Miniature Thermal Power Plant Using TEG Transducer For Domestic Applications

Snehanshu A.Sakhare[1], Premanand Salame[2],Amit Dethe[3], Pranjali Wankhede[4]

Department of Electrical Engineering, KDK College of Engineering, Nagpur-440009, Maharashtra, India[1, 2, 3]

[1]snehanshusakhare@yahoo.in

[2]premanandsalame@gmail.com

[3]dethe.amit1@gmail.com

ABSTRACT:Non-conventional energy systems very essential at this time to our nation. The objective of this project is to convert the Heat energy in to electrical energy using TEG Transducer device which converts heat energy into electrical energy. This energy is stored in a battery and Super capacitor's, The control mechanism carries the A.C ripples neutralizer, unidirectional current controller and 12V Rechargeable battery, from this battery supply is connected to the inverter and it is used to drive AC loads. Use of embedded technology makes this system efficient and reliable. Finally, an introduction to the new renewable energy sources and storage devices, with performance characteristics is provided in this paper.

Index Terms- Thermoelectric generator, Super capacitors, Performance characteristics of TEG & Super capacitors, Analytical model.

I. INTRODUCTION

A. Thermo Electric Generator:

The thermo electric generator (TEG) is the system used to generate power from low temperatures that is less than 1000K as heat input. It is best method for recovery of exhaust heat. It can be used in many fields such as automobiles, boilers wood stoves etc. The efficiency of a TEG depends on the thermo electric materials. The main research of the world is to use the renewable energy. The main advantage of TEG is that it uses green energy. The TEG is mainly based on the principle of Seebeck effect. The efficiency of a thermo electric generator is about 5%. A heat source provides the high temperature, and the heat flows through a thermoelectric converter to a heat sink, which is maintained at a temperature below that of the source. The temperature differential across the converter produces direct current (DC) to a load (RL) having a terminal voltage (V) and a terminal current (I).[9] There is no intermediate energy conversion process. For this reason, thermoelectric power generation is classified as direct power conversion. The amount of electrical power generated is given by I2RL, or VI.

A unique aspect of thermoelectric energy conversion is that the direction of energy flow is reversible. So, for instance, if the load resistor is removed and a DC power supply is substituted, the thermoelectric device can be used to draw heat from the "heat source" element and lower its temperature. In this configuration, the reversed energy-conversion process of thermoelectric devices is invoked, using electrical power to pump heat and produce refrigeration.[9]

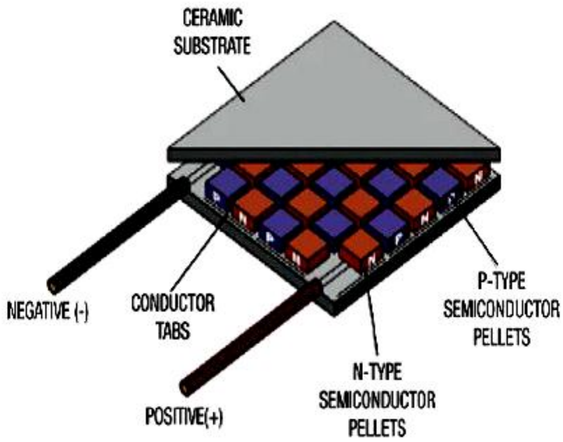


Fig.1 TEG module

B. Thermo Electric Material

Thermoelectric materials (those which are employed in commercial applications) can be conveniently divided into three groupings based on the temperature range of operation. Alloys based on Bismuth (Bi) in combinations with Antimony (An), Tellurium (Te) or Selenium (Se) are referred to as low temperature materials and can be used at temperatures up to around 450K. The intermediate temperature range - up to around 850K is the regime of materials based on alloys of Lead (Pb) while thermo-elements employed at the highest temperatures are fabricated from SiGe alloys and operate up to 1300K. Although the above mentioned materials still remain the cornerstone for commercial and practical applications in thermoelectric power generation, significant advances have been made in synthesizing new materials and fabricating material structures with improved thermoelectric performance. Efforts have focused primarily on improving the material's figure-of-merit, and hence the conversion efficiency, by reducing the lattice thermal conductivity[2].

FACTORS AFFCTING THE EFFICENCY OF TEG

- Thermo Electric Material
- Hot source
- Cold source
- Heat transfer

II. EXPERIMENTAL SETUP

The experimental setup for testing is shown

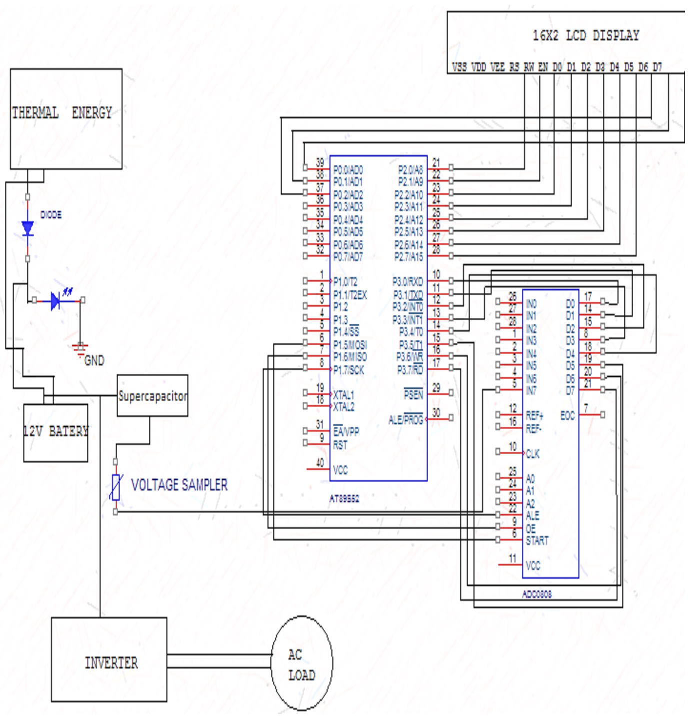


Fig: 2. Experimental setup

Fig (2) shows the connection of TEG and battery. It consist of 4 section;

1. TEG setup
2. Super capacitor
3. Microcontroller
4. Inverter Circuit

2.1 TEG SETUP: It consist of a Stand for mounting TEG made of Steel strip. TEG is made up of Bismuth Telluride material. It provides balancing base for generating components. After this candle stand is fixed and attached to the steel strip with the help of screws at the bottom of the setup. Candle stand is attached to the steel strip with the help of screws. TEG has two terminals i.e., hot side and cold side where insulation is provided to hot side of TEG likewise cold side have heat sink. TEG module is sandwich between the insulation and heat sink with the help of screws. The insulation may be of ceramic or steel, iron etc.

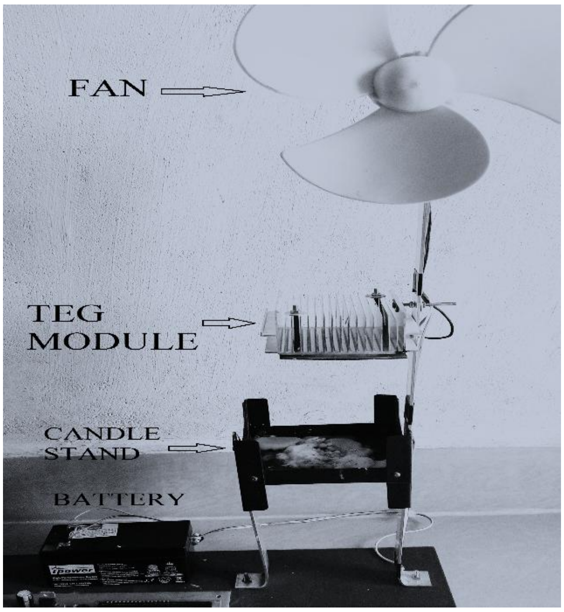


Fig:3 TEG setup

After that DC motor along with the DC load fan is fixed at the top of the setup in steel strip. This DC motor rated at 12 volt, 1.92 watt. This is the overall generating setup.

2.2 SUPER CAPACITOR SETUP: The super capacitor setup contains two super capacitors, two resistances, one diode, relay switch 4 input and output pins and LED light. The two super capacitor both rated at 1F,

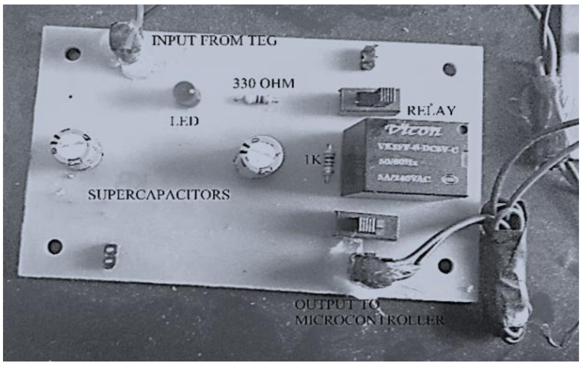


Fig: 4 Supercapacitor Setup

2.5 volt. The two resistances R1 is 330 ohm and R2 is 1K. Diode used is 1N4002. Relay switch is operates on 5V.

2.3 INVERTER CIRCUIT SETUP:The aim of the inverter circuit setup it to convert 12 Volt DC to 230 Volt AC. The inverter circuit consist of inverter, transformer and RLC circuit two capacitors C1 and C2 and 2 MOSFETS. The step up transformer 12V/180V is used. The two MOSFET are CTC2233 used.

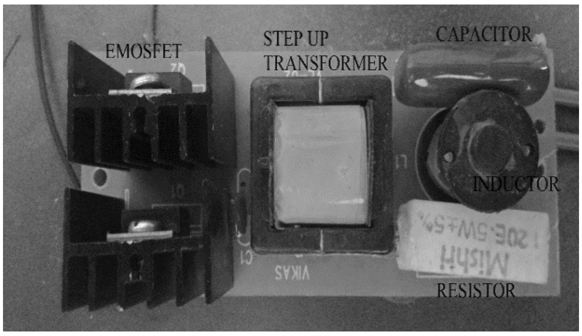
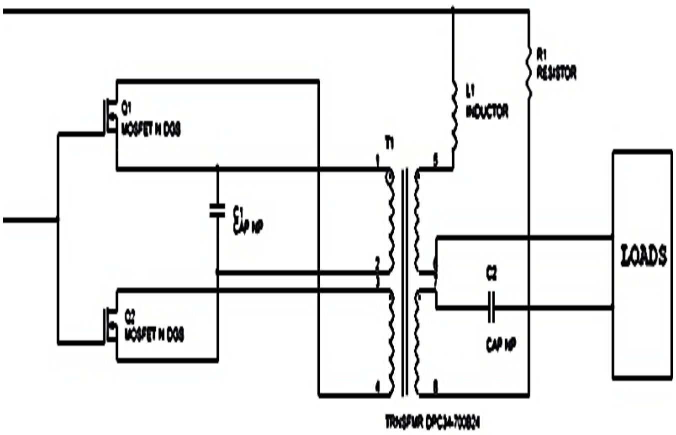


Fig: 5 Inverter circuit



2.4 WORKING: To start the generation of electrical energy we need to provide heat energy to TEG module. The candle is used to provide heat energy to the thermoelectric generator. According to the principle of Seebeck effect," the temperature difference between the two junctions of two different materials produces an electric voltage and an electric current flows when the electric circuit is closed". The TEG converts heat energy of candle into electrical energy. This electrical energy is used to run the DC motor. The fan is attached to the DC motor. The rotation of fan will indicates that the generation is started. Now this generated electrical power is used to charge the battery.

In the supercapacitor circuit one relay is connected. This relay will operate manually to charge a super capacitor. After the generation process the battery is fully charged then we will switch the relay ON and supercapacitor will start to charge. In this project we are displaying the charging value of battery on the LCD display. Now the Microcontroller come in operation which works on 5V, this 5V is taken from supercapacitor circuit.The microcontroller (AT89S52) 8 bit 40 pin IC is connected along with 28 pin (HJ940AB/ADC0808CCN) analog to digital converter .the voltage regulator IC CL7812CV is connected to a constant +5V to ADC (above toggle switch crystal oscillator, two potentiometer).

At last the output of the battery is connected to the inverter circuit. An MOSFET based inverter circuit is implemented here, which will convert the supercapacitor banks output into the 180-230v, 50Hz at the output of the inverter circuit. This is then given to the different AC loads Here the positive terminal of the Capacitor bank is connected to the two power MOSFETS Q1 & Q2.Q1 and Q2 drain terminals are connected to the primary side of the transformer (12-0-12). The capacitor C1 is connected to eliminate the ripple contents of the circuit. The 12v input is cycled by the Q1 for the positive half cycle and Q2 for the negative half cycle. In this way we will get the ac output. Then this output is used for different ac appliances. Capacitor C2 is used to reduce the ripple content of the output.

TE-GENERATOR

Based on this Seebeck effect, thermoelectric devices can act as electrical power generators. A schematic diagram of a simple thermoelectric power generator operating based on Seebeck effect.

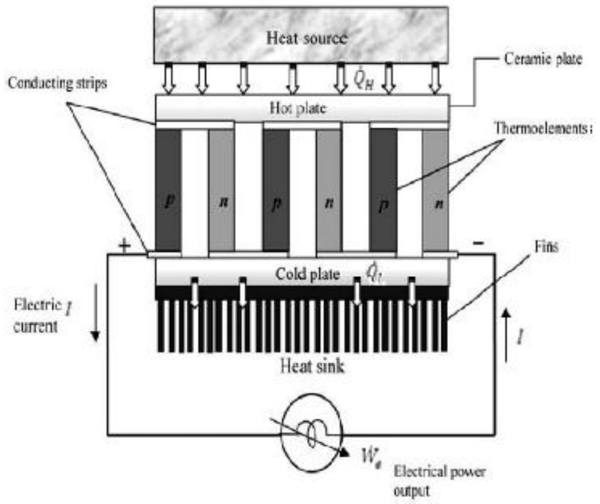


Fig: 5 principle of TEG

As shown in figure, heat is transferred at a rate of Qh from a high-temperature heat source maintained at Th to the hot junction, and it is rejected at a rate of Ql to a low temperature sink maintained at Tl from the cold junction. Based on Seebeck effect, the heat supplied at the hot junction causes an electric current to flow in the circuit and electrical power is produced.

Using the first-law of thermodynamics (energy conservation principle) the difference between Qh and Ql is the electrical power output we. It should be noted that this power cycle intimately resembles the power cycle of a heat engine (Carnot engine), thus in this respect a thermoelectric power generator can be considered as a unique heat engine.

Charge carriers in the materials (electrons in metals, electrons and holes in semiconductors, ions in ionic conductors) will diffuse when one end of a conductor is at a different temperature than the other. Hot carriers diffuse from the hot end to the cold end, since there is a lower density of hot carriers at the cold end of the conductor. Cold carriers diffuse from the cold end to the hot end for the same reason. If the conductor were left to reach equilibrium, this process would result in heat being distributed evenly throughout the conductor. The movement of heat (in the form of hot charge carriers) from one end to the other is called a heat current. As charge carriers are moving, it is also an electrical current.

In a system where both ends are kept at a constant temperature relative to each other (a constant heat current flows from one end to the other), there is a constant diffusion of carriers. If the rate of diffusion of hot and cold carriers were equal, there would be no net change in charge. However, the diffusing charges are scattered by impurities, imperfections, and lattice vibrations. If the scattering is energy dependent, the hot and cold carriers will diffuse at different rates. This will create a higher density of carriers at one end of the material, and the distance between the positive and negative charges produces a potential difference; an electrostatic voltage.

This electric field, however, will oppose the uneven scattering of carriers, and equilibrium will be reached where the net number of carriers diffusing in one direction is cancelled by the net number of carriers moving in the opposite direction from the electrostatic field. This means the thermo power of a material depends greatly on impurities, imperfections, and structural changes (which often vary themselves with temperature and electric field), and the thermo power of a material is a collection of many different effects.

III. THERMOELECTRIC MATERIALS

Among the vast number of materials known to date, only a relatively few are identified as thermoelectric materials. In Figure 3 is displayed the figure-of-merit **Z** of a number of thermoelectric materials together with potential generating applications.

Established thermoelectric materials (those which are employed in commercial applications) can be conveniently divided into three groupings with each dependent upon the temperature range of operation. Alloys based on bismuth in combinations with antimony, tellurium or selenium are referred to as low temperature materials and can be used at temperatures up to around 450K.

The efficiency of a thermoelectric generator is given by following equation:

$$\eta = \frac{\text{Energy Supplied to the load}}{Heat\ energy\ absorbed\ at\ hot\ junction} \quad (1)$$

Where the energy supplied to the load is the output power of the TEG and the heat energy absorbed at the hot junction is the input power of the TEG [1].

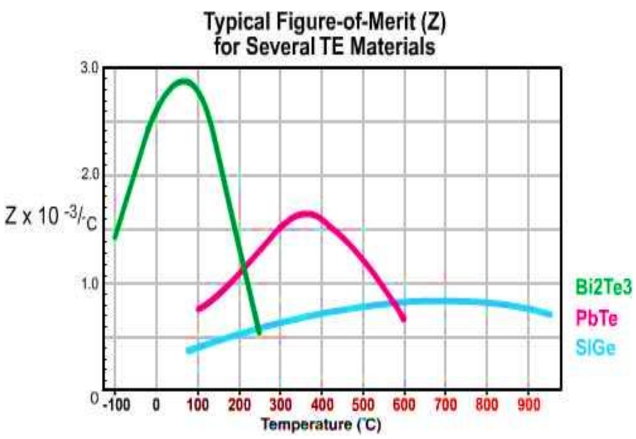


Fig:6 Performance of Thermoelectric Materials at Various Temperatures

A semiconductor power measurement used in a TEG is given as the figure of merit (ZT). The semiconductor power measurement of the figure of merit ZT is given by:

$$ZT = \frac{\alpha^2}{\mathrm{KR}} T \qquad (2)$$

where *T* is the temperature (Kelvin), α ($\alpha = \alpha pn = |\alpha p| + |\alpha n|$) is the Seebeck coefficient (*V/°C*), *K* is the thermal conductivity (*W/mK*) and *R* is the electrical resistance (Ω)[3] . In addition, the efficiency is given as a function of the *ZT* and the temperature difference between the surfaces ΔT ($TH - TC$) in the TEG. In recent years, *ZT* of the produced TEGs is higher. Therefore, it has been a significant increase in efficiency.
The TEG efficiency is also expressed in terms of Carnot efficiency. Carnot efficiency is given by following equation:

$$\eta_{max} = \frac{T_h - T_c}{T_c} \frac{\sqrt{1 + ZTm} - 1}{\sqrt{1 + ZTm} + \frac{T_c}{T_h}}$$

Fig. Shows the TEG Specifications and according to it the output of teg we get is given below:

T_h	T_c	V	I
250^0	45^0	0.39v	0.22A

HOT SOURCE

The Hot source is the waste heat of candle. A copper plate is used to transmit the heat from the candle to the generator. Copper has the high thermal conductivity and high melting point.

COLD SOURCE

The cold source is given by the air cooling system with the help of the fins. The fins are made up of aluminum. Aluminum is used because of its light weight and more cooling capacity. Based on the heat to be dissipated number of fins is calculated as 20.

Air cooling system is efficient than water cooling system and also water cooling system requires a separate tank and a circulation system.

The cold sources temperature is the room temperature and it is around 26-30°C.

Fig.6 Aluminum fin

III. RESULT

EXPERIMENT OUTPUT

The experiment setup is made and following results were inhered.

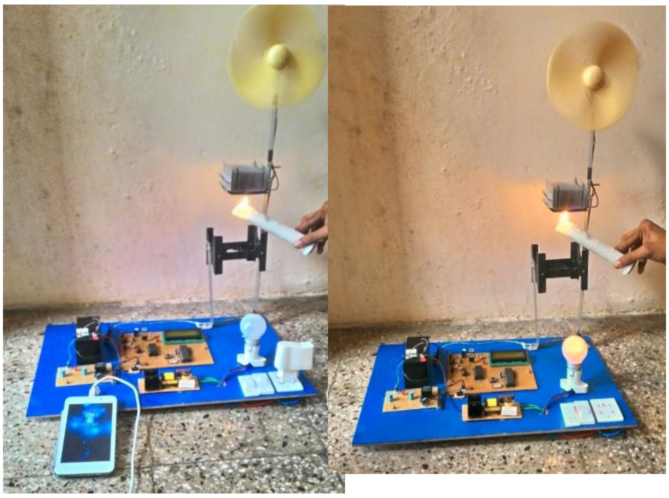


Fig: 7 charging mobile & lighting light

IV. CONCLUSION

The project **"**MINIATURE THERMAL POWER PLANT USING TEP TRANSDUCER FOR DOMESTIC AND INDUSTRIAL APPLICATIONS**"** is successfully tested and implemented which is the best economical, affordable energy solution to common people. And we are interfacing a 16X2 LCD with AT89S52 controller to have a display of the charge stored in Lead Acid Rechargeable battery.

REFERANCES

[1] Jorge Martins, Francisco P. Brito, L.M. Goncalves, Joaquim Antunes, "Thermoelectric Exhaust Energy Recovery With Temperature Control Through Heat Pipes",

P-2, Universidade Do Minho, Portugal, 2011 Sae International.

[2] David Michael Rowe, “Thermoelectric Waste Heat Recovery As A Renewable Energy Source”, International Journal Of Innovations In Energy Systems And Power, Vol. 1, No. 1 (November 2006).

[3] G. Jeffrey Snyder, “Small Thermoelectric Generators”, The Electrochemical Society Interface Fall, 2008.

[4] Sowmini priya. S, Rajakumar. S “An Energy Storage System for Wind Turbine Generators- Battery and Supercapacitor”, International Journal of Engineering Research andApplications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 2, March -April 2013, pp.1219-1223.

[5] Samuel Weaver “Thermoelectrics: The Seebeck Effect and Peltier Effect” Literature Review, November 4, 2013. Section B-Physics.

[6] Marin S. Halper, James C. Ellenbogen, “Supercapacitors: A Brief Overview”,MITRE Nanosystems Group,The MITRE Corporation, McLean, Virginia, USA. March 2006.

[7] Gou X, Xiao H, Yang S. Modeling, experimental study and optimization on low-temperature waste heat thermoelectric generator system. Appl Energ 2010; 87: 3131–3136.

[8] Barton,P,J. and Infield,G,D., Energy storage and its use with intermittent renewable energy, *IEEE Trans. Energy Convers.*, *19(2)*, 2004, 441–448.

[9] Aravind Karuppaiah, Ganesh, Dileepan., Jayabharathi, Fabrication and Analysis of Thermo Electric Generator For Power Generator,International Conference on Engineering Technology and Science-(ICETS’14).