Experimental investigation of cooling photovoltaic (PV) panels using (TiO2) nanofluid in water -polyethylene glycol mixture and (Al2O3) nanofluid in water- cetyltrimethylammonium bromide mixture


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ABSTRACT

Cooling of photovoltaic (PV) panels was investigated experimentally outdoors using two nanofluids and water as a cooling medium for volume flow rate ranging from 500 to 5000 mL/min at concentrations (0.01 wt.%, 0.05 wt.%, and 0.1 wt.%) under different radiation intensity. Two types of nanofluids were used, namely Al2O3 in water -polyethylene glycol mixture at pH 5.7, and TiO2 in water- cetyltrimethylammonium bromide mixture at pH 9.7, respectively. The cooling of PV panel required incorporating a heat exchanger of aluminium rectangular cross section at its back surface to accommodate different volume flow rate of the cooling medium aforementioned. The system was tested under climate conditions of Jerash-Jordan. Determination of flow characteristics; friction factor, f and product of friction factor Reynolds number, of TiO2, Al2O3 nanofluids and water as a cooling medium were investigated. Also, a f/Re comparison of the temperature between the cooled PV cell and without cooling for volume flow rate ranging from 500 to 5000 mL/min was presented. Results showed that the nanofluid cooled PV cell in both types caused higher decrease in the average PV cell temperature compared with the cooled cell with water and without cooling. In addition, Al2O3 nanofluid showed better performance than TiO2 nanofluid. Furthermore, experimental results showed that higher concentration of nanofluid produces a better cooling effect of the PV cell for all the studied range of volume flow rate. Also, electrical analysis of power and efficiency showed that TiO2 nanofluid gives better performance for the studied range of volume flow rate and concentrations compared with water cooling and without cooling.

1. Introduction

It is well known that global warming and climate change was caused by greenhouse gas emissions whereby a high percentage of emissions is due to burning fossil fuels. To reduce the environmental impacts of these gases, photovoltaic (PV) technology can be considered an ideal solution. However, one of the main problems which limit the extensive use of PV systems is the rising in temperature of PV panels. Overheating of a PV panel is by reducing the operating temperature of its surface. This can be achieved by either using conventional method of cooling by water and air with natural or forced convection or by what is called nanofluid which was introduced by Choi and Estman [3] in 1995.

Many researchers have proposed various techniques of water cooling to reduce PV surface temperature, and improve the performance of PV systems. Among them is the work done by Krauter [4] in which a thin film of water nozzles running over the surface panel was utilized. It was noticed that water decreased cell temperature up to 22°C and electrical yield by 10.3%. Odeh and Behnia [5] used water trickling method on the upper surface of the PV panel and obtained an increase of about 15% in system output at peak radiation conditions. Hosseini et al. [6] carried out an experimental study to compare the performance of a PV system combined with a cooling system with conventional PV. The results showed that combined system yielded higher power output and efficiency compared to the conventional one. Royne and Dey [7] used the technique of jet impingement cooling devices for arrays of densely packed PV cells. Their results showed that using this technique had only a weak effect on the electrical output of the photovoltaic system compared with the effect of changing the...
Whereas hydraulic diameter of heat exchanger channel for non-cooling. A height of heat exchanger channel thermal conductivity of nanoparicles power output of the PV cell thermal conductivity of base fluid power input of the PV cell °C power input of the PV cell dynamic viscosity density of base fluid volume fraction of nanoparticles °C density of base fluid °C mass of nanoparticles P power P_{\text{max}} maximum power

Symbols

Nomenclature

Symbols

Greek letters

average temperature of the cells. Hence it was concluded that liquid jet impingement would be a promising method for dissipating heat efficiently from densely packed cells. Abdolzadeh and Ameri [8] found that spraying water over the front of PV cells improved the performance of a PV system, while Nizetic et al. [9] reported that better performance could be achieved by spraying water on the front and back surfaces of a PV panel. However, Bahaidarah et al. [10] used water coolant on the back surface and front surface to evaluate performance of PV module by using EES software. They found that the EES results for surface coolant; the cell temperature was 35°C whereas 37.8°C for non-cooling. In the contrast, for the back surface cooling; the cell temperature was 25.9°C with 42.8°C for non-cooling. A similar work by Azadeh [11] showed that the electrical power output and efficiency increased noticeably by cooling the PV cells with a thin film of water. Rosa et al. [12] and Tina et al. [13] carried out work to study the behaviour of PV panel submerged in water. Both observed an average increase in the electrical efficiency. Furushima and Nawata [14] used a cooling siphonage device for enhancing the performance of a PV power generation system. In the same context, many researchers [15–19] and [20–23] have investigated the effect of water and air based cooling, respectively, on the performance of hybrid photo voltaic thermal units of PV/T systems. From the analysis of the above mentioned articles, it is clear that cooling leads to an improvement in the performance of PV systems.

The thermal conductivity of nanofluids is much improved when compared with usual suspensions. The enhancement of the thermal conductivity of nanofluids over that of the base fluid is often a few times better than what would have been given by micrometer-sized suspensions. Lee et al. [24] presented conductivity measurements on fluids that contained Al2O3 and CuO nanoparticles in water and ethylene glycol. The results clearly indicated that the thermal conductivity enhancement of the Al2O3 and CuO nanofluids were high. They used volume fractions of only 1–5%. The enhancement was higher when ethylene glycol was the base fluid. An enhancement of 20% was observed at 4% volume fraction of CuO. The enhancement when water was the base fluid was lower but still substantial, with 12% enhancement at 3.5% CuO, and 10% enhancement with 4% Al2O3. Wang et al. [25] also measured the thermal conductivity of CuO–water and Al2O3–water nanofluids but their particle size was smaller (23 nm for CuO and 28 nm for Al2O3). They also measured the nanofluids with ethylene glycol and engine oil (Pennzoil10W-30) as the base fluids. The measurements showed a clear effect of the particle size and method of dispersion. The measurements showed a clear effect of the particle size and method of dispersion. Xie et al. [26] measured the thermal conductivity of aqueous Al2O3 nanofluids with even smaller particles (1.2–302 nm). They also observed the effect of particle size in addition to the effect of the base solution. Murshed et al. [27], who measured the thermal conductivity of aqueous solutions of spherical and cylindrically shaped TiO2 nanoparticles, found that 15 nm-sized spherical particles show slightly less enhancement than 10 × 40 nm rods, which showed an enhancement of 33% for a volume fraction of 5%. However, the enhancement was far more than that predicted by the Hamilton-Crosser model. Same researchers [28] developed a combined model for the effective thermal conductivity. Wang et al. [29] found that compared with usual suspensions, the enhancement of thermal conductivity from densely packed cells.

Many researchers carried out different reviews on nanofluids characteristics, heat transfer and properties. Zhou et al. [33] presented a review on development of nanofluid preparation and characterization. Lee et al. [34] carried out a review of thermal conductivity data, mechanisms and models for nanofluids while Ghamdi et al. [35] was related to nanofluid stability properties and characterization in stationary conditions. On the same context Fan and Wang [36] presented a review of heat conduction in nanofluids while Vajjha and Dass [37] worked a review and analysis on influence of temperature and concentration of nanofluids on thermophysical properties, heat transfer and pumping power. Reviews of thermophysical characteristics of nanofluids and heat transfer were carried out by [38–40].

The influence of nanofluid on different solar thermal applications was investigated by many researchers. One of these applications is the solar collector whereby several papers were found in the literature. Among these is the work carried out by Luo et al. [41] in which they prepared nanofluids by dispersing and oscillating TiO2, Al2O3, Ag, Cu, SiO2, graphite nanoparticles, and carbon nanotubes into Texatherm oil to study the performance of a DAC solar collector. Their results showed that the use of nanofluid in solar collector can improve the outlet temperature and efficiency. Rahman et al. [42] performed a numerical study for a triangular shape solar collector with nanofluids TiO2, Al2O3,