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Research Article

Enhancement of the Photovoltaic Cell Performance

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ABSTRACT

The world is looking for new sources of electrical energy instead of traditional sources because two main reasons: to create a clean environment and to have lower energy costs. Solar energy is coming to be at the forefront of renewable and sustainable energy; it assists to treat global pollution and considers an effective and reliable source of electrical energy. Solar Photovoltaic technology is one of the most important resources of the clean energy. It uses the cells to convert sunlight energy into electrical energy. This source of electrical energy has wider use than other sources of renewable energy due to the amount of power that can be produced. However, photovoltaic cells utilize only a small portion of the radiation emitted by the sun which is the visible light while the entire spectrum of solar radiation can potentially be converted into heat. The temperature plays an important role in the performance of the solar cell system. As the cell temperature increases, the performance of the system goes down. In this paper, thermal and visible radiations have been combined as a hybrid system for treating the temperature effects and achieving the high efficiency of the new solar module.

Keywords: Electrical energy; Renewable energy; Photovoltaic cell; Solar radiation; Thermo-electric generator; Solar panel system

INTRODUCTION

Nowadays, oil prices have raised, so solar power in Saudi Arabia has become more important to the country as another source of power. In 2012, The Saudi agency announced that the nation would install around 200 GW of solar capacity at the end of 2030 [1]. Neom is a huge project in Saudi Arabia that depends on solar energy using solar photovoltaic systems. It covers a total area of 26,500 km^2 [2]. However, as was mentioned that temperature plays an important role in the performance of the solar cell System.

Solar PV systems use cells to convert only sunlight into electricity while infrared radiation affects the system. Many researchers are working to improve the efficiency of the solar cell by eliminating the high temperature that causes low performance. Gouvea et al. investigated that due to high photovoltaic cell temperature, the energy generation capacity was decreased [3]. In addition, Abderrazzak proved experimentally that the different solar panel stations do not work effectively once the temperature exceeds 45°C [4]. In 2016, Amelia et al. examined the effects of operating temperature on a monocrystalline PV panel [5]. They found that the simulation results implied that the output power of the PV panel decreases with the increase of its working temperature. Thong et al. showed experimentally that the measured voltage and power output decrease when the temperature of the photovoltaic panel increases [6]. As it is known, there are three types of solar spectrum radiation that come from the sun to the ground: Visible, infrared, and ultraviolet radiation (0.1 μm to 100 μm). The infrared radiation increases the temperature of the solar panels which affects the performance of the solar cell. This issue can be treated in several ways, such as system cooling, and solar coating. In 2017, Attyagalle et al. identified experimentally the temperature effect on the solar photovoltaic panel and employed the idea of using the cooling system for achieving high performance [7]. They found that solar panel efficiency can be increased up to 12% with measured power output. In 2019, Ahmed et al. reduced the cell surface temperature to low rates for improving the solar PV efficiency and increasing the power output [8]. They attained good results by cooling the solar panels with water at different flow rates. The study observed that the solar panels with cooling are better than the solar panels without cooling and when making the comparison between each one of the cooling PV panels surfaces with the solar panel without cooling at 12:30 pm the highest efficiency increase was at cooling in 3 liters/hour, and it was 8.3%. Satish et al. found that the water-cooling system is more efficient compared with other cooling techniques, such as Phase Change Materials, and air-cooling systems [9]. Using the water-cooling technique on both sides of the solar panels, the efficiency increased to 14.1% with the temperature reduction from 54°C to 24°C. The active

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cooling technique is considered an effective way to improve solar photovoltaic performance [10-12].

However, there are other methods that can treat the high temperature of the solar panel issue and convert it into useful energy. A thermoelectric generator is an electric device that converts heat energy produced from a heat source directly into electrical energy. Prapawan has built hybrid system co-generating electricity from solar cells and a thermoelectric generator [13]. The system used in the experiment consists of a 10-watt solar panel installed with thermoelectric modules. The heat that is lost under the solar cell is used to generate electricity by thermoelectric generator modules which can convert the heat energy into DC power according to the phenomena of according to the see beck effect. In July 2018 in Thailand at 12:30 PM, It was found that the temperature of the solar panel surface was 59.42˚C. Using ten of the thermoelectric modules installed in the solar panel, Prapawan achieved 220.16 MW of power output with the temperature difference was 24˚C. Many researchers have proved that the PV panel efficiency performance is increased based on the amount of thermal energy successfully removed from its surface [14-18]. In 2019, a paper showed promising results with the highest electrical efficiency to reach 42% using the hybrid solar panel and thermoelectric generator. Nano coating is another important factor that can assist in raising solar panel efficiency [19-21]. Hatem et al. investigated the effect of the coating on the performance of the solar PV panel [22]. They found that the use of SiO_2 coating for PV panels attained increasing in overall efficiency by 15%.

New model of Solar Photovoltaic system

Considering all the above studies and works, a new design of a hybrid system has been developed for attaining high efficiency. The new design as shown in the Figure 1. It consists of a 100-Watt Polycrystalline solar panel with size a length of 119.5 cm, a width of 54.1 cm, and a thickness of 3.5 cm, also shown in Figure 2. The solar panel is supported by a selective solar absorber made of Aluminium with a size of 119.5 cm × 54.1 cm, shown in Figure 3. The solar absorber is installed with 189 thermoelectric generator modules, each module with size: a length of 6.5 cm, and a width of 6.5 cm. The thermoelectric generator consists of 241 couples. The cold side of the thermo-electric generator is cooled by a cooling system. The new solar system design is experimented with in open space at Jazan University Campus for testing the design under real and different weather. This new model is called a "Hybrid system" because it collects to kinds of energies from solar radiation. The photovoltaic panel converts light energy into electrical energy while the infrared radiation that affects the performance of the solar panel can be converted into useful electrical energy using the thermoelectric generator (Figure 4).

METHODOLOGY

Using a thermometer device for reading air temperature, the results in the graph above have shown that the minimum air temperature in Jazan city is 29˚C in 2021 while the maximum temperature is 41˚C which was read in June and July 2021.

RESULTS

Based on the results, the average temperature during the year was 35.348˚C .This result is a good indicator that Jazan city has a great opportunity for using the thermal radiation coming through the sun for raising the performance of the solar panel system (Figure 5).

According to the datasheet of the solar panel, we have that the out peak power is 100 Watt with the dimensions 119.5 cm × 54.1 cm, therefore the maximum efficiency for this module is 15.5%. By adding the thermoelectric generator module under the solar panel, supported by sheet metal. Because the efficiency of the TEG depends clearly on the temperature difference between the hot and cold junctions, the cold side was cooled using cold water with a temperature of 20˚C on January 30, 2022, at 12:45 pm, the measured power output of the thermoelectric generator module was 0.46 Watt at a hot junction temperature of 64˚C, and the cold junction temperature was 20˚C. The cold junction was cooled by cold water. By installing 364 modules in the system, the maximum hybrid solar panel system power output will raise from 100 Watt to 262.708 Watt with an efficiency of more than 40%. It is shown in Figure 6 that the power output of the TEG depends clearly on the temperature difference.

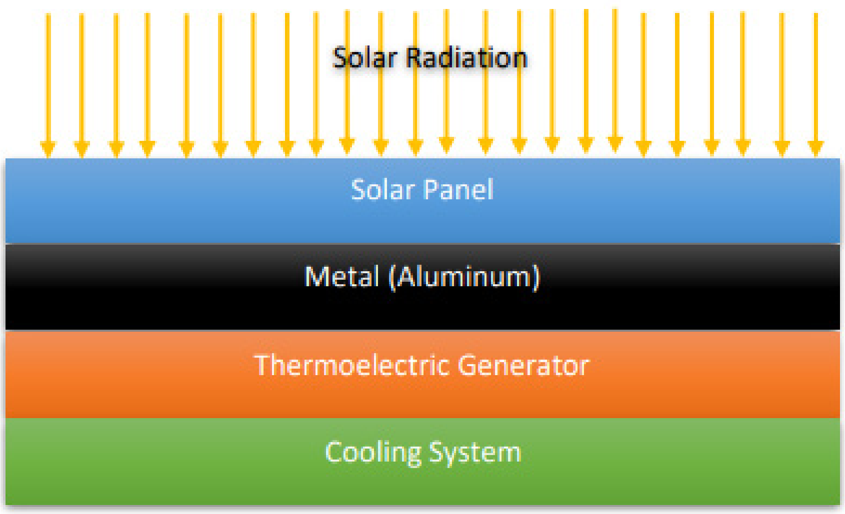

Figure 1: New solar panel and TEG design (Hybrid system).

Figure 2: Polycrystalline solar panel.

Figure 3: A metal of Aluminium.

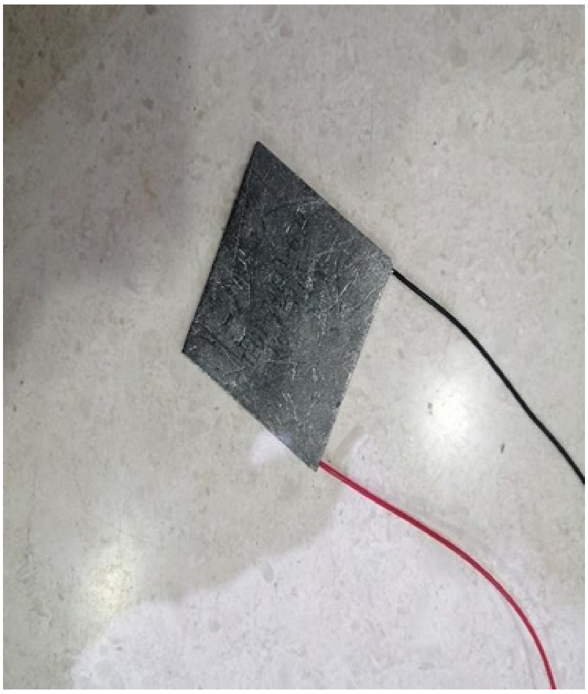

Figure 4: A thermoelectric generator module.

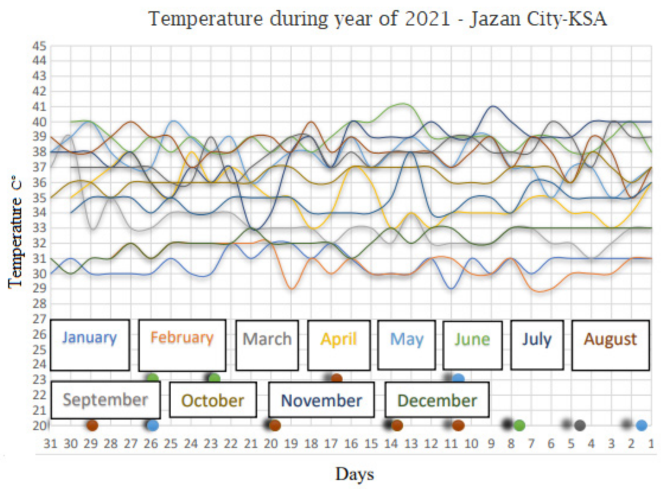

Figure 5: Temperature versus days during year of 2021 in Jazan City–KSA.

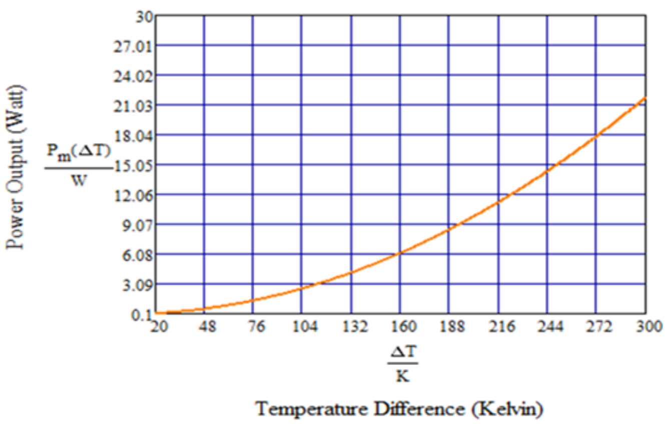

Figure 6: Power output versus temperature difference. Note: (——) factor analysis.

DISCUSSION AND CONCLUSION

Infrared and visible radiations have been combined as a hybrid system for treating the temperature effects and achieving the high efficiency of the new solar module. It is a promising future for the solar panel to attain real high efficiency and treat the impact of the high temperature on the solar panel. By installing 364 TEG modules with one Polycrystalline solar panel, the hybrid solar panel system can achieve an efficiency of 40%. Next experiment, this hybrid system will include a washer tool for cleaning the solar panel under bad environmental conditions. The cleaner tool will be powered using the direct current coming from the TEG by the heat losses produced from the solar panel. In this work, a traditional electrical source was used for cooling the cold junction of the thermoelectric generator. Therefore, a natural cooling system will be considered using the optimum design of a cooling heat sink in the next work to lower the cost and contribute to having a green and clean environment.

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