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Efficiency Improvement of Photovoltaic Panels by Design Improvement of Cooling System using Back Water Cooling Tubes

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***Abstract* — In this paper an experimental setup is designed in which array of water tube is fitted to back of solar panel to reduce its temperature and bring temperature to normal operating point. Before this both air-cooling model and water-cooling model conditions are investigated under normal operating condition. After getting result for various model we compared our back water cooling tube array results with the ordinary solar panel. A maximum photoelectric conversion efficiency difference is 2.6%, and the temperature decreases by 1-2 degree Celsius, the output power generation efficiency is increases by 0.5 to 1 % for the solar PV panel when using heat pipe for air-cooling,**

Keywords— Photoelectric conversion efficiency, Maximum allowable temperature, solar panel cooling, back water heat tube array

1. INTRODUCTION

Cooling of solar PV module is important because it have a non-linear voltage-current characteristic with a unique point where the power produced is maximum. Maximum power point depends on module temperature and irradiance conditions. Both this conditions change during the day and are different for different places depending on the season of the year. Moreover, irradiation can alter rapidly due to varying atmospheric conditions such as clouds and sky. It is important to track the maximum power point accurately under all possible conditions so that the maximum available power is always obtained. Temperature of solar PV module is decreased by providing back water tube filled with water and circulate it by using natural convection technique. In this paper an experimental setup (Fig 2.1) is designed in which array of water tube is fitted to back of solar panel to reduce its temperature and bring temperature to normal operating point. Before this both air-cooling model and water-cooling model conditions are investigated under normal operating condition. After getting result for various model we compared our back water cooling tube array results with the ordinary solar panel. The efficiency of a PV plant is affected mainly by the factors like: the efficiency of the PV panel (in commercial PV panels it is between 8-15%), the efficiency of the inverter (95-98 %) and the efficiency of generation due to increase in module temperature. The efficiency of photovoltaic solar panel decreases with increase in operating temperature. This is because, the photo voltaic modules take only the visible light intensity for converting it to electrical energy and rest of the spectrum of light is converted to heat leading to the increase in operating temperature. Reflection from top surface is another reason for increase in operating temperature.

2. EXPERIMENTAL SETUP

A working experimental setup is developed to determine how long it takes to cool down the module based on proposed cooling system. Fig 2.2 water circulation tank use natural convection to circulate water. An experimental validation of hat rate model and cooling rate model has been done. Based on heating and cooling rate model it is found that the PV panel yields the highest output energy if cooling of the module starts. The work done in this thesis proposes modeling of photovoltaic model in which temperature and sun's irradiance, of the PV array is taken into account.

To check the correctness of the solar PV model predicted values of solar radiation data are compared with calculated hourly values. The radiation effect of solar radiation on the tilted surfaces and vertical surfaces for different orientations from horizontal, have also been calculated. The calculated values and results are found to be very close agreement with measured values. The method presented in this thesis can be used to do approximation hourly, global, diffuse solar radiation on inclined and vertical surfaces and horizontal surfaces and at different angles with greater accuracy for any location. This tells us the power generation capacity rated of power plant with the actual power generation capacity of the plant.

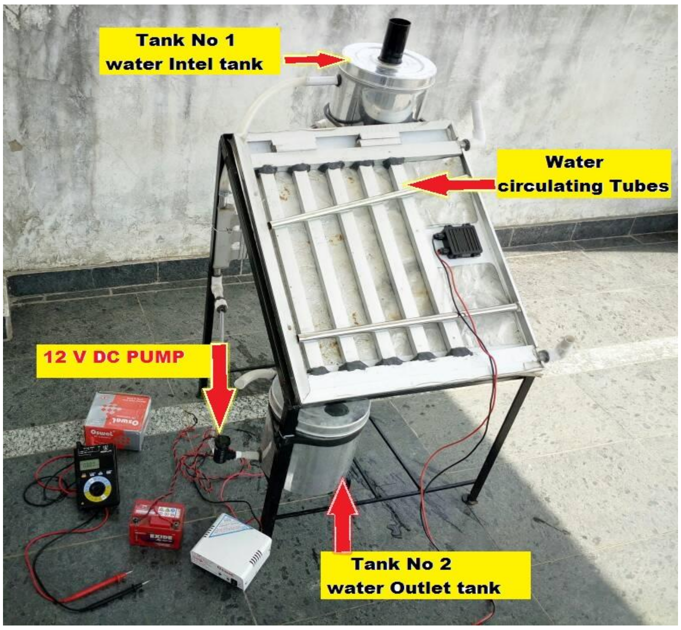

Fig 2.1 PV modules fitted with aluminium tube of rectangular cross-section tube filled with water to cool PV module

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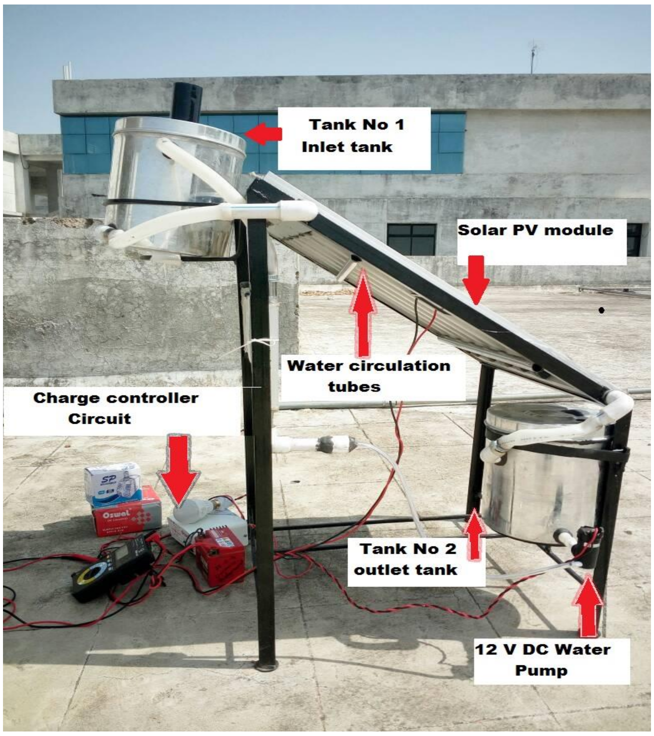

Fig 2.2 water circulation tanks for force convection to circulate water

3. ELEXTRICAL SPECIFICATION OF MODULE USED

Nominal Maximum Power at STC (Pmax):	RNG-50P (50 W)
Optimum Operating Voltage (Vmp):	17.8V
Optimum Operating Current (Imp):	2.84A
Open Circuit Voltage (Voc):	22.4 V
Short Circuit (Isc):	2.95 A
Operating Temperature:	-40°C ~ +75°C
Maximum System Voltage:	600VDC(UL)
Power Tolerance:	+5W
Temp Coefficient of Pmax	-0.44%/°C
Temp Coefficient of Voc	-0.30%/°C
Temp Coefficient of Isc	0.04%/°C
Max series fuse size rating	15A
Fire rating	Class C
Module Efficiency:	12.35%

4. EXPERIMENTAL SCHEME

Watts (STC)	**50 W**
Watts (PTC)	42 W
Max Power Voltage (VMPP)	17.33 V
Max Power Current (IMPP)	2.9 A
Open Circuit Voltage (VOC)	21.27 V
Short Circuit Current (ISC)	1.88 A
Max System Voltage	DC 1000 V
Module Efficiency	12.35%
Cell Efficiency	14.72%

A working experimental setup (fig 3) is developed to determine how long it takes to cool down the module based on proposed cooling system. An experimental validation of heat rate model and cooling rate model has been done. Based on heating and cooling rate model it is found that the PV panel yields the highest output energy if cooling of the module starts.

The work done in this thesis proposes modeling of photovoltaic model in which temperature and sun's irradiance, of the PV array is taken into account .A photovoltaic system is modeled and its voltage , current characteristics and the power are calculated. This makes the dynamics of PV system to be easily simulated and optimized. It is worth noticed that the output characteristics of a PV module are affected by the environmental factors such as temperature, cloud and wind .Due to this the conversion efficiency is low. Therefore, a cooling technique is needed to decrease the temperature of solar module so as to increase the peak power to maximize level .By doing so the generated output power is increase to a certain height.

5. AIM OF THE WORK

The key aspect of a solar PV power Plant is to Increasing its efficiency so the power produce increases. The efficiency of a PV plant is affected mainly by the factors like: the efficiency of the PV panel (in commercial PV panels it is between 8-15%), the efficiency of the inverter (95-98 %) and the efficiency of generation due to increase in module temperature.

The efficiency of photovoltaic solar panel decreases with increase in operating temperature. This is because, the photo voltaic modules take only the visible light intensity for converting it to electrical energy and rest of the spectrum of light is converted to heat leading to the increase in operating temperature. Reflection from top surface is another reason for increase in operating temperature.

It will increase the incomes, consequently lowering the cost of the power generated so it will move toward the decreasing the cost of the power produced from other sources

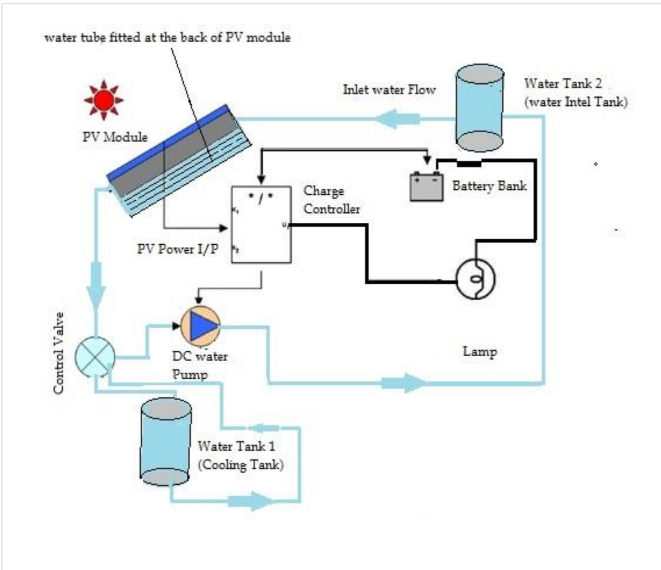

Fig 3. Schematic diagram of the experimental set-up water circulation tank use natural convection to circulate water

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The whole project is designed in consideration of cooling effect of water to decrease module temperature by forced convection technique using water. A 12 Volt DC water pump is used to force water from lower cooling tank to upper water inlet tank which further send water to the rectangular aluminium water tube fitted at the back side of PV module. When required cooling is achieved then water is again collected in the lower tank for cooling and this action is controlled by a control valve fitted at the inlet of lower water tank. The design set up of a photovoltaic system is modeled and its voltage, current characteristics and the power are calculated. This makes the dynamics of PV system to be easily simulated and optimized. It is worth noticed that the output characteristics of a PV module are affected by the environmental factors such as temperature, cloud and wind .Due to this the conversion efficiency is low. Therefore, a cooling technique is needed to decrease the temperature of solar module so as to increase the peak power to maximize level .By doing so the generated output power is increase to a certain height. In the fig 18 we saw how actual model is designed to calculate the efficiency improvement by using cooling technique by using back water cooling tubes.

A aluminium sheet is also used on which the copper tube is placed .The purpose of aluminium sheet is to increase the surface area so maximum heat is dissipated from the surface of module and water in the tube cool's down the module .Water at normal temperature is feed in the cooling tube via a tank which serves as storage for cool water and also for hot water coming from the tube .Water in the tube is circulated throughout day by a 12V DC water Pump. The flow rate of water inside tube is done by forced convection method used here. The temperature of front and back side of module is measured and shown in Fig: 19 comparison of hourly temperature of solar module cooling by air and with water .Temperature of back side of module is reduced from 38 degree Celsius to 35.5 degree Celsius. The temperature difference between back and front side of PV module is measured to know the cooling rate of water flowing in the back water tubes.

6. RESULTS & DISCUSSION

There are so many different cooling techniques used before to achieve maximum power efficiency by minimizing thermal losses, if we want to compare different cooling effect, we need to identify the universal value that describes the cooling effect on solar PV module. Since very few works were made to decrease module temperature by water cooling. Due to which complete measurements and calculations of generated power, the total increase in relative and generated efficiency, and complete description of the cooling method used, it is very difficult to compare the gained results with the predicted one. If maximum power gain is taken into account and divided with the effective surface of the PV cell, a specific power gain per surface can be defined for each experiment. Unfortunately, experiments without those information's can't be taken into consideration. Also, this way of comparing is only qualitative, because, in several works, crucial information's are missing and can only be logically deduced (i.e. the effective area deduced approximately from total area, etc.).

The calculated result is near to the predicted value in this work. Module temperature is decreased by 1 to 2% of overall temperature of front and back side when compared.

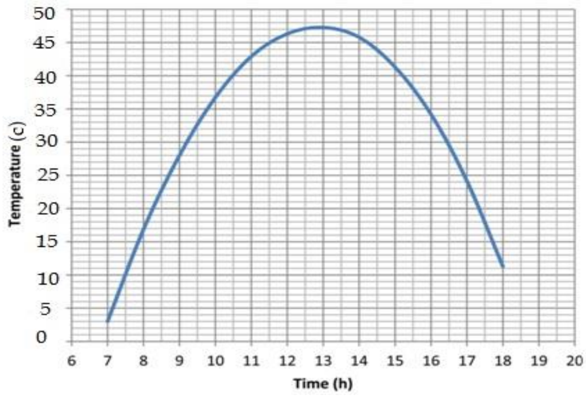

Fig 4.1 Temperature Vs time graph of PV module

From above we can Say that when temperature of PV module is increased to a certain level its efficiency get decreased. Fig 4.1 shows Module temperatures as a function of solar irradiation

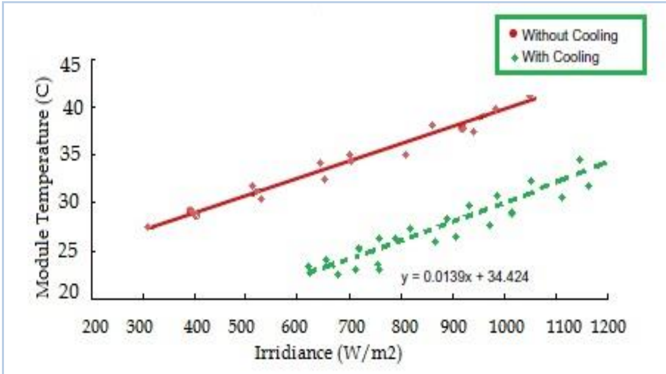

Fig 4.2 Module temperatures as a function of solar irradiation

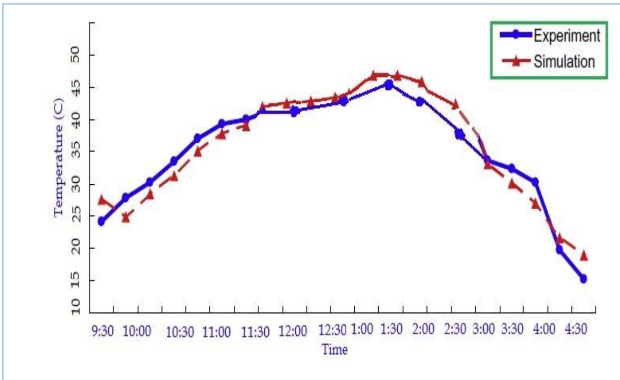

Fig 4.3 comparison of simulation and experiment in the temperature profile of the back of PV module

7. CONCLUSION

This thesis reports an Experimental Study and Comparison of Performance & efficiency of a PV (photovoltaic) module by rear face water cooling for hot climatic environment passive cooling system, which could be used for cool the PV modules in order to increase electrical efficiency. The most significant point of this approach is that it utilizes rainwater and solar energy to cool the PV panels improving PV system efficiency with no requirement for additional energy input. The authors believe that it has the potential for further exploration.

The influences of the absorbing surface area on the water supply volume are not obvious, whereas a water tank with larger volume significantly increases the water supply. However, the actual chamber size should be comprehensively considered with roof area and available rainwater capacity. On the design day, the solar-driven water cooling system is able fill at least 10L of water to backwater tubes of PV modules. The maximum reduction in the temperature of the cells reaches 1-2°C and average electrical yield is increased by 0.5 to 1%.

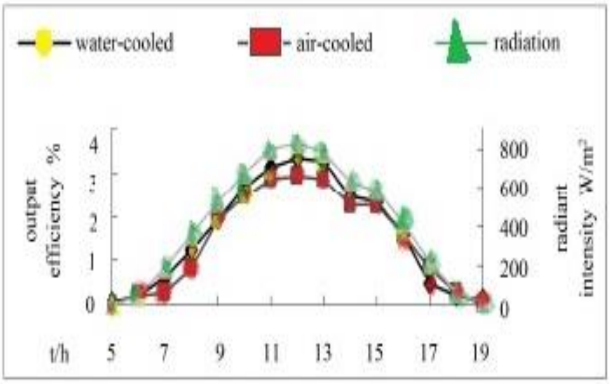

Fig: 5.1 Comparison of output efficiency of PV Panel cooling by air and by back water cooling tube.

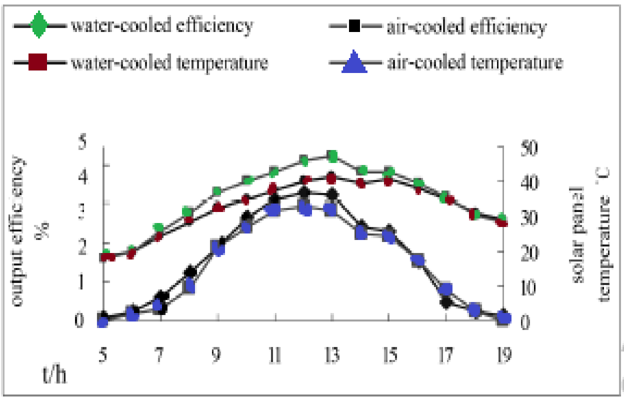

Fig: 5.2 Comparison of hourly output efficiency of PV Panel cooling by air and by back water cooling tube.

The global solar irradiance on horizontal surfaces has been measured. A computer model has been prepared to calculate the monthly average daily solar irradiance and hourly solar irradiance on inclined surfaces from the global solar irradiance. The hourly diffuse solar radiation and the average monthly daily diffuse solar irradiance are estimated.

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