voltage, Current and power output variations are to be noted as per time mentioned.
- At the reaching of PV PCM at its maximum temperature it starts to use the PCM energy from the rear side of the panel which is from the PCM in Liquid state.
- At the reaching of PV PCM at its maximum temperature it starts to use the PCM energy from the rear side of the panel which is from the PCM in liquid state.
- That the energy from the PCM is transferred to the PV cell to generate output current that connected the load.
- As per the tabulated values and observations the power output(V*I) and the efficiency of the PV cell will be calculated.
- The performance characteristics of PV cell were drawn.

FORMULAS:

POWER

POWER OUTPUT = *V* × *I*

Where:

V = voltage of the PV cell in volts
I = current from the PV cell in ampere
P = power in watt

EFFICIENCY:

$$\eta = \frac{\text{power output of pv cell}}{\text{input solar energy(radiation)} * \text{area of PV cell}}$$

Δη=Improved Efficiency

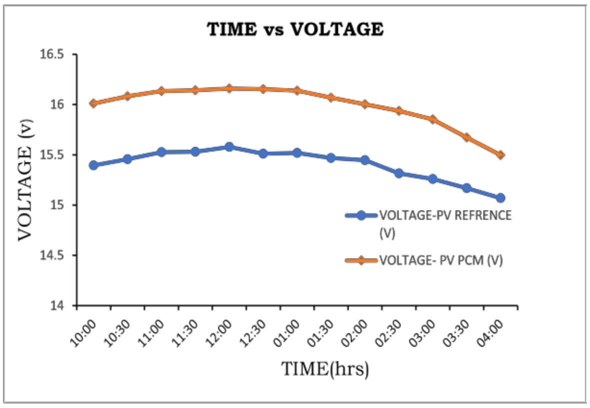
$$\Delta\eta = \frac{\text{efficiency of PV PCM} - \text{efficiency of reference PCM}}{\text{efficiency of reference PCM}}$$

- Power output = voltage × current
- Power Input = solar radiation × area of the PV cell
- Area of PV cell = length × width
- Volume of PCM admitted = length × width × thickness

Table's:

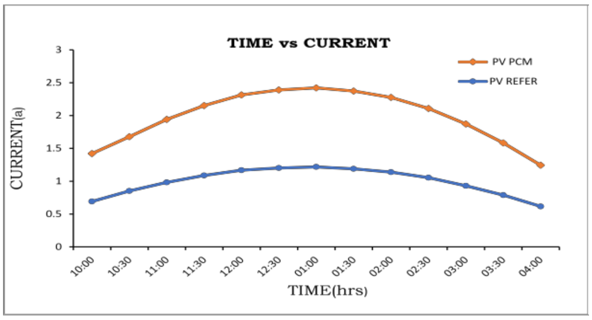
Time vs voltage

Time(hrs)	Voltage-PV Refrance(v)	Voltage-pv pcm
10:00	15.394	16.011
10:30	15.457	16.081
11:00	15.526	16.135
11:30	15.531	16.141
12:00	15.578	16.159
12:30	15.511	16.154
1:00	15.518	16.138
1:30	15.469	16.069
2:00	15.448	16.002
2:30	15.315	15.936
3:00	15.26	15.852
3:30	15.169	15.671
4:00	15.069	15.497



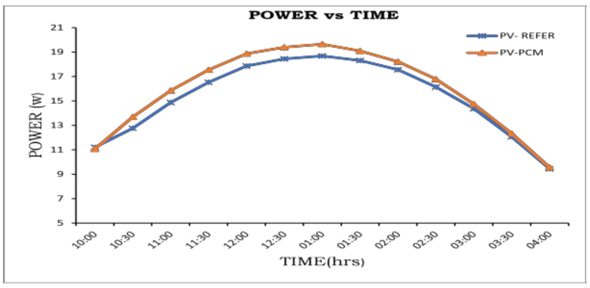
Time vs Current

Time(hrs)	PV Refer current (a)	pv pcm Current
10:00	0.691437	0.728076
10:30	0.851253	0.825581
11:00	0.982708	0.958006
11:30	1.087107	1.064387
12:00	1.167523	1.146745
12:30	1.201003	1.189156
1:00	1.217437	1.20415
1:30	1.188188	1.183852
2:00	1.13842	1.136523
2:30	1.053025	1.053803
3:00	0.929977	0.941547
3:30	0.787569	0.795834
4:00	0.616765	0.626983



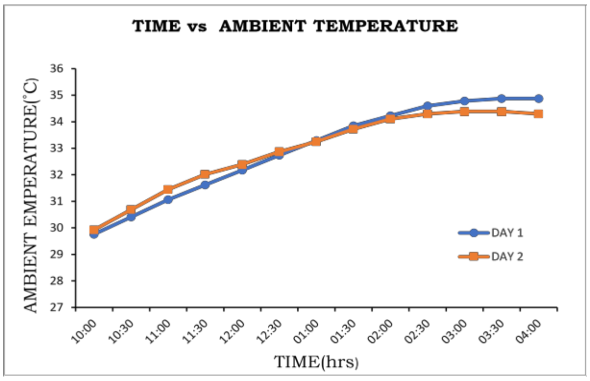
TIME vs POWER

TIME (hrs)	PV-REFER POWER(w)	PV-PCM POWER(w)
10:00	11.208	11.0706
10:30	12.761	13.689
11:00	14.874	15.856
11:30	16.531	17.547
12:00	17.864	18.866
12:30	18.445	19.401
01:00	18.686	19.647
01:30	18.313	19.093
02:00	17.557	18.217
02:30	16.139	16.781
03:00	14.368	14.742
03:30	12.072	12.342
04:00	9.448	9.558



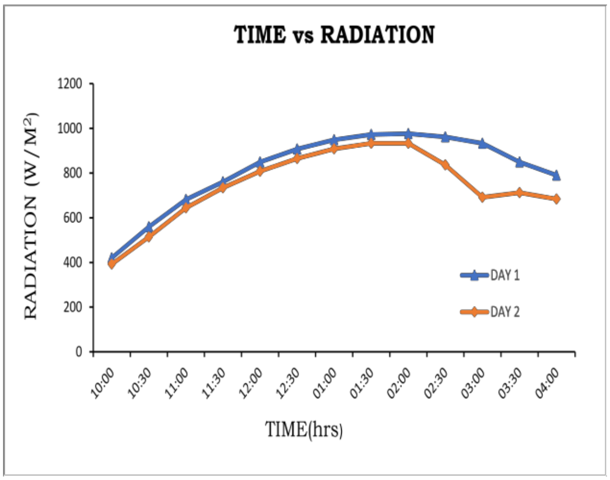
TIME vs AMBIENT TEMPERATURE

TIME (hrs)	DAY 1 TEMP	DAY2 TEMP
10:00	29.76	29.925
10:30	30.411	30.685
11:00	31.062	31.445
11:30	31.62	32.015
12:00	32.178	32.395
12:30	32.736	32.87
01:00	33.294	33.25
01:30	33.852	33.725
02:00	34.224	34.105
02:30	34.596	34.295
03:00	34.782	34.39
03:30	34.875	34.39



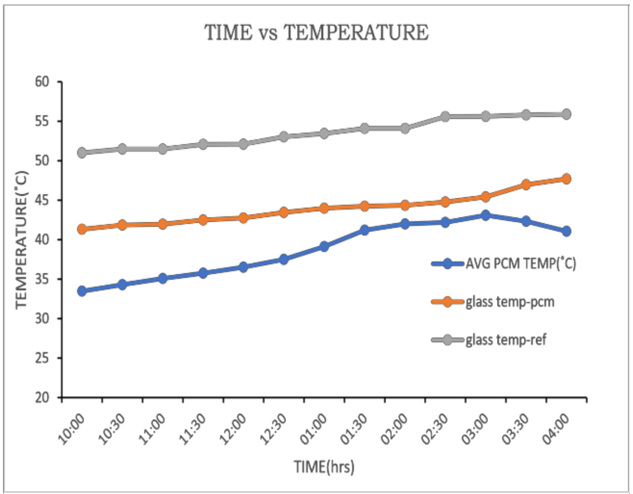
TIME vs RADIATION

TIME (hrs)	DAY 1 RADIATION	DAY 2 RADIATION
10:00	420.66	392.33
10:30	559.330	514.330
11:00	682	644
11:30	760.66	734.33
12:00	849.33	807.66
12:30	907.33	864.66
01:00	948.66	908
01:30	972.33	933
02:00	976.33	932.66
02:30	961.66	836.33
03:00	933	692
03:30	849	712.33



Graphs:

By taking various readings in tabular form various graphs are drawn with that readings.
For example, graph of a time vs Temperature by using pcm and without pcm is drawn below.



Note: As per the plotted results the temperature of the PV cell can be controlled by using PCM in the energy conversion.

- Glass temperature without any cooling medium shows high temperatures which effect the PV cell performance
- While Average PCM shows moderate and uniform temperature by using a suitable cooling medium
- So, the energy stored in the PCM (wax) in molten state, that is transferred to convert thermal energy in to electrical energy similar as solar radiation.
- From this the cooling method is effective to enhance PV cell performance.

COST ESTIMATION:

Material	**Cost (in rupees)**
Monocrystalline Solar Panel	4000
Multi meter	700
Thermocouple	500
Wax	400
Battery	300
Frame	600
TOTAL	6500

CONCLUSION: -

The present work exhibited experimental studies of the effect of using of PCM on the thermal behavior and electrical performance of a PV panel presented to analyze the system thermal behavior and correlate it to the electrical outputs.

The use of PCM can decrease the temperature of the solar PV panel at the mid-day 10^0c i.e., at 1 pm the temperature of PV panel without pcm (reference) is 53.45^0c and temperature of the PV panel with the pcm is 43.90^0c.
At 1 pm- Power output by the PV reference is (18.686w) is lower than by the PV PCM (19.647w) is due to the presence of PCM(WAX) inside the PV cell this helps in producing more power output per given unit area and efficiency also enhanced by the presence of PCM.
The overall improved efficiency of the PV panel with pcm is (7%to12%) when compared to the reference PV panel.

Use of PHASE CHANGE MATERIALs in energy conversion is a better cooling technic and can be productive as much as without cooling medium.

REFERENCES:

[1] Ionel Laurentiu Alboteanu, Constantin Florin Ocoleanu, Cornelia Aida Bulucea, "Cooling system for photovoltaic module" University of Craiova, Craiova, ISBN: 978-1-61804-110-4.
[2] H.G. Teo, P.S. Lee, M.N.A. Hawlader, "An active cooling system for photovoltaic modules," applied energy 2012; 90: 309-315.
[3] K.A. Moharram, M.S. Abd-Elhady, H.A. Kandil, H. EI-Sherif, "Enhancing the performance of photovoltaic panels by water cooling," Ain Shams Engineering Journal 2013; 4: 869-877.
[4] Jiang Wu, Zhou Shi, Shuai Zheng, Lalu Zhao, Qiaobo Feng, Hancheng Luo Sheng Yang, Yujing Wang, "Research on heat transfer characteristics of solar cells and heat exchanger combined system and its optimization," Energy Procedia 2012; 14: 393- 398.
[5] R. Hosseini, N. Hosseini, H. Khorasanizadeh, "An experimental study of combining a photovoltaic system with a heating system," World Renewable Energy Congress, Sweden 2011.
[6] Y. M. Irwan, W.Z. Leow, M. Irwanto, Fareq.M, A.R. Amelia, N. Gomesh, I. Safwati, "Indoor Test Performance of PV Panel through Water Cooling Method," Energy Procedia 2015; 79: 604-611.
[7] Bjornar Sandnes, John Rekstad, "A photovoltaic / thermal collector with a polymer absorber plate: experimental study and analytical model," Department of physics, Norway, 1997.
[8] Zhen Hua Quan, Ning Jun Li, Yao Hua Zhao, "experimental study of solar photovoltaic / thermal system based on flat plate heat pipe," Beijing university of technology, china.

PICTURES: