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Design of a Biomass Cook stove with Co-generation Using Thermoelectric Generators

D.Poornima[1], S.Sangeetha[2]

Department of Electrical and Electronics Engineering,
Sri Ramakrishna Institute of Technology, Coimbatore, Tamilnadu, India.

Abstract

As of Indian census 2011, only 55.3% of rural households have access to electricity and also 63% of the rural households depend on firewood for cooking. Again, around 80% of India's rural population relay on biomass fuel for cooking. This biomass cook stove emits smoke and particles which are harmful for the people in and around the house. It is the women and children who are worst affected by this as the women in remote villages spent half of their time cooking food for the family. Keeping these facts in mind, a thermoelectric generator (TEG) equipped cook stove is developed, which achieves a cleaner fuel burning along with cogenerating electricity. A metal portable stove is used which conducts the heat of the fire inside. A thermoelectric generator strip is used to convert the heat to electricity and a converter circuit is used to maintain the desired voltage. The waste heat from the cook stove is used to run a fan.

Keywords: Thermoelectric generator (TEG); Biomass cook stove; Luo converter.

INTRODUCTION

Buoy up the use of renewable energy, efficient use of available fossil fuels; cogeneration and careful use of alternate fuels are the main mottos of the current energy sector all over the world. The ultimate aim is to reduce the carbon footprint and make the world a greener place for the future generations. India has also joined this venture but with more than 1.2 billion people, it already suffers from significant energy poverty and pervasive electricity deficits.

Another major problem faced by the people of remote Indian villages is that of cooking fuel. Statistics show that nearly 63% (105million) households in rural India depend on firewood for cooking. Only 11% of rural households report the usage of Liquid Petroleum Gas (LPG) as their primary cooking fuel (Census of India, 2011). Several interventions on access to cooking energy have been in operation for the past three decades in India through government initiated programmes like the National Biogas and Manure Management Programme (NBMMP), the National Programme on Improved Cookstoves (NPIC), National Biomass Cook stove Initiatives, the Jawaharlal Nehru National Solar Mission and the Rajiv Gandhi Gramin LPG Vitrak Yojna. All these programmes identify improved cook stoves, LPG, biogas and solar cookers as drivers to address the issue of energy access for clean cooking. The Government of India has been providing universal price subsidies on LPG for domestic cooking to accelerate to the use of clean cooking fuels for a long time now. However, this subsidy has had a limited impact on household fuel transitions across varied levels of household income groups and rural–urban landscapes [9]. Further, 23% of Indian population use crop residue and cow dung cakes as cooking fuels (Census of India, 2011).All these leads to more deforestation and that push these people into deeper poverty. They also use traditional cook stoves made of mud, built inside the house. These cook stoves emit harmful smoke and particles. It is observed that female-headed households are the worst off in terms of clean fuel use. [6]This arises from the fact that the quantity of oxygen required for burning of biomass is not sufficient in traditional cook stoves. It is from this rural scenario that we have derived our inspiration for developing a Thermo Electric Generator (TEG) equipped cooking stove which will cogenerate electricity on a small scale along with cooking the food in a cleaner way. [7] The electricity generated from this thermoelectric generator is used to drive a fan.

BIOMASS COOKSTOVE

About 2.7 billion people, or 40% of world population, are using dirty solid-fuel stoves as their main means for cooking. The people, from large part of the countries like India, China, Africa etc. do cook their food in a traditional manner using biomass and charcoal. In view of environmental changes aspects, these traditional cook stove emits high smoke and harmful particles that lead to many diseases. The use of biomass cook stoves is widespread in the rural communities of developing countries. [1]It is important to improve the efficiency of these stoves in order to reduce the global warming contribution.

An improved biomass fired stove has been developed in our laboratory and a prototype has been built. The combustion chamber is designed to achieve the almost complete combustion of wood thus increasing the efficiency and decreasing indoor air pollution. Galvanized iron sheet used to design the cook stove. The cost of the Galvanized iron sheet is cheaper. The four legs are made using iron rod. The height of the leg is 37cm. GI sheet has been wrapped around the four legs to make a box like structure. Then cooktop has been made and fixed into the box like structure. Using an iron rod, a grate of 14cm has been designed. It is placed at top of the cooktop. The ash tray is designed to collect the ash and is placed at the bottom of the cook stove. Simple, cheaper to

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build and enough space for air circulation make it emit less pollutants and smoke.

Figure 1. Biomass cook stove

THERMOELECTRIC GENERATORS

Thermoelectric generator is a device that works on the thermoelectric effect. The thermoelectric effect is the direct conversion of temperature differences to electric voltage or vice-versa. It is a major device that can convert waste heat into electricity. In the 1820's Thomas Seebeck (Germany) discovered that a thermal gradient formed between two dissimilar conductors can produce electricity. At the heart of the thermoelectric effect is the fact that a temperature gradient in a conducting material results in heat flow; this results in the diffusion of charge carriers. The flow of charge between the hot and cold regions generates a voltage difference. The emf is proportional to the temperature difference. The potential difference, $V = \alpha\Delta T$, where, $\Delta T = T_h - T_c$ and α is the Seebeck coefficient or thermopower expressed in µV. The sign of α is considered positive if emf drives an electric current through the wire from the hot to cold junction. The thermoelectric modules is made up of two different semiconductor materials which are known as Seebeck cells or Thermo elements. The TEG module has many semiconductors elements connected electrically in series to increase the generated voltage. A single thermocouple comprises of two thermo element, p-type and n-type. The thermo elements of the n and p-semiconductors are connected thermally in parallel and electrically in series. [1]. The advantages of TEGs are direct energy conversion, no moving parts and no working fluids inside, a long lifespan, no scale, noiseless operations, any working position is possible.

LUO CONVERTERS

The generated power supplies, especially from renewable source are very small. In order to make the voltage suitable for the device, a DC-DC converter is used. [10] Because of the effect of parasitic elements, the output voltage and power transfer efficiency of all DC-DC converters is restricted. The voltage lift technique is a popular method that is widely applied in electronic circuit design. It can lead to improvement of DC-DC converter characteristics. After long-term research, this technique has been successfully applied for the design of DC-DC converter. Positive output Luo converters are a series of new DC-DC step-up (boost) converters, which were developed from prototypes using the voltage lift technique. [10] These converters perform positive to positive DC-DC voltage increasing conversion with high power density, high efficiency and cheap topology in simple structure. They are different from any other existing DC-DC step-up converters and possess many advantages including the high output voltage with small ripples [10].

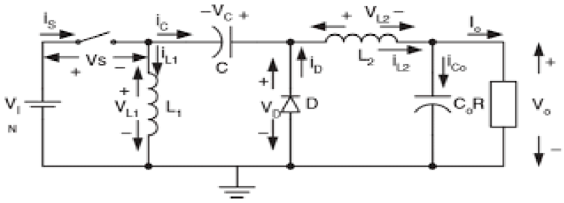

Figure 2. Elementary Luo Converter Circuit

This circuit can perform step-down and step-up DC-DC conversion. Other positive Luo converters are derived from this circuit. They are the self-lift circuit; re-lift circuit and multiple-lift circuits. Switch S in the diagram is a p-channel power MOSFET device (PMOS).It is driven by a pulse width modulated (PWM) switching signal with repeating frequency f and conduction duty k. For all circuits, the load is usually resistive, i.e. $R=V_0/I_0$. The combined inductor $L= L_1L_2/(L_1+L_2)$. The Luo converter consists of a pump circuit S-L_1-C-D and low pass filter L_2-C_0. The switching repeating period is T=1/f, so that the switch-on period is kT and switch-off period is (1-k) T. The pump inductor L_1 transfers the energy from the source to capacitor C is delivered to load R during switch-on. When the switch S turned off the current i_D flows through the free-wheeling diode D. This current descends in whole switching-off period (1-k) T. If current i_D does not become zero before switch S turned again, this state to be continuous mode. If current i_D becomes zero before switch S turned again, this state to discontinuous mode.[12]

The elementary circuit is shown in Fig 2 when the switch S is on, the source current $i_I= i_{L1} + i_{L2}$. Inductor L_1 absorbs energy from the source. At the same time inductor L_2 absorbs energy from source and capacitor C. The both current i_{L1} and i_{L2} increase. When the switch S is off source current i_I=0. Current i_{L1} flows through the free-wheeling diode D to charge capacitor C. Inductor L_1 transfers its stored energy to capacitor C. In the meantime, current i_{L2} flows through the diode D to keep continuous. Both currents i_{L1} and i_{L2} decrease. [13]

During switch off:

The charge on the capacitor increases during switch off.

$$Q_1=(1-k)T_IL_1$$

The source current at off conditions,

$$I_I = 0$$

During switch on:

The charge on the capacitor decreases during switch off.

$$Q_1 = kT_I L_2$$

The source current at on conditions,

$$I_I = I_{L1} + I_{L2}$$

During both the periods, $Q_1 = Q_2$. Thus,

$$I_{L2} = \frac{1-k}{k} I_{L1}$$

Hence, the output current is

$$I_0 = \frac{1-k}{k} I_1$$

Therefore, output voltage is

$$V_0 = \frac{k}{1-k} V_1$$

Current i_t, increases and is supplied by V_I during switch on. It decreases and is reversely biased by -Vc during switch-off. Therefore,

$$kTV_I = (1 - k)TV_c$$

The average voltage across capacitor C is

$$V_c = \frac{k}{1-k} V_I = v_0$$

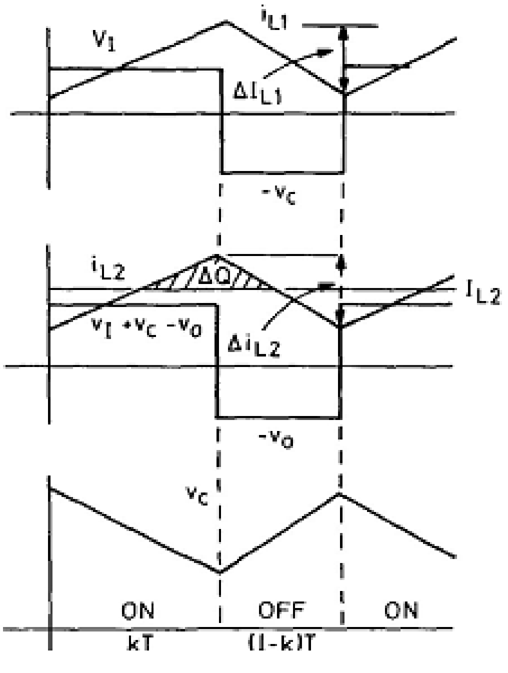

Figure 3. Luo converter waveform

Luo Converter and possess many advantages including, low or no inrush current ,low harmonics, high power density, high efficiency, simple structure, high voltage transfer gain. Based on the duty ratio, it is possible to have buck or boost operation. [10]

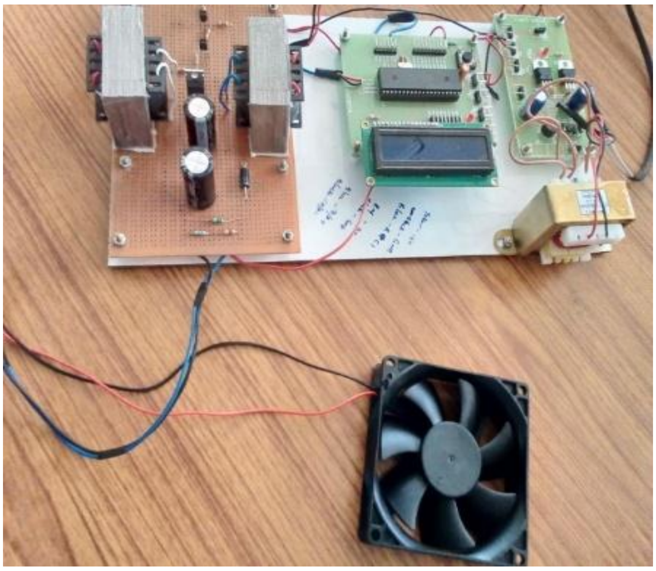

Figure 4. Luo converter

EXPERIMENTAL SET UP

The luo converter has been designed with the following parametersTABLE 1

Table Column Head	
Parameters	***Values***
L_1	3mH
C	1.1mF
L_2	3mH
C_0	1.1mF

The designed luo converter is shown in Fig.4.Both simulation and hardware of this were developed. An output of 18V was obtained during simulation and 12V in the hardware for an input of 6 V. The simulation output is shown in Fig.5.

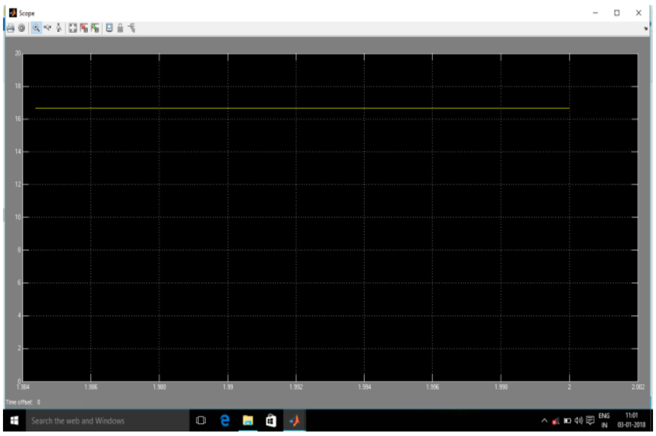

Figure 5. Luo Converter Output

Figure 6. Integrated Setup

RESULTS AND DISCUSSION

The table shows the variation of the output voltage of the TEG with respect to temperature changes. This shows that as the temperatue difference increases the output of the TEG also increases.

Table 2

S.No.	Table Column Head	
	Temperature Difference	***Output of TEG (Volts)***
1	143	0.73
2	233	1.25
3	334	1.70
4	347	2.1
5	360	2.42
6	389	2.91

CONCLUSION

This project makes use of the waste heat which is dissipated from the cook stove. This waste heat is utilized and the heat energy is converted into electrical energy by means of a TEG. This helps to create a better living environment by reducing the pollution and also serves as a source energy. Therefore, the dependence of fossil fuels for energy generation gets reduced. So, this project serves as an eco-friendly way of energy generation.

We have limited the number of TEG used. To get more energy we can cover the entire cook stove with TEG strip and harness much more energy. The conversion and utilization of this DC energy is left as future work.

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