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Design of Cooling System for Photovoltaic Panel to Increase Electrical Efficiency

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Abstract

Photovoltaic panel system was introduced to meet the thermal and electrical energy demand. The heat removal by air or water prevents the reduction of the PV cell efficiency due to the overheating of cells. An alternative cooling technique for investigating total water spray cooling effect on PV panel performance, the sides of PV panel were cooled. The project primarily aims on analysis of different water cooled system to find out the best one. Secondly maximum efficiency is targeted by changing physical parameters of heat exchanger. One of the important characteristic such as Power which a conventional PV can provide is calculated and compared to water cooled PV. To study the water cooled panel process an excel spread sheet was created and in this sheet all physical parameters from the panel were changed and results were analyzed. The impacts on every change were recorded. Maximum efficiency of panel can be obtained by Water Spray Technique. An total increase in electrical efficiency of 18.17% (effective 5.9%) can be achieved by using proposed cooling technique.Water cooled photovoltaic seems to be most reliable and efficient, results showed. Along with higher efficiency it also can provide extra heat which can be used for domestic application, which proved to be feasible. Further it also showed that changing various parameters of system it had different efficiencies output.

Keyword:*PV (Photovoltaic panel).*

1. Introduction

Worlds 80% energy is produced by Fossil Fuels, but these resources are being exhausted due to its massive exploitation which is imposing real threat to environment mainly in terms of global warming and acidification of water cycle. This causes uneven distribution of fossil fuels. The countries in middle east have more than half of oil reserves. This causes economical instabilities disturbing the geopolitical system. This system cannot be continued for more than 2 generation. The effect has both on environment and human beings which cannot be argued. First is Greenhouse effect whose effect is the capacity of atmosphere to retain heat. The earth radiates energy at wavelength of body at 18 degrees. But the average surface temperature is 33 degrees higher due to different gases which are transparent to solar radiation but opaque to infrared radiation of earth. The gases get trapped between surface and mid atmosphere, out of which CO_2 is important. By burning of fossil fuels, CO_2 is produced. This means that there would of double of CO_2 concentration in next 20 years which will increase temperature by 3to5 degrees. This kind of heating will have major consequences on humanity. Majority of polar ice cap will melt and there will be increase in sea level. Since this change cannot be coped many ecosystems will be destroyed.

1.1 Need for cooling

Most of the energy generation should there from the solar cell. PV panel systems are the electrical energy generation. In which presently from economical configuration due to low efficiency of PV panel system. The main reasons low efficiency of PV panel. If due to overheating the expected efficiency can't be achieve and there improve the efficiency PV panel. The water cooling of PV panels system by discussing the furthermost notable reasons and effects of non-uniformity on the solar cell. Due to the losses such as optical losses, reflection losses, tracking losses and non-uniform illumination so that solar cell in concentration undergoes a series of losses based on the concentrator geometry (PalanichamyGandhidasan, et al). All of these losses arise in the system to growing the temperature of the cell and series resistance which drops the efficiency. There is an irregular distribution of radiation flux and non-uniform temperature across the PV panel surface. Performance of PV system changes the series resistance, cell temperature and efficiency. Non-uniformity results in:

- PV cell temperature increases.
- Series resistance of panel increase.
- Reduction in fill factor.
- Conversion electrical efficiency is decreases.

1.2 Background of research

Present photovoltaic cooling system has been valuable inflated as 1941. PV panels are used as the profession application of electricity source in planetary missions and satellites. The charge of producing electricity for residence applications has forsaken dramatically and PV panels are becoming greater and preferably economic viable. New materials have been developed and new system has created PV panels system at efficiencies of 20% in more amount cases. In this cases many handout researches the cooling of back and front PV panel surfaces was found to be best cooling alternative. The water circulation system specified increase in power output, electrical efficiency and also average power loss. The economic practicality of the cooling technique can be ensured by water cooling technique. The linear dependence of electrical panel efficiency was shown by Water spray flow subject to feasibility angle in decision of water spray flow magnitude.

2. Literature survey

The present work objective cooling panel is the task. There are two types of system classification active cooling and passive cooling. Many researchers has been investigate and proposed various methods of optimizing the PV panel system.

The cooling technique is classified the active cooling and passive cooling technique. Cooling techniques for heat applications has been proposed early on in PV exploitation. The main advantage of cooling is evident: higher electrical output. However, cooling requires a separate system which will remove heat to some extent. The construction and maintenance of that system can be expensive and there is a possibility that the cost of system maintenance could outweigh the benefits of the improved electrical yield.

A special type of passive cooling is phase change material cooling, PCM. Although this can’t be viewed as cooling in the strict sense, it has the result of maintaining the same temperature. It can still be counted as a passive technique mainly because of the fact that no additional work is needed to take away the heat - it is dissipated mostly conductively. In the(RokStropnik, et al, 2016) authors has showed that, with the right type of PCM material, a decrease of 15 °C relative to reference PV cell can be achieved, for a period of 5 hours, at insolation of 1000 W/m^2 . PV modules with nominal power of 65W were used, with 50 mm of PCM material from the back, with vertical aluminum fins to enhance conduction. The power gain was higher by 9.7 % than that from a reference PV module. (S.S. Chandel, et al,2017) used a V-through reflective panel to gain concentration of 2 suns. A PV panel of 0.133 m^2 surface was used, with 10 W of nominal power. Using 5.5 kg of PCM material mixed with turning shavings decreased the maximum temperature from 85 °C to 65 °C. The rise in efficiency was about 55 %.

Active cooling methods can be considered as those methods that continuously consume power in order to cool the PV module(H.G.Teo, et al,2010). Most of the methods used are based on air or water cooling. Hence, main consumption system is pump or fan needed for maintaining fluid circulation. In general, active cooling methods result in more produced power and more accessible thermal energy, but when power consumption is taken into account, question arises if cooling system can support itself. When concentrated PV cells are used, active cooling system can easily be applied, mainly because of fluid-to-cell mass ratio and the ability to use less cooling fluid. Two cells have been compared, one with and the other without cooling. The cooling cell has aluminum casing on the back side, which acts as flow channel. The work omits information about mass flow of the cooling air. Instead, fan specification was given. From it, mass flow can be approximated to 0.035 kg/s. Results show a maximum relative efficiency increase of 8.9 % and a decrease in temperature of maximum 12 °C. Also, relation of type of flow with heat dissipation is discussed in (RokStropnik, et al, 2016). It was shown that high velocity fluid fluxes (jets) have a capability to drastically take away the heat from the PV cell. The downside is the need for high pressures in the system.

The other works in literature on PV-PCM based thermal /buildingIntegrated / thermoelectric systems and important finding water cooling system. These include PV/T systems, BIPV systems, office buildings, study of various parameters affecting the PV-PCM performance and studies on modeling PV-PCM behavior. Literature reveals that PCM based PV systems when integrated with air conditioning or water heating systems could decrease the overall system cost while making it more effective.

(K.A. Moharram, et al, 2013)It has beenstudy the P–V characteristic the relation between solar cell of the electrical maximum power output and the average of voltage output V, while the solar irradiance E, and module temperature of panel, Tm, are kept constant. Two factors are name of T_m and E, this factor whole characteristic is change.The PV panel temperature coefficient used is -0.5%/°C, which shows that every 1°C of temperature rise corresponds to a drop in the efficiency by 0.5%. The output of the panel is affected due to heating significantly.

The experimentally tested and proposed a water spray cooling technique on mono crystalline photovoltaic panel for different cooling conditions by (S. Nizetic, et al, 2013). The front and backside PV panel surface for simultaneous cooling is the best cooling option. Due to the water circulation system specified a relative growth in power output, electrical efficiency and also an effective increase with included power loss for equivalent average.

3. Formulation of problem

3.1 Thermal modeling.

A comprehensive thermal model for photovoltaic system taking both energy and exergy analysis into account has been compiled by in solar radiation relevant works and the outcomes obtained from energy analysis are listed as below: Solar cell and absorber plate temperatures have been calculated by considering thermal balance among different layers of the solar PV module.

Solar cell temperature

$$T_c = \frac{\tau_g \beta_c (\alpha_c - \eta_{el}) G + U_t T_a + U_p T_p}{U_t + U_p} \quad (1)$$

Absorber plate temperature

$$T_p = \frac{[\tau_g^2 \alpha_p (1-\beta_c) + \tau_g \beta_c (\alpha_c - \eta_{el}) h_{p1}] G + U_{tp} T_a + U_f T_f}{U_{tp} + U_f} \quad (2)$$

Where $h_{p1} = \frac{U_p}{U_t + U_p}$ and $U_{tp} = \frac{U_t U_p}{U_t + U_p}$

Water outlet temperature of the PVT is a function of ambient and water inlet temperatures, it also depends on the value of heat removal factor, i.e., the rate at which heat is being taken away from the PV module.

Outlet flow temperature

$$T_{f,out} = \left(T_a - T_{f,in} + \frac{(\alpha\tau)_{eff} G}{U_L}\right)\left(\frac{F_R U_L b L}{\dot{m} C_p}\right) + T_{f,in} \quad (3)$$

Heat removal factor is calculated as

$$F_R = \frac{\dot{m} C_p}{U_L b L}\left[1 - exp\left(\frac{-bF' U_L L}{\dot{m} C_p}\right)\right] \quad (4)$$

Rate of useful thermal energy that may be harvested from the PVT is computed by the amount of heat content of the coolant fluid which depends on its specific heat capacity, mass flow rate and the temperature difference between the inlet and outlet.

$$Q_u = \dot{m} C_p (T_{f,out} - T_{f,in}) = F_R b L [(\alpha\tau)_{eff} G - U_L (T_{f,in} - T_a)] \quad (5)$$

Thermal efficiency of the PVT water collector

$$\eta_{th} = \frac{Q_u}{G A_{PVT}} = F_R \left[(\alpha\tau)_{eff} - \frac{U_L (T_{f,in} - T_a)}{G}\right] \quad (6)$$

In calculating the electrical efficiency of the PVT, the power consumed by the pump must be taken into account. So, PVT electrical efficiency is calculated as below

$$\eta_{el} = \frac{V_m I_m}{G A_{PVT}} \quad (7)$$

The incident solar energy is not entirely utilized as effective input to the PV module. The net input exergy rate of PVT water collector is a function of both the sun and the ambient temperatures.

The outcomes obtained from exergy analysis are listed as below:

$$m \sum \dot{E}X_{in,net} = \dot{E}X_{Q,S} = G A_{PVT} \left[1 - \frac{4}{3}\left(\frac{T_a}{T_s}\right) + \frac{1}{3}\left(\frac{T_a}{T_s}\right)^4\right] \quad (8)$$

The net output exergy rate of PVT consists of two components, one is thermal exergy and the other one is electrical exergy.

$$\dot{E}X_{in,net} = \dot{E}X_{th} + \dot{E}X_{el} \quad (9)$$

The thermal exergy includes the exergy changes of water flow in PVT collector.

$$\dot{E}X_{th} = \dot{Q}_u \left(1 - \frac{T_a}{T_{f,out}}\right) \quad (10)$$

Heat transfer from the storage tank. Calculate the sensible heat transfer.

$$\dot{Q}_{loss} = \frac{K A . \Delta T}{L} \quad (11)$$

3.2 Electrical modeling

The energy analysis creates the analysis reliant on the electrical model for electrical efficiency. To enhance the calculation accuracy for the PV system, the five parameter models for both electrical efficiency and its electrical parameters, such as the maximum power point voltage, short-circuit current, open circuit voltage and maximum power point current.

In this system, the PV cell is represented by the equivalent circuit shown in fig. 1. The current-voltage (I-V) characteristics of this model were defined by the following governing equation:

$$I = I_L - I_O . \left(exp\left(\frac{V + I.R_s}{a}\right) - 1\right) - \frac{V + I.R_s}{R_{sh}} \quad (12)$$

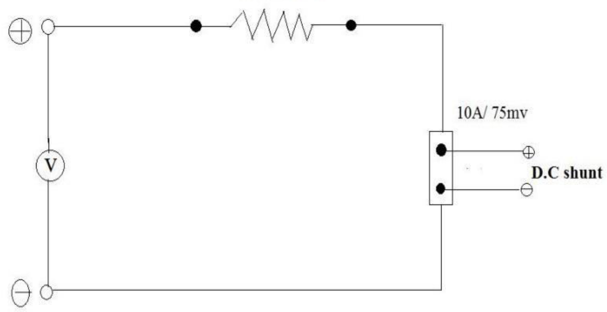

Fig.1 Equivalent circuit for an individual PV cell

Table 1 Conditions used in the five-parameter model

Condition	Equation
At short circuit voltage	$[dV/dV]_{sc} = -1/R_{sh,ref}$
At open circuit voltage	I = 0, V = $V_{oc,ref}$
At short circuit current	I = $I_{sc,ref}$, V = 0
At maximum power point	I = $I_{mp,ref}$, V = $V_{mp,ref}$
At maximum power point	$[dVI/dV]_{mp}$ = 0

The maximum power (P_{mp}) extracted from the module and the electrical efficiency is then estimated from (13)as shown by

$$P_{mp} = I_{mp} . V_{mp} \quad (13)$$

$$\eta = \frac{I_m . V_m}{G . A} \quad (14)$$

4. Formulation of problem

4.1Construction detail

Experimental setup consists of solar PV panel system having 280watt capacities of power. There are one water tank having area of 310mm by 580mm, having insulation material are used. The PV panel outlet water collector is made to pass through one of the storage tank and is then distributed to storage tank. Photographs of the experimental setup shown with the solar PV panel system connected to the storage tank. The plastic storage tanks has capacity of about 100 liters, out of which 32 liters is stored as per day to the use of water spray and the remaining half is stored with water and this arrangement is capable of supplying water for a family of domestic application. The dimensions of PV panel is same i.e. 1980mm length and 1000mm width. The PV panel material is havingpolycrystalline more power generated; hence their mono crystalline panel is compared with polycrystalline panel.Maximum possible heat transfer take place at the upper portion, hence the decision of placing the water spray on the upper portion is taken. RTDs are provided at four different locations of the storage tank, ambient temperature, PV panel front temperature and back panel temperature. There is multimeter provided to the measure current and voltage to connect the positive and negative port.

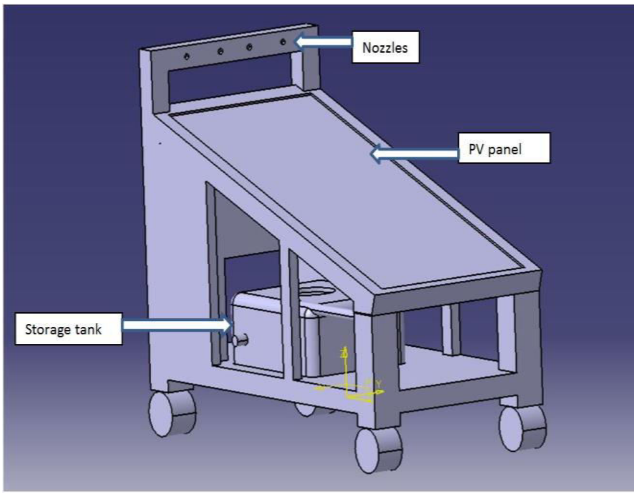

Fig. 2 Mathematical Model

These connections are mounted on a PV panel stand under the cabin. These three arrangements of tanks are having same stand to measure temperature and power. A cooling system has been built up as shown in Fig.3 this cooling system consists of four main parts as follows:
1. PV modules of 280 W peak-output.
2. Water tank of 100 liter capacity.
5. 4 water nozzles for spraying water over the panels.
6. Drain pipe for collecting the water and return it back to the storage tank.
According to the literature survey done, the orientation of the solar PV panel collector should be in south-west direction. We need to point them in the direction that captures the most sun, to get the most from solar panels. For the best direction, there are lots of variable in figuring. In our location, this system is designed to help us find the best placement of solar panel system. To get energy from the sun, it applies to any type of panel. The panel can be adjusted seasonally to tilt or has a fixed to assume us. This angle should be tilt on 22° at location of pimprichichwad collage of engineering, nigdi, pune.

Table.2 Specification of the PV module used

Solar PV module parameters	Value
Module type	WS-280
Maximum power (P_{mp})	280 W
Maximum power current (I_{mp})	8.00 A
Maximum power point efficiency (h_{mp})	17.5 %
Maximum power voltage (P_{mp})	35.0 V
Open circuit voltage (V_{oc})	43.00 V
Short circuit current (I_{sc})	8.68 A
Area of the module (A)	1.62 m²

Fig. 3 Actual experiment set up

4.2Precautions before Experimentation

Before starting the actual Experiment, there is a need to monitor the entire setup to find out the working status before taking the actual readings. For this, monitoring is an essential work prior to experimentation. This includes

- Checking the correct connecting the power output of the PV panel.
- Checking the correct working of the RTD sensor.
- Checking the correct working of the spray nozzle.

Checking the pressure drop inside the nozzles from PV panel collector to the tanks.

4.3 Measurement error analysis

To applied measurement equipment and final influence on the influential measured parameters were briefly discussed to expected measurement error in this section. The temperature transducer and multimeter are used in the experimental analysis. The temperature error influence is not a significant one error is ±0.3%as the guaranteedmeasurement, if we analysis specific data. The applied water spray flow magnitudeis not a significant impact in relation, to expect measurement error in the water flow meter sensor case is ±3.0%. In this case also solar irradiation measurement error is ±0.6%. PV panel electric power output is in the amount of error ±1.5%, to measure regarding indirectly.It should be considered accurate more precise results.

5. Result and discussion

Factor likes solar radiation and ambient temperature influence performance of PV system. Water is sprayed on front side of the PV surface. The purpose of the applied water spray cooling system was to achieve rise in heat rejection to the atmospheres and obtain lower panel temperature, i.e. to increase PV panel electric power output. We investigate the heat exchange circumstances a simultaneously cooled PV panel (water spray applied front sides of the PV panel surface).

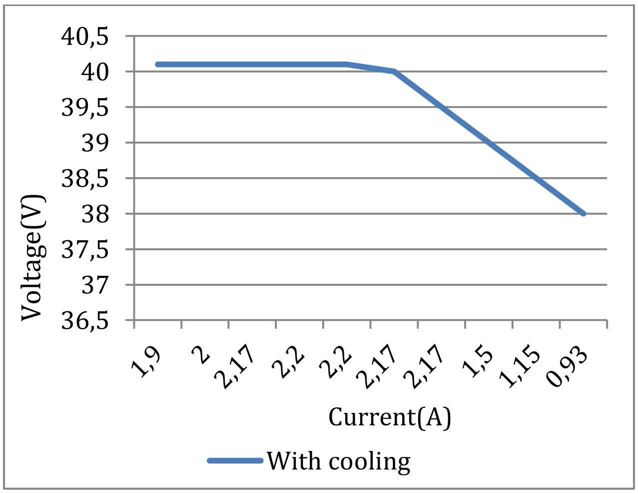

Fig.5 I-V characteristic performance of cure with cooling

The maximum value of radiation was observed at noon. PV module of efficiency is show in Fig.6. It can be observed that the electrical efficiency is a linear function of module temperature. With increase in temperature the efficiency of PV module decreases. During the experiment, cooling and without cooling cases were considered the system. The temperature of without water spray is higher as compare to the cooling case. The result is the in lower electrical efficiency of the PV module. The panel was tested at PCCOENigdipune on a clear summer day. The average temperatures of the surrounding air ranged from 27°C and up to 30°C.

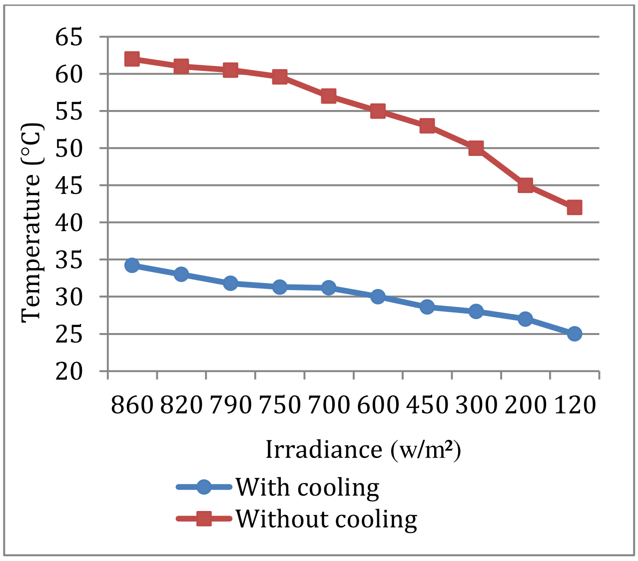

Fig. 6 Effect of the induced velocity on the temperature at diverse irradiance

Measurements were considered the temperature of with cooling and without cooling from fig. 6. During this time measuring the solarirradiation ranged from 810 W/m² to 850 W/m², the highest solar irradiation period of the peak value is 858 W/m² recorded by pyranometer.

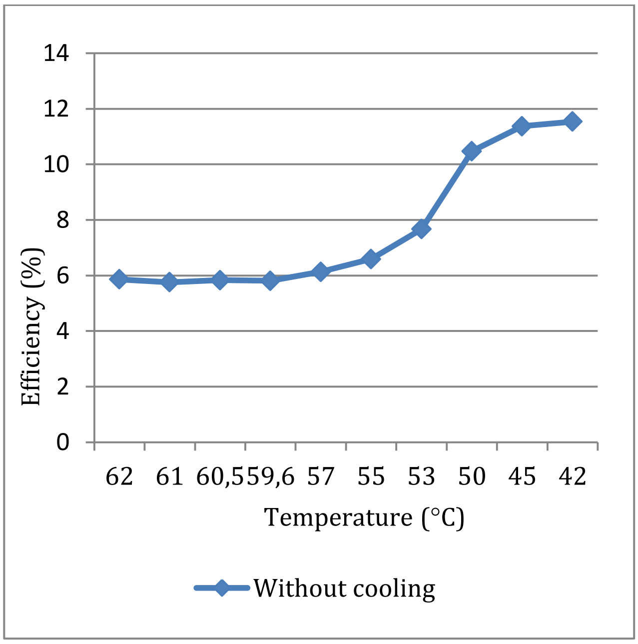

Fig.6 Without cooling system for mean maximal efficiency

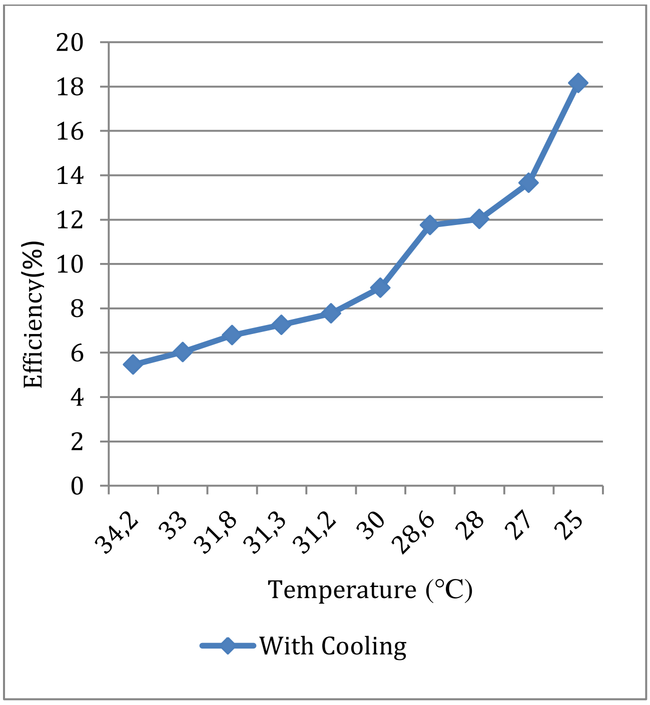

Fig.7 With cooling system for mean maximal efficiency

Based on the experimental data,Fig. 6 and Fig. 7 showed that the graph with cooling and without cooling electrical efficiency is about 3% to 6.63% higher electrical efficiency. The temperature difference can be predictable to the module of output connection used in the current may result in a drop in the electrical efficiency. There are four PV modules connected both in series and parallel in this experimental set up. Electrical efficiencies vary for different temperature of PV module thus compromising the overall system efficiency. A cooling technique that employs simultaneous water supply on both sides of the PV panel has been reported (M. Hasanuzzaman et al. 2016). The increase in PV panel total electric power output and total electrical efficiency found to be 18.16% and 11.75% respectively under peak solar irradiation. In addition, the panel temperature was decreased from an average 54°C (non-cooled PV panel) to 24°C. The principal achievements of this cooling technique are shown by the following Fig. 7. From Fig. 8, it is clear that when front sides of the panel are cooled at the same time, efficiency improves the most and panel mean temperature falls to its lowest. The reduction in temperature achieved between non-cooled PV and cooled PV panel is shown in Fig. 8.

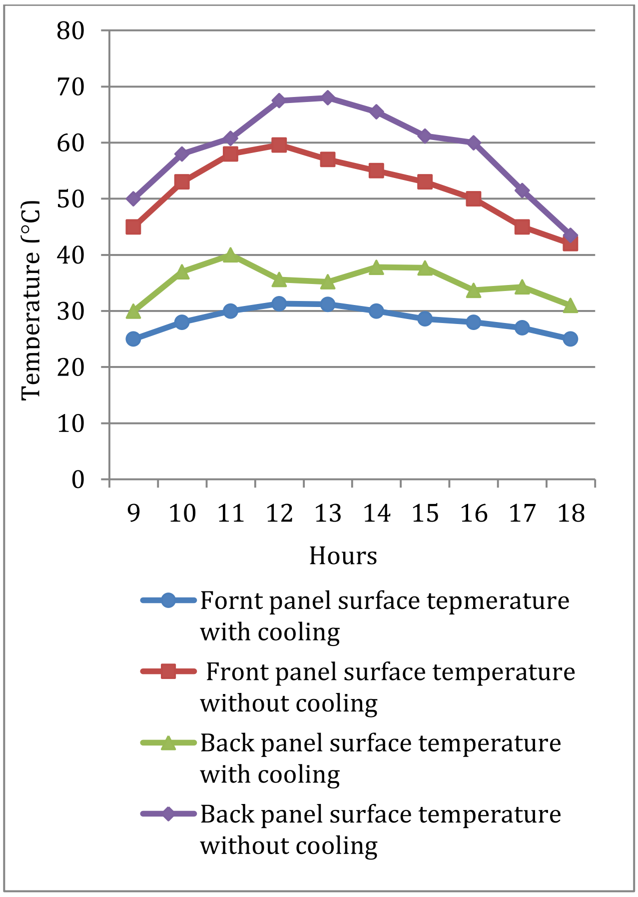

Fig.8 Temperature for different cooling regimes under highest solar irradiation

The scheme is illustrated in Fig. 6. The PV system under different operating conditions is presented in Fig. 5along with the radiation data. A maximum reduction in module temperature of 20°C (from 65 to 45°C) was achieved which is equivalent to 30% reduction. A maximum of 10.4% efficiency has been obtained by using water. On the other hand, efficiency drops to its least of 9.0% without cooling. The maximum rise in electrical efficiency is obtained with the use of water in numeral which is 18.17%.

Conclusions

An active cooling method has been designed and modeled for photovoltaic module using water cooling system aimed to improve the PV efficiency and life expectancy. To analysis the performance of PV panel with and without the water cooling mechanism is the main objective. Further the performance of water cooling system has been evaluated for ambient temperature transitions and solar insolation variation separately. Effect of solar insolation and ambient temperature transition on PV power generation is also studied and modeled for computing optimal PV module temperature. As the set temperature increased, its efficiency increased since the temperature increased of the collector output water. The increase in the set temperature increased the average thermal efficiency of the whole system. The increase in the set temperature from 45°C to 55°C increased the temperature of the module with a cooling. To study the influence of cooling on the performance of efficiency of PV panels an experimental setup has been developed. It can be said from the results of this study that:

1) Using the PV panel cool and clean proposed cooling system in hot and dusty regions.
2) Front side of PV panel is cooled to achieve relative and effective increase in the panel power output by 18.17% and 5.9% of relative increase in PV panel electrical efficiency.
3) Decrease of operating temperature by 5°C - 23°C with a water cooling mechanism increase the power output of the PV panel by 8 - 18 %..

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