The use of Water Cooling Photovoltaic Thermal (PV/T) System in Domestic Heating Water

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Abstract-Thermal photovoltaic systems are new systems designed to reduce the temperature of a photovoltaic cell and to increase its productivity and utilize heat removed in other applications. In the present study, practical experiments were conducted to evaluate the performance of the thermal photoelectric system and to study the atmospheric effects (temperature and solar radiation intensity) on the system in the conditions of the city of Baghdad, Iraq. This city is characterized by high radiation intensity up to the maximum in August of summer (880 watts/m^2) and this intensity is very high and close to the Solar Belt countries. A commercial polycrystalline PV module was used to make the PV/T collector. The test results show that the studied PV/T solar collector can provide good thermal efficiency. This study introduces the concept of primary energy efficiency to evaluate the PV/T system.

Keywords-*Solar Energy, Photovoltaic Thermal (PV/T), Irradiance, PV Panel Temperature*

I. INTRODUCTION

The planet is in grave danger of global warming, which is causing elevated warming temperatures that has so far produced serious effects such as melting North Poleice and climate change [1]. It has been noted that excessive burning of fossil fuels to produce energy, whether electrical or energy-powered, is the cause of this serious phenomenon [2]. The burning of gasoline and diesel in cars, vehicles, ships, trains and ships emits dangerous pollutants, the most important of which are carbon dioxide and methane, both of which cause global warming [3, 4]. The disproportionate increase in population around the world has exacerbated this problem. Moreover, the discovered and exploited oil reservoirs began to decay and decrease due to their consumption [5].As a result of the risks, the world has come together to change the policy of fossil fuel appropriation and the need to reduce greenhouse gases by moving towards clean and environmentally friendly renewable energies. These energies include wind energy, tides, waves, geothermal heat, hydrogen and fuel cells, the sun and others [6].

The sun sends radiant light and heat to the surface of the Earth planet facing it and the intensity of this radiation varies after entering the atmosphere as it is cleared of ultraviolet rays. Most areas affected by high intensity sunlight are called the Solar Belt and the intensity of solar radiation up to 1300 W/m^2[7]. Less radiation of this magnitude can benefit from the light and heat it carries in many applications. The sun is harnessed using a range of technologies to utilize heat in applications such as residential water heating [8], air heating for comfort purposes [9], Trombe wall for ventilation and heating [10, 11], solar water distillation [12, 13], and solar gradient salt ponds [14, 15]. Electric power can also be produced from the sun either by heating the air in solar chimney [16, 17], or by using mirrors in concentrated power plants [18, 19]. Electricity can also be produced directly using photovoltaics [20, 21].

The main component of a solar cell is a semiconductor, because this is the part that converts light into electricity. Semiconductors can perform this conversion due to the structure of electronic energy levels [22]. The rapid development in the quality and productivity of these cells causes their rapid spread and popularity globally [23]. These cells can work stand alone or connected to the grid [24, 25], with other energy systems such as wind, diesel generators or batteries [26]. It is also highly flexible in its construction sites whether in the seas, desert, plains or mountains [27]. These systems are currently used in street lighting [28], car parking garages [29], Telecommunication and broadcasting stations and towers [30], remote clinics and border guards [31].

Photovoltaic cells suffer from several constraints that reduce their productivity and increase the need for maintenance [32]. For example, solar cells are affected by the accumulated dust [33], which causes the quality of air to decay partially reduce the radiation that reaches the surface of the accumulated on the cell prevents the arrival of these rays completely [34], which reduces their productivity. Solar rays on the surface of the cell go to a large part of the heating of the cell and the remaining part is either reflected or absorbed to produce electricity [35]. The high temperature of the PV cell causes a significant decrease in its productivity and efficiency [36]. As the increase in the intensity of solar radiation increases the power generated, at the same time cause an increase in temperature and therefore reduced this power [37]. Researchers have recently proposed the use of thermal photovoltaic systems [38].

Researchers have worked hard to study PV/T systems because they offer important advantages such as reducing the temperature of the PV panel and thus improving its productivity, as well as making use of this heat in other applications [39-42]. The researchers used to cool photovoltaic cells: air, water, different cooling fluids, nanofluids, phase change material (PCM), PCM with nanoparticles and PCM with nanoparticles and nanofluids [43-46]. Each of these methods has its advantages and disadvantages but they all promise to reach an ideal system in terms of utilizing the electrical and thermal energy produced [47-52].

Iraq suffers from a severe shortage of electricity supply up to 5,000 MW and summer to 7500 MW [53]. Iraqis used to fill this lack of equipment by using diesel or gasoline generators, either personal or collective. These generators have increased environmental pollutionreaching dangerous stages, which already Iraq suffers from. The shift towards the use of photovoltaic cells is unlikely because of the dusty atmosphere of Iraq [54].In addition to the hottest weather most days with high intensity of solar radiation causing high temperatures of solar panels and thus reduce their efficiency [55]. Therefore, the use of high-efficiency PV/T systems can be considered as the best solution to liberate Iraq from the lack of energy supply it suffers from.

In this study we are trying hard to understand the potential of PV/T systems in the atmosphere of Iraq and the suitability of this atmosphere. Water was selected as a cooling fluid first to be available in most parts of Iraq and secondly to be used for domestic purposes in winter.

II. EXPERIMENTAL SETUP

A PV panel was used in the construction of the PV/T system while the collector consisted of copper tubes welded on the back of the cell. The photovoltaic cell produces electricity while the water in the collector absorbs the heat from the PV panel body causing a reduction in its temperature and as a result the productivity of the cell is increased. Fig. 1 represents the PV/T system used.

Figure 1: the PV/T system used in tests

In this system, cold water is used to absorb heat from the solar cells by means of water pump from the tank and passing it through pipes to reach the cell. In addition, this cell was fitted with pipes of copper from its back while circulating the cooling water. The PV cell body temperature increases due to incident solar irradiance and the heat starts to transfer to the cold water, which goes to the tank. To evaluate the effect of irradiance and heat on the current and voltage sensors were connected to the cell and entering and exiting pipes from the used PV/T system. The temperature, current and voltage were connected to Arduino, which in turn transmits the results and shows it on the computer.

III. RESULTS AND DISCUSSION

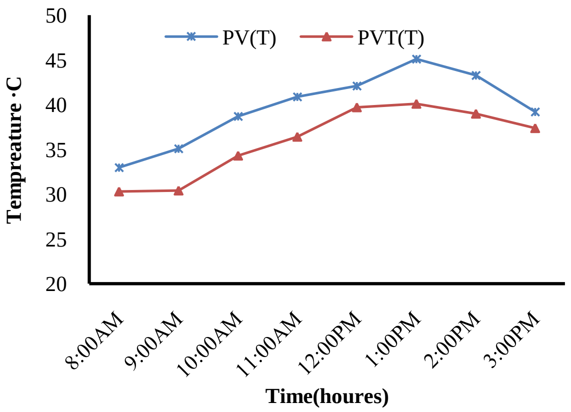

Figure 2: Temperature variation with time for studied PV and PV/T systems

Fig. 2 represents the variation in solar cell body temperature with time. Although the study was conducted in January, which the mid of winter season for Baghdad city, the cells' bodies temperature have increased with time to reach 45ºC, at 1.0 PM for the PV system. The PV/T gained the same heat but its temperatures were less than the PV cell, because of the cooling effect of circulated water. The reduction rate for all the measurements period was 11.25%. The figure results come consistent with Ref. [56] findings.

Fig.3 shows the variation in the studied systems current with time. The reduction in the PV/T system temperature resulted in higher current than the PV cell. It is well known that the current is related directly to the cell temperature. The increment rate for all the measurements period was 10.68%.

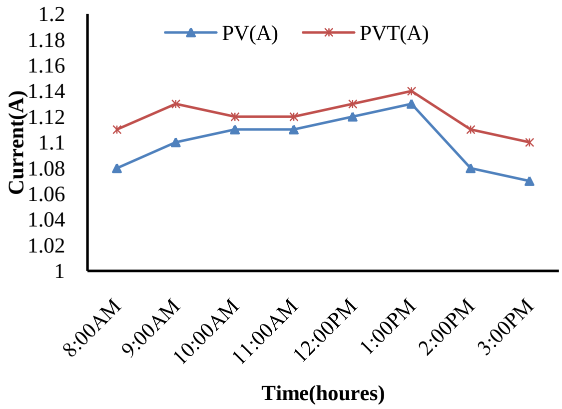

Figure 3: The relationship between PV (V) and PVT (V) in specific time

Fig. 4 shows the studied systems voltage variation with time. The reduction in PV/T cell's temperature showed a clear reduction in its voltage compared to the PV module. In the same time the current was increased the voltage of the PV/t was decreased. The reduction rate in PV/T voltage was 8.43%. As the study was conducted in January and the PV cell temperature increasing rate is medium if we compared with summer where the ambient temperature in Baghdad city rises more than 50ºC and the irradiance increases more than 850 W/m^{2}it is expected that the water cooling effect will be more reliable and active.

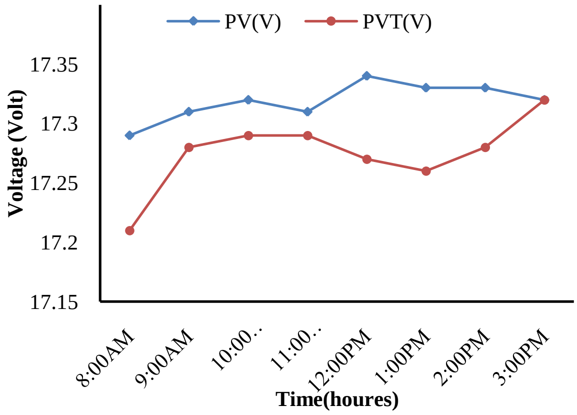

Figure 4: The relationship between PV (V) and PVT (V) in specific time.

Fig. 5 shows the output power of the studied systems variation with time. In general, the power generated by the PV/T system is higher than that of PV cell. The generated power increase rate for PV/T system compared to PV cell was 4.87% for the tested period of time.

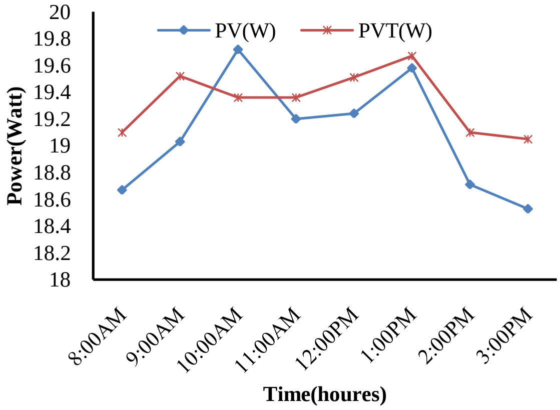

Figure 5: The relationship between PV (W) and PVT (W) in specific time

CONCLUSIONS

Iraq suffers for lack in electricity supply for many hours per day due to damage of most of the power stations in the American invention and occupy in 2003. To date, this reduction in supply is not solved and the Iraqi people using diesel and gasoline generators to compensate this lack in supply. In this study we suggested the use of PV/T system cooled by water as a suitable solution for clean and sustainable electricity supply for Iraqi houses and buildings.

The practical results show that the temperature of the tested cells body increased with time, but the cooled cell (PV/T) increased lower than PV cell. The PV/T cell generated more current than the standalone PV, less voltage than PV cell, and more power than PV. The increment rate in current was 10.68%, while the reduction rate in voltage was 8.43%. The power generated by PV/T rose by 4.87% than the standalone PV module.

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