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An experimental study on using natural vaporization for cooling of a photovoltaic solar cell ☆

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ABSTRACT

This study attempts to investigate a new way for cooling PV cell using natural vapor as coolant. The performance of solar cell was examined on simulated sunlight. The natural vapor encountered backside of PV cell vertically in various distribution and different mass flow rates. Also, the effect of natural vapor temperature in cooling performance was analyzed. Results indicated that the temperature of PV cell drops significantly with increasing natural vapor mass flow rate. In detail, the PV cell temperature decreased about 7 to 16 °C when flow rate reaches 1.6 to 5 gr min^{-1}. It causes increasing electrical efficiency about 12.12% to 22.9%. The best performance of PV cell can be achieved at high natural vapor flow rate, low natural vapor temperature and the obtained optimum distribution condition.

1. Introduction

With growing concerns about the damages to the environment caused by burning fossil fuels, and due to ever increasing oil demand, recently there have been numerous attempts to find out an energy source which can serve as an alternate energy for fossil fuel. Harnessing solar energy holds great promise for the world's energy demands, and it will be heavily called upon as fossil fuels are depleted. Photovoltaic solar cells (PV) are used to convert some part of solar energy to electricity and they are the best choices for utilizing solar energy. Another technology to utilize the solar energy is the hybrid photovoltaic/thermal (PV/T) technology. This technology can simultaneously generate electrical and thermal energies by integrating a photovoltaic cell and a solar thermal collector. In the recent years numerous studies were carried out to investigate the applications of solar technology. There are many papers that report the effects of temperature on the electrical efficiency of the PV cells [1–3]. The efficiency of PV cells decreases with increasing the temperature of PV module [4]. Researchers proposed practical ways to reduce the temperature of PV cell. Tripanagnostopoulos et al. [5] experimentally investigated the improvement in the electrical performance of a photovoltaic. It was achieved by using fins and naturally circulating air. Chen et al. [6] used the refrigerant R134a for cooling PV modules insulated by glass vacuum tubes. The PV panel was coupled with a heat pump system. Some researchers have shown an increased interest in the development of micro cooling technology for various applications because of the ability of microchannel heat sink to remove a large amount of heat from a small area [7–11]. Karami et al. [12] used Boehmite nanofluid in microchannel heat sinks to achieve as high thermal performance as possible. In hybrid photovoltaic/thermal solar energy systems cooling the PV module can be combined with a useful fluid heating [13–15]. Raghuraman [16] performed two separate one-dimensional numerical methods to predict the performance of PV/T flat plate collectors using water and air as heat carrier. They tried to maximize the energy extracted from the collectors. Teo et al. [17] employed an active-cooled hybrid PV/T system to cool down the PV cell. Their results indicated that active cooling improves the efficiency considerably. Tchinda et al. [18] studied theoretically thermal processes in a CPC collector with a flat one-sided absorber. They concluded that the selectively coated CPC with flat one-sided collector is more efficient than the black painted one with the same condition. Othman et al. [19] studied both theoretically and experimentally the performance of hybrid photovoltaic–thermal solar collector. They improved the performance of PV/T solar air collector by the use of a double-pass collector and fins. In another study [20], they designed a double-pass PV/T solar collector with fins and compound parabolic concentrator (CPC) to increase the performance and reduce the cost of photovoltaic electricity. The CPC was used to increase the radiation intensity falling on the solar cells.

However traditional water-type PV/T collectors/systems are practical, but they are not used in regions with natural climates because the freezing of water to ice can break up the collectors. In the regions with natural climate, the integration of a heat pipe and a solar collector can be incorporated into a practical design for a PV/T collector [21]. Many other studies on PV/T systems have been conducted on heat pipe PV/T systems [22–25]. Jie et al. [26] represented numerical and experimental

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Nomenclature

As	PV cell area (m^2)
A_h	area covered with natural vapor (m^2)
I_{PV}	photovoltaic arrays current (A)
P_{max}	maximum power of PV arrays (W)
$P_{cooling}$	PV power by cooling (W)
$P_{without\ cooling}$	reference power (W)
PV	photovoltaic
Q	mass flow rate (kg/s)
T_c	PV cell temperature (°C)
T_v	natural vapor temperature (°C)
U_v	velocity (m/s)
V_{PV}	photovoltaic voltage (v)

investigations on the performance of the photovoltaic solar assisted heat pump (PV-SAHP). Their results implied that the PV-SAHP has a better coefficient of performance and photovoltaic efficiency in comparison with the separate units. Installation of panels on the river canals was done practically in some places [27,28]. Those studies showed that the canal-top solar power equipment produces 15% more power than the plant set up on land as the water vapor flowing underneath of the panels keeps the solar panels relatively cool and helps more power generation.

The main objective of this research is to illustrate a new method to reduce the temperature of PV module and improve the efficiency of PV cell. In order to achieve the best performance of PV cell, the PV panel has been cooled using natural vapor as coolant. The vapor has a temperature in the range of temperature of natural vapor escape from rivers, water channels, etc. The effects of the natural vapor flow rate, natural vapor temperature and natural vapor distribution on the performance of PV cell have been discussed. Because of the limitations that exist in real states during the test, such as wind and variable in intensity, vapor flow rates and vapor temperature, all experiments are done in laboratory. Therefore the situations are controlled in each step to highlight the effect of parameters.

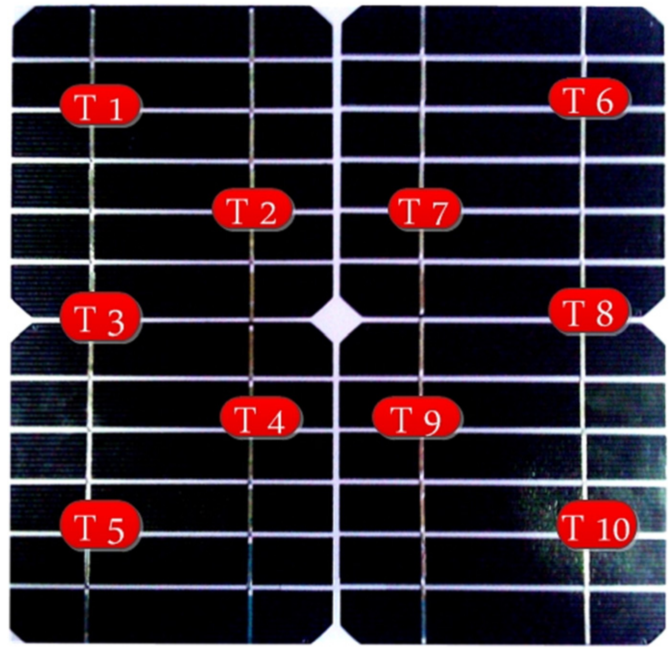

Fig. 2. The thermocouple positions.

2. Experiment setup

The schematic illustration of testing setup is depicted in Fig. 1. According to the figure, this system consists of natural vapor generator and photovoltaic systems. Solar simulator, natural vapor simulator and

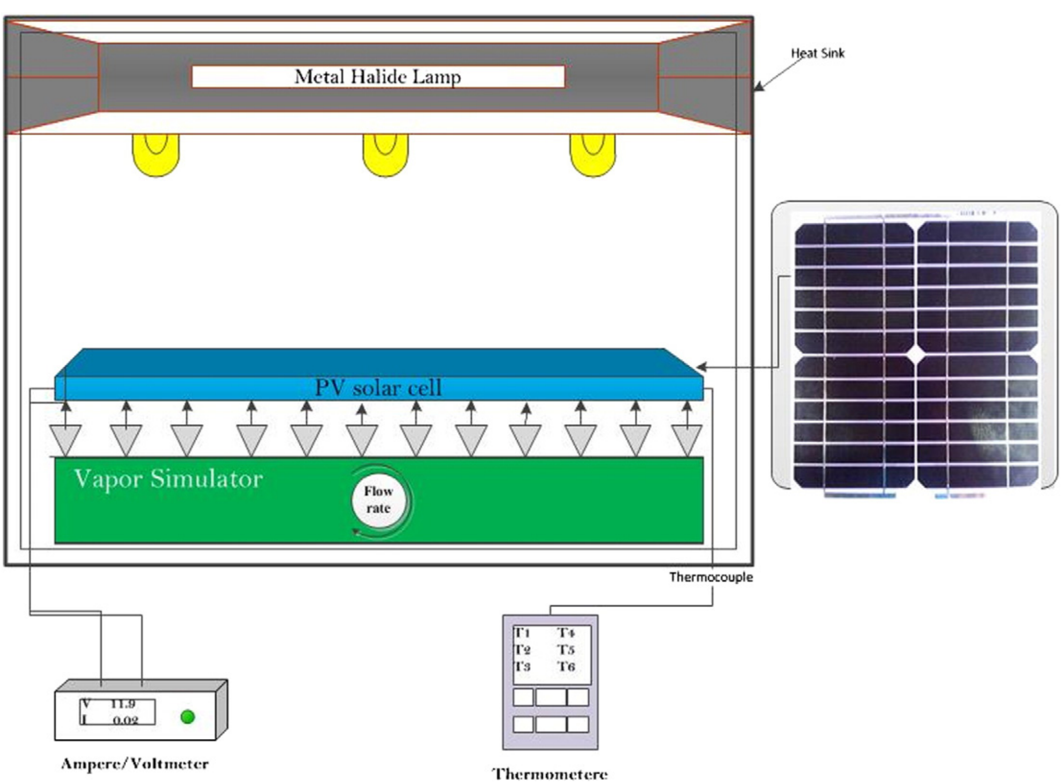

Fig. 1. The scheme of experimental setup.