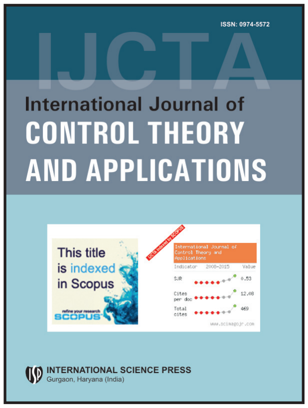

International Journal of Control Theory and Applications

ISSN : 0974-5572

© International Science Press

Volume 10 • Number 16 • 2017

Extraction and Conversion of Heat Energy Using TEG Module

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Abstract: Energy is vital for the progress of the nation and it has to be conserved in an efficient manner. Nowadays increasing worldwide problem is shortage of energy. Solar Thermal Energy (STE) is a form of energy and a technology for harnessing solar energy to generate thermal energy or electrical energy for use in industry, and in the residential and commercial sectors. Our Project focus on utilization of solar heat into useful electrical energy by using Seebeck effect where in Thermoelectric Generators (TEG) are being focused by Fresnel lens for concentrating solar heat for converting heat directly into electrical energy. Thermoelectric generators are highly doped semiconductor solid state devices. The output voltage of the thermoelectric generator is given to a dc super lift converter circuit. The output of the super lift converter is used for battery charging.

***Keywords*:** Elementary additional series positive output super-lift converter (DC-DC converter), Thermo Electric Generator (TEG).

1. INTRODUCTION

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric gadget makes voltage when there is an alternate temperature on each side. Then again, when a voltage is connected to it, it makes a temperature distinction. At the nuclear scale, a connected temperature inclination causes charge bearers in the material to diffuse from the hot side to the icy side. This effect can be used to generate electricity. It is based on the Seebeck effect, Peltier effect, and Thomson effect. This impact can be utilized to produce power, measure temperature or change the temperature of items [1-3]. Since the course of warming and cooling is dictated by the extremity of the connected voltage, thermoelectric gadgets can be utilized as temperature controllers. Thermocouples depend on the impact that the intersection between two distinct metals creates a voltage which increments with temperature. They are much of the time utilized as a part of broilers, heaters, vent gas estimation and different regions with temperatures above around 250°C [5].

2. THERMO ELECTRIC GENERATOR

When two metals are connected together, a thermoelectric voltage is produced due to the different binding energies of the electrons to the metal ions. This voltage depends on the metals themselves, and in addition on the temperature. All together for this warm voltage to create a stream of current the two metals should obviously be likewise associated together at the flip side so that a shut circuit is framed. In this way a thermal voltage is produced at the second junction [3-6]. In the event that there is a similar temperature at the two intersections there is no stream of current since the incomplete voltages delivered at the two focuses wipe out each other. With different temperatures at the junctions the voltages generated are different and a current flows. The measurement point is the junction which is exposed to the measured temperature. The reference intersection is the intersection at the known temperature. Since the known temperature is usually lower than the measured temperature, the reference junction is generally called the cold junction [9].

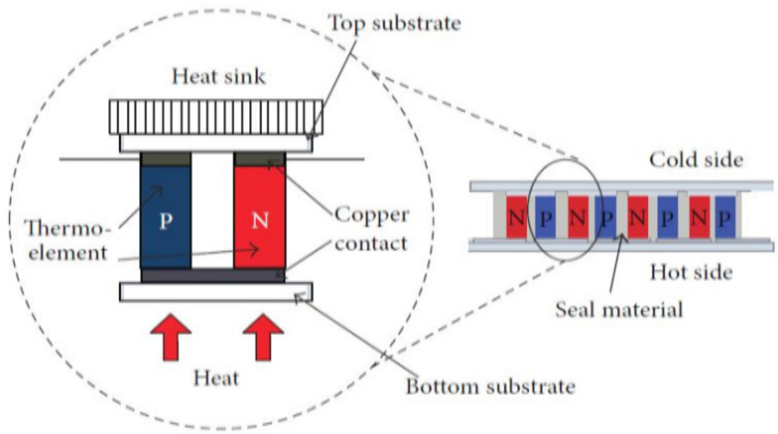

Figure 1: Thermoelectric Generator Internal View

Elementary Additional Series Positive Output Super Lift Converter

Super lift converter is a new series of DC/DC converter possessing high voltage transfer gain, high efficiency, reduced ripple voltage and current. Super lift technique armed by split capacitors increases the output voltage in higher geometric progression [4]. It is a class of Switched-Mode Power Supply (SMPS) containing no less than two semiconductor switches (a diode and a transistor) and no less than one vitality stockpiling component, a capacitor, inductor, or the two in mix. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple [5].

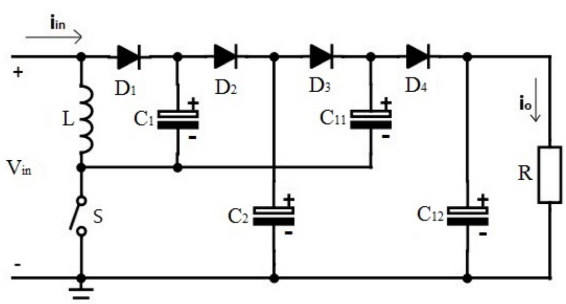

Figure 2: Super lift converter

In the event that the switch is cycled sufficiently quick, the inductor won't release completely in the middle of charging stages, and the heap will dependably observe a voltage more noteworthy than that of the info source alone when the switch is opened. Likewise while the switch is opened, the capacitor in parallel with the heap is charged to this consolidated voltage. At the point when the switch is then shut and the correct hand side is shorted out from the left hand side, the capacitor is accordingly ready to give the voltage and vitality to the heap [7-9].

Amid this time, the blocking diode keeps the capacitor from releasing through the switch. At the point when the switch is then shut and the correct hand side is shorted out from the left hand side, the capacitor is along these lines ready to give the voltage and vitality to the heap. The Voltage gain is

$$G = \frac{V_0}{V_{in}} = \frac{3 - K}{1 - K} \tag{1}$$

On state operation is shown below:

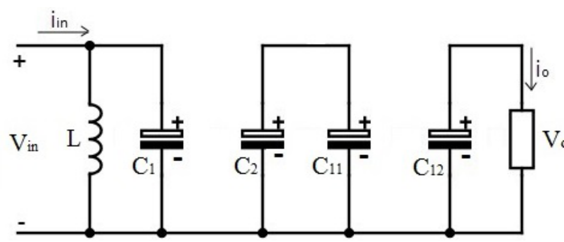

Figure 3: ON state working diagram

At the point when the switch is shut, current courses through the inductor in clockwise heading and the inductor stores some vitality by creating an attractive field. Polarity of the left side of the inductor is positive.

$$V_1 = \frac{V_{in}}{L_1} \tag{2}$$

$$V_2 = \frac{V_{in}}{C_1 R_{in}} - \frac{V_1}{C_1} \tag{3}$$

$$V_3 = -\frac{V_3}{RC_2} \tag{4}$$

Off state operation is shown below:

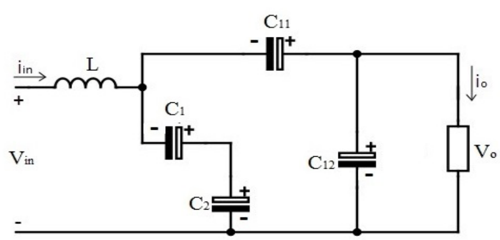

Figure 4: OFF state working diagram

At the point when the switch is opened, current will be diminished as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current flow towards the load. Accordingly the extremity will be turned around (means left half of inductor will be negative at this point). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

$$V_1 = \frac{V_{in}}{L_1} - \frac{V_2}{L_1} - \frac{V_3}{L_1} \tag{5}$$

$$V_2 = \frac{V_1}{C_1} \tag{6}$$

$$V_3 = \frac{V_1}{C_2} - \frac{V_3}{RC_2} \quad (7)$$

3. TEG POWER AND EFFICIENCY CALCULATION

The conversion efficiency η is defined as the ratio of the generated electrical power P_T and the heat input into the module Q_H, Q_c – heat removed from the cooled side.

$$\eta = \frac{P_T}{Q_H} = \frac{P_T}{Q_C + P_T} \quad (8)$$

There are four basic physical entities that are involved in the operation of Thermo Electric Generators (TEG), namely, the Thomson effect, the Joule effect, the Seebeck effect and the Peltier effect. Under steady state conditions, these entities together explain the phenomena of energy flow below.

$$TJ\frac{da}{dx} + \tau J\frac{dT}{dx} - \rho J^2 - \frac{d}{dx}\left(k\frac{dT}{dx}\right) = 0 \quad (9)$$

where, T – temperature

J – electrical current density

α – Seebeck coefficient

τ – Thomson coefficient

ρ – electrical resistivity

k – thermal conductivity of the material

The equation of heat flow at hot side is:

$$Q_H = K_T \cdot (T_H - T_C) + S_T \,.\, T_H \,.\, I - \frac{1}{2} I^2 R_T \quad (10)$$

where, $K_T = N(k_n + k_p)G$ – total thermal conductance of N couples.

$S_T = N(a_n + a_p)$ – total seebeck coefficient.

$R_T = N(\rho_n + \rho_p)/G$ – total resistance.

G = area/length – Geometry factor.

Heat flow at cold side is:

$$Q_H = K_T \cdot (T_H - T_C) + S_T \,.\, T_c \,.\, I - \frac{1}{2} I^2 R_T \quad (11)$$

Thus the net power produced by the module P_T is

$$P_T = Q_H - Q_C = S_T \cdot (T_H - T_C) \cdot I - I^2R_T = [S_T(T_H - T_C) - IR_T] \cdot I = V_T I \quad (12)$$

And the voltage produced by the module V_T is

$$V_T = S_T(T_H - T_C) - IR_T \quad (13)$$

Therefore, the P_T, Q_H, Q_C, η can easily be calculated, if the material properties are known. In practice, it is impossible to measure the temperature of both the hot and cold junction.

$$W_H = (W_{T1} + W_{T2} + W_{T3} + W_{CR}) \tag{14}$$

where, W_H – Total thermal resistance between T_1 and W_H.

W_{T1}, W_{T2}, W_{T3} – Thermal conductivity resistances.

W_{CR} – Thermal contact resistance.

The hot junction temperature T_H is given by

$$T_H = T_1 + Q_H W_{TC} \tag{15}$$

Similarly, the hot junction temperature T_H is given by

$$T_C = T_2 - Q_C W_{TC} \tag{16}$$

where, W_{TC} – Total thermal resistance between T_C and T_2.

Thus relating to the power produced by the peltier module with that of the output gain of the super lift converter it gives the improved power from the output of the gain and it is given by the following relation,

$$P_O = P_T \cdot G \tag{17}$$

$$P_O = P_0 = V_T I. \frac{V_0}{V_{in}} \tag{18}$$

where, P_O – Improved stepped up power of the module from the output terminals of the super lift converter.

4. HARDWARE IMPLEMENTATION

The hardware implementation of a THERMO ELECTRIC CONVERTER to convert waste heat obtained on exhaust surface is discussed and its working is explained in detail

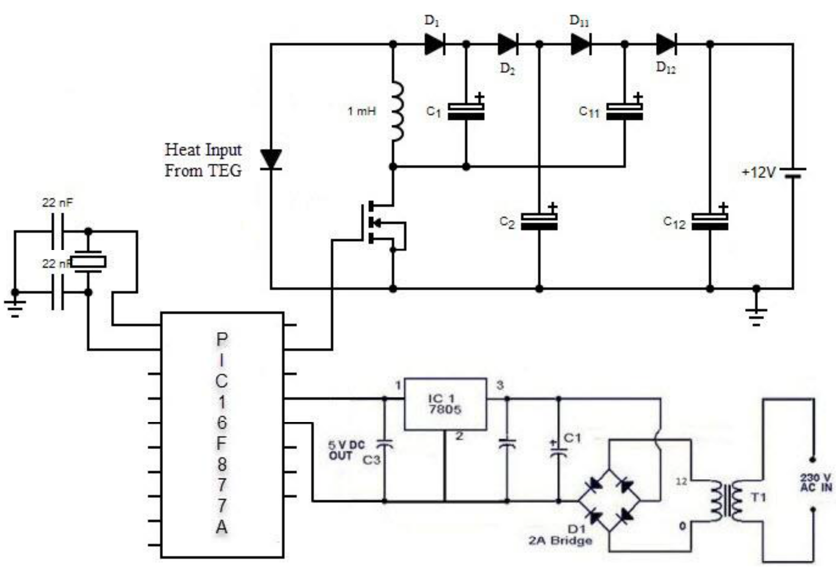

Figure 5: Schematic Diagram of Heat to electrical energy converter

Figure 5 circuit consists of power supply unit, peltier device (TEC 1-12706), Elementary additional series super lift converter with MOSFET switch IRFB40, PIC-16F877A Microcontroller provided with a buffer DM74A, Voltage Regulator 7805, X1 crystal Oscillator to maintain constant 20MHz frequency and a 230/12v 1A transformer.

B. Thermo Electric Generator (TEC 1-12706) Setup

TEG is an acronym for "Thermo Electric Generator". Here we have connected 6 TEG modules in series to obtain higher voltage. These series connected modules are embedded between 2 aluminium plates in order to retain the heat on the top side and to provide better thermal conduction on the bottom side. These 2 plates are fixed with thermal paste for better conduction and transfer of heat between the plates and TEG modules. The top side of the aluminium plate is concentrated with the solar heat rays obtained from the Fresnel lens array fixed at their focal point at 17cm from the top aluminium plate[9]. The bottom aluminium plate is coupled with a heat sink and a fan for providing air cooling system.

Figure 6: Series connected TEG Modules with Fresnel lens setup

In below Figure 6 TEC1-12706 which is placed between the Aluminum plates being concentrated by the solar rays obtained from Fresnel lens array is shown. We implemented this setup to utilize solar heat and generate electrical energy and it is used to charge the battery from which the load is powered

Figure 6: Hardware Implementation

The Temperature Measurement is shown below:

Figure 7: Temperature Measurement

The output measurement is shown below

Table 1
Varying voltage with respect to temperature

Temperature (°C)	*Output Voltage (V)*
42	1.5
56	1.9
62	2.2
71	3.1
87	4.2

C. Hardware Output

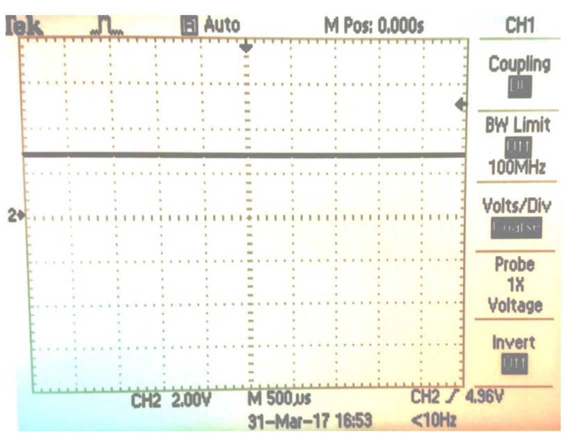

Figure 8: Input Voltage

Figure 8 indicates the output from the TEG module which feeds as the input to the elementary additional series positive output super lift converter circuit. The input voltage is in the range of 3V which is then boosted using the super lift converter circuit to charge a 12V battery for serving the load.

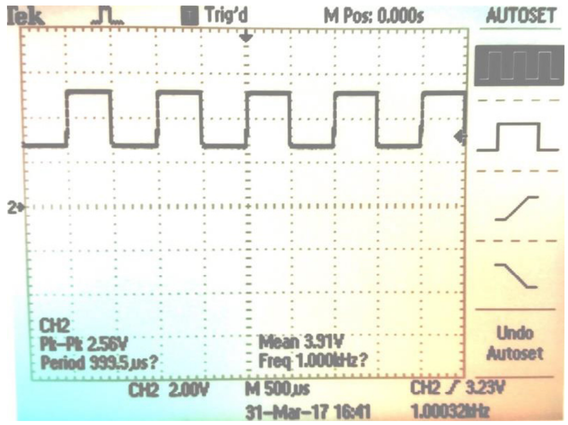

Figure 9: Input Pulse

Figure 9 represents the input pulse waveform given to the mosfet as the driving pulse from the microcontroller circuit and Figure 10 represents the boosted output voltage obtained from the elementary additional series positive output super lift converter circuit to serve the purpose of battery charging of this prototype which is further used to supply the load.

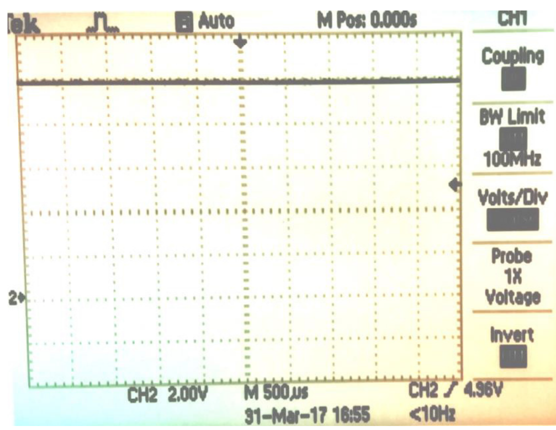

Figure 10: Output voltage

Table 2
Comparison between TEG module and PV module Properties

	TEG Module	*PV Module*
Size	Compact in size compared to the large PV array setups.	Larger in size thus occupying more space.
Weight	Heavier than the PV module array	Less in weight
Cost	Negligible difference	
Efficiency	More efficient than PV modules since there is no degrading factors like irradiation factor, shadow etc.	Lesser efficient since the output efficiency depends on many factors like irradiation factor, direction of light, shadow, temperature raise etc.
Maintenance	No maintenance required.	Requires lots of maintenance from cleaning the PV arrays from covered dust particles to alignment.
Life span	Nothing particular lasts longer then PV modules without any maintenance or services.	Maximum of 25years with proper maintenance and frequent service.

5. CONCLUSION

Extraction and conversion of solar heat into electrical energy was successfully implemented using seeback effect. Here solar heat obtained from the array of Fresnel lens concentrated on a aluminium plate is utilized and converted as electrical energy and stored in the battery. This method is more advantageous for Indian climatic conditions since we have solar heat energy for at least 8 months in a year.

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