Solar Heated Thermoelectric Generator

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Abstract:

Fossil fuels are the non renewable energies which are used as majority for fulfilling our desires of fuel, energy and Power. According to EIA report 2012 the whole world is dependent on 67 % fossil fuels for the production of electricity. This shows our dependency on fossil fuels. Fossil fuels have a number of disadvantages and will come to an end on day. They are not environment friendly. The use of fossil fuels has increased the ratio of CO_2 in the atmosphere, thus responsible for global warming. The price of fossil fuels is not stable and fluctuates too much due the monopoly of Multinational companies. Moreover they are also responsible for acid rains too. These acid rains have affected the agriculture which in turn has affected directly the health of human beings. The biggest disadvantage of fossil fuels is that the rate of consumption of fossil fuels is very much greater as compared to rate of production. These harsh drawbacks of fossil fuels make us to move towards renewable energy sources.
Renewable energy resources are that resources that are sustainable. They will never come to an end. They use natural resources for the generation purposes. They have no hazard to the environment neither they have any harmful yield. Thermoelectric generators are also the renewable energy devices that convert heat difference directly into electricity. One side of TEG is kept hotter by some source and other is kept cold. This difference in the temperature on the both sides of the TEG is responsible for the production of electricity.

Index Terms: Thermoelectricity, thermoelectric devices, solar heating

I-Introduction

Fossil fuels are used as major source for the production of electricity. There are a number of problems that arises due to the use of these fossil fuels. The main problem is of Global warming. The use of fossil fuels is peaking. Fossil fuels give CO_2 which results in global warming. The ratio of CO_2 is highest in the history of Humans. Fossil fuels are responsible for the 56 % CO_2 released in the atmosphere [1].The Global temperature of the Earth that rise in the 150 years from 1850-1900 was 0.78 %(0.72-0.85 ^{0}C) which changed to 0.85%(0.65-1.05 ^{0}C) from 1880 to 2012.During the last 15 years the global temperature changed 0.05 % and it is expected that this temperature will give rise to 2 ^{0}C until 2100[2].

The prices of Fossil fuels fluctuate too much and therefore are not stable. The price of fossil fuels were at 100$ per barrel in 2008 which is 57.6$ per Barrel according to 28th May 2015.During the last 3 months, there was an increase in 13.4 % in the crude oil prices from February 2015 to May 2015 .

Fossil Fuels are subjected to several oil leakages thus impacting the life of aquatic habitat. It is estimated that the 47 % of crude oil is entering to the marine environment from natural seeps, whereas 53% results from leaks and spills during the extraction, transportation, refining, storage, and utilization of petroleum. The amount of natural crude-oil seepage is currently estimated to be 600,000 metric tons per year, with a range of uncertainty of 200,000 to 2,000,000 metric tons per year[3].A disaster took place at Gulf of Mexico, On April 2010 where British Petroleum rig exploded, thus killing 11 workers on work and spreading tens of thousands of Barrels of crude oil into to the Gulf Of Mexico[4].It killed a lot of aquatic habitat Including 125 dolphins in the 3 months of this Leakage. [5]

Keeping in view all the aspects it is the need of hours that we should move towards renewable energies. Although the work is done renewable technologies but that is not enough. The trends have shifted from non-renewable energies to renewable energies In 1980 the whole world was dependent on 74 % fossil fuels which has reduced to 67% in

2012.European countries are at top who made more progress in terms of renewable energies. In 1980 European countries were dependent 73% fossil fuels for the production of electricity. In the last 35 years, they changed their trend and they made a great effort to reduce their dependency on fossil fuels. In 2012 they were depending on 47 % fossil fuels for the production of electricity.[6]

Renewable energy sources include wind, solar photovoltaic, hydroelectric, geo thermal, tidal, biomass, nuclear and thermoelectric generators. All the renewable energies are of worth importance yet the consideration needs to be paid on thermoelectric technology to get its benefit on large scale for the production of electricity.

Thermoelectric generators are the devices that generate electricity by using thermoelectric effect, which states that temperature difference can be directly converted into electricity. These devices uses an effect known as "seed beck effect" for the production of electricity, named after Thomas Seed Beck who invented this phenomenon in 1821.

Thermoelectric generators have a very low efficiency typically up to 5 %.A bi-Te Based thermoelectric module having figure of merit of thermoelectric generators ZT=1 and operating at 200K temperature difference will have an efficiency of maximum 5 %.[7] .Efforts can be put to increase the efficiency of thermoelectric generators.

One side of TEG is kept cooler and other is hotter and thus we get the power as output. Sunlight is the biggest sources of renewable energy and we have abundant sunlight falling on this earth. It is estimated that Earth is receiving energy at the rate of 120 Petawatt (peta=10^{15} watts). This in turn means that the total energy received by the earth surface is enough to fulfill the energy requirements for the coming 20 years [7].All we need is to utilize this energy in an efficient way. Most of this sunlight energy is wasted. We can utilize this waste energy to utilize them for the generation of electricity.

We can utilize this sunlight to focus it on the TEG hotter side. Hotter side of TEG module can be directly exposed to sunlight or we can use solar concentrator to concentrate sunlight and focus it on hotter side of TEG. Different devices can be used as solar concentrators like parabolic dishes, convex lenses, Concave mirror and solar troughs. Although light can be concentrated, yet we are using Solar light to experiment only. We will utilize this solar light only to see our results. In Pakistan we have 1700 to 2200 hours sunshine per year with solar radiation approximately 2000 KWh/m^2[8]

There can be a number of ways through which we can make other side of thermoelectric generator cooler .This includes circulating the water on the cooler side of the thermoelectric generator. The other option can be touching ice to the cooler side of thermoelectric generator. The second option is good and can result in more efficient cooling of thermoelectric generator module.

The module used for this purpose is TEC 1-12706.This module is 60 Watts in rating. The Dimensions of this module is 40mm*40mm*4mm.This module is composed of Alumina as its ceramic material. Solder construction is made at 138^{o}C.

There can be 2 ways to increase the efficiency of thermoelectric modules.

1-Improve ZT characteristics of thermoelectric module

2-Concentrate sunlight to increase the temperature difference on both sides.

Second option will be under consideration in this experiment. Solar heaters will be used to concentrate the sunlight and pass it to module.

II-Experimental Setup:

An Experimental setup is necessary to prove our results. Figure.1the block diagram of Experimental setup

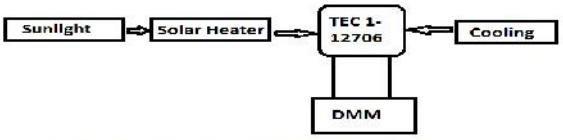


Fig.1 Block Diagram of Eperimental Setup

The radiations coming from the sunlight can be made to store by solar heater. The material used for the preparation of Solar heater is Zinc Metal sheet having a thermal conductivity of 116 $W \cdot m^{-1} \cdot K^{-1}$ .A glass sheet is used and Zinc metal sheet plate is made black in order to absorb more radiation and make the zinc Metal sheet hot in less time. In order to make this solar heater working efficiently we need to insulate the heat so that it may not flow to the outer atmosphere. Polystyrene have a very low thermal conductivity (0.033 $W \cdot m^{-1} \cdot K^{-1}$) and therefore is a very good insulator. Basically this technique is inspired by greenhouse effect and black body to maintain temperature which is needed for operation. Using this Technique We achieved our desired temperatures from this technique. 84^{o}C temperature was achieved on the inner surface of solar heater and 75^{o}C on the outer surface of the Solar heater. This 75^{o}C which is going to touch the hotter side of TEC module is enough to give us good results.

Fig.2 Temperature achieved from solar heater

The change in temperature is directly proportional to voltage on the output side of the TEC. Nothing can be better than ice bags in such a condition. Ice bags are cool and are very helpful in keeping the cooler side of Module cooler. They will serve 2 purposes. They will maintain the temperature of module and will prevent the module from overheating.

III-**Calculation and results:**

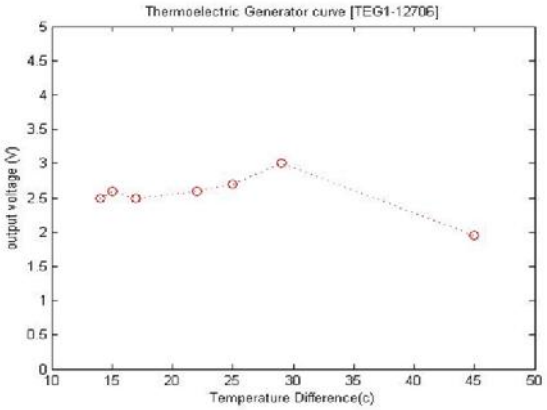
Sunlight is preserved by solar heater and transferred to the hotter side of module. The lower side is maintained cool by cold water aided with ice bags. Output can be seen by attaching a Digital Multi-meter to the wires of the module.

These reading are shown in the Table below

Hotter side Temperature (T_1)	Cold side Temperature (T_2)	Change in Temperature ($\nabla T = T_2 - T_1$)	Open Circuit Voltage (V_{oc})
56	42	14	2.5
61	46	15	2.6
53	36	17	2.5
61	39	22	2.7
56	33	25	2.77
59	30	29	3

Table 1 Temperature versus Voltage Readings

Figure 3 shows the graphical representation of table 1



It is evident from the table 1 and figure 3 that rise in temperature is directly proportional to voltage produced. This is what see beck effect says. This can be stated by the Formula Below

$$\nabla V = \alpha \nabla T \quad (1)$$

Where

∇T=Change in temperature

∇V=Open Circuit Voltage corresponding to change in temperature

α =See Beck Coefficient

α can be calculated by putting the values in equation.1

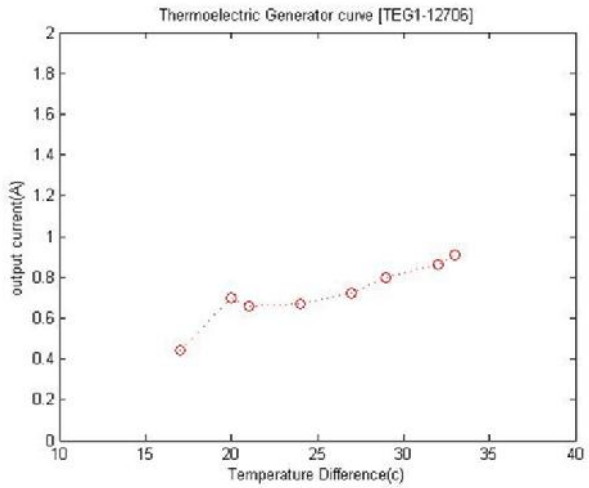
$$\alpha = \nabla V / \nabla T$$

α=3/30

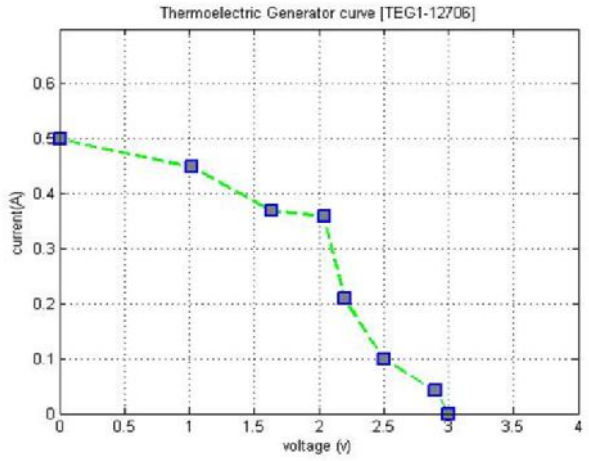
α=.1 v/^{0}C (417 µV/K)

This means that for 0.1 volts will be produced per change in ^{0}C of temperature. Generally the modules having the see beck coefficient of 100-300 µV/K are considered good. So Good results can be carried out by this thermoelectric module.

The graph of temperature gradient versus output current is shown in figure 4



The output voltage versus output current is shown by the figure 5



What we have major concern with is none other than the output power of the module. The output power can be calculated by the equation given below

$P=V_m * I_m$ (2)

The calculation of the power of Tec 1 12706 is done in the Table 2

Resistance (ohm)	Open Circuit Voltage (V_m)	Short Circuit Current (I_m)	Output Power ($P=V_m*I_m$)
Open	3	0	0
68.8	2.9	0.042	0.122
24	2.5	0.1	0.25
10.5	2.2	.21	0.46
5.5	2.04	0.37	0.75
4.5	1.64	0.36	0.59
2.2	1.02	0.45	0.46
Short Circuit	0	0.5	0

Table 2: Output Power Of Tec 1-12706

We have got 0.75 Watt as output power from a single module having area of $16cm^2$ (4cm*4cm).Power per centimeter square can be found by

16 cm^2 produce power=0.75 watts

1 cm^2 will produce power=0.75/16= 0.046 Watt

1 m^2 will produce power=0.046*10000=460 Watts.

A-Comparison with Photovoltaic solar cells:

Photovoltaic power per m^2= 120 Watts

TEG power per m^2 =460 Watts

It can be clearly seen that thermoelectric generator is capable of giving 4 times more power generation than solar photovoltaic cells.

Let's make a comparison of solar photovoltaic cells and TEG in terms of cost.

Value	Solar Photovoltaic $	Thermoelectric generator $
Custom available data	66.6 ($6480cm^2$)	1.94 ($16cm^2$)
Cost per 1 cm^2	0.0102	0.12
Cost Per 1 m^2	102.77	1212

Table 3: Analysis of Cost per m^2 Of TEG and PV solar cells

Table 4 shows the comparison of TEG and PV solar panel in terms of comparison of cost per watt

Value	Solar Photovoltaic $	Thermoelectric generator $
Custom available data	66.6 (100 watt)	1.94 (0.75 watt)
Cost per Watt	0.66	2.586
Cost Per KW	666	2586

Table 4: Analysis of Cost per Watt

There is a huge difference when it comes to price, but that thing is of no worries since solar photovoltaic was expensive from thermoelectric generator in its early stages. In 1954, Calvin and Daryl Chapin created the silicon solar cell that costs 286 US $/ Watt. Comparing it with early solar silicon solar cells, thermoelectric generators will no longer be looking costly.

IV-Conclusion:

Thermoelectric generators can give 4 times more power than solar photovoltaic cells. They have a number of more advantages as compared to solar photovoltaic cells. Solar photovoltaic panel can operate in day light only. The result get worst if the day is cloudy. There is no such matter with thermoelectric modules. They can keep on running for 24 hours continuously. In the day time they can run with solar light and in the night they can be run by getting heat from phase change materials (PCM's). Locally installed hot water pipes are also good option. TEG's have life time up to 20,000 hours. Although they are expensive but in the coming few decades they are going to be cheaper than Solar photovoltaic. They can be considered as best competitors of Solar photovoltaic cells. In the coming few decades the market will be of TEG, that's sure.

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