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Characterization of thermoelectric generator for energy harvesting

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ABSTRACT

This paper presents a system for characterization of thermoelectric generators (TEGs) for energy harvesting. This system can monitor and characterize up to three TEGs simultaneously and it is comprised by two main electronic circuits: The first one is composed by twelve input channels being three for reading voltage, three for reading current by making use of instrumentation amplifiers (reference ACS712) and six thermocouples for signal reading (<400 °C). The second electronic circuit consists of a proportional–integral–derivative (PID) controller with two pulse width modulation (PWM) input channels for controlling the heat (thermoresistance) and cooling (controlled cooler) sources respectively, following a pre-defined temperature gradient. The TEG measured data for the voltage, current and temperature can be acquired in real-time with development in Delphi® language and displayed through both a numeric and graphical display. In order to validate the precision and accuracy two commercial TEG modules (reference inbC1-127.08HTS) compatible with temperatures up to 200 °C without signal degradation were used in series. The acquisition system resulted in a precision of ±5%, ±2% and ±1.5% for the temperature, voltage and current respectively, with a maximum error value of 1%. Its possible utilizing this acquisition system acquire data from TEG obtain graphics response and determinate some characteristics how internal resistance, open circuit voltage, power output and temperatures gradient form any conditions of operation. All of these features combined with the low-cost under R$973.80 (≈324.43 €) makes this system suitable for a wide range of applications for standalone power system or heat recycling systems for cogeneration of electricity. Knowledge of the electrical characteristics of TEGs is of great interest in co-generation systems to design the same in order to achieve the best possible performance.

1. Introduction

The use of modern technologies and new energy sources generated changes in human life providing not only increased economic productivity but also to an improved quality of life [1]. According to Camacho-Medina et al., it is estimated that by 2035 the world energy consumption will increase by around 40%, which leads to the search for new technologies of generation [2].

One of the alternative technologies is the search for sources that allow increasing the supply of energy in a sustainable way [3,4].

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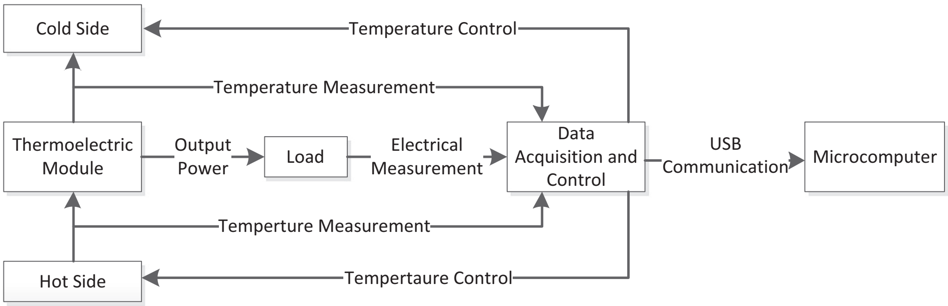

Fig. 1. Acquisition system diagram.

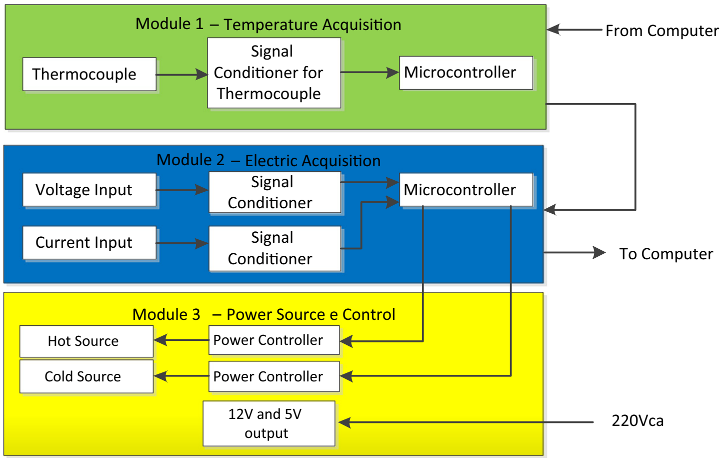

Fig. 2. Schematic's hardware structure.

In this context comes the solid-state generator as a promising alternative that based on Seebeck effect of thermoelectric materials enabling the conversion of thermal energy into electrical energy [5,6]. With the use of solid state generators is possible generate clean energy for energy harvesting in a simple and reliable way, with advantages of no moving parts, low complexity, silent operation, low maintenance cost and no environment impact [7]. Because they are solid state devices that operate in extreme conditions, a temperature gradient is necessary to generate power with an energy efficiency of 5–15% which is considered good [8,9].

In this context, an integrated data acquisition system (hardware and software) for monitoring TEG is presents in this paper. The thermal part of the process consists of a heating and cooling system capable of generating a temperature gradient, this system is controlled by a microprocessor. The acquisition system is set to make the temperature reading of the high temperature surface and the low temperature surface of the thermoelectric material in addition to the voltage and generated power. The software displays graphically the readings of the experiment showing the performance curves. Lastly, the system validation and the characterization of TEG are presented.

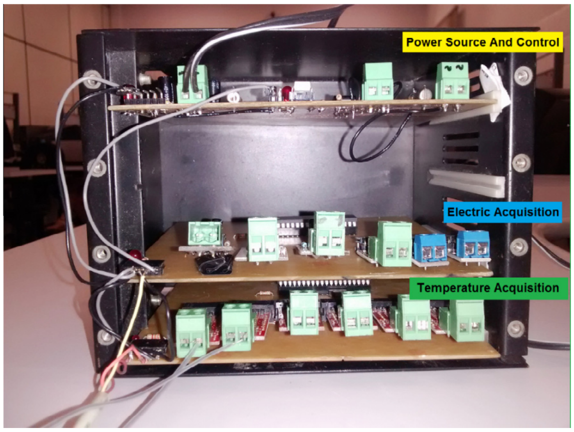

Fig. 3. Acquisition system structure.

2. System architecture

The complete system architecture, involving heating, cooling and data acquisition is shown in Fig. 1. This architecture is the continuation of a work described in an earlier paper [10].