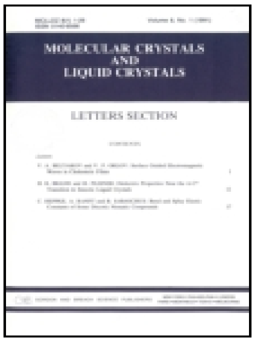

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New material connected with Matlab for physicals characteristics tracer of a thermogenerator

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ABSTRACT

This paper presents new hardware equipments low-cost and the software for researcher to monitoring and diagnosis of thermo-electric generator modules (TEG). The system designed to allow the physical characteristics tracer and reveals the internal resistance of thermogenerator modules where tested under different values of temperature, and provides also the information of maximum power point. This tracer developed based on a microcontroller board family called ChipKIT Max32 which is connected to Matlab\ Simulink. The load of this tracer based on a capacitor varying. The output results data acquisition of TEG can be traced on an oscilloscope or using Matlab environment. These results showed the effectiveness of the present prototype.

KEYWORDS

thermogenerator; physical characteristics tracer; ChipKIT board; Simulink/Matlab

1. Introduction

In recent years, the researchers are proposed many works about the thermoelectric (TE) power generator and their applications, medical, military, space and harvesting MMS systems.

Thermoelectric generator can convert heat energy to electrical power directly by Seebeck effect[1,2]. It consists of a large number of thermocouples that are connected electrically in series and thermally in parallel. The Seebeck effect describes why a thermoelectric material can generate voltage (potential different) when a temperature gradient exists bitewing the hot and cold side[3].

Physical characteristics of thermoelectric material and the manufacturing technique of thermoelectric modules are objectives of many researchers. In order to reveal the internal resistance and also to improving and maximize the power generation performance of thermoelectric generator, the researchers are based on the physical properties ameliorations of the thermal materials [2].

Presence of several defects and anomalies of a TE generator array, where are connected in series and/or parallel causes a decrease in the generation electrical performance of the system. All these adverse consequences are obviously going to reduce productivity and therefore

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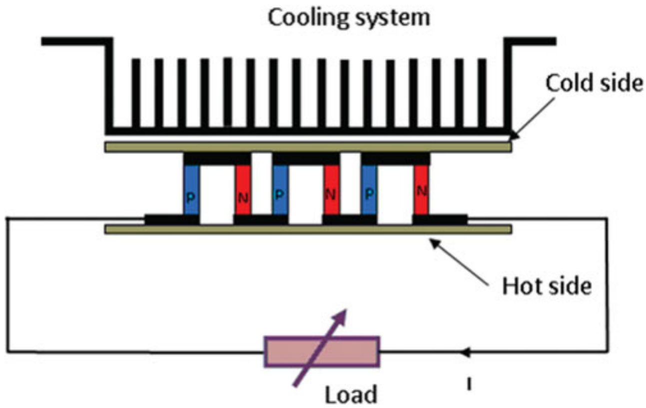

Figure 1. Schematic diagram of a typical TEG.

reduce the performance of the plant and increase the cost of maintenance to make the system operating in normal state [4].

The physical properties curves measurements provide direct performance characterization and verification TEG system performance assessments. Tracing different characteristics of TEG, give the most information of the systems studies. The tracer curves, is the best way to gain an understanding of different physical phenomenon, since it provides a graphical representation of the TEG system operating Characteristics.

The most precise and inexpensive measuring method is represented in capacitor charging by the TEG generator. Using the equivalent circuit of the TEG generator with a capacitor as load and applying on it a transient analysis, we obtain the capacitor charging voltage and current as a function of time.

The principal of this work, is to develop a TEG tracer of different physical characteristics, based on the use of graphical user interface (GUI) by using Arduino Support from Matlab Simulink which is intended for Arduino boards and by using the chipKIT Max32 board of Digilent, where the chipKIT Max32 platform helps students understand the workflow for designing an embedded system without using manual programming. Students can use Simulink to create algorithms for control system and robotic applications. They can apply industry proven techniques for model based design to verify that their algorithms work during simulation [4,5].

2. Thermoelectricity

The thermoelectricity is the conversion of thermal energy into electrical energy through a temperature gradient. This phenomenon is reversible Fig 1, and is mainly based on the Seebeck effect and the Peltier effect [2,5–6].

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 [5]. 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.

In 1834 Charles Jean Peltier discovered another thermoelectric effect known as Peltier effect, which unlike the Seebeck effect, when electric current (direct current) flowing in the

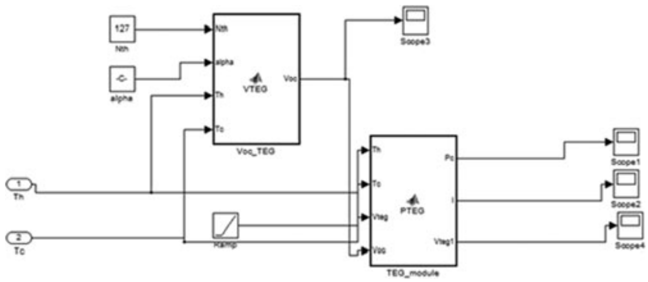

Figure 2. Simulink/Matlab model of TEG.

circuit made up of different conductors causes the conductors coupling the cool or warm, depending on the direction of the current. The amount of heat consumed is proportional to the current flowing in the conductors [1,5].

3. Model of thermoelectric generator (TEG)

The equivalent electrical circuit of the thermogenerator can be given by a source voltage with internal resistance R_{TEG}.

According to Seebeck's effect, the open-circuit voltage, Voc, of the TEG enclosed in the thermal energy, which is composed of N_{th} thermocouples connected electrically in series and thermally in parallel, is given as[7].

$$V_{oc} = S.\Delta T = \eta.\alpha\,(T_h - T_c) \tag{1}$$

Where α and S represent the Seebeck's coefficient of a TEG, respectively.

The electrical current I_{TEG}, when a gradient of temperature is applied ΔT, is given by equation (3).

$$I_{TEG} = \frac{V_{oc} - V_{TEG}}{R_{TEG}} = \frac{\eta.\alpha\,(T_h - T_c) - V_{TEG}}{R_{TEG}} \tag{2}$$

The output power P_{TEG} delivered by the TEG to the load, R_L, can be determined by using equation (2) and the output voltage V_{TEG} of TEG, which is given by

$$P_{TEG} = V_{TEG}.I_{TEG} = V_{TEG}.\frac{\eta.\alpha\,(T_h - T_c) - V_{TEG}}{R_{TEG}} \tag{3}$$

The model of TEG with Simulink/Matlab is presented in Fig 2.

4. Simulation results

The simulation results of the P-V curve and P-R curve of one TE module generator TEC1-12706 for different temperature gradient are presented in Fig 3 and Fig 4.

5. Matlab/Simulink environment and the Max32 board

Matlab is one of the representatives of high-performance language for the CACSD, where Simulink environment is known as a software package for modeling, simulating, and analyzing dynamic systems.

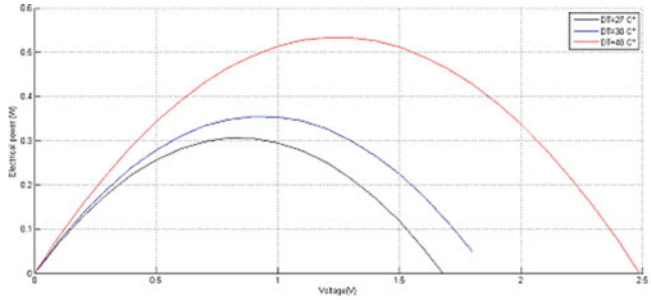

Figure 3. P-V Curve of TEG (TEC1-12706).

Matlab supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Simulation is an interactive process, so one can change parameters "on the fly" and immediately see what happens.

One has instant access to all of the analysis tools in Matlab, so one can analyze and visualize the results. With Simulink, one can move beyond idealized linear models to explore more realistic nonlinear models. For modeling, Simulink provides a graphic user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations [4].

The chipKIT Max32 shown in Fig 5, is a microcontroller board based on the microchip PIC32MX795F512L, a member of the 32-bit PIC32 microcontroller family. The Max32 boards are compatible with the popular Arduino microcontroller board shields.

The Max32 is designed to be easy to use and suitable for use by anyone from beginners to advanced users for experimenting with electronics and embedded control systems. The Max32 is intended to be used with the Multi-Platform IDE, (modified Arduino IDE), MPIDE, and contains everything needed to start developing embedded applications [4].

To operate the chipKIT Max32 correctly with Matlab, initially download and install the Arduino IDE and driver, ensure that you select the right IDE and Board on the Tools menu (chipKIT Max32), and then connect your chipKIT Max32 board to the USB port and Find the COM port associated with chipKIT. At this time we can explore the Arduino library of device driver blocks in Matlab Simulink. The required Matlab is R2011b or the more recent.

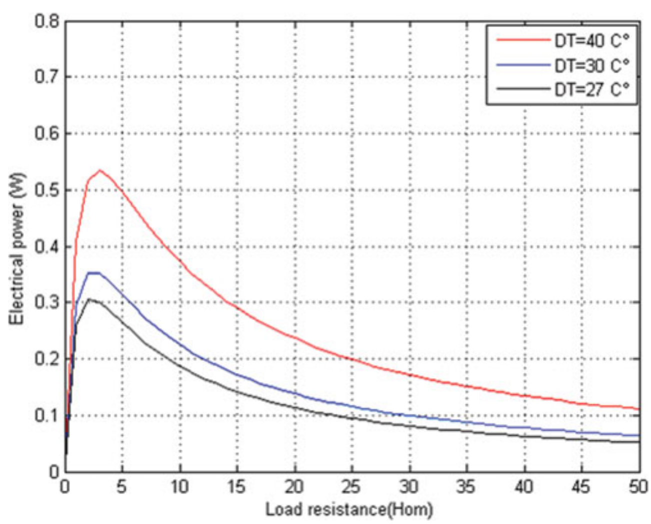

Figure 4. P-R Curve of TEG (TEC 12706).

Figure 5. ChipKIT Max32 board.

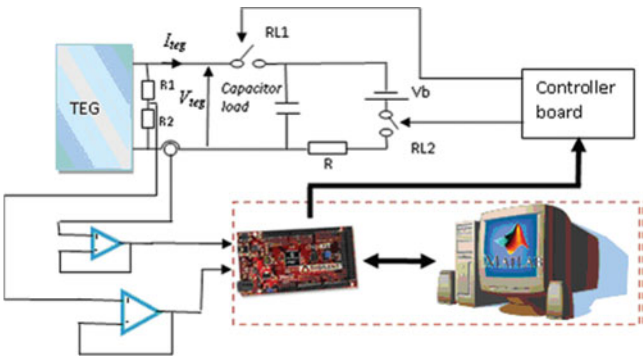

Figure 6. Principals elements of the proposed tracer.

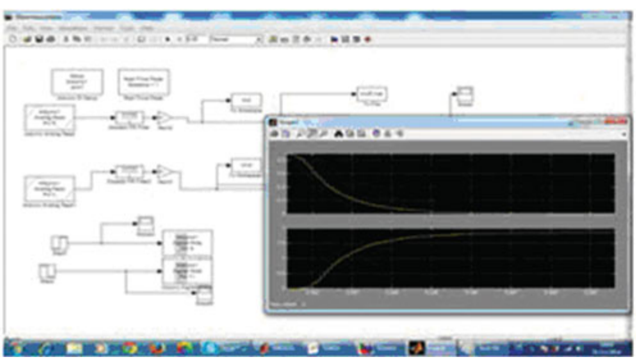

Figure 7. ChipKIT blocks used by Matlab.

For our application shown in Fig 6, two analog inputs are required to Measure current and voltage of the TEG. For our measures the Arduino IO Analog Read block is used and shown in Fig 7. Every time this block is executed it asks the server program running on the Max32 to perform an analog input that reads the voltage from on a given pin and to return the value (0 to 1023) via serial port. This value is then set as the output of the block [4].

A digital filter and again are used to reconstruct the current and the voltage of our TEG.

We also need two signals for controlling opto-couplers and that is to close the Relay REL1 when the capacitor is charged by the TEG generator and to close the Relay REL2 when the capacitor is charged with a negative voltage by the Vb battery for generating these control

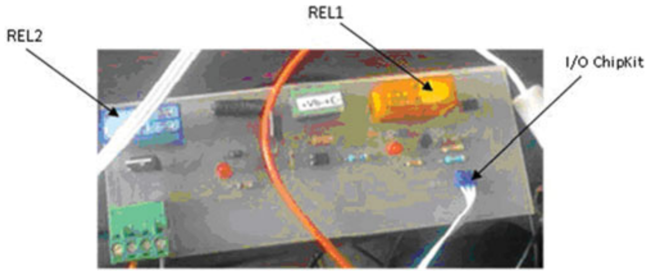

Figure 8. Controller board.

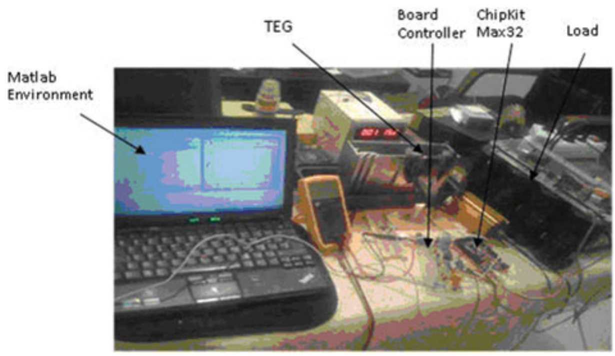

Figure 9. Global experimental system.

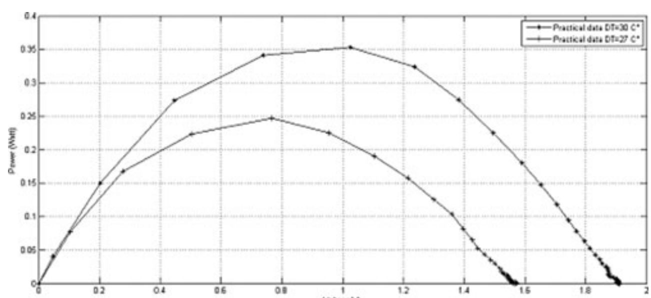

Figure 10. Experimental measurement P-V of one TEG (TEC-1 12706).

signals we used the block Arduino IO digital write, this board is shown in Fig 8; every time this block is executed it gets the value (0 or 1) at its input and sends to the server program running on the chipKIT Max32 a command to set that value as the digital output of a given pin. These blocks are preceded by a step of generating signals with an adequate time for the charging and discharging of the capacitor Fig 6. It is essential to use the block Matlab (Arduino IO Setup).

This block instantiates an Arduino object before starting simulation. The object is then used by the other Arduino IO blocks in the Simulink model and is deleted at the end of the simulation. The first mask parameter is the name of the Arduino object and the second is the serial port which is connected to it.

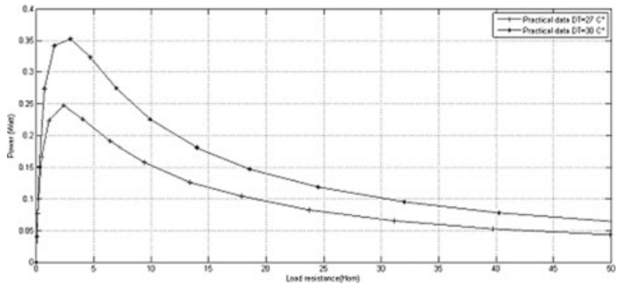

Figure 11. Experimental measurement P-R of one TEG (TEC-1 12706).

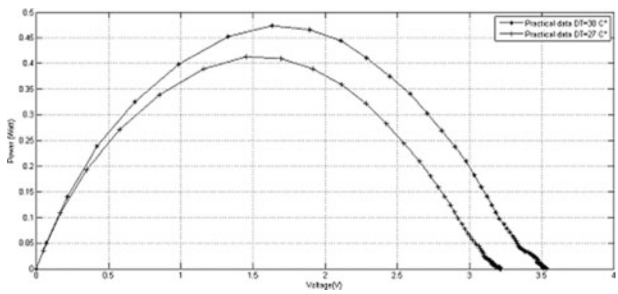

Figure 12. Experimental measurement P-V curve of tow TEG.

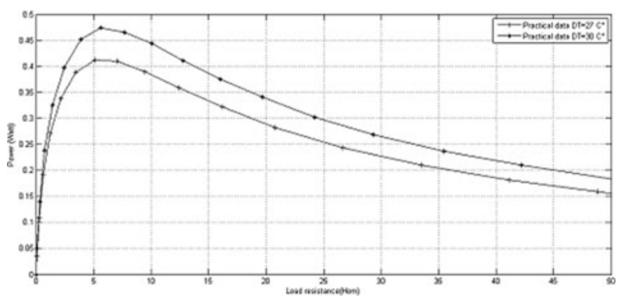

Figure 13. Experimental measurement P-R curve of tow TEG.

6. Experimental results and discussions

In order to verify the performance of the TEG physical characteristics tracer (TEGPCT) realized in this paper, two tests of TEG experimental systems are builds, the first system is composed with one TEG and the second with two TEGs connected a series. The experiment system is shown in Fig 9.

The module TE used in this paper is the TEC-1 12706 where is composed by 127 thermocouple and can delivered 50Watt and 6A maximum like cited in her datasheet. The heat source of TE module is produced by a heating plate made of aluminum and could source is assured by a water-cooling plate made of aluminum.

The results from Fig 10 and Fig 11, shows respectively the experimental curve P-V and curve P-R measurement of one TEG under tow different non-uniformly temperatures, the first test for a gradient and the second test for.

The second test of the proposed tracer is consider tow TEGs connected a series, and their practical results of P-V curve and P-R curve are shows in Fig 12 and Fig 13 respectively.

The advantage of using the tracer developed in this paper is that can provide directly the information about the maximum power delivered by thermogenerator to the load, this information is grate signification for the application of maximum power point tracking (MPPT), and also to give the value of the internal resistance. The values of the internal resistance shown in Fig 13 are the sum of tow TEG.

7. Conclusion

The studies and analyses of different physical characteristics of thermogenerator modules TEG are the great importance for improving their outputs power. For this reason we are proposed in this paper, a new developed tracer, where is using for monitoring and processing voltage and current of TEG modules, by tracing their P-V and P-R characteristics. The present tracer is based on low-cost chipKIT Max32 board and Simulink/Matlab environment. The load of this tracer is a varying capacitor was controlled by a board controller for charging and discharging. The galvanic isolation of tow data acquisitions assured the safety of the board ChipKIT by using tow operational amplifier.

The developed system is connected a Simulink/Matlab through ChipKIT Max32. The experiment results show the performance of the tracer developed in this paper.

References

[1] Rowe, D. M. (1995). *CRC Handbook of Thermoelectric*. 1st ed. CRC Press, USA: Boca Raton, FL.

[2] Admasu, B. T., Luo, X., & Yao, J. (2013). *Ener. Conv. Manage.*, *76*, 533.

[3] Kumar, S., Heister, S. D., Xu, X., Salvador, J. R., & Meisner, G. P. (2013). *J. Electron. Mater.*, 42, 6, 944–955.

[4] Khenfer, R., Mostefai, M., Benahdouga, S., & Maddad, M. (2014). *Int. J. Photoenergy*, 2014, Article ID 350345, 9 pages, http://dx.doi.org/10.1155/2014/350345.

[5] Noz J. M., & Lorenzo, E. (2006). *Solar Energy*, 31, 2198.

[6] Kinsella, C. E., O'Shaughnessy, S. M., Deasy, M. J., Duffy, M., & Robinson, A. J. (2014). *Appl. Energy*, 114, 80.

[7] Tan, Y. K., & Panda, S. K. (2011). *IEEET Trans. Indus. Electron.*, 58.