International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Green Energy: Modeling and Simulation of Thermoelectric Generator for Production of Electricity from Air Conditioner Waste Heat

K. Kanimozhi, B. Raja Mohamed Rabi

Abstract*: *In this paper modeling and simulation of thermoelectric generator (TEG)modules is validated using MATLAB. The TEG model is developed with suitable mfiles and further the model is extended for generating electricity from waste heat liberated by air conditioners. These waste heat may lead to global warming and causes pollution. Hence this problem is addressed in this paper and thermoelectric generators are used to generate power. TEG is called a green technology as all parts are fixed and power produced is not wasted. Thermoelectric power generator converts waste heat in to electric energy. Hence thermoelectric power generation technique aids in the conversion of waste-heat energy into electrical power .So the economical wastage of thermal energy is avoided .The power production is abundant and also atmospheric pollution is avoided. As a result overall conversion efficiency of system is enhanced. The produced energy can be used for lighting a LED bulb, charging the mobile batteries.

Keywords*: *Green energy, Modeling, Thermoelectric generator modules , Waste heat.

I. INTRODUCTION

TEG's follow the principle of Seeback effect and thermal energy is converted into electrical energy [1].The advantages of TEG devices are silent operation, compact, reliable and stable. As these devices have fixed part these advantages are achievable. In spite of lesser energy conversion efficiency, TEGs are being applied in various fields due to their unique advantages. With a suitable temperature gradient TEGs can be used to utilize waste heat for production of electric power. A few applications are power generation in spacecraft systems and as thermocouples for temperature measurement. [2]

The design stages of TEGs are made easy by following suitable modeling and simulation techniques. Equivalent circuit models of TEGs have been built using SPICE software. In this technique specification from data sheets have been used for module analysis and model parameters extraction.[3] But the disadvantage is that this methodology is suitable for power electronic circuits. For waste power conversion a TEG model can be built using the Matlab/Simulink package. In Simulink package Sim Power System tool and control system tool box may be used for the development of temperature control and maximum power point tracking (MPPT) technologies .[4]

The human population in this universe relies on fossil fuels for power production. But fossil fuel are dwindling and depleting. Thus an alternative to fossil fuels are green energy production methods. These are environmental friendly with low investment. The various non-conventional energy techniques are, solar energy, wind energy, hydro energy, tidal energy, etc. These methods also have some demerits.[5].Hence in this paper, TEG equipment is modelled to generate electricity.

Solar energy is the order of the day and used in many applications, residential solar lighting system, street lighting system and agricultural purposes. But if the intensity of sunlight is less the power production efficiency will be reduced. And also storage techniques for solar energy are very costly and more research need to be done. [6]Wind energy is seasonal and as river waters are non-perennial hydel power generation is also difficult and insufficient. [7] The device by converting heat energy to electrical energy. Hence TEG is suitable power generation method for the modern society. For example, thermoelectric devices can be used in vehicles to producing electricity using the waste heat of the engine also. [8] Therefore in this paper a methodology is proposed to harness waste energy liberated form air conditioners and convert to useful electrical energy. Hence it is a green technology.

In this paper the conversion of waste heat from air conditioners is converted into electricity by using thermoelectric generator. The power generated can be used to charge mobile batteries and also storage of energy in a rechargeable lead acid battery is possible.

II. MATERIALS AND METHODS

The scope of the proposed work is primarily modelling of TEGs . Next using thermoelectric generator connecting in series /parallel maximum power has to be generated from waste head liberated from air conditioners. The generated power can be used to charge the portable equipment like laptop , mobile etc.

A. TEG Principle

Solid state devices that modifies thermal energy into electrical energy are termed as Thermo Electric Generators (TEGs). The applications of TEGS are limited to medical, military and space telecommunications due to heavy cost and poor efficiency of 5%. Similar to solar cells, an array of TEGs can be arranged in series or parallel.

Manuscript published on 30 August 2019.
***Correspondence Author(s)**
K.Kanimozhi, Professor, Electrical and Electronics Engineering, Sethu Institute of Technology, Kariapatti, Tamil Nadu, India.
B. Raja Mohamed Rabi, Professor, Mechanical Engineering, Sethu Institute of Technology, Kariapatti, Tamil Nadu, India.

This arrangement aids in achieving maximum voltage and current. The general structure of TEG is shown in Figure 1.

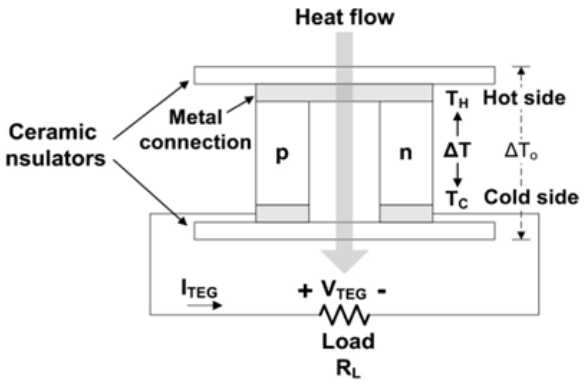

Fig. 1. TEG Model

The physical properties of TEGs are compactness, durability, and module arrangement. These properties makes TEG's distinguishably suitable for unmanned space applications. In such applications regular maintenance is not possible. The power generated from the Thermo electric modules (TEMs) is optimized by suitable maximum power point tracking algorithms (MPPT).The MPPT algorithms are of many types online, offline and hybrid. This consists of a microcontroller-operated DC-DC converter that obeys maximum power transfer theorem equalizing load and source impedances to produce maximum power.

B. TEG material selection and modelling

In the proposed work, Thermo electric (TE) modules uses segmented structures. In a structure, each material is to be positioned at their best temperature range (BTR). Generally, the BTR of TE material is chosen in such a way that ZT value is above 80% of its peak value. From the analysis made on a few TE materials various inferences were arrived. The materials have been grouped based on the BTR in automotive thermal conditions. Equivalent circuit of TEG is shown in figure 2.

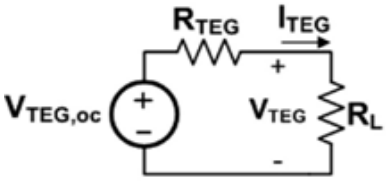

Fig. 2. Equivalent circuit of TEG

TEG manufacturers specify the following parameters for the products. The parameters are listed in table 1.

Table- I: TEG Data Sheet

S.No	*Parameter*	*Details*
1	$D_{Tmax,}$	Maximal temperature difference between the cold and hot sides of the TEC
2	I_{max}	Current input to produce D_{Tmax} for a given level of TH
3	V_{max}	Voltage input to produce D_{Tmax} for a given level of TH

In a TEC the hottest area temperature is always constant. It equals the temperature of the material used in the cooling system. Measuring the hot side temperature is easier as the surface area is outside the cooling device.

Assumptions to be made for cooling are,

$T_E = T_H$ and

T_A =¼ T_H D_T

Q_A = zero for thermal insolation.

The Simulink model of TEG user defined block is shown in figure 3. Figure 4 depicts the Simulink model of TEG module.

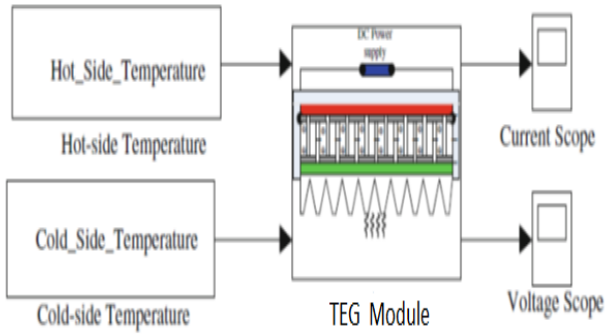

Fig. 3. Simulink model of TEG user defined block

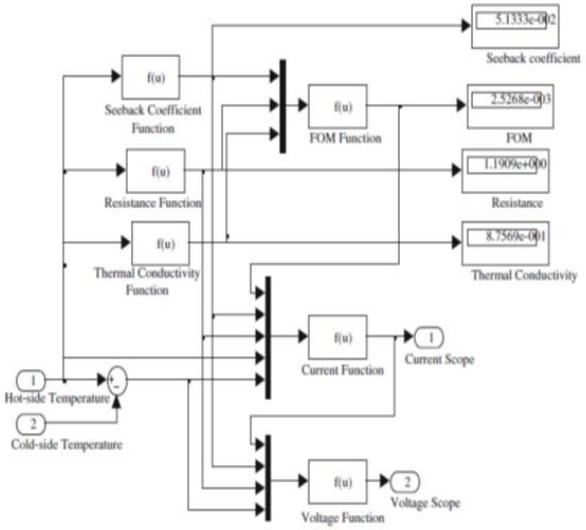

Fig. 4. Simulink model of TEG module

Hence the model developed validates the efficient working of TEG module. This would further help in hardware implementation.

III. RESULT AND DISCUSSION

A. Experimental setup and results

Generally, the purpose of air-conditioner (AC) is to maintain the indoor air quality and to provide thermal comfort inside the area. The regular use of air-conditioning system in daily life makes residences or occupants to be more comfortable especially in a warm climate country like India. The usage of split unit system are very popular for small scale application especially household.

Commonly, air-conditioning system can be divided into two categories, which are unitary refrigerant system, and the other one is centralized system. Both of these systems are known as conventional air-conditioning system, which depending on the vapor compression cycle. However, the waste generated from condenser was not fully utilize. A split AC comprises of two major units: the outdoor unit and the indoor unit. The outdoor unit is placed on or near the wall outside of the area or room which needs to be cooled. The outdoor unit includes the compressor, condenser coil and the expansion coil. The simple and elegant indoor unit comprises the cooling coil, a long blower and an air filter. In this research work, the heat liberated from the compressor discharge pipe is harnessed for power production.An air conditioning (split unit system) 1.5 Horsepower (HP), with cooling capacity 15 000 btu/hr (non-inverter) is used in this research work. The TEG module was developed to be attach at outdoor unit as shown in figure 5 to make sure heat generated can be harvest and turn to electricity.

Fig. 5. TEG Arrangement Fitted To The Exhaust Of Air Conditioner

In this section the components used in designing TEG arrangement is discussed. A thermoelectric power generation (TEPG) TEC12706 devices is installed in the discharge pipe of AC. The working principle is that

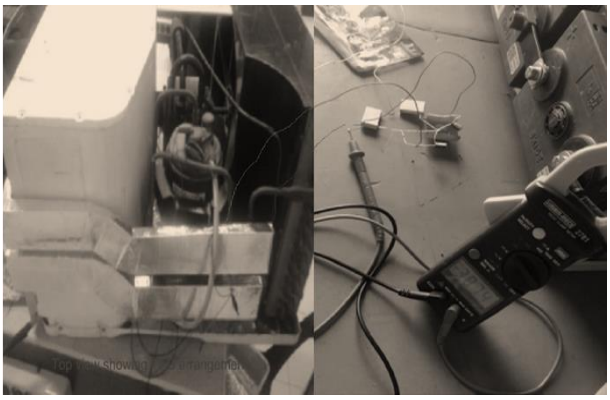

Fig. 6. Experimental Set Up Showing Measured Output Voltage

application of heat on one side causes a continuous flow of electron or holes. The flow of electrons is continuously dependent on the temperature of heat. With increase in temperature the voltage increases and with decrease in temperature voltage falls. As a result the other side of thermoelectric generator is cold.

The voltage generated from the TEG is to be regulated to a required level to charge mobile batteries. The regulated voltage is sent to the battery terminal to charge the mobile. The voltage level produced is in compliance with the required specification: 3.8 v li-ion batteries. The mobile battery charges consistently under desired voltage condition. LED lamp indicates the charging state in mobile battery. An Inverter is installed for the conversion of variable dc to fixed ac voltage.

A complete set up of TEG arrangement fitted to AC to harness electrical energy is shown in figure 5. The waste heat discharged form discharge pipe in the hot side is absorbed by the TEG. Now heat absorbed in the one side is rejected on the other side ie. Cold side. Hence heat is transferred from hot surface to cold surface. Due to change in temperature a thermal gradient is produced and so electron will flow through copper conductor in the entire circuit. Regulation of voltage is achieved. Finally the voltage required to charge the mobile battery is obtained at the output terminal and the value is 3.8 volt .The figure 6 shows the voltage generated.

Heat transfer originates from heat applied side and finishes of in the cold side. The connection scheme of TEGs with two terminals are : positive terminal is connected to diode and the other terminal is connected to ground. Circuit elements are listed in table 2.

Table- II: TEG Control Circuit Specifications

S.No	*Circuit element*	*Type and Rating*
1	Diode	BY127
2	Potentiometer	10kpot
3	Capacitor	50micro farad
4	Zener diode	6v
5	LED	3.5v
6	Mobile battery	3.8v

An array of TEGs are to be connected in cascade to generate maximum voltage. The advantage of using diode is that it avoids the reverse flow of electron to TEG. Hence continuously electron flow is achieved through diode .The voltage control is made possible with Potentiometer .Zener diode acts a s a regulator and maintains voltage at required level. Hence excess voltage flow to the battery is negelected. LED acts as an indicator depicting that battery is charging. LED does not glow when there is no voltage or voltage is more than 3.5 volt .This work can be used for reducing the waste heat liberated into atmosphere leading to global warming and so many environmental effects. This system generates 3.8 V which is capable to charge a mobile battery. Hence this methodology can be rightly called as green technology.

IV. CONCLUSION

Thus the proposed methodology has produced green energy in a economical way of power generation method for mobile battery charging as well as to store charge for future use. The proposed methodology aids in reducing waste heat liberated into atmosphere causing ecological imbalance. An experimental work has been carried out to probe into the electricity production by using a TEG fitted to 1.5 ton airconditioner outlet.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The characteristics of TEG was validated in an open circuit mode by connecting the multimeter directly to the TEG and in a closed circuit mode by connecting different load to the TEG. The research findings shows that an output voltage of 1 V and 30 mW power is generated in open circuit condition. Also TEG could generate an output voltage of 0.5 V and 25 mW in the closed circuit conditions. During these cases the maximum temperature differences across the TEG is about 21 °C. The power output could be increased by using more than one TEG module. The generated power shall charge a mobile battery or LEDs during cooking. Further the research can be extended to charge all portable device batteries.

ACKNOWLEDGMENT

The authors would like to thank the management and Principal of Sethu Institute of Technology for their continuous support.

REFERENCES

1. K. Kanimozhi , B.Raja Mohamed Rabi , “Parameter analysis method for enhancing efficiency of photovoltaic cells” International Journal of Chemtech Research, No. 9, 2016,pp.276-281.
2. M. F. Remeli, K. Verojporn, B. Singh, L. Kiatbodin, A. Date, and A. Akbarzadeh, “Passive Heat Recovery System Using Combination of Heat Pipe and Thermoelectric Generator,” Energy Procedia, vol. 75, 2015,pp. 608–614.
3. K. Kanimozhi , B.Raja Mohamed Rabi, “Development of Hybrid MPPT algorithm under partial shading conditons for low power applications”,Journal of Electrical Engineering,17(2)2,2017,pp.1-6.
4. K. Kanimozhi, A. Shunmugalatha , “Maximum peak power tracking of photovoltaic systems using adaptive sliding mode controller”, International Journal of Applied Engineering Reserach., Vol.10,2015,pp.3073-3078.
5. B. Orr and A. Akbarzadeh, “Prospects of Waste Heat Recovery and Power Generation Using Thermoelectric Generators,” Energy Procedia, vol. 110, no. December 2016, pp. 250–255,
6. ASHRAE, ASHRAE Handbook 2013, American Society of Heating, Refrigerating and Air Conditioning Engineers (Fundamentals). 2013.
7. B. Orr, A. Akbarzadeh, M. Mochizuki, and R. Singh, “A review of car waste heat recovery systems utilising thermoelectric generators and heat pipes,” Applied Thermal Engineering, vol. 101,2016, pp. 490–495.
8. S. B. Riffat and G. Qiu, “Comparative investigation of thermoelectric air-conditioners versus vapour compression and absorption air-conditioners,” Applied Thermal Engineering, vol. 24, no. 14–15, 2004,pp. 1979– 1993.
9. K. Kanimozhi ,B.Raja Mohamed Rabi, “Hydrogen synthesis from solar reactor using reverse Photosynthesis “International Journal of Chemtech Research, Vol. 10,No. 9, 2017,pp.212-219.
10. K. Kanimozhi ,B.Raja Mohamed Rabi, “Neural Network Controlled Primitive Fault Analysis and Monitoring of Wind Turbine Gear Box”, International Journal of Recent Technology and Engineering,vol.8(2),2019,pp.764-768.

AUTHORS PROFILE

Dr.K.Kanimozhi,is a Professor, of Department of EEE in Sethu Institute of Technology. She completed her BE in EEE department at Thiagaraja College of Engineering.She completed her M.E in Applied Electronics at Anna University. She has completed her Ph.D at Anna University Her research interests are artificial intelligence, Renewable energy and Power Electronics. She is a member in ISTE and IAENG.

Dr.B.Raja Mohamed Rabi,is a Professor, of Department of Mechanical Engineering in Sethu Institute of Technology. He completed his BE in Mechanical Engineering department at RVS College of Engineering and Technology. He completed his M.E in CAD at Madras University .He has completed her Ph.D at Anna University His research interests are artificial intelligence, Machine Design, Renewable energy and Optimization. He is a member in ISTE and IAENG.