Development of a Thermoelectric Micro generation based on Seebeck Effect

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ABSTRACT: *This paper presents a study of the national electric power, showing the Brazil consumes electricity in a year and how much you could save if thermoelectric modules were used in some industries and new cars and planes to capture and transformation of residual thermal energy into electrical energy. The conclusion appears really attractive economically, given the fact that many processes generate residual thermal energy and also energy cogeneration using thermoelectric modules is totally clean, which prevents the emission of greenhouse gases to the environment.*

Keywords: *Cogeneration, Economics, Energy Harvesting and Thermoelectric Modules.*

I. INTRODUCTION

With technological development and concern about global warming, the quest for power generation through alternative sources is increasing [1]. Today, electricity is a pretty basic for the development of the population, which improves the quality of life by providing social and economic growth.

Currently we live in an energy crisis that has been evidenced by the limits of energy supply required for the demand of the development, which is based primarily on non-renewable sources [2]. Along with the great dependence of these types of sources, has also the environmental impact, mainly due to the pollution that is a result of production activities that use these types of energy resources.

In view of this, the energy issue has become vital for all countries of the world, are extremely important to reduce dependence on fossil fuels, which today is the most widely used form of generation, finding sustainable solutions to help energy matrix of all countries and minimize the overall environmental impacts, prioritizing the need to replace this by other renewable energy source [3].

For Brazil, the stakes are high for the energetic exploitation of natural resources, as they are scattered unevenly in various regions of the country. Often, the Brazilian potential for generating energy through renewable resources is touted as one of the largest in the world [4].

With the increasing need for clean energy sources, renewable energy from the thermoelectric phenomenon has emerged as an alternative among the possibilities. This is due to the fact the thermoelectric modules present certain advantages, such as high durability, high accuracy and low volume, besides being a way of generating totally clean.

Thus, this paper presents the advantages and applications of thermoelectric modules in the domestic market, using the residual energy harvesting for power cogeneration. Thus, the analysis of their impact on the electricity sector and improving the overall energy efficiency of electrical systems will be shown, proving environmental and economic benefits of the use of thermoelectric modules.

II. THERMOELECTRIC MODULE

A thermoelectric module converts thermal energy into electrical energy and vice versa consisting of a matrix formed by multiple bimetallic junctions connected in series to increase output voltage, and in parallel to increase output current [5, 6].

These are able to operate as generators temperature gradient or as generators of electricity in direct current [5, 6]. Each bimetallic junction element is constituted by a p-type semiconductor and n-type; they are connected in series and grouped in pairs surrounded by a sheath ceramics. The ceramic plates have copper bus way that allows linking semiconductors electrically in series and thermally in parallel [1].

Currently, we use many joints to maximize the power delivered by the module. In Figure 1 presents a series of junctions grouped in matrix form, forming a set, known thermoelectric module.

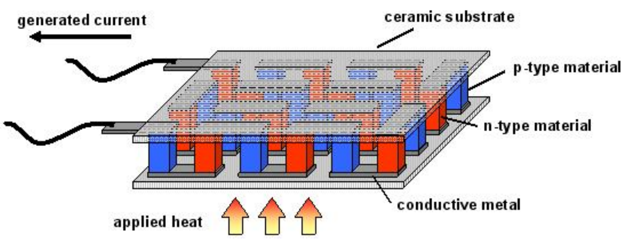

Fig. 1 - Statement of junctions Thermoelectric Module.

III. THERMOELECTRIC GENERATION

The thermoelectric power generation is based on the Seebeck effect. When heat is applied to the junction of two different conductors, a voltage is generated. The temperature difference between the hot side and the cold face is directly proportional to the voltage generated. When heat is applied to a surface of the thermoelectric generator, electrons from the n - type semiconductor and the gaps of the p-type semiconductor will move away from the heat source. This movement of electrons and holes gives rise to an electric current. The current direction is opposite to the movement of electrons, so in the same sense that the movement of the gaps. [3]

The performance of a system for generating electrical power using thermoelectric modules depends not only on the characteristics of the thermoelectric modules used, but a number of factors directly influence , like for example the temperature gradient , the converter used and charge on which to feed. [7]

The temperatures at which the system is exposed to influence the overall yield of the system because the greater the temperature difference, the greater is the voltage output of the modules. In addition, they generate oscillations in the output voltage of the thermoelectric modules, which will be mitigated by the converter responsible for decrease or increase the output voltage. This converter, in turn, also has certain income that affects the system.

The charge also influences the yield, since the maximum energy transfer is obtained when the electric resistance inside of the module is equal to the electrical resistance of the load.

IV. EXPERIMENTAL PROCEDURE

The purpose of the experimental procedure was to prove that it is possible to feed a load with the voltage generated by the thermoelectric modules. For this, followed the methodology developed for designing a thermoelectric generator. In this it is clear that to begin development of a thermoelectric generator is needed some data, such as:

- Load power;
- Supply Voltage;
- Temperature of the hot wall;
- Temperature of the cold wall;
- Number of hours that the system is connected;
- Performance Curve;
- Choose the thermoelectric module.

The load chosen was a lamp with 6 LEDs of 1W power each, totaling an output of 6W, with a supply voltage equal to 17V. It is known that the generation of a thermoelectric system has its voltage as a function of the temperature difference, and that varies continuously in thermal systems. Based on this information, it was possible to maintain the noting that 17V is needed to apply the DC-DC converter. A DC-DC converter may have its input voltage ranging that it will convert this voltage to a value of the output voltage always constant.

The DC-DC converter chosen was a Buck - Boost, where its output voltage can be higher or lower than its input voltage. This had the following characteristics:

- Input Voltage - 3.5 to 30V
- Output voltage - 4 to 30V

The following variables were to find the temperature of the hot side and cold. To simulate a hot wall was used a hot plate, whose even reached a temperature of 300°C. As for the temperature on the cold side, is mounted a system for circulating water. In this system, a pump is sucking water from a tank, causing it to flow through a piece of aluminum. The material chosen is aluminum due to its high thermal conductivity and to have better prices than other similar materials.

In the designed system, the stove is underneath and cooling block sits on top, and they are placed between the thermoelectric modules. Since the heat exchange between the hot part and the cold part, both by conduction and by radiation is too large, rock wool was placed between the stove and refrigerator block to reduce this heat exchange.

With all the data found, choose the left thermoelectric modules. For this step we analyzed the datasheets of some models. The model chosen was the module 1261G - 7L31 - 24CX1 of Custom Thermoelectric. This can resist a maximum temperature of 300°C in a hot face.

Acquired 6 thermoelectric modules of the above model, the temperature of the stove was placed to 250°C, to avoid the risk of damaging the thermoelectric module. Analyzing the graph of the voltage curve with respect to temperature difference, it was found that 250°C at the hot face of the module at 30°C and cold side can achieve a voltage of 3.2 V at the output of each module. Then, with six modules resultant voltage is equal to 19.2 V. Figure 2 shows the graph of the voltage curve present in the datasheet of the selected module.

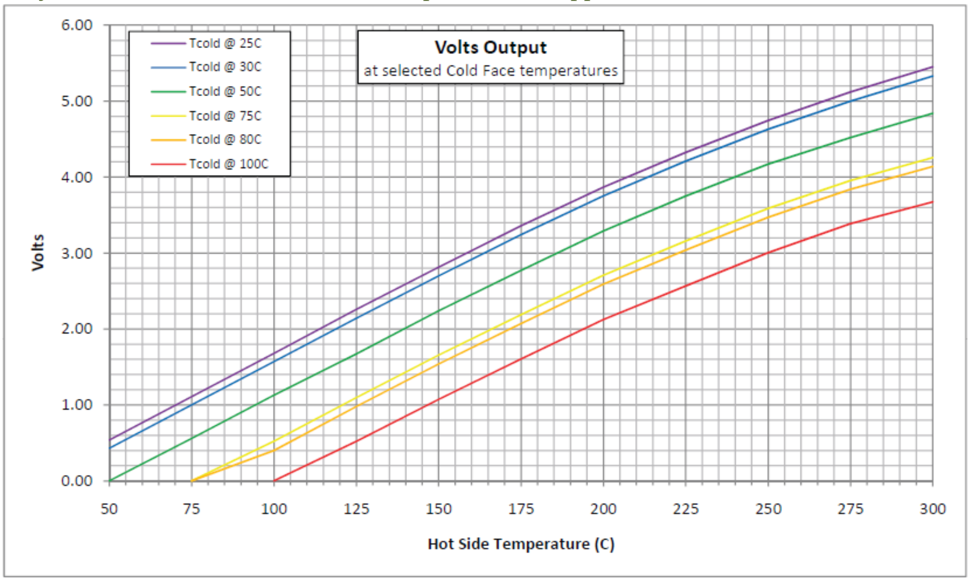

Fig. 2 - Voltage curve as a function of temperature for the thermoelectric module 1261G-7L31-24CX1

The charge, as has already filed a power of 6W. Thus, the current will circulate through it is equal to 350mA because its voltage is 17V. This current is found which will pass through the converter output, but the maximum current is obtained when the input voltage is low, namely equal to 3.5 V. Therefore, knowing that the output power is equal to the power input, the input current is that current which will circulate in the thermoelectric modules is equivalent to approximately 1.7 A. Analyzing the graph of the current applied thermoelectric module, note that with the same temperatures for the maximum current voltage module will bear is greater than 2A, the necessity of supplying easily load.

Getting all the material necessary to perform the experiment began mounting system. First, the hotplate was turned over and the same was placed a sheet of iron to achieve a greater area of application. On this plate were placed 6 parts aluminum, available as a 3 x 2 matrix, with holes for inserting the thermocouple. This process step can be seen in Figure 3.

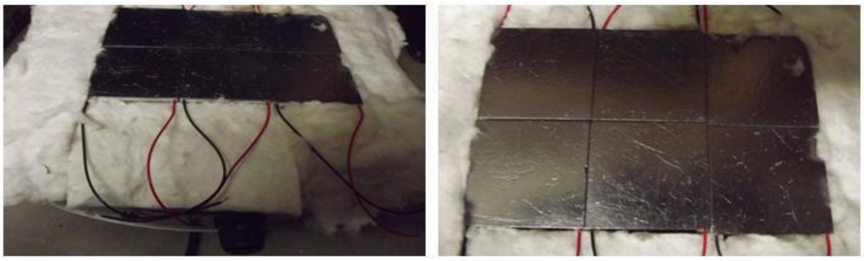

Fig. 3 - Providing aluminum plates on the stove

At the time the temperature reached values close to 230°C it has stabilized. With this, the 6 thermoelectric modules that were already connected in series were placed on each piece of aluminum.

Then, the aluminum block cooled by ice water was drawn from a tank with the aid of a pump, was applied on the cold face of the thermoelectric modules. Instantly, the temperature of the hot side is decreased and stabilized at around 170 ° C due to heat exchange. Figure 4 shows the curve of this temperature fall when the cooling block entered into the system, and the red curve correspond to warm temperature, the curve of the blue and green cold side the difference between these temperatures.

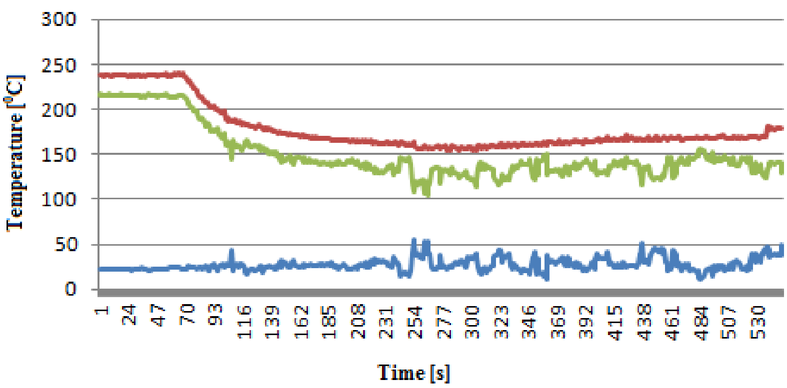

Fig. 4 - Figure temperature when the cooling block is added to the system

In the figure 4, note also that the cold end temperature was stabilized with values close to 30ºC. It is argued then that the equilibrium temperatures of the system were 170ºC and 30ºC. In Figure 5 we can see the picture of the process in thermal equilibrium.

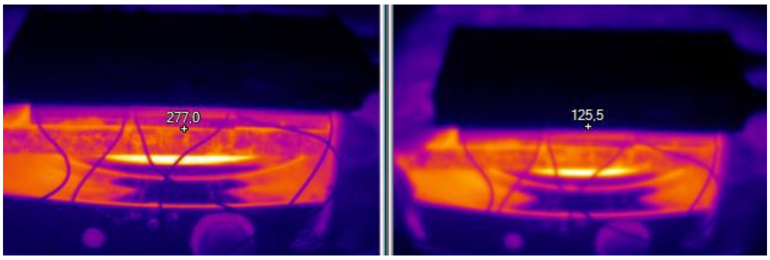

Fig. 5 - Photo thermal experiment

Anyway, the thermoelectric modules with the whole system began to generate electricity, but the results were not expected. The output voltage total module was only 5V, but it still was possible to feed the DC-DC converter. Measuring the 17V outlet in your lamp was connected to the system. The lamp was ignited and turned on during the whole process, and even when thermal equilibrium has entered the lamp still kept on, as expected. In Figure 6 displays the photo with lighted lamp fed by the converter.

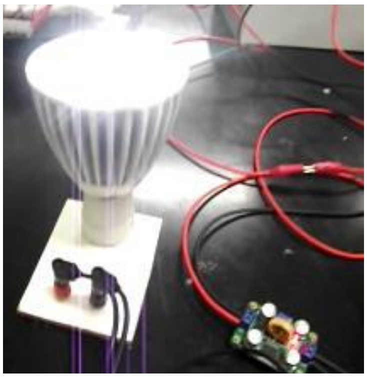

Fig. 6 - Photo of the validation experiment

As already shown the temperature of the system take some time to stabilize. At first, the temperature gradient is greater, therefore the voltage was also higher (5V). This, in turn, has been gradually decreasing as the temperature difference was reduced. When the measured voltage was close to 4V load (lamp) entered the system. Instantly the voltage was reduced to values around 2.8V, making current to be high.

In the graph (Fig. 7) for the voltage variation, is displayed as the value of the voltage is decreasing as the temperature difference diminished by validating the information that voltage generated by a thermoelectric module is directly linked to the temperature gradient. In the same graph perceives a variation of about 1V voltage when the lamp is lit, and after stabilization of the system, as previously mentioned.

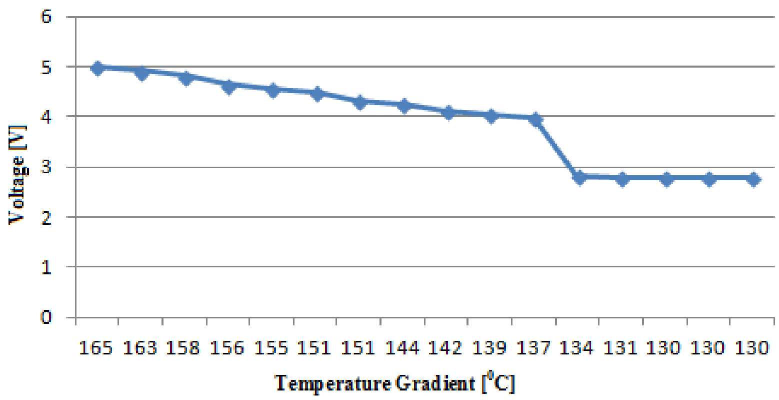

Fig. 7 - Figure referring to the voltage variation due to the temperature gradient

In the graph of the current, present in Figure 8, is seen the opposite of what happened with the tension. In this, we see an increase in current at the time the load is connected. This increase is proportional to the decrease in voltage, since the output power of the converter is equal to the input power then with a lower potential difference in the input current will be larger. Upon entry of the load also is noted that the current remains constant with system heat balance.

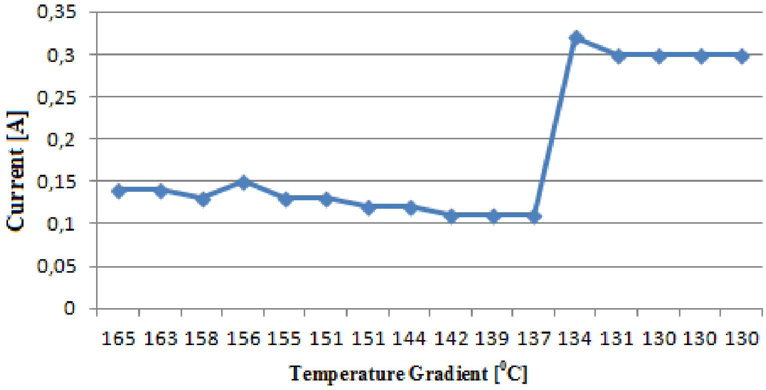

Fig. 8 - Figure respect to the variation of current as a function of the temperature gradient

After the voltage, current and power the system was operating for about 30 minutes, and the lamp went on. It is worth to stress that in real systems changes in temperature are constant, so did the use of a DC-DC converter.

Test to validate the application of cogeneration system, some difficulties were encountered. First, the temperature gradient was not as high as possible, and when the temperatures have stabilized the difference between the hot side and the cold side was at 140°C. Even so, with this temperature difference related to stress response system done, was much lower than expected, since with the temperature read each module would have to generate a little more than 2V, as presented in the manufacturer's datasheet, which together would result in a voltage exceeding 12V.

V. CONCLUSIONS

Based on the research and information exposed, it is clear that cogeneration power using thermoelectric modules is a promising source and presents results feasibly economical with their use, especially if implemented on a wide scale. The results were very significant, considering that only a few systems have been analyzed in this model can be applied cogeneration.

It is also considered that studies and researches are made constantly to improve their efficiency and the requirements for reducing emissions of gases that cause global warming, as well as the need to use renewable sources are increasing, making the applications of thermoelectric modules become increasingly interesting and most sought after because arouses the interest of the government and industries to utilize this technology.

Ends up emphasizing that there are other industries with great potential to capture energy waste to energy cogeneration . Among these are the power plants (8.5% of the national power generation) processes, foundries and potteries , and especially the fleet of buses and trucks .

REFERENCES

[1] S.A. M. Bastos, *Pulseira para Geração de Energia*. Dissertação (Mestrado). Universidade Do Minho. Braga, 2010.

[2] L.P. Santos, *Análise de Desempenho de um Gerador Termoelétrico Baseado no Efeito Seebeck.* Dissertação (Mestrado). Universidade De Taubaté. Taubaté, 2010.

[3] J.A.A. Antunes, *Reaproveitamento de Calor para Geração de Energia Eléctrica no Automóvel*. Dissertação (Mestrado). Universidade Do Minho. Braga, 2011.

[4] A.L.P.F. Landim L.P. Azevedo, O Aproveitamento Energético do Biogás em Aterros Sanitários: Unindo O Inútil Ao Sustentável. *BNDES Setorial*, Rio de Janeiro, p.59-100, mar. 2008.

[5] P.P. Alves, *A Experiência de Joule Revisitada.* Dissertação (Mestrado). Universidade Nova de Lisboa. Lisboa, 2008.

[6] A.V. Rosa. *Fundamentals of renewable energy processes*. 3.ed. Amsterdam; Boston: Elsevier Academic Press, 2013. 689 p.

[7] D.M. Rowe. *CRC Handbook of thermoelectrics.* New York: CRC Press, 1995.