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Performance Investigation of Photovoltaic Thermal System Incorporating Nano Coolant - Review

Nitin Patil[1], Salman Shaikh[2], Akshay Jadhav[3], Nikhil Patil[4], Mr. Pravin Thorat[5]
[1]*Department of Mechanical Engineering,* [2, 3] *Suman Ramesh Tulsiani Technical Campus Faculty of Engineering, Khamshet, Pune, Maharashtra*

Abstract: Photovoltaic (PV) modules experience a reduction in electrical performance when their surface temperature rises beyond the recommended operating range. Most of the incident solar energy is converted into heat rather than electricity, leading to efficiency loss and reduced panel life. This project investigates a photovoltaic-thermal (PVT) system using nano-coolant-based cooling to regulate PV surface temperature and enhance overall performance. Experimental studies were carried out under outdoor conditions to evaluate the effect of cooling on voltage, current, power output, and electrical efficiency. The results demonstrate that controlled cooling significantly reduces panel temperature, improves voltage output, and increases electrical efficiency compared to a conventional PV system. The proposed approach offers an effective solution for performance enhancement and thermal management of solar panels.
Keywords: Photovoltaic-Thermal (PVT) System, Nanofluid, Thermal Management, Solar Panel Efficiency, Renewable Energy.

I. INTRODUCTION

The increasing demand for energy, depletion of fossil fuels, and environmental concerns have accelerated the shift toward renewable energy sources. Solar energy is one of the most abundant, clean, and sustainable energy resources available.

Photovoltaic systems directly convert solar radiation into electrical energy; however, their efficiency is limited due to temperature rise during operation. As the PV panel temperature increases, the voltage output decreases, resulting in reduced power generation and shorter panel lifespan.

To overcome this limitation, photovoltaic-thermal (PVT) systems combine electrical power generation with thermal energy recovery. By incorporating an effective cooling mechanism such as nano-coolant circulation, the excess heat can be removed, thereby stabilizing panel temperature and improving electrical performance. This project focuses on evaluating such a hybrid system experimentally.

II. SYNTHESIS OF NANO COOLANT

The nano-coolant is made by adding nanoparticles like Al_2O_3 or CuO to distilled water using the two-step method. The required amount of nanoparticles is carefully measured and mixed properly using stirring and ultrasonication to get a stable solution. This nanofluid helps remove heat more effectively, lowers the PV panel temperature, and improves its electrical performance.

III. NEEDS OF NANO COOLANT

1) Reduces PV panel temperature by removing excess heat effectively.
2) Improves electrical efficiency by maintaining optimal operating temperature.
3) Enhances heat transfer due to higher thermal conductivity than water.
4) Increases overall performance and lifespan of the PVT system.

IV. APPLICATION OF NANO COOLANT

1) Industrial Sector – Used in heat exchangers, boilers, and thermal power systems for improved heat transfer.
2) Automotive Sector – Applied in engine cooling systems, radiators, welding equipment, and transmission fluids
3) Renewable Energy Systems – Used in photovoltaic-thermal (PVT) systems and solar collectors for efficient cooling.
4) Electronic Applications – Used for cooling microchips, computers, laptops, and other electronic devices to prevent overheating.

V. LITERATURE SURVEY

Masalha et al. (2021) [1] used an Al_2O_3 nanofluid cooling system in an experimental and numerical study to increase the efficiency of photovoltaic (PV) modules. Using a backside cooling channel, the study examined two nanoparticle concentrations (0.05 weight percent and 0.1 weight percent) at various flow rates (1–2 L/min). The best results were obtained with 0.1 weight percent Al2O3 nanofluid at 2 L/min, which reduced panel temperature by about 38% and increased power output by about 9.6%. With nanofluid cooling, the electrical efficiency increased from 14% (without cooling) to 15.7%. According to the study's findings, nanofluids greatly improve convective heat transfer, which raises the performance of PV systems as a whole.

Sarafraz et al. (2019) [2] Using nanofluids as a cooling medium, conducted an experiment on a PV/T system. To find out how different kinds and concentrations of nanoparticles impact the system's functionality, they conducted tests. According to the study, nanofluids lowered the panel temperature and were more effective at removing heat than regular water. Both electrical and thermal efficiency increased as a result of improved cooling. This demonstrates how nanofluids can enhance PV/T system performance.

Shahad et al. (2021) [3] investigated the use of nanofluids to cool photovoltaic (PV) panels and enhance their performance. The primary goal was to lower the panel's temperature by extracting heat from its rear. The impact of various nanofluid concentrations on thermal and electrical efficiency was examined. The findings demonstrated that nanofluid cooling outperformed conventional cooling techniques in reducing the panel temperature, resulting in a higher electrical output. According to the study's findings, employing nanofluids to enhance PV system performance is an easy and efficient method.

Baniasadi et al. (2025) [4] looked into a numerical study about a photovoltaic thermal (PVT) system that uses nano-graphene coolant and a better fin design. They checked out how different things like the number of fins, their thickness, the concentration of nanofluid, flow rate, and solar radiation impacted how well the system worked. The findings showed that if you add more fins and use a 0.5 wt% graphene nanofluid, it actually lowers the panel temperature and boosts electrical efficiency. They found thermal efficiency went up by around 18%, and the panel temperature dropped by almost 7°C. In the end, the study pointed out that mixing nanofluids with the right fin design can really enhance the performance of PVT systems.

Mosaad R. Sharaby (2025) et al [5] conducted a study on a photovoltaic-thermal (PVT) system utilizing nanofluid cooling to enhance performance. The research involved testing various concentrations of nanoparticles under different operating conditions to assess their impact on heat transfer and overall efficiency. Findings indicated that nanofluids are more effective in heat removal compared to standard fluids, resulting in lower panel temperatures and improved electrical efficiency. The study concluded that incorporating nanofluid cooling significantly boosts the performance of PVT systems

Kazem et al. (2022) explored [6] how adding a small amount of silicon carbide (SiC) nanoparticles to water can help cool solar panels more effectively in Oman’s hot climate.

They found that this nanofluid cooling reduced the panel temperature and improved performance — electrical efficiency increased by about 25%, and thermal efficiency nearly doubled compared to normal water cooling.

In simple terms, better cooling means better solar performance, especially in very hot regions.

Almitani and Elamin (2023) [7] used computer simulations to study how adding alumina (Al_2O_3) nanofluid and V-shaped fins inside a cooling duct can improve a PV/T system.

They found that the fins slightly improved electrical efficiency and boosted thermal efficiency. Increasing the inlet flow speed helped cool the PV panel further, reducing its temperature and improving heat removal.

In simple terms, combining smart duct design with nanofluid cooling helps solar panels run cooler and perform better.

Ehsan Baniasadi (2025) [8] investigated the performance of a PV/T system using nano-graphene coolant combined with an enhanced fin design. The study showed that optimizing flow rate, fin geometry, and nanoparticle concentration improved heat removal from the PV surface. As a result, panel temperature decreased and both electrical and thermal efficiencies increased compared to conventional water cooling. Overall, the use of nano-enhanced coolant with improved fin configuration enhanced the system’s energy output.

Satpute et al. (2025) [9] studied how cooling a PV/T system with CuO-water nanofluid affects its performance, comparing it with non-cooled and water-cooled systems.

They found that panel temperature dropped significantly with nanofluid cooling, which improved electrical efficiency from 5.74% (non-cooled) to 9.05%. Thermal efficiency also increased, reaching 67.4% at higher nanoparticle concentration.

However, adding more nanoparticles increased flow resistance and pressure drop. Overall, the study shows that using the right amount of nanofluid can greatly improve both thermal and electrical performance.

Rachmanto et al. (2025) [10] compared three nanofluids—Al_2O_3, CuO, and TiO_2—in a finned PV/T system to see which one cools better.

All three improved performance, but CuO gave the best results, achieving the highest thermal and electrical efficiencies. It provided better cooling, which helped the solar panel produce more power.

In simple terms, the type of nanofluid used makes a big difference, and CuO turned out to be the most effective among the three.

VI. CONCLUSIONS

From the reviewed studies, it is clear that using nanofluids is an effective way to cool solar panels and improve their performance. Nanoparticles like Al_2O_3, CuO, SiC, and graphene help reduce panel temperature, which increases electrical efficiency and overall energy output. Proper fin design and the right nanoparticle concentration further improve heat removal. Overall, combining nanofluid cooling with good thermal design is a simple and practical way to enhance solar system efficiency, especially in hot climates.

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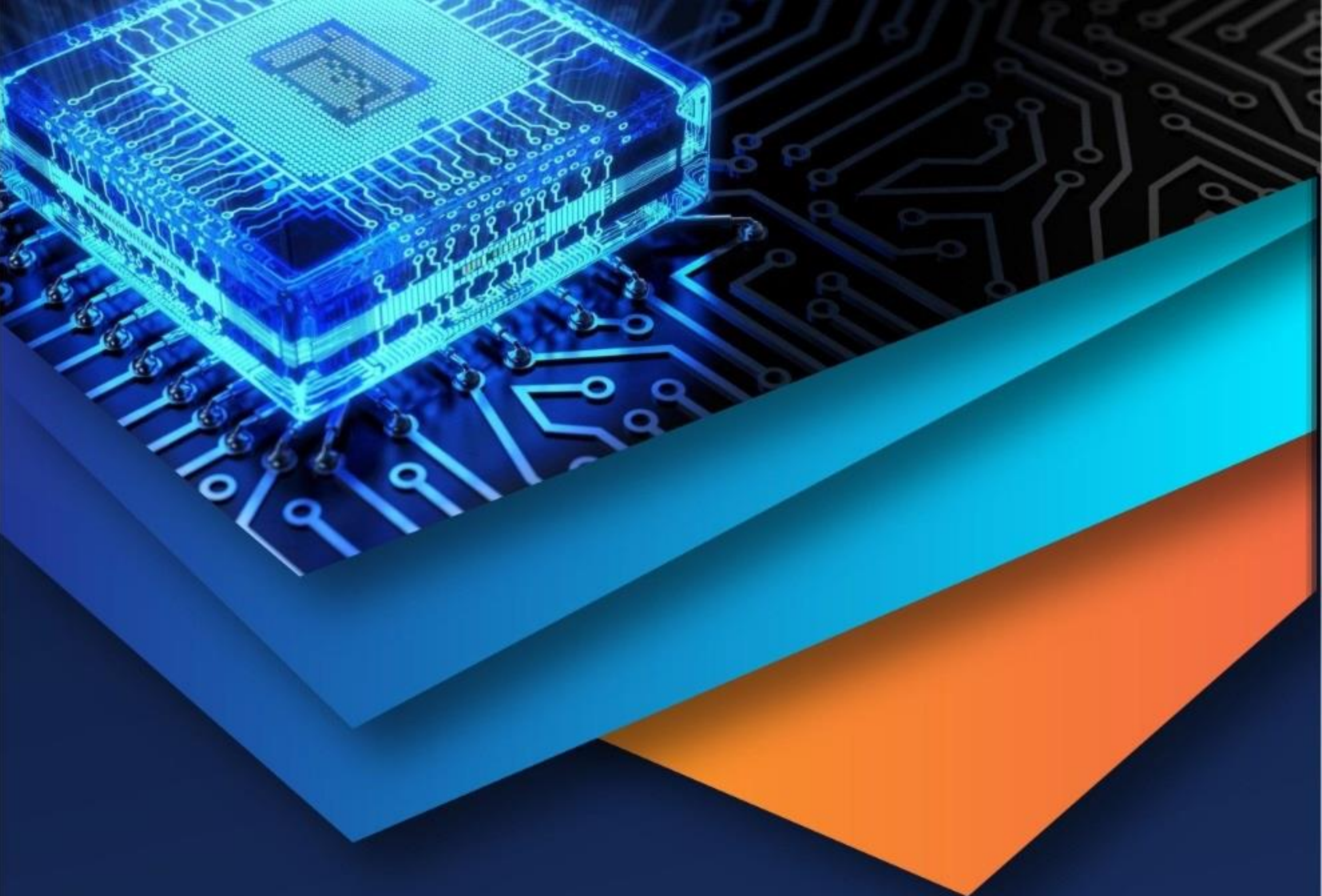

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