Thermoelectric Effect – An Alternative Energy Source

Mohini Kher
Electrical department
Fr. C..Rodrigues Institute of Technology,
Vashi, Navi Mumbai, India

***Abstract*—In recent years the energy demand is increasing tremendously. To fulfil the demand major conventional energy producing sources require large/mega capacity plants. Along with that the importance of non-conventional energy sources is also getting emphasize due to their advantages such as fuel is free of cost, availability of fuel, less transmission losses etc. consequently solar energy (photovoltaic/thermal);wind energy are very popular. The Seeback effect also can be used to produce the small amount of electricity from the various places where heat produced is a loss in the process. Thermoelectric generators which are used to generate electricity can play important role in achieving sustainable energy solution.**

In this paper a study of thermoelectric generation (TEG) is done to observe the effectiveness of temperature difference to produce electricity from the waste heat of various equipment.

Keywords— ***Thermoelectric generation, waste heat, thermoelectric cooling***)

I. Introduction

The non-conventional energy sources such as solar photovoltaic, solar thermal, wind energy, tidal energy etc. are playing key role in the electricity generation. The awareness about these sources is increasing in the society and people are looking towards these resources as future. The technology is developing very fast to increase the efficiency and reliability of these sources and further research is going on in the same direction.

Besides this the conventional sources which are using combustion for producing energy for various applications such as for driving vehicles, production of electricity, cooking etc. also has major losses in terms of heat. This heat can be used to produce electricity with the help of Seeback effect. The effect if it is used in the reverse manner can be used as Thermo Electric Cooler(TEC) also which is known as Peltier Effect.

In this paper, the study of basic theory of electricity generation and cooling effect has been done [1]. The various resources like geothermal [1] earthen gas stove[2] for production of electricity are studied. Thermoelectric refrigeration [3] and as anemometer [4] are also studied. As solar photovoltaic and thermoelectric both works on temperature effectiveness the comparison of both has been studied[5] and it is found that TEG is also equivalent and effective as PV.

II. Conventional Sources

So far today's electrical energy production is utilising generators based on electromagnetic induction. Reciprocating steam engines, internal combustion engines, and steam and gas turbines have been coupled with such generators in utilizing chemical heat sources such as oil, coal and natural gas and nuclear heat for the production of electrical energy. All these power plants designs have, however, a common disadvantage; the conversion of thermal energy into electric energy is accomplished by the utilization of moving and wear-subjected machinery. The massive mass of equipment, the process irreversibilities , complexities of controls & operation involved in these conversion methods propel the need of more direct method for conversion of thermal energy into electrical energy with no moving parts. The degree of directness of a particular conversion process may depend on whether the original form of the energy is chemical, solar or heat. There are several methods known for direct conversion of thermal energy into electricity,
such as:

- the thermoelectric conversion,
- the thermionic conversion,

III. Thermoelectric Effect

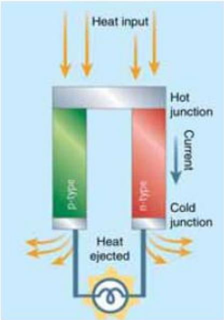
Thermal energy is usually a byproduct of other forms of energy such as chemical energy, mechanical energy and electrical energy. The process in which electrical energy is transformed into thermal energy is called Joule's Effect. This causes wires to heat up when currents flows through them.

When two ends of a conductor are held at different temperatures, electrons at the hot junction at higher thermal velocities diffuse to the cold junction and produces EMF between two ends. Similarly the junction of two dissimilar materials has diffusion current which produces magnetic field and EMF is induced at a junction. The EMF produced between the two junctions depends on the material and on the temperature difference. The potential difference can be calculated with help of Seeback coefficient S.

$$\nabla V = S \times \nabla T_{12} \quad (1)$$

Where ∇V – Potential difference produced
S – Seeback coefficient
∇T_{12} - .temperature difference at junction

Thus the core component of thermoelectric model is thermocouple. The thermocouple consists of two dissimilar semiconductors as p type and N type are connected together by a metal plate. Thermoelectric generation occurs when the couple is put in a thermal gradient by making top plate hotter than bottom plate.



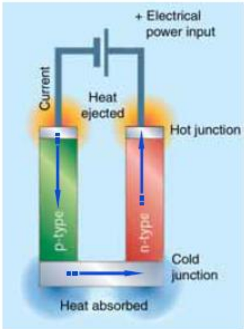


Fig.1 Thermoelectric Generator[1]   Fig.2 Thermoelectric cooler   [1]

Thermoelectric cooling occurs when current is supplied to the junction. In this case thermocouple cools on one side and heats up other side. This is called as Peltier effect.

IV. THERMOELECTRIC GENERATION

Thermoelectric generation is possible wherever the sufficient temperature gradient is available. The temperature difference between two legs of thermocouple produces voltage or potential difference in them and when load is connected across it, current starts flowing through it.

The main advantages of thermoelectric generation with non-moving parts over moving parts, maintenance requirement, the high modularity possibility of utilizing heat sources over a wide temperature range. Efficient solid state energy conversion based on the Seebeck effect calls for materials with high electrical conductivity σ , high Seebeck coefficient α and low thermal conductivity λ .

TABLE.I TYPICAL MATERIALS FOR DIFFERENT TEMPERATURES

temperature	Low 300-450K	Intermediate (upto 850K)	High Upto 1300K)
Material	Bi	PbTe	SiGe

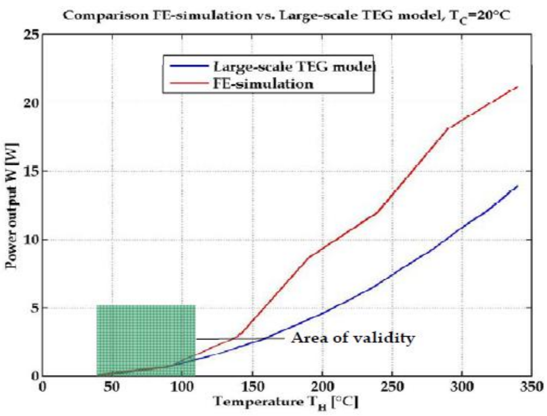


Fig. 3. Typical power output from TEG

For commercial electricity generation it is necessary to seriously consider generation costs. Thermoelectric suffer from low efficiency, however, when the heat source is nearly free of charge the low generating cost will offset the capital cost of the thermoelectric generator over its lifetime..

Temperature gradient is available in geothermal energy[1], cooking stove[2], in automobile inlet and exhaust etc.

In geothermal energy extraction the heat from the depth is taken and inserted on the hot side of the TEG[1]. With typical parameter values of a temperature difference of 60 K, a heat transfer coefficient of 1000 W/m^2K and considering heat transfer tubes of 10 m length and a cross sectional area of a 55x15 mm^2 an overall system efficiency of 1.1% and a characteristic minimal volume of 0.25 m^3/kW appears achievable with the type module investigated [1].

The other source of TEG studied is integrated biomass operated earthen cook stove[2]. Heat energy production with burning of coal, wood, cow dung is a very usual technique in rural areas. The thermoelectric generator module is integrated with a double chambered forced draft cook stove. The voltage generated by TEG can further be step up with DC to DC converter. This is used to run the fan. The fan serves two purposes one of it is to cool the second side of thermoelectric unit and another one is to provide the additional air for burning of fuel for cook stove. This improved air-fuel mixture makes the effective burning of fuel. The construction is shown in fig. 4.

Fig 4. Front and rear view of integrated cook stove[4].

The heat produced in vehicles also can be utilized to produce electricity. The temperature of exhaust gas of vehicle is very high. The temperature gradient can be obtained between exhaust pipe temperature and a pipe carrying engine cooling fluid. The researchers of BMW and Fraunhofer Institute are trying this technology in BMW 535i model. the test car is using TEG instead of alternator in this model.

V. COMPARISON OF THERMOELECTRIC GENERATION AND PHOTOVOLTAIC CELLS[5]

Thermoelectric generators (TEG) are devices that convert temperature differences into usable electricity. TEGs are made from thermoelectric modules which are solid-state integrated circuits that employ three established thermoelectric effects known as the Peltier, Seebeck and Thomson effects. TEGs require heat as an energy source and can generate power as long as there is a heat source such as gas or oil flame, stove, camp fire, industrial machinery, and furnace. Solar modules which convert light energy into usable electricity need direct sunlight to generate maximum rated power. Usually solar tracking systems are used to receive direct sun light to increase the efficiency of the modules. This type of setup increases the cost of the photovoltaic systems. The studies indicate efficiency, power generation capability and capacity, cost, size, potential consumer applications, and system installation complexity to generate power. Devices were tested as per the required input conditions and potential application envisaged at site. A solar PV module was tested under sun light whereas TEG module was tested inside an air conditioner condenser unit on same days. Table 2. Gives the comparison between TEG and PV with respect to cost, area required, weight and power output.

TABLE II. COMPARISON OF TEG AND PV

	Cost in $	Area requied (sq.in)	Weight (lbs)	Power output (watt)
Solar	250	760	18	65
TEG	400	20	0.56	19.1

VI. CONCLUSION

Depending on the application, one of the two types may be preferred. In some applications, the size of the energy generation module maybe a concern; TEG may be considered if there is sufficient input available to generate power output. For the solar module, as long as sunlight is available, the solar module will generate power. It implies that for indoor design applications TEGs are effective candidates to generate power. However, it is not easy to reach an appreciable amount of temperature difference such as 150□F – 300□F. Costs of solar modules have been rapidly dropping, making them good candidates for energy generation in appropriate climates. For the space required, TEGs are good modules when compared with solar panels. TEGs are better than a single solar module in terms of weight. For comparable power output of a single solar module there may be multtiple TEGs connected together which increases the cost of TEGs. This can become a disadvantage of TEGs when compared with solar panels. However, weight and size (area) are still advantages of TEG modules for the appropriate application, environment and power requirement.

REFERENCES:

[1] Mr. Andreas Bistchi “Modelling of Thermoelectric devices for electrical power generation” DSc dissertation “Swiss Federal Institute of Technology, Zurich – 2009

[2] Risha Mal et al “Thermoelectric Power generator Integrated : A sustainable approach of waste heat to energy conversion”, IJRET-e ISSN: 2319-1163, Vol.3, Issue-12, June 2014.

[3] C.E.Paghi et al “ Circuit topologies for Peltier effect anemometer”-Laborotorio de Circuitos Integrados-LCI

[4] Manoj Kumar Rawat et al “ A review of development pof thermoelectric refrigeration and air-conditioning system: A novel potential green refrigeration and air conditioning technology”-International Journal of Emerging technologies and Advance Engineering,Vol.3 sp. Issue 3 Feb 2013, pg 362-367

[5] Dr. Frank Yidliz et al “ An applied comparison study: Solar Energy Vs. Thermoelectric 120th ASEE Annual conference and Exposition, Atlanta, June 23-26, 2013,paper ID: 5845