Experimental Results Analysis of the Energy Conversion Efficiency of Thermoelectric Generators

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Abstract. Thermoelectric generators can be used for conversion of heat to electricity wherever a temperature difference exists. Such differences of temperatures are available in many applications, often without being used. In the case of photovoltaic panels the temperature difference is in the order of 50 °C.
This study experimentally examines the performance of two commercial thermoelectric generators. The resistance, open circuit voltage and short circuit current are measured. The maximum power output and the overall conversion efficiency are calculated and the results of the two generators compared.
Infrared thermographic pictures are taken in order to evaluate the temperature distribution over the generator induced by the experimental setup.
It is shown that the power output as well as the conversion efficiency at temperature difference smaller than 50 °C is very low and therefore the implementation of thermoelectric generators in combination with photovoltaic panels might not be economic.

Key words

Thermoelectric generator, Renewable Energy, Electricity Conversion Efficiency, Infrared pictures

1. Introduction

Thermoelectric generators (TEG) make use of the Seebeck effect, where a temperature difference induces a voltage [1-3]. They have been used for many years in space applications, with radio-isotopes as the heat source, because of their reliability and robustness. When it comes to terrestrial applications, electricity generation out of waste heat or geothermal energy can be named [4-8]. Pilot projects are also being conducted by using the temperature difference existing between the ocean's surface and greater depths [9].

Although TEGs have very low efficiencies (5 to 10 % in the above mentioned applications), their usage makes sense where the heat source is freely available and would otherwise be lost to the environment. One such example is a photovoltaic (PV) panel, where only a certain bandwidth of the incident light is transformed to electricity. The absorbed infrared radiation in particular only heats the upper side of the panels without contributing to the PV conversion efficiency. This leads to a temperature difference between the upper and the lower side of the photovoltaic panel which can be used with thermoelectric generators. The temperature difference is however rather small, typically in the order of 50 °C on a hot summer day with a clear sky in Portugal. Besides providing an additional method to generate electrical energy, the use of TEGs in PV panels helps improving the photovoltaic efficiency. This condition is related with the PV efficiency decrease with temperature.

If this combination of photovoltaic cells and thermoelectric generators is to be used in a larger scale, commercially available TEGs must be used. Commercial TEGs however are usually designed for higher temperature difference with a main intended purpose in the field of waste heat from high temperature processes.
Two modules from different suppliers are tested in this study in order to assess the behaviour and conversion efficiency of TEGs at temperature difference below 50 °C.

During the test series both the hot side temperature and the cold side temperature as well as the short circuit current and the open circuit voltage are measured. Further the measured internal resistance of the modules is compared to the values provided by the suppliers.

To complement the experimental results, infrared thermographic pictures were taken in order to evaluate the temperature distribution over the TEG surface during the measurement process.

The models tested are a TEG127-50A from EVERREDtronics Ltd. [10] and a HZ-20 from Hi-Z Technology Inc. [11]. The former is referred to as TEG 1, the latter as TEG 2.