Review of Water Cooling Techniques for Enhancement Performance of Photovoltaic Panel

Faez Abid Muslim Abd Ali[1], Ahmed A. Taher[2], Muna Hameed Alturaihi3
1Mechanical Dept., Engineering Faculty, University of Kufa. E-mail: Faeza.abdali@uokufa.edu.iq
2Mechanical Dept., Engineering Faculty, University of Kufa. E-mail: ahmed.abosabeeh@uokufa.edu.iq
3Mechanical Dept., Engineering Faculty, University of Kufa. E-mail: Monah.alturaihi@uokufa.edu.iq

Abstract

This study discusses various water-based cooling solutions for lowering the operative temperature of the electrical phenomena panel The goal of this review study is to improve the performance of micro electrical phenomenon the panel temperature the impact operative and temperature panel of electrical phenomena is explored using a variety of cooling strategies The advantages and disadvantages of evaporative cooling, water spray cooling, and immersion cooling were investigated in this research in order to determine their impact electrical phenomenon was well known evaporating cool system, which uses cold water to cool it, has effect with electrical phenomenon performance As a result, in a very hot climate, cool water was the ideal so improve electrical potency of electrical phenomenon.

Keyword-Photovoltaic Panels, Water Cooling Techniques and Performance

1. Introductory paragraph

The usage of renewable energy is becoming more popular as the human population grows, as well as environmental issues such as pollution and non-sustainability of traditional energy sources Alternative most important types piqued the interest of many scholars all over the world The stellar energy will be converted into two types of energy: electricity and heat energy Electricity is far more useful than thermal energy, owing to its capacity to be easily translated to figures Mistreatment electrical phenomena (PV) cells may be used to generate electricity The best, property, and environment-friendly technologies are solar cells, which immediately convert incident a location of power. remainder radiation is raises cells temperature and diminishes the electrical phenomenon panel's performance [1].

When the star irradiance is 1,000 W/m^2, the absorption rate is 70%, and there are no winds, the electrical phenomenon cells temperature is 60 °C, however when the winds speed is greater than four m/s, the electrical phenomenon cells temperature is below 40 °C [2]

However, it has been demonstrated that when the temperature rises, the potency of the general electrical phenomena cells decreases dramatically Depending on the cell material employed, the rate of decline ranges from zero.25 percent to 0.5 percent per degree [3].

The most output power, short current, and open-circuit voltage are the most metrics that are affected by temperature changes in the cells. As a result, as the temperature rises, the open-circuit voltage and hence the greatest output power fall, but the short current rises [4].

C.U. Ike et al. [5] claimed that the electrical phenomenon's output power and the location's close temperature are indirectly proportional. As a result, the electrical phenomena produces more output power at low near temperatures than at high close temperatures

N.H. Zaini et al. [6] used an experiment to investigate the effect of temperature on a poly-crystalline electrical device in a hot Asian climate It was discovered that when the temperature of the diode rose, the potency and power of the diode decreased

Faez et al. [7] conduct an experimental and theoretical study of the heat pipe cooling of an electrical phenomenon panel and compare it to a standard panel The experimental thermal results show that the technique is effective in cooling the electrical device, with the module cooling at a faster pace than the old panel (15-35) Try to boost the electrical potency by (11-14). Theoretical results revealed reasonable agreement with a small variance of about (3-6).

Zaoui et al. [8] investigate the temperature effect of an electrical phenomenon PV with continuous radiation worth using an experiment and numerical analysis The study found that the potency and output cells decrease as temperature cells rises To address this issue, scientists are investigating a variety of cooling approaches that might reduce the rising temperature of the electrical phenomenon panel by misusing action or applying extra power or half to the device, which would aid in cooling the panel[9]. The active cooling, passive cooling, heat pipe cooling, Nano-fluid cooling, thermoelectrically cooling, PCM cooling, liquid immersion cooling, thermos-photovoltaic cooling, Al vessel, thin-film panels, and state change cooling are some of the cooling methods described in the literature [10]. The results are shown in table (1) below.

Table 1: Improvements in temperature and efficiency for various approaches.

Techniques	Authors	Temperature of Cell	Efficiency Gain
Passive Cooling	Othman.et. al.[39]	$\Delta T= 8^{\circ}$ C	+7.13%
Active Cooling	Moharram et.al. [40] Dubey et.al. [41]	45°C 40-90° C	+12.5% +8.5-10.5%
Heat Pipe Cooling	William J. Anderson[42]	-	-
PCM Cooling	Huang et.al.[43] Malti et. al.[44] Cellura et.al.[45]	34°C 65-68°C 40-50°C	- +5.4% -
Nano Fluid Cooling	S.M. Mursheed[23]	34.9	+12.1%
Thermo Electric	Hussein Mosh [24]	32°C	+3.24%
Submerging the panels	Sourabh Mehrotra[26]	$\Delta T = 25^{\circ}$ C	+17.8%

With reference to the above data, we can deduce the significance of immersing the PV in the fluid, which gives the best potency and a temperature reduction of twenty-five degrees Celsius, Nano-fluids also attempted to work within the growing potency and keep the temperature of the panels within stipulated limits.

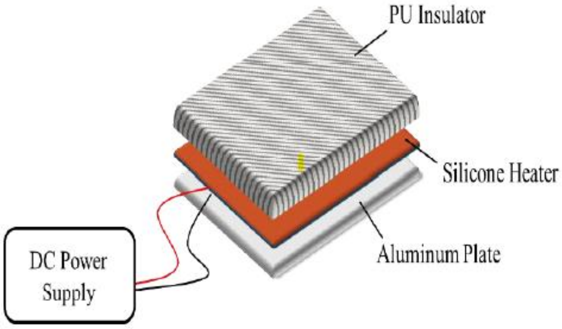
Any method that uses fluid to transmit heat is more effective in terms of increasing potency [11] As a result; this research can focus on various ways for cooling the solar battery with liquids, particularly water, in a very hot climate.

2. Cooling by evaporation

The evaporation cooling is a type of latent heat cooling in which water evaporates to create phase equilibrium with the surrounding air is water vapour.

2.1 Wetted Salo Fabric Evaporative Cooling

thermal of models that may use like style to increase panel potency of a specific electrical phenomenon panel and to estimate the electrical phenomenon panel's rear surface temperature. There were two cases investigated: (a) a simple electrical phenomenon and (b) an electrical phenomenon with a cooling mechanism, as shown in the figures (1 and 2). To validate the thermal models, an experiment is being set up that uses an electrical phenomena model made from an atomic number 13 coupled to a silicone polymer imitate electrical phenomenon panel the experiment was carried out a environment.



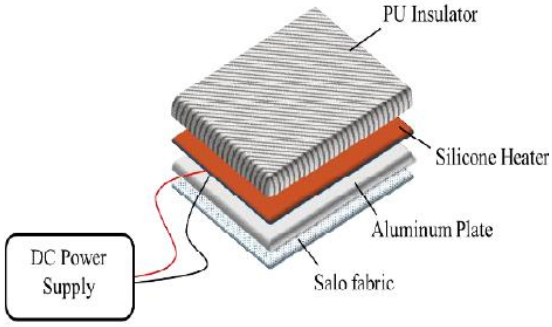


Fig. 1. shows a simple photovoltaic model. **Fig. 2.** a photovoltaic with a cooling.

Investigation validated thermal models of an electrical phenomena panel with and without a Salo cloth phase transition, cooling when compared to the experiment data; the thermal models will almost accurately forecast the rear surface temperature profile. As a result, these thermal models can be used like tool of specific electrical phenomena panel Using a wetted a phase transition cool device of an electrical phenomena model was beneficial in this work because electrical phenomenon model by 24.5%, as shown in figure (3) [12].

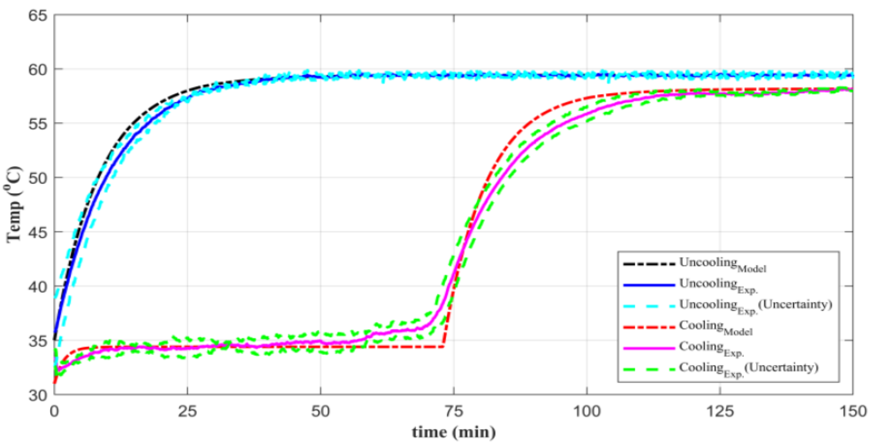


Fig. 3. Thermal model and experimental results for plain photovoltaic and photovoltaic with cooling device.

For ordinary photovoltaic and photovoltaic with cooling device, a thermal model was developed and experimental results were obtained.

2.2 Cooling by evaporation via an item of clothing

A piece of fabric of material was attached to the back surface of the cooled photovoltaic panel, and water comes from a tank was allowed to flow and wet the cloth via rubber pipes connected to the panel back surface, figure (4).

Fig. 4. Cooled the rear panel, the fabric and pipes configuration.

Testing were carried out in the open air A series of studies were done and studied in the real-world conditions of Saudi Arabia's capital city to demonstrate the tactic's success The method succeeded in lowering the electrical phenomenon panel temperature by nearly 20°C, resulting in a 14 percent increase in power generating potency as compared to an uncooled panel [13] The temperature of the two panels is shown in Figure (5) with time.

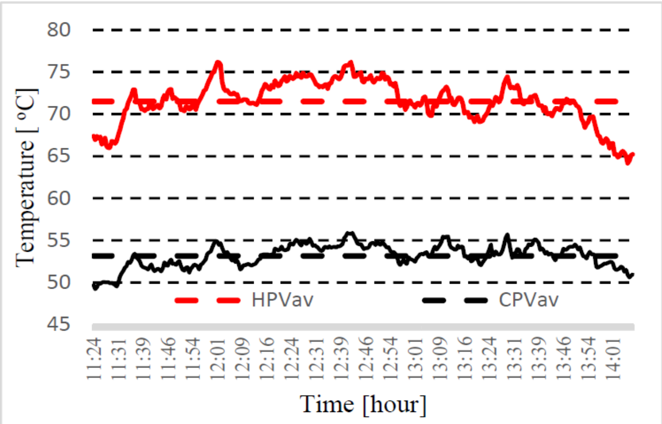


Fig. 5. The temperature of the two panels changes over time

2.3 Evaporative cooling by saturating both PV surfaces with cold water

In Bagdad, an experimental inspection rig was built and tested under hot and dusty conditions to reduce the temperature of each electrical phenomena surface, a powerful cooling system with an additional subsurface tank was employed to deliver cold water as a fluid across each electrical phenomenon surface. Figure (6) shows how the polysaccharide pad is structured on the back surface and sprays cooling on the front facet. During this examination, there square measure two identical electrical phenomenon panels: one without cooling and the other using a phase change water approach Two electrical phenomen on panels were installed on an inclined structure that allows water to outflow through attraction, as seen in figure (6).

Fig. 6. Photovoltaic panels are being tested in this arrangement.

In a fast visit, the usual temperatures of the cooled electrical phenomena panel were around twelve.2 two degrees Celsius lower than the typical temperature of the uncooled electrical phenomenon panel, which measured about sixty four.250 degrees Celsius, figure (7). The facility of the cooled electrical phenomenon panel enhanced by 15.6%, and its potency by 15.8%, according to the experimental results in this case [14].

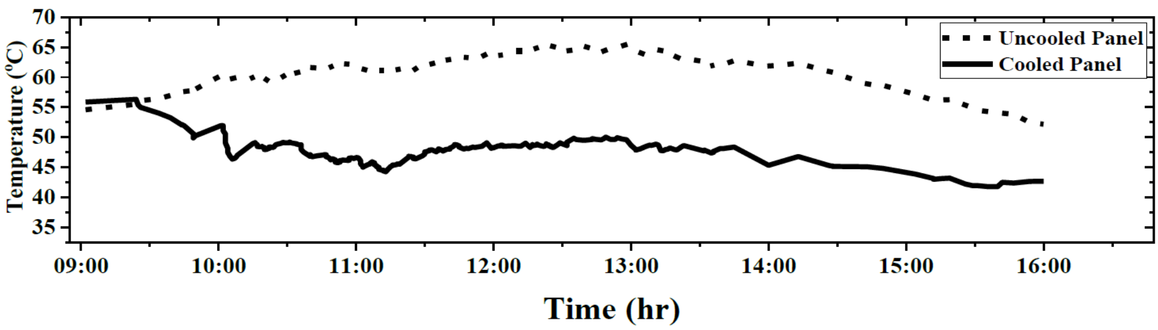


Fig. 7. PV Panel temperatures over time

2.4 Using a Clay Pot for Evaporative Cooling

Three distinct electrical phenomenon panels make up the experimental setup. Two sets of panels employed a combination system with a film water running over the prime surface without front glass and an additional made-up mechanism to use the panel's warmth. As a reference panel, the opposing panel might be a regular PVA tube with a slit on it has been installed on the highest finish of the electrical phenomenon panel to supply a movie of water across the electrical phenomenon panel. The electrical occurrence for electrical phenomena panels, water, thermal system, and clay pot state change cooling water area unit cooling medium. Figure (8) shows how sprayed the water evenly over the photovoltaic panel.

Fig. 8. Experimental set up

View of experimental setup as seen through the lens of a camera The results show that, thanks to the water flow and additional cooling provided by water evaporation, the operating temperature of the PV/Thermal panels is significantly lower than that of the standard reference ,The most temperature distinction of 8, 12, 20 area unit ascertained electrical phenomenon, cool, with thermal panels [15]. the variation of module temperature thermal panels are shown in figure (9), with the most temperature distinction of 8, 12, and 20 area unit ascertained with plain electrical phenomenon, cool,

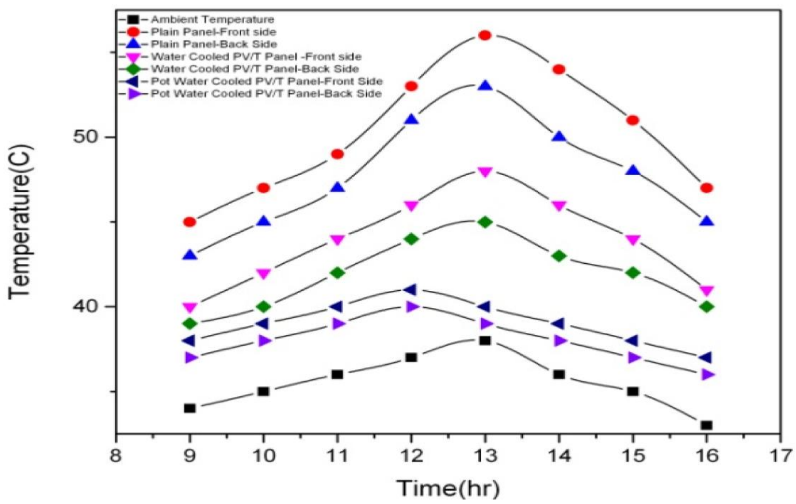


Fig. 9. PV module temperature and PV/T temperature variations

2.5 Using Synthetic Clay for Evaporative Cooling

There are two primary components to the experimental setup. Within the first, the near temperatures of four entirely distinct enclosures are compared evaluate flexibility of clay system's ability of reduce enclosure's total heat through testing A physical change cooling component of copper sheet bordered from one facet by an artificial the layer of clay can be used in three of the four enclosures This layer's thickness can vary three enclosures for getting simplest thickness a specific cool component's length. Figure (10) [16] shows the fourth enclosure, which will not contain a cooling component and would instead operate like management cooling results, will be compared.

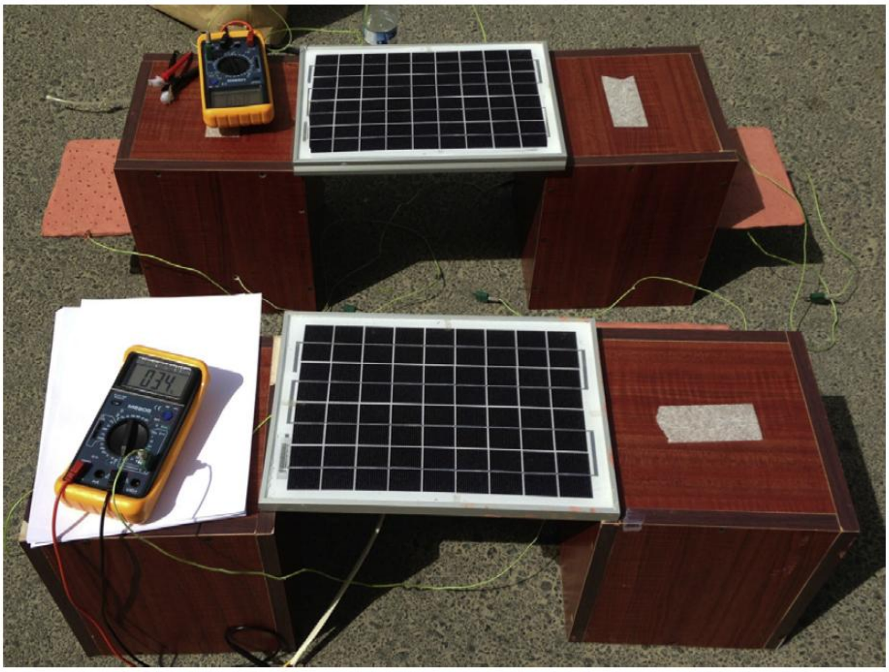


Fig. 10. PV Setup module for testing.

Out comes demonstrated technical feasibility strategy from lowering the panel temperature from 41 to 27 degrees Celsius on average and demonstrating a 19.4 percent maximum increase in output with 19.1 percent in clay power inclusion was highly, inexpensive, silent, and friendly, as seen in the diagram (11).

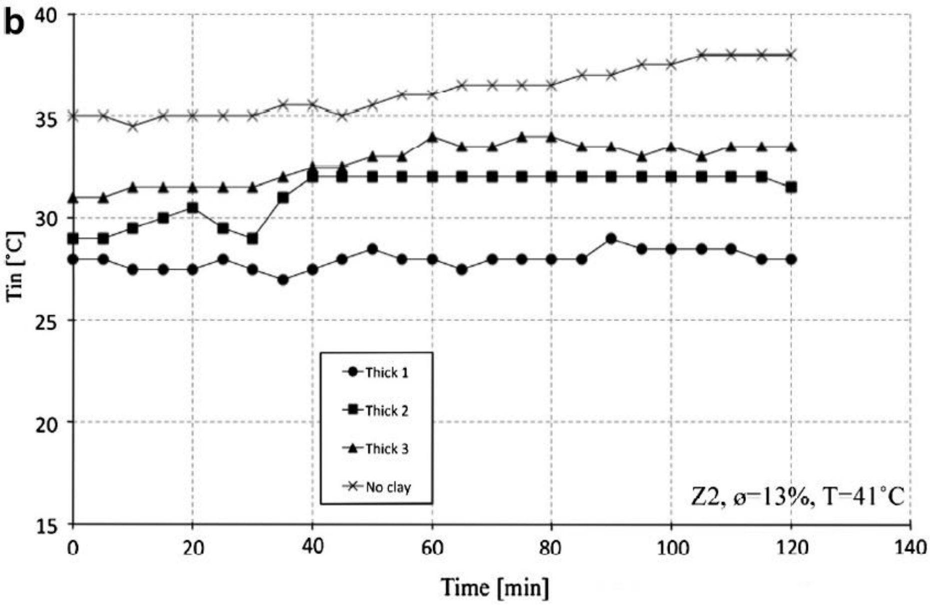


Fig. 11. PV module power voltage curves with and without clay

3. Water-based direct cooling

As demonstrated below, there are several ways to use water to cool the solar battery, which resulted in a significant reduction in temperature, enhanced the panel's performance, and increased its potency.

3.1 Water splatters on the panel's surface

The angle of spray, nozzle variation, and rhythmic spray of water on photovoltaic performance area unit were explored in an experimental investigation. Figure (12) shows the spray angles, which ranged from 15 to 50 degrees.

Fig. 12. With its unique experimental configuration, a photovoltaic module is cooled by water spray.

When the spray angles are compared, it is shown that when angle decreases at 15° increases of potency the electrical phenomena by 19.78% At the same time, the normal electrical phenomenon causes the panel temperature to drop 64 °C (for case non-cooled) to 24 °C (figure) (13) In addition, the distance between the nozzle and the electrical phenomenon panel was increased from ten to fifty centimeters A twenty-five.86 percent increase in power production produced the easiest outcome for all-time low distance Studies of various frequencies demonstrate that raising the water spraying frequency will increase or reduce the electrical potency for evaporation also radiation intensity [17].

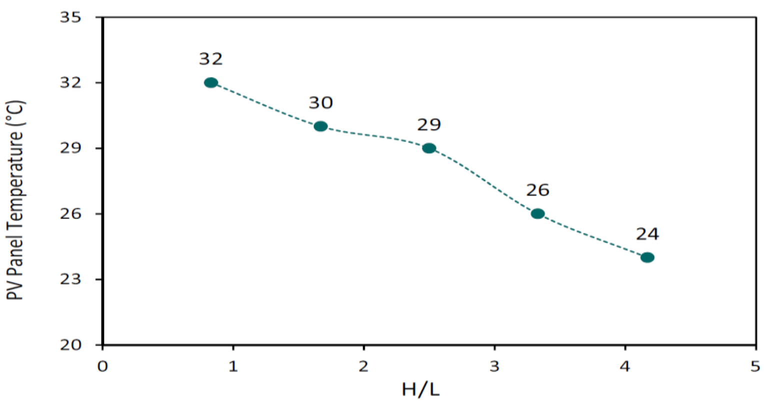
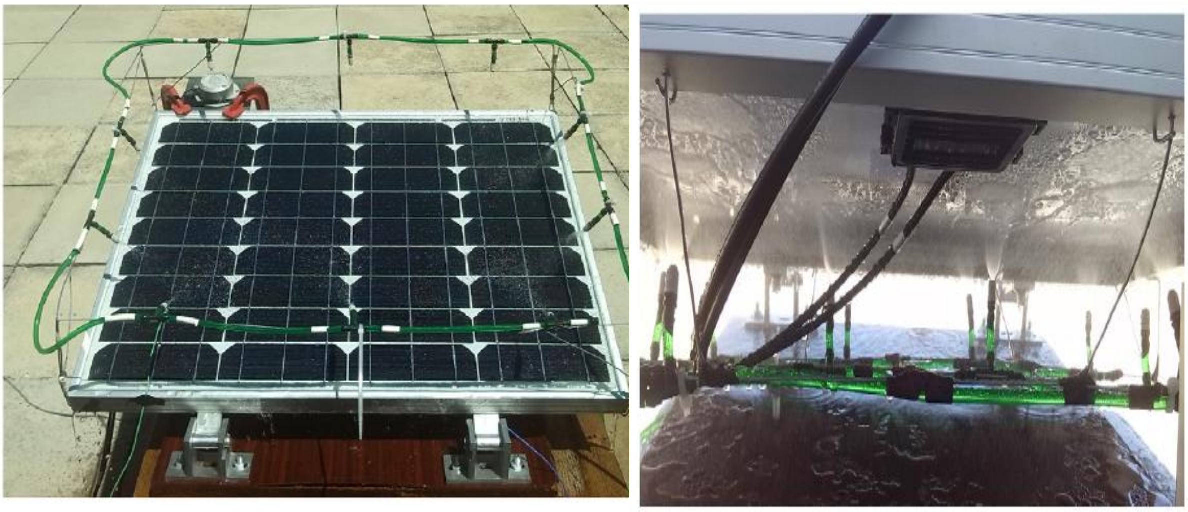


Fig. 13. Surface temperature of photovoltaic panels' vs H/L with cooling

3.2 Both sides are sprayed with water.

cooling technique which sides of PV panel was cooled at same time in order to investigate the full influence of spray cooling under full star irradiation stage a experimental were meticulously established, and created cooling system the panel were put to the test in a very specific geographical region with a typical Mediterranean environment, as shown in Figure (14).



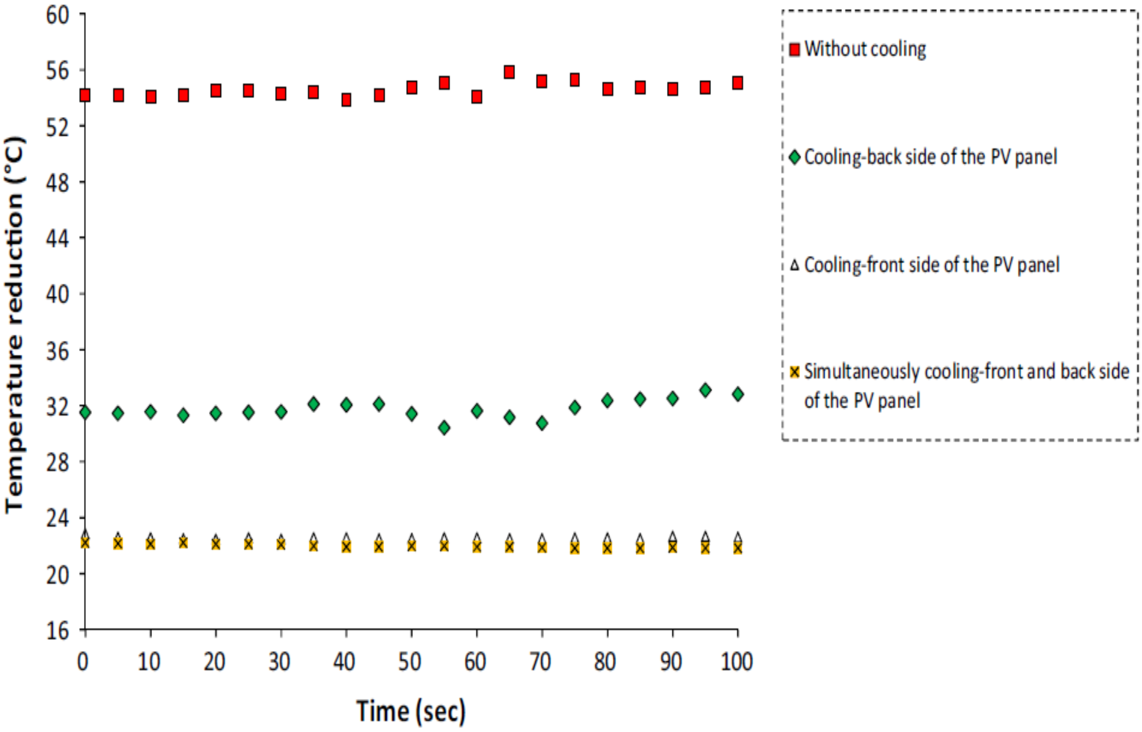


Fig. 15. Temperature of photovoltaic panels with time

3.3 water flow over photovoltaic panels' fronts

Two liters water per minute was pumped to an enlarged reservoir under the module into a small tank over it, 12 nozzles positioned on the module's highest point created a jet water that adhered to cell's face at thickness 1mm figure (16).

Fig. 16. A line of nozzles creates a water on PV module

When compared to a reference module (conventional), which was measured at the same time by a twenty-two ^{o}C figure (17), operating temperatures were significantly lower. As a result, conversion potency and voltage generation have improved [19].

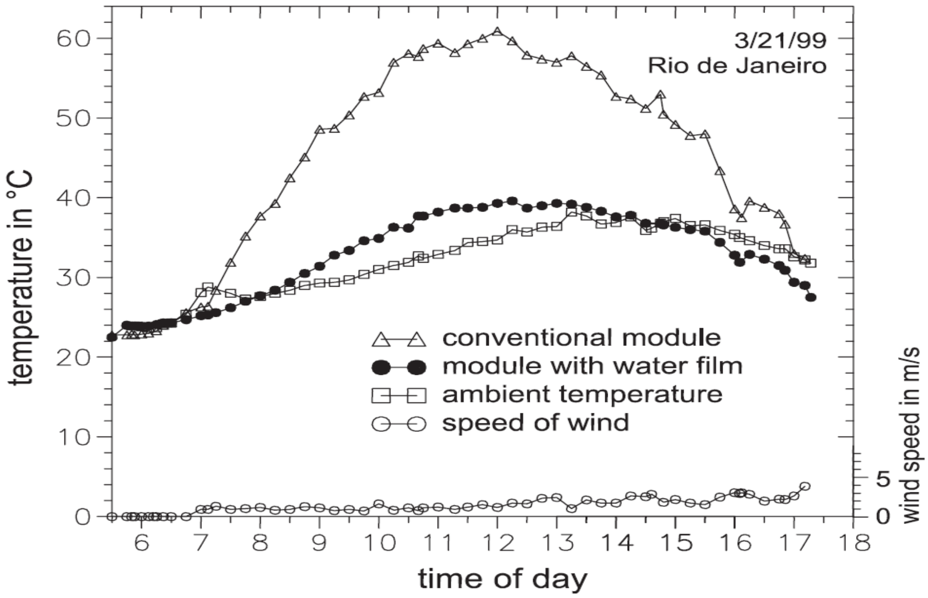


Fig. 17. temperatures Cell of a typical PV module with a PV module and water flow are compared.

3.4 Immersion in water

A crystalline semiconducting material electrical device is used to construct the star electrical phenomena system. The panel's world is zero.033 m^2 Water is used as associate degree immersed fluid in a plastic box with a depth of ten. 8 cm Water serves as a source of heat dissipation, allowing an electric cell's surface temperature to be maintained (18).

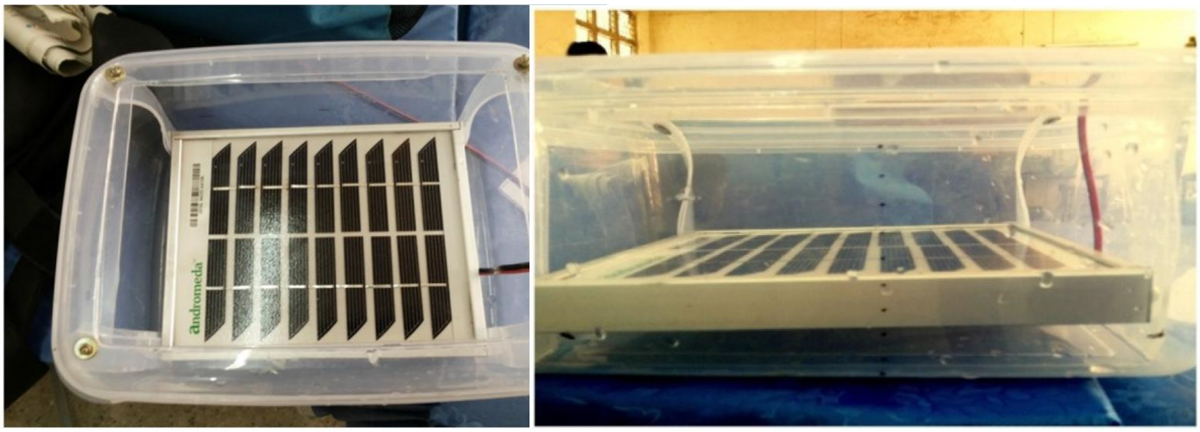


Fig. 18. Solar panels submerged under water.

The results reveal that as the depth increases, the surface temperature of the panel lowers from 60oC to 30^{o}C, and as a result, the electrical potency increases to a predetermined depth when it starts to plummet A maximum rise of 17.8% in the panel's electrical potency was discovered, thus demonstrating the panel's improvement in performance [20].

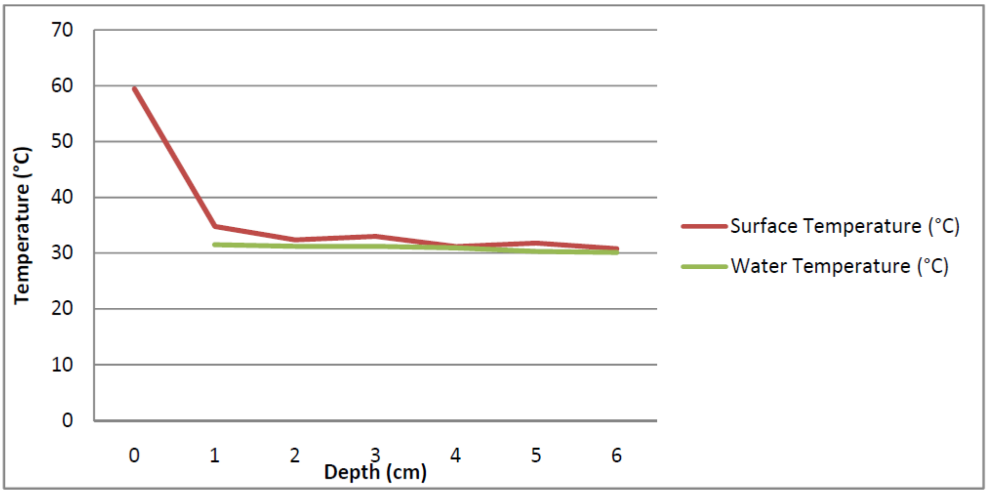


Fig. 19. Variation in the panel's surface and water temperature as a function water submersion depth

4. Final Thoughts

The current article has highlighted a variety of cooling solutions for electrical phenomena panels using water as a cooling fluid. It has been completed:

- The procedures worked flawlessly when the electrical phenomena temperature dropped and the potency increased.
- Depending on water temperature, photovoltaic temperature drops from 55-60 ^{o}C to 24-12 ^{o}C; this reduction cannot be achieved merely by using water-cooling in a hot region.
- The procedures are feasible, simple, and cost-effective.
- Using water as a cooling medium helps to eliminate debris, which minimizes the absorption of radiation from the panel's surface.

- In the evaporation and spray technique, co-occurring cooling of the front and backside electrical phenomenon panel surfaces was shown to be the most effective cooling option.

References

1. M.M. Rahman, M. Hasanuzzaman, N.A Rahim, Energ. Convers. Manage. 103 (2015).
2. Y. Du, C.J. Fell, B. Duck, D. Chen, K. Liffman, Y. Zhang, M. Gu, Y. Zhu, Energ. Convers Manage. **108** (2016)
3. F. Grubišić-Čabo, S. Nižetić, T. Giuseppe Marco, (2016), "Photovoltaic Panels: A Review of the Cooling Techniques", transactions of famena xl - special issue 1, University of Catania, Italy.
4. N.H. Zaini, M.Z. Ab Kadir, M. Izadi, N.I. Ahmad, M.A. M Radzi, N. Aziz, IEEE, (2015).
5. C.U. Ike, Int. J. Eng. Sci, **3** (2013)
6. N.H. Zaini, M.Z. Ab Kadir, M. Izadi, N.I. Ahmad, M.A.M Radzi, N. Aziz, IEEE, (2015).
7. Laith Jaafer Habeeb, Dheya Ghanim Mutasher, Faez Abid Muslim Abd Ali," cooling photovoltaic thermal solar panel by using heat pipe at baghdad climate", International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol: 17 No: 06.
8. F. Zaoui, A. Titaouine, M. Becherif, M. Emziane, A. Aboubou, Energ. Procedia, **75** (2015).
9. Fateiger and C. A. Lane, ScholarWorks @ UMass Amherst What Will it Take to Make Solar Panels Cool, vol. 22. 2017, p. 15.
10. Krishna Kant Dixit, Indresh Yadav, Gaurav Kumar Gupta," A Review on Cooling Techniques Used For photovoltaic panels", International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC) GLA University, Mathura, UP, India. Feb 28-29, 2020.
11. Swar A. Zubeer, H.A. Mohammed, and Mustafa Ilkan," A review of photovoltaic cells cooling techniques", ASEE17, E3S Web of Conferences 22, 00205 (2017).
12. B Gleebpratum, S Salakij," Thermal Models for Evaporative Cooling on Photovoltaic Panel Attached with a Wetted Salo Fabric", IOP Conf. Series: Earth and Environmental Science 566 (2020) 012005.
13. Zeyad A. Haidara, Jamel Orfib, Zakariya Kaneesamkandib," Experimental investigation of evaporative cooling for enhancing photovoltaic panels efficiency", Results in Physics 11 (2018) 690–697.
14. Arwa Mahmood Kadhim, Issam Mohamed Ali Aljubury,"Experimental Evaluation of Evaporative Cooling for Enhancing Photovoltaic Panels Efficiency Using Underground Water", Journal of Engineering, Number 8 Volume 26 August 2020.
15. R. Ramkumar, M. Kesavan, C.M. Raguraman, A. Ragupathy," Enhancing the Performance of Photovoltaic Module Using Clay Pot Evaporative Cooling Water", IEEE 978-1-4673-9925-2016.
16. Abdul Hai Alami,"Effects of evaporative cooling on efficiency of photovoltaic modules", Energy Conversion and Management 77 (2014) 668–679.

17. Mojtaba Nateqi, Mehran Rajabi Zargarabadi, Roohollah Rafee,"Experimental investigations of spray flow rate and angle in enhancing the performance of PV panels by steady and pulsating water spray system", Springer Nature journal, 2021.
18. S. Nizˇetic´, D. Cˇoko, A. Yadav, F. Grubišic´-Cˇabo," Water spray cooling technique applied on a photovoltaic panel: The performance response", Energy Conversion and Management, 108 (2016) 287–296.
19. Stefan Krauter." Increased electrical yield via water flow over the front of photovoltaic panels", Solar Energy Materials & Solar Cells 82 (2004) 131–137.
20. Saurabh Mehrotra, Pratish Rawat, Mary Debbarma , K. Sudhakar," performance of a solar panel with water immersion cooling technique", International Journal of Science, Environment ISSN 2278-3687, and Technology, Vol. 3, No 3, 2014, 1161 – 1172.