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Boosting Solar Panel Efficiency Through Mirror Based Light Reflection Technology

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ABSTRACT—

This research undertakes a comprehensive investigation into innovative techniques aimed at amplifying solar panel efficiency, with a specific focus on mirror and aluminum foil reflection methods. A thorough analysis of three distinct scenarios is conducted to evaluate the effectiveness of these reflection techniques in enhancing energy output. The experimental findings reveal a notable enhancement in energy output, with the mirror reflection technique yielding a significant increase in power output. Furthermore, the combination of mirrors and aluminum foil results in a remarkable efficiency of 93%, demonstrating a substantial improvement in energy harvesting. The study demonstrates the practical viability and benefits of these reflection techniques, highlighting their potential to enhance the performance of solar panels, reduce costs, and promote sustainable energy generation. The findings of this research have significant implications for the development of more efficient solar panel systems, and provide valuable insights for policymakers, practitioners, and researchers in the field of renewable energy.

Keywords— Photovoltaic panel, light reflector, light source, Instantaneous light, Solar tower.

1. INTRODUCTION

The proliferation of electrical power energy applications has accelerated in recent years, driven by digitalization, industrialization, and technological advancements. Consequently, electrical power utility applications have expanded significantly, fueled by innovative inventions. However, the pressing issue of climate change necessitates a shift towards non-vulnerable energy sources for power generation. Fortunately, various non-vulnerable energy sources, including bio gas, hydal, wind, and solar energy, offer socio-economically sustainable energy generation options [1] [2] [3] [4]. Photovoltaic-based sustainable energy is a prominent environmentally friendly energy source that provides an auxiliary power source to grid-connected power systems. Nevertheless, the intermittent nature of solar photovoltaic (PV) energy generation poses a significant challenge [5] [6]. Furthermore, the limited power output of solar PV systems necessitates the use of larger panels to meet substantial load current requirements, which increases costs and space requirements. Although multiple maximum power point tracking (MPPT) schemes have been developed to address this issue, they often fail to provide optimal solutions in terms of cost and space constraints [7-12]. Recently, researchers have explored the concept of light reflection to enhance power generation under limited light source conditions, as illustrated in Figure 1 [13] [14] [15]. While this approach has shown promise, its potential for opto-economical extreme power generation remains limited [16]. Therefore, further research into light reflection methodologies is necessary to achieve efficient and cost-effective solar PV energy generation. This study investigates the concept of light reflection and presents experimental findings that demonstrate its potential for enhancing solar panel efficiency.

Figure 1. PV panel under sunlight reflection

2. CONCEPT OF LIGHT REFLECTION TECHNIQUE

Solar PV cells are p-n junction semiconductor devices working on the photovoltaic effect, converting incident solar light energy into electricity. Sunlight comprises various light intensity rays with different energy levels. Typically, a minimum of 3 eV photon energy is required to activate electrons in the p-n semiconductor device's depletion region. However, only ultraviolet light rays possess this energy, and they are limited in our atmosphere [14]. Therefore, improving commercial PV cell efficiency requires increasing input light energy. Although increasing sunlight intensity is impractical, designing PV panels with strategically placed light-reflecting materials can provide multiple sunlight reflections, augmenting usual solar light incidence. Light reflections are classified into regular and irregular reflections, as shown in Figure 2 [15] [16]. This study focuses on regular reflections due to the plane surface nature of light-reflecting materials. Mirrors are arranged at suitable reflecting angles on the top side of solar PV panels, and aluminum foil is employed on the bottom side to achieve optimal power generation within space constraints. The study is described in the following sections. However, using mirrors is limited due to concentrated heat generation on cells, which can be nullified by suggesting proper reflecting angles.

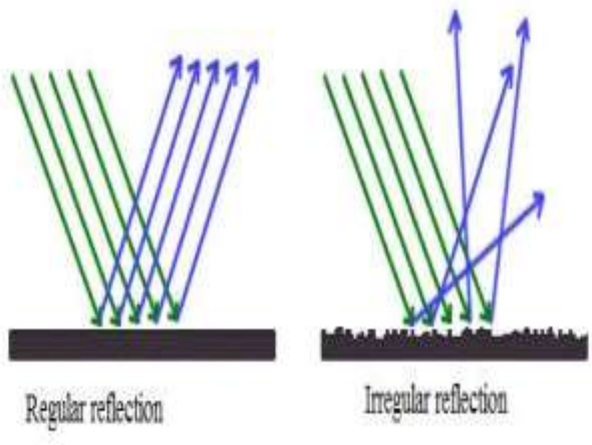

Figure 2. Regular and Irregular surface based light reflections

3. EXPERIMENTAL RESULTS

To evaluate the innovative light source reflection methodology, various experimental investigations are carried out using PV panels. The small size PV panels rated with 18.25 volts and 280 mA shown in figure 3 .

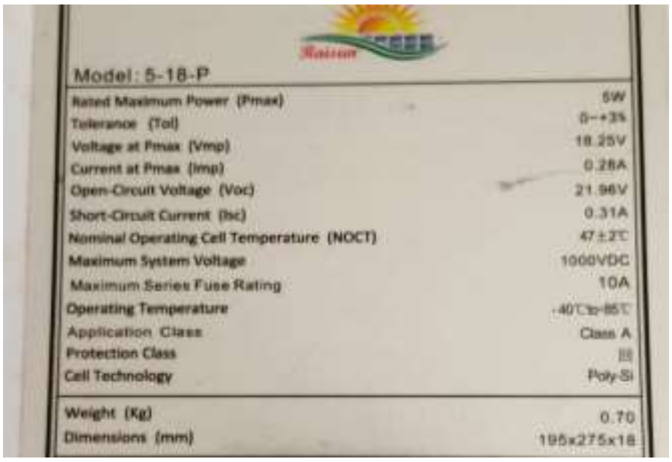

Figure 3. PV panel ratings.

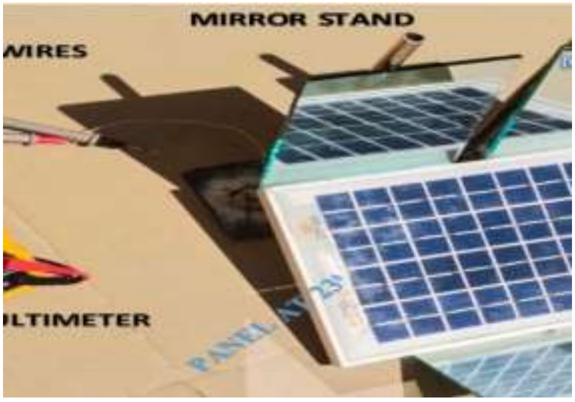

Figure 4. PV panel design arrangement outside.

A. CASE STUDY 1: Without mirrors and without Aluminum foil

The design arrangements consist PV panels are arranged.For this design configuration, experimental measurements are carried out under direct sun exposure shown in figure 5 and figure 6.

Figure 5. PV panel ampers

Figure 6. PV panel with voltage

The experimental measurements are recorded at 17 V and 182.2 mA per panel .

B. CASE STUDY 2: With mirrors and with out Aluminum foil

The experimental investigations are extended to consider the application of mirrors with PV panels. First, one mirror was arranged for multiple tilt angle positions from 10° to 80° to conquer the maximum current drawn from the panel. Mirror tilt angles at 30° and 45° approximately conquers the maximum current generation. Also, the measurements are continued for two mirror design arrangement at same tilt angles which shown in figure 7.

Figure 7.Ampers reading for PV panel with mirrror

The results show that the use of mirrors without aluminum foil increases the output power by 15.3% compared to the standard panel, and achieves an efficiency of 18.92%. This demonstrates the potential of mirrors to enhance the performance of solar panels, even without the use of aluminum foil.

Figure 8. Volatge reading for PV panel with mirror

C. CASE STUDY 3: With mirrors and with Aluminum foil

The experimental investigations are extended to consider the application of mirrors with PV panels. First, one mirror was arranged for multiple tilt angle positions from 10° to 80° to conquer the maximum current drawn from the panel. Mirror tilt angles at 30° and 45° approximately conquers the maximum current generation

Figure 9.Ampers reading for PV panel with mirrror & aluminium foil

Figure 10.Voltage reading for PV panel with mirrror & aluminium foil

The experimental results presented in Table 1 demonstrate substantial improvements in panel efficiencies. A notable achievement is the 93% panel efficiency and 4.65 W output power attained through the application of mirrors and aluminum foil. This represents a significant increase in efficiency compared to the standard panel. Furthermore, the results reveal that the proposed light reflection methodology can enhance the performance of solar panels, reducing the need for larger panels and promoting optimal space utilization. This outcome substantiates the effectiveness of the proposed light reflection technology in enabling cost-effective operation and sustainable energy generation.

Table 1. Comparison of the PV panel efficiencies for various panel design configurations.

Item/ Description				Efficiency (%)
	Voltage (V)	Current (mA)	Output Power (W)	
With out Mirrors and with out Aluminum foil	17.1	182.2	3.11	62.2
With Mirrors and with out Aluminum foil	18.92	190.7	3.59	71.8
With Mirrors and with Aluminum foil	20.7	225.1	4.65	93

4. CONCLUSION

The experimental investigation demonstrates the effectiveness of the proposed light reflection technology in enhancing the efficiency and output power of solar panels. The results show that the combination of mirrors and aluminum foil achieves the highest efficiency of 93%.

Compared to the standard panel without mirrors and aluminum foil, the proposed technology increases the efficiency by 50.7% (from 62.2% to 93%). These findings confirm that the proposed light reflection technology has the potential to improve the performance of solar panels, reduce the need for larger panels, and promote sustainable energy generation.

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