Cooling Methods for Increasing Efficiency of PV Panel

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ABSTRACT - PV module generates electricity by incident solar radiation. The operating temperature of PV module increases when it absorbs solar radiation resulting in decrease in photovoltaic efficiency. Overheating of a PV module decreases the performance of output power by 0.4-0.5% per rise of 1°C over its Standard Test Conditions (STC). Hence, the concept of "cooling of PV" has become so important. The cooling of PV module helps to increase the photovoltaic efficiency. The active and passive cooling methods are used to cool the PV module. This works summarizes the different active and passive cooling methods for increasing the PV module efficiency and also way to extract the heat energy.

I. INTRODUCTION

All over the world energy is essential issue for human. Energy can be classified into two categories which are namely, non-renewable energy and renewable energy. As the development outcomes of world economy, the world can't continue depend for long on fossils fuels like natural gas, coal, peat and oil. Most of world 86 % [1] energy is generated from fossil fuels. The reserves of fossil fuels are limited, which lead to the price of fossil fuel is continuously increasing. Global renewable installed capacity is 673 GW, Solar share is 168.25 GW [1]. Global solar: 177 GW and India is placed at 11th position with 3.3GW [1].
Renewable energy sources have become so-important as these are significant benefits. Among all the renewable sources, solar energy, photovoltaics in particular, is a very effective solution for renewable energy because of its non-polluting nature, abundance and availability at free of cost. Energy from the sun has been used to provide electricity for many years. This form of renewable energy occupies less space compared to the space occupied by non-renewable energy.
The amount of solar energy incident on earth surface is approximately $1.5*10^{18}$ kWh/year, [2] which is about 10000 times the current annual energy consumption of the entire world.
The solar energy may be utilized in two ways

- By collecting the radiant heat and using it in a thermal system.
- By collecting and converting it directly to electrical energy using a solar photovoltaic system.

PV energy is energy that comes from the sun converting light into electricity. Nowadays, the PV system is recognized and widely using in electric power applications. It directly produces electrical energy without any harm to the environment.

Solar photovoltaic system:
Solar photovoltaic systems or solar cell is a device convert photons in solar rays to Direct-Current (DC) and voltage. The associated technology is called solar photovoltaics. A typical silicon PV cell is a thin wafer consisting of a very thin layer of phosphorous-doped (n-type) silicon on top of a thicker layer of boron-doped (p-type) silicon. An electrical field is created near the top surface of the cell where these two materials in contact it forms p-n junction. When the sunlight is incident on the semiconductor surface, an electron springs up and is attracted towards the n-type semiconductor material. This will cause more negatives in n-type and more positive in p-type semiconductor which result generating a higher flow of electricity. This is known as photovoltaic effect.

Factors that affect the solar photovoltaic efficiency:
One of the main obstacles that face the operation of the PV panel is very low PV cell conversion electrical efficiency. This is also a key obstacle of scientists and researchers to enhance the electrical efficiency of PV cells. The power output yield by the PV system depends on several factor such as

- Solar radiation
- Operating temperature of PV panel

Why PV Module Cooling Required?
Solar cell perform better in cold climate than in hot climate. An effective way of improving efficiency and reducing the rate of thermal degradation of a photovoltaic module is by reducing the operating temperature of its surface. This can be achieved by cooling the module and reducing the heat stored inside a PV cell during operation. Crystalline silicon currently offers a yield of 15-16% [3]. And some studies consider that its limits would be reached approximately 25% under laboratory conditions. [3]
Solar panels are tested under laboratory conditions called Standard Test Conditions (STC): at an Irradiance of 1000 W/m^2 with a temperature of 25°C.
Overheating of a PV module decreases performance of output power by 0.4-0.5% per rise of 1°C over its Standard Test Conditions (STC) [3]. This is way the concept of "cooling of PV" has become so important.

II. LITERATURE SURVEY

H.G. Teo et al. [4] carried out an active cooling system for photovoltaic modules. To cool the PV cells a parallel array of ducts with inlet and outlet manifold designed for uniform air flow distribution was attached to the back of PV module. The experiment was carried out with and without active cooling. Without active cooling, the temperature of the module was high and solar cell achieved an efficiency of 8-9%. For the module operated under active cooling condition, the temperature of the module dropped significantly and solar cell achieved efficiency of 12-14%.

Heat transfer simulation model was developed to compare the actual temperature of the PV module and it has good agreement between the simulation and experimental result obtained.

K.A. Moharram et al. [5] carried out experiment for enhancing the performance of photovoltaic panels by water spraying. When the temperature of PV panel reached maximum allowable temperature of 45^{o}C the temperature sensor runs the motor resulting in water spraying on PV module and cools the PV cell to normal operating temperature of 35^{o}C. From the result it was found that PV panels yield the highest output energy by cooling the PV panels to the normal operating temperature at cooling rate of the solar module 2^{0}C/min.

Jiang Wu et al. [6] studied on heat-transfer characteristics of solar cells and heat exchanger combined system and its optimization. The gravity heat pipe was installed on the back surface of a solar panel, so that heat from the solar panel can be transferred to evaporator section of gravity heat pipe exchanger and the evaporated fluid moves to the condenser section there by cooling the condensate. This condensate vapor was again sent to evaporator by gravity. The result was that keep the PV module cool and photovoltaic efficiency of PV module was increased.

R. Hosseini et al. [7] carried out an experimental study of combining a photovoltaic system with a heating system by cooling them during the operating period. In this experimental study PV system was cooled by a thin film of water flow on the PV panel. It was observed that the overall efficiency of combined system at some hours is one order of magnitude more than the efficiency of conventional panel.

Y.M. Irwan et al. [8] carried out indoor test performance of PV panel through water cooling method. In this method water was made to flow on the front surface of the PV module to reduce the PV module temperature. This experiment was carried out using halogen lamp bulbs, the halogen lamp bulb acted as a natural sun light to produce radiation of 413, 620, 812, and 1016 W/m^2. The results show the decrement of operating temperature and increase of power output of the PV panel with water cooling mechanism based on different values of fixed solar radiation. They carried out the experiment for different radiation using solar lamp and compare the PV performance parameter with and without cooling under constant and different radiation. During the experiment PV panel temperature mentioned at 5-23^{o}C it increases the power output by 9-22%.

Bjornar sandnes et al. [9] worked on a photovoltaic and thermal collector with a polymer absorber plate and carried out experimental study using on analytical model. In this experiment, solar heat collector is combined with photovoltaic cells to form hybrid energy generating unit and this hybrid system simultaneously maintain the PV cell temperature low and produce high efficiency.

Hence radiant energy from sun is partly converted to electricity using a photovoltaic cell and excess heat generated in the photovoltaic cells serves as input for the thermal system, then this heat can be utilized in domestic hot water system or space heating.

The absorber plate is modified and contains an internal wall to wall channels filled with ceramic granulates. As the temperature of PV module increases the heat is transferred to the absorber plate and then to ceramic granulates. When water is pumped through the channel, it carries the heat from absorber plate and ceramic granulates thus resulting in cooling of PV module and increases the photovoltaic and thermal efficiency.

Zhen Hua Quan et al. [10] carried out an experimental study of photovoltaic and thermal system based on flat plate heat pipe. To improve the utilization of solar energy, the flat plate heat pipe is fixed to the back side of PV module.

Heat dissipated in the condenser section is utilized for domestic hot water system and radiant floor heating. Here a 900W solar panel used to meet the heating demand of a 15m^2 building. The flat pipe heat pipe is used to extract the heat from the PV module and this heat is used for heating of building. The thermal efficiency of system reaches 25.8% and photovoltaic conversion efficiency is nearly 14.5% and overall efficiency is up to 40.3%. The output power increases by 0.2-0.5% per 1K temperature decrease of the solar cell.

Ashwin Date et al. [11] worked on cooling of solar cells by chimney-induced natural draft of air. It was observed that the solar cell voltage decreased close to linearly with increase of cell operating temperature and the operating surface temperature of a PV panel was typically 20-30^{o}C higher than the ambient temperature. On the basis of these considerations, a method to increase the efficiency of solar panel was derived by maintaining their operating temperature as low as possible. Because of the inherent low efficiency of the panel, use of an active cooling system such as forced air and water cooling was not a suitable option. A theoretical analysis and experimental results on the thermal control of flat plate solar panels using natural convection induced by the chimney effect was carried out. The solar cooling chimney was designed, in the form of rectangular duct, which covers the back of the solar panel and extends one meter above the panel top. The solar cooling chimney had an inclined surface painted black to increase its solar thermal absorptivity. The absorber surface faces the sun in order to capture maximum solar radiation. Solar radiation passes through a transparent sheet and increases the temperature of the absorber surface of the solar cooling chimney. The hot surface transfers heat to the air in the rectangular chamber. Because of the in density of the air inside the absorber area and the exterior of the chimney the air convects upwards and provides the desired cooling flow for the solar cells.

In this method the natural draft achieved by buoyancy effect in chimney it can be used to cool the photovoltaic module. The cooling effect can be increased by increasing the velocity of air inside the chimney by constructing the higher stack height chimney.

R. Mazon et al. [12] worked on an analytical model and experimental validation of the heat transfer and the induced flow in a PV cooling duct in environmental conditions. In this method the solar installation consisted of two PV panels arranged, first panel was used as reference panel, and second panel was modified to test different ducts with different cross section. The experiment carried out under 1000 W/m^2 radiation and PV panel surface temperature, voltage, current, wind velocity, flow rate, are measured and compare the parameter of PV panel with and without duct.
Bhaskar B. Gardas et al. [13] designed a cooling system for photovoltaic panel to increase its electrical efficiency. The hybrid system consisted of a PV module attached to an absorber plate and fins to the other side of the absorber surface. A single pass flow carried out at a mass flow rate of 0.00275 kg/s of air and 1000 W/m^2 of radiation, and pass a various gases like hydrogen, oxygen, water vapor, nitrogen, methane, carbon dioxide, finally compare the fin efficiency and suggest the water vapor as cooling medium because it has high fin efficiency.
Qunzhi Zhu et al. [14] worked on electrical outputs and thermal outputs of water or air cooled amorphous-silicon photovoltaic modules. The water or air channel was sandwiched between the backside of the PV module and a metal sheet. The experimental study on the electrical and thermal output of a PV module was carried out with active water cooling and these results were compared with those passive air ventilation. The water cooling decreased the PV panel temperature significantly and improved the electrical power by at least 3%, and the overall energy conversion efficiency was greater than 40%. The experiment was carried out for different flow rates. The temperature of water cooled PV module was found to lower than the air cooled PV module, and hence was conducted that water cooled module could generate more electrical power than the air cooled one.
Marath Prakash et al. [15] carried out experiment on the system to regulate the temperature of photovoltaic modules to improve energy yield, by use of a heat exchanger using a forced convection with water. The heat exchanger was attached to the back side of PV module and had a single pass heat exchanger system. The heat exchanger system decreased the module operating temperature by 18-20^{o}C and resulting in power output increase of nearly 10%.

III. CONCLUSIONS

With ever increasing dependence on non-renewable energy sources, use of solar energy, photovoltaics in particular, is seeing an upward trend. Numerous attempts are being made to discover alternate materials for use, increase of efficiency.

This paper summarizes some of the methods utilized to increase the efficiency. Although many more such methods are available, cost of these cooling system is still debatable. It is a complex process to suggest a single cooling method which is both efficient and cost effective.
It can concluded that of active and passive cooling methods, active methods have been used in large as it may produce additional working system which may be used for miscellaneous purposes.

References

[1] http://cseindia.org/docs/photogallery/ifs/Renewable%20Energy%20in%20India%20Growth%20and%20Targets.pdf

[2] http://recap.apctt.org/Docs/SOLAR.pdf

[3] Ionel Laurentiu Alboteanu, Constantin Florin Ocoleanu, Cornelia Aida Bulucea, "Cooling system for photovoltaic module" University of Craiova, Craiova, ISBN: 978-1-61804-110-4.

[4] H.G. Teo, P.S. Lee, M.N.A. Hawlader, "An active cooling system for photovoltaic modules," applied energy 2012; 90: 309-315.

[5] K.A. Moharram, M.S. Abd-Elhady, H.A. Kandil, H. EI-Sherif, "Enhancing the performance of photovoltaic panels by water cooling," Ain Shams Engineering Journal 2013; 4: 869-877.

[6] Jiang Wu, Zhou Shi, Shuai Zheng, Lalu Zhao, Qiaobo Feng, Hancheng Luo Sheng Yang, Yujing Wang, "Research on heat transfer characteristics of solar cells and heat exchanger combined system and its optimization," Energy Procedia 2012; 14: 393-398.

[7] R. Hosseini, N. Hosseini, H. Khorasanizadeh, "An experimental study of combining a photovoltaic system with a heating system," World Renewable Energy Congress, Sweden 2011.

[8] Y. M. Irwan, W.Z. Leow, M. Irwanto, Fareq.M, A.R. Amelia, N.Gomesh, I.Safwati, "Indoor Test Performance of PV Panel through Water Cooling Method," Energy Procedia 2015; 79 : 604-611.

[9] Bjornar Sandnes, John Rekstad, "A photovoltaic / thermal collector with a polymer absorber plate: experimental study and analytical model," Department of physics, Norway, 1997.

[10] Zhen Hua Quan, Ning Jun Li, Yao Hua Zhao, "experimental study of solar photovoltaic / thermal system based on flat plate heat pipe," Beijing university of technology, china.

[11] Ashwin Date, Randeep Singh, Abhijit Date, Aliakbar Akbarzadeh, “Cooling of solar cells by chimney induced natural draft of air,” RMIT University, Victoria.

[12] R. Mazon, A.S. Kaiser, B. Zamora, J.R. Garcia, F. Vera, “Analytical model and experimental validation of the heat transfer and the induced flow in a PV cooling duct in environmental conditions,” World Renewable Energy Congress, Sweden 2011.

[13] Bhaskar B, Gardas, M.V. Tendolkar,”Design of Cooling System for Photovoltaic Panel for Increasing its Electrical Efficiency,” Department of Mechanical Engineering, Mumbai University, India.

[14] Qunzhi Zhu, Leilei si, “Electrical Outputs and Thermal Outputs of Water/Air Cooled Amorphous Silicon Photovoltaic Modules.” International conference on Environmental Engineering and Technology, China 2012.

[15] Marath Prakash, Paresh Nasikkar, Sandeep Koppikar, Nagendra Cherukupalli,“System to regulate the temperature of photovoltaic modules to improve energy yield,” SunEdison, AEDCEE Conference Proceeding, Bangkok 2013.