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Performance Improvement of Solar PV Cells using Various Cooling Methods: A Review

Chetan patel
Mechanical engineering department
PG-STUDENTS-LDRP-ITR
Patelchetan8387@gmail.com

Pavit Shah
Mechanical engineering department
LECTURER-LDRP-ITR
pavit_me@ldrp.ac.in

Amit I. Pandey
Mechanical engineering department
LECTURER-LDRP-ITR
amit_me@ldrp.ac.in

Abstract- Cooling the operating surface is a key operational factor to take into consideration to achieve higher efficiency when operating solar photovoltaic system. Proper cooling can improve the electric efficiency and decrease the rate of cell degradation with time, resulting in maximization of the life span of photovoltaic modules. The excessive heat removed by the cooling system used in domestic, commercial or industrial applications. Various cooling methods available for PV cells Such as Active and Passive cooling system. In this paper use various cooling methods for PV panel. Just like it heat pipe, floating, PCM used in back side of PV panel, evaporative cooling for PV panel.

Keywords- *Active cooling, passive cooling, Photovoltaic Panel*

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I.Introduction

Day by day population and uses of resources (petroleum, coal, Gas) are increasing. That's why solar energy is better option because of solar cell was a low maintenance and long lasting source of energy. It cans also none polluting and silent sources of energy. The solar energy is freely and illimitably available through the world [1]. Operating temperature has a significant o impact on the efficiency of PV modules and the decreasing operating temperature tends to increasing of the module efficiency [2]. The use of PV system in a water context can create a maximum energy increasing. For this context, they can be classified according to different criteria, such as: Position in relation to the water surface- over or under, Type of water fresh (lake and river) or Salt (seashore), Type of PV module- Flexible and Rigid [3]. If the temperature of Panel increases so that resistance of panel decreases and current is increases. But another side voltage of panel decreases due to separation of higher temperature [4]. PV panel work efficiently when it is at lower temperature. PV panels can be cooled on variety of ways: active and passive. Active cooling system comprise of heat extraction utilizing device such as fans (Forced Convection).Wide variety of passive cooling system are available, such as uses of PCM, Heat pipe, Floating etc [5].

Various parameters affecting of solar cell [6]

1) Short circuit current (Isc)
2) Open circuit current (Voc)
3) Maximum power input
4) Current at maximum power input
5) Voltage at maximum power input
6) Efficiency

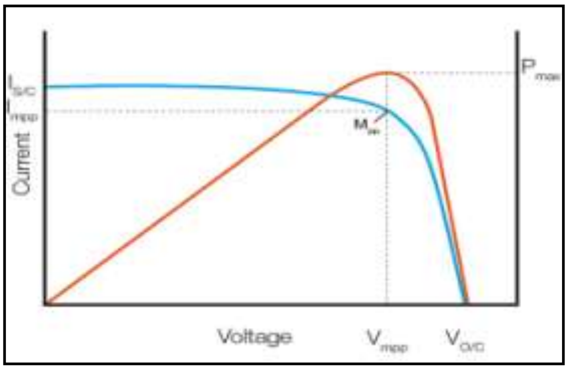

Figure 1: Current VS Voltage curve for PV cell [6].

Siecker J.et at [8] have performed, cooling the solar photovoltaic system and achieve higher efficiency. They performed to various methods that can be used to minimize the negative impacts of the increased temperature while making to enhance the efficiency of photovoltaic solar panel operating beyond the recommended temperature of the Standard Test Condition (STC). They used to various cooling technologies namely Floating tracking concentration cooling system (FTCC); hybrid solar photovoltaic /Thermal system cooled by water spraying; Hybrid Solar Photovoltaic/Thermal (PV/T) cooled by forced water circulation; Hybrid Solar Photovoltaic/ Thermoelectric PV/TE system cooled by heat sink; Improving the performance of solar panel through the use of phase change materials; Solar panel with water immersion cooling technique; Solar PV panel cooled by transparent coating. They used this kind of various method used be to keep the operating surface temperature low and stable, be simple and reliable, enable the use extracted thermal to heat to enhance the overall conversion efficiency. Peng Zhijun et al [9] have performed to investigate practical effect of solar PV surface temperature on output performance in particular efficiency.

They experiment under different radiation condition exploring the variation of output voltage, current, output power and efficiency. As test result show the efficiency of solar PV can have an increasing rate of 47% with the cooled condition. The system performance and life cycle assessment suggest setup that the annual PV electric output efficiencies can increases up to 35%. The cost payback time can be reduced to 12.1 years, compared to 15 years of the baseline of a similar system without cooling sub-system. Sargunanathan S. et al [7] have performed enhancement of solar photovoltaic cells using various cooling methods. The increase in operating temperature of the PV cells leads to reduction in open circuit voltage, fill factor and power output for mono and polycrystalline PV cells which are used in most of the power applications. The net result leads to the loss of conversion efficiency and irreversible damage to the PV cells materials. They performed on passive cooling by heat pipe based and by fins, active cooling by spraying water, liquid immersion cooling and cooling by employing phase change material (PCM) to enhance the performance of the commercially available PV and concentrated (CPV) cells. They performed passive cooling with attaching the fins on back side of the module may effectively reduce the operating temperature; improve the power output and efficiency but their performance mainly depends on the heat transfer area and wind velocity. Therefore further research is needed to find the dimension of the fin and number of fins required for commercial modules. And using with active cooling by spraying the water over front surface of module will yield very good performance. From using this method can reduce operating temperature up to 26 Ċ0 and reduce the losses by 2.4%. Atkin peter et. al [10] have performed to improving the efficiency of photovoltaic cells using PCM infused graphite and aluminum fins. They using Mat-lab modeling and performing experiment whether the use of Phase change material (PCM) infused graphite with an external finned heat sink is viable as a method of PV thermal regulation. The effect of four different thermal regulation techniques on the thermal performance on the thermal performance, point based efficiency and overall efficiency of a PV panel have been studied. In first case the PV panel with no thermal regulation, in second case the PV panel with 30mm thick PCM infused graphite attached to the rear , in third case the PV with a finned heat sink attached to the rear , in fourth case PV panel with a combination of PCM infused graphite and finned heat sink. Out of the four thermal regulation techniques last fourth case is the most effective at increasing overall efficiency of the PV panel with the greatest overall efficiency of 12.97%.Hasan A. et al [11] have performed yearly energy performance of a photovoltaic-phase change material in hot climate. A photovoltaic phase change material system is employed in extremely hot environment in UAE to evaluate its saving performance throughout the year. A paraffin based PCM with melting range of 38-43 Ċ0 is integrated at the back of PV panel and its cooling effect is monitored. They result on heat transfer model employing enthalpy based formulation is developed and validated with the experimental data. The PCM produced less cooling in peak cool and peak hot months attributed to its incomplete melting and solidification, respectively. The PV-PCM system enhanced the PV annual enhanced the PV annual electrical energy yield by 5.9% in the hot climate condition. Result of this performance is PCM achieved the peak-time temperature drop of 13 Ċ0 in APRIL and 8 Ċ0 in JUNE. The PCM eventually achieved 10.5 Ċ0 drop in PV temperature on average at peak time resulting in 5.9% increases in PV power output on yearly basis. Sahu Alok et al [1] have performed floating photovoltaic power plant. To conserve the valuable land & water, installing Solar PV system on water bodies like ocean, lakes, lagoons, reservoir, irrigation ponds, waste water treatment plants, wineries, fish farms, dams and canals can be an attractive option. Floating type solar photovoltaic panel have numerous, convenient, energy efficiency, higher power generation efficiency owing to its lower temperature underneath the panels. They are using pontoon, floats, mooring system, Solar PV module, cable and connectors kind of component for floating of PV system. The efficiency of floating solar plant is 11% higher and reduces the water evaporation by 70%. Remote sensing and GIS based techniques can be used to determine the potential of floating Solar PV projects. Koundinya sandeep et al [4] have performed to comparison with the computational study on cooling of PV solar panel using finned heat pipe technology. They consider special kind date of solar panel and heat pipe. After calculation they find mainly 40 numbers of fins are used is 40.after the experiment that the temperature decreases using finned heat pipe and the efficiency of the solar panel increases. Result has shown maximum decreases of 13.8K by adopting this method. Stropnik Rok et al [5] have performed increasing the efficiency of PV panel with the use of PCM. They are focusing the work on experimental study and using TRASYS software. A modification of both PV panel Canadian Solar CS6P-M was made with phase change material RT28HC, where RT is Rubitherm. They compared the actual data of cell temperature on a PV Panel with and without PCM. After experiment result show that maximum temperature difference on the surface of PV panel without PCM was 35.6 Ċ0 higher than on a panel with PCM in period of one day. Final result of their experiment they shows that electrical production of PV-PCM panel for city was higher 7.3% in a period of one year. Radziemska ewa Klugmann et al [12] have performed photovoltaic module temperature stabilization with the use of PCM. They have performed how to useful to decreases the module temperature by removing the heat in a hybrid system that combines a PV module and thermal collector into a (PV/T) system. They results of the experiment are promising : for constant solar irradiance and apply 42-44 paraffin to the module without cooling which made possible to lower the temperature of the module by 7k. They are maintained this temperature more than 5h. Hasanuzzaman H. et al [13] have performed global advancement of cooling technologies PV system. They have performed much experimental work with active cooling system and passive cooling system. After that he concluded the passive cooling system are found to achieve a reduction in PV module temperature in the range of 6-20 Ċ0 with an improvement in electrical efficiency up to 154.5% maximum. And another side active cooling systems performance are better to achieve a reduction in PV module temperature as high as 30 Ċ0 with an improvement in electrical efficiency up to 22% maximum along with additional thermal energy output with efficiency reaching as high as 60%. Moharram K.A. et al [14] have performed cooling of PV panel by water cooling. Main objective for this research is Minimize the amount of water electrical energy needed for cooling of the solar panel. They make a mathematical model. It can be used to determine when start of cooling of the PV panel and find the temperature of panel reaches the maximum allowable temperature. These cooling model are used to reduce temperature. At last they completed experiment, they concluded reducing of heating model and cooling model. If founds that the PV panel yields the highest output energy if cooling of panel reaches a maximum allowable temperature. Chandel S.S. et al [15] have performed, reviewed of cooling technologies using phase change material for enhancing efficiency of photovoltaic power system. They can be used Capric Palmitic acid (CaCl2 * 6 H2O) with melting point 22.4 Ċ0. It can be found PV/T-PCM system having heat storage capacity was become twice the PV/T system. Temperature difference 5 Ċ0 was observed with PCM system compared to Simple system and also observed electrical efficiency 1% increases. They can be concluded temperature difference rise to 15 Ċ0 for 12 fin-PCM system. Best performance was obtained with mixture of two inorganic PCM's. Shukla A. et al [16] have performed cooling methodologies of photovoltaic module cooling of photovoltaic module for enhancing for review of various methods. For using air circulation method we can find out this method is low initial cost. No maintenance. Similarly when used forced circulation method is method is used higher heat transfer rate. We can also use heat pipe because its cost is also low and can be easily integrate. After experiment of various methods that concluded in forced circulation in polycrystalline are used temperature reduction 40 Ċ0 and increment in efficiency 3.9%. Biwole P.H. et al [17] have performed how to improve the performance of solar panel by PCM. They can be attached PCM on back side of panel and it can be maintained the panel's operating temperature under 40 Ċ0 for 80 minute under constant solar radiation of 1000 W/m2. They make mathematical model and numerical model. A Volume force is added to the buoyancy term in the navier stokes momentum conservation equation in order to force the velocity field to be zero when the PCM is solid. Limitation of this research is they cannot consider real atmosphere in numerical model. So for future work we should include experimental validations of this numerical model using real solar panels under real climate condition. Irwan Y.M. et al [18] have performed what is the effect of solar PV panel through water cooling method in Indoor condition. Solar simulator system with halogen lamp bulbs has been successfully designed and fabricated. They can be used DC water pump for purpose of solve the problem of low efficiency of PV panel with water flow over the front surface of PV panel. It can be final experiment result mentioned that the decrement of operating temperature and increases the power output of PV panel with water cooling mechanism based on different fixed of solar radiation. Water spraying can be reduced heat on the front surface of PV panel. After experiment result mentioned that the decrement of operating temperature is around 5-23 Ċ0 and increases power output of the PV panel with water cooling mechanism by 9-22%. Chandrasekhar M. et al [19] they have performed passive cooling of standalone flat PV module with cotton wick structure, they have consisting of cotton wick structure in combination with water, Al2O3 /Water nano fluid and CuO/Water nano fluid are invested experimentally. They can conclude temperature of PV module is reduced to about 45 Ċ0 when cooling is provided with cotton wick in combination with water. They can also concluded temperature of PV module is reduced to about 59 Ċ0 and 54 Ċ0 when cooling is provided with cotton wick combination with CuO/Water and Al2O3/Water nano fluid respectively. For PV module installation, determining the flow and convective heat transfer inclined cooling ducts [20].

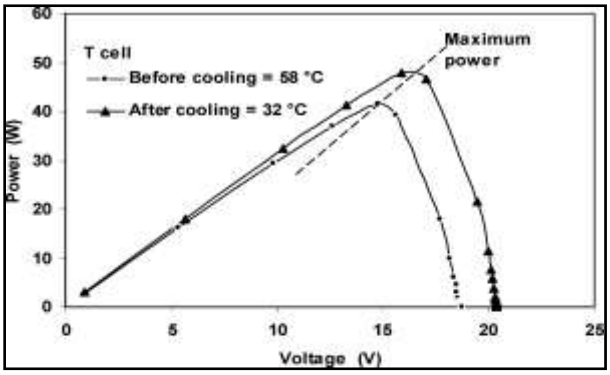

Figure 2: The effect of water cooling on voltage-power characteristic curve [21].

II. TYPES OF COOLING SYSTEM

A. Heat pipe cooling system: heat pipe is a device which is used a transport heat by two phase flow of working fluid from one place to other place. Heat pipe consist of evaporator section, adiabatic section and condenser section. At evaporator section of the heat pipe is attached to the back side of the PV cells to absorb the heat from them [1]. Copper/water heat pipe with aluminum fins can be used to remove the heat from PV cell with using natural convection method **[22].**

B. **Floating method**: Supporting Structures for floating photovoltaic system different from the conventional because they lack a solid anchoring means of problem of wind folding and have an uneven surface. Simple PV module when unguarded to wind and water loads can suffer from crack formation, due to their finite flexibility and mechanical properties [23].

C. **PCM (phase change material):** Use of PCM in PV panel is more complex system. Cooling of PV panel with PCM is preferable because does not need any traditional energy for cooling [24].

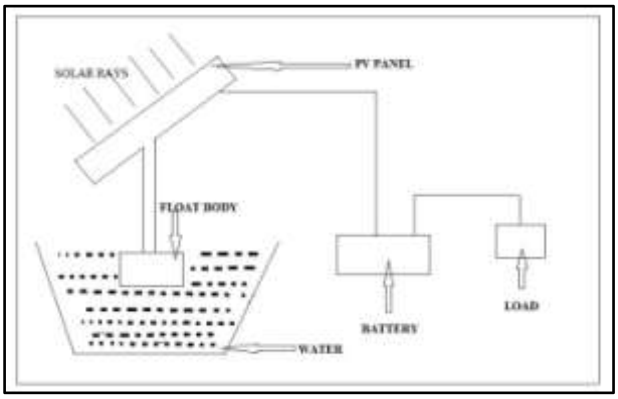

Figure 3 : Floating structure

Thermal properties of the PCM (Paraffinic organic type RT28Hc) [24]

➢ Melting peak Ċ0	28
➢ Latent heat of fusion (kJ/kg)	245
➢ Thermal conductivity (W/m K)	0.2
➢ Density (solid) (kg/m3)	880
➢ Density (fluid) (kg/m3)	770
➢ Specific heat capacity (kJ/kg K)	2

D. Evaporative cooling

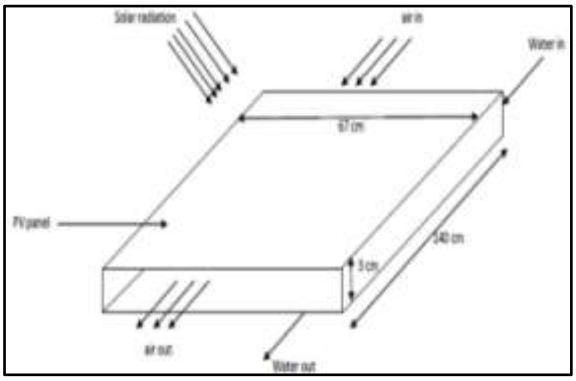

Figure 5: A schematic diagram for the PV panel with evaporative cooling [25]

With the using of PV panel with evaporating cooling temperature can reduced about 6 Ċ0 [25].

III. ADVANTAGE AND DISADVANTAGE OF VARIOUS COOLING METHODS

A. Floating Method

Advantage:

- Avoid energy dispersion problems.
- Avoid electric grid stress when using a pumping scheme.
- Operates highly efficiently.

Disadvantages:

- Evaporation causes water wastage.
- Sprinklers cannot spray whole surface of PV module.
- High capital cost.

B. PCM Method

Advantage:

- To store large amounts of heat with small temperature changes.
- Phase-change occurs at a constant temperature.
- Heat absorbed can be used to heat buildings.

Disadvantages:

- Paraffin has low thermal conductivity in its solid state.
- Segregation reducing active volume available for heat storage.
- Less efficient in colder areas.

C. Hybrid Solar PV/T system

Advantage:

- Electrical efficiency increased
- To Supplies hot water for domestic applications.
- More efficient combined than separated.

Disadvantages:

- It cannot achieve optimal efficiency, due to constant flow rate.
- It has High initial cost.

- Subsidies needed for these systems

IV .CONCLUSION

1) Output of solar panel is directly proportional to solar radiation. If solar radiation increases than power output increases.
2) Power output of panel depends on orientation of panel. In winter season inclination angle is more than power output increases and summer season inclination angle is less than power output is higher. Therefore achieve standardization output, take it latitude angle for particular location. For Gandhinagar latitude angle become 230.
3) In day time calculate power output four times 10AM, 12PM, 2PM, 4PM. Than after calculate average power output for particular day. Therefore can calculate at which time obtain maximum power output.

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