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A REVIEW ON COOLING OF SOLAR PHOTOVOLTAIC PANELS USING NOVEL TECHNIQUES.

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Abstract

In this paper various novel cooling techniques which can be used in enhancing the performance of the solar photovoltaic cell are being discussed. The solar energy is available abundant in nature and easy to harvest it, and provides a natural solution to move ahead in fulfilling the energy requirement. We know that Solar Photovoltaic cell converts solar energy to electrical energy. It has been seen that the decrease in panel temperature will lead to an increase in electrical efficiency, so in recent years different cooling techniques have been proposed and tested, whereas with the rise in temperature of panel the electrical efficiency drops to a magnitude of 0.55%C. Several other cooling techniques including conductive cooling, phase change material cooling, ribbed wall heat sink cooling, air duet cooling and water spray cooling system etc are also being tested and used to identify their effective impact on Photovoltaic panel performance. Finally, various novel cooling techniques for the enhancement of performance of solar photovoltaic cells are being elaborated and discussed in this paper.

Introduction

The renewable energy use becomes more popular during the increase of human population and the environmental issues. The solar energy is one of the important types of the renewable energy sources that had attracted many researchers around the world to work on. There are two types of energy that can be produced from the solar energy: electrical energy and thermal energy. The electrical energy can be produced by using photovoltaic (PV) cells. The PV cell directly converts the incident solar irradiance to electricity. The most efficient, sustainable, and eco-friendly systems are the PV modules which convert small part of the solar irradiance to electricity. The remaining part of the solar irradiation then converts into heat, which increases the temperature of the cells and reduces the performance of the PV module [1]. The maximum expected PV cells temperature with solar irradiance of 1000 W/m2, 70% of absorption rate and no-winds is 60°C while for the winds speed of higher than 4 m/s the PV cells temperature is lower than 40°C [2]. The maximum output power, open circuit voltage, and short circuit current are the main parameters which are influenced by the temperature variation of the cells temperature. Thus, the open circuit voltage and the maximum output power reduce with the temperature increase whereas the short circuit current rises [3]. Harnessing solar energy through photovoltaic cells is the future and the most renewable source of energy to be dependent upon which allows one to directly convert the solar radiations into electricity by use of solar photovoltaic cell, i.e. heat energy into electrical energy. However, while operating the solar photovoltaic cell its output and its efficiency are affected by various factors over the course of operation cycle and certainly it decreases the durable electrical performance of the cell. The major factor to affect the electrical output of the cell significantly is temperature and specially in hot, humid areas and conditions when the solar photovoltaic cell is addressed for the performance and output, the cell inside and on surface temperature crosses 70 °C mark, and as prevailing to such conditions the output of solar photovoltaic cell certainly may decrease by 0.55–0.65%/K and conversion rate of radiations to electricity by 0.08%/K of the solar photovoltaic cell because of operation above the permissible temperature [4-6].

Research Work

Citing the various problems about many studies and practical research have been carried out in order to cut short the problems stated, for the same to overcome the issue, it is proposed that as similar to heat exchanger a cooling system for photovoltaic cell is essential higher degree of solar radiations and hot system temperature conditions. Conductive cooling mostly ends up with air passive cooling, but an important difference is that the prevailing mechanism of heat transfer from PV cells is conductive in nature. Cuce et al. [7] worked on an experimental study on polycrystalline PV cells in controlled conditions. Two PV cells were used: one with aluminum fins as a heat sink, with thermal grease applied and one without a heat sink. Illumination was varied from 200 to 800 W/m2.

A special type of passive conductive 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 [8] 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 1 000 W/m2. 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.

Heat sink is also a cooling way in which a high thermal conductivity metal is used to remove the heat from photovoltaic cell. Farhana et al. [9] studied experimentally the operating temperature variation for the PV module with and without active cooling system to realize the electrical performance of the PV module. Popovici et al. [10] investigated numerically the temperature reduction of the PV panels during a clear day of summer by using different arrangements of ribbed wall heat sink of air and passive cooling. It was found that the maximum temperature of the panel for the angle 45° was less than that for the angle 135°. The study found that the maximum power produced by PV panel in case of using heat sink was increased by 6.97% and 7.55% compared to the reference case, for angles of the ribs from 90° and 45°, respectively.

Krauter in his research studies proposed a method for reducing the incident reflections in order to cool the solar photovoltaic cell by replacing the surface glass with a 1-mm transparent glass over the solar photovoltaic cell surface; as a following result the system temperature of solar photovoltaic cell reduced to 22 °C further resulting to an increase of 10.3% of electrical performance over the day; the major drawback for this study was non-homogenous water film thickness which was duly necessary in order to actually obtain the optimum thickness of water film which was used to increase the optical performance of the earlier designs and efficiency of solar photo voltaic cell [11].

El-Seesy et al. [12] made an attempt to cool down the PV cell with a thermosyphon effect, Fig.2. A polycrystalline silicon module, with a total area of 0.260 m2 was used, along with a copper sheet and tubing installed on the back of the module, and a thermosyphon water system with a water capacity of 80 liters. Nizetic et al. [13] investigated experimentally the impact of water spray cooling on the performance of the PV panel in highest solar irradiation level environment. Both sides of the PV panel were cooled at the same time by utilizing twenty nozzles, ten on each side as shown in Fig. 8. The results were measured for three different cases of cooling: front side cooling, rear side cooling and both sides together and compared with non-cooling case. The research indicated that the water spray cooling has achieved a suitable effect on the PV panel performance and the best case was the simultaneous front and back sides cooling PV panel. Lastly, depending on the experimental results, as presented in Table 1, the water spray cooling system had a proper impact on the PV panel performance.

Hosseini et al. studied the effectiveness by merely sprinkling the water as coolant over the surface of solar photovoltaic cell rather than directly flowing a laminar vertex flow of coolant over the surface, casually without taking in account the power rating of the pump used for spraying of coolant. This model was able to lower down the overall temperature of the solar photovoltaic cell and in turn increasing the electrical output performance at 18% [14] ; further on readjusting the water pump for allowing to flow a channel of water layer over the surface for a due course of time, this model was able to increase the efficiency to 26% in instantaneous peak output of module [14].

Teo et al. [15] cooled four polycrystalline PV modules of 55W nominal power, from back side. The surface of PV module is 0.78 m2. Special flow channel was manufactured and CFD analysis was used to optimize its shape. Total efficiency gain was around 1 %, depending of the irradiation. Optimal air flow beneath the panel is 0.055 kg/s, although no ambient temperature was given. This information is therefore reliable only for this specific case. Nevertheless, this information can be valuable when trying to evaluate the amount of air needed to cool down standard PV module.

Irwan et al. [16] studied experimentally the performance of the PV panel by using water cooling method. Indoor test was carried out by a solar simulator consisted of twenty 500 W halogen lamps. Two units of 50W Mono crystalline PV panel were used in the test. A DC water pump was used to spray water was connected to the front surface of one of the panel and the other panel was used as a base panel. It was observed from the experimental results that the operating temperature of the PV panel with water cooling system was reduced by 5–23°C and the power output was increased by 9–22%.

Peng et al. prepared an experimental setup using a polycrystalline-Si module using incandescent electric lamps to simulate solar radiation. The average radiation values were maintained from 160 to 400 W/m2. The experimental result showed that as the surface temperature increased the current. The maximum value of current was 0.15 A, after that it becomes constant. The surface temperature at 400 W/m2 radiation flux was 38 °C [17].

Nowee et al. [18] used a set of heat pipes to cool down mono crystalline PV module of 0.150 m2. At the condenser end of heat pipes, water boxes have been placed, to act as heat storage and to enhance cooling of heat pipes. A decrease of approximately 13 °C of rear side temperature was observed for summer and spring measurements. An average increase of 1.2 W was achieved, which roughly corresponds with relative increase in efficiency of about 6 %. It ought to be noted that this is realistic application of heat pipe for PV cooling.

Conclusion

A review study has presented the practical implication with electrical output and thermal efficiency of a solar photovoltaic cell with various cooling techniques used and their outcomes on efficiency. Cooling system with fins is efficient to reduce the temperature of the PV panel and enhance the electrical efficiency of the PV panel. In the thermal photovoltaic cell with tested practical work, it has been observed that by applying a film of water for cooling photovoltaic cell resulted in decreasing the system temperature of solar photovoltaic cell which will initially reduce the reflection rate with cooling down of solar panel and gradually increasing the electrical efficiency of solar panel. The net efficiency output of solar photovoltaic cell is very sensitive in relation to temperature which exponentially decreases with rise in system temperature of solar photovoltaic cell. Water spray cooling has a considerable effect on the performance of the PV cell, even for the low flow rate of the water spray the performance of the system enhances remarkably.

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