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# Simulation of Thermoelectric Standard Simplified Model Applied in a Pressure Cooker

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**Abstract**—Recuperation of a waste thermal in a traditional a combustible gazes is an important challenge for developing countries. Adding thermoelectric generators can provide electricity that permits the satisfaction of basic needs: light, phones and other electronic devices. To test the TE modules, this paper focuses on use of the thermoelectric element where the walls of the pressure cooker are considered as the hold sources. Therefore, we are simulating it by a simplified standard model of the thermoelectric module. The alternative results show that the use of Thermoelectric is an alternative to maintain the functioning of electronic devices even if without any sources of electricity.

**Keywords**—component; Temperature, standard simplified model, thermoelectric module, efficiency.

## I. INTRODUCTION

Much research in recent years has focused on thermoelectricity to produce electricity [1-4]. Each day, we lose enormous amounts of energy in the form of heat, and nobody gets frustrated. This heat, which is expelled from many devices we use every day, is known as waste heat. It's an inefficiency, which is accepted, in our energy squandering society. A thermoelectric generator (TEG) takes this pesky waste heat and converts it to profitable electrical energy. So, TEG (Thermoelectric generators) directly converts a portion thermal power to electrical power and only requires functioning the presence of a temperature gradient. These phenomena are known more specifically as the Seebeck effect (converting temperature to current), Peltier effect (converting current to temperature), and Thomson effect (conductor heating/cooling).

The expected power generation from the TEG is to run a fan for complete combustion and also for basic needs like lighting,

radio and charging cell phones as well as other small electronic devices. Hence, such pressure cooker can be equipped with a thermoelectric generator either for example in those walls which can be fed with hot flue gases from gas cylinder and ambient and can create the temperature difference. In rural household, still people use traditional pressure cooker. Most of the houses are without electricity. Only a fraction of the houses in typical "electrified". Few Moroccan villages have acquired domestic connections for electric lighting; the remaining houses depend on kerosene lamps and candles. In Morocco energy consumption per capita is 826.40 kWh is very low as compared to developed countries. The fuel gases that is presented can provide basic needs of the people such as lighting and mobile charging to the low income populations living mostly in rural areas. The TEG modules integrated with pressure cooker are an essential and interesting option to provide electricity.

The TEG offers also advantages of being recovered lost heat, high reliability, silence and low environmental impact and can use amounts of waste heat as an energy source in a simple and easy manner. The flame heat from the gas cylinder serves as input to the TEG and no extra energy is required, TEG is very rugged and almost maintenance free; whole module is placed indoor only battery needs replacement when exhausted or can be recharged with module power continuously. TEG starts working as the pressure cooker is set on fire irrespective of day and night, windy or rainy weather unlike solar panels. Rechargeable batteries serve the purpose and need not be oversized batteries as used in solar panels to store energy. Other elements surrounding this module, however, are essential for an industrial use of these modules [5]:

- The Heat exchangers allows amplifying the heat transfer between the thermoelectric module and the heat sources.

- The power converter will reconditioning the signal input to a voltage level corresponding to that of the storage device (batteries, capacitors ...) and, or that corresponding to the need of the user.

The efficiency of a thermoelectric device for electricity generation, (defined as the quotient of energy provided to the load by heat energy absorbed at the hot junction) is given by  $\eta_{TE}$  [6]:

$$\eta_{TE} = \frac{We}{Qh} \frac{\Delta T}{Th} \cdot \frac{\sqrt{1+zT} - \frac{Tc}{Th}}{\sqrt{1+zT}} \quad (1)$$

Where  $T_h$ , is the temperature at the hot junction,  $T_c$  is the temperature at the surface being cooled.  $\Delta T = T_h - T_c$  The temperature difference,  $T$  the mean temperature and  $z$  is the figure of merit. The current values for  $zT$ , dimensionless figure of merit are around one. This approximate expression of the thermoelectric generator efficiency highlights the work to be performed for an efficient generator and reflect needing the Research works on:

- The thermoelectric materials interests to obtain the largest possible of  $zT$ ;
- The heat exchangers for the largest temperature difference at the two sides of thermoelectric materials;
- The electrical converters that need to be optimized for  $\eta_E$  very near 1 and which will also through an algorithm of "maximum power point tracking" optimize the point of electrical operation of TEG in order to transfer maximum electrical power.

These aspects are unfortunately dependent and the global optimization requires many interactions and very powerful calculating tools. Furthermore, the sources nature also plays an important role in temperature deference. Most of the choice heat sources are the fluids or gases natures. The exchanges between the heat or cold sources and the thermoelectric generator are thus occurring primarily by convection. The convective exchange coefficients are generally low and will improve a large temperature difference between the gas temperature and the temperature of the heat exchanger.

In order to attend this aim, we are applied simplified model of thermoelectric element to a pressure cooker. The temperature of the pressure cooker walls is considered as the heat sources and the ambient temperature as the cold sources. The temperature gradient in faces of thermoelectric element is large. Therefore permits to produce a useful electrical energy. The temperature dependence of the thermoelectric coefficients [7, 8] has also been reported to be properly modeled in the standard simplified model.

## II. BASIC PRINCIPLE OF STANDARD SIMPLIFIED MODEL TO THERMOELECTRIC ELEMENT

The theory of this model has inspired in [9]. The simplest approach to model a thermoelectric element is to set up an overall thermal balance, assuming a symmetrical distribution of the Joule effect between the hot and cold sides of the elements. This assumption is will used to describe thermoelectric elements in TEG mode.

The Seebeck coefficient  $\alpha$ , the thermal conductivity  $K$ , and the electrical conductivity  $R$  of the thermoelectric element are kept constant in the material and estimated from the mean temperature of the hot  $\bar{T} = \frac{T_h + T_c}{2}$  and cold sides at  $T_h$

and  $T_c$ , respectively.

Based on these assumptions, global energy balance in the whole leg produces the following expressions for the heat fluxes on the hot and cold sides, in TEG:

$$Q_H = \alpha_H I T_H - \bar{K} \Delta T + \frac{1}{2} \bar{R} I^2 - \frac{1}{2} \bar{\tau} I \Delta T \quad (2)$$

$$Q_C = \alpha_C I T_C - \bar{K} \Delta T - \frac{1}{2} \bar{R} I^2 + \frac{1}{2} \bar{\tau} I \Delta T \quad (3)$$

Where,

$$\bar{R} = \frac{L}{\sigma A} \text{ is electrical resistance}$$

$$\bar{K} = \frac{\bar{k} A}{L} \text{ is thermal conductance}$$

$$\bar{\tau} \text{ is a Thomson coefficient}$$

The parameters  $A$ ,  $L$ ,  $\sigma$  and  $k$  are respectively semiconductor section, semiconductor length, electrical conductivity and thermal conductivity.

As shown in equations (2) and (3), the heat flow at the hot junction involves three terms: the heat associated with the Seebeck effect, the half of joule heating, and the thermal conduction. The electrical power is the difference between the hot and cold thermal fluxes:

$$P = Q_H - Q_C \quad (4)$$

This leads to:

$$P = (\alpha_H I T_H - \alpha_C I T_C) I + \bar{R} I^2 - \bar{\tau} I \Delta T \quad (5)$$

The electrical efficiency is:

$$\eta_{TE} = \frac{P}{Q_H} \quad (6)$$

### III. EXPERIMENTAL RESULTS

In order to apply the present experiment in realistic conditions, it is necessary to stick the thermoelectric modules on the walls of the pressure cooker and the other side of this module is connected to the ambient temperature. So, the thermoelectric energy is harvesting from transient temperature gradients between the temperature of cooker pressure walls and the ambient temperature. For our research, we are developing a standard simplified model that represents the behavior of thermoelectric element. To ensure a reliable model, equivalent circuit model of the TEG had been developed using MATLAB software.

The figure 1 shown the process where we are applied the standard simplified model. It contains the gas cylinder that permits to cook food on the pressure cooker and a thermometer to measure a temperature on the walls and the ambient temperature.



Figure 1. Mesure of temperature on pressure cooker walls

The main aim of this experiment is to study the feasibility of using TEG in the existing or new pressure cooker when cooking food for generation of electricity. For that, firstly we are measuring the temperature on the walls of pressure of cooker as the hot sources and the ambient temperature as the cold sources. So, the following operating conditions are

considered for the TEG mode ( $T_H = 403$  K and  $T_C = 299$  K). The gradient temperature is introduced in the programmed standard simplified model for simulating the present system.

In order to get the algorithm of standard simplified model simulated in operating condition like real condition. We are chosen the thermoelectric module characterized by the length and the cross-sectional area of the thermoelement where are estimated respectively by  $l = 1.4 \cdot 10^{-3}$  m and  $S = 1.4 \cdot 10^{-6}$  m<sup>2</sup> as shown in figure 2. These dimensional are known in commercial thermoelectric elements.

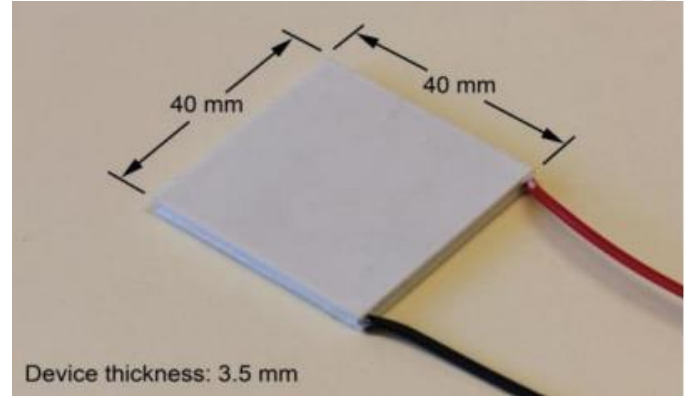


Figure 2. Thermoelectric power generator (TEG).

The commercially available TEG for ambient air application and with reasonable price is Bismuth Telluride  $Bi_2Te_3$ . These modules are specifically designed to withstand operation up to about 230 °C. These modules are larger in size and have no insulating layers at the hot and cold ends but have insulation between the p and n junctions. The power produced per module higher mostly due to the large cross section area (4 cm × 4 cm × 0.35 cm) with many thermoelements. For better insulation ceramic wafers are attached to the TEG with the help of heat conductive grease (Figure 3).

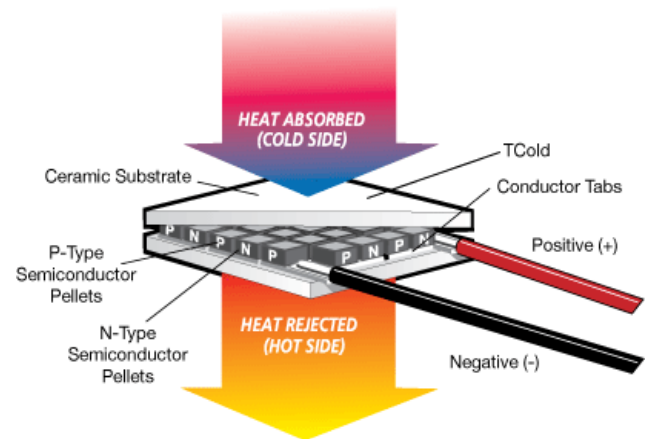


Figure 3. Basic thermoelectric elements configured in a generator mode.

Semiconductor arrays are configured in pairs of N and P pellets where N pellets are doped with N type impurities so the

majority carriers are electrons and P type pellets are doped with P type impurities so the majority carriers are holes. The configuration of the N/P pellet pairing determines the direction of current flow within the module. N/P pellet pairs are configured so that they are connected electrically in series, but thermally in parallel as seen in the thermoelectric voltage figure. The pellet array is sandwiched between a metalized ceramic substrate which holds the pellets and provides conductive tabs that connect them together. The ceramic substrate also serves as an electric insulator and heat transfer medium between the pellet arrays owing to the requirement for specialized material. Multiple thermoelectric modules may be arranged in groups with either series, parallel, or series/parallel electrical connections or in some specialized applications used stacked series multistage heat transfer configurations [10-13]. Figure 4 shows the voltage and electrical power in terms of current for the standard simplified model.

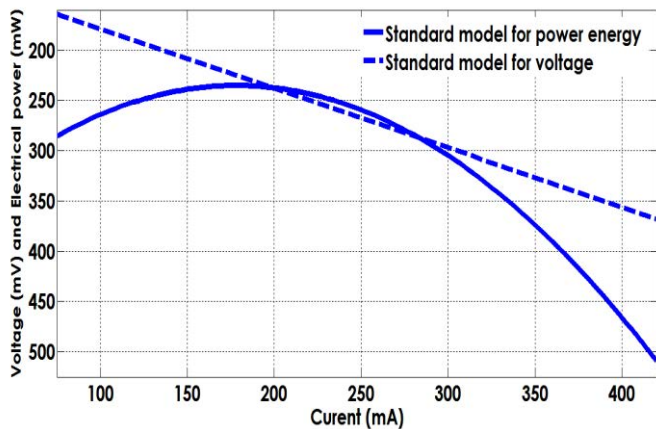


Figure 4. Electrical power in terms of current

It can be seen that the maximum power is between the 0.2 A and 0.3 A equivalent to 0.26 W and 0.3 W. These intervals can be considered as the operating point and make a maximum of the electrical power. For that we are presented in figure 5 the efficiency obtained by simulating this experience.

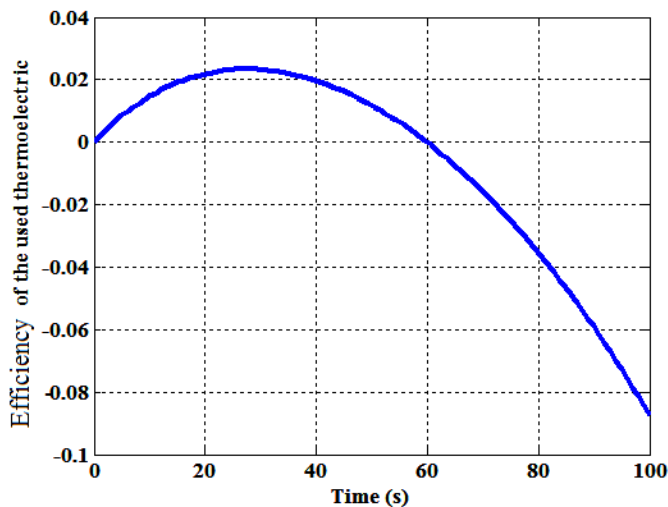


Figure 5. Efficiency of the thermoelectric collected on the pressure cooker walls

Figure 5 shows that the efficiency attains the value of 0.02 and is very good. In order to improve it, we can add the other modules that can be implemented in parallel or in series structures to maximize the electrical power. The major advantage of this experience is to recuperate the wasting temperature and translate it on the need useful electrical energy.

#### IV. CONCLUSION

The purpose of this paper is to use the thermoelectric element on the pressure cooker. It permits to recuperate the wasting temperature and translate it to useful electrical energy. However, in this experience we are using a module which is not sufficient to aliment all known electronic devices such as charging the battery of cell phone.

Thermoelectric generators which are capable of producing a small amount of electricity should allow us to run many devices. The simulation conditions, tests were performed showing that in normal operation the pressure will produce sufficient electrical energy by adding modules and heat sinks. The major advantage of these modules is it is possible to use it in remote areas without electricity.

So, in the future work, we propose to employ a variety of modules that produce maximum of electrical power. Therefore, these modules will be integrated in forms of series and parallels according to the need of either voltage or current.

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