

# Performance of solar cells using thermoelectric module in hot sites



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## ABSTRACT

The ambient temperature at Madinah site is between 40 °C and 50 °C during the summer months and sometimes is over 50 °C. The cell temperature reaches the value of 83 °C. This affects the behaviors of solar cells (SC) and decreases their efficiency. The performance of solar cells is presented in this work using thermoelectric module (TEM) as cooling system. In fact, we have found experimentally that the efficiency of solar cells decreases with increase in its temperature. The efficiency of solar cells drops by 0.5% per °C rise in temperature. So, it's necessary to operate them at lower temperature in order to increase their efficiency. Cooling the solar cells would enhance its performance. The hybrid PV/TEM system is proposed for PV applications in hot sites.

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## 1. Introduction

Solar energy represents a great potential of renewable energy source in the world. The solar irradiation and the ambient temperature affect the output power of photovoltaic (PV) system. The efficiency of solar panels decreases when the temperature of the solar panels increases [1]. The cooling of solar panels improves its efficiency.

The application of thermoelectric technology to cool micro-electronic circuits is not new. It has been established for some time that the technology can be used in cooling, heating and micro-power generation applications, and can offer some distinct advantages over other technologies. For example, in cooling or refrigeration, the technology does not require any chlorofluorocarbons or other fluid that may need to be replaced; can achieve temperature control to within  $\pm 0.1$  °C; is electrically quiet in operation; the modules are relatively small in size and weight; and do not import dust or other particles which may cause an electrical short circuit [2].

A standard thermoelectric module utilizes the Seebeck, Peltier and Thomson effects and can operate as a heat pump, providing heating or cooling of an object connected to one side of the module if a DC current is applied to the module terminals. Alternatively, a

module can generate a small amount of electrical power if a temperature difference is maintained between two terminals [2]. Historically, the motivation for using thermoelectric modules to cool microelectronic integrated circuits in the computer industry has been used to increase their clock speed below ambient temperatures, which can be advantageous in some situations [3,4]. As integrated circuit power and power density continue to increase, the computer industry may begin to approach the limit of forced-air cooled systems and will need to find alternative solutions [3]. Thermoelectric technology has been highlighted as a possible solution to these problems [5], and there is evidence of ongoing research into cooling the whole of a microprocessor with a thermoelectric module, and focus on cooling microprocessor 'hot spots' using embedded micro-thermoelectric devices incorporated into the microprocessor die [6].

Recent research has been investigated for PV cooling system. Water cooling systems have been studied using water spray [7,8]. In order to cool the building integrated photovoltaic (BIPV) system, a thermoelectric module (TEM) system has been developed [9]. In this late, the authors proved that the combined system TEM/PV can be operated at a solar panel temperature of 53 °C, without loss of solar panels power. Thus, solar panels were cooling at the temperature of 10 °C, which will improve the efficiency of solar panels.

Simulation software has been used to study the performances of solar cells using thermoelectric modules which allowed the increase in the efficiency of solar cell from 6.8% up to 10.92% at 83 °C [10]. Other work has been investigated using thermoelectric

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cooling system to improve the efficiency of PV array. The results showed that the efficiency of solar cells varied from 8.35% to 11.46% without cooling system and reached the values of 12.26% up to 13.27% with cooling system [11]. Otherwise, the temperature of the solar cells can rise up to 70 °C, which allow the deterioration of solar cells minimizing its life and getting a low efficiency [12]. For this, the authors tried to remove excess heat generated by solar cells to get good performance of solar cells. In the other hand, thermal behaviors of a hybrid PV/TEM system integrating a pin heat sink were investigated. In particular case, when integrating the heat sink under condition of natural convection, the whole PV/TEM system was cooled better than using the PV only with heat sink module and the cooling efficiency is better [13].

One of the most problems of using the PV systems in Saudi Arabia is the high ambient temperature which can reach the value of 55 °C in summer months. So, this will increase the solar cells temperature and affect the performance of PV panels. For this, we propose the hybrid system solar cell/thermoelectric module, not only to cool the solar cell but also to avoid the heat generated by the other side of thermoelectric module.

## 2. Data Base of Temperature at Madinah Site

Madinah site (Latitude = 24.46°N and Longitude = 39.62°E) is classified as semi-arid area and has a great potential of solar radiation [14], with a daily annual average yield ranges from 4.5 KWh/m<sup>2</sup>/day until 8.5 KWh/m<sup>2</sup>/day, received on tilt PV surface. The data have been recorded in our laboratory at Physics Department since 2008 until June 2015. From the observed data, we note that the ambient temperature at Madinah site is between 40 °C and 50 °C during the summer months as indicated in the Fig. 1. Sometimes, the ambient temperature is over 50 °C as shown in Fig. 2(a–c) corresponding to the year 2011, 2013 and 2014 respectively. So, this will increase the solar cells temperature and affect the performance of PV panels. For this, we propose the hybrid system solar cell/thermoelectric module which is a solution to improve the performance of solar cells in hot locations like Madinah site.

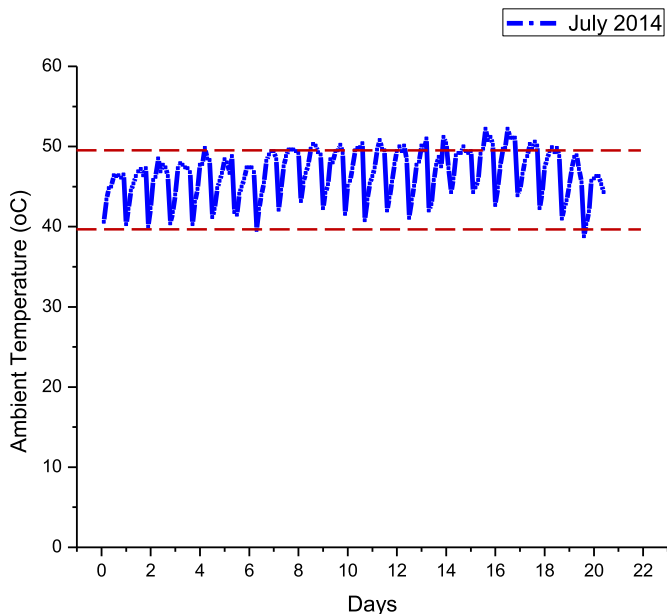


Fig. 1. The ambient temperature at Madinah during July 2014.

## 3. Thermoelectric Effect

Thermoelectric technology is an alternative method of power generation. The main building structure is the thermoelectric module (TEM) that can directly convert heat to electricity. This phenomenon was first observed by Seebeck [15]. The simple concept is to apply temperature difference between two terminals that trigger the generation of small amount of power (Fig. 3). Alternatively, this thermoelectric module can function as a heat pump according to Seebeck/Peltier effects. As shown in Fig. 3, two electrical insulating ceramic plates enclose several p-type and n-type thermo elements that are electrically connected in series and thermally parallel with electrical insulation. As TEM is bi-functional device which can either operate as Heating/Cooling device [16] or generate power, this portability feature can well be exploited in BIPV system for cooling PV module and simultaneously generating extra power [17].

Thermoelectric module can be used as cooling system using Peltier effect. The principle is to get a heat flux between the junction of two thermo elements P and N. A Peltier cooler allow the transfer of heat from one side of Peltier module to the other depending on the current's direction [18]. We can also use the Peltier cooler or thermoelectric cooler (TEC) as generator. If, we want to use the thermoelectric as cooler, we apply a voltage across the device and then we get that one side of the device is hot and the other side is cold. The performance of TEC depends on ambient temperature, design of the heat exchanger, Peltier parameters and geometry of Peltier module.

When we apply a voltage between two different conductors A and B, we will get a heat at the junction. The rate  $dQ/dt$  of the generated heat is given as follow:

$$dQ/dt = (\pi_A - \pi_B)I \quad (1)$$

where  $I$  represents the current (from A to B),  $\pi_A$  and  $\pi_B$  are Peltier's parameters of the conductors.

## 4. Solar Cells Model

Many models have been studied in literature for solar cells [19,20] showing the influence of serial resistance  $R_S$ , shunt resistance  $R_{SH}$  and temperature  $T$  on IV characterization. Fig. 4 shows the equivalent circuit of solar cells [21].

Fig. 4 shows that the current  $I$  generated by the solar cell is given as follow:

$$I = I_L - I_D - I_{SH} \quad (2)$$

where  $I_L$  is the generated photocurrent,  $I_D$  is the diode current and  $I_{SH}$  is the current through the shunt resistance  $R_{SH}$ .

The output voltage  $V$  delivered by the solar cell is given as follow:

$$V = V_j - I \cdot R_S \quad (3)$$

where  $V_j$  is the voltage across both diode and shunt resistance and  $R_S$  is the serial resistance.

The current  $I_D$  is given by the Shockley diode equation:

$$I_D = I_0 \left\{ \exp \left[ \frac{qV_j}{nkT} \right] - 1 \right\} \quad (4)$$

Where  $I_0$  is the reverse saturation current,  $n$  is the diode ideality factor,  $q$  is the elementary charge,  $k$  is the Boltzmann's constant,  $T$  is the absolute temperature and  $kT/q$  is equal to 0.0259 V at a temperature of 25 °C.

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