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ABSTRACT
In this work we propose a new approach to recovering thermoelectricity to improving the efficiency of a photovoltaic (PV) generator under the high temperature as the desert weather. The proposed system composed on two parts, the first is the thermo generator, when is used for a thermo energy harvesting from the PV temperature, the second is to use the energy recovered by the thermo generator to power a fan to cool a photovoltaic panel PV cells. Tests based on such low power fan cooling system show a 3% increase on the voltage generated by a PV panel.

KEYWORDS
Photovoltaic cells; thermoelectric generator; cooling system

1. Introduction

The photovoltaic power generation has been widely spread in different applications, ranging from space systems to the residential and commercial installations in buildings, telecommunication stations, power plants, and industrial applications. During operation, a PV generator is subject to several temperatures, Typically a PV module converts only 10–15% of the incident power to electricity, while the remaining power is largely rejected as heat [1]. In addition, the PV panel also generates its own heat due to the photovoltaic action and further heating occurs due to the energy radiated at the infrared wavelength of the solar spectrum [2]. The temperature of PV can up at 65°C and greatly minimizes the output power generated by the PV system [3]. To minimize the effect of temperature and maximize the performance and efficiency of PV systems, cooling systems for the PV generator is essential. in this work the temperature of the PV is exploited by a thermal generator to supply ventilator, the air generated is used to cooling the surface of the PV and also inside of the thermo generator.

2. PV cell model

It is a model named single diode model. As shown in Figure (1), a current source and a diode in parallel with a resistor in series, but in this model a added shunt resistor Rsh having an

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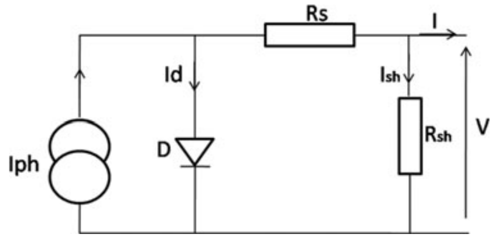

Figure 1. One diode PV cell model.

influence on the current generated by the model and which is close aware of a real cell. Physically, the shunt resistor is used for modeling losses around the junction due to impurities and on the corners of the cell [4, 5].

This model is the most used in many research through his behavior that is closer to a PV cell with respect to series resistance model (simplified) on the one hand, and simplicity for the mathematical calculation from the model two diodes (described below) on the other hand.

The current generated by this model is given by:

$$I = Iph - Id - Ish \tag{1}$$

With:

$$Ish = \left(\frac{V + Rs.I}{Rsh}\right) \tag{2}$$

Therefore:

$$I{=}Iph - Is\left(exp\left(\frac{V + Rs.I}{A.Vt}\right) - 1\right) - \frac{V + Rs.I}{Rsh} \tag{3}$$

The model of the expression (3) is also named “implicit model with five parameters” Iph, (Is, Rs, Rsh, A) [6].

Rs is the series resistance and Rsh the shunt resistor, k is the Boltzmann constant, q is the elementary charge, A is the ideality factor and Is is the saturation current, The photocurrent is given by:

$$I_{ph} = I_{ph,STC}.\left(\frac{G}{G_{STC}}\right) \cdot [1 + \alpha_1(T - T_{STC})] \tag{4}$$

This information is always given with reference to the nominal conditions (STC) of temperature and solar radiation (1000 W/m2 and 25°C).

Some manufacturers provide I (V) curves for several conditions of temperature and radiation. These curves facilitate adjustment and validation of the desired mathematical equation. Basically, this is all the information can get from the data sheet of the PV module (Table 1).

Table 1. Technical data of PV module.

parameters	explication
Voc	open circuit voltage
Csi	the short-circuit current
Vmp	the voltage at maximum point
Imp	the current at maximum point
KV	Coefficient of open circuit voltage / temperature
KI	Coefficient of the short-circuit current / temperature
Pmax	power of experimental maximum peak output

3. Effect of temperature on photovoltaic cells

The Algerian Sahara represents a very elevated level of illumination during all the year, but the climate of the Sahara, hot, sunny and dry, is typical of that of a hot desert daytime temperatures are very high, exceeding 50°C in shadow, which to a negative effect on the performance and the materials of PV cells, the effect of the temperature on the power produced by PV cells is represented in the Figures (2) and (3).

A further disadvantage of the abnormal temperature rise on PV cells is shown in Figure (4) present a hotspot; hotspot is an area of a PV module that has a very high temperature and which may damage the cell or any other element of the module. The hot spot might be the

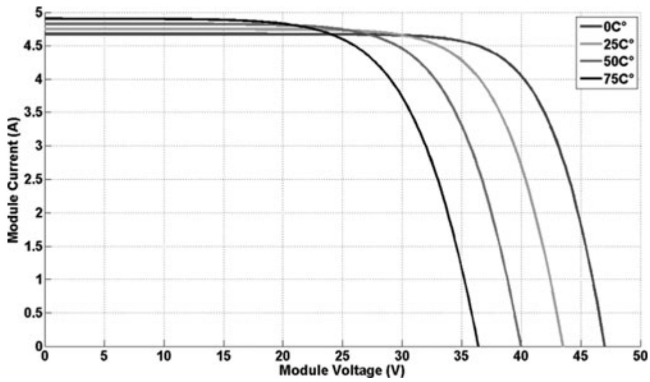

Figure 2. I (V) characteristic for different temperatures.

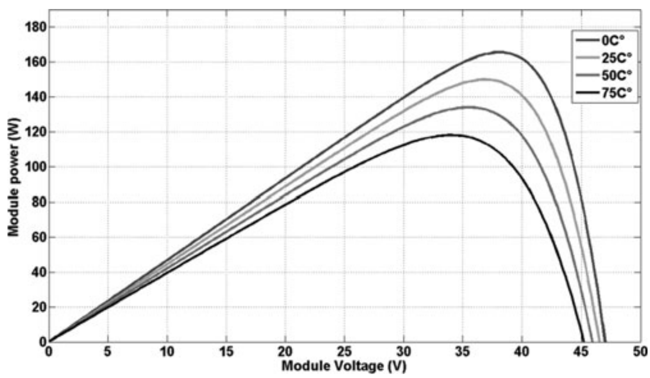

Figure 3. P (V) characteristic for different temperatures.

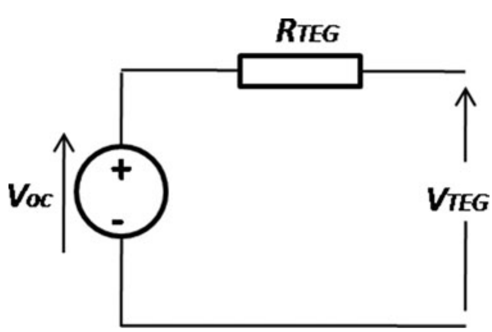

Figure 4. TEG electrical mode.l

cause of many defects in the cell, including partial shading, the difference between cells. As builders guarantee difference characteristics I (V) of +/− 3% between two PV cells [7], and therefore the series connection of these cells therefore generates considerable losses. Another cause or consequence is poor connection between the cells [8].

4. Thermoelectricity

The thermoelectricity is the conversion of thermal energy into electrical energy through a temperature gradient. This phenomenon is reversible, and is mainly based on the Seebeck effect and the Peltier effect. The Seebeck effect was discovered accidentally in 1821 by Thomas Seebeck, verifying that two conductors of different states at their tips and a temperature difference between them, metal materials made with a needle that was between them was shifted. Between 1822 and 1823 Thomas Seebeck published his findings stating that conductors (or semiconductors) produce a different voltage when they are united with the ends and subjected to a temperature gradient [9].

The model of an electric generator TEG is presented by the circuit of Figure (4).

The side's difference temperature of the TEG is given by:

$$\Delta T_{TEG} = T_h - T_c \tag{5}$$

Voc voltage is represented by:

$$V_{oc} = S.\Delta T \; = \eta.\alpha(T_h - T_c) \tag{6}$$

α is Seebeck's coefficient and n is the numbers of thermocouples.

From the circuit shown in Figure (4) and Equation (5), we can deduce the TEG current equation:

$$I_{TEG} = \frac{V_{oc} - V_{TEG}}{R_{TEG}} = \frac{\eta.\alpha(T_h - T_c) - V_{TEG}}{R_{TEG}} \tag{7}$$

Where $Rs,_{TEG}$ is the internal electrical resistance of the TEG

We can calculate the power PETG by the equation:

$$P_{TEG} = V_{TEG} \cdot I_{TEG} = V_{TEG} \cdot \frac{\eta.\alpha(T_h - T_c) - V_{TEG}}{R_{TEG}} \tag{8}$$

The Figure (5) shows the TEG power delivered for several temperatures.

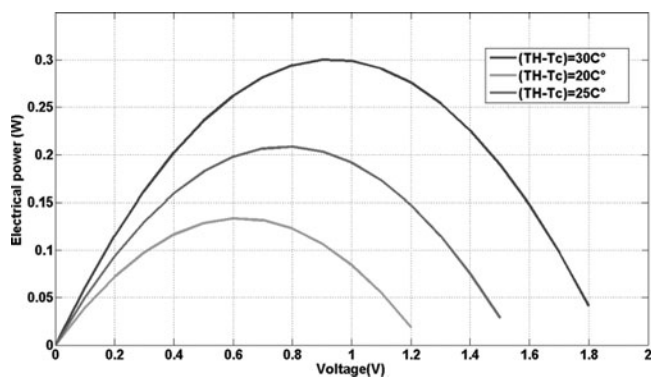

Figure 5. TEG power for several temperatures.

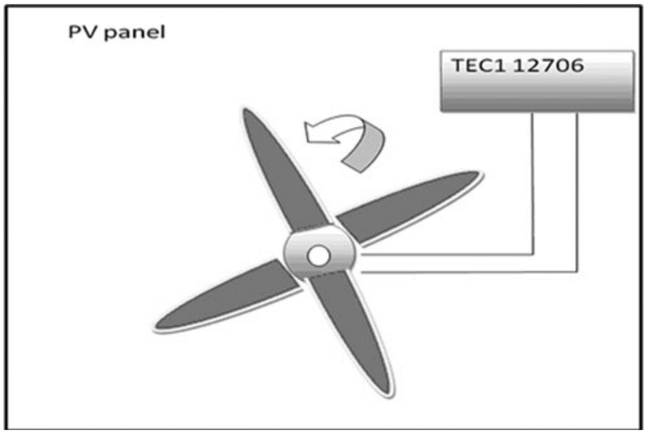

Figure 6. TEG cooling PV system.

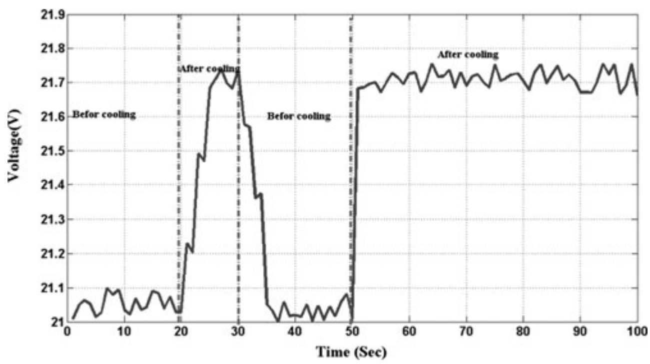

Figure 7. Effect of cooling on VOC of PV.

5. The proposed cooling system

In this part a TEG is used on the rear face of the photovoltaic panel for converting the temperature of the PV cells into electrical energy that electric power is used for powering a ventilator Figure (6).

The number of TEG and type of serial or parallel connections is according to the required power for the ventilators power, this ventilator with two roles, one is the cooling of the back side of the PV cells, the second it provides cooling of the face cold face of TEG and therefore increasing the power generated by the TEG, once the panel is cooled the ventilator turn off, it is best to use a low-power ventilator, the Figure (7) shows the effect of cooling system on improving the performance of PV panels, anything yield does not exceed 3% but a positive effect over time.

6. Conclusion

In this work a cooling system is presented based on the recovery of electric power by the use of a thermo generator and a low power fan, the analysis of the characteristic of the photovoltaic cells and the power generated according to the temperature show that the temperature at a negative effect on the power generated and in particular the open circuit voltage, the operating temperature of the PV cells amounted to show that the recovery thereof is very promising as this so to convert the temperature to the electricity or to improve the performance of the PV cell by the use of a low-cost cooling system; a cooling system based on low energy consumption fan mount a yield improvement of 3% on the voltage, it is clear that little improvement but a significant impact over time.

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