International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review of Energy and Exergy Analysis of Photo Voltaic Module

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ABSTRACT

The paper presents a comprehensive study on the performance analysis of solar photovoltaic (PV) modules with a focus on energy and exergy perspectives under varying environmental conditions. It explores the working principles of PV systems, types of solar cells, and their efficiencies. An extensive literature review highlights the impact of factors such as temperature, wind, spectral variations, and material types on the performance of PV modules. Various experimental and modeling approaches are discussed, emphasizing the significance of accurate thermal behavior prediction and optimization techniques, including the use of hybrid systems and artificial neural networks (ANNs). The study concludes that enhancing material properties and adapting to climatic conditions are key to improving PV module efficiency, making solar energy a more viable and sustainable energy solution.

Keywords: Solar Photovoltaic (PV) Module, Energy Analysis, Exergy Analysis, PV Efficiency, Spectral Irradiation, Thermal Behavior.

1. INTRODUCTION

1.1 Principal of Solar Module

Sunlight is converted into electrical power using photovoltaic panels. Semiconductor materials are used to make modules. By absorbing solar energy, they are transformed from incident solar radiation into thermal energy. Silicone semiconductor crystals are currently the most often used variety. The n-type and p-type layers of silicon crystal are laminated and stacked on top of one another. Electricity is produced via the "photovoltaic effect," which is caused by light striking crystals. Direct current (DC) is used to produce power, which can be used right away or stored in a battery. Direct current is the power produced by solar panels. Installing the inverter does not require this. It can be used normally once the alternating current to direct current inverter is set up to be in parallel with the mains electricity.

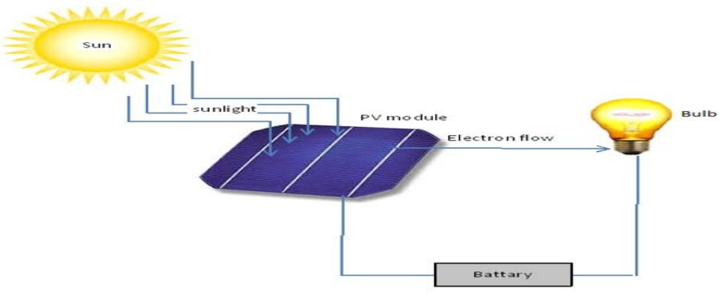

Fig.1.1 Basic concept of PV module

1.2 Types of PV system

The following types of PV system materials are grouped according to their intended application;

i. Silicon solar cells
ii. Single crystalline silicon
iii. Polycrystalline silicon
iv. Amorphous silicon

Table 1.1 Performance of Photovoltaic and Photo eletro chemical Solar Cell

Type of cell	Efficiency (%)		Research and technology needs
	cell	module	
crystalline silicon	24	10-15	Higher production yields, lowering of cost and energy content
multicrystalline silicon	18	9-12	Lower manufacturing costs and complexity
amorphous silicon	13	7	Lower production costs, increase production volume and stability, improve efficiency
Culnse2	19	12	Replace indium (too expensive and limited supply), replace CdS window layer, scale up production
Dye- sensitized	10-11	7	Improve efficiency and high nanostructured materials temperature stability, scale up production.
Bipolar AIGaAs/Si	19-20	-	Reduce materials cost, scale up photo electrochemical cells.
Organic solar cells	2-3	-	Improve stability and efficiency

2. LITERATURE REVIEW

2.1. Literature is Based on Energy and Exergy Analysis

In this chapter, a thorough review of the literature has been conducted on a number of research topics, including hybrid culture of solar power generation of solar photovoltaic (SPV) systems and thermal analysis (Energy and Exergy) at various climatic conditions, particularly at spectral solar irrediation variation. Since one of the goals of the thesis is to assess solar photovoltaic (SPV) systems using the body of knowledge on exergo economics, a survey of the literature on the subject has also been completed. The literature includes the following: -

NuruddeenAbdullahi et. al. [1] Researchers have produced a substantial impact and program in this effort to comprehend the modelling principles and performance of PV modules under a variety of situations, including wind, dust, and snow, which frequently and may cause PV module degradation. An analysis of an 85W monocrystalline PV module's performance under various circumstances is presented in this publication, with measurements made both indoors and outdoors. According to the measurement results, the module can produce 17.75W/m2 with an efficiency of 7% from indoor office buildings and 138W/m2 with an efficiency of 8% from outdoor conditions during the summer. This allows PV researchers to contribute to the identification of appropriate applications, such as embedded devices.

JannikHeusinger et. al. [2] With routinely available meterological input, this new energy balance model accurately simulates the full diurnal dynamics of PV module thermal behaviour. The model is thoroughly tested against sensible heat flux measurements, electrical output, and observed module surface temperature (daily and nighttime). Additionally, it is shown that by varying the total amount of energy received on the PV surface, various tracking systems significantly impact the module temperature and sensible heat fluxes. The sky is clear and overcast when this experiment is conducted.

M. R. Abdelkader [3] This study assesses how well various solar modules function in Jordan's semi-arid climate. At various points during the year, an experiment is carried out to examine the performance of two photovoltaic modules. This article measures the following parameters: sun intensity, ambient temperature, and the PV modules' output open circuit voltage and short circuit current. According to the trial, the efficiency and performance of monocrystalline PV modules were found to be 18% and multicrystalline PV modules to be 16%. The PV solar module's performance value is determined and contrasted with other PV models and the output values provided by the PV module manufacturer.

T.T.Chow [4] A review of hybrid solar technology that combines photovoltaic and thermal technologies. They provide details on fundamental ideas, early research, technology advancements in the 1990s, and PV system performance evaluation. The kind of flat-plant PVT collection system, concentrator-type design development, and other commercial and miscellaneous development during the past ten years are also covered.

Alcantara S.P., Del et.al. [5] One technology that directly converts solar radiation into electrical and thermal energy is the solar photovoltaic (SPV) system. There are two direct ways to use solar energy that reaches the earth's surface: first, by using solar photovoltaic modules to turn it directly into electrical energy (electricity); second, by using solar collectors to heat the medium for low-temperature heating applications. The majority of solar photovoltaic (SPV) modules on the market today are based on crystalline silicon technology, which may be broadly divided into three types: ribbon silicon, multi-crystalline silicon (mc-Si), and mono-crystalline silicon (m-Si).

R. Gottschalag et.al. [6] In order to understand the impact of spectrum change in a marine climate on the performance of single and double junction amorphous silicon solar cells, the authors of this work have presented an accurate prediction of system performance together with an experimental examination. According to the experiment's findings, the spectrum fluctuation affects the fill factor, the short circuit current, the current at the maximum power point, and the overall efficiency. Both single and double junction amorphous silicon cells were used in the experiment.

Ricardo Ruther et. al. [7] This study compared the monitoring and outer door operation of amorphous silicon with the conventional and well-understood operation of crystalline silicon. As a photovolatic feature, the phrase "fill factor" is used to assess the module's performance. The effects of spectral effects on fill factor are assessed after the PV cells are subjected to various seasonal conditions at varying sun spectral contents and intensities. The performance of amorphus silicon modules should be handled more precisely with regard to spectra in order to expose their genuine operational features, according to this paper, which also describes and quantifies the voltage-dependent spectral responses of amorphus silicon devices.

GiuseppinaCiulla et.al. [8] This work optimises the energy production process by implementing a hybrid system that combines the generation of thermal and electric energy. The PV module's temperature is the essential operating parameter to take into account. An alternate technique based on the use of artificial neural networks (ANNs) was put forth in this work to forecast the PV module's operating temperature. This approach offers outstanding results for every type of module, whether monocrystalline or polycrystalline, and is distinguished by its high degree of flexibility and dependability.

D.G.Infield et.al. [9] This study examined the extent of incident solar spectrum variation and its possible impact on thin-film solar cell performance in a maritime environment. Amorphus silicon is found to be the most vulnerable to changes in the spectral distribution, with the useful frication of the light varying between +6% and -9% of the annual average, with the maximum occurring in the summer. The experimental work was carried out at the same location in the UK at 10-minute intervals over a 30-month period, and the magnitude of spectral variation is presented on a daily basis.

K. Sudhakar et al. [10] energy and exergy analysis 36-watt photovoltaic solar module It has been determined that exergy is a more effective and efficient instrument for analysing the solar panel's performance.

Pankaj Yadav et.al. [11] To concentrate solar radiation on a monocrystalline silicon-based photovoltaic module, a piecework linear parabolic trough collector is designed in this work. Electrical energy and exergy analysis of the flow concentration PV system operating under real-world test conditions is done using a theoretical model. As a result of this work, the LCPV system's energy efficiency ranges from 5.1% to 4.82% when the input energy rate increases from 30.81W to 96.12W and the concentration ratio shifts from 1.85 to 5.17. The outcome demonstrates that the silicon solar PV module that is sold commercially operates effectively at low concentrations.

Sahin et al. [12] Using energy analysis, the thermodynamic properties of solar photovoltaic (PV) cells are examined. They created and implemented the novel method for evaluating PV cells, and they discovered that it was practical since it takes thermodynamic parameters like entropy and enthalpy into consideration. Additionally, they examined the PV cells' energy and exergy efficiencies; they discovered that the energy efficiency varied during the day, ranging from 7 to 12%.

Joshi et al. [13] energy and exergy study to determine the performance parameters of photovoltaic (PV) and photovoltaic-thermal (PV/T) systems in New Delhi, India. They discovered that the energy efficiency of PV/T ranges from 33 to 45%, while the equivalent energy efficiency ranges from 11 to 16%. However, for a typical set of operational circumstances, the exergy efficiency for PV alone was shown to vary between 8 and 14%. In order to understand the behaviour of the SPV systems' energy efficiency, they also computed the fill factor. They discovered that the higher the fill factor, the higher the exergy efficiency.

K.N.Shukla et.al. [14] Based on measurable variables like solar intensity, ambient temperature, wind speed, and module temperature, the energy, exergy, and power conversion efficiencies of both modules have been assessed. Over the course of the day, the energetic efficiency of polycrystalline PV modules ranged from 4.83% to 8.32%, whereas that of amorphous PV modules varied from 2.44% to 3.92%. It is discovered that both modules' energy efficiencies are consistently greater than their power conversion and energy efficiency.

Akashkumarshukla et.al. [15] A thorough examination of the energy and exergy analysis of building integrated photovoltaic modules to assess electrical performance, exergy destruction, and exergy efficiency with photonic method has been covered in this paper, which reviews the exergetic assessment of BIPV modules using parametric and photonic energy methods.

Tiwari et al. [16] Applications for thermal modelling of photovoltaic (PV) modules. Various PV module applications based on electrical and thermal output have been discussed in the review article. The comprehensive description and thermal model of PV and hybrid photovoltaic thermal (HPVT) systems, which use air and water as the working fluids, were also included in that article. In this study, the thermal and electrical output of PV and HPVT has been numerically modelled and analysed in terms of total thermal energy and exergy. They concluded from their thorough literature assessment that photovoltaic-thermal (PVT) modules were extremely promising technologies with plenty of room for performance improvement.

Soteris A. Kalogirou et.al. [17] The solar thermal system's energy analysis is presented in this review study. Additionally, it provides information on the many kinds of solar collectors and how solar thermal systems are used. Exergy analysis provides additional information and a representative performance evaluation, which is a useful technique to assess and compare potential configurations of this performance evaluation. Solar collectors are a significant technology when sustainability is taken into account.

S. Armstrong et al. [18] The determination of the PV panel's thermal reaction time is of interest, as is a thermal model for the panels under various atmospheric circumstances. Convective and radioactive heat loss from the PV panel is calculated using data of wind speed, global radiation, back surface temperature, and ambient temperature. The measured time constant under the three distinct wind speeds is contrasted with the projected time constant values.

Arvind Tiwari, et. al. [19] Integrated photovoltaic thermal solar water heater energy analysis under constant flow rate and constant collection temperature modes, as well as performance evaluation of solar photovoltaic/thermal systems. Overall energy efficiency is found to be 0.006 kg/s, which is the optimal flow rate as previously stated. However, up to 0.006 kg/s, thermal efficiency increases significantly; after that, the improvement is modest, as predicted. Solar cell efficiency, water temperature, back surface PV module, and solar cell hourly change have all been assessed for comparison.

LatifaSabri et. al. [20] This study examines experimentally how ambient conditions affect the thermal characteristics of photovoltaic cells made of crystalline and amorphous silicon. The effect of cell temperature on thermal properties, including specific heat and thermal conductivity, demonstrates that specific heat rises exponentially with increasing cell temperature and that, for both crystalline and amorphous silicon, thermal conductivity falls linearly.

Dubey et. al. [21] In terms of thermal energy, electrical energy, and exergy gain, the PV/T air collector with the air duct above the absorber plate performs better than the one with the air duct below the absorber plate, according to an evaluation of their energetic and exergy-related performance.

Swapnil Dubey et. al. [22] Analysis of PV/T air collectors connected in series in terms of energy and exergy. The hourly change between cell temperature and efficiency demonstrates that cell efficiency falls with increasing temperature. According to the results, the cell efficiency of the current PV module design decreases by 1.6% when the cell temperature rises by 24.48C.

Adarshkumarpandey et. al. [23] They examined the energy and exergy performance assessment of a standard solar photovoltaic module, obtaining cell efficiency of 19.9 and module efficiency of 17.4 of PV module efficiency using various module parameters.

C. Schwingshackl et. al. [24] Wind effect on PV module temperature: Various methods for a precise estimate were examined and tested on a number of current models to assess the PV module temperature in relation to wind, ambient temperature, and solar irradiation. We made use of information from a sizable photovoltaic power facility in Bolzano, Italy, which is situated at the base of an alpine valley. This PV power plant uses a variety of PV technologies and has a number of equipment to track the temperature of the PV cells, the surrounding air, wind direction and speed, and solar radiation.

M. Pathak et. al. [25] Optimising Limited Solar Roof Access through Exergy Analysis of Solar Thermal, Photovoltaic, and Hybrid Thermal Systems These systems outperform PV+T or PV only systems in terms of exergy performance since they can use all of the thermal and electrical energy produced.

MehidHosseini et. al. [26] They are examined. Fuel cell energy and exergy are integrated heat and power systems, which makes them hybrid systems suitable for home use. The PV system's energy and exergy efficiency was discovered. They are, respectively, 17% and 18.3%.

NouarAoun et. al. [27] Investigation of Monocrystalline PV Panel Experimental Energy and Exergy According to this article, on cloudy days, energy efficiency ranged from 22.3% to 17.2%, exergy efficiency from 5.3% to 12%, and power energy efficiency from 12.3% to 16.1%. But from the days of clarity. Exergy efficiency ranged from 7.98% to 14.54%, power energy efficiency ranged from 8.1% to 16.38%, and energy efficiency ranged from 10.83% to 21.85%. Exergy efficiency ranges from 1.8% to 15.5%, power energy efficiency ranges from 7.55% to 16.83%, and energy efficiency ranges from 9.28% to 22.1% during the clear days (March 23).

Cheikh El Banany et. al. [28] Examination of monocrystalline solar module performance outdoors and the impact of temperature on energy efficiency. The monocrystalline 30 W PV module's exergetic efficiency ranges from 14.87 to 17.93% each day, according to the results. Additionally, the results demonstrate a drop in efficiency as the module operating temperature rises and a difference in energetic efficiency for the same irradiance.

3. CONCLUSION

It is concluded from the study that PV modules are extremely promising power generation devices that can deliver a longer energy supply at a lower cost. All of these analyses and evaluations will lead to recommendations that will help increase the efficiency of PV modules while also making them more affordable and suitable for today's market. PV module installation facilities should be available in every Indian location so that a vast amount of spectral energy can be efficiently converted into electrical energy to meet our daily needs for electricity. From the literature survey it was found that material plays an important role for increasing the efficiency of PV module. Various methods for a precise estimate were examined and tested on a number of current models to assess the PV module temperature in relation to wind, ambient temperature, and solar irradiation so efficiency is dependent on climatic conditions.

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