PERFORMANCE ASSESMENT AND COMPARISON OF DIFFERENT SOLAR PHOTOVOLTAIC TECHNOLOGY

Sapna verma[1] , Ashima Kalra [2] Arvind Sharma [3] Menika Sharma [4]

[1]*Department of Electronics and Communication Engineering,*
S.S.E.T Punjab Technical University, (India)
[2]*Professor & Head in Electronics and Communication Engineering Department,*
S.S.E.T Punjab Technical University, (India)
[3]*Fellow at Solar Lighting Laboratory TERI University, New Delhi, (India)*
[4]*Assistant Professor in Electrical Engineering Department,*
S.S.E.T Punjab Technical University, (India)

ABSTRACT

This paper represents the technical performance evaluation and comparison of different solar PV technology in real time conditions for the selected location in New Delhi. By examining the SPV technology, the performance of modules of different technology at the same time and same environment conditions, i.e. how the module of different type of technologies behaves in different climatic conditions and parameter such as average energy generated, solar operational efficiency, maximum generated power, efficiency of modules are calculated. The number of experiments has been performed to examine the performance of different types of modules CdTe (80Wp) and polycrystalline (75Wp) in real time conditions of New Delhi (Latitude 28°37N, Longitude 77°04E).One indoor experiment has been also performed with sun simulator to compare the average energy generated in indoor as well as outdoor conditions.

Keywords: Energy, Modules, Sun simulator, SPV technology.

I. INTRODUCTION

India depends heavily on fossil fuels and nuclear power to generate its electricity. The environment pollution and depleting nature of these resources has raised lot of challenges-for keeping them as source of energy. Renewable energy is clean and safer to meet present increasing demand of electrical power. From the aspect of global warming and shortage of natural gaseous, scientists and engineers are looking for clean, renewable energy solutions. Only the sun is source of solar energy. Using sun's energy is very useful because it is an everlasting, clean, renewable ener [1].

Hence solar energy is the one of the best option to replace a part of fossil fuel energy because earth receives 3.8 YJ of energy which is 6000 times greater than the world's total energy consumption [2]. Sun's energy is clean energy so for environment there is no bad effect. Sun's energy is free it do not cause pollution and mostly available at all location. India has 300-310 sunny days per year. The government of India comprising a national solar policy called as Jawaharlal Nehru National Solar Mission (JNNSM) was launched on the 11th January,

2010 by the Prime Minister. Its vision is based to develop solar power in India. The objective of the JNNSM is to establish India as a global leader in solar energy [3]. JNNSM has set target for different phases. The JNNSM mission set target of adding 20 GW of grid connected and 2 GW of off-grid capacity by 2022 in three phases. In phase 1(2010-2013) the target of 1100 MW grid connected and 200 MW for off grid. In phase 2 (2013-2017) the target of 10,000 MW grid connected and 1000 MW for off grid. In phase 3(2017-2022) the target of 20,000 MW grid connected and 2000 MW for off grid [4]. Phase one is completed and achievement for phase 1 is 252.5 MW. Currently the phase 2 is going on. The first cost-effective applications for photovoltaics were stand-alone systems. Wherever it was not possible to install electricity supply from the mains utility grid, or where this was not cost-effective or desirable, stand-alone photovoltaic systems could be installed. The applications of stand-alone system is constantly increased. Stand- alone PV systems are using greatly in developing countries, where large areas are frequently not connected to an electrical grid [5]. Elhodeiby et.al. [6], conducted performance analysis of 3.6 kW Rooftop Thin Film Photovoltaic system in Egypt. The performance of the PV system are evaluated which include: average generated kWh per day, average system efficiency, average inverter efficiency , average array efficiency, average power output, solar irradiation around the year.

This paper presents a comparison between two solar PV technologies i.e. CdTe (thin film) polycrystalline silicon. The outdoor hourly performance parameters of the stand alone solar PV system components are measured in real time conditions and in the climatic conditions of New Delhi. By examining the solar PV technology, we can get the performance of modules of different technology at the same time and same environment conditions, i.e. how the module of different type of technologies behaves in real time conditions. The daily readings from 9 AM to 5 PM are taken on hourly basis to calculate the parameters like total energy generated throughout day, efficiency, maximum power generated ,etc are determined and details are given in this paper.

The primary objective of this study is the technological description of the photovoltaic system and measure the operation of solar modules in different surroundings and also to measure the function of electronic circuitry in PV system. The place of work is Solar Lighting Laboratory, TERI (The Energy and Resources Institute), New Delhi (Latitude 28°37N, Longitude 77°04E).

II. MATERIALS AND METHODS

The location chosen for study area is TERI University in New Delhi. The typical stand alone solar photovoltaic modules were installed at rooftop of solar lighting laboratory TERI (The Energy and Resources Institute), New Delhi (Latitude 28°37N, Longitude 77°04E). There are two kinds of PV modules; one is CdTe (thin film) and polycrystalline silicon. These PV modules are kept at inclination equal to latitude of place as per to gain maximum solar insolation radiation. Two PV modules CdTe and Polycrystalline silicon is of 80 Wp and 75 Wp respectively. The experimental study of PV modules has been done at climatic conditions of New Delhi. The measured parameter includes the solar radiation, open circuit voltage, short circuit current, ambient temperature, back panel temperature.

After having data of each day of different modules at the same time different calculations have been made by using the above measured parameters. The setup of the solar PV modules is shown in fig 1. And block diagram of experimental setup is shown in fig.2.

III. EXPERIMENTAL PERFORMANCE EVALUATION

The Performance analysis of different modules is evaluated by different experiments. An experimental photovoltaic outdoor test facility with two different photovoltaic technology module arrays: p-Si and CdTe (Thin Film) have been set up at Solar Lighting Lab, TERI (The Energy and Research Centre), New Delhi (Latitude 28°37N, Longitude 77°04E). The CdTe module of 80 Wp and Poly Crystalline of 74 Wp are taken for analysis.

Fig.1 Solar PV System at Solar Lighting Laboratory Teri

3.1 Experiment Number 1

The main objective of this experiment is to compare and analysis two different solar module technologies i.e. Polycrystalline and CdTe. for compare the Energy yield of both modules. The test is done at 28 ^{0} tilt and at same environment conditions. This test is done to calculate the performance parameters for both Crystalline and CdTe modules.

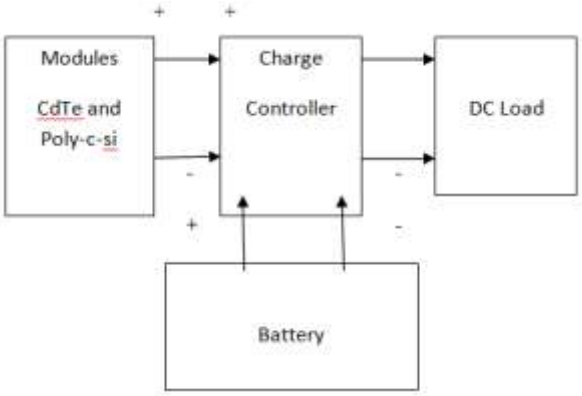


Fig.2 Block Diagram of Experiment

3.1.1 Methodology or Procedure for Evaluation

The three cycles of charging and discharging can be done in evaluating the energy generated by modules of different technology. The charging and discharging is performed with the MPPT charge controller at same climatic conditions and at the same interval of time (From 9 AM to 5 PM) in outdoor conditions of New Delhi. Two identical (12 V 100 Ah) Lead Acid Batteries were charged with both modules and discharged with a Street

Light and Home lighting Load of 10 W for 8 hours (from 9 AM to 5 PM) the help of a MPPT based charge controller and its performance parameters such as Average of Total Energy Generated throughout the day. The energy generated by both the modules is calculated and then both the modules of different technologies are compared to find out that which module is performing better.

While charging the battery from the different modules, observations such as the insolation, back temperature of modules, ambient temperature and electrical specifications are noted down at every half an hour for analysis purpose.

3.1.2 Performance Parameters Evaluated

a) Total Energy Generated: is the total Wh generated by the module in a day while charging and is represented by

$$E = \Sigma E_T \quad (1)$$

Where, E_t is energy generated in each hour.

t= time (1 to 8) hours.

b) Solar operational efficiency: It is the ratio of total output power, to the rated power.

$$\text{Solar operational efficiency} = \frac{\text{Output power (Wh)}}{\text{Rated power}} * 100 \quad (2)$$

Losses or electronics efficiency: It is the ratio of total power used by load, to the total power generated by the module.

$$\text{Losses or electronics efficiency} = \frac{\text{Total power used by load}}{\text{Total power generated by the module.}} * 100 \quad (3)$$

3.2 Experiment Number 2

The experimental setup for this is same as experiment no 1. I-V Curve Testing of different solar PV modules. The main objective is to Calculate and compare the efficiency and Fill factor of two different solar module technologies i.e. Polycrystalline and CdTe. This test is done to calculate the performance parameters for both Crystalline and CdTe modules.

3.2.1 Methodology or Procedure for Evaluation

In this case, the modules of CdTe and polycrystalline technologies are taken. The test is done to draw I-V curve of both the modules in the same interval of time (9 AM to 5 PM) and at same outdoor conditions. The Five cycles of I-V curve testing can be done using rheostat in evaluating the efficiency and Fill factor of modules of CdTe and Polycrystalline technology. While drawing the I-V curve then observations such as the insolation, back temperature of modules, ambient temperature and electrical specifications are noted down at every half an hour for analysis purpose.

3.2.2 Performance Parameters

a) Maximum power: is the product of maximum voltage and maximum current of module.

$$P_{max} = V_{mp} * I_{mp} \quad (4)$$

b) Efficiency: It is the ratio of output energy to the input power.

Efficiency (%) = Output Energy (Wh) *100
Radiation* Area (5)

c) Fill Factor*:* It is the ratio of maximum power generated by the module to the product of open circuit voltage and short circuit current of module.

Fill Factor = maximum power
Voc*Isc (6)

3.3 Experiment Number 3

The main objective of this experiment is to compare and analysis of two 40Wps Polycrystalline solar module technologies one having spot and another is clear surface respectively at outdoor condition.

a) To compare and analysis of two 40Wps Polycrystalline solar module technologies one having spot and another is clear surface respectively in indoor condition.

b) To compare and analysis of two 40Wps Polycrystalline solar module technologies one having spot and another is clear surface respectively in indoor condition.

An experimental photovoltaic outdoor test facility with photovoltaic technology ,two Polycrystalline module have been set up at Solar Lighting Lab, TERI (The Energy and Research Centre), New Delhi (Latitude 28°37N, Longitude 77°04E).Both module of 40 Wp are taken for compare the Energy yield of both modules. The difference in modules is that one module is having spot in single cell and another module is clear. The test is done at 28 ^{0} tilt and at same environment conditions. This test is done to calculate the performance parameters for both Polycrystalline modules.

3.3.1 Methodology or Procedure for Evaluation

The one cycles of charging and discharging can be done in evaluating the energy generated by modules of same one having spot and another is clear.

CASE 1

The charging and discharging is performed with the MPPT charge controller at same climatic conditions and at the same interval of time (From 9 AM to 5 PM) in outdoor conditions of New Delhi. Two identical (12 V 100 Ah) Lead Acid Batteries were charged with both modules and discharged with a Street Light and Home lighting Load of 14.4 W for 8 hours (from 9 AM to 5 PM) the help of a MPPT based charge controller and its performance parameters such as Average of Total Energy Generated throughout the day. The energy generated by both the modules is calculated and then both the modules are compared to find out that which module is performing better .While charging the battery from the different modules, observations such as the insolation, back temperature of modules, ambient temperature and electrical specifications are noted down at every half an hour for analysis purpose.

CASE 2

The experiment is performed with the SUN SIMULATOR at same climatic conditions and at the same time in indoor conditions in New Delhi. The experiment is performed at two levels of insolations i.e. 600 W/^{m2} and 800 W/^{m2}.

3.3.2 Performance Parameter

a)Total Energy Generated: is the total Wh generated by the module in a day while charging and is represented by: $E = \Sigma E_t$

Where, E_t is energy generated in each hour.

IV. RESULTS AND DISCUSSION

4.1 Experiment Number 1

This experiment evaluate the comparison of the average produced energy on the performance between two different module technologies using MPPT charge controllers.

4.1.1

In the First cycle the average energy output of the CdTe was 222.40 Wh .In the second cycle the average energy output of the CdTe was 284.03 Wh. In the third cycle the average energy output of the CdTe was 185.06 Wh as shown in fig3.In first cycle the energy generated by polycrystalline module was 181.24. In second cycle energy generated was and 234.61 Wh. In third cycle energy generated was and 153.73Wh as shown in fig 4.

The result shows that CdTe module performed better as compared to Polycrystalline module with MPPT charge controller.

4.1.2

The electronics efficiency is also compared for two modules; it can be observed in fig.5 that in the first cycle the total losses of CdTe and poly-c-si module was 16.06 % and 16.80 % respectively. In second cycle the total losses of CdTe and poly-c-si module was 8.71 % and 11.72 % respectively. In third cycle the total losses of CdTe and poly-c-si module was 12.29% and 14.68 % respectively. So it can be seen that the losses of Cdte were less than the polycrystalline module in all the three cycles. So CdTe module performed better than the polycrystalline module.

4.2 Experiment Number 2

This experiment investigates comparison of the efficiency, Fill factor of two different module technologies using MPPT charge controllers.

4.2.1

In the First cycle the Operational efficiency of the CdTe and p-Si module 9-12 % was and 8-12 % Wh respectively as shown in fig.6. In the Second cycle the Operational efficiency of the CdTe and p-Si module 9-12 % was and 9-12 % Wh respectively as shown in fig 7.. In the Third cycle the Operational efficiency of the CdTe and p-Si module 10-13 % was and 9-12 % Wh respectively as shown in fig 8.. In the Fourth cycle the Operational efficiency of the CdTe and p-Si module 5-13 % was and 10-12 % Wh respectively as shown in fig.9. In the Fifth cycle the Operational efficiency of the CdTe and p-Si module 10-12 % was and 9-12 % Wh respectively as shown in fig10. so it can be Observed that the operational efficiency of CdTe was better than polycrystalline.

4.3 Experiment Number 3

This experiment evaluates the comparison of the average produced energy on the performance between two same module technologies using MPPT charge controllers and SUN SIMULATOR

4.3.1 CASE 1

In this result shows that module having spot is performed slightly better as compared to the clear module with MPPT charge controller. In this cycle the average energy output of module with spot and clear module was 13.182 and 13.104 Wh respectively as .The sun hour in whole day is 4.21 hours as represented in fig.11.

4.3.2 CASE 2

In this result shows that clear module is performed slightly better as compared to the module having spot with SUN SIMULATOR. In this the average energy output of module with spot and clear module at insolation 600 W/^{m2} was 39.51and 40 W respectively and at insolation 800 W/^{m2} was 29.91 and 30.33 respectively as represented in fig.12.

In complete experiment also the comparison with in same module at indoor and outdoor conditions is carried out and . In indoor conditions at radiation 600 W/m2 the power output was 29.91 W and at 800 W/m2 the output power was 39.51 W as shown in fig 13. In outdoor conditions at radiation 600 W/m2 the power output was 25.55 W and at 800 W/m2 the output power was 28.35 W. Power output generated by the module good module/without spot at outdoor and indoor conditions. In indoor conditions at radiation 600 W/m2 the power output was 30.33 W and at 800 W/m2 the output power was 40 W. In outdoor conditions at radiation 600 W/m2 the power output was 24.87 W and at 800 W/m2 the output power was 27.03 W as shown in fig 14.

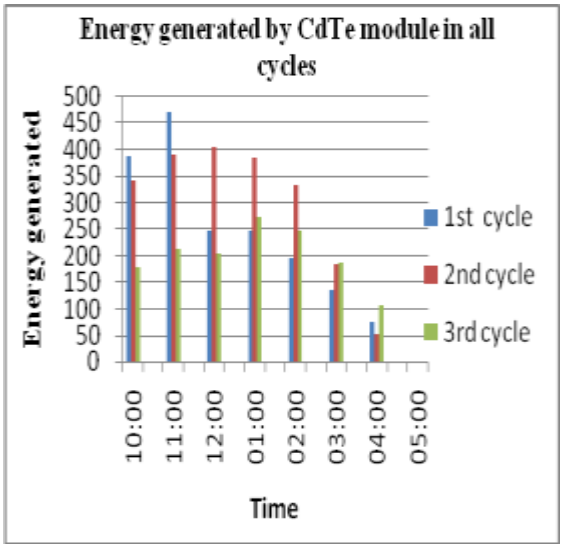


Fig.3 Energy Generated Cdte Throughout All Cycles

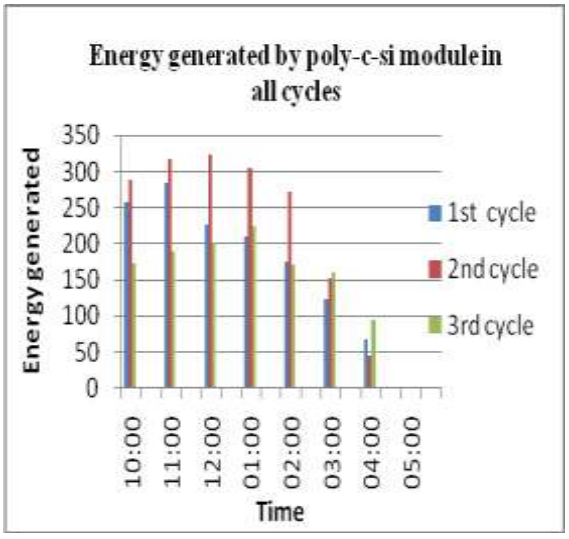


Fig4. Energy Generated Poly-Crystalline In All Cycles

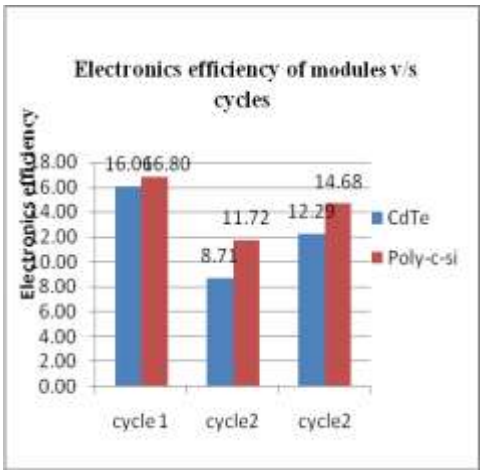


Fig.5. Electronics Efficiency of Modules.

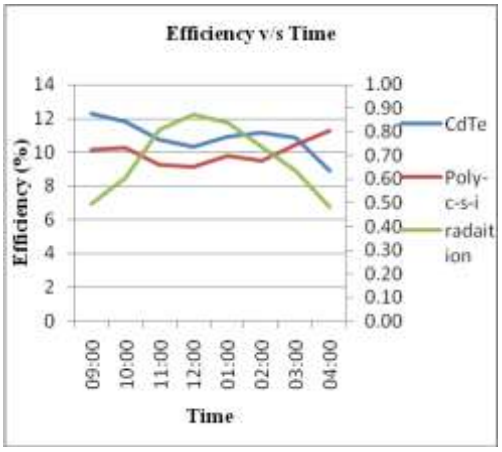


Fig.6 Efficiency of Modules Throughout Day 1

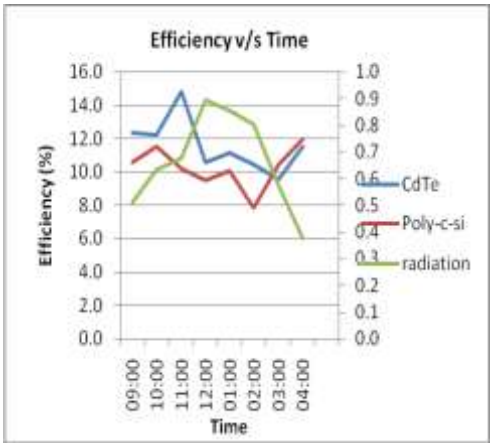


Fig.7 Efficiency of Modules Throughout Day 2

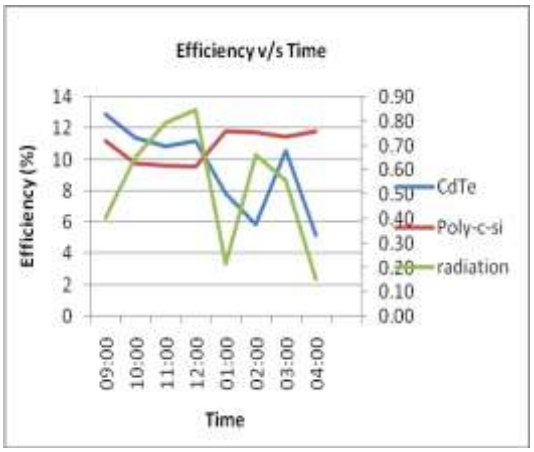


Fig.8.Efficiency of Modules Throughout Day 3

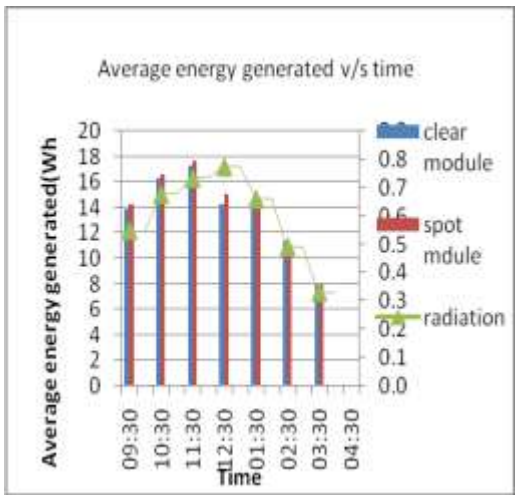


Fig 11.Energy Generated by Modules

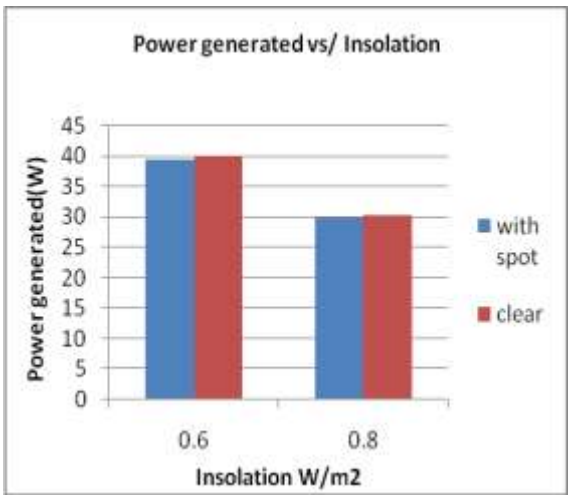
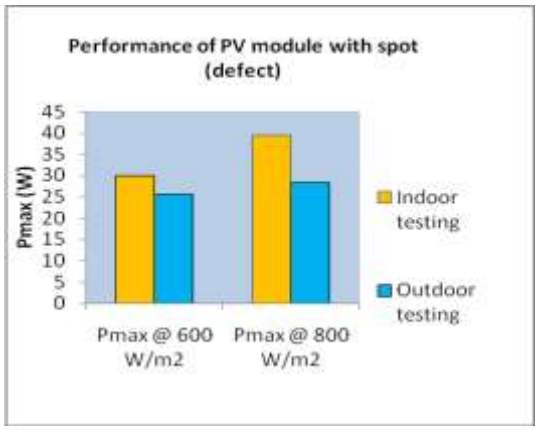


Fig.12. Power Generated With Sun Simulator



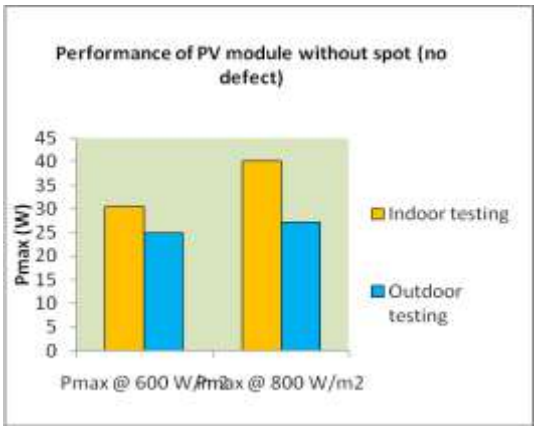


Fig.13 Performance Of Pv Module With Spot **Fig.14 Performance Of Pv Module Without Spot**

V. CONCLUSIONS

Three tests were conducted for the performance of modules.

5.1 First Test

I. The performance of two modules polycrystalline and CdTe (Thin film) is examined and compared at the same climatic condition with MPPT charge controller.

II. The conclusion is CdTe module performed better than P-Si with MPPT charge controller because of its high open circuit voltage.

III. Average Energy generated throughout the day is more for CdTe module compared to polycrystalline.

5.2 Second Test

I. The performance of Efficiency of two modules CdTe (Thin film) and Polycrystalline is examined and compared at the same climatic condition with same Rheostat.

II. The conclusion is CdTe module have better efficiency than P-Si. But ideally the efficiency of polycrystalline modules (12 - 14 %) is better than the CdTe modules (10- 12 %).

III. In this case the module of polycrystalline is of bad quality, the cells in module are not made up of good material that's why efficiency of polycrystalline module is poor than the CdTe module.

5.3 Third Test

I. The performance of both modules polycrystalline is examined and compared at the same climatic condition with MPPT charge controller and with SUN SIMULATOR. The conclusion is when observed in outdoor conditions then the module with spot generated slightly more energy than the clear module.

II. In Real time conditions module with spot is performing better than solar module. But in case of the SUN SIMULATOR solar module generated more energy than the spot module.

III. It shows that the spot in module is at its initial stage that's why it does not affect the energy generated. SUN SIMULATOR is efficient, so that both the modules are tested with SUN SIMULATOR to know the better results.

REFERENCES:

[1] www.PVresources.com

[2] http://www.nrel.gov/solar research.

[3] http://www.Mnre.gov.in

[4] Rakhi Sharma, G.N. Tiwari "Technical performance evaluation of stand-alone photovoltaic array for outdoor field conditions of New Delhi" Centre for Energy Studies (CES), *Applied Energy 92 (2012) 644–652.*

[5] M. Z. Kadir, Y. Rafeeu, N. M. Adam "Prospective scenarios for the full solar energy development in Malaysia"; *Renewable and Sustainable Energy Reviews 14 (2010) 3023–3031.*

[6] A.S. Elhodeiby, H.M.B. Metwally, and M.A. Farahat, "Performance analysis of 3.6kW Roof Top Grid Connected Photovoltaic System in Egypt", International Conference on Energy Systems and Technologies *(ICEST 2011)11-14 March 2011, Cairo, Egypt.*