Fabrication of Solar Operated Thermoelectric Refrigerator cum Oven - a Review

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Abstract—*A Thermoelectric module (TEM) is used instead of compressor so that it become portable, as it is based on the principles of Peltier effect. The use of Peltier effect is to create a heating side and a cooling side and also to maintain effectiveness. Thermoelectric cooler (TEC) is a solid state heat pump uses the semiconductor materials, by the principle of Peltier effect, to provide instantaneous cooling or heating. It has no moving parts and thus maintenance free. It is an pollution less project, made by using thermoelectric module. It supports for both heating and cooling. Hence it proves to be very helpful. The research focused on simulation of a thermoelectric refrigerator maintained at 4oC. The solar thermoelectric avoids any unnecessary electrical hazards and provides a very environment friendly product and also the thermoelectric refrigerator does not produce chlorofluorocarbon (CFC). It is pollutant free-contains no liquids or gases, portable, compact, creates no vibration or noise because of the difference in the mechanics of the system. The project has various applications like military or aerospace, refrigeration purpose, medical and pharmaceutical equipment etc.*

Keywords— Refrigerator, oven, solar, TEC, TEM

I. INTRODUCTION

Thermoelectric refrigerator also called as thermoelectric cooler module. Heat will moved through module from one side to other, by applying low voltage DC power source to the thermoelectric module. As a result, one face of module gets heated and other face will be cooled. Thermoelectric refrigerators and conventional refrigerators are governed by the laws of thermodynamics and both refrigeration systems are works on same principles but different in forms. Till now scientists have discovered, many laws effect are one of them. A Thermoelectric module is a solid state energy converter composed of two ceramic substrates that serve as a foundation from dissimilar semiconductor material (P-N type). Which on joining, they will appear thermally in parallel and electrical in series. This module can be used for cooling and heating. The cooling effect generated by TEM has various applications in thermal management and control of microelectronic devices [1].

When two junctions in closed circuit of two dissimilar metals is formed and current will flow between the junction or the circuit, this phenomenon is known as seebeck effect. The combination of semiconductor affects the flow of current. A French scientist, Jean C. Peltier discovered a reversed effect of seebeck. He discovered that, by joining of dissimilar metals heat pump can be made. He also found that joining of two dissimilar metals if current is passing through junction; the temperature difference will create between two junctions. The basis of our project is one junction becomes hot and other becomes cool [2].

II. LITERATURE REVIEW

In early 1800's the modern thermoelectric coolers are invented which are based on the physical principles of thermoelectric cooling and heating. Thermoelectric modules were made available in late 60's. A German scientist, Thomas seebeck , found that continuous flow of electric current in a closed circuit which is made up of two dissimilar metals where as at two different temperatures junction of metals were maintained. In 1834, A French physicist, Jean Peltier, investigated the seebeck effect and found out the opposite phenomenon in which, the electric current flow within the closed circuit whereby thermal energy is absorbed at one dissimilar metal junction and discharged at other junction. This is the basic fundamental principle of thermoelectric systems.

The performance characteristic of three domestic refrigerators, vapour compression refrigeration system, thermoelectric refrigeration system, and vapour absorption refrigeration system were investigated and compared by Bansal and Martin. These two reported that thermoelectric technology is advancing and reliability and the cost of thermoelectric cooling systems have changed considerably. In present condition thermoelectric systems are easily available for domestic market at reasonable prices. Min and Rowe studied number of prototypes of thermoelectric cooler and evaluated their performance in terms of COP. There results on experimental investigation on portable solar thermoelectric refrigerator is that the following unit can maintain the inside cooling temperature 5-10, and have approximate COP of 0.3.[1]. Onoroh Francis, Chukuneke Jeremiah Lekwuwa, Itoje Harrison John -Thermoelectric refrigerator is designed and simulated to maintain the temperature of enclosure at 40C. The minimum temperature, allowable module power, current equations presented useful means to perform trade-off analysis to assess whether or not thermoelectric argumentation will be advantageous over conventional techniques. C.O.P against current, the coefficient of performance of devices is dependent on the temperature difference between the hot and cold side of the module, for maximum C.O.P, the temperature is kept to the barest minimum which is also a function of the ambient condition or room temperature, a figure of 1.3 is obtained for a temperature difference of 200C [1].

[2] The study shows how the manufacturer's data for thermoelectric cooler as well as for thermoelectric generators can be used to extract parameter of the proposed model. The model could be helpful for analyzing the drive requirement of TECs and loading effect of TEGs. Another important application of proposed model is when the performance of the TEM needs to be analyzed under specific conditions such as heat leakage, non-ideal thermal insulation etc. Using the model can analyzed not only existing modules, but also specify an optimal module for a specific problem. The present model is compatible with

PSPICE or other electric circuit simulators for DC, AC, and TRANSIENT simulation types and will thus be an excellent tool for solving problems of temperature control [2].

[3]. ChakibAlaoui-A model is developed to simulate the transient state for a Peltier thermoelectric module. This model used to control sources and lumped parameters, hence can be easily simulated with simulation software like Spice. The model parameters were calculated by using the manufacturer's datasheet. In order to validate this model, a refrigeration chamber that uses Peltier modules was designed and fabricated. The overall system was tested and simulated with Spice under various values of input currents. The result is a good fit between the simulation and the experimental data. This model can easily extend with lumped parameters R's and C's representing the thermal resistance and the heat capacity of a thermal system [3].

[4]. Prof. Vivek R. Gandhewar, Miss. Priti G. Bhadake, Mr. Mukesh P. Mangtani- In this work, a portable solar operated system unit is fabricated and tested for the cooling and heating purpose. The system was designed based on the principle of a thermoelectric module to create a hot side and cold side. The cold side of the thermoelectric module was utilized for cooling purposes whereas the rejected heat from the hot side of the module was eliminated using heat sinks and fans. And hot side of the thermo electrical module was utilized for heating purpose. In order to utilize renewable energy, solar energy was integrated to power the thermoelectric module in order to drive the system. Furthermore, the solar thermoelectric cooling and heating system avoids any unnecessary electrical hazards and proves to be environment friendly [4].

[5] Sandip Kumar Singh and Arvind Kumar - The performance of the refrigerator was simulated using Mat lab under different operating conditions. The system consisted of the refrigeration chamber, thermoelectric modules, heat source and heat sink. The performance of thermoelectric solar refrigerator was simulated using Mat lab under varying operating conditions. The system consisted of the thermoelectric solar refrigeration chamber, thermoelectric modules, heat source and heat sink. Results show that the coefficient of performance (C.O.P) which is a criterion of performance of such device is a function of the temperature between the source and sink. A temperature reduction of 120C without any heat load and 100C with 100 ml of water in refrigeration space at 240C ambient temperature in first 30 minutes has been experimentally found at optimized operating conditions.[5]

[6] Mr. Swapnil B. Patond, Miss. Priti G. Bhadake, Mr. Chetan B. Patond- The heating & cooling rates for different modes of heat transfer (conduction & convection) for water; fruit (orange) & metal (Al) are analyzed. Analysis of various materials such as metal, fruit and water is plotted on graph as time on X-axis and temperature on Y-axis. The analysis of various materials indicates that (a) cooling rate for conduction of water is higher compared with convection of water. (b) The heating rate of water is higher than cooling rate. Further improvement in the efficiency of the system may be possible through improving module contact-resistance & thermal interfaces. This could be achieved by installing more modules in order to cover a greater surface area of the system [6].

[7]. P. Dasthagiri, H.Ranganna, G. Maruthi Prasad Yadav- The Refrigerator consists of compressor, condenser coils, expansion devices and evaporator coils. In this system a hermitically sealed compressor having capacity of about 120 watts, an air cooled condenser, an evaporator coil are generally used. In The present work a domestic refrigerator is modified to serve both the purposes as refrigerator and water dispenser. Suitable design and operation conditions were modified with a view to save space, initial cost and maintenance costs. In the present work a refrigerator is modified to serve both purposes of refrigerator and also dispenser of cold water. It is found that a small modification saved power as well as ease in operation and use of the refrigerator. Temperature inside the cabinet are not much altered and C.O.P of the system did not changed. It shows that chilled water is dispensed and even then C.O.P is not changed means that system gives superior performance with this modification [7].

III. PRINCIPLES OF OPERATION

Peltier effect is the basis of thermoelectric module operating principle. In peltier effect, on applying the voltage between two electrodes connected to sample of semiconductor material, temperature difference is created. In thermoelectric module one of the sides is cold and other side is hot. If hot side having the ambient temperature, then we can get lower temperature on cold side. The degree of cooling depends on current value that is leaking through thermoelectric module [8].

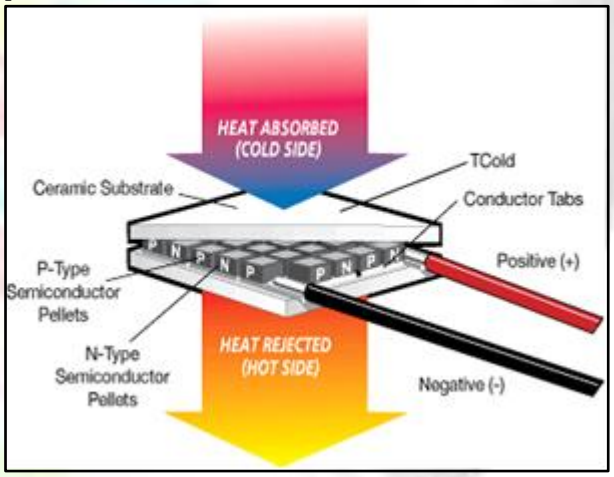

Fig. 1: Principles of Thermoelectric Cooling, Heating

4. CONSTRUCTION

In this system, thermodynamic processes are carried out by using thermoelectric module. The construction set up for solar operated thermoelectric refrigerator cum oven require following parts:

1. Solar panel
2. Charge controller
3. Battery
4. Fins, thermostat
5. Exhaust fan, circuit kit
6. Thermoelectric module.
7. Metal (aluminum box, sheets)

A. Solar Panel

The photovoltaic effect is used for direct conversion of solar energy into electrical energy. In photovoltaic effect light or other electromagnetic radiation is converted into electricity. Solar cell is used to convert the heat directly into electricity, also known as photovoltaic cell. In fabrication, the solar panel having input capacity of 16v and output capacity of 12v is used.

B. Charge Controller

The charge controller is a simple and very efficient device. It is a precise controller device designed to operate with conventional devices such as solar panels and wind generators to prevent overcharge and it has multi-layer timing for overload protection. Charge controller is an globally latest and advanced technology and Output drives current 1.0 Amps. The temperature compensation for better battery charging on various climates, also electronic blocking system is used to save precious energy saved in battery.

C. Battery

The battery is an electrochemical device. It is used to convert the chemical energy into electrical energy. The operating of cranking motor and other electrical units depends on the battery, as the current is being supplied by the battery. The capacity of battery is 12v.

D. Thermoelectric Module

On applying DC voltage to the module, the array of pellet having positive and negative charge carriers absorb heat energy from one substrate and eventually release it to the substrate at opposite side . In this process, cold surface appeared due to absorption of heat energy. This absorbed heat energy is being released to the opposite surface, becomes hot. this simple approach is used in "heat pumping", thermoelectric technology has wide-varied application which are applicable to small laser diode coolers, portable refrigerators, scientific thermal conditioning, liquid coolers etc., Each thermoelectric system is well designed and have a unique capacity of heat pumping and many factors will influenced by these devices. The variables which are frequently used are ambient temperature, physical and electrical characteristics of thermoelectric module employed and efficiency of the heat dissipation system. The heat pumping range of typical thermo electric applications are form several mill watts to hundred of watts. Bismuth and Tellurium have different free electron densities at same temperature. Both P-N type materials are alloys of Bismuth and Tellurium. N-type has excess of electron while P-type dice are composed of material having deficiency of electrons. The current flows up and down through the module and attempts to establish the equilibrium within the materials. P-type material needed to cool down as current treat it as a hot junction and N-type is a cold junction needing to be heated. The materials are at same temperature so the result is that, hot side becomes hotter while cold side becomes cooler. Cooling side and heating side is determined by the direction of current i.e. by reversing the polarity one can able to switch the hot and cold sides [4].

5. WORKING OF THERMOELECTRIC MODULE

Thermoelectric modules are operates on the peltier effect. These modules consist of array of P-type semiconductor elements which are heavily doped with electrical carriers. The elements which are thermally connected in parallel and electrically connected in series are arranged into an array. This array is then affixed to two ceramic substrates one on each side of elements. The P-type material is doped with the atoms which have fewer electrons than necessary to complete the atomic bonds within the crystal lattice. On applying the voltage, the conducting electron tends to complete the atomic bonds. On doing this, conducting electron leave holes which essentially are atoms within the crystal lattice which now have local positive charges. Electrons are moving on to the next available hole, continuously dropping in and being bumped out of the hole in the path.

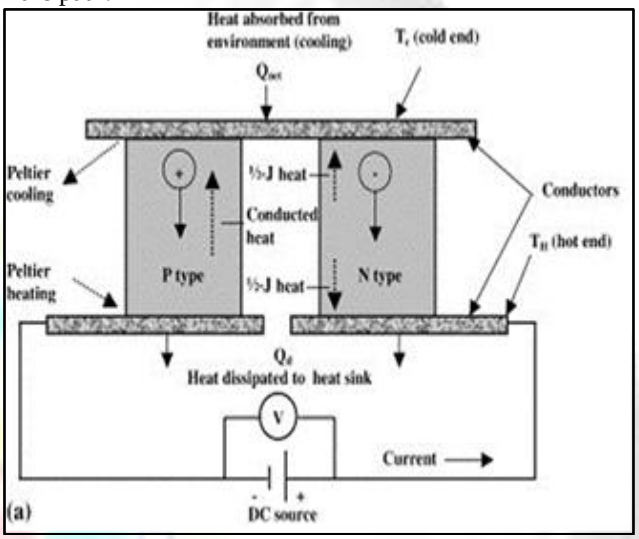

Fig. 2: Schematic diagram of thermoelectric cooling

The holes are acting as electrical carriers. Electrons are not moved easily in semiconductor but are easily movable in copper conductor. On leaving the p-type they enters into the copper on cold side the electron jump out to the higher energy level by the holes which are created in P-type to match the energy level of electrons. Which are already moving in copper. The excessive energy comes by absorbing the heat to create their holes at the same time, new holes travel downwards on the hot side i.e. to the copper. Electron move into P-type from hot side of copper and drop into holes, and releases the excess energy in form of heat.

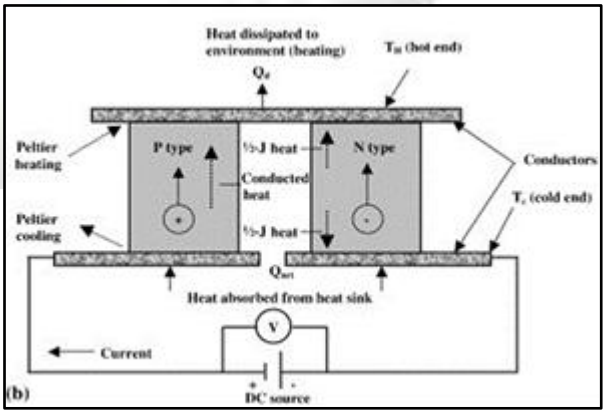

Fig.3: Schematic diagram of thermoelectric heating

The N-type material is doped with atoms which provide extra amount of electrons to complete the atomic bond within the crystal lattice. On applying the voltage this extra electron can be easily moved into conduction band. Extra amount of energy is required to get N-type electrons to match energy level of incoming electron from cold side copper. Finally, on leaving the hot sided N-type they once again move freely in copper. They release the heat in process by doping down to the lower energy level [4].

IV. ADVANTAGES

The advantages of solar operated refrigeration cum oven system are as follows:

1) No moving parts in the system
2) Refrigerants are not required
3) Precise temperature control
4) High reliability & durability
5) Compact size and light weighted
6) Noiseless operation
7) Relatively low cost and high effectiveness
8) Easy for maintenance
9) Eco-friendly C-pentane, CFC free insulation.

V. DISADVANTAGES

1) C.O.P. is less as compared to conventional refrigeration system.
2) Suitable only for low cooling capacity.
3) The initial cost of project is high.
4) The availability of components is less.
5) Charging of battery with solar panel takes time.

VI. LIMITATION

Our project is based on solar energy, thus solar energy is very necessary for the working of our project. But in rainy season it cannot be possible to charge battery from solar .this is the limitation of our project but this problem can be solved by giving direct current supply.

VII. APPLICATIONS OF SYSTEMS

1) It can be uses as remote place where electric supply is not available.
2) In restaurants /hotels
3) At public places
4) Laboratory, scientific instruments, computers and video cameras.
5) Medical and pharmaceutical equipment.
6) Military applications.

VIII. CONCLUSION

A portable Heating & Cooling system can be fabricated by using thermoelectric module & electric control unit for the cooling and heating purpose. The system is self-powers & can be used in isolated & a remote part of the country where load-shading is a major problem. Thus project can be concluded that solar energy systems must be implemented to overcome increasing electricity Crisis. In order to utilize renewable energy, solar energy is integrated to power the thermoelectric module to drive the system. After studying the prototypes, we can conclude that solar thermoelectric cooling is a futuristic technology. It's an eco friendly initiative, thus it promote green technology for the future. This technology has not been widely accepted due to its initial cost, but by using the waste heat, the system becomes very efficient compared to its traditional counterpart.

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