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Experimental Study of PV Module on Different Climatic conditions

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Abstract
With the growing population and increasing of pollution at a faster rate by using a conventional source of energy leads to global warming, natural hazards, access earth mining worldwide and demand of energy at low cost focusing the researcher on substituting the renewable energy system to meet the requirement of energy consumption has reached to peak level worldwide. Hence,Solar Energy is becoming one of the important energy in the future as a great renewable energy source.However,solar PV cells' cost is still several times higher than the conventional power generation. So it is very necessary to improve the efficiency of the solar PV cells. It is necessary to have that source available easily and in sufficient quantity so that with the diminishing non-renewable source,the basic need forenergy can be fulfilled. This source can be an all-time available source. This paper seeks the tremendous progress made in recent years on photovoltaic (PV) cells materials, geometrical shapes, and devices in terms of their conversion efficiencies.Solar cells vary its performance under temperature changes or say that climate change is variable concerning climatic change. Climate condition is also variable with seasonal change (i.e., summer, rainy, and winter) even hours to hours, and day today. Change in temperature affects its power generation. The rapid development of solar PV cells has created a challenging environment in the future. Efficiency can be increased either by changing PV material, concentrating solar rays, or using a solar tracking system. This paper deals with a brief overview of the recent progress in PV cell efficiencies, energy and power generation based on different climatic conditions, and the selection of good quality materials and devices so that maximum sun heat can be absorbed and power conversion occurs.

Keywords: *PV cells,Energy, Efficiency & Power generation, Variable temperature, climate change.*

I. Introduction: Today, renewable energy source, which is inexpensive and readily available on earth need to discover. It is used to reduce the cost of energy production. So that renewable energy sources are going to the main substitute for fossil fuels in the future. Growing carbon emissions to the environment cause that they are the direct cause of global warming increases. There are different types of renewable energy sources that are available on earth. They are like solar energy, wind energy, biomass energy, geothermal energy, ocean energy, hydroelectric power, etc. Solar energy is the best alternative source for non-renewable energy sources because it is abundant on earth. Photovoltaic is also one of the most innovative and environmentally friendly technologies. Photovoltaic sys1tems have easy to install, and it is very easy to use by industry and households purpose. For the production of solar energy in India is very good climate conditions, 200 to 300 sunny days throughout the year are available here. 70% of India's total power generation from fossil fuel, it can be said that India is largely dependent on fossil fuels. So that Ecologically sustainable development, Government of India is doing to promote solar energy and launched the Jawaharlal Nehru national solar mission (JNNSM), This session the Prime Minister and his Cabinet given an approval to increase our budget five times for India's solar power capacity target work over the hand of Jawaharlal Nehru National Solar Mission (JNNSM). They are reaching up to 1 00,000 MW by 2022. With this ambitious goal in the world, India will become one of the largest producers of solar energy, provided many developed countries. The purpose of Energy analysis is to determine Energy losses (true thermodynamic losses) in processes & systems and to the minimization of losses/optimization of driving forces

II. LITERATURE REVIEW: A comprehensive review of the literature has been done on thermal analysis (Energy and Energy) Solar photovoltaic (SPV) systems in the present chapter.The literature review on emerge economics has also been done as one of the objectives of the thesis is to evaluate the Solar photovoltaic (SPV) systems on the basis of available literature on emerging economic then. The literature is:-

Sahin et al.[1] The thermodynamic characteristics of the solar photovoltaic (PV) cells using Energy analysis are done in this work. He developed and applied the new approach for the assessment of PV cells and found that the presented approach was realistic as it accounts for thermodynamic quantities such as enthalpy and entropy. They also analyzed the PV cells on the basis of the energy and energy efficiencies. The energy efficiency was found to be varying between 7-12% during the day while the Energy efficiency was found to be varying between 2-8%.

Joshi et al. [2]In his work, the performance characteristics of a photovoltaic (PV) and photovoltaic-thermal (PV/T) system using Energy and Energy analysis is done for the location of New Delhi, India. He found that in the case of PV/T, the energy efficiency varies between 33-45%, while the corresponding Energy efficiency varies between 11-16%. On the other hand, for PV alone, the Energy efficiency was found to be varying in the range of 8-14% for a typical set of operating parameters. He has also calculated the fill factor in order to know the behavior of the EnergyEfficiency of the

SPV systems and found that the higher the fill factor better would be the Energy efficiency.

K.N.Shukla etal. [3]The Energy, Energy, and power conversion efficiencies of both the modules have been evaluated based on measured parameters such as solar intensity, ambient temperature, wind speed, and module temperature. Exergetic efficiency of the amorphous PV module varied from 2.44% to 3.92%, whereas it varied from 4.83% to 8.32% for the polycrystalline PV module throughout the day. The energy efficiencies of both the modules are found to be always higher than that of Energy efficiencies and power conversion efficiencies.

M. R. Abdelkader et al.[4]This paper evaluates the performance of different solar modules in a semi-arid climate as in Jordanian. An experiment to investigate the performance of two photovoltaic modules is conducted at different times of the year. The measured parameters in this paper are: output open circuit voltage and short circuit current from the PV modules, ambient temperature, and solar intensity. The relationship between the performance and the efficiency of mono-crystalline was reached 18% of the PV module, and the multi-crystalline PV module was reached 16% measured by the experiment. The performance value of the PV solar module is identified and compared with the output values supplied by the producer of the PV modules and with other PV models.

T.T.Chow et al. [5] A review paper on photovoltaic/thermal hybrid solar technology. They give information about basic concepts, early work, technological development in the 1990s, and performance assessment of the PV system. They also give information about the type of flat-plant PVT collector system and development of concentrator- type design reported in the last decade and miscellaneous and commercial development in the last decade.

Akash Kumar Shukla et al.[6]A review of exergetic assessment of BIPV module using parametric and photonic energy methods in this paper, a detailed review on energy and Energy analysis of building integrated photovoltaic module to evaluate the electrical performance, Energy destruction and Energy efficiency with photonic method has been discussed

Tiwari et al. **[7]**Thermal modelling of photovoltaic (PV) modules and their applications. In this review article, different applications of PV module based on electrical and thermal output has been covered. Also, in that article, he analyzed the detailed description and thermal model of PV and hybrid photovoltaic thermal (HPVT) systems, using water and air as the working fluid. The numerical modelling and analysis of thermal and electrical output of PV and HPVT in terms of overall thermal energy and energy has been carried out in this study. From their extensive literature review, they found that the photovoltaic-thermal (PVT) modules were very promising devices, and there exists a lot of scopes to further improve the performances. The CIGS solar cells in the BIPVT system are the most suitable from the energy payback time (EPBT) and energy production factor (EPF) point of view. However, mono-crystalline solar cells in the BIPVT system were found to be the most suitable from the life cycle conversion efficiency (LCCE) point of view.

Soteris A. Kalogirou et al. [8] This review paper presents the Energy analysis of the solar thermal system. It also gives information about various types of solar collectors and the application of solar thermal systems. As solar collectors are an important technology when sustainability is considered, Energy analysis gives more information, and representative performance evaluation is a valuable method to evaluate and compare possible configurations of this performance evaluation.

S. Armstrong et al. **[9]**A thermal model for photovoltaic panels under varying atmospheric conditions, and it is interested in determiningthe thermal response time of the PV panel, are analyzed on his work. It is measurements the wind speed, global radiation, PV panel back surface temperature, and ambient temperature are used to calculate the convective and radioactive heat loss from the panel. The predicted time constant values are compared to the measured time constant under the three different wind speeds.

Arvind Tiwari, et al. [10] Performance evaluation of solar photovoltaic/thermal systems and also analyzed to Energy analysis of integrated photovoltaic thermal solar water heater under Constant flow rate and constant collection temperature modes. It is observed that the overall Energy efficiency indicating the optimum value of flow rate of 0.006 kg/s as reported earlier. However, thermal efficiency increases significantly with an increase of flow rate up to 0.006 kg/s, and then increase is marginal as expected. For comparison, the hourly variation of the solar cell, back surface PV module, water temperature, and solar cell efficiency has been evaluated.

Latifa Sabri et al.[11]In this study, experimental research concerning the effect of Ambient Conditions on Thermal Properties of Photovoltaic Cells are analyzed,and comparison has been made on Crystalline and Amorphous Silicon.The influence of cell temperature on the thermal characteristics such as the specific heat and thermal conductivity of the cell shows that specific heat increases exponentially by increasing the cell temperature and also indicates the thermal conductivity decreases linearly for both crystalline and amorphous silicon.

Dubey et al. [12] Evaluated the energetic and exergetic performance of a PV/T air collector with an air duct above the absorber plate and the one with an air duct below the absorber plate. It is found that the latter gives better results in terms of thermal energy, electrical energy, and Energy gain.

K. Sudhakar et al.[13]analysis of Energy and Energy 36 W solar photovoltaic modules,it is concluded that energy is a more effective and more efficient tool for the performance analysis of the solar panel.

Swapnil Dubey et al. [14] Energy and energy analysis of PV/T air collectors connected in series. The hourly variation of cell temperature and cell efficiency shows that as the temperature increases, cell efficiency decreases. The result shows that forthe present design of the PV module, the cell efficiency decrease by 1.6% with an increase in cell temperature by 24.4 8C.

Adarsh Kumar Pandey et al. [15] investigated the Energy and Energy performance evaluation of a typical solar photovoltaic module, Using different parameters of the module obtain the cell efficiency =19.9 and module efficiency = 17.4 of PV module efficiency.

C. Schwingshackl et al.[16]Wind effect on PV module temperature: Analysis of different techniques for an accurate estimationwas tested on several existing models to evaluate the PV module temperature as a function of solar irradiance, ambient temperature, and wind. Here the data are taken from a large PV power plant from the city of Bolzano (Italy) located at the bottom of an alpine valley. This PV power plant consists of different PV technologies and is equipped with several instruments to monitor solar radiation, wind speed and direction, ambient, and PV cell temperatures.

M. Pathak et al.**[17]**Optimizing Limited Solar Roof Access by Energy Analysis of Solar Thermal, Photovoltaic, and Hybrid Thermal Systems, Which are able to utilize all of the thermal and electrical energy generated, are superior in Energy performance to either PV+T or PV only systems.

Mehid Hosseini et al.[18]They are analyzed Energy and Energy of fuel cell; they are combined heat and power type systems, means a hybrid system for residential applications. It was found the energy and Energy efficiency of the PV system. They are 17% and 18.3% respectively.

Nouar Aoun et al.[19]Study of Experimental Energy and Energy of mono-crystalline PV Panel In this paper,it is found from the cloudy day that the energy efficiency varied between 22.3% and 17.2%, the Energy efficiency varies between 5.3% and 12% and power energy efficiency varies from 12.3% to 16.1%. However, from the clear days. The energy efficiency varied between 10.83% and 21.85%, and the Energy efficiency varies between 7.98% and 14.54%, and power energy efficiency varies from 8.1% to 16.38%. While from the clear days (i.e., March 23), the energy efficiency varied between 9.28%

Problems identification and Objectives: After reading the above-mentioned literature review, it is found that many experiments have been performed, and models have been developed to evaluate the performance of the PV module. Based on the work and results from this experiment and models, the following observations are made:-

- Some previous observation was taking an only hazy day
- This observation was only one day work
- Single crystalline, Amorphous, and hybrid solar cell efficiency are less as compared to the polycrystalline solar cells.

The objectives of the work are:-

- To determine the energy analysis of the PV module for the different climatic condition at Bhopal
- To determine Energy analysis of PV module for the different climatic condition at Bhopal

III.Experimental methodology: In this work, evaluating the performance of 10W solar modules for different climatic conditions like clear sky, hazy day, and cloudy day at Bhopal India. Experimental test reading is conducted at the Energy centre MANIT Bhopal, India, for the different climatic conditionson different days. The performance efficiency of the PV module is calculated by energy analysis as energy analysis is very convenient for predicting the efficiency of solar panels than energy analysis. The calculation is done by taking climatic conditions into account because parameters like wind speed, ambient temperature, and solar intensity were varying with time throughout the day.The specifications of various instrumentsused for measuring the design parameters in terms of range, resolution, and sampling time for the photovoltaic module, initial climatic conditions, and PV module (RE 1216)specification are listed in Table1 2 & 3,respectively.Before performing an experiment on the PV module, the following assumptions have been made-

- It includes both heat transfer coefficient like convective and radiative in the overall heat transfer coefficient (U).
- All the parameters (climatic, operating and design) are considered at standard test condition (STC).
- Fill factor (FF) varies according to ambient temperature and solar radiation intensity despite that it is assumed to be constant.
- For the assessment of Thermal, electrical and Energy efficiency of the PV system, it has been assumed that energy content received by the photovoltaic surface is fully utilized to generate maximum electrical energy.

Table No.1 Specification of measuring tools used.

SN	Name of measuring instrument	Manufacturing and model no.	Rating	Application
1.	Solar power meter	TM-207 (Taiwan)	0 – 1999W/m^2	Solar radiation intensity
2.	solar module analyzer	MECO (9009) (india)	V_{oc}= 0-60V I_{sc}= 0-12A	PV module characteristics
3.	Infrared Gun (thermometer)	Raytek (China)	0-500 °C	Ambient temperature and Humidity
4.	Thermo Hygrometer	HT-3006A (China)	0-100% 0-100 °C	Ambient temperature and Humidity
5.	Multimeter	Rish muth 155 (india)	R , 0-100 Ω V, 0-1000V I, 0-300mA,0-10A	PV module output current and voltage

Table No. 2 Climatic,operatinganddesignparameters

Inputparameters	Values
Nominaloperatingmoduletemperature(T_{mod})	41°C
Ambienttemperature (T_{amb})	35°C
Solarradiation(I_S)	1000W/m^2
StefanBoltzmannconstant (σ)	5.67×10^{-8}W/m^2k
The emissivityofthepanel(ε)	0.9
Suntemperature(T_{sun})	5760K
Average windvelocity(u_{air})	0.5m/s

Table No.3 Specificationsof(polycrystalline model no-RE 1216) PV module

Parameters	Specifications
Maximumpower (P_m)	10W
Open-circuit voltage (V_{oc})	21.5V
Short-circuit current(I_{sc})	650Ma
Numberofcell'sinmodule	36
Specificsizeofthemodule(A_{mod})	34×28 cm
Maximumpowerpointvoltage(V_{mp})	17.8V
Maximumpowerpointcurrent(I_{mp})	590 Ma
Fillfactor (FF)	0.78
Tolerance atpeak power	+5%
Standard test condition (STC) Irradiation, spectrum and cell temperature	1000W/m^2, $AM_{1.5}$, 25°C

IV. EXPERIMENTAL DATA SHEET: An experiment was conducted on a RE 1216 PV module at the different climatic condition of Bhopal, India at a different time in 2016 from 9 a.m. to 5 p.m. the following table showing the measured average value of three continuous days of a clear day, hazy day and cloudy days respectively.

Table No.4 Average of Three days' Experimental Data For Clear Day (Month January)

Time	Ambient Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)	Solar Intensity (W/m²)	Module Temperature (°C)	Energy efficiency					
						V_{oc}	V_m	I_{sc}	I_m	P_{max}	η
09:00 AM	12	1.49	34.6	681.66	15	15.14	15.75	0.33	0.34	5.45	8.25
10:00 AM	14	2.37	35.63	751.66	17	15.23	15.88	0.36	0.37	5.87	8.21
11:00 AM	19	1.76	35.94	860	23	15.78	16.25	0.46	0.50	8.17	9.97
12:00 AM	23	1.85	37.47	967.66	28	16.26	17.08	0.49	0.54	9.33	10.12
01:00 PM	24	1.60	36.61	990.33	29	16.48	17.68	0.53	0.56	10.01	10.61
02:00 PM	25	2.34	39.18	975	30	16.90	17.28	0.52	0.56	9.73	10.48
03:00 PM	22	1.34	40.14	848.33	28	16.51	17.0	0.46	0.48	8.25	10.22
04:00 PM	20	1.49	38.61	746.66	23	15.76	16.29	0.33	0.38	6.29	8.84
05:00 PM	17	1.65	38.48	636.66	19	14.79	15.81	0.3	0.33	5.32	8.77

Table No. 5 Average of Three Days' Experimental Data for Hazy Day (Month June)

Time	Ambient Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)	Solar Intensity (W/m²)	Module Temperature (°C)	Energy efficiency					
						V_{oc}	V_m	I_{sc}	I_m	P_{max}	η
09:00AM	32	1.53	55	626.66	33	13.82	15.14	0.10	0.12	1.81	2.63
10:00AM	35	1.44	51.13	690	37	13.9	15.29	0.12	0.15	2.32	3.53
11:00AM	37	2.1	45.8	638.33	39	13.98	14.74	0.18	0.19	2.79	3.76
12:00AM	38	1.42	39.66	581.33	40	14.74	15.17	0.24	0.24	3.73	6.44
01:00PM	39	0.42	36.33	756.66	45	13.86	15.30	0.22	0.29	4.62	4.62
02:00PM	40	1.80	33.4	542	46	13.98	15.07	0.15	0.16	2.40	4.16
03:00PM	38	0.82	40.73	514.33	45	13.86	15.42	0.16	0.19	2.92	5.87
04:00PM	37	1.90	37.86	95	38	11.68	12.96	0.07	0.08	1.04	5.46
05:00PM	36	1.18	40.1	49.33	37	11.95	11.53	0.01	0.01	0.23	1.72

Table No.6 Average Three days of the experimental data sheetfor cloudy days (Month August)

Time	Ambient Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)	Solar Intensity (W/m²)	Module Temperature (°C)	Energy efficiency					
						V_{oc}	V_m	I_{sc}	I_m	P_{max}	η
09:00 AM	25	1.86	39.66	45.66	28	8.91	9.46	0.061	0.06	0.592	0.39
10:00 AM	27	1.93	38	68	30	9.37	9.96	0.083	0.08	0.819	0.55
11:00 AM	29	2.3	37.33	93.33	31	9.67	10.27	0.35	0.09	0.975	0.91
12:00 AM	32	2.1	38.66	163	35	9.77	10.48	0.107	0.1	1.21	1.40
01:00 PM	34	1.83	40.5	218.33	38	10.37	10.98	0.117	0.103	1.32	1.25
02:00 PM	36	1.93	41.66	265	40	10.90	11.62	0.122	0.111	1.23	2.17
03:00 PM	32	1.63	31.96	163.66	38	10.38	11.02	0.358	0.092	1.022	1.34
04:00 PM	29	1.9	29.86	66.66	33	9.24	10	0.079	0.070	0.702	0.72
05:00 PM	27	0.83	26.63	31	31	9.06	9.28	0.038	0.027	0.253	0.37

V. RESULTS AND DISCUSSION

Results: The effect of climatic change, operating, and design parameters on the performance of the polycrystalline PV module is observed using selective instruments. Analysis of this work provides information about the Energy efficiency of solar PV module, which has been measure on the basis of the second law of thermodynamics, using the energy from solar radiation. Convective heat transfer coefficient (h_{conv}) between the PV module surface and the ambient air does not affect the performance of the PV module. The following fig. shows the variation of energy and energy efficiency at the different climatic conditions with respect to time.

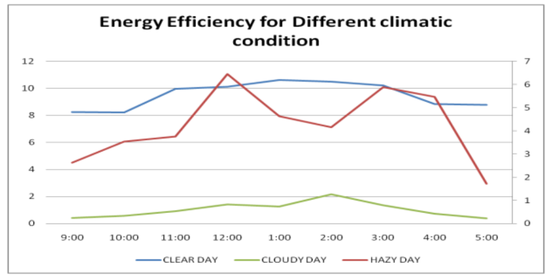

Fig.1 shows a comparison of energy efficiency for the different climatic conditions of the 10-watt polycrystalline module.

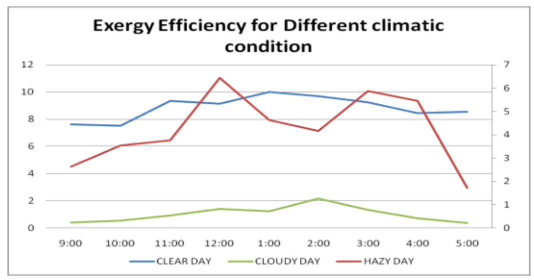

Fig.2 shows a comparison of Energy efficiencies for the different climatic conditions of the 10-watt polycrystalline module.

Discussion: Energy analysis is more convenient than the energy analysis for predicting the efficiency of the solar module. In this experiment, energy (η_{en}) and Energy (η_{ex}) efficiency for Different climatic conditions of a 10 watt polycrystalline PV module were found. Energy efficiency for the clear day is very between 10.61-8.21%. For a hazy day, it is very between 6.44-1.72 %and cloudy day. It is very between 2.17-0.37%, respectively. Energy efficiency for the clear day is very between 10.01-7.53%;for hazy day 5.98-1.03% and the cloudy day, it is very between 1.96-0.22%,respectively. from the experimental study point of view, the clear day of the module shows better performance than a hazy day, but a cloudy day gives very low performance than both days. the slight decrement in the Energy and Energy efficiency is due to the fact that experiments are carried out in actual outdoor environment conditions. the factors that influence the measurement like wind speed, ambient temperature, and Humidity are taken into account in this work.

VI.Conclusions: This thesis presents the experimental study of 10 Watt polycrystalline PV modules for different ambient conditions. PV module based on thermal analysis (Energy and Energy) of the Crystalline Silicon Photovoltaic Solar Module for the different ambient conditions has been carried out. This experimental data was obtained by some basic measuring instruments giving accurate measurement during the end days of summer. The experimental data obtained through measurements during the experiment was analyzed to find the optimum temperature, which leads to the Energy efficiency analysis and to calculate maximum efficiency and maximum solar power conversion efficiency of the module. The Energy loss in the photovoltaic conversion process of the module has also been found out by this analysis.

The following conclusions are written by the experimental and theoretical study:

- The result showed that cloudy day for PV module has a low Energy efficiency (η_{ex}= 1.96%) as compared to both days Energy efficiency, i.e.,the clear day was (η_{ex}= 10.01) to hazy day was (η_{ex}= 5.98%) the Energy analysis showed that for all different climatic conditions take very little advantage of the high Energy content of solar radiation.
- For three days of work of the module, the average values of Energy efficiency (η_{ex}) and power conversion efficiency (η_{spce}) for the clear, hazy and cloudy day are found to be (η_{ex} = 7.42, η_{ex} = 5.32 and η_{ex} = 1.47) and (η_{spce} = 8.55, η_{spce} =6.33 and η_{spce} = 3.33) respectively.
- The average value of energy efficiency for a clear day, Hazy day, and cloudy day are found to be (η_{en}= 10.61, η_{en}= 6.44, and η_{en}= 2.17), respectively. It is shown that energy efficiency (η_{en}) is always higher than the other efficiencies.
- The result showed that the polycrystalline photovoltaic module is dependent on the solar intensity of the sun. When the intensity of the sun is the low efficiency of the module is also low when intensity is high-efficiency is also maximum to achieved by the module.
- Energy analysis is a more effective and more efficient tool for the performance analysis of the solar panel.
- When solar radiation and ambient temperature increases on summer days due to increasing the cell temperature and loss of energy (irreversibility) of the module. That condition output energy generation (Electricity) increases.

Future scope of work

- The study can be conducted for further improvement of the energy of the solar module.
- Effectiveness can be studied by developing low-cost Semiconductor materials.
- Study on minimizing losses of modules.

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