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THERMAL PRACTICAL APPROACH OF PLOYCRYSATALLINE PV MODULE ON VARIOUS CLIMATIC SPECTRAL VARIATIONS

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Abstract: Solar renewable energy source has the potential to fullfill the energy demands with the groth of radiation absorvent material and futher improvement of emerging technology in upcoming years and reserchers are working on the level best. Solar Energy demand globally has been growing day-by-day and at about 30% per annum over the past 15 years. In comparison, the hydrocarbon demand growth rate is 0-2% per annum. This high growth rate in solar energy is due to many reasons – increasing cost of petroleum products and the parallel decreasing cost of producing power from solar, and a concern world over on the harmful effects of using fossil fuels. Thesis presents thermal analysis for 10 W polycrystalline solar photovoltaic modules with regard to the first and second laws of thermodynamics by taking analytical and experimental test readings at, Bhopal and observations were taken for different ambient conditions. Evaluation was done energy, exergy or availability, and power conversion efficiency of the module. This evaluation depends on various parameters like Sectral wavelength variation, solar intensity, wind speed module temperature and ambient temperature. On Earth surface temperature varies with the geographical location so its is neccessity to evaluate the thermal performance of PV module at various gegraphical location so installation facility successfulluy improved with maximum power production in an efficeint manner.

Both spectral irradiation wavelength and temperature are mutually reciprocal to each other and variable in nature with earth climatic change. Energy efficiency of PV module clear day, Hazy day and cloudy day at different spectral wavelength are found to be (η_{en}= 10.61, η_{en}= 6.44 and η_{en}= 2.17), Exergetic efficiency of polycrystalline photovoltaic module varied from (η_{ex} = 10.01, η_{ex}= 7.42, η_{ex} = 5.32 and η_{ex} = 1.47) to 0.37% for different ambient conditions and power conversion efficiency (η_{spce}) for different ambient conditions (η_{spce} = 8.55, η_{spce} =6.33 and η_{spce} = 3.33). Through the study is clear that PV modules are very promising devices for power generation and can provide longer energy supply at lesser cost. All these evaluation and analysis will result to give recommendation that will benefit to improve the efficiency of PV module, along with making it cost effective and more compatible in today's market and installation facilities of PV module should be prevailing at each geographic location in India so that huge amount of spectral energy can be effectively utilized into electrical energy to full fill our daily electric demand.

Key Words: - Spectral Wavelength Variation, Energy efficiency, Exergy efficiency, Climatic Condition, power conversion efficiency, PV module, Renewable energy.

I. INTRODUCTION

Today, renewable energy source, which are 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 causes that they are the direct cause of global warming increases. There are different type of renewable energy sources are available on the earth. They are likes solar energy, wind energy, biomass energy, geothermal energy, ocean energy, hydroelectric power etc. While solar energy is best alternative source for non renewable energy sources because it is abundant on earth are available. 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 condition, 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 a 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). 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 exergy analysis is to determine exergy losses (true thermodynamic losses) in processes & systems and to minimization of losses / optimization of driving forces.

II. LITERATURE REVIEW

A comprehensive review of the literature has been done on thermal analysis (Energy and Exergy) Solar photovoltaic (SPV) systems in the present chapter. The literature review on the exergo 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 exergo economic then the literature are:-

Nuruddeen Abdullahi et. al. [1] in this work researchers have been made a significant effect and program to understand the performance and modeling concepts of PV module under various conditions such as wind, dust and snow which are often and may lead to the degradation of PV module. This paper presents a study on the performance of an 85W mono crystalline PV module under different conditions with measurement being taken under indoor and outdoor condition. The measure result have shown that the module is capable of generating 17.75W/m^2 with an efficiency of 7% and 138W/m^2 with an efficiency of 8% from indoor office building and outdoor condition respectively during summer time which makes it possible to contribution of PV researchers to identify the suitable applications such as embedded device.

Jannik Heusinger et. al. [2] In this a new energy balance model that accurately simulates the complete diurnal dynamics of PV module thermal behavior with routinely available meterological input, the model is evaluated extensively against observed module surface temperature (Day & night time), electrical output and sensible heat flux measurements. It is also demonstrated that different tracking systems have a significant effect on module temperature and sensible heat fluxes by moduling the total radiation received on the PV surface. This experiment work is performed on clear and cloudy sky.

M. R. Abdelkader [3] this paper evaluates the performance of different solar modules in 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 PV module and multi crystalline PV module was reached 16% measured by 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 [4] 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 PV system. They also give information about 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.

Alcantara S.P., Del et.al. [5] Solar photovoltaic (SPV) systems are a device which is directly convert solar radiation in the form of heat and electrical energy. Solar energy reaching on the earth surface can be utilized directly in two ways, firstly by converting directly electrical energy (electricity) through solar photovoltaic Modules secondly, by heating the medium by means of solar collectors for low temperature heating applications. Currently, most of solar photovoltaic (SPV) modules are based on crystalline silicon technology which is basically dived into three technologies viz. Mono-crystalline silicon (m-Si), multi-crystalline silicon (mc-Si) and ribbon silicon. In general it has been found that the mono-crystalline- silicon is more expensive than that of multi-crystalline-silicon and as far as the efficiency is concerned, so it is proved that m-Si based module is better than that of mc-Si module. The single crystal silicon is made of a cylindrical ingot and the crystal lattice of the entire sample is continuous with no grain boundaries. On the other hand, the multi-crystalline are made of square ingot and composed of multiple small silicon crystals.

R. Gottschalag et.al. [6] in this work they have presented an accurate modelling of system performance with an experimental investigation to know the effect of spectral variation in a maritime climatic condition on the performance of single and double junction amorphus silicon solar cell. After experiment the result found that the spectral variation impacts on the short circuit current, the current at the maximum power point, the fill factor and the overall efficiency. The experiment was conducted on a single and double junction amorphus silicon cells.

Ricardo Ruther et. al. [7] in this work the comparative study was done on outer door operation and monitoring of amorphus silicon and traditional and qquite well understood operation of the crystalline silicon. To evaluate the module performance the term fill factor playing an interested role as a photovolatic characteristic. The PV cells are exposed to different seasonal condition at different solar spectral vcontents and intensities and evaluated the reults of spectral effects on fill factor. In this work voltage dependent spectral responds of a amorphus silicon devices is also described and quantified and also find that the performance of amorphus silicon modules should be treated more precisely with respect to spectra to reveal their true operational characteristics.

Giuseppina Ciulla et.al. [8] In this work hybrid system for combined production of electric and thermal energy is implemented to optimize the process of energy production. The necessary operating parameter considers is temperature of PV module. In this work an alternative method which is based on the employment of artificial neural network (ANNs) was proposed to predict the operating temperature of PV module. This methodology is characterized by a great flexibility and reliability providing excellent results for any kind of modules mono crystalline or polycrystalline.

D.G.Infield et.al. [9] In this work the magnitude of variation of incident solar spectrum and its potential influence on the performance of thin film solar cell in s maritime climate has been investigated. The experimental work conducted at same location in UK at 10 minute interval over a period of 30 months and magnitude of spectral variation is presented on a daily basis and it is found that amorphus silicon is the most susceptible to changes in the spectral distribution with the useful frication of the light varying in the range of +6% to –9% of the annual avg, with the maximum occurring in summer time.

K. Sudhakar et al. [10] analysis of Energy and exergy 36 W solar photovoltaic module it is concluded that exergy is a more effective and more efficient tool for the performance analysis of the solar panel.

Pankaj Yadav et.al. [11] In this work a piecework linear parabolic trough collector is designed to concentrate solar radiation on mono cryatalline silicon based PV module for which a theoretical model is used to perform electrical energy and exergy analysis of flow concentration PV system working under actual test condition. The result of this work is exergy efficiency of LCPV system is in the range from 5.1% to 4.82% with increasing rate of input exergy rate from 30.81W to 96.12W when concentration ratio changes from 1.85 to 5.17. the result confirm that the commercially available silicon solar Pv module performs satisfactorily under low concentration.

Sahin et al. [12] The thermodynamic characteristics of the solar photovoltaic (PV) cells using exergy analysis. They 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 exergy efficiencies, the energy efficiency was found to be varying between 7-12% during the day while, the exergy efficiency was found to be varying between 2-8% Investigated by.

Joshi et al. [13] The performance characteristics of a photovoltaic (PV) and photovoltaic-thermal (PV/T) system using energy and exergy analysis for the New Delhi, India. They found that in the case of PV/T, the energy efficiency varies between 33-45%, \while the corresponding exergy efficiency varies between 11-16%. On the other hand, for PV alone, the exergy efficiency was found to be varying in the range of 8-14% for a typical set of operating parameters. They also calculated the fill factor in order to know the behavior of the exergy efficiency of the SPV systems and found that the higher the fill factor better would be the exergy efficiency .

K.N.Shukla et.al. [14] The energy, exergy, 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 amorphous PV module varied from 2.44% to 3.92% whereas it varied from 4.83% to 8.32% for polycrystalline PV module throughout the day. The energy efficiencies of both the modules are found to be always higher than that of exergy efficiencies and power conversion efficiencies.

Akash kumar shukla et.al. [15] A review of exergetic assessment of BIPV module using parametric and photonic energy methods in this paper, a detailed review on energy and exergy analysis of building integrated photovoltaic module to evaluate the electrical performance, exergy destruction and exergy efficiency with photonic method has been discussed

Tiwari et al. [16] Thermal modeling of photovoltaic (PV) modules and their applications. In the review article different applications of PV module based on electrical and thermal output has been covered. Also in that article they covered 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 an overall thermal energy and exergy 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 scope 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. [17] This review paper presents the exergy analysis of solar thermal system. It also gives the information about various types of solar collectors and application of solar thermal systems. As solar collectors are an important technology when sustainability is considered, exergy 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. [18] A thermal model for photovoltaic panels under varying atmospheric conditions and It is a interested to determined thermal response time of the PV panel. 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.

III. 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 PV module. Based on the work and results from these experiment and models, the following observations are made:-

- Some previous observation was taking only hazy day
- These observation was only one day work
- Single crystalline, Amorphous and hybrid solar cell efficiency is less as compared to poly crystalline solar cell.
- Identification of variable solar spectral irradiation at different climatic change.

The objectives of the work are:-

- To determine energy analysis of PV module for different climatic Spectral condition at Bhopal
- To determine exergy analysis of PV module for different climatic Spectral condition at Bhopal

IV. EXPERIMENTAL METHODOLOGY

In this work evaluating the performance of 10W solar modules at various spectral wavelength for different climatic conditions like clear sky, hazy day and cloudy day at Bhopal India. Experimental test reading is conducted at the NRI Institute of Research and Technology Bhopal, India for different climatic condition at different Spectral wavelength in different days. The performance efficiency of PV module is calculated by exergy analysis. As exergy analysis is very convenient for predicting efficiency of solar panel than energy analysis. 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 at various spectral wavelenth variation. The specifications of various instruments used for measuring the design parameters in terms of range, resolution and sampling time for photovoltaic module, initial climatic conditions and PV module (RE 1216) specification are listed in Table 1 & 2 respectively. Before performing an experiment on PV module the following assumptions have been made-

- It includes both heat transfer coefficient like convective and radiative in 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 of that it is assumed to be constant.
For the assessment of Thermal, electrical and exergy efficiency of the PV system it has been assumed that exergy content received by photovoltaic surface is fully utilized to generate maximum electrical energy.

Table No.1 Specification of measuring tools used.

Serial No.	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

Table No. 2 Climatic, operating and design parameters

Input parameters	***Values***
Nominal operating module temperature (T_{mod})	41°C
Ambient temperature (T_{amb})	35°C
Solar radiation (I_S)	1000W/m^2
Stefan Boltzmann constant (σ)	5.67×10^{-8} W/m^2k
Emissivity of the panel (ε)	0.9
Sun temperature (T_{sun})	5760K
Average wind velocity (u_{air})	0.5m/s

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

Parameters	***Specifications***
Maximum power (P_m)	10W
Open-circuit voltage (V_{OC})	21.5V
Short-circuit current (I_{SC})	650Ma
Number of cell's in module	36
Specific size of the module (A_{mod})	34×28 cm
Maximum power point voltage (V_{mp})	17.8V
Maximum power point current (I_{mp})	590 Ma
Fill factor (*FF*)	0.78
Tolerance at peak power	+5%
Standard test condition (STC) Irradiation, spectrum and cell temperature	1000W/m^2, $AM_{1.5}$, 25°C

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

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

Time	Thermal Wavelength (m-K)	Ambient Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)	Solar Intensity (W/m^2)	Module Temperature (°C)	Energy efficiency					
							V_{oc}	V_m	I_{sc}	I_m	P_{max}	η
09:00AM	1.008×10^{-5}	12	1.49	34.6	681.66	15	15.14	15.75	0.33	0.34	5.45	8.25
10:00AM	1.004×10^{-5}	14	2.37	35.63	751.66	17	15.23	15.88	0.36	0.37	5.87	8.21
11:00AM	1.015×10^{-5}	19	1.76	35.94	860	23	15.78	16.25	0.46	0.50	8.17	9.97
12:00AM	9.707×10^{-6}	23	1.85	37.47	967.66	28	16.26	17.08	0.49	0.54	9.33	10.12
01:00PM	1.015×10^{-5}	24	1.60	36.61	990.33	29	16.48	17.68	0.53	0.56	10.01	10.61
02:00PM	1.012×10^{-5}	25	2.34	39.18	975	30	16.90	17.28	0.52	0.56	9.73	10.48
03:00PM	1.019×10^{-5}	22	1.34	40.14	848.33	28	16.51	17.0	0.46	0.48	8.25	10.22
04:00PM	9.944×10^{-6}	20	1.49	38.61	746.66	23	15.76	16.29	0.33	0.38	6.29	8.84
05:00PM	1.006×10^{-5}	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	Thermal Wavelength (m-K)	Ambient Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)	Solar Intensity (W/m^2)	Module Temperature (°C)	Energy efficiency					
							V_{oc}	V_m	I_{sc}	I_m	P_{max}	η
09:00AM	9.595×10^{-6}	32	1.53	55	626.66	33	13.82	15.14	0.10	0.12	1.81	2.63
10:00AM	9.500×10^{-6}	35	1.44	51.13	690	37	13.9	15.29	0.12	0.15	2.32	3.53
11:00AM	9.439×10^{-6}	37	2.1	45.8	638.33	39	13.98	14.74	0.18	0.19	2.79	3.76
12:00AM	9.317×10^{-6}	38	1.42	39.66	581.33	40	14.74	15.17	0.24	0.24	3.73	6.44
01:00PM	9.287×10^{-6}	39	0.42	36.33	756.66	45	13.86	15.30	0.22	0.29	4.62	4.62
02:00PM	9.258×10^{-6}	40	1.80	33.4	542	46	13.98	15.07	0.15	0.16	2.40	4.16
03:00PM	9.408×10^{-6}	38	0.82	40.73	514.33	45	13.86	15.42	0.16	0.19	2.92	5.87
04:00PM	9.439×10^{-6}	37	1.90	37.86	95	38	11.68	12.96	0.07	0.08	1.04	5.46
05:00PM	9.469×10^{-6}	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 experimental data sheet for cloudy days (Month August)

Time	Thermal Wavelength (m-K)	Ambient Temperature (°C)	Wind Speed (m/s)	Relative Humidity (%)	Solar Intensity (W/m^2)	Module Temperature (°C)	Energy efficiency					
							V_{oc}	V_m	I_{sc}	I_m	P_{max}	η
09:00AM	9.724×10^{-6}	25	1.86	39.66	45.66	28	8.91	9.46	0.061	0.06	0.592	0.39
10:00AM	9.659×10^{-6}	27	1.93	38	68	30	9.37	9.96	0.083	0.08	0.819	0.55
11:00AM	9.595×10^{-6}	29	2.3	37.33	93.33	31	9.67	10.27	0.35	0.09	0.975	0.91
12:00AM	9.500×10^{-6}	32	2.1	38.66	163	35	9.77	10.48	0.107	0.1	1.21	1.40
01:00PM	9.439×10^{-6}	34	1.83	40.5	218.33	38	10.37	10.98	0.117	0.103	1.32	1.25
02:00PM	9.377×10^{-6}	36	1.93	41.66	265	40	10.90	11.62	0.122	0.111	1.23	2.17
03:00PM	9.500×10^{-6}	32	1.63	31.96	163.66	38	10.38	11.02	0.358	0.092	1.022	1.34
04:00PM	9.595×10^{-6}	29	1.9	29.86	66.66	33	9.2	10	0.079	0.07	0.702	0.72

							4			0		
05:00PM	$9.659\times10^{\wedge-6}$	27	0.83	26.63	31	31	9.0 6	9.28	0.038	0.02 7	0.253	0.37

V. RESULTS AND DISCUSION

Results: The effect of climatic change, operating, and design parameters on the performance of polycrystalline PV module is observed with respect to various spectral wavelength at different climatic change, using selective instruments. In this paper the summary of complete work is mentioning in the form of some data tables which are an average of three days measurements at all season with respect to climatic change and also in figure form. Analysis of this work provides the information about the exergy efficiency of solar PV module, which has been measure on the basis of 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 PV module. The following fig. shows the variation of energy, exergy, power and efficiency at different climatic condition with respect to time and at different spectral wavelength.

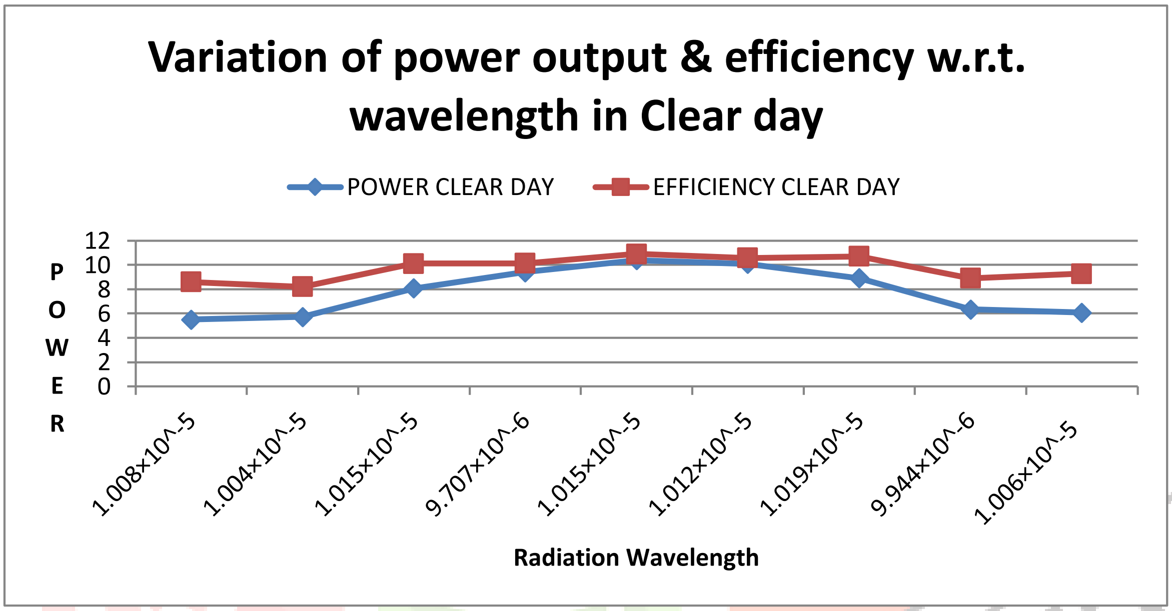

Fig.1 Variation of Power and efficiency w.r.t average radiation wavelength of three days in Clear Day.

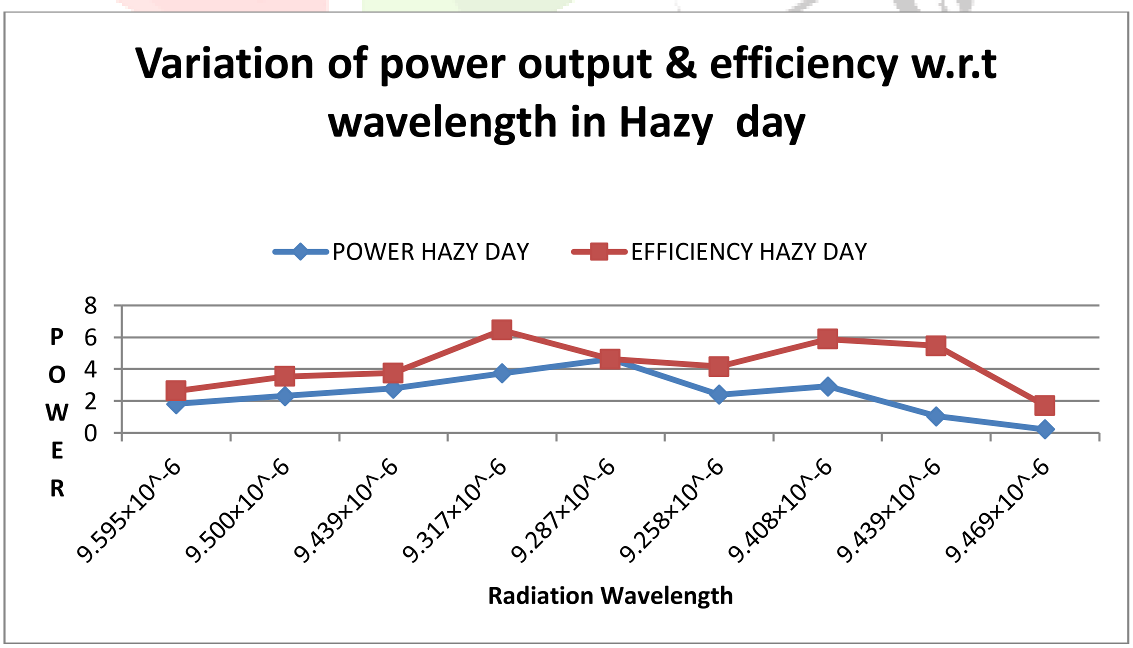

Fig.2 Variation of Power and efficiency w.r.t average radiation wavelength of three days in Hazy Day.

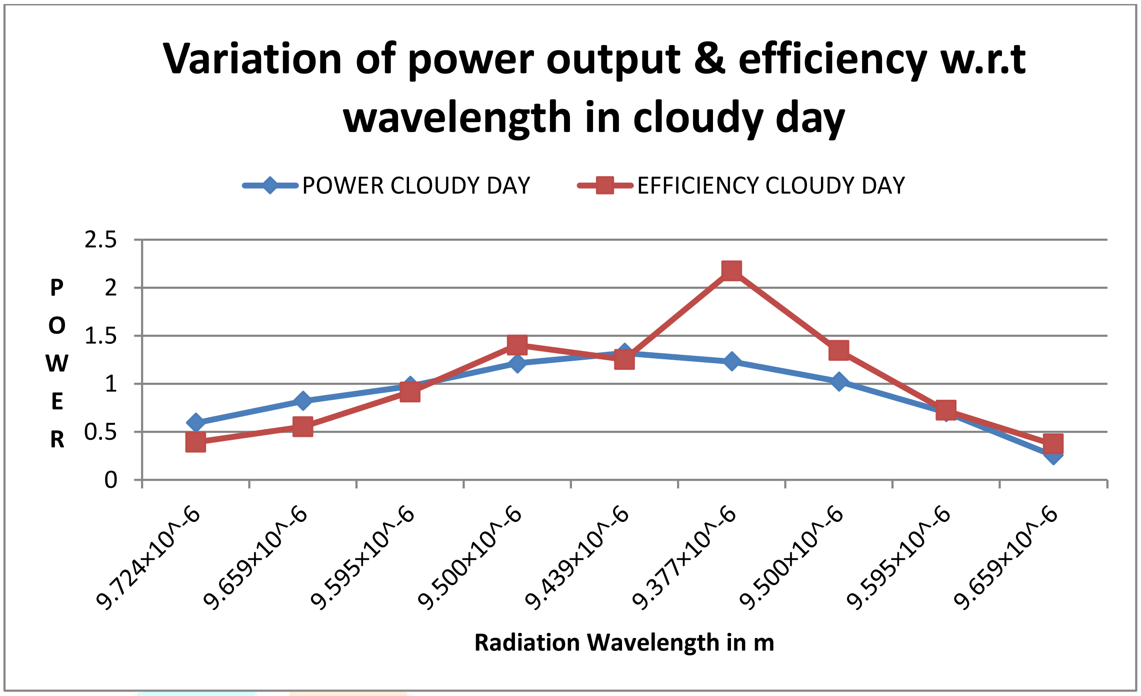

Fig.3 Variation of Power and efficiency w.r.t average radiation wavelength of three days in Cloudy Day.

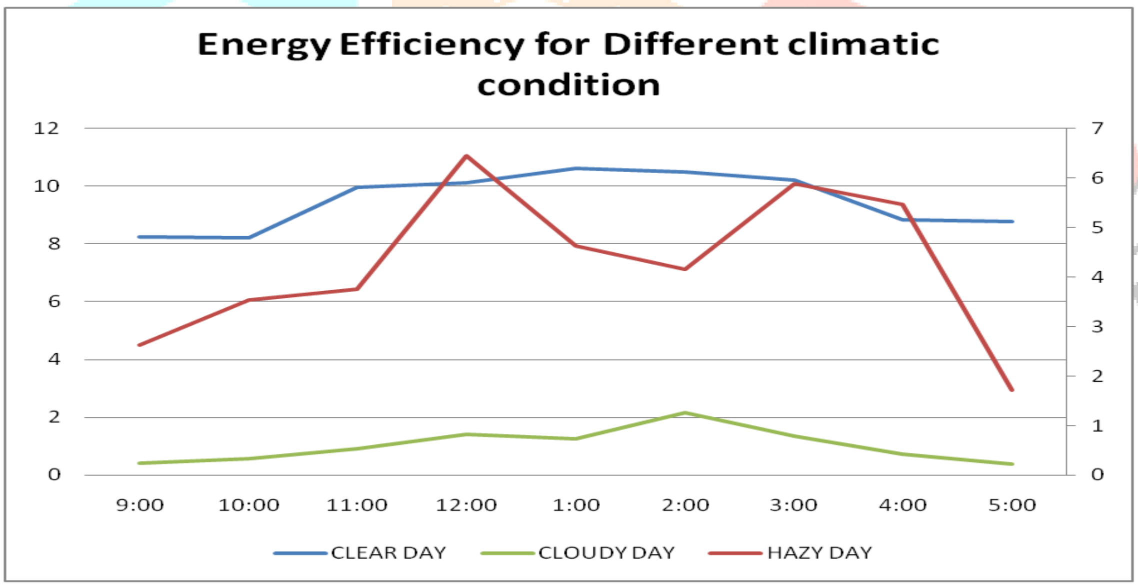

Fig.4 shows comparison of energy efficiency for different climatic condition of 10 watt polycrystalline module.

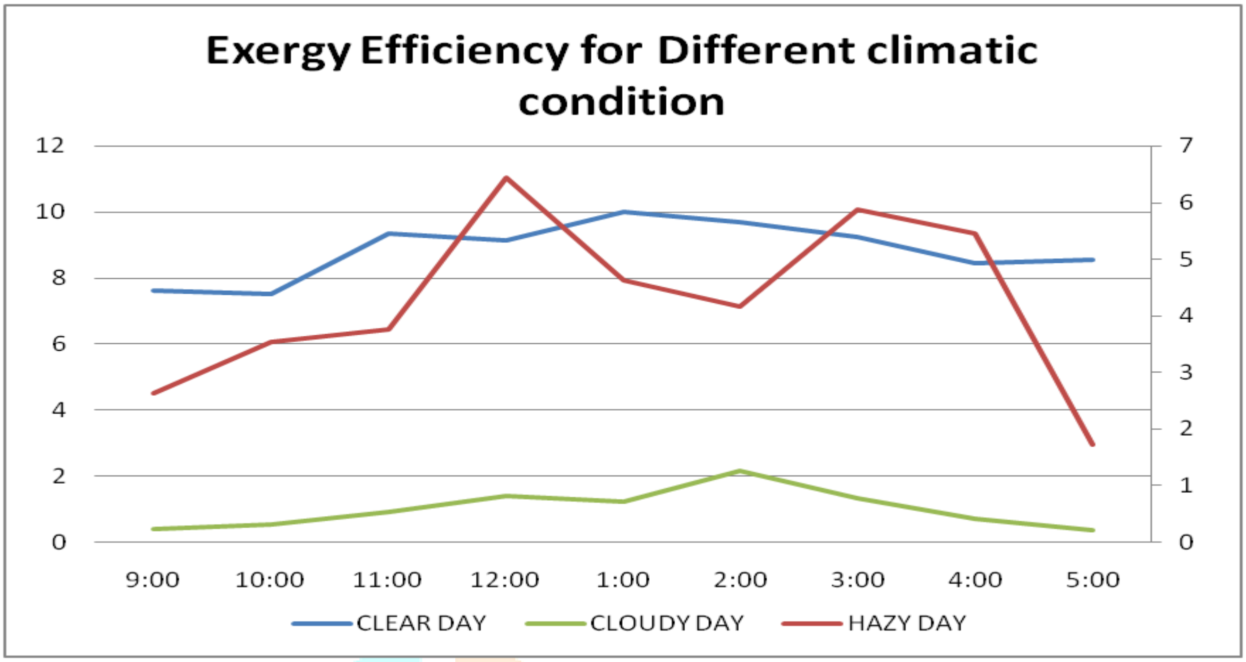

Fig.5 shows comparison of exergy efficiencies for different climatic condition of 10 watt polycrystalline module.

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

Conclusions: This thesis presents the experimental study of 10 Watt polycrystalline PV module for different ambient conditions. PV module based on thermal analysis (Energy and Exergy) of Crystalline Silicon Photovoltaic Solar Module for different ambient condition has been carried out. This experimental data was obtained by some basic measuring instrument 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 exergy efficiency analysis and to calculate maximum efficiency and maximum solar power conversion efficiency of the module. The exergy loss in photovoltaic conversion process of module has also been found out by this analysis.
The following conclusions are written by experimental and theoretical study:

- The result showed that cloudy day for PV module have a low exergy efficiency (η_{ex}= 1.96%) as compared to both days Exergy efficiency i.e clear day was (η_{ex}= 10.01) to hazy day was (η_{ex}= 5.98%) the exergy analysis showed that for all different climatic conditions take very little advantage of the high exergy content of solar radiation.
- For three days work of the module the average values of exergy efficiency (η_{ex}) and power conversion efficiency (η_{spce}) for 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 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 show that energy efficiency (η_{en}) is always higher than the other efficiencies.
- The result showed that polycrystalline photovoltaic module is dependent on solar intensity of the sun. When intensity of the sun is low efficiency of the module is also low when intensity is high-efficiency is also maximum to achieved by the module.
- Exergy analysis is more effective and more efficient tool for the performance analysis of the solar panel.
- When solar radiation and ambient temperature increases in summer days due to increasing the cell temperature and loss of energy (irreversibility) of the module. That condition output energy generation (Electricity) increases.

VI. Future scope of work

- Study can be conducted for further improvement of energy of solar module at various geographical location of earth.
- At various spectral wavelength Effectiveness can be studied by developing low cost Semiconductor materials.
- Study on minimizing losses of modules.

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