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DESIGN AND DEVELOPMENT OF COOLING SYSTEMS FOR PV CELLS PERFORMANCE IMPROVEMENT

BY

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Abstract. This paper presents a concise review of cooling techniques for the solar PV systems.

The photovoltaic effect was firstly experimentally demonstrated by the French physicist Edmond Becquer in 1839. The first useful solar cell (6% energy efficiency) was performed by the Bell Laboratories (1950). They realized that the semiconducting materials such silicon were more efficient than selenium.

The following conditions have a significant impact on solar panel's efficiency, in real-world use: irradiance (W/m^2), shading, orientation and temperature. The ambient temperature, wind speed, time of day and the amount of solar irradiance (W/m^2) make real variation in cells temperature that often rises above $25^{\circ}C$. The optimum internal cell temperature is typically $25-30^{\circ}C$ above the ambient air temperature and solar cell performance decreases with increasing temperature with 8-15% in total power output. That's why engineers design cooling systems to improve the efficiency of solar panels that operate in non-optimal conditions.

Keywords: Photovoltaic, cooling systems, solar energy, cells performance, efficiency.

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1. Introduction

Photovoltaic (PV) systems represent an environmentally friendly and sustainable solution for electricity generation, and the performance of PV cells plays a crucial role in the efficiency of these systems. One of the main obstacles to improving the performance of photovoltaic cells is their overheating, which can significantly impact energy production. Therefore, the development and implementation of adequate cooling systems for PV cells represent an essential research direction for enhancing their performance.

The growth of the population, the development of human activities both horizontally and vertically, global economic growth and urbanization, technological advancement and digitization, the development of facilities that enhance the standard of living and comfort, industrialization and diversification of production processes, all require increasingly more energy from year to year.

In order to manage this growing energy demand in a responsible and sustainable manner, humanity faces the challenge of meeting its energy needs while reducing the impact on the environment and dependence on finite and polluting resources.

The solar panel efficiency might reach today almost 47.1%, this value was attained in 2019 by using multi-junction concentrator solar cells, developed at National Renewable Energy Laboratory. However, this technology differs from traditional solar cell because it uses a monolithic six junction material structure that is operated under the direct spectrum at 143 Suns concentration. Lately, at NREL, they made a set of a new solar cell with terrestrial efficiency of 39.5%, also accomplished under lighting condition to the sun which is an obvious change to the previous achievement, when the cell was exposed to extremely concentrated light. They achieved that with inverted metamorphic multi-junction (IMM) cells, with three layers, each made of a different material (gallium indium phosphide on top, gallium arsenide in center, and gallium indium arsenide on the bottom). So, the improvement of the solar cells was obtained in researches using various types of construction design of the solar cell and solar panel.

In real life, conditions are different than the laboratory ones. Besides manufacturing factors that were improved with time and are playing a significant role in the increasing solar cell efficiency (reflectance, efficiency, charge carrier separation efficiency, charge carrier collection efficiency and conduction efficiency values), there are also external important elements that alter the energetic performance of the panel:

1. natural causes, i.e., operational temperature, wind, irradiance level, hail, rain (snow, ice), chemical residues;
2. operational restrictive conditions such as shading, panel orientation, location, dust and dirt, aspects that can be smoothly controlled when panels are installed.

2. The solar cell and the significance of its cooling

A solar cell:

- is a semiconductor device that converts the light energy directly into electricity by the photovoltaic effect;
- is a P-N junction with a large surface area. The N type material is kept thin to allow light to pass through the PN junction;
- it acts both as a current and voltage source (which depends on the incident solar radiation);
- is sensitive to temperature, as any other semiconductor devices.

The photovoltaic panel (PV module) is constructed from a series of solar cells connected in series and/or parallel, covered by a glass sheet, and held together by a metal frame, with cables and circuits behind the cells to collect the electric current flow from the solar cells.

The temperature increase in a solar cell has significant implications for its performance. The band gap, which determines the energy required to break bonds within the semiconductor material, decreases as temperature rises. This results in lower energy being needed for electron transitions, enhancing the overall conductivity of the material. However, the open-circuit voltage, representing the maximum voltage output of the solar cell, is negatively affected by temperature. As temperature increases, more electron-hole pairs recombine, leading to a decrease in the open-circuit voltage. These thermal effects have a critical impact on the efficiency and power output of solar cells.

Managing the temperature of solar cells is essential for optimizing their performance. Implementing effective cooling strategies, such as incorporating cooling systems or heat sinks, helps dissipate excess heat and mitigates efficiency losses caused by temperature increase. By maintaining lower operating temperatures, the band gap and open-circuit voltage can be preserved, ensuring that the solar cell operates at its highest potential and achieves maximum energy conversion efficiency.

We can model the current-voltage relationship of semiconductors diodes with Eq. (1), the Shockley diode equation:

$$I_D = I_S \left(e^{\frac{V_D}{nV_T}} - 1 \right) \quad (1)$$

The absorbed heat raises the cells temperature up to 70°C and every degree gained affects the electrical conversion efficiency of the cell with approximately 0.5%, at temperatures exceeding 25°C.

This is the reason why cooling methods (Fig. 2) for PV panels, are so important.

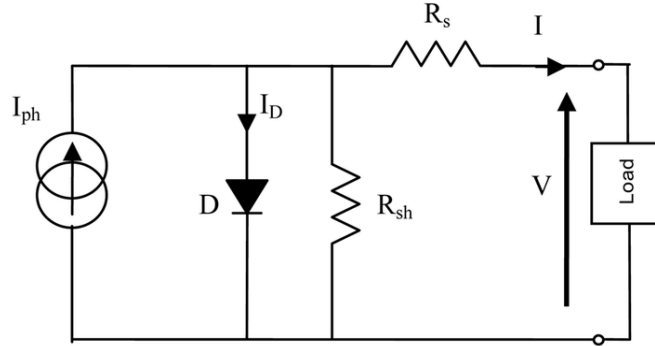


Fig. 1 – Solar cell electrical equivalent circuit.

The main equation (Sangram and Saini, 2016) for analyzing the solar cell with single-diode model is derived from the Shockley equation:

$$I = I_{ph} - I_s \left[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1 \right] - \frac{V + IR_s}{R_{sh}} \quad (2)$$

where:

I_D - is the diode current;

I_s - is the reverse bias saturation current;

I_{ph} - is the photo-generated current;

V - is the voltage across the solar cell;

V_D - is the voltage across the diode;

V_T - is the thermal voltage;

n - is the ideality factor (quality factor or emission coefficient);

R_s - is the series resistance, which is associated with the resistance of the solar cell material and contacts;

R_{sh} - is the shunt resistance, which is associated with current that flows through the solar cell but does not contribute to power production;

In the Eq. (2) V_T can also be written as follow:

$$V_T = \frac{kT}{q} \quad (3)$$

where:

k - is the Boltzmann constant;

T - is the absolute temperature of the P-N junction;

q - is the elementary charge;

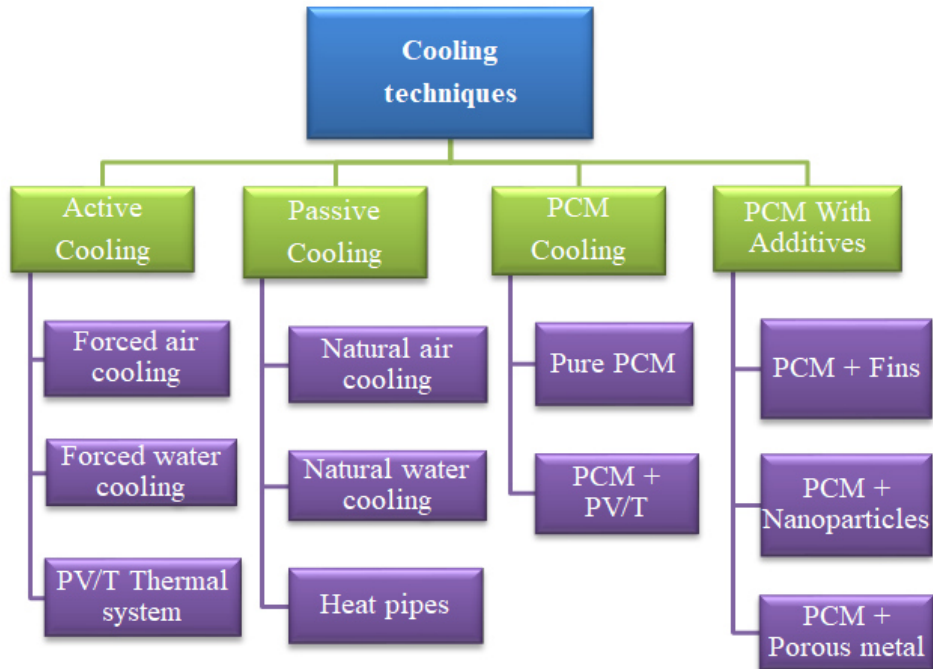


Fig. 2 – Cooling methods for PV panels.

Effective cooling techniques are essential for solar panels to maintain peak performance and counteract the adverse impacts of overheating. Various cooling methods are employed to achieve this. Here are several widely adopted cooling techniques for solar panels, in sections 3 and 4:

3. Passive cooling techniques

This method relies on natural convection and heat dissipation mechanisms to regulate the temperature of solar panels. This approach involves incorporating design features such as air gaps or materials with high thermal conductivity to facilitate efficient heat transfer. Furthermore, the integration of shading elements or reflective coatings helps minimize solar irradiance and reduce heat absorption.

3.1. Passive air cooling

The passive method of cooling photovoltaic panels and balance of systems using natural air convection is a popular and simple technique. It involves the natural movement of air over the panels, which removes heat through convection. This method does not require additional materials and is cost-effective. It is worth noting that air passing over the panels is more effective than air moving under them.

In one investigation on the effect of backside air cooling (Nizetic *et al.*, 2016b), it was reported that the back surface of the PV suffers high temperatures (45-55°C) even with cooling. The main problem discovered was the flow separation which occurred on the panel backside and acts as thermal insulation.

Another study was conducted (Valeh-E-Sheyda *et al.*, 2014) on the air cooling effect of a passive cooling method utilizing a wind-driven rooftop turbine ventilator. This ventilation system, equipped with a dynamo, is positioned beneath the PV module and operates by harnessing wind energy to generate power, facilitate air flow cooling of the PV module, and provide ventilation. The rotation of the turbine enables multi-functional benefits, including cooling, power generation, and ventilation, thereby enhancing the performance and efficiency of the PV system.

3.2. Passive air cooling with fins

The enhancement of PV panel cooling can be achieved through the utilization of metallic materials equipped with fins on the rear surface of the panels, which enables improved airflow circulation. This implementation promotes efficient heat dissipation. Additionally, the creation of an airspace between the walls and the PV system allows for effective temperature control, ensuring that the panels remain below the critical threshold of 40°C.

The study (Brinkworth *et al.*, 1997) explores a passive cooling method for vertical PV modules integrated into buildings. By utilizing natural convective heat transfer and buoyancy-induced airflow in a channel, the cell temperature of the PV module can be maintained below 40°C. This approach demonstrates potential for mitigating temperature-related performance issues and enhancing overall PV system efficiency.

A heat sink is a heat exchanger that dissipates heat generated by a PV panel to a fluid medium, such as air or a liquid coolant. This process helps regulate the temperature of the device. The rate of heat dissipation depends on natural convection and varies with the angle of the heat sink.

In a study (Nair *et al.*, 2016) a passive cooling technique using a heat sink was employed to reduce the temperature of a PV panel. The experiment, conducted on a clear summer day, demonstrated that the temperature of the PV panel at a heat-sink angle of 45 degrees was lower than that at 135 degrees, the latter being the maximum temperature recorded. Furthermore, the study found that the maximum power production increased by 7.0% at a heat-sink angle of 90 degrees and 7.6% at 45 degrees, compared to benchmark PV panels without any cooling. This suggests that the use of a heat sink can enhance the efficiency of PV panels by effectively managing heat dissipation.

3.3. Heat Pipe

It is a passive cooling device that transfers energy from the source to the sink through the evaporation and condensation of fluid in a sealed system. It typically consists of a sealed pipe made of high thermal conductivity materials, such as copper or aluminum, at both the evaporator and condenser ends (Fig. 3).

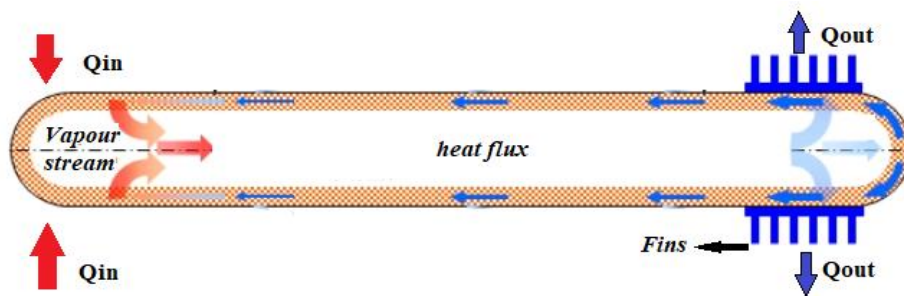


Fig. 3 – Heat Pipe section.

One experimental study (Tang, 2010) investigated the use of a heat pipe array for cooling photovoltaic (P.V.) systems using air and water circulation. They found that air-cooling led to a temperature reduction of 4.7°C and an 8.4% increase in power output compared to conventional solar panels. Furthermore, water-cooling resulted in an 8°C temperature decrease and a significant 13.9% increase in output power. These findings suggest that both air and water-based cooling methods can effectively enhance the performance of photovoltaic systems, with water-cooling yielding greater improvements in temperature reduction and power output.

3.4. Phase change material (PCM)

Phase Change Materials (PCMs) offer an effective solution for passive cooling in solar panels. PCMs have the ability to absorb and release significant amounts of thermal energy during phase transitions. When integrated into solar panels, PCMs can regulate the panel's temperature by absorbing excess heat and storing it through phase transitions.

During periods of high solar radiation or elevated temperatures, the PCM absorb thermal energy, preventing overheating and maintaining optimal operating conditions for the solar panel. This passive cooling mechanism improves the overall performance and lifespan of the solar panel system.

PCMs used in passive cooling systems for solar panels can be classified into different categories, including organic oils, inorganic salt hydrates, and eutectics. Organic PCMs, such as paraffins or vegetable oils, are derived from organic compounds and offer favorable thermal properties. Inorganic PCMs, such as salt hydrates and eutectics, exhibit high thermal conductivity and

stability. The selection of a specific PCM type depends on factors like temperature range, thermal properties, availability, and cost. Choosing the appropriate PCM is crucial for effective passive cooling in solar panels, considering the desired operating temperature range and thermal energy storage capacity required.

A study of a photovoltaic-phase change material (PV-PCM) system made in the hot climate of the UAE (Sarwar *et al.*, 2017), shows that the integration of a paraffin-based PCM with a melting range of 38-43°C at the back of the PV panel provides cooling. The PV-PCM system enhances the annual electrical energy yield of the PV panels by 5.9%. The PCM exhibits consistent performance throughout the year, except in peak cool and peak hot months where its effectiveness is reduced.

In an experiment developed in India (Sharma *et al.*, 2016), the integration of phase change materials (PCMs) in a solar panel system resulted in a 7.7% increase in electrical efficiency, accompanied by an average temperature reduction of 3.8°C. The study further observed that the effectiveness of the PCMs varied with different levels of irradiance. At an irradiance of 500 W/m², the electrical efficiency increased by 1.15%. With an irradiance of 750 W/m², the electrical efficiency saw a greater improvement of 4.20%. The highest increase in electrical efficiency was observed at an irradiance of 1200 W/m², with a notable 6.80% improvement.

4. Active cooling techniques

Active cooling methods involve the use of external devices or systems to actively cool solar panels. This approach is employed to regulate the temperature of the panels and maintain their optimal performance, especially in challenging environmental conditions or situations where passive cooling methods may not be sufficient.

4.1. Active air-cooling

Active air-cooling systems utilize fans or other mechanisms to generate airflow, enhancing the cooling of PV panels. These systems can be designed in a way that utilizes the waste heat generated by the solar panels. By installing metallic materials with fins on the back surface of the PV panels, airflow and heat dissipation are improved, resulting in more effective cooling.

Forced convection cooling with this method was examined (Mazon-Hernandez *et al.*, 2013) at the University of Cartagena and was observed an overall efficiency increase of 2% and the maximum cell temperature decrease of 15°C. A great impact on the PV performance was given by the mass flow rate of air, the distance between the roof and the module and the surrounding temperature.

4.2. Active water-cooling

Water or a mixture of water and glycol is circulated through pipes or channels attached to the rear side of the solar panels. This method utilizes the high heat capacity of water to absorb and carry away excess heat, effectively cooling the panels. Water-based cooling systems can be categorized as direct or indirect, depending on whether the water directly contacts the panel surface or transfers heat through a heat exchanger.

Water cooling techniques for solar panels, includes:

- water spraying;
- forced water circulation;
- liquid immersion.

They offer effective solutions for reducing panel temperatures and improving performance. Water spraying involves periodically spraying water onto the panels to utilize evaporative cooling. Forced water circulation circulates water through pipes or channels attached to the panels, utilizing its high heat capacity. Liquid immersion cooling involves immersing the entire panel in a cooling liquid. Each method has its advantages and considerations.

A theoretical model for evaluating the performance of the photovoltaic/thermal (PV/T) system with heat pipes was developed (Wu *et al.*, 2011). The results obtained indicate that the PV/T system with heat pipes can achieve overall thermal, electrical, and exergy efficiencies of 63.65%, 8.45%, and 10.26%, respectively, under the specified operating conditions. Additionally, it was observed that the operating temperature of the solar cell on the absorber plate varies by less than 2.5°C. Nevertheless, the utilization of this method leads to significant expenses in terms of installation and materials, making forced water circulation cooling impractical for large-scale solar plants.

Implementing an immersion cooling technique involves submerging PV modules underwater, leading to significant improvements in efficiency through heat absorption by water. Studies (Mehrota *et al.*, 2014) have shown that even with a depth of just 1 cm, electrical efficiency can be enhanced by 17.8%. This technique offers minimal environmental impact and has the potential to reduce module temperatures effectively. However, it should be noted that immersion cooling is not suitable for floating solar systems.

The water spraying technique involves using a pump, connected to a system of pipes and nozzles, to spray water onto the surface of the PV panels. This process effectively cleans and cools the panels, leading to an increase in electrical efficiency. One research (Nizetic *et al.*, 2016a) evaluated the outcome of water spray with cooling on the both sides of the PV, with the result of a maximal total increase of 16.3% (effective 7.7%) in electrical power output.

A system was developed (Moharrama *et al.*, 2013) for cooling the PV in hot arid regions (Egypt). The device consists in PV modules, a storage tank, pump, filter, nozzles and drain pipe. The design was developed to minimize the

water consumption. The result was the cooling from the 45° to 35°C in 4.7 minute. The optimum temperature for starting the cooling process was 45°C.

4.3. PV/T systems

The process of circulating cooling agents, such as air, water, or glycol, around solar panels serve two purposes: cooling the solar cells and generating hot fluid that can be utilized for other heating applications. While this cooling method may not maximize the electrical performance of the cells, it offers a more efficient approach to harnessing solar energy overall.

Among the various cooling techniques, water cooling proves to be superior due to its enhanced heat transfer capacity. Consequently, in situations where water preheating is required, PV/T collectors (Fig. 4) are considered the most efficient technology choice. By employing cooling agents, solar panels can effectively maintain optimal operating temperatures while simultaneously contributing to sustainable and efficient energy utilization. The utilization of water as a cooling agent particularly enhances the heat transfer capacity, resulting in improved performance of the panels. Ultimately, the integration of PV/T collectors enables the optimized utilization of solar energy by simultaneously generating electricity and preheating water.

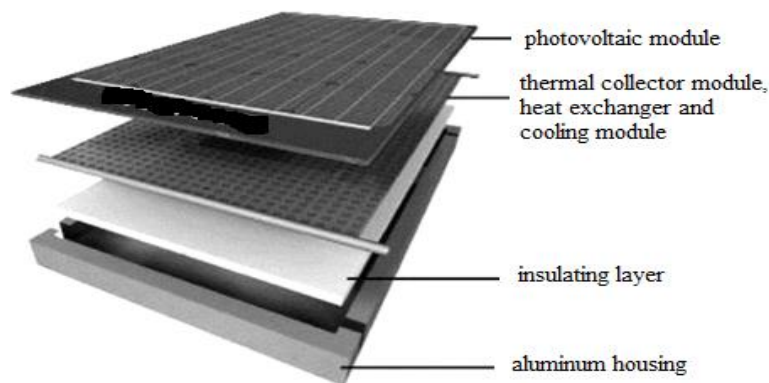


Fig. 4 – The schematic of a PV/T module.

There are multiple systems for cooling and heating (or both of them) with PV/T collectors integrated, involving different types of collectors (various designs, geometrical configurations and different thermal management concepts).

A model (Ahmad *et al.*, 2020) was designed for achieving heating and cooling with the highest possible efficiency. The required power for the compressor is obtained from the solar panel, and the cooling fluid is water.

The required heat was obtained by passing the cooling water through a heater and two heat exchangers.

4.4. Active PCM cooling

Active PCM cooling, usually used in conjunction with other cooling methods such as PV/T, is an effective approach to enhance the cooling efficiency and performance of solar panels.

Active PCM cooling involves actively circulating a PCM, typically in liquid form, through a system integrated with the solar panel. In a PV/T system, the PCM is used to absorb excess heat generated by the solar cells. This helps regulate the temperature of the panel, preventing overheating and improving overall efficiency. The PCM absorbs the heat from the solar cells during peak sunlight hours and releases it later when temperatures drop or when additional heat is needed for other purposes.

A system with cooled PVT with a heat tank based on PCMs was designed (Muhammad *et al.*, 2018) for a residential building in Saudi Arabia. The comparison made, with and without thermal storage, showed that the presence of PCM battery improved the electrical performance with 11.7%. Thermal storage added to the system had covered 27.3% of the residential heat needs and 77% of the residential electric load.

Another PVT/PCM system was analyzed in India (Maatallah *et al.*, 2019). The system was tested in various outside ambient conditions. The conclusion was that PCM improved thermal performance by 26.87% and the overall performance by 40.59%. Compared to the conventional PV panels, the electrical efficiency was upgraded by 17.33%.

In an experimental approach (Gao *et al.*, 2022), a phase change cooling technique was combined with porous media in a photovoltaic-thermal (PV-T) collector. The results showed that this combination led to a significant enhancement in the average electrical efficiency of the PV panel. Specifically, the efficiency improved by 9.7% at a flow rate of 0.004 kg/s, 17% at a flow rate of 0.007 kg/s, and 15% at a flow rate of 0.009 kg/s. This suggests that the integration of phase change cooling techniques with porous media can effectively improve the performance of PV-T collectors.

5. Conclusions

✓ Active water cooling has been identified as the easiest and most effective cooling technique, but its practicality is limited by the requirement for a steady supply of cool water and the need for large arrays to offset energy consumption.

✓ Passive cooling through natural convection is a simple method but has limitations, as air is a less effective coolant compared to water.

✓ Water-based cooling systems are more suitable for applications where there is a match between hot water and energy requirements, such as restaurants, hotels, and process industries.

- ✓ Water cooling systems offer the additional benefit of cleaning PV modules from dust accumulation, and the water used for cleaning can be recycled for agricultural purposes.
- ✓ PCM cooling is a highly capable technique due to its higher energy density per unit volume.
- ✓ Both air and water cooling methods have been widely used as they provide additional thermal energy that can be utilized for various purposes.
- ✓ Further assessment of the performance effectiveness and economic viability of cooling systems is necessary, along with refining, optimizing, and scaling up each method for large-scale solar farms.
- ✓ Future research should focus on economic analysis and environmental assessment to identify cost-effective cooling solutions.
- ✓ The development of hybrid cooling methods that aim to maintain low and stable surface temperatures should be a future direction of technology development, with a focus on active water cooling and combined heat pipe and sink cooling techniques.
- ✓ There are a lot of conditions to consider for every application (location, weather, orientation, shading, space, consumer needs, budget and so on), that makes impossible to name the best method for cooling the PV system or to give a classification.
- ✓ Life cycle assessment, key performance indicator such as payback time and life-cycle savings, CO₂ emission saving potential, the impact on global warming and the carbon footprint are other challenges that we have to overcome in choosing the suitable design for a cooled PV system.

REFERENCES

- Ahmad Zarei, Mohammad Liravi, Marzie Babaie Rabiee, Maryam Ghodrat, *A Novel, eco-friendly combined solar cooling and heating system, powered by hybrid Photovoltaic thermal (PVT) collector for domestic application*, Energy Conversion and Management **222**, ID: 113198, (2020).
- Brinkworth B.J., Cross B.M., Marshall R.H., Yang H., *Thermal regulation of photovoltaic cladding*, Solar Energy **61**, 169-178, (1997).
- Gao Y., Hu G., Zhang Y., Zhang X., *An experimental study of a hybrid photovoltaic thermal system based on ethanol phase change self-circulation technology*, Energy and exergy analysis. Energy, Part A, ID 121663, (2022).
- Maatallah T., Zachariah R., Al-Amri F.G., *Exergo-economic analysis of a serpentine flow type water based photovoltaic thermal system with phase change material (PVT-PCM/water)*, Solar Energy **193**, 195-204, (2019).
- Mazon-Hernandez R., García-Cascales J.R., Vera-García F., Kaiser A.S., Zamora B., *Improving the electrical parameters of a photovoltaic panel by means of an induced or forced air stream*, Int. J. Photoenergy **10**, ID: 830968, (2013).
- Mehrotra S., Rawat P., Debbarma M., Sudhakar K., *Performance of a solar panel with water immersion cooling technique*, Int. J. Sci. Environ. Technol. **3**, 1161-1172, (2014).

- Moharrama K.A.S., Abd-Elhadyb H., Kandila M.S., El-Sherif A.H., *Enhancing the performance of photovoltaic panels by water cooling*, Ain Shams Eng. J. **4**, 869-877, (2013).
- Muhammad O. Lari, Ahmet Z. Sahin, *Effect of retrofitting a silver/water nanofluid-based photovoltaic/thermal (PV/T) system with a PCM-thermal battery for residential applications*, Renewable Energy **122**, 98-107, (2018).
- Nair K.K., Jose J., Ravindran A., *Analysis of temperature dependent parameters on solar cell efficiency using MATLAB*, Int J Eng Dev Res **4**, 536-541, (2016).
- Nizetic S., Coko D., Yadav A., Grubisic-Cabo F., *Water spray cooling technique applied on a photovoltaic panel: the performance response*, Energy Convers. Manag. **108**, 287-296, (2016a).
- Nizetic S., Grubisic – Cabo F., Marinic - Kragic I., Papadopoulus A.M., *Experimental and numerical investigation of a backside convective cooling mechanism on photovoltaic panels*, Energy, Volume **111**, 211-225, (2016b).
- Sangram Bana, Saini R.P., *A mathematical modeling framework to evaluate the performance of single diode and double diode based SPV systems*, Energy Reports **2**, 171-187, (2016).
- Sarwar Hasan J., Alnoman H., Abdelbaqi S., *Yearly energy performance of a photovoltaic-phase change material (PV-PCM) system in hot climate*, Sol. Energy **146**, 417-429, (2017).
- Sharma S., Tahir A., Reddy K.S., Mallick T.K., *Performance enhancement of a Building-Integrated Concentrating Photovoltaic system using phase change material*, Sol. Energy Mater. Sol. Cells **149**, 29-39, (2016).
- Tang X., Z. Quan, Y. Zhao, *Experimental investigation of solar panel cooling by a novel micro heat pipe array*, Energy Power Eng. **2**, 171-174, (2010).
- Valeh-E-Sheyda P., Rahimi M., Parsamoghadam A., Masahi M.M., *Using a wind-driven ventilator to enhance a photovoltaic cell power generation*, Energy and Buildings **73**, 115-119, (2014).
- Wu S.Y.A, Zhang Q.L., Xiao L.X., Guo F.H., *A heat pipe photovoltaic/thermal (PV/T) hybrid system and its performance evaluation*, Energy Build. **43**, 3558-3567, (2011).

PROIECTAREA ȘI DEZVOLTAREA SISTEMELOR DE RĂCIRE PENTRU ÎMBUNĂTĂȚIREA PERFORMANȚEI CELULELOR FOTOVOLTAICE

(Rezumat)

Acest articol prezintă o sinteză concisă a tehnicilor de răcire pentru sistemele fotovoltaice (PV). Efectul fotovoltaic a fost demonstrat experimental pentru prima dată de către fizicianul francez Edmond Becquél în 1839. Primul panou solar util (cu o eficiență energetică de 6%) a fost realizat de către Laboratoarele Bell în anul 1950. Aceștia au constatat că materialele semiconductoare precum siliciul sunt mai eficiente decât seleniul.

Următoarele condiții au un impact semnificativ asupra eficienței panourilor solare în utilizarea în practică: radiația (W/m^2), umbrirea, orientarea și temperatura. Temperatura ambientală, viteza vântului, perioada zilei și cantitatea de radiație solară (W/m^2) determină variații reale ale temperaturii celulelor, care adesea depășește $25^{\circ}C$.

Temperatura internă optimă a celulei este în general cu 25-30°C peste temperatura aerului ambiental, iar performanța celulei solare scade cu 8-15% ca nivel de putere generată odată cu creșterea temperaturii. De aceea, inginerii proiectează sisteme de răcire pentru a îmbunătăți eficiența panourilor solare care funcționează în condiții ce nu sunt optime.