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Increasingperformance of (PVT) solar cells by using nanofluids:A review

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Abstract: *Heat losses from PVT causes increasing temperature of cell's surface that is affecting upon overall efficiency of PVT.Usingof nanofluids as a coolant in(PV/T) systemis one method to increase the electrical and thermal efficiency of (PV/T) system. This article consists ofthree partitions: one of them is reviewing the numerical studies, second of them isreporting experimental studies and finally the studies that contained both numerical and experimental studies.The aim of this article is to summarize all studies that using a pure water and nanofluid as a coolantand compare between nanofluid types.This study reveals why we interest about study on the photovoltaic thermal collector. In addition, this review will indicate types of nanofluid and thermo physical properties.*

Keywords: *solar energy, nanofluid, photovoltaic thermal collectors, heat transfer boosting.*

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I. INTRODUCTION

The trend of global warming and environmental pollution has risen with the use of traditional sources like a fossil fuel.Most work in the twenty-first century is attempting to develop applications of renewable energy.Unconventional energy sources such as solar energy are renewable, sustainable and environmentally friendly.Most significant applications of solar energy are solar cogeneration systems or photovoltaic thermal collectors (PVTs) that can be described as solar devices receiving solar radiation to simultaneously produce electrical and heat energy.PVT considers a combination system from a photovoltaic cell plus a thermal collector where the heat absorbed by the thermal collector transferred by conduction heat transfer crosses the absorber plate and is transferred by the circulating fluid as a convection to be used for heating purposes as shown in Figure (1)[1].

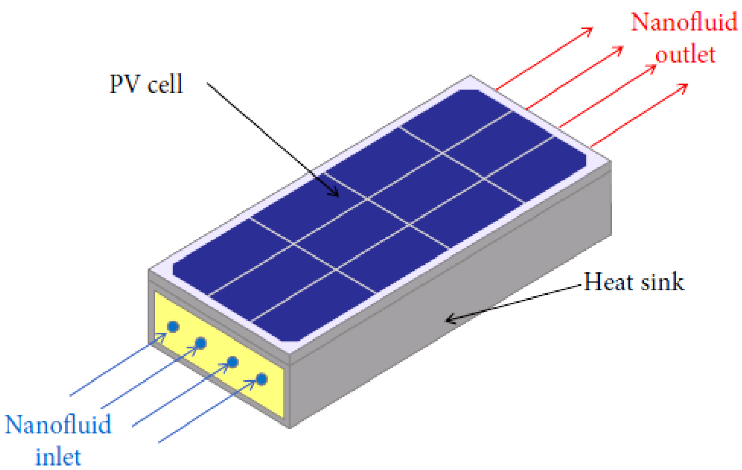

Figure (1): block diagram of PVT system.

Teoetal., [2] studied an experimental investigation to indicate electrical efficiency of the PVT system. Thermal part of the PVT includes parallel array of ducts. The Temperature of cell panel considers a significant parameter effects on the electrical efficiency of the cell. The inspection was used both passive and active cooling. The author concluded that the efficiency was at without Cooling achieved 8-9%.Otherwise, the efficiency was at active cooling achieved 12-14%. The study reveals the solar cells with and without cooling was changing the electrical efficiency.

Nanofluid

Nanofluidis played as the active role for enhancement the physical properties of base fluids such as thermal conductivity, heat transfer coefficient, density, viscosity, specific heat transfer coefficient. The nanofluid can be defined as a stability mixture of infinitesimal particles called nanoparticles and base fluid such as (water, thermal oil, ethyl glycol and refrigerant). The nanoparticles have diameter (from 1nm to 100 nm) which have different types based on metal, carbon based and composite nanoparticles [3].

Thermo-physical properties of nanofluid

Viscosity

The phenomenological hydrodynamic equations were the first equations to compute the effective viscosity of a spherical solid suspension by Einstein (1956) [4].

$$\mu_{eff} = (1 + 2.5\varphi_p)\mu_b \quad (1)$$

After that researchers have made developments based on the Einstein's initial working to expand the Einstein theoryin several directions such as expanding in higher concentrations of nanoparticles, the maximum volume concentration of nanoparticle has infinity value of the viscosity and develop this theory to comprehend non-spherical particle concentrations.

Thermal conductivity

Really, to indicate the eccentric thermal conductivity of nanofluids there are several experimental studies. The result of experiments has produced some semi-empirical correlations which have used to calculate the thermal conductivity of nanofluids. However, there is no governed theory equation to estimate the thermal conductivity of nanofluids. There are many parameters which influenced on the thermal conductivity are: volume concentration of nanoparticles, the figure of nanoparticles, the temperature of nanofluid and thermal conductivities of the working fluid and nanoparticles.The reference equation for solid-liquid mixtures to estimate thermal conductivityis the Maxwellmodel. Moreover, all theoretical studies have been based on it [5].

$$k_{eff} = \frac{k_p + 2k_b + 2(k_p - k_b)\varphi}{k_p + 2k_b - (k_p - k_b)\varphi} k_b \quad (2)$$

Masuda et al., [6] conducted an experimental study by using different types of nanoparticles such as alumina, silica and other oxides to increase thermal conductivity of base fluid (water). The author concluded that at volume fraction of 4.3%, the thermal conductivity raised to 30%.

Density

The density of nanofluids change proportional directly with increased the volume concentration of nanoparticles. The density of nanofluids can be calculated directly based on the mixture law [7]:

$$\rho_{eff} = (1 - \varphi_p)\rho_b + \varphi_b\rho_p \quad (3)$$

Specific Heat

Similarly, the specific heat of nanofluid can be calculated directly based on mixture law [7].

$$c_{p,eff} = \frac{(1-\varphi_p)(\rho c_p)_b + \varphi_p(\rho c_p)_p}{(1-\varphi_p)\rho_b + \varphi_p\rho_p} \quad (4)$$

Heat transfer coefficient

Heat transfer coefficient is one of important thermo physical properties of nanofluids.Heattransfer coefficient considered a better pointer than sufficient thermal conductivity for nanofluid utilized as a coolant in thermal applications. Authors have been focusing on the heat transfer coefficient in the nanofluids but their studies limited and they are in the early step. Conventional equations are governed for all heat transfer coefficient equations such as Dittus-Boelter equation (Dittus and Boelter, 1930) or the Gnielinski equation (Gnielinski, 1976) with experimental parameters added. Thus, these equations are used for small parameter ranges. All theoretical studies have been based on them. The Nusslet number for turbulent and laminar flow determined by [8]:

$$Nu_{nf} = c_1(1 + c_2\varphi^{c_3}Pe_d^{c_4})Re_{nf}^{c_5}Pr_{nf}^{0.4} \quad (5)$$

Polidori et al., [9] studied an integral formalism approach to estimate natural convection heat transfer of Newtonian γ by using Al_2O_3/water nanofluids in a laminar external boundary-layer. This study governed by macroscopic modelling and thermo physical nanofluid properties were constant, the results of this study presented that the viscosity of nanofluids showed an important parameter as well to the natural convection heat transfer in the heat transfer.

Numerical study

Rawadan et al., [10] conducted a numerical study by using of Al_2O_3/water and SiC/water. They proved that nanofluids at low Reynolds number decreased temperature of PV, furthermore, in comparison of pure water were best, so they showed the volume fraction concentration was one of the most important parameters which effected on the system performance.

Rejeb et al., [11] indicated a numerical study by using of four types of nanofluids consist of Al_2O_3 or Cu nanoparticles into water or ethylene glycol base fluids in three cities of Lyon (France), Mashhad (Iran) and Monastir (Tunisia) to estimate the performance of a sheet and tube PV/T. they concluded that water based nanofluids are more activity in comparison with ethylene glycol based nanofluids, where the best thermal performance achieved by Cu/water state. Moreover, the higher electrical output of PV/T system was limited in Monastir city.

Khanjari et al., [12] explained a numerical analysis by using of Al_2O_3/water and Ag/water nanofluid in a sheet and tube for cooling of PV/T system. They showed that the energy and exergy efficiency of system boost more when they used Ag/water nanofluid. Also, they revealed that the overall energy and exergy efficiency have positive effect by increased nanoparticle concentration, while they decrease with increases velocity.

Experimental study

Karami and Rahimi [13] conducted an experimental study of non-concentrated PV cells with micro-channel cooling which using the Boehmite nanofluid as working medium in laminar flow. Hence, disagreeing results have been conveyed on the effect of different nanofluids by nanoparticle concentration on PV temperature, which can be recognized to different type of PV/T systems andnanoparticles.

Ghadiri et al., [14] conducted an experimental study of sheet and tube PV/T system by using the ferrofluid of Fe_3O_4/water nanofluid as a coolant and inspected the system under three states: constant, alternating magnetic field and no field condition. This study showed that using the ferrofluid under the alternating magnetic field can enhance the efficiency of energy and exergy more contrasted to the another states.Al-Shamani et al., [15] tested TiO_2/water, SiO_2/water, SiC/water as a working fluid in PV/T system that contains twisting figured absorber design with rectangular cross section. The results show that the highest overall efficiency was by using SiC/water nanofluid.Whereas, aforementioned studies used the nanofluid coolant widely under the PV cells in contrast, above the PV cells.An et al., [16] conducted an experimental study by using Cu_9S_5/ Oleylamine nanofluid and polypyrrole nanofluid as the spectral filters in a Fresnel lens CPV/T system. Also, in this study to reduce the temperature of the cell placed the water channel at the back of PV cells. This study exhibited that using the nanofluid spectral filter can enhance the system efficiency. They concluded the electrical and overall efficiency boosted when raising a nanoparticle concentration, while thermal efficiency decreased.Additionally, a glazing above the optical filter enhanced the thermal energy but reduction in the electrical energy.

Experimental and Numerical studies

Gholampour et al., [17] conducted both an experimentally and theoretically investigation to indicate the efficiency of photovoltaic/thermal unglazed transpired solar collectors (PV/UTCs). This study presented the amount of air mass flow rate flowed through the transpired plate was an important parameter that effect on the amount of photovoltaic cooling in this system.Sardarabadi and Passandideh-Fard [18] conducted an experimental and numerical study by using Al_2O_3/water, TiO_2/water, ZnO/water nanofluids to cool a sheet and tube PV/T system. This study exhibited that TiO_2/water and ZnO/water nanofluids have best electrical efficiency compared to Al_2O_3/water, whereas ZnO/water nanofluid shows the better thermal performance among all.

Hjerrild et al., [19] studied an experimental and numerical investigation by using silver-silica nanofluid and carbon nanotubes mixed into water to cool a PV/T system that using multi-particle nanofluid filter. This study presented the higher overall efficiency of this system due to nanofluid contained disc shape nanoparticles.Shahsavar and Ameri [20] studied a theoretical and experimental investigation by using the natural and forced air convective heat transfer to cool a glazed and unglazed direct-coupled PV/T system. They concluded that increase in thermal efficiency and a decrease in electrical efficiency due to glaze system.Sardarabadi and Passandideh-Fard[21] conducted a numerical and experimental investigation by using different types of nanofluids t flowing through copper tubes to cool the PV of a photovoltaic. The nanoparticles were as follows: AL2O3,TiO 2,andZnO. The results of the study present that TiO2/water and ZnO/ water boost the electrical efficiency more than AL2O3/ water.whereas, the thermal efficiency , ZnO/water revealed important values if compared with the two other types .Additionally, the researchers investigate the eff ect of raising the mass fraction of ZnO from 0.05 to 10% by weight. Whereas, the thermal efficiency raised four times, the temperature decreased by only 2% and the electrical efficiency decreased by 0.02%.

II. CONCLUSION

This paper has summarized some of studies that deal with enhancement (PV/T) system by using nanofluids. All studies proved that the electrical and thermal efficiencies increased by using nanofluids.Some of researchers studied numericalinvestigations; they concluded some information is: the electrical efficiency increased at low Reynold number, the volume fraction of nanoparticle considered one of the most important parameters which affected on the PVT system and Ag/water and Cu/water nanofluids increased the overall efficiency of PVT more than Al2O3/water nanofluid. Other authors conduct experimental studies, some results of these studies are:the electrical energy achieved high value at a low concentration of Boehmite, the overall efficiency of PVT enhanced when raising the nanoparticle mass fraction of Silica/water from 1% to 3%, energy and exergy efficiencies boosted when using the Ferro-fluid under the alternating magnetic field, the highest overall efficiency achieved by using Sic /water nanofluid compared with TiO2/water and SiO2/water and the thermal efficiency of PVT increased by 45% when using CuO/water instead of the pure water. Some of them used experimental and numerical studies together, these results were: the electrical efficiency of PVT enhanced when using TiO2/water and ZnO/water compared to Al2O3/water and the thermal efficiency of PVT rose four times when the mass fraction of ZnO increased from 5% to 10%.Finally, my research will study an experimental and numerical investigationtogether by using Fe3O4/water nanofluid with different concentrations to denote affected it upon electrical and thermal efficiencies of the flat plate PV/T system.

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