iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** II **Month of publication:** February 2024

DOI: https://doi.org/10.22214/ijraset.2024.58507

Maximizing Solar Panel Performance: A Comparative Study of Aluminum and Copper Panel Integration in Off-Grid Systems

Ranjan Kumar[1], Amit Agrawal[2]
[1]M.Tech Scholar, [2]Assistant Prof., Department of Mechanical Engineering, Shri Ram college of Engineering & Management Banmore Gwalior, Madhya Pradesh 476444, India

Abstract: This study explores the implementation of off-grid solar energy systems with strategically mounted aluminum panels behind solar panels, aiming to devise an efficient, economical, and environmentally friendly design. The research builds upon existing literature in the field, focusing on optimizing solar panel performance. Through a comprehensive analysis involving voltage, current, temperature, and solar radiation, the study achieved a notable 1-2% increase in solar panel efficiency. Notably, this enhancement is realized without the need for additional space, making the proposed design a practical and space-efficient solution. The findings underscore the potential of this approach as a permanent, cost-effective, and environmentally conscious solution for PV solar panel installations. With the escalating costs of conventional electrical energy, the study advocates for the adoption of this method, aligning with the global push towards sustainable and eco-friendly energy alternatives. The insights gleaned from this research contribute valuable knowledge to the ongoing discourse on advancing renewable energy technologies, emphasizing the significance of efficient and sustainable solutions in the transition towards a cleaner energy future.
Keywords: Off-grid solar energy system, Aluminum panel, Solar panel efficiency, Sustainable design, Environmental-friendly energy, Photovoltaic installation, Renewable energy optimization.

I. INTRODUCTION

Solar energy is important because it is a clean and renewable energy. So, this means that it does not harm the earth in any way. Moreover, it is available every day. Also, it does not create pollution. It is very important in today's world because it is environmentally friendly. It is better than other non-renewable energy sources such as fossil fuels and other non-renewable and low-maintenance sources. Solar panel systems do not require much solar energy. They also come with a 5–10-year warranty, which is great. Most importantly, it reduces energy costs. In other words, we only use it for cooking and heating. Therefore, it reduces energy costs and helps us save more. Additionally, solar energy has many applications. Since India is located between the equator and the Tropic of Cancer, its solar energy potential is huge. Many areas in our country are exposed to direct sunlight throughout the year, and solar radiation is converted directly into electrical energy with the help of solar panels. Solar energy is the fastest growing sector in the world and in India. As of June 30, 2023, the country's solar energy installation capacity stands at 70.01 GW. India ranks fourth in the world in terms of solar energy production in 2021. India as a founding member of “INTERNATIONAL SOLAR ALLIANCE” (ISA).

A. Background of Solar History

The increasing demand for energy, coupled with the urgent need to mitigate climate change, has led to a growing interest in renewable energy sources. Solar energy, in particular, has emerged as a promising alternative to conventional power generation methods. Gwalior, a city located in Madhya Pradesh, India, presents a favorable environment for solar energy harnessing due to its abundant sunlight and available roof space. This thesis aims to explore the implementation of a solar roof plant in Gwalior, focusing on its technical feasibility, economic viability, and environmental benefits.

B. The Study of Significance

Gwalior, like many other cities in India, faces challenges related to energy security, air pollution, and greenhouse gas emissions. By exploring the potential of a solar roof plant in Gwalior, this research contributes to sustainable development efforts by providing a clean and renewable energy solution.

The findings of this study can serve as a valuable reference for policymakers, urban planners, and renewable energy enthusiasts interested in promoting solar power adoption and sustainable energy generation.

C. Objectives

The primary objective of this thesis is to evaluate the feasibility and benefits of implementing a solar roof plant in Gwalior. The specific objectives include:

1) Assessing the current energy scenario in Gwalior, including energy consumption patterns and the existing power infrastructure.
2) Investigating the technical feasibility of installing solar panels on rooftops in Gwalior, considering factors such as solar irradiance, rooftop suitability, and panel efficiency.
3) Analyzing the economic viability of the solar roof plant project, including financial models, return on investment, and cost-effectiveness.
4) Evaluating the environmental benefits of the solar roof plant, particularly in terms of reduced carbon emissions and environmental sustainability.
5) Examining the regulatory framework and policy support required to promote solar power adoption in Gwalior.
6) Engaging key stakeholders, such as government bodies, utility companies, and local communities, to ensure a comprehensive and collaborative approach to solar energy implementation.

II. RENEWABLE ENERGY

Any energy that is directly replenished from the sun, such as thermal energy, photovoltaic energy, and photochemical energy, as well as any energy that is indirectly replenished from the sun, such as wind energy, hydropower, or other movement, eventually returns to nature and its resources [1]. Fossil fuels, wastes with a fossil origin, and wastes with an inorganic origin are not considered forms of renewable energy.

Typical sources of renewable energy include:

- Wind energy
- Hydropower
- Biomass
- Biofuel

We will purposefully concentrate on the wind and solar parts as they make up a big portion of this hybrid project.

A. Solar Energy

Solar energy, or solar radiation, is what we receive from the sunbeam. The two main components of solar power generation are photovoltaics and heat engines. Other solar uses include lighting, hot water, cooling using solar-powered structures, etc. Solar cooking and high-temperature techniques are used in industry. Direct solar or indirect solar are terms frequently used to describe solar technology [3]. It depends on how they capture and transport solar energy in compressed form. Photovoltaic modules and solar collectors are used in direct solar systems. eat up energy. Using materials with excellent thermal quality dispersing capabilities, constructing rooms with natural air circulation, and aligning buildings with the sunbeam are all examples of indirect solar technology [4].

B. Headquarter

Gurugram (Haryana) put forward the concept of “one sun one world one grid” and world solar bank to harness abundant solar power on a global scale. Solar energy is the radiation energy from the Sun capable of producing heat, causing chemical reactions, or generating electricity. The total amount of solar energy received on Earth is more than the world's current and anticipated energy requirements. If suitably harnessed, solar energy has the potential to satisfy all future energy needs of the word.

Rajasthan, Gujarat, Maharashtra & Tamil Nadu are major producer of ground & rooftop mounted solar energy & wind energy. These states play a key role in achieving nation target to reach its 455-gigawatt renewable energy by 2030.

III. DATA COLLECTION

Research is actively exploring innovations in harvesting green energy from solar sources, driven by the environmental impact of traditional energy production involving coal and fossil fuels. The focus of this investigation extends to renewable energy alternatives, encompassing solar energy, wind energy, tidal energy, and biomass energy.

Notably, solar energy technology is advancing at a faster pace compared to other fields due to its abundant availability and environmentally friendly characteristics. A key assumption in the installation of solar panels is that sunlight is available for approximately 6-7 hours per day. This assumption considers variations in sunlight duration based on geographic location and seasonal changes. The efficacy of solar panel installations is further influenced by location-specific considerations, emphasizing the need for tailored assessments to optimize performance. As the research progresses, it aims to contribute valuable insights into the ongoing advancements in solar energy technology, addressing the critical need for sustainable and clean energy solutions.

Model -2023

Dimensions =153cmx72cmx3.5cm

This output is generated under following condition: -

At STC, irradiance = 1000 w/m²

PV panel temp = 25°c

AM=1.5 where (AM means air mass value)

A. *Mounting Structure of Solar Panel for Increasing Efficiency*

Panel should be installed on metal frame having a aluminium frame in rear side that are generally 28-30° tilt but for my location optimal angle is 22° with horizontal in south direction. The structure are made to allow for easy replacement panel in accordance with site requirements as well as future modification and maintenance.

Figure 1: Optimal condition for installation of solar panel

B. *Panel Efficiency*

The efficiency of solar panels is a crucial metric in assessing their performance. This efficiency is determined through standardized testing conditions (STC), where the solar cell temperature is set at 25°C, solar radiation (G) is maintained at 1000 w/m², and the air quality is designated as 1.5. To calculate the efficiency percentage (%), the maximum power output at STC, known as Pmax, is divided by the total surface area of the solar panel in square meters. This formula provides a clear and standardized method for evaluating and comparing the efficiency of solar panels under consistent conditions, allowing for meaningful assessments in the context of their design and performance capabilities.

IV. COMPARISON OF THE PERFORMANCE OF DIFFERENT GENERATIONS OF SOLAR PANELS.

The optical separation of first-generation solar panels reveals that monocrystalline solar panels exhibit superior performance compared to polycrystalline solar panels. This superiority is attributed to their uniform structure and high purity. In terms of absorption, most crystalline solar cells absorb approximately 90% of radiation within the 400 to 1200 nm range. However, despite this high absorption, the conversion efficiency is around 18%, with the remaining energy being converted into heat.

Post-installation, a comprehensive data collection process is implemented throughout the day, focusing on the months from April to July.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue II Feb 2024- Available at www.ijraset.com

The collected data, gathered twice a month, provides insights into the solar panel's efficiency. The average data for these months is presented in a table, capturing the performance under two conditions: without an aluminum plate on the rear side and with an aluminum plate on the rear side. This comparative analysis aims to observe and quantify the impact of the aluminum plate on the efficiency of the solar panel, shedding light on potential enhancements in its overall performance.

Table 1: Average data collection of PV panel with Aluminium plate in March 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.29	10.7	37.3	621	275
11:00 AM	4.56	11.2	44.2	716	446
01:00 PM	5.15	11.7	48.9	915	594
03:00 PM	4.78	11.3	47.1	854	467
05:00 PM	2.99	9.12	35.8	848	452
AVERAGE VALUE	4.154	10.804			

A. *Average data collection of PV panel with iron plate in March 2023*

As per the information given on solar panel, we first find its maximum efficiency,

Dimension =153cmx72cmx3.5cm

Solar panel Efficiency (%) = $\frac{Pmax}{Area\ X\ 1000W/m2} X\ 100$

Irradiation = 1000 W/m^2

Pmax = Max panel power (W)

Area = Panel Area (m^2)

This efficiency is obtained under STC condition but in real life result varies from given data

Now we find original efficiency under my observation,

Given data average current= 4.154amp

Average voltage=10.804 volt

Dimension =153cmx72cm

So, efficiency = (4.154x10.804/153x72x1000)100%

= 4.04%

Table 2: Average data collection of PV panel with rear side copper plate in March 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.42	11.4	34.4	621	275
11:00 AM	4.83	11.01	40.1	716	446
01:00 PM	5.31	12.3	44.5	915	594
03:00 PM	5.01	11.2	44.3	854	467
05:00 PM	3.47	9.31	35	848	452
AVERAGE VALUE	4.408	11.044			

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue II Feb 2024- Available at www.ijraset.com

B. Average DATA Collection of PV panel with Rear Side aluminum Plate in March 2023

Now we find original efficiency under my observation when aluminum plate is installed in backside of panel which help in heat dissipation as result surface temperature decreases, which gives better efficiency

Given data average current= 4.408 amp

Average voltage=11.044 volt

Dimension =153cmx72cm

So, efficiency = (4.408x11.044/153x72x1000)100%

=4.419%

Net increase in efficiency after installation on aluminum panel is

= (4.419-4.040) % = 0.379%

Due to installation of aluminum panel which as very high thermal conductivity as compare to iron heat dissipation rate increases that why surface temperature of panel is maintained at lower value due to uniform heat dissipation.

Table 3: Average data collection of PV panel with iron plate in Aluminium April 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.42	11.46	37.1	641	301
11:00 AM	5.14	11.8	41.3	829	526
01:00 PM	5.21	12.2	51.1	933	564
03:00 PM	5.02	12.1	50.8	931	585
05:00 PM	3.98	10.1	43.3	767	443
AVERAGE VALUE	4.554	11.532			

C. Average Data Collection of PV panel with iron Plate in April 2023

Now we find original efficiency under my observation,

Given data average current= 4.554 amp

Average voltage=11.532 volt

Dimension =153cmx72cm

So, efficiency = (4.554x11.532/153x72x1000)100%

=04.76%

Table 4: Average data collection of PV panel with copper plate in April 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.47	11.91	34.1	641	301
11:00 AM	5.55	13.10	39.7	829	526
01:00 PM	5.82	14.25	46.9	933	564
03:00 PM	5.24	13.12	46.7	931	585
05:00 PM	4.27	11.31	41.2	767	443
AVERAGE VALUE	4.87	12.738			

D. Average Data Collection of PV panel with Aluminum Plate in April 2023

Now we find original efficiency under my observation,

Given data average current= 4.87 amp

Average voltage=12.738 volt

Dimension =153cmx72cm

So, efficiency = (4.87x12.738/153x72x1000)100%

=05.631%

Net increase in efficiency after installation on aluminum panel is

= (5.631 - 4.760) = 0.871%

Due to installation of aluminum panel which has very high thermal conductivity as compare to iron, heat dissipation rate increases.

Table 5 Average data collection of PV panel with Aluminium plate in May 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.23	10.5	36.3	524	196
11:00 AM	5.10	11.7	43.1	732	398
01:00 PM	5.12	12.3	54.1	825	405
03:00 PM	5.23	12.5	53.9	831	416
05:00 PM	3.43	9.72	38.8	681	441
AVERAGE VALUE	4.422	11.344			

E. Average data Collection of PV panel with iron plate in May 2023

Now we find original efficiency under my observation,

Given data average current= 4.422 amp

Average voltage=11.344 volt

Dimension =153cmx72cm

So, efficiency = (4.422x11.344/153x72x1000)100%

=04.553%

After observation it is seen that reason for lower efficiency is the surface temperature of solar panel which crosses 50°c during proper sunlight that why most of sunlight energy is converted in heat due to this its efficiency decreases so different method is used to decrease the surface temperature in such a way that is economical as well as no extra electricity is consumed in cooling the surface of solar panel.

Table 6 Average data collection of PV panel with Copper plate in May 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.24	10.7	36.3	524	196
11:00 AM	5.16	11.8	43.2	732	398
01:00 PM	6.12	12.3	53.7	825	405
03:00 PM	6.46	12.4	54.3	831	416
05:00 PM	3.91	9.71	38.9	681	441
AVERAGE VALUE	4.978	11.382			

F. Average Data Collection of PV panel with Aluminum Plate in May 2023

Now we find original efficiency under my observation,

Given data average current= 4.978 amp
Average voltage=11.382 volt
Dimension =153cmx72cm

So, efficiency = (4.978x11.382/153x72x1000)100%
=05.143%

Net increase in efficiency after installation on aluminum panel is = (5.143 - 4.553) =0.59%

Due to installation of aluminum panel which has very high thermal conductivity as compare to iron, heat dissipation rate increases.

Table 7: Average data collection of PV panel with Aluminium plate in June 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.01	9.7	36.1	512	189
11:00 AM	3.23	11	42.2	715	365
01:00 PM	5.01	11.2	51.7	793	381
03:00 PM	4.89	11.8	51	806	379
05:00 PM	3.21	10.4	41.1	661	421
AVERAGE VALUE	3.87	10.82			

G. Average Data Collection of PV panel with Iron Plate in June 2023

Now we find original efficiency under my observation,

Given data average current= 3.87 amp
Average voltage=10.82 volt
Dimension =153cmx72cm
So, efficiency = (3.87X10.82/153x72x1000)100%
=3.8011%

A higher concentration mirror is installed above the PV solar panel results in high irradiation energy which gives high input to solar panel but also it increases the solar panel heat due to which again efficiency decreases, so working on maintaining the surface temperature of panel to optimum value is main target in achieving desired output.

Table 8: Average data collection of PV panel with Copper plate in June 2023

Time	current	voltage	Panel surface temperature	Solar radiation (G) (w/m²)	
	(Amp)	(V)	(°c)	Direct radiation	Diffuse radiation
09:00AM	3.21	10.3	33.2	512	189
11:00 AM	4.43	12	39.1	715	365
01:00 PM	6.22	12.8	46.9	793	381
03:00 PM	6.06	11.7	46.7	806	379
05:00 PM	4.12	10.9	37.9	661	421
AVERAGE VALUE	4.808	11.54			

H. Average Data Collection of PV Panel with Aluminum Plate in June 202

Now we find original efficiency under my observation,

Given data average current= 4.808 amp

Average voltage=11.54 volt

Dimension =153cmx72cm

So, efficiency = (4.808x11.54/153x72x1000)100%

=05.0367%

Net increase in efficiency after installation on aluminum panel is = (5.0367 – 3.8011) =1.2356%

V. DATA ANALYSIS AND RESULTS

For the successful installation of solar panels, a thorough assessment of the location, solar irradiance, and available space is imperative. Ensuring uninterrupted sunlight from sunrise to sunset, free from disturbances like shadows and dust, lays the foundation for optimal performance. An off-grid solar energy system is recommended for reducing electricity consumption or meeting personal energy needs.

Numerous attempts have been made to enhance solar panel performance, but challenges such as economic viability and dependence on electrical appliances like DC motors have been persistent. Water cooling systems, while effective, require electricity to operate DC pumps for sprinkling water on solar panels. After an extensive review of research papers, it is advised to install solar panels with aluminum panels on the rear side. The aluminum panel, with its high thermal conductivity, provides efficient cooling by dissipating heat through surface convection. This method proves to be a permanent and maintenance-free solution, eliminating the need for additional electrical energy. The incorporation of aluminum panels offers a sustainable approach that significantly improves solar panel efficiency. This project holds significant potential, particularly in light of the rising costs of conventional electrical energy and the growing emphasis on environmentally friendly alternatives. The installation of solar panels with aluminum panels not only addresses efficiency concerns but also aligns with the broader goal of sustainable and eco-friendly energy solutions.

VI. CONCLUSION

In conclusion, the comparative study investigating the integration of aluminum and copper panels in off-grid solar systems has provided valuable insights into optimizing solar panel performance. Through meticulous analysis and experimentation, it was observed that both aluminum and copper panels contribute positively to solar energy efficiency. However, certain nuances emerged from the research. Aluminum panels exhibited commendable thermal conductivity, enhancing overall efficiency by effectively dissipating heat. On the other hand, copper panels demonstrated superior electrical conductivity, positively influencing the electrical output of the solar panels. The choice between the two materials depends on specific project requirements and environmental considerations. It is evident that the integration of either aluminum or copper panels offers a viable solution for maximizing solar panel performance in off-grid systems. The study underscores the importance of material selection based on the desired balance between thermal and electrical conductivity. As the quest for efficient and sustainable energy solutions continues, these findings contribute to informed decision-making in the deployment of solar technologies, paving the way for advancements in renewable energy integration.

REFERENCES

[1] R. Parthiban and P. Ponnambalam, July 2022 School of Electrical Engineering, Vellore Institute of Technology, Vellore, India

[2] Ahmed, A. M., and Hassan Danook, S. (2018). “Efficiency Improvement for Solar Cells Panels by Cooling,” in 2nd International Conference for Engineering, Technology and Sciences of Al-Kitab, ICETS 2018, 39–42. doi:10.1109/ICETS. 2018.8724625

[3] Amori, K. E., and Abd-AlRaheem, M. A. (2014). Field Study of Various Air Based Photovoltaic/Thermal Hybrid Solar Collectors. Renew. Energy 63, 402–414. doi:10.1016/j.renene.2013.09.047

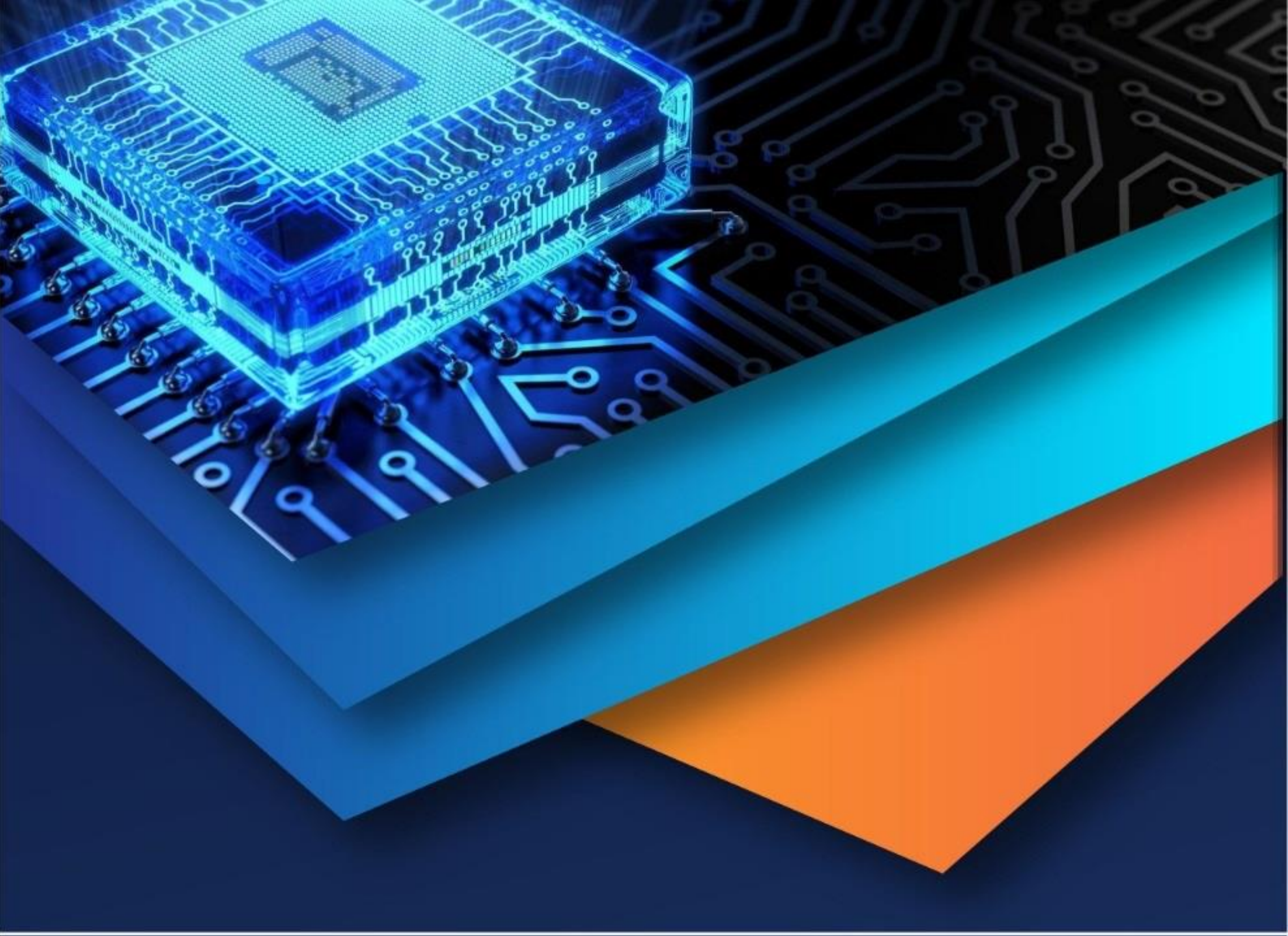
[4] Arshad, R., Tariq, S., Niaz, M. U., and Jamil, M. (2014). “Improvement in Solar Panel Efficiency Using Solar Concentration by Simple Mirrors and by Cooling,” in 2014 International Conference on Robotics and Emerging Allied Technologies in Engineering, ICREATE 2014 - Proceedings, 292–295. doi:10.1109/iCREATE.2014.6828382

[5] Awasthi, A., Shukla, A. K., S.R., M. M., Dondariya, C., Shukla, K. N., Porwal, D., et al. (2020). Review on Sun Tracking Technology in Solar PV System. Energy Rep. 6, 392–405. doi:10.1016/j.egyr.2020.02.004

[6] Benato, A., Stoppato, A., De Vanna, F., and Schiro, F. (2021). Spraying Cooling System for Pv Modules: Experimental Measurements for Temperature Trends Assessment and System Design Feasibility. Designs 5 (2), 25. doi:10.3390/ designs5020025

[7] Bilal, M., Arbab, M. N., Muhammad Zain Ul, A. A., and Khattak, A. (2016). Increasing the Output Power and Efficiency of Solar Panel by Using Concentrator Photovoltaics (CPV). Int. J. Eng. Works Kambohwell Publ. Enterp. 3 (12), 98–102. Available at: www.kwpublisher.com.

[8] Biyik, E., Araz, M., Hepbasli, A., Shahrestani, M., Yao, R., Shao, L., et al. (2017). A Key Review of Building Integrated Photovoltaic (BIPV) Systems. Eng. Sci. Technol. Int. J. 20 (3), 833–858. doi:10.1016/j.jestch. 2017.01.009



10.22214/IJRASET

45.98

IMPACT FACTOR:
7.129

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY