Experimental Analysis on Solar Operated Thermoelectric Refrigeration System

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Abstract: A refrigerator is a common house hold appliance that consists of a thermally insulated compartment and a heat pump that transfer heat from the inside of the refrigerator to its surrounding so that the inside of the refrigerator is cooled to a temperature below the ambient temperature of the room. Thermoelectric Cooling (TEC) solar refrigerator runs on energy provided by sun, which includes photovoltaic or solar thermal energy. Peltier Jean (1834) discovered the Thermoelectric (TE) property about two centuries ago; thermoelectric device have commercialized during recent years. The applications of TE vary from small to large refrigerators. The Thermoelectric module refrigerator work on the principle of Peltier effect. Recently, the application of TEC modules in an industry is dramatically increased. The main objective of our project is to design & make analysis of a Heating & Cooling system which utilizes non-conventional energy source (i.e. Solar Energy) with the help of Thermoelectric Module which works on the principle of the Peltier effect. This will be a suitable & affordable system for the people living in remote part of India where load-shading is a major problem. The major difference between the existing system & our system is that, our project works without use of mechanical device & without refrigerant too. As the module is compact in size one can design (i.e. shape, capacity) the system according to his requirement. In this paper an attempt has been made to conduct an experimental study on small scale solar operated thermoelectric Heating & Cooling system.

Keywords: Thermo-Electric Module, Peltier Effect, Solar Energy

1. Introduction

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump, which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is Peltier device, Peltier heat pump, solid-state refrigerator, or thermoelectric cooler (TEC). It was used either for heating or for cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools. This technology is far less commonly applied to refrigeration than vapour-compression refrigeration is. The primary advantages of a Peltier cooler compared to a vapour-compression refrigerator are its lack of moving parts or circulating liquid, very long life, invulnerability to leaks, small size and flexible shape. Its main disadvantage is high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are both cheap and efficient.

A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the device, and as a result, a difference in temperature will build up between the two sides. When operated as a generator, one side of the device is heated to a temperature greater than the other side, and as a result, a difference in voltage will build up between the two sides (the Seebeck effect). However, a well- designed Peltier cooler will be a mediocre thermoelectric generator and vice versa, due to different design and packaging requirements.

Renewable & alternative non-conventional green energy technologies used for heat-pumping applications have shown

real merits and received renewed interest in recent years especially in small-scale portable heating applications. Solar-driven thermoelectric heat pumping is one of these innovative technologies [1]. Solar energy is the most low cost, competition free, universal source of energy as sunshine's throughout. This energy can be converted into useful electrical energy using photovoltaic technology. Thermoelectric heating (or cooling) technology has received renewed interest recently due to its distinct features compared to conventional technologies, such as vapourcompression and electric heating (or cooling) systems. Thermoelectric (TE) modules are solid-state heat pumps (or refrigerators in case of cooling) that utilize the Peltier effect between the junctions of two semiconductors. The TE modules require a DC power supply so that the current flows through the TE module in order to cause heat to be transferred from one side of the TE module to other, thus creating a hot and cold side . Heat sinks are used with highpower semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the basic device is insufficient to moderate its temperature. cabinet may be crate by Plastic is a material consisting of any of a wide range of synthetic or semi-synthetic organics that are malleable and can be moulded into solid objects of diverse shapes. Plastics are typically organic polymers of high molecular mass, but they often contain other substances. They are usually synthetic, most commonly derived from petrochemicals, but many are partially natural. Plasticity is the general property of all materials that are able to irreversibly deform without breaking, but this occurs to such a degree with this class of mouldable polymers that their name is an emphasis on this ability

The main objective of the heating & cooling system service is to be suitable for use by the people who live in the remote areas of country where load-shading is a major problem. The system can also be used for remote parts of the world or outer conditions where electric power supply is not readily available.

2. Literature Review

1) As we know that, the physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800's, although commercial thermoelectric (TE) modules were not available until almost 1960. The first important discovery relating to thermoelectricity occurred in 1821 when a German scientist, Thomas Seebeck, found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals provided that the junctions of the metals were maintained at two different temperatures. In 1834, a French watchmaker and part time physicist, Jean Peltier, while investigating the "Seebeck Effect," discovered the "Peltier Effect" and it is the fundamental principal behind a thermo-electric system.

2) There are a number of experimental and numerical studies that characterized the performance of TE heating and cooling systems. For example, Luo, et al. performed experiments and verified that a TEHP system is more efficient than an electrical heating device, for its heating coefficient reached more than 1.6 with suitable operating conditions. Riffat and Qiu [7] compared the performance of the thermoelectric air-conditioner with two other types of domestic air-conditioners, namely the vapour compression air- conditioner.

3)"Performance Evaluation of Thermoelectric а Refrigerator", Onoroh Francis, Chukuneke Jeremiah Lekwuwa, Itoje Harrison John International Journal of Engineering and Innovative Technology (IJEIT) Volume 2. From above research paper we have studied about the Seebeck effect, thermoelectric refrigerator, hybrid refrigerator and thermo electric materials. Thermoelectric cooling provides a promising alternative R&AC technology due to their distinct advantages. Use of Thermoelectric effect to increase the COP of existing cooling.

4) "A Review on use of Peltier Effects", Ajitkumar Nikam Dr. Jitendra hole Mechanical Engineering Department, RajashriShahu college of engineering, Pune. From above research paper we have studied about use of peltier plate in refrigerator. 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. For maximum efficiency the temperature difference is to be kept to the barest minimum.

5) Solar Energy for Cooling and of Warwick, Coventry CV4 7AL, UK. From this research paper, the need to replace the peak load demand for electricity for air conditioning applications coupled with the desire of gas utilities to balance their heating loads with a summer alternative has lead to the development of heat powered Refrigeration Dr. R.E. Critoph and Mr. K. Thompson Engineering Department, University refrigeration cycles. The result has been research into improved desiccant materials and cycles to both improve performance and reduce costs.

3. Concept of Project

Before making decisions on which components to use for the box, theory had to be reviewed and some preliminary calculations performed.

1) Passive Heat Load

The passive heat load for the unit was first calculated based upon a 25cm x 25cm interior volume. Two inches of polystyrene insulated was assumed (k=0.027w/mK). Also included were a rubber seal on the door which was 50 cm2 in area.

$$q_{tot} = k_{ins} \frac{\Delta T}{\Delta x} + k_{rubber} \frac{\Delta T}{\Delta x}$$

where: qtot is the heat transfer in watts, kins is the resistance to heat transfer, and krubber is 0.014w/mK

 ΔT is assumed to be 20 °C and Δx is 0.50m. This gives a qtot of 10 W.

2) Active Heat Load

The active heat load is the equivalent of the cooling power that the unit will need to provide when the sample at room temperature is placed in the container. It was decided that one litter of water at room Q = 82800J and dividing by 3600s to get power (W), Qdot = 23 W for the active heat load. Therefore, the total load is 23 + 11 W = 34 W of power required. This assumes that there is no thermal resistance between the sample and the air in the unit. This may be an incorrect assumption but it does overestimate the cooling load. Temperature would be the test sample for which all calibration and calculations would be made. The time to cool this load from 25 °C to 5 °C was determined to be 1 hour, or 3600 seconds. Based on these values: If the Cp of water is 4.14 KJ/kg*K, then.

3) Heat Load Required To Be Dissipated By Heat Sink

The Peltier module is running at 12V and 5.2 amps of current. The following Vin vs. I graph1 shows a normal operating range of the TEM.



Figure: Thermoelectric Module Performance

The power consumed by the TEM is assumed in the worst case scenario to be added to the heat on the hot side. Division by two denotes that we have two TEM's, two hot side heat sinks and two cold side heat sinks to improve system efficiency. Therefore, qtot= 107W. This is the maximum heat load to the hot side of each TEC and therefore each of the heat sinks.

$$q_{hot} = P_{TEC} + \frac{Q_{passive} + Q_{sample} + Q_{safetyfactor}}{2}$$

4) Maximum Temperature Rise on Hot Side of TEC

Max temp rise = 107W x 0.17 °C/W = 18.2 °C. The Δ T over the TEC is 25 – 5 +18.2 (°C) = 38.2 °C, where 25 is the ambient temperature on the hot side, 5 is inside desired temperature and 18 is the added heat load. The following table will show that the operating point for heat removal of 18W (for each TEC) and a Δ T of 38°C only requires a current draw of 4.5Amps.



Figure: Thermoelectric Performance Graph

Construction

Here this system heat or cool the product using thermoelectric module. the construction set up for this system require following parts

- 1) Solar panel,
- 2) Insulated Box (2 chambers),
- 3) Charge controller,
- 4) Battery
- 5) Fins, thermister,
- 6) Exaust fan, circuit kit,
- 7) Thermoelectric module.
- 8) Metal (aluminium box, sheets)

Part Name	Quantity	Size
1) Solar Panel	1	1*2 feet
2) Insulated box	1	4 lit
3) Charge Controller	1	For 12 v dc battery
4) Battery	1	12v
5) Thermister	1	-
6) Exhaust Fan	1	-
7) Thermoelectric module	1	20w
8) 8. Metal (Sheets)	-	-

Project Model



Figure: Designed Thermoelectric Heating & Cooling System

4. Experimental Analysis

A. Cooling of water by Convection

We were doing experiments and note down readings Temperature vs Time and drawn this graph. In this graph we use insulator (thermocol) between metal bowl and surface of cooling chamber. Graph shows temp decreases from 30°C to 20°C within 90 minutes. The cooling rate of water by convection in cooling chamber (30-20)/90=0.111.



Figure: Graphical representation of cooling of water by convection

B. Cooling of water by Conduction:

In above graph we cooling water by conduction means there was direct contact between metal bowls in which we taken water and surfaces of the cooling chamber. Graph show the cooling rate is higher at the starting up to 22° . Within 90 minutes' temp decreases from 30° C to 17° C. The cooling rate of water by conduction is (30-17)/90=0.144. The cooling rate of water by conduction is higher than the cooling rate of water by convection



Figure: Graphical representation of cooling of water by conduction

C. Cooling of Fruit (Orange):

We also analyze on fruits like Orange. Here orange fruit is cooled in cooling chamber. Then note down readings Temperature Vs Time graph shows initially fruit cooled fastly. Temp decreases from 28°C to 22°C.within 20 minutes and then took 80 minutes to decrease another 4°C. The cooling rate for Orange is (28-22)/20=0.3.

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Figure: Graphical representation of cooling temperature of fruit (orange)

E. Heating of Water by Conduction

In this graph we analyze heating effect. We use direct contact of metal bowl in the heating chamber for heating of water by conduction .Graph indicates temp increases linearly with time. Water gains 17° C to 50.3° C within 49minutes. The heating rate is (50.3-17)/49=0.679. We found that the heating rate is higher than cooling rate.



Figure: Graphical representation of heating of water by conduction

5. Results

Thermoelectric module for producing effective heating and cooling placed inside an aluminium cabinet. By using a temperature sensor inside the cabinet surface, we get the corresponding temperature values for each instant which are displayed in an LCD (Liquid crystal display). The graph between temperature produced inside the cabinet against corresponding time interval are also presented and results are in line with the predictions. The advantages of the thermoelectric heater cum refrigeration on comparison with the existing heater and refrigeration system are elaborated. The physical dimensions and specifications of the thermoelectric module are presented. It is observed that the life span of thermo electric heater cum refrigeration system is more than twice the life span of existing conventional refrigeration or heater system.

6. Conclusion

A portable Heating & Cooling system was fabricated using thermoelectric module & electric control unit & tested 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. The important aspect to be noted is that it is a onetime investment & is free from maintenance. 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.

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