


Energy and Exergy Analysis of Solar PV System

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Abstract: The solar PV arrangement produces thermal and electrical energy together using solar PV energy. An experimental attempt has been made in this paper to calculate the energy production and the exergy yield of a solar PV panel mounted at Guntur. Energy and Exergy were analyzed using the first and second rules of thermodynamics to calculate Exergy and energy. This process's structure includes ambient temperature, total heat flow, short-circuit current, solar radiations, open-circuit voltage, fill factor, etc. The heat from the PV solar module is expected to have the greatest impact on the efficiencies. Heat may be eliminated with the aid of water or air to increase both energy and exergy efficiencies.

Keywords: Solar PV module, Thermal Exergy, Electrical Exergy, Electrical efficiency and Exergy efficiency.

1. Introduction

Considering the last few decades, we are creating clean energy sources to supplement traditional energy sources [1-2]. India is sacred with plentiful solar radiation. India is located concerning latitudes 6 and 32 N. In a year, there are 250-300 days of decent sunlit conditions. The atmosphere in India is favorable. We are currently facing environmental challenges, including global warming and resource depletion. Solar energy systems, except for water heating, are not commonly used. Solar cells transform 25% of the energy emitted by the sun into electrical energy.

A solar cell is an electrical system that uses the photovoltaic effect to transform light energy into electrical energy. As light enters the p-n junction, photons will quickly penetrate the junction due to the very thin p-type coating. Since vitality analysis is focused on the quality of vitality potential and the quantities of resources used, energy potential is ignored. Exergy is the maximum work potential gained from energy [3]. Many engineers recognize exergy research for evaluating a thermodynamic device's economic and thermodynamic efficiency [4]. Exergy research is dependent on available capacity and energy availability [5].

Finding the energy consumption potential of an energy conversion device utilizing exergy research. Exergy research is concerned with maximizing exergy distribution. For the efficiency of Exergy and energy tests of solar PV modules, the input and yield of Exergy and energy are analyzed. Geng, Cenegal, and Turner [6] conduct an experimental evaluation of a solar rainwater heating expedient and a study of energy and exergy efficiencies. Hepbasli [7] studied the exergetics research and assessment of clean energy bases for a sustainable future. The significance of this module is as follows: 1) To investigate the exergy and energy research of a solar PV module and 2) Determine the Exergy harms in the solar PV module.

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2. Methodology

2.1 Energy efficiency of the solar PV module

The exergy equation is provided by applying the first rule of thermodynamics to a steady-state open system as (1)

$$Ex_{in} = Ex_{out} \quad (1)$$

$$Ex_{in} - Ex_{out} = Ex_{loss} \quad (2)$$

Equation (2) is an energy balance general equation. When Ex_{in} supply energy for a system then is Ex_{out} is the extreme volume of Exergy obtained from that system. The amount of Exergy absorbed is smaller than the amount of Exergy lost. The energy productivity of a solar PV module is described as the percentage of yield power to input supply. The solar PV module's yield power and energy effectiveness vary conditional on PV insolation and exterior heat. The energy translation efficacy [8] of a PV module is determined using the resulting equation (3)

$$\eta_{energy} = \frac{V_{oc} \times I_{sc} \times ff}{A \times G} \quad (3)$$

Current and voltage of solar PV system in a simple form (4)

$$I = I_1 - I_0 \exp^{(q(V-IR_s))/(AKT)} \quad (4)$$

Electric power production of solar PV module is (5)

$$P_{out} = I * V \quad (5)$$

The extreme power production of solar PV module is presented in Eq. (6)

$$P_{max} = V_{oc} * I_{sc} * ff = V_{mp} * I_{mp} \quad (6)$$

By ignoring convection, conduction, and radiation, the solar PV module transforms solar energy into electrical and thermal energy. The solar PV performance declines as the top surface temperature rises, and the solar PV module may be cooled to increase performance by providing water or air.

2.2 Exergy efficiency of the solar PV module

Exergy research requires energy efficiency, which allows for the utilization of energy capacity. The total exergy equilibrium equation for a solar PV module under steady flow is (7)

$$Exergy In = Exergy Out + Exergy Loss + Irreversibility \quad (7)$$

The ratio of exergy output to the exergy input is known as exergy efficiency (8).

$$\eta_{ex} = \frac{Ex output}{Ex input} \quad (8)$$

Input exergy of a solar PV module: It comprises only solar energy concentration exergy, which effects on solar PV module is given by (9)

$$Ex_{in} = AG \left[1 - \frac{4}{3} \left(\frac{T_{ab}}{T_{sum}} \right) + \frac{1}{3} \left(\frac{T_{ab}}{T_{sum}} \right)^4 \right] \quad (9)$$

Output exergy of a solar PV module: It is calculated as outlet of PV modules includes thermal Exergy and electrical Exergy (10)

$$Ex out = Ex thermal + Ex electrical \quad (10)$$

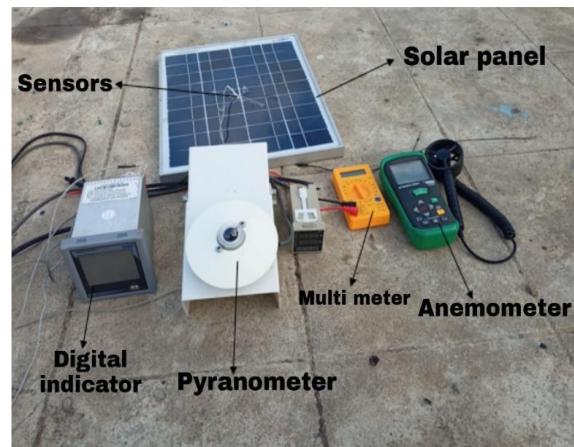


Fig. 1: 20W solar PV module at Guntur

2.3 Experimental investigations

The investigational education was done in the south section of India. The location lies in 13° 17' 50.28" N Latitude and 77° 32' 18.24" E Longitude. The ambient temperature varying between 10°- 40°C during a year in Guntur. The solar PV module was experienced

under some restrictions such as V_{oc} , I_{sc} , V_w , T_a , solar irradiance, etc. The module was tested under the time interval of 9:00 am to 4:00 pm. By using an anemometer the airstream velocity was measured and ambient temperature was dignified by exhausting a temperature indicator. Below tables 1-3 below lists the specifications of a module and the parameters which are analyzed. The input parameter is and specification of the solar PV segment is presented in Table. 1.

Table. 1: Specifications of the experimental setup

Parameter	ECO 020
Maximum power	20 W
Open circuit voltage	21.6 V
Short circuit current	1.29 A
Maximum voltage	600 V
Dimensions	449*354*21
Weight	2.31 Kg
Fill factor	1.19

3. Results and Discussion

The experimental data were collected in January, and the testing was directed at Guntur. In latitude

13.2957 N and longitude 77.5364 E. This experiment is carried out on a sunny day in January. The second rule of thermodynamics is used to quantify exergy performance. Exergy analysis is significant in the study of the solar photovoltaic panel established on experimental results. Variations of solar radiation, atmospheric temperature, and time are presented in Fig.2. The solar radiation levels range from 629 W/m² to 987 W/m². When the solar energy rises, so does the temperature of the solar cells, resulting in a decline in performance. Fig. 3 depicts the differences of solar radiation and Exergy in the solar strength and Exergy radiations are depicted in the above figure. The Exergy in ranges between 80.18 and 188.19. The temperature of the surrounding environment determines the solar radiations. Fig. 4 depicts four fluctuations in global radiation and wind velocity. The above figure depicts the fluctuations of global radiations and wind velocity. The wind intensity ranges from 0.5 m/s to 2.2 m/s. And global radiation levels range from 425 W/m² to 987 W/m². Heat flow between the surface of the module and its environment varies due to differences in wind direction.

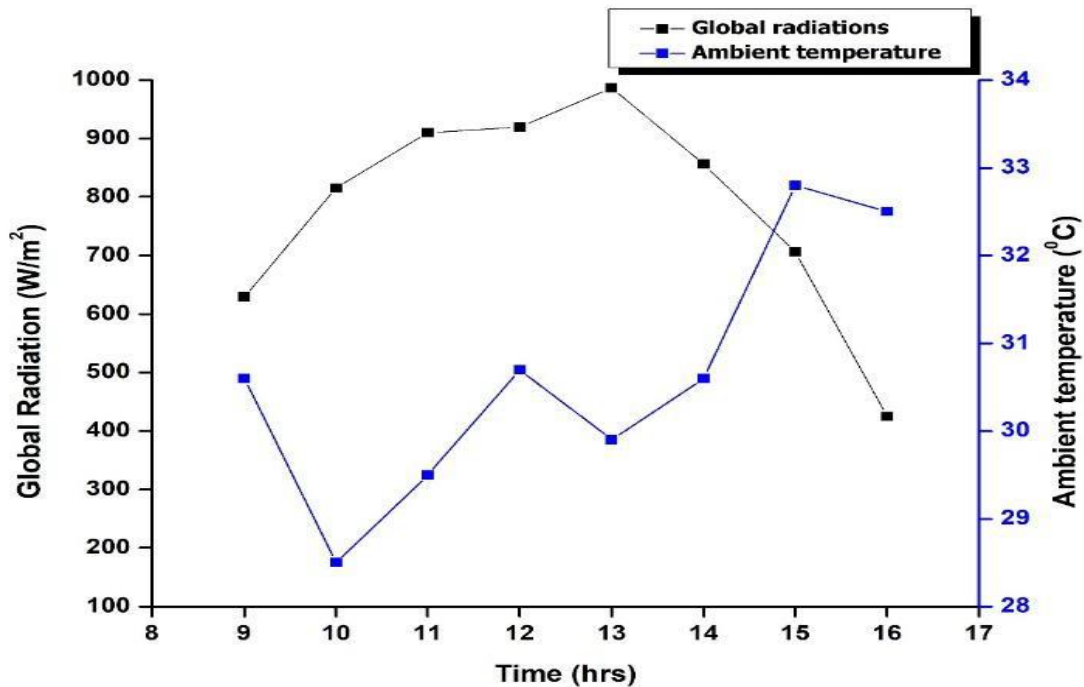


Fig. 2: The above figure depicts the difference of solar radiation strength during the test day.

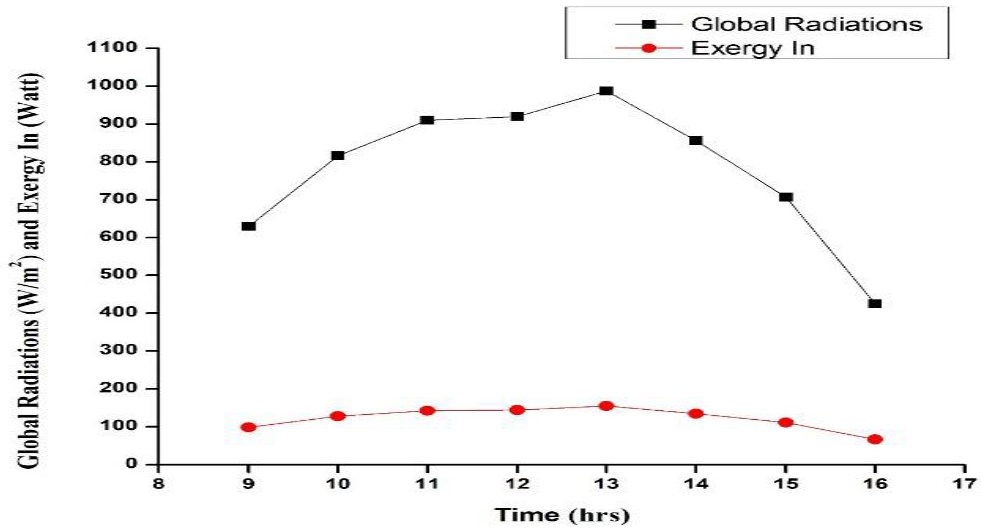


Fig. 3: Variations of solar radiations and exergy

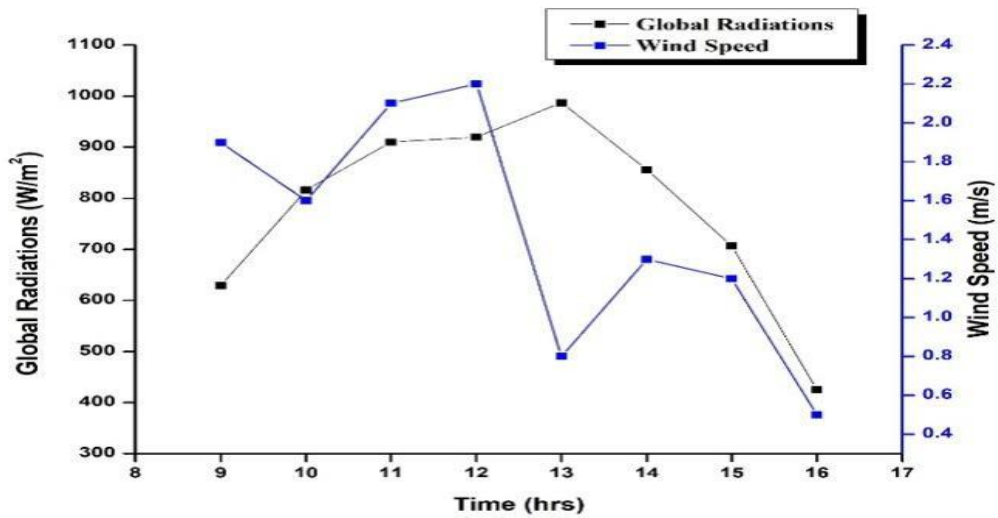


Fig. 4: Variations of global radiations and wind velocity

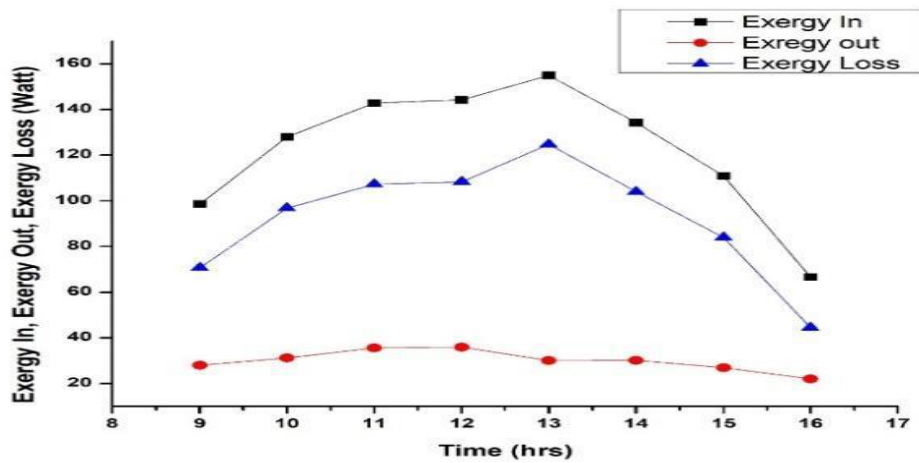


Fig. 5: Variations between Exergy in, Exergy out, and Exergy loss.

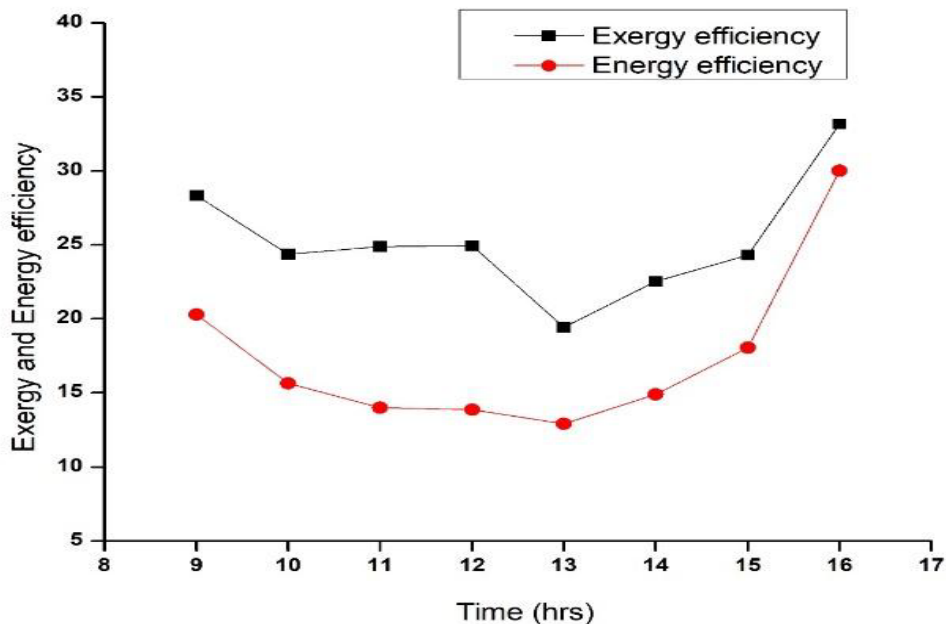


Fig. 6: Exergy and Energy performance of the PV module

Exergy in, Exergy out, and Exergy loss in 5 different ways. Above Fig. 5 illustrates the differences between Exergy in, Exergy out, and Exergy loss. The Exergy in differs between 66.65W and 144.33W, the Exergy out varies between 22.101W and 35.97W, and the exergy loss varies between 44.54W and 108.35W. Above Fig.6 illustrates the variation between exergy performance and energy efficiency. Exergy productivity reduces as the temperature rises, and Exergy performance is increased by cooling the PV module.

4. Conclusion

An exergy and energy review of a 20W solar photovoltaic element was performed at Guntur, India, for this research. An analysis was approved out to analyze the efficiency of a 20W solar photovoltaic module. The investigational findings were achieved by accurately measuring various parameters on a sunny day in January 2021. The collected data is used to determine the optimal exergy performance, exergy losses, and optimum temperature. This experimental research yielded the following results. 1) The outcome result indicates that the PV module has the lowest exergy performance (ex=42.2%) compared to the solar PV module. 2) The air temperature rises when PV exergy falls due to increased cell temperature, and production energy rises as well. 3) The exergy efficiency improves due to solar radiation at first and

then decreases until achieving a limit. 4) Research and development efforts are aimed at developing low-cost semiconductor materials, the performance of solar modules, and lowering the cost of solar PV electricity.

Conflict of Interest

The authors declare that they do not have any conflict of interest

References

- [1] K. Sudhakar and T. Srivastava "Energy and exergy analysis of 36 W solar photovoltaic module", *International Journal of Ambient Energy*, Vol. 35, No. 1, pp. 51-57, 2014.
- [2] Farooqui, S. Zaki. "Impact of load variation on the energy and exergy efficiencies of a single vacuum tube based solar cooker", *Renewable energy*, Vol. 77, pp. 152-158, 2015.
- [3] J. Yoon "Chapter 9 Power Output Characteristics of Transparent a-Si Bi PV Window Module", *Intech Open*, 2011
- [4] A. S. Joshi "Performance analysis of photovoltaic systems: A review", *Renewable and Sustainable Energy Reviews*, Vol. 13, No. 8, pp. 1884-1897, 2009.
- [5] P. Rawat "Performance analysis of partially covered photovoltaic thermal (PVT) water

- collector", *International Journal of Research in Engineering and Technology*, 2016
- [6] F. Sarhaddi "Exergy efficiency of a solar photovoltaic array based on exergy destructions", *Proceedings of the Institution of Mechanical Engineers Part A Journal of Power and Energy*, Vol. 224, No. 6, pp. 813-825, 2010.
- [7] M. A. Deriche, A. Hafaifa, K. Mohammadi "Performance evaluation of A-Si and CdTe solar photovoltaic using energy and exergy analysis", *International Journal of Exergy*, Vol. 32, No. 4, pp. 373-387, 2020
- [8] N. L. Panwar, S. C. Kaushik, S. Kothari "Experimental investigation of energy and exergy efficiencies of domestic size parabolic dish solar cooker", *Journal of Renewable and Sustainable Energy*, Vol. 4, No. 2, pp. 023111, 2012.



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