

An Enhancement of the Solar Panel Efficiency: A Comprehensive Review

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Abstract— In recent years, solar panels have emerged as one of the most promising non-conventional energy sources for generating clean and sustainable electricity. However, a major limitation lies in the decline of photovoltaic efficiency with rising ambient temperatures. For every 1 °C increase above Standard Test Conditions (STC), the energy output decreases by approximately 0.33%. As a result, the power generated may become insufficient to meet the required load demand. This challenge is particularly critical in applications like standalone electric vehicles, where the available space restricts the installation of additional solar panels to compensate for the reduced output. To overcome this issue, effective cooling solutions are necessary to minimize excess heat and improve performance. Various cooling approaches, categorized into active and passive techniques, have been explored. This paper provides a comprehensive review of different cooling methods aimed at enhancing solar panel efficiency, with particular attention to the integration of thermoelectric generators (TEGs) for further performance improvement.

Keywords— PV-cleaning, Solar Panel, , IoT- real time monitoring, efficiency maintenance, performance parameters.

I. Introduction

A growing number of innovations are emerging to harness green electricity, particularly in the solar power generation sector. Conventional energy sources such as coal and fossil fuels produce electricity by burning these resources to generate steam, which raises concerns about sustainability and environmental pollution. Consequently, research focus has shifted toward non-conventional energy sources such as solar, wind, tidal and biomass. Among these, solar technology stands out as the most prominent and rapidly developing option due to its widespread availability and clean energy potential

(Rahman et al., 2017).

In photovoltaic (PV) conversion, operating temperature plays a critical role in determining system performance (Skoplaki & Palyvos, 2009). An increase in ambient temperature reduces the output power of PV panels (Kalogirou & Tripanagnostopoulos, 2006) and decreases efficiency due to bandgap shrinkage caused by impurity concentration at elevated temperatures (Yildiz et al., 2017). While expanding the surface area of solar panels can enhance power generation, this approach is impractical in applications such as electric vehicles, where space is limited (Saleh et al., 2021).

To address this limitation, various cooling techniques have been explored to improve PV efficiency. Cooling arrangements include air cooling, water cooling, hybrid air-water systems, phase change materials (PCMs), fins, heat sinks, nanofluids, and cotton wicks (Dwivedi et al., 2020). Additionally, integrating Thermoelectric Generators (TEGs) with PV panels has been proposed to recover waste heat and further enhance efficiency. Through the Seebeck effect, TEGs convert temperature differences into electrical energy, thereby generating additional power while simultaneously reducing PV panel temperature (Chen et al., 2017; Jaziri et al., 2020; Makki et al., 2016). For effective operation, TEGs require one side to be cooled while the other side is heated by solar irradiance transmitted from the PV panel (Zelazna & Gołębiewska, 2020).

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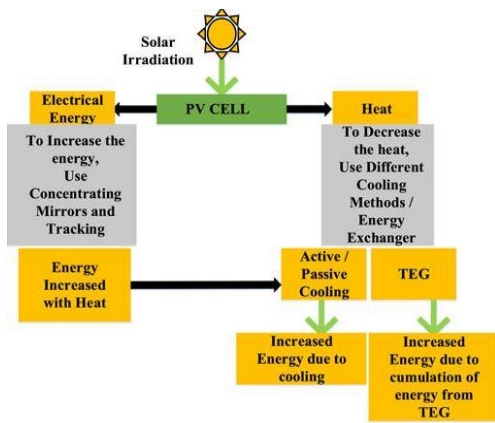


FIG1. Basic structure of photovoltaic energy enhancement using a cooling system

II. Comparison of Efficiency for Different Solar Panels

Solar panels are generally classified into three generations (Kibria et al., 2014). The first generation is based on wafer-based silicon cells, the second generation on thin-film technology, and the third generation includes emerging technologies such as nanocrystal-based, polymer-based, dye-sensitized, and perovskite-based solar cells. *Figure 2* illustrates the classification of solar cells according to different parameters, while *Table 1* presents a comparative analysis of the three generations (Guerra et al., 2018; Rathore et al., 2019; Engineering, 2018; Gaur and Tiwari, 2013). Within first-generation solar panels, monocrystalline cells exhibit better performance compared to polycrystalline cells due to their uniform structure and high purity (Taşcıoğlu et al., 2016). Crystalline solar cells typically absorb about 90% of irradiance within the 400–1200 nm wavelength range; however, their conversion efficiency remains limited to around 18%, with the remaining energy dissipated as heat. The performance of photovoltaic (PV) modules is conventionally evaluated under AM1.5 spectrum and Standard Test Conditions (STC) (Sathe and Dhoble, 2017). Notably, their efficiency decreases by approximately 0.4–0.5% for each 1°C rise in temperature.

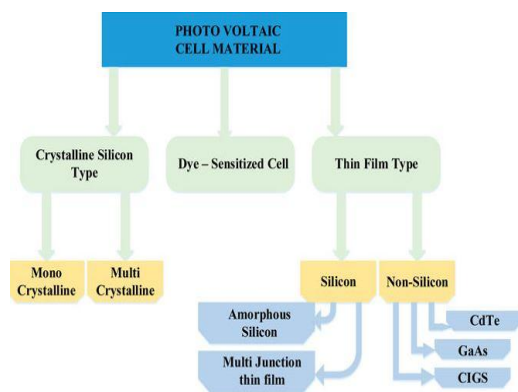


FIG2. Basic structure of photovoltaic material

Generation	Type of Solar Cells	Module Efficiency (%)	Applications
First Generation	Monocrystalline Polycrystalline	14-17.5 12-14	Used in conventional surroundings
Second Generation	Thin film solar cells CIGS Amorphous cells	16-17 10-12 4-8	Used in BiPV on smaller power systems
Third Generation	Nanocrystal Dye-sensitized Polymer Perovskites CdTe type solar panels	7-8 10 3-10 31 9-11	Best suited for areas with normal irradiation

TABLE1. Comparison of Efficiency with different generations of cells

III. Various Methods to Enhance the Efficiency of Solar Panels

To achieve maximum efficiency from photovoltaic (PV) panels, several additional arrangements are required such as implementing sun-tracking systems (Awasthi et al., 2020), utilizing concentrating mirrors (Bilal et al., 2016) and applying cooling techniques, which can be broadly categorized into active and passive methods.

1. Tracking Systems

Solar panels are usually installed at fixed slopes and azimuth angles. However, to achieve maximum solar irradiation, sun-tracking systems are required. These systems continuously adjust the orientation of the panels to optimize the angle of incidence and maximize energy capture throughout the day (Deen Verma et al., 2020). Despite their benefits, solar trackers are relatively expensive due to their moving parts and complex mechanisms, typically adding around \$0.08–0.10 per watt depending on system size and location (Bushong, 2016). Based on the axis of rotation, tracking systems are generally classified as single-axis and dual-axis. A single-axis tracker allows movement along one direction, whereas a dual-axis tracker adjusts along two directions, enabling more precise alignment with the Sun. As a result, dual-axis trackers offer higher efficiency compared to single-axis systems. Experimental results by Dhanabal et al. (2013) demonstrated that dual-axis tracking achieved an efficiency of 81.68%, while single-axis tracking improved output by only 32.17% compared to fixed panels.

The average daily solar intensity per unit area has been reported to increase by 13.8% and 22.5% with single-axis and dual-axis tracking systems, respectively, compared to a fixed mount. Correspondingly, system efficiency improved by 10%

and 20.7% (Hassan, 2015). Rubio et al. (2007) developed a precise Sun tracker that combined an automatic tracking mechanism with a hybrid system. In this design, the solar movement was modeled through an open-loop system, while a feedback controller operated in a closed-loop configuration, thereby ensuring that the motor did not consume additional energy. Similarly, Taherbaneh et al. (2010) introduced a fuzzy-based Maximum Power Point Tracking (MPPT) method, which achieved an output of 23 W—equivalent to 51% of the nominal power. A second method, fuzzy-based Sun tracking, yielded around 11 W, representing 24.5% of the nominal power. When both approaches were integrated, the system's output power increased significantly, reaching 78% of the nominal capacity. Quantum dot solar cells can harness high-energy photons to generate multiple electron-hole pairs, thereby enhancing overall efficiency. Similarly, the adoption of dual-axis solar tracking technology results in a significant improvement in energy output. Solar tracking systems are typically classified based on their drives, axis orientation, control mechanisms, and tracking strategies, as illustrated in Figure 3. The integration of solar panels with a tracking system enables continuous adjustment of their position to maximize solar irradiation throughout the day. Malek et al. (2012) conducted experiments on PV panels with and without a tracking system, and the measured voltage and current values for both cases are presented in Table 2.

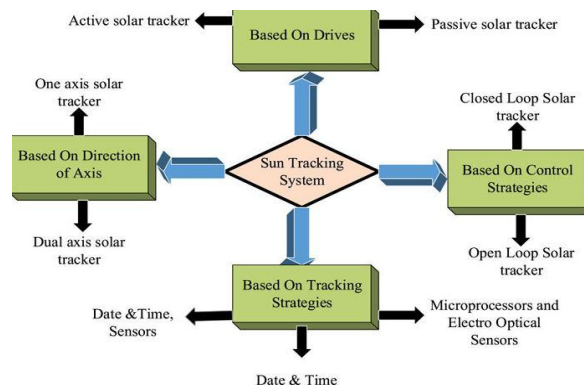


FIG3. Various solar tracking systems

Time	Without Tracking		With Tracking	
	Voltage	Current	Voltage	Current
9:00	10.9	0.3	11.2	0.6
11:00	11.3	0.65	12.7	0.74
13:00	11.6	0.60	11.2	0.82
15:00	10.1	0.31	11.2	0.30

TABLE2. Voltage and current values without and with tracking

Sun tracking systems are generally classified into two main categories: **active (electrical) trackers** and **passive (mechanical) trackers**. Active trackers rely on electrical mechanisms and can be further divided into PC-controlled time and date-based systems, auxiliary bi-facial solar cell-based systems, and electro-optical sensor and microprocessor-based systems. In contrast, passive trackers operate through mechanical principles, utilizing shape-memory alloys and the thermal expansion of materials (Mousazadeh et al., 2009; Ponnambalam, 2018). The adoption of Sun tracking technology can enhance the efficiency of solar panels by up to **37.02%**. However, the resulting concentration of solar radiation and elevated operating temperatures often lead to overheating, making efficiency losses due to thermal effects inevitable.

2. Using Concentrating Mirrors

The efficiency of photovoltaic (PV) systems can be enhanced by integrating concentrating mirrors with solar panels combined with sun-tracking technology. However, the power output of PV modules decreases with rising temperature and increases when the temperature is lowered (Nazar, 2015). Efficiency losses are also attributed to factors such as tilt angle, dust deposition (Charabi & Gastli, 2013), and shading effects. In fixed-tilt tracking systems, dust accumulation diminishes as the tilt angle increases; at an inclination of approximately 20° from the horizontal, photovoltaic thermal (PVT) systems can achieve maximum energy production (Sun et al., 2016). Moreover, nonlinear shading causes mismatches in short-circuit current, leading to additional power losses (Ballal et al., 2015).

Unlike conventional photovoltaics, concentrated photovoltaic (CPV) systems employ lenses or curved mirrors to focus sunlight onto a smaller cell area, thereby improving light-to-electricity conversion efficiency. Concentrators are generally a cost-effective approach for improving PV performance, producing electricity in the range of 7–15 cents/kWh depending on system size and geographic location (Swanson, 2000). Table 3 presents voltage and current data under various operating conditions (Khamooshi et al., 2014).

From Table 3, it is evident that the use of mirrors and coolants significantly enhances the output power, with the increase in the number of mirrors yielding approximately a 52% improvement. Quantum dot concentrators offer additional advantages, including fewer heat dissipation issues, low-cost sheets, compatibility with architectural components, and a non-tracking property, making them more efficient compared to other concentrator types (Khamooshi et al., 2014). The PV panel is generally tilted at an inclination angle corresponding to the Sun's

irradiation. However, regular cleaning and maintenance of mirrors are necessary to sustain optimum performance (Rahman and Khan, 2010). Experimental studies on trough-concentrated photovoltaic thermal systems revealed that GaAs cell arrays exhibit superior electrical performance compared to crystalline silicon solar cell arrays, although the thermal performance trend is reversed (Li et al., 2011).

Condition	Voltage (V)	Current (C)	Power (P)
Without mirror and cooling	12.98	1.91	24.84
With 2 mirrors and without cooling	16.11	1.94	31.25
With 2 mirrors and with cooling	16.5	1.94	32
With 3 mirrors and without cooling	16.71	1.95	36.93
With 3 mirrors and with cooling	16.91	2.23	37.71

TABLE3. Voltage and current values with and without using mirrors and cooling (Arshad et al., 2014)

IV. Different Cooling Methods to Enhance the Efficiency of Solar Panels

PV panels primarily absorb the visible spectrum of light to generate electrical energy (P. Kumar and Dubey, 2018). The remaining portion of the spectrum is converted into heat, which reduces output performance by approximately 0.4–0.5% for every 1°C rise in temperature under standard testing conditions (Indugowda and Ranjith, 2016). Literature indicates that the open-circuit voltage increases logarithmically with ambient irradiation, whereas the short-circuit current varies linearly with it. However, as the cell temperature rises, the open-circuit voltage decreases linearly, resulting in reduced PV panel efficiency. In contrast, the short-circuit current shows only a marginal increase with higher cell temperature (Joshi, Dincer, and Reddy, 2009).

Figure 4 illustrates the structures of various cooling systems, each influenced by factors such as the type of PV technology, installation location, and prevailing weather conditions (Dubey, Sarvaiya, and Seshadri 2013). Based on these factors, heat dissipation from solar panels can be effectively achieved through either active or passive cooling approaches. Active cooling systems involve movable components, while passive cooling systems operate without moving parts. Although active systems generally provide higher

efficiency compared to passive systems, they are less favorable in terms of cost (Kalaiselvan et al., 2018).

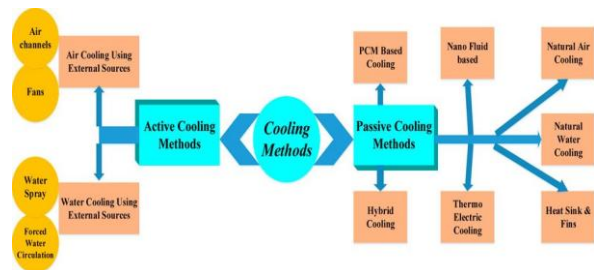


FIGURE4. Various cooling methods used in PV panels to enhance efficiency

1. Active Cooling System

Active cooling systems require external electrical or mechanical energy, such as fans for air circulation or pumps for water circulation, to dissipate heat from the panels (Shan et al., 2014). The incorporation of a water-based cooling arrangement can enhance efficiency by approximately 2% (Pradhan et al., 2017).

1.1. Water Cooling Method

M. Abdolzadeh et al. investigated the direct spraying of water on PV panels, which improved the performance efficiency of the PV cell, subsystem, and overall system by 3.26%, 1.40%, and 1.13%, respectively, when a 225 W PV panel was operated with a spraying flow rate of 644 L/h at a 16 m head. Efficiency enhancement was achieved across different water flow rates. Ahmed A.M. et al. experimented with water flowing through tubes perforated with 2 mm holes at flow rates of 3, 6, and 9 L/h, yielding efficiencies of 8.3%, 6.8%, and 3.28%, respectively (Ahmed and Hassan Danook, 2018). Similarly, Musthafa (2015) reported that water-cooling technology reduced the PV panel temperature by about 4°C, thereby improving performance efficiency by nearly 12%. Further improvement was observed with functionally graded material (FGM) water tube systems: PV cell efficiency increased by 30–50%, while PV-TEG systems showed gains of 25–40% (Yang and Yin, 2011). Benato et al. (2021) also studied spraying technology at 1.5 bar pressure and found efficiency and power generation increased from 11.18% to 13.27% and from 178.88 W to 212.31 W, respectively. Another advantage of water spraying is the increased input surface radiation due to refraction through the water layer (Odeh and Behnia, 2009).

To optimize space utilization, Elminshawy et al. (2019) employed a V-trough CPV system with a buried water heat exchanger for active cooling. The system successfully reduced panel temperature from 72.5°C to 47.2°C, 45.5°C, 41.8°C, and 39.3°C at flow rates of 0.01, 0.02, 0.03, and 0.04 kg/s, respectively.

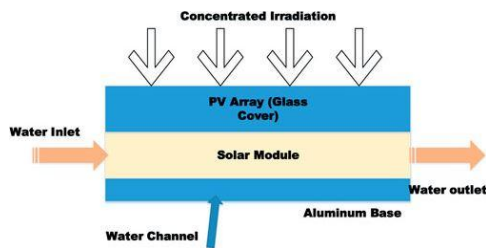


FIGURE5. Cooling method by a water channel

1.2. Air Cooling Method

The structure of the air-cooling method is illustrated in Figure 6. Under high irradiation conditions, forced convection (using either air or water) is more effective than natural convection, achieving up to a 15% gain in efficiency along with significant temperature reduction (Mazón-Hernández et al., 2013). Amori et al. investigated a PV system integrated with a flat plate collector at a constant air velocity of 0.0091 kg/s, reporting a temperature reduction of 15.52 °C with a single-pass air channel (Amori and Adil Abd-AlRaheem, 2014). The mass flow rate plays a critical role in PV cooling, as it reduces the outlet temperature of channels and tubes, thereby enhancing overall system performance (Othman et al., 2016).

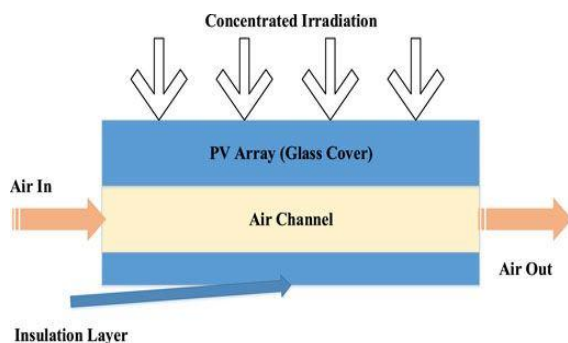


FIGURE6. Cooling method by an air channel

2. Passive Cooling System

It encompasses all natural processes and techniques of heat dissipation and modulation without relying on external energy sources. The integration of photovoltaic and thermal collectors, known as PV/T systems, offers several advantages over standalone PV modules. These include reduced space requirements (Al-Waeli et al., 2016), shorter economic payback periods, and the ability to capture the otherwise wasted heat through a solar collector positioned behind the PV panel. In a PV/T system, heat absorbed from the Sun is transferred from the PV cells into a working fluid, which not only cools the cells—thereby improving electrical efficiency—but also makes the recovered heat available for practical applications such as water heating or serving as a low-temperature source for heat pumps.

The dissipated heat energy from PV panels can thus be harnessed in multiple ways to generate additional energy. To achieve effective heat extraction, PV/T systems employ different components and techniques, including air collectors, water collectors (Besheer et al., 2016), nanofluids (Sardarabadi and Passandideh-Fard, 2016), thermoelectric generators (Greppi and Fabbri, 2021), and phase change materials (Rao, Reddy, and Rao, 2020), all of which contribute to enhancing system efficiency.

2.1 Nanofluid Based Coolants

When acetone is used as a refrigerant in micro-channel heat pipes under vacuum conditions, the instantaneous electrical efficiency reaches 7.6%, while the thermal efficiency is 54% (Verma and Kumar Tiwari, 2015). Under irradiation levels between 367 and 787 W/m², the electrical gain of PVT-MHP increases from 17 to 74 W (Modjinou et al., 2017). The use of nanofluids such as Al₂O₃–water and silicon carbide (SiC)–water as coolants in low-concentration PVT systems results in a significant reduction in PV module temperature, particularly at higher concentration ratios and Reynolds numbers (Radwan, Ahmed, and Ookawara, 2016). Sardarabadi et al. (2017) investigated various coolants, including PVT/Water, PVT/ZnO, PVT/TiO₂, and PVT/Al₂O₃, and reported efficiency improvements of 12.34%, 15.45%, 15.93%, and 18.27%, respectively. However, the primary drawback of nanofluids lies in their limited time stability. Nevertheless, heat exchange channels utilizing water-based nanofluids as coolants demonstrate higher electrical efficiency compared to those using only the base fluid (Karami and Rahimi, 2014).

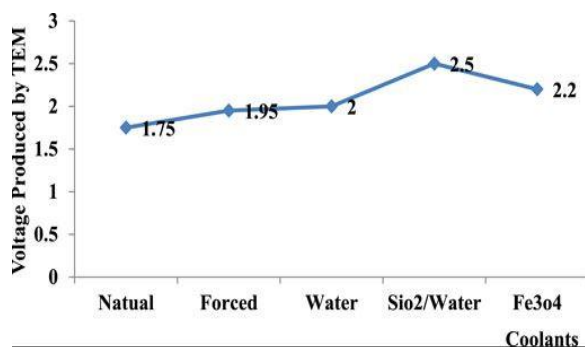


FIGURE7. TEM produced voltage for different coolants

2.2 Thermo Electric Generators

In recent developments for enhancing PV module performance, thermoelectric generators (TEGs) have shown significant potential. Heat transfer from the PV array via conduction and from the CO₂ layer via convection is directed toward the TEG hot side to maximize efficiency (Koushik et al., 2018).

TEGs are devices that convert thermal energy into electrical energy through the Seebeck effect. They operate similarly to thermocouples, but with p- and n-type semiconductor thermoelements, where heat is applied to the hot side and extracted from the cold side, both junctions being connected with copper. When integrated with PV panels, TEGs improve overall system performance while reducing heat dissipation (Sahin et al., 2020). However, the output of TEGs typically varies nonlinearly with temperature, as the thermoelectric material properties themselves are temperature-dependent (Björk and Nielsen, 2015).

Careful thermal management is essential to ensure efficient temperature distribution from PV to TEG. Studies have shown that the open-circuit voltage of a photovoltaic-thermal hybrid solar generator can increase by 1.3% compared to standalone PV operation (Mizoshiri, Mikami, and Ozaki, 2012), contributing about 10% additional output power in a hybrid system (Ju et al., 2012). In PVT-TEG systems, concentrator-type thermal collectors enhance performance by accumulating higher heat flux at a single point (Lin, Liao, and Lin, 2015).

The thermal efficiency of TEGs depends primarily on the temperature difference across their hot and cold surfaces. Thus, effective thermal design is crucial to maximize this temperature gradient (Karthick et al., 2018). Furthermore, an optimized heat recirculation strategy can significantly improve the conversion efficiency of TEGs (Min Gao and Rowe, 2007).

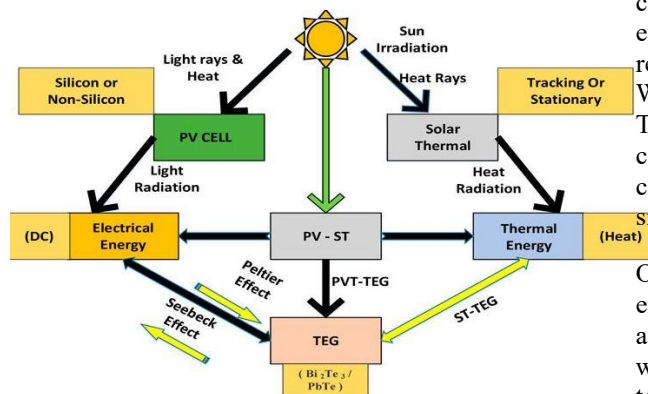


FIGURE8. Perational Structure of PV-ST-TEG

V. Necessity of Building-Integrated PV

Building-integrated photovoltaic (BIPV) systems replace conventional building materials in parts of the building envelope—such as roofs, skylights, and facades—or are embedded directly into the structure (Strong, 2016). Depending on the type of solar cell, only about 6–16% of the incoming solar irradiation is converted into electricity, while the remainder is either transmitted as heat or reflected. In BIPV/T

installations, PV modules also block solar radiation from reaching the original wall.

Unlike building-applied PV (BAPV) systems, which are mounted above rooftops and limited to roof surfaces, BIPV systems can cover a much larger portion of the building envelope by integrating photovoltaics directly into architectural components (Biyik et al., 2017). This replacement alters the solar absorptivity of the building—for example, substituting a reflective roof with PV modules increases absorption. Semi-transparent PV modules further affect visible light transmittance, influencing indoor daylight availability and artificial lighting energy demand.

VI. Conclusion

The efficiency of solar PV panels can be improved by incorporating tracking systems and using mirrors to concentrate solar radiation. However, these methods also lead to higher heat generation, which reduces overall performance and offsets the intended benefits.

To mitigate this heat, various active and passive cooling techniques have been explored, including air cooling, water cooling, hybrid air–water systems, nanofluids, phase change materials (PCMs), and heat sinks. Each method demonstrated different levels of efficiency enhancement depending on the system design and operating conditions.

Thermoelectric generators (TEGs) offer a complementary passive approach by converting excess heat into additional electrical energy, thereby reducing panel temperature while increasing output. When integrated with PV modules (forming PVT-TEG systems), they provide dual benefits: enhanced cooling and extra electricity generation. Furthermore, certain cooling methods can be applied to the cold side of the TEG to further improve its performance.

Overall, this review highlights methodologies to enhance PV panel efficiency without requiring additional land area. By combining TEG integration with appropriate cooling techniques, solar PV technology can become more space-efficient, making it particularly suitable for solar-powered transportation applications—where limited surface area is often a major constraint.

References

- [1] Ahiska, R., Nykyruy, L., Omer, G., and Mateik, G. (2016). The Thermoelectric Solar Panels. *jpnu* 3 (1), 9–14. doi:10.15330/jpnu.3.1.9-14
- [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 AI-

Kitab, ICETS 2018, 39–42.
doi:10.1109/ICETS.2018.8724625

[3] Al-Waeli, A. H., Sopian, K., Kazem, H. A., and Chaichan, M. T. (2016). Photovoltaic Solar Thermal (PV/T) Collectors Past, Present and Future: A Review. *Int. J. Appl. Eng. Res.* 11 (22), 10757–10765.

[4] 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

[5] Arifin, Z., Tjahjana, D. D. D. P., Hadi, S., Rachmanto, R. A., Setyohandoko, G., and Sutanto, B. (2020). Numerical and Experimental Investigation of Air Cooling for Photovoltaic Panels Using Aluminum Heat Sinks. *Int. J. Photoenergy* 2020, 1–9. doi:10.1155/2020/1574274

[6] 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

[7] 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.egy.2020.02.004

[8] Babu, C., and Ponnambalam, P. (2017). The Role of Thermoelectric Generators in the Hybrid PV/T Systems: A Review. *Energy Convers. Manag.* 151 (June), 368–385. doi:10.1016/j.enconman.2017.08.060

[9] Ballal, Rajkiran, Lakshmi, P. S., and Kumar, Girish (2015). PV Module, Irradiation, Shading, Fill Factor; PV Module, Irradiation, Shading. *Fill Factor* 5 (1A), 1–4. doi:10.5923/c.ep.201501.01

[10] 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

[11] Besheer, A. H., Smyth, M., Zacharopoulos, A., Mondol, J., Pugsley, A., and Adrian, Pugsley (2016). Review on Recent Approaches for Hybrid PV/T Solar Technology. *Int. J. Energy Res.* 40 (15), 2038–2053. doi:10.1002/er.3567

[12] 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.

[13] 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

[14] Chandrasekar, M., Suresh, S., Senthilkumar, T., and Ganesh Karthikeyan, M. (2013). Passive Cooling of Standalone Flat PV Module with Cotton Wick Structures. *Energy Convers. Manag.* 71, 43–50. doi:10.1016/j.enconman.2013.03.012

[15] Charabi, Y., and Gastli, A. (2013). Integration of Temperature and Dust Effects in Siting Large PV Power Plant in Hot Arid Area. *Renew. Energy* 57, 635–644. doi:10.1016/j.renene.2013.02.031

[16] Chen, J., Li, K., Liu, C., Li, M., Lv, Y., Jia, L., et al. (2017). Enhanced Efficiency of Thermoelectric Generator by Optimizing Mechanical and Electrical Structures. *Energies* 10 (9), 1329–1415. doi:10.3390/en10091329

[17] Cuce, E., Bali, T., and Sekucoglu, S. A. (2011). Effects of Passive Cooling on Performance of Silicon Photovoltaic Cells. *Int. J. Low-Carbon Tech.* 6 (4), 299–308. doi:10.1093/ijlct/ctr018

[18] Deen Verma, B., Anurag Gour, A., and Dr. Mukesh Pandey, Dr. (2020). A Review Paper on Solar Tracking System for Photovoltaic Power Plant. *Ijert V9* (02), 160–166. doi:10.17577/ijertv9is020103

[19] D. Raut, P., V. Shukla, V., and S.Joshi, S. (2018). Recent Developments in Photovoltaic-Thermoelectric Combined System. *Ijet* 7 (4), 2619–2627. doi:10.14419/ijet.v7i4.1270910.14419/ijet.v7i2.18.12709

[20] Dwivedi, P., Sudhakar, K., Soni, A., Solomin, E., and Kirpichnikova, I. (2020). Advanced Cooling Techniques of P.V. Modules: A State of Art. *Case Stud. Therm. Eng.* 21 (June), 100674. doi:10.1016/j.csite.2020.100674

[21] Elbreki, A. M., Muftah, A. F., Sopian, K., Jarimi, H., Fazlizan, A., and Ibrahim, A. (2021). Experimental and Economic Analysis of Passive Cooling PV Module Using Fins and Planar Reflector. *Case Stud. Therm. Eng.* 23 (December 2020), 100801. doi:10.1016/j.csite.2020.100801