Energy Harvesting From Waste Heat Of Iron Box Using Thermo Electric Generators

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Abstract—Thermo electric generation converts heat energy into electrical energy. Power generated from TEG build upon the temperature variance 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, Maximum Power Point Tracking,MATLAB,TE, Seebeck Effect

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 [6].

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[5,7].

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 [2]. MPPT algorithms are used to maximize the power generation Din the systems.The algorithms used for MPPT process in these converters is Perturb and observation (P&O) algorithm [8].

From the data sheet provided by the manufacturer maximum power, current, and voltage of TEG forimpedance matching are known. They ensure hot and cold surface temperatures that can be reached by TEGs{9]. Seebeck coefficientindicated 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 givethe power value taken from the TEG [10].

II. SYSTEM DESCRIPTION

1.TEG ARRAY

A TE is formed when p -type and n- type semiconductors are combined .Series connection of TE's results in increase in output voltage .When TE's are connected in parallel using ceramic plates, thermal conductivity is increased. Heat transfer occurs between hot surface and cold surface when a temperature difference is maintained between them. This causes the flow of electrons from n-type to p-type semiconductors [1,6]. The expression for voltage produced in a TEG is

$$V_0 = S.\Delta T \qquad (1)$$

Where V_0 is the voltage of the TEG under open circuit expressed in Volts,S is the Seebeck coefficient in Volt/Kelvin, and ΔT is the temperature difference in Kelvin. The temperature difference between the hot surface Th, and the cold surfaces, Tc is

$$\Delta T = Th - Tc \qquad (2)$$

2. DC- DC converter

The variation of voltage from low value to high value is obtained with the help of DC- DC converter. Boost converter is used for proposed system.

3 Controller

As the conversion efficiency of TEG is too low, a controller, Maximum power point tracking (MPPT) algorithm is used which helps to achieve maximum power. When temperature varies, output power varies which causes change in peak power point. This also helps in controlling duty ratio of boost converter [4].

4. Load

Here Load is a series of LED strip with output voltage of 12V

5. Battery Lead acid battery of normal voltage 12 V is used for charging purpose as the load condition is varied

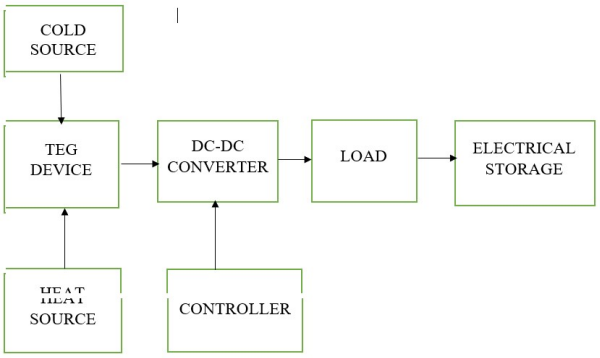

FIG 1: BLOCK DIAGRAM OF PROPOSED SYSTEM

III. TEG MODELLING WITH MATLAB

A. TEG Array

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

Hot surface temperature,T_h	250◦C
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

HereTEG is modelled and simulated through MATLAB/Simulink is shown as a temperature-dependentvoltage source TEG output power is obtained by Seebeckeffect provided a temperature difference between hot and cold surface .

By series and parallel connection of the TEGs., power generated by TEG is increased. The modelling of TEGs connected in series and parallel is depicted in Figure1. Two modules are connected in series in TEG mode. When a separate model consisting of 2 TEGs was added to the series connected model in parallel, power generation is increased. To increase the power, number of modules used can be increased.

B. Proposed Simulation Model

By using series and parallel combination of TEGs, power output is increased. A boost converter with P&O MPPT was included in the designed modelBoost converter regulates the voltage generated by TEG[3]. When output resistance is equal to input resistance of a system, maximum power is obtained the output voltage of TEG is regulated with the help of controller. With the change in temperature gradient MPPT converter respond accurately Load is connected when the switch is in ON position Battery charging is done through bidirectional boost converter [8].

C. MPPT

TEG characteristics can be verified with MPPT algorithm. To acquire maximum power transfer condition, MPPT algorithm helps to vary the load resistance accordingly so as to match with input resistance of TEG module.It improves efficiency of overall system[4, 6].

MPPT algorithm is implemented to constantly adjust the impedance of TEG array so as to keep the system operating close to maximum power point condition on the power voltage curve.

The current and voltage output of TEG array is connected to the input of MPPT. The MPPT with P & O algorithm helps in determining peak point by changing the voltage [8].

D. 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.

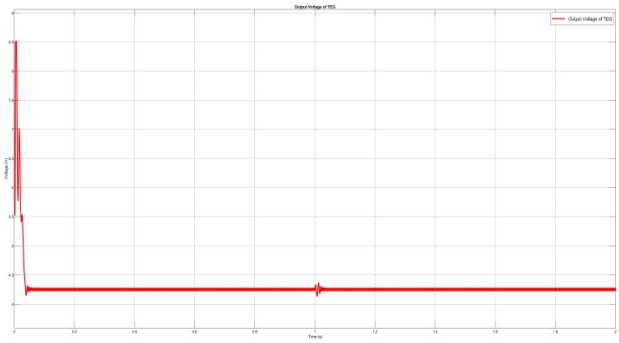

Fig 2 Output Voltage of TEG Array

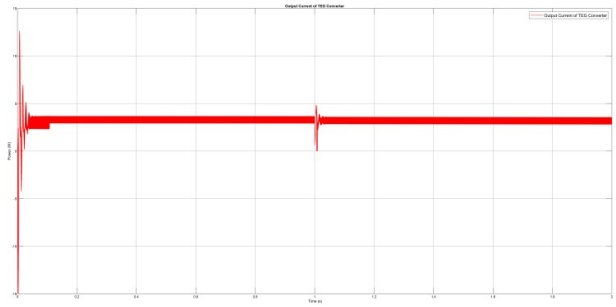

Fig 3. Output current of TEG array

The output current from the battery shows that the battery is charging. Since the battery is charging even when Load is connected, the load can be increased to up to 30Wsafely.

When switch is turned OFF or Load is disconnected, charging current increasesfrom 0.65A to 3A. The rapid growth ofcharging current causes the SOC to increase faster.

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

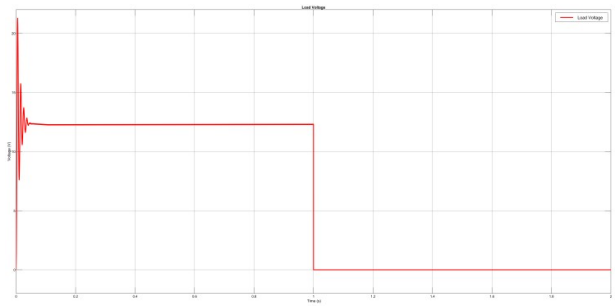

Fig 4. Output Voltage of Load

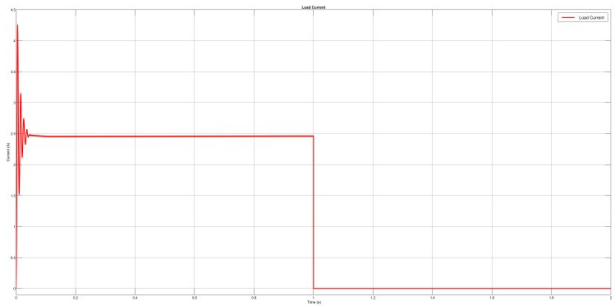

Fig 5 Output Current of Load

From Fig. 4it is evident that the proposed model can generate a stable 12V output, and capable of running a 30W to 40W load. The direction of current flow with variation in load can be checked while the model operates.

IV HARDWARE IMPLEMENTATION

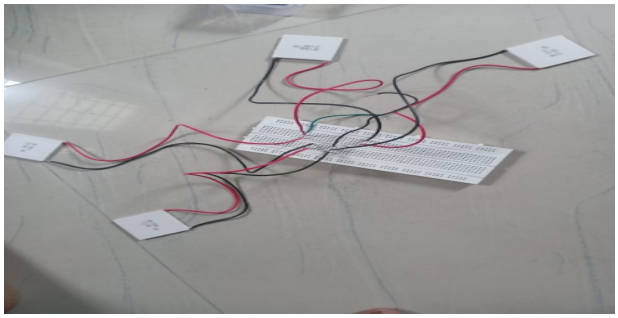

Fig6 TEG module connected in series

Fig6 shows two TEG's connected in series to form TEG array and TEG arrays such formed are connected in parallel on a bread board This arrangement will increase power output Here two of TEG device are connected in series so that voltage level is increase .

When there is no temperature difference in the system initial voltage is found to be 0.65 volt

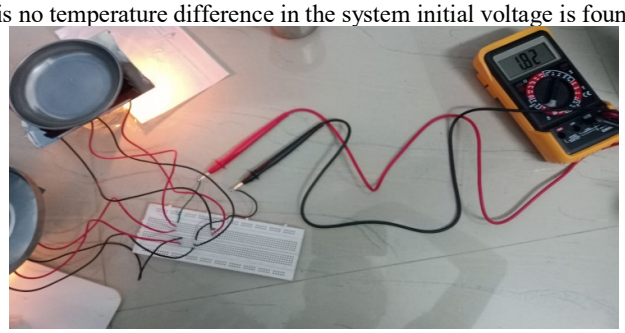

Fig 7 Voltage Generation with Candle Light

Here candle light and ice cubes act as hot source and cold source respectively so that a temperature difference is maintained at the input of TEG .Here a small output voltage of 1.5 Volt is generated as the temperature difference is small.

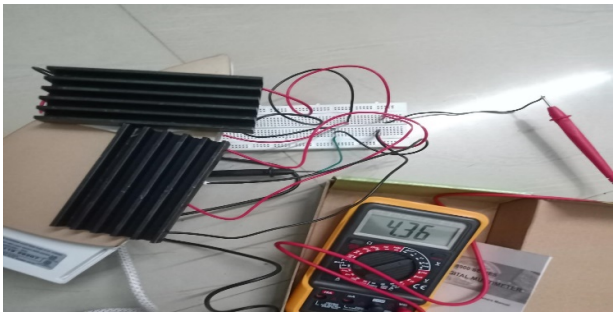

Fig8: Experimental setup with TEG and iron box for voltage generation

The proposed system contain iron box as the heat source. The output voltage of TEG array is measured as 4.36 Volt. The output current is measured as 0.7 A. The power output is nearly 3 Watts. Greater the temperature difference will produce power output of 30 to 40 Watts.

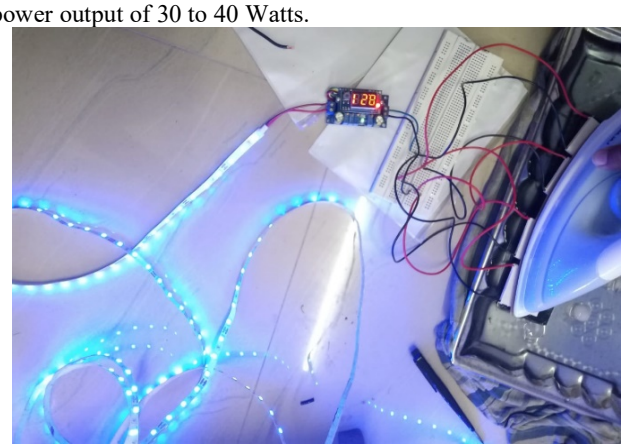

Fig 9 TEG with load

As the temperature of iron box is varied more voltage is generated across TEG array. Boost converter controls the TEGoutput with MPPT algorithm and LED strip glows.

IV. CONCLUSION

The modeling of TEGs using MATLAB was discusses 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.

Experimental setup of proposed system is fast and stable in operation. The waste heat energy from automobiles can provide more output which in turn increases the efficiency of the vehicle.

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