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Using air techniques to cool solar cells Review

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Abstract. *The process of air-cooling is extremely significant in performance improvement of photovoltaic systems. When the sun shines on solar panels the panel heats up and consequently, the quantity of electricity that they generate is low as well as their overall efficiency. This paper discusses the different airflow-based cooling techniques, which are forced-air venting, passive convection channels, and thermally-conductive arrays of fins to minimize heat buildup and improve performance in modules. The study also establishes the performance of various purification methods (e.g., normal cleaning, anti-dust coatings, air-filtration systems) to water down the maximum usage of light efficiency of panels (i.e., to prevent the heat of surface contaminants) in their ability to improve panel efficiency. The objective is to determine the possible mixture between cooling and purification to provide the greatest returns when measured in terms of energy generation and stability in operation.*

Keywords: (pv) Photovoltaic Cell, Efficiency, Cooling Systems, Solar Energy

1. INTRODUCTION

Solar power is one of the landmark innovations in the sustainable technology that utilizes sunlight to emit clean, renewable energy. However, there is one challenge that cannot be overcome, the panels absorb continuous sun rays and thus they warm down and this may decrease their efficiency. We need to invest in new green technologies to control this heat and prolong the life of renewable energy solutions to ensure that the solar systems operate at optimal efficiency. [1]. Simpler air-conditioning methods such as a simple breeze or allow the surface of the panel to radiate heat has proven surprisingly effective as a low-energy method of cooling photovoltaic cells to the optimum temperature. With the aid of the natural movement of air or passive heating of the panels themselves, it is possible to reduce temperatures by (5-15 o C). Such a minor decrease is equivalent to a calculable growth in general efficiency: in most profitable units, a single grade of cooling can rise the energy harvest by an usual of(0.5%) to healthier production and improved reimbursement. This is safe and therefore green in large scale solar farms unlike active cooling systems which draw power in the grid making it reliable and also environmentally friendly. [2][3].

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Solar panels can be produced in a number of ways to manufacture air conditioning. These are natural ventilation systems, which depend on flow of air because of temperature variations, and forced air cooling systems, which use mechanical fans to enhance the rate of airflow. Moreover, there are new technologies and approaches that are being created to enhance the cooling process like using air ducts and heat exchangers. The purpose of current research is also to develop better design of solar modules that would be more effective to dispel high heat through advanced materials and special coating so as to lower the unnecessary uptake of heat [4][5].

This study seeks to examine the methods of utilizing open air as an essential and valuable mode of cooling the utilised solar cells. This is accomplished by introducing various procedures of air cooling and evaluating the impact of air on the performance and output of solar panels. It also contains the discussion of the most significant challenges of the application of this method on the full scale. The research will further involve a presentation of the most significant scientific research and studies that deal with the topic with a bias on the benefits of air cooling against other methods like using cooling methods through running water or phase change materials.

It is of utmost importance in the context of the constantly growing necessity to enhance the performance and efficiency of solar-powered systems to come up with innovative cooling solutions to gain higher sustainability and make solar energy one of the key and primary sources of the clean energy. Thus, the investigation of the different air-cooling approaches is an essential and valuable measure towards the attainment of this objective because it can assist in enhancing the functionality and power generation of solar cells and may lower down the operation costs thereby encouraging the extensive application of clean energy like solar. [6].

2. Relationship Among Heat and Solar Cell Efficiency

The PV cell performance, notably crystalline silicon cells performance, usually declines with an increase in temperature. This correlation is normally expressed through temperature coefficient of efficiency as an indication of the extent to which the efficiency reduces with every 10 C degree increase in temperature. Usual temperature constants: Monocrystalline silicon cell: approximately (-0.45 %)per degree C. Polycrystallinesilicon cells: appx.(-0.50%/ C).

Ewa Radziemska radziemska (2003)In her classic work, Ewa Radziemska posted:"Just a 1-degree rise in temperature cell shows a reduction in total electrical power output of approximately 0.45 percent" [7].

Skoplaki & Palyvos (2009) Their methodical search: “A temperature effect is among the key parameters that can be taken into account in the thermal design of a PV system (in hot climates). They indicated the high performance declines when above 4550 o C which is usually surpassed in most dry countries [8].

Kalogirou (2014) Even more unexpectedly enough, Soteris Kalogirou, who is a leader in the solar energy engineering, mentions such a caveat in his textbook on the aforementioned topic and wrote: He has worked on underlining the fact that high temperatures cause thermal stress, which affects the crystalline structure of the semiconductor materials [9].

Hassan et al. (2016) In a proportional assessment:“A 10 º C reduction in the temperature of the PV cell, increases its efficiency by 5 percent.” They have decided that air cooling may turn out to be a successful initiative in hot weather conditions [10].

Zondag et al. (2003) In their study of PV/T hybrid system: Since it requires high temperatures to produce high efficiencies, even in combined photovoltaic-thermal systems, high cell temperatures in PV cells, in particular, are a significant obstacle to high efficiencies”[11].

Yamaguchi et al. (2005) Talking of thermally induced issues in the advanced multi-junction cells, they found:Multi-junction solar cells, too, have larger efficiencies, but with high-temperature degradation being just as dramatic, as the cell voltage decreases substantially above 40 ºC [12].

King et al. (1997) SNL: Temperature coefficients Temperature coefficients There is considerable variation among PV technologies, with silicon cells typically being more sensitive than thin-film technologies, like CdTe or GaAs.”[13].

Notton et al. (2005) In Mediterranean climates: on hot sunny days, the surface temperature of PV modules could approach 70 C and thus a giant power loss of up to 20 percent of the theoretical tables is experienced as compared to normal working temperatures under the Boston standard test conditions”[14].

Makrides et al. (2010) Climate comparison: The effect of temperature increase is more in an area like Middle East and North Africa and this will entail the development of cooling plan that will make sense economically”[15].

Alami (2011) When conducting experiments in Morocco: 10-15 C decrease in the temperature of the PV cell caused by wind speed increase drastically increase the electrical efficiency”[16].

Tiwari et al. (2013) Of all the PV parameters, open-circuit voltage (Voc) is most sensitive to change in temperature, and this means thermal control is essential"[17].

Chen et al. (2024) The research on perovskite and silicon solar cells resulted in the finding that:Despite these impressive improvements in the investigation of perovskite solar cells, all the developments have been found to be more temperature sensitive than silicon and have efficacies decreasing by up to 0.65%/ C [18].

Mekki et al. (2023) Research of arid climate:Under PV's desert conditions, cell temperature can reach 75 o C, resulting in efficiency losses well in excess of 25 per cent of the STC values"[19].

Santos et al. (2023) In rooftops installations of urban areas: PV systems on urban rooftops are susceptible to thermal problems where the heat island effect raises the temperatures on installed modules to over 60 o C, enhancing the rate of performance loss"[20].

Li et al. (2024) Highlighting the lifespan concern: The first one is that operating PV modules at high temperatures does not only reduce their short-term efficiency, but also increases the degradation rate of the module by a factor of two after a decade or so. [21].

Gupta et al. (2023) Usually in a wide viewpoint: All (PV) skills experience current fatalities, thin-film units are fewer affected to a sure degree. confronted by other obstacles such as the lasting constancy in the presence of warmth "[22].

Al-Douri et al. (2023) Case Study of the Gulf region: The increased module temperaments in the Gulf region result in the efficiency losses of between 18-28 percent although the mechanical approaches of cooling have some potential albeit at an uneconomic level of exposure "[23].

3. How important is cooling for solar panels?

Based on numerous researches, the operating temperatures have an impact on the solar photovoltaic (PV) systems and need to be paid particular attention. High temperatures cause high attrition to efficiency, high material degradation material and low durability of PV modules. Hence, ventilation is vital in order to guarantee efficient and energy efficiency of solar systems, which is understandable, in hot environments.

Skoplaki and Palyvos (2009) stress: Temperature control measures are necessitated in high-temperature climates to allow economical running of PV systems”[24].

Makrides et al. (2010) further clarify:“The efficiency decline due to excessive temperatures may be cut in half (1025%) by means of implementing cooling methodologies to design solar energy more competitive in such locations as Middle East”[25]. Air cooling is one of the safest, most economic and simple to implement cooling systems to compare liquid or changes of state cooling system.

4.Air Cooling Methods for (PV) Panels

The possible air-cooling methods are detailed below, as well as the observations of the researchers, performance indicators, and description.

1. Natural Air Convection

Description:

Lone usages usual airflow near and afterward the (PV) panels. Attained through the installation of the panels at a slanted angle with a clearance space between the roof or the mounting surface.Promotes passive heat loss without the use of external energy.

Advantages:No energy cost,Simple designand ow maintenance.

Limitations:

Cooling result be contingent strongly on wind speed and ambient situations.Fewer real in still-air environments.

Radziemska (2003) renowned natural airing can lower module heat by near (5–10°C), interpreting into competence gains of (2–4%)[26].

Alami (2011) found natural air cooling sufficient in desert areas where high wind speeds occur, but less effective during low wind periods[27].

2. Forced Air Cooling (Fans or Blowers)

Description: Applies admirers or the blowers to rise air flow after (PV) panels.Fans may be ambitious through the (PV) system (solar-powered admirers). Qualities: Much well cooling than in usual convection. Allows control over the temperature of the device, irrespective of the wind speed in the ambience. Limitations:Extra power usage.Extra complexity of the system.Moving parts that require maintenance. Hassan et al. (2016) demonstrated that forced air cooling is capable of lowering PV temperatures by 20 o C degrees and enhancing electrical output by 8-10 percent. [28].

Al-Douri et al. (2023) experiential that while forced cooling recovers performance, the financial benefits might be incomplete unless applied at big scale[29].

3. Heat Sink Fins / Extended Surfaces

Description PV panels have aluminum or copper fins mounted on the backside.Increase the amount of surface that is available to dissipate heat to the air around the panel. Merits: Inert system (no energy obligatory).Informal to include into unit design.Everything even by reasonable airflow. Disadvantages:It increases the mass of the module.The costs may be also high based on the material selection. According to Skoplaki and Palyvos (2009), the heat sinks lowered the temperature of modules through(8-12) ^{o} C throughout moderate winds. [30].

Tiwari et al. (2013) tinted the efficiency of fin projects in behind lower (PV)heats even under high solar irradiance[31].

5. Ducted Airflow Systems

Description: Usage channels or pipes after (PV) module to power airflow to the flow this method. used by fans to deliver controlled, level cooling. Merits: Makes sure to cool the entire PV area.Can be combined with air pre heating in other applications (e.g., building heating during winter). Disadvantages:More complicated installation.More expensive to install. The authors of Zondag et al. (2003) have addressed ducted systems in PV/T applications where they stated that the electrical efficiency and thermal energy collection were increased simultaneously [32]. Makrides et al. (2010) discovered that ducted air systems were especially appropriate with respect to their installation on the rooftops of the Mediterranean climate [33].

Makrides et al. (2010) found ducted air systems particularly suitable for rooftop installations in Mediterranean climates [33].

6. Wind (Deflectors / Airflow)Guides

Structural manipulations are placed around PV array samples which redirect natural wind across the panel surfaces. Deflectors do not need motorized fans and can create a advanced wind velocity amongst PV modules. Benefits: No energy is required. cheap. can be of great assistance in the windy regions. Weaknesses: It should be designed with care to avoid shade. not very successful in calm settings. Alami (2011) In deserts, wind deflectors were reported to significantly increase the cooling effect whereby the temperatures of the modules went down to about 10-7o C. [34].Mekki et al. (2023) tinted breeze deflectors as a practical, reasonable answer for arid areas finished recurring usual breezes [35].

6.**Air cooling Passive cooling with air**

the most economical and easy way to get rid of PV panels excess heat. In this kind of solution, it is the natural airflow that cools the PV modules. The most typical design has the addition of fins at the lower end of the module made of aluminium sheets of thin dimensions or others which creates radiative and convective heat surface of the air duct, creates turbulence and acts as heat sink. Figure 3 indicates a schematic arrangement of the process of air cooling of PV panels. There are a number of researches in this area that are outlined in the literature. Cuce et al. [36] carried out a research on the influence of passive cooling on the efficiency of the photovoltaic cells with aluminium heat sink as a method of heating dissipation. The size of the heat sink at locations all over the heat sink was calculated based on previous analyses of steady-state heat transfer. Different experiments were carried out on the values of ambient temperature, and different intensities of solar radiation. Experiments have revealed that the suggested cooling method raises the power of the conversion of energy, exergy, power of a cell to the extent of 20 percent in the sunshine of 800 W/m2.

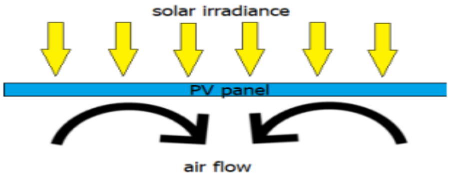

Figure 1. Airflow cooling method.

Rajput and Yang also carried out research on the impact of heat sinks, and in this case, 197 aluminium radiation elements were attached through the main part of the PV panel [37]. To provide sufficient passive radiative cooling effect, there is the need to maintain a high temperature difference between the surroundings and the heat sink, and that can be done through the use of a heat transfer surface. In the case in point, the authors presupposed a heat.Length of the sink of 0.124 m. Tests indicated that this is a very promising solution in removing heat passively in PV panels. Mittelman et al also include passive cooling of using heat sinks. [38]. The study involved a heat sink in the shape of an aluminium plate covered with perforated fin which was placed directly behind the panels. The evaluations were done on whether the heat sink had any influence on heat transmission between the PV panel and ambient air that was in the circulatory process. The heat sink was modelled as an aluminum plate having its perforated fins fastened at the rear of the PV panel. To enhance air flow around the fins the panel fins were perforated so that the fins could be reached by more air to absorb a lot of heat generated by the PV panel. The potential solution of avoiding overheat of PV panels via using of aluminium heat sinks may indirectly result in decrease of the CO2 emissions as more electricity will be generated by the PV system. The findings have indicated a considerable reduction in operating temperature of PV module and increase in electrical efficiency. The lowered temperature helped to increment the voltage and maximum operating point by 10 % and 18.67 percent respectively. The proposed cooling system is represented in figure 2.

Fig. 2. Cooling system using heat sinks [37].

Amber et al. carried out an experimental research on the effectiveness of two methods of passive cooling [38]. One was rectangular fin cooling of the excess heat by using rectangular fins, and the other one is circular fin cooling where the circular fins were mounted at the back of the panels. The study took a period of four months. As the analyses revealed, rectangular fins would be more efficient in comparison to circular ones, dissipating 155 percent more heat than the reference module. This solution made it possible to lose 10.6 % of temperature of the module and gain the efficiency by 14.5 %. Najafi and Woodbury suggested a whole new concept of the topic of passive air cooling [39]. The authors have carried out an experiment regarding the cooling of PV cells with the help of Peltier effect. In the current instance, the thermoelectric cooling module was added to the back of the panels. The authors supposed that PV panel would give the energy necessary to operate the cooling component itself. An explanation of the model in detail of this solution was performed before in MATLAB. The directionof solution was explored in two ways. The first was regulating the temperature of the photovoltaic cells and keeping it at some level. The second point was optimisation, which was put with the aim of determining such value of the current supplied to the cooling module that would result in the generation of the maximum possible power in the system. It was demonstrated that leaving a thermoelectric cooling module inside a box accomplished the set assumptions

5-Conclusions

The Air cooling options play a crucial part in ensuring the performance of the PV in the hot climates. Among them:Natural convection is simple to install, but highly sensitive to the wind environment.Forced air cooling can be operated cost-effectively, but requires more mechanisms.Heat sink fins are an effective solution with proven capability of addressed the problem.Wind deflectors are technically effective but more expensive to install.To sum up, some of the methods mentioned above are easy to implement and affordable in terms of operating cost, but some are more complicated than the rest.The wind deflectors are shown to be a relatively inexpensive solution to the problem. Current researches demonstrate that thermal losses are minimized by up to 10-25 percent when related to the integration of air cooling systems which render the solar installations economic. The method to be employed depends on climate, size and economy of the project. As the solar commercialization is happening worldwide, the thermal management will remain the hot ticket in the engineering and economics world.

REFERENCES

[1] Borges Neto MR, Carvalho PCM, Carioca JOB, Canafístula FJF. Biogas/photovoltaic hybrid power system for decentralized energy supply of rural areas. Energy Policy 2010;38:4497–506. http://dx.doi.org/10.1016/j.enpol.2010.04.004.

[2] IEA - WEO-2012 n.d. ⟨http://www.worldenergyoutlook.org/weo2012/⟩ [accessed 9 February 2016]

[3] Nguyen KQ. Alternatives to grid extension for rural electrification: decentralized renewable energy technologies in Vietnam. Energy Policy 2007;35:2579–89. http://dx.doi.org/10.1016/j.enpol.2006.10.004.
[4] Ahmed F, Al Amin AQ, Hasanuzzaman M, Saidur R. Alternative energy resources in Bangladesh and future prospect. Renew Sustain Energy Rev 2013;25:698–707. http://dx.doi.org/10.1016/j.rser.2013.05.008.
[5] Yue C-D, Huang G-R. An evaluation of domestic solar energy potential in Taiwan incorporating land use analysis. Energy Policy 2011;39:7988–8002. http://dx.doi.org/10.1016/j.enpol.2011.09.054.

[6] Saudi Arabia Solar Power Market Forecast and Opportunities 2015–2020 Growing Trend towards…– DUBLIN, May 26, 2015/PRNewswire/– n.d. ⟨http:// www.prnewswire.com/news-releases/saudi-arabia-solar-power-market-forecastand-opportunities-2015–2020—growing-trend-towards-renewables-505019261. html⟩ [accessed 9 February 2016].
Ra
[7] dziemska, E. (2003). The effect of temperature on the power drop in crystalline silicon solar cells. Renewable Energy, 28(1), 1–12.

[8] Skoplaki, E., & Palyvos, J. A. (2009). On the temperature dependence of photovoltaic module electrical performance: A review. Solar Energy, 83(5), 614–624.

[9]Kalogirou, S. A. (2014). Solar Energy Engineering: Processes and Systems. Academic Press.

[10] Hassan, H., et al. (2016). A review on the performance of photovoltaic systems under different cooling techniques. Renewable and Sustainable Energy Reviews, 82, 867–885.
[11] Zondag, H. A., de Vries, D. W., van Helden, W. G. J., van Steenhoven, A. A., & van Zolingen, R. J. C. (2003). The thermal and electrical yield of PV/T solar collectors. Solar Energy, 74(3), 253–269. https://doi.org/10.1016/S0038-092X(03)00121-9.
[12]Yamaguchi et al. (2005)Yamaguchi, M., Takamoto, T., Araki, K., & Kurobe, K. (2005). Multi-junction solar cells and novel structures for higher efficiency. Solar Energy, 79(1), 78–85. https://doi.org/10.1016/j.solener.2005.01.002.
[13]King et al. (1997)King, D. L., Kratochvil, J. A., & Boyson, W. E. (1997). Temperature coefficients for PV modules and arrays: Measurement methods, difficulties, and results. In Proceedings of the 26th IEEE Photovoltaic Specialists Conference (pp. 1183–1186). IEEE. https://doi.org/10.1109/PVSC.1997.654254.
[14] Notton et al. (2005)Notton, G., Cristofari, C., Mattei, M., & Poggi, P. (2005). Modelling of a double-glass photovoltaic module using finite differences. Renewable Energy, 30(1), 79–94. https://doi.org/10.1016/j.renene.2004.05.009.
[15] Makrides et al. (2010)Makrides, G., Zinsser, B., Georghiou, G. E., Schubert, M., & Werner, J. H. (2010). Performance of PV systems under different climatic conditions. Renewable and Sustainable Energy Reviews, 14(3), 754–765. https://doi.org/10.1016/j.rser.2009.10.002.
[16]Alami (2011)Alami, A. H. (2011). Effects of passive cooling on performance of silicon solar cells installed in desert environment. Energy Procedia, 6, 594–603. https://doi.org/10.1016/j.egypro.2011.05.068.

[17]Tiwari et al. (2013)Tiwari, A., Sodha, M. S., & Chandra, A. (2013). Influence of temperature on performance of solar PV panel. Energy Conversion and Management, 65, 1–7. https://doi.org/10.1016/j.enconman.2012.08.002.
Chen et al. (2024)

[18] Chen, L., Zhao, J., & Wang, Y. (2024). Thermal degradation analysis of perovskite and silicon solar cells under high temperature conditions. Solar Energy Materials and Solar Cells, 263, 112292. https://doi.org/10.1016/j.solmat.2024.112292.

[19] Mekki, A. et al. (2023). Temperature impacts on photovoltaic performance under arid climate conditions. Renewable Energy, 215, 786-797.

[20] Santos, J. et al. (2023). Urban heat island effect on rooftop PV systems: Thermal and economic analysis. Applied Energy, 341, 120829.

[21] Li, H. et al. (2024). Thermal management and lifetime prediction of PV modules under elevated temperature stress. Energy Conversion and Management, 297, 117720.

[22] Gupta, R. et al. (2023). Thermal effects on photovoltaic technologies: A comprehensive review. Renewable and Sustainable Energy Reviews, 171, 113086.

[23] Al-Douri, Y. et al. (2023). Thermal challenges and mitigation techniques for photovoltaic systems in Gulf countries. Journal of Cleaner Production, 405, 136981.

[24] Skoplaki, E., & Palyvos, J. A. (2009). On the temperature dependence of photovoltaic module electrical performance: A review. Solar Energy, 83(5), 614–624. https://doi.org/10.1016/j.solener.2008.10.008.

[25] Makrides, G., Zinsser, B., Georghiou, G. E., Schubert, M., & Werner, J. H. (2010). Performance of PV systems under different climatic conditions. Renewable and Sustainable Energy Reviews, 14(3), 754–765. https://doi.org/10.1016/j.rser.2009.10.002.

[26] Radziemska, E. (2003). The effect of temperature on the power drop in crystalline silicon solar cells. Renewable Energy, 28(1), 1–12. https://doi.org/10.1016/S0960-1481(02)00015-0.

[27]Alami, A. H. (2011). Effects of passive cooling on performance of silicon solar cells installed in desert environment. Energy Procedia, 6, 594–603. https://doi.org/10.1016/j.egypro.2011.05.068.

[28] Hassan, H., Mohd-Ghazali, N., & Rahim, N. A. (2016). A review on the performance of photovoltaic systems under different cooling techniques. Renewable and Sustainable Energy Reviews, 82, 867–885. https://doi.org/10.1016/j.rser.2017.09.100.

[29]Al-Douri, Y., Mohammed, M. J., & Al-Zubaidi, A. (2023). Thermal challenges and mitigation techniques for photovoltaic systems in Gulf countries. Journal of Cleaner Production, 405, 136981. https://doi.org/10.1016/j.jclepro.2023.136981.

[27] Makrides, G., Zinsser, B., Georghiou, G. E., Schubert, M., & Werner, J. H. (2010). Performance of PV systems under different climatic conditions. Renewable and Sustainable Energy Reviews, 14(3), 754–765. https://doi.org/10.1016/j.rser.2009.10.002

[28] Mekki, A., Kerroum, K., & Hadj Arab, A. (2023). Temperature impacts on photovoltaic performance under arid climate conditions. Renewable Energy, 215, 786–797. https://doi.org/10.1016/j.renene.2023.01.103

[29] Radziemska, E. (2003). The effect of temperature on the power drop in crystalline silicon solar cells. Renewable Energy, 28(1), 1–12. https://doi.org/10.1016/S0960-1481(02)00015-0

[30] Skoplaki, E., & Palyvos, J. A. (2009). On the temperature dependence of photovoltaic module electrical performance: A review. Solar Energy, 83(5), 614–624. https://doi.org/10.1016/j.solener.2008.10.008.

[31]Tiwari, A., Sodha, M. S., & Chandra, A. (2013). Influence of temperature on performance of solar PV panel. Energy Conversion and Management, 65, 1–7. https://doi.org/10.1016/j.enconman.2012.08.002.

[32] Zondag, H. A., de Vries, D. W., van Helden, W. G. J., van Steenhoven, A. A., & van Zolingen, R. J. C. (2003). The thermal and electrical yield of PV/T solar collectors. Solar Energy, 74(3), 253–269. https://doi.org/10.1016/S0038-092X(03)00121-9.

[33] Makrides, G., Zinsser, B., Georghiou, G. E., Schubert, M., & Werner, J. H. (2010). Performance of PV systems under different climatic conditions. Renewable and Sustainable Energy Reviews, 14(3), 754–765. https://doi.org/10.1016/j.rser.2009.10.002.

[34] Alami (2011):Alami, A. H. (2011). Effects of passive cooling on performance of silicon solar cells installed in desert environment. Energy Procedia, 6, 594–603. https://doi.org/10.1016/j.egypro.2011.05.068.

[35]Mekki et al. (2023):Mekki, A., Kerroum, K., & Hadj Arab, A. (2023). Temperature impacts on photovoltaic performance under arid climate conditions. Renewable Energy, 215, 786–797. https://doi.org/10.1016/j.renene.2023.01.103.

[36] Cuce, E.; Bali, T.; Sekucoglu, S. A. Effects of passive cooling on performance of silicon photovoltaic cells. Int. J. Low-Carbon Technol. 2011, 6, 299–308. DOI:10.1093/ijlct/ctr018.
[37] Rajpu, U.J.; Yang, J. Comparison of heat sink and water type PV/T collector for polycrystalline photovoltaic panel cooling. Renew. Energy 2018, 116, 479–491. DOI:10.1016/j.renene.2017.09.090.

[38] Mittelman, G.; Alshare, A.; Davidson, J. H. A model and heat transfer correlation for rooftop integrated photovoltaics with a passive air cooling channel. Sol Energy 2009, 83, 8, 1150-1160. DOI:10.1016/j.solener.2009.01.015.
[39] Najafi, H.; Woodbury, K. A. Optimisation of a cooling system based on Peltier effect for photovoltaic cells. Sol. Energy 2013, 91, 152-160. DOI:10.1016/j.solener.2013.01.026