IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor: 5.731
Volume 10, Issue 1, October 2021

Generation of Electricity from Waste Heat

Deepa S[1], Mohammad Rizan[2], Amaldev M Lal[3], Tritin Thomas[4], Fathima Hussain[5]
Associate Professor, Department of Electronics and Electrical Engineering[1]
Students, Department of Electronics and Electrical Engineering[2,3,4,5]
SCMS School of Engineering and Technology (of KTU), Ernakulam, Kerala, India

Abstract: *Thermo electric generation converts heat energy into electrical energy . Power generated from TEG depends on the temperature difference between hot and cold surface . To improve the efficiency of TEG, MPPT algorithm with boost converter is used . Maximum power is obtained in the system when the output resistance of the system matches with the input resistance of TEG. By modelling the power variations generated from TEG system in series and parallel were minimized . The proposed system consists of TEG with boost converter having P& O MPPT . This paper presents simulation model of TEG module using MATLAB and is successful in generating a stable output.*

Keywords: TEG, MPPT, MATLAB

I. Introduction

Heat energy from waste heat source is directly converted into electrical energy in a thermoelectric generator .Seebeck affect is the basic principle behind the thermo electric generation [1]. By using series and parallel combination of the TEGs , power generation can be increased.[2].

The principal advantages of TEG are that they do not have any moving part and they do not produce greenhouse gases. Low efficiency is the major drawback of TEG.[3].Waste heat energy from different sources can be tapped and converted into useful energy. By using TEG system, energy efficiency of automobiles can be improved.[4]

This proposed work uses converters that perform both maximum power point tracking (MPPT) and power regulation.. Impedance matching is obtained by making internal resistance of TEG equal to the load resistance [6] .MPPT algorithms are used to maximize the power generation in the systems. The algorithms used for MPPT process in these converters is Perturb and observation (P&O) algorithm [8-9].

From the data sheet provided by the manufacturer maximum power, current, and voltage of TEG for impedance matching are known. They ensure hot and cold surface temperatures that can be reached by TEGs. Seebeck coefficient indicated in the data sheet is one of the most important criteria. Simulation of TEG is done using temperature difference and Seebeck coefficient which in turn give the power value taken from the TEG.

II. TEG

A TE is formed by combining p and n type semiconductors. The TEs are connected in series with each other to increase the voltage. TEGs are made up by connecting the TEs in parallel with the help of ceramic plates in order to raise thermal conductivity. When a temperature difference between the ceramic plates is generated, heat transfer from the hot surface to the cold surface becomes possible. The heat transfer leads to electron flow from the n-type to the p-type semiconductors[1]. Thus, a voltage generated is as follows:

$$VOC = \alpha.\Delta T \quad (1)$$

where VOC is the open circuit voltage (V) of the TEG, α is the Seebeck coefficient (V/K), and ΔT is the temperature difference (K). The temperature difference is between the hot, Th , and the cold surfaces, Tc , ($\Delta T = Th - Tc$)

III. TEG Modelling with MATLAB

3.1 TEG Array

TEG properties: Specifications of TEG are given by the manufacturer.

Hot surface temperature, T_h	250◦C

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor: 5.731

Volume 10, Issue 1, October 2021

Cold surface temperature, T_c	20◦C
Open circuit voltage, V_{OC}	4±0.4
Short circuit current, I_{SC}	5.8±0.6
Load matching resistance, R_{in}=R_L	0.7Ω
Load matching output voltage	2.0±0.2
Load matching output current	2.9±0.3
Load matching output power, R_{in}=R_L	5.8 W
Seebeck coefficient	185µV/K

Modelling of a TEG modelled and simulated through MATLAB/Simulink is shown as a temperature-dependent controlled voltage source in Fig1.In the modelling, the TEG output power was obtained by Seebeck coefficient and hot/cold side temperatures.

Increasing the power generated from TEGs is carried out by series and parallel connection of the TEGs. The modelling of TEGs connected in series and parallel is depicted in Figure1. The number of connected modules in the TEG modelling was 2 in series. In order to increase the generated power, a separate model consisting of 2 TEGs was added to the series connected model in parallel. The number of modules used can be increased in order to increase the power.

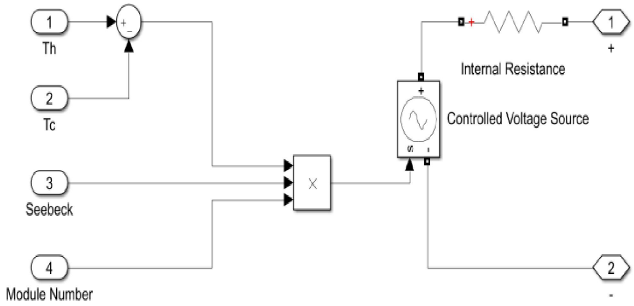

Figure 1: TEG array

3.2 Proposed Model

Increasing the power generated from TEGs is carried out by series and parallel connection of the TEGs.A boost converter with P&O MPPT was included in the designed modelling. Load is connected when the switch is ON. Battery charging is done through bidirectional boost converter.

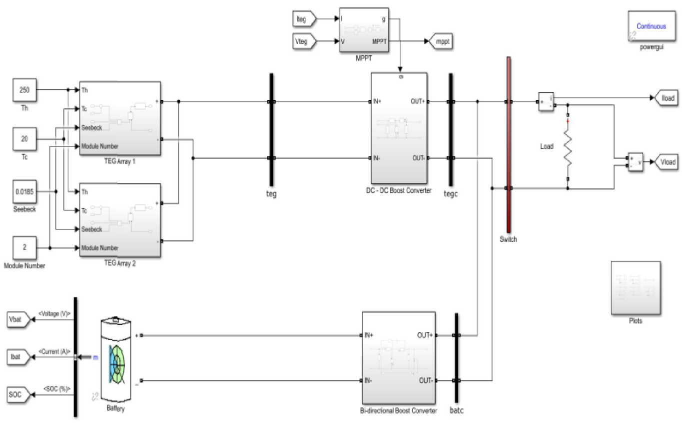

Figure 2: Proposed Simulation Model

IJARSCT

ISSN (Online) 2581-9429

IJARSCT
Impact Factor: 5.731

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 10, Issue 1, October 2021

3.3 MPPT

Maximum power point tracking (MPPT) is an algorithm implemented to continuously adjust the impedance seen by the TEG array to keep the system operating at, or close to, the peak power point of the. MPPT algorithms are implemented to maximize the power generated by the systems. The algorithms control the voltage to ensure that the system operates at "maximum power point" (or peak voltage) on the power voltage curve[10].

For determining the value of MPPT, the current and voltage indicators from the TEG Arrays were connected to the input of the MPPT. The MPPT uses P&O algorithmto find the Maximum power point by varying the voltage.

3.4 Output Graphs

The TEG Arrays are operating in MPPT mode so the output voltage from the TEG Arrays varies to provide maximum power. The output voltage from the TEG Arrays is depended on the temperature difference across the TEG Arrays.

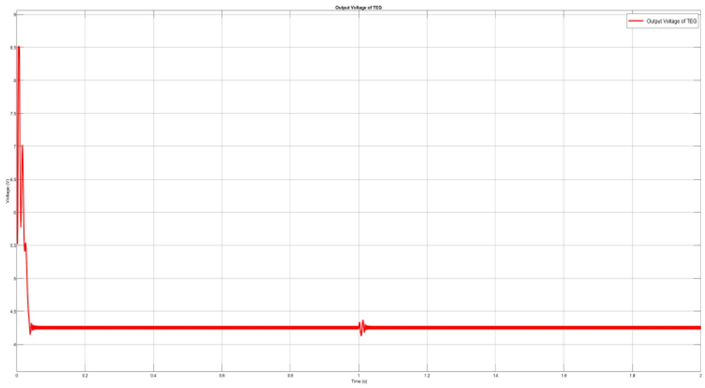

Figure 3: Output Voltage of TEG Array

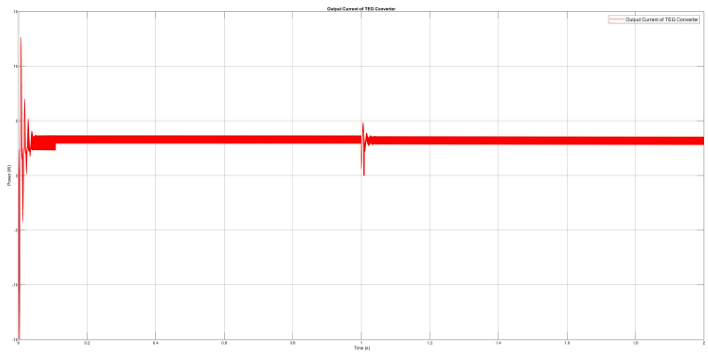

Figure 4: Output current

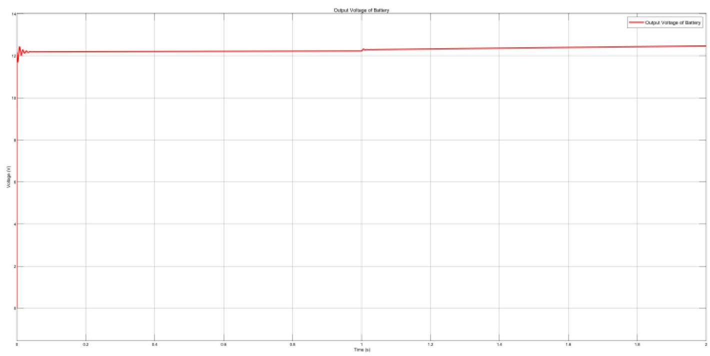

Figure 5: Output Voltage of Battery

DOI: 10.48175/IJARSCT-2055

IJARSCT

ISSN (Online) 2581-9429

IJARSCT
Impact Factor: 5.731

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 10, Issue 1, October 2021

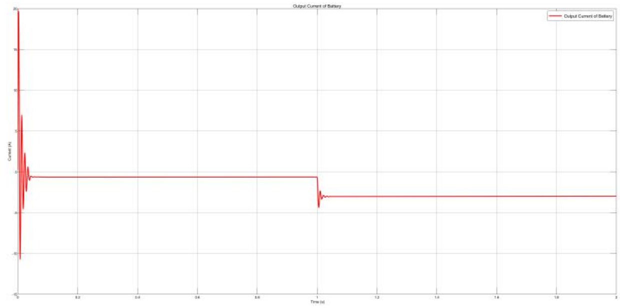

Figure 6: Output Current of Battery

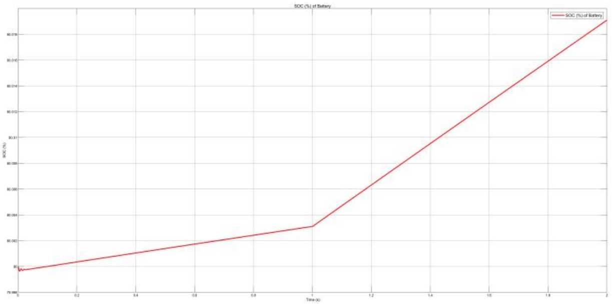

Figure 7: SOC

As shown in Fig. 6 the output current from the battery is -0.65A till 1sec mark, which shows that the battery is charging. Since the battery is charging even when the switch is ON (Load is connected), the load can be increased to higher wattage than 30W.

After the 1sec mark the switch is turned OFF (Load is disconnected), which results in the charging current increasing from 0.65A to 3A. From Fig. 7 it is evident that the resulting increase in the charging current causes the SOC to increase faster.

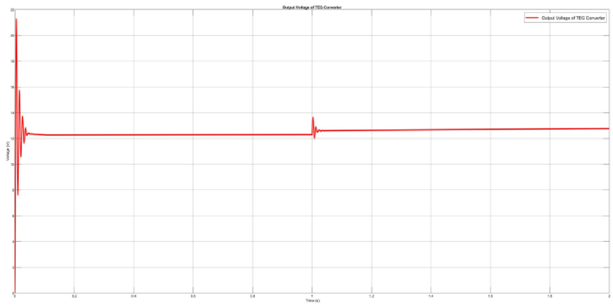

Figure 8: Output Voltage of TEG Converter

Since the converter is working in MPPT mode the output current from the converters varies to provide maximum power.

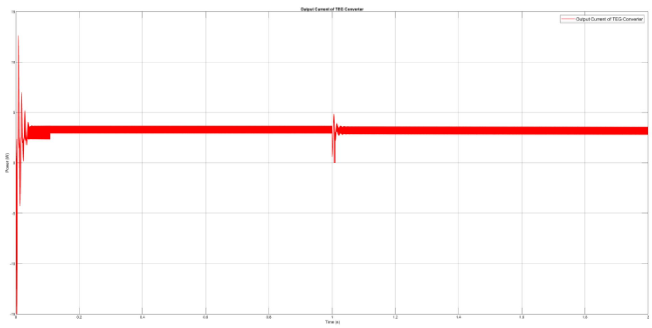

Figure 9: Output Current of TEG Converter

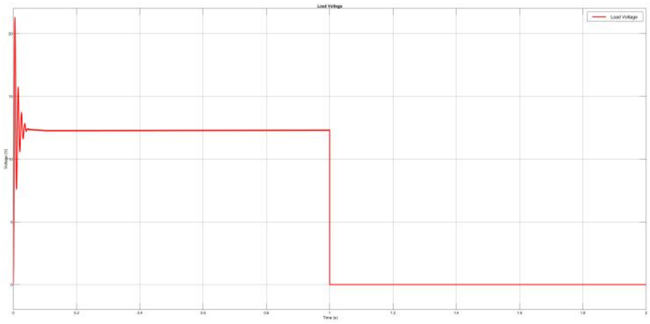

Figure 10: Output Voltage of Load

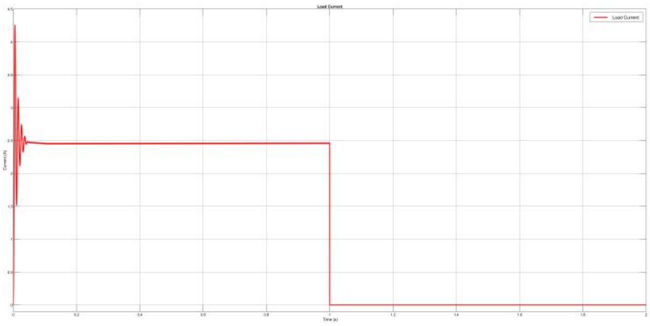

Figure 11: Output Current of Load

From Fig. 10 it is evident that the proposed model is successful at generating a stable 12V output, and capable of running a 30W to 40W load. The direction of current flow with variation in load can be witnessed while the model works.

IV. Conclusion

The modeling of TEGs using MATLAB was presented depending on the Seebeck coefficient and temperature values specified by the TEG manufacturers. The model was simulated in such a way that the number of TEGs connected in series and parallel can be determined and could be entered. Increasing the number of TEGs increases the output power. The load connection with the P&O MPPT boost converter model was carried out to emphasize the importance of impedance matching between the load and TEG internal resistance.

The use of TEG system in automobiles can capture waste heat energy from exhaust and convert it to useful electrical energy. It can be used to power the appliances within the automobile and energy can be stored. This system can thus be used to increase the efficiency of vehicle.

References

[1]. Mamur H, Ahiska, R. A review: thermoelectric generators in renewable energy. International Journal of Renewable Energy Research (IJRER) 2014; 4 (1): 128-136.

[2]. Thermoelectric generators: a review of applications. Energy Conversion and Management 2017; 140: 167-181. doi: 10.1016/j.enconman.2017.02.070

[3]. Application of a DC–DC boost converter with maximum power point tracking for low power thermoelectric generators. Energy Conversion and Management 2015; 97: 265-272. doi: 10.1016/j.enconman.2015.03.068

[4]. Heat pipes thermoelectric solar collectors for energy applications. International Journal of Hydrogen Energy 2017; 42 (12): 8310-8313. doi: 10.1016/j.ijhydene.2017.01.132

[5]. Jagadish PR, Khalid M, Li LP, Hajibeigy MT, Amin N et al. Cost effective thermoelectric composites from recycled carbon fibre: from waste to energy. Journal of Cleaner Production 2018; 195: 1015-1025. doi: 10.1016/j.jclepro.2018.05.238

[6]. A hybrid maximum power point tracking method for automobile exhaust thermoelectric generator. Journal of Electronic Materials 2017; 46 (5): 2676-2683. doi: 10.1007/s11664-016-4875-9

[7]. Comparative assessment of maximum power point tracking procedures for photovoltaic systems. Green Energy & Environment 2017; 2 (1): 5-17. doi: 10.1016/j.gee.2016.11.001

[8]. A new maximum power point tracking (MPPT) algorithm for thermoelectric generators with reduced voltage sensors count control. Energies 2018; 11 (7): 1-16. doi: 10.3390/en1107182

[9]. Energy management for thermoelectric generators based on maximum power point and load power tracking. Energy Conversion and Management 2018; doi: 10.1016/j.enconman.2018.09.040

[10]. An automotive thermoelectric–photovoltaic hybrid energy system using maximum power point tracking. Energy Conversion and Management 2011; 52 (1): 641-647. doi: 10.1016/j.enconman.2010.07.041