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Design and Development of Prototype for Generation of Electricity Using Seebeck Effect

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Abstract-In this work, effort is made to design a device which can generate electricity, by getting heat from hot water from solar water heater , when it is not needed. It works on the principle of seebeck effect. A hot water junction and a cold water junction are created and peltier modules are sandwiched between them. Then according to seebeck effect, emf will be generated in peltier modules. The device is likely to recover its cost in less than 3 years.

Index Terms- Seebeck effect ; Peltier module ; Solar water heater; Electricity.

1. INTRODUCTION

Solar water heaters are generally used for heating water in winters only. While in summers, space occupied by solar water heater and money invested in their installation become idle. So, a device is developed to bring solar water heaters into use for whole the year. As hot water from solar water heater is waste in summers, it can be used to create hot water junction for peltier module and cold water junction can be created by flowing cold water from general purpose tank through it. As there is temperature difference between two junctions, peltier module can be sandwiched between these hot water junction and cold water junction. Due to temperature difference on both sides of peltier module, according to seebeck effect, it will generate electricity.

In general, hot water from solar water heater is needed for use approximately 5 months a year. For other 7 months they remain idle. So, they can be utilized to produce electricity using peltier modules which works on the principle of Seebeck effect. According to Seebeck effect 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. Seebeck discovered that making one end of a metal bar hotter or colder than the other produced an EMF between the two ends. He experimented with junctions (simple mechanical connections) made between different conducting materials. He found that if he created a temperature difference between two electrically connected junctions (e.g. heating one of the junctions and cooling the other) the wire connecting the two junctions would cause a compass needle to deflect. He thought that he had discovered a way to transform thermal energy into a magnetic field. Later it was shown that a the electron diffusion current produced the magnetic field in the circuit a changing emf V (Lenz's Law).

Flowing hot water from Solar water heater is used to create hot junction. As outlet of hot water from flat plate solar water heater is from upper side and inlet of cold water is from lower side, no extra pump is needed to supply that water back to solar water heater in summers and in winters when that hot water is needed for use, it will be supplied to taps in place of solar water heater. As solar water heater works on basis of thermosyphon principle cold water supplied to solar water heater from lower side will automatically rise above when heated and supplied to our device and then cooled down and supplied again to solar water heater from lower side.

Also the electricity generated will be from the renewable source of energy and will not cause any pollution. Also it will use the assets and space which we had already occupied, and is used seasonally, it will utilize it for whole the year.

2. EXPERIMENT

Components used in this prototype and its testing are as follows:

2.1. *Peltier Module*

Peltier module works on the principle of Seebeck effect. It is used to convert thermal energy directly into electric energy. There is much potential in thermoelectricity in near future, using these modules. The advantages of these types of modules over conventional systems are such as no moving mechanical parts, long-lived, quiet, environmentally friendly and require little maintenance. The phenomenon of the conversion of thermal energy into electrical energy is known as thermoelectric

conversion. The reverse of this phenomenon is also equally valid.

When the thermoelectric device is used to generate electricity i.e. to convert thermal energy into electric energy it is termed a thermoelectric generator (TEG). The source of thermal energy is used to create hot junction for thermoelectric generator, while for cold junction it is sometimes left open to the surroundings if hot side temperature is adequately large, or sometimes it is cooled using some low temperature providing material. The temperature difference across the TEG created in this manner is useful to generate electricity . When thermoelectric device is used for heating or cooling i.e. converting electric energy into thermal energy then device is termed a thermoelectric cooler (TEC). Similarly, the thermoelectric device produces heating or cooling that takes the form a heat flux which then induces a temperature difference across the TEC.

Two unique semiconductors are used in thermoelectric devices because they need to have different electron densities. So one n-type and one p-type semiconductor are used in these modules. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. Modules are typically connected side by side and sandwiched between two ceramic plates. When two conductors are placed in electric contact, electrons flow out of the one in which the electrons are less bound, into the one where the electrons are more bound. The reason for this is a difference in the so-

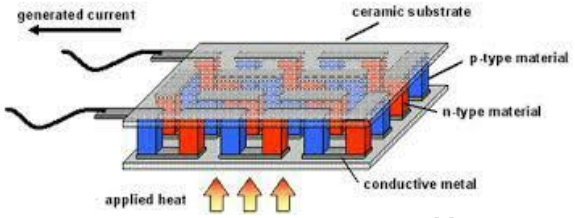

Fig. 1 Thermoelectric module[1]

called Fermi level. Between the two conductors Fermi level represents the demarcation in energy within the conduction band of a metal, between the energy levels occupied by electrons and those that are unoccupied. When two conductors with different Fermi levels make contact, electrons flow from the conductor with the higher level, until the change in electrostatic potential brings the two Fermi levels to the same value. (This electrostatic potential is called the contact potential.). Current passing across the junction results in either a forward or reverse bias.

When the temperature difference is provided on the both sides of the module, electrons will start flowing.

2.2. *Solar Water Heater*

Solar thermal collectors are used to convert sunlight to heat energy used for water heating, the whole process is called solar water heating A variety of configurations are available at varying cost to provide solutions in different climates and latitudes. Solar water heaters are widely used for residential applications where these are used to heat water for household in winters. Also solar water heaters are used for some industrial applications. These can be categorized into two types according to working. In first type water is directly heater which is flowing through pipes in the solar thermal collectors. While in second type working fluid is used which flows through the pipes in solar thermal collectors. Heat trapped in working fluid by flowing through it is then transferred to water by flowing water and working fluid through heat exchanger where water is heated by getting heat from working fluid. A sun-facing collector heats a working fluid that passes into a storage system for later use. SWH are active (pumped) and passive (convection-driven). They use water only, or both water and a working fluid. They are heated directly or via light-concentrating mirrors. They operate independently or as hybrids with electric or gas heaters. In large-scale installations, mirrors may concentrate sunlight onto a smaller collector.

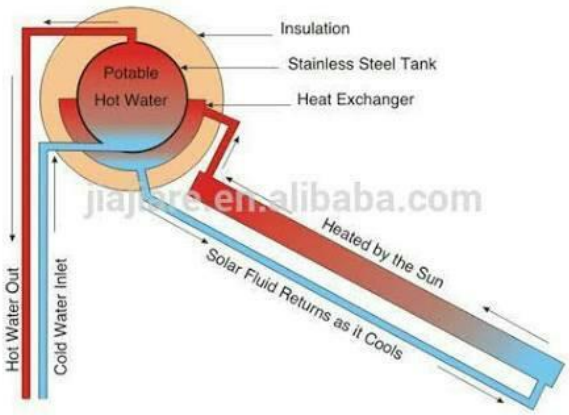

Fig. 2 Flat plate Solar water heater[2]

In our experiment, flat plate collector solar water heater without working fluid are used. Flat plate collectors are an extension of the idea to place a collector in an 'oven'-like box with glass directly facing the Sun. Most flat plate collectors have two

horizontal pipes at the top and bottom, called headers, and many smaller vertical pipes connecting them, called risers. The risers are welded (or similarly connected) to thin absorber fins. Heat-transfer fluid (water or water/antifreeze mix) is pumped from the hot water storage tank or heat exchanger into the collectors' bottom header, and it travels up the risers, collecting heat from the absorber fins, and then exits the collector out of the top header. Serpentine flat plate collectors differ slightly from this "harp" design, and instead use a single pipe that travels up and down the collector. However, since they cannot be properly drained of water, serpentine flat plate collectors cannot be used in drain back systems.

The type of glass used in flat plate collectors is almost always low-iron, tempered glass. Such glass can withstand significant hail without breaking, which is one of the reasons that flat-plate collectors are considered the most durable collector type.

2.3. *Glasswool*

Glass wool is used aa insulating material in our device. It is made from fibre of glass arranged using a binder into a texture similar to wool. It traps many small pockets of air between the glass, and these small air pockets result in high thermal insulation properties. It is used in the device to insulate hot water junction so that it will not loose much heat to the surrounding.

2.4 Aluminum boxes

Aluminum boxes are use to create hot water and cold water junctions by passing water through it. Aluminum is choose because it is cheap and is a good conductor of heat.

For experiment and to test feasibility of the concept small prototype using 4 modules is developed and tested. Also the device with 36 modules is designed which will recover its cost in less then 3 years and will produce approximately 500 kW electricity per year.

Fig. 3 prototype of device

3. RESULTS

Module	Voltage (in V)	Current (in A)
TEG 1	3.560	0.83
TEG 2	3.589	0.84
TEC 1	3.490	0.79
TEC 2	3.531	0.82

Table 1

Here,

Fig. 3 Prototype of device using 4 modules

Cold side temperature , T_1= 3ºC
Hot side temperature , T_2 = 83ºC
Temperature difference = 80ºC

Avg. V=V_a = 3.543 V
Avg. I =$I_{a=}$ 0.82 A

$V_a= I_aR_a$
$3.543= 0.82*R_a$
$R_a= 4.321$

When modules are connected in series,
Total resistance , $R_t= 36*R_a$
$R_t=36*4.321=155.556$

$V_t= I_a*R_t$
$V_t=0.82*155.556$
$V_t=127.556$ V

Total Power, $P=V_t*I_a$
$P=127.556*0.82=104.596$W

For 1 day, 36 modules,
P=104.596*15=1568.94W

For 1 year, 36 modules
P=1568.94*285=447,147.9W=447.148kW

Cost of electricity = Rs. 7.47/kW

Price of electricity produced per year = 447.148*7.47 =Rs 3340.20

Approximate cost of device= Rs. 9000

Time to recover cost= 9000/3340.20=2.69 years

Therefore, device will recover its cost within less then 3 years

4. CONCLUSION

A prototype of the device using 4 peltier modules was developed for testing and to check the feasibility of the idea. The actual device will have 36 modules and calculations are done for that it will generate 447 kW

electricity per year. Which will be of the cost Rs.3340 and the device will recover the money invested on it in less than 3 years. Also it is beneficial for clean environment as it will not generate any polluting gases. Also energy used in it is from renewable source of energy. It also gives us the more value of money and space which is invested in solar water heater ,but it remain idle for long period of time every year. In future efforts can be made to make changes in the design of the device to get higher efficiency from it. Changes possible are may be like applying pressure over modules, as they work better under that condition or other change which is possible is to mount the modules over the hot water storage tank, where hot water is available almost all the time , to extract extra heat from it. □

5. FUTURE SCOPE

Following things can be done to make the performance of this device even better:

1. Instead of using small peltier modules available in market, company can manufacture peltier modules by its own, which will be upto 4 times the size of the regular peltier module. It will make the device more cost efficient and it will be also easy during the production of device.

2. Instead of installing this device in separate space than solar water heater, peltier modules can be installed in the walls of storage tank which stores hot water from the solar water heater. Also the heat will be continually available there , instead of abstracting it from flowing hot water. The modules would be installed in inner side of insulation of the storage tank.

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