Photovoltaic Driven Thermoelectric Refrigerator for Car Heat Dissipation During Sunny Days

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Abstract

This project outlines the implementation of photovoltaic driven refrigerator in cars powered from solar panels with a battery bank. People normally don't tend to park cars under the sunlight during afternoon time as it causes great discomfort to the person when entering the vehicle after sometime. In order to prevent this thermoelectric module is placed to dissipate the heat that gets built up in the car cabin. This thermoelectric module is powered using nonconventional method, i.e. using solar energy. Hence not using any energy produced by the engine. This method does not cool the cabin but keep it maintained at an optimum temperature. Different from conventional refrigeration systems, thermoelectric refrigeration, based on the Peltier effect, does not require any compressor, expansion valves, absorbers, condensers or solution pumps. Moreover, it does not require working fluids or any moving parts, which is friendly to the environment and results in an increase in reliability. Thermoelectric refrigeration replaces the three main working parts with: a cold junction, a heat sink and a DC power source. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. This phenomenon can be useful when it is necessary to transfer heat from one medium to another. 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.

Keywords: Solar Panel, Peltier module, Photovoltaic Driven Refrigerator

I. INTRODUCTION

In the automobile industry, existing air-conditioning system give arise to numerous problems such as pollution to environment (CFC emission), increase in the usage of fuel and decreased engine performance. Moreover, the current air-conditioning system is not capable to be used during the parked session. The conventional air conditioning system consumes much energy of the engine, when the car parked in sun is cooled. This scenario could be subdued by the introduction of thermoelectric device as an alternating cooling option for car interior. By using this option pollution, fuel usage and decreased engine performance can be prevented since the latter option was in the bracket of 'Go Green' region. Basically, the thermoelectric device known as peltier module is a semiconductor based heat pump, where heat is absorbed from one side and dissipated on the opposite side of the module.

The peltier module (Fig. 1.1) was discovered by a French watchmaker during the 19th century. It is described as a solid state method of heat transfer generated primarily through the use of dissimilar semiconductor material (P-type and N-type). A typical thermoelectric module is composed of two ceramic substrates that serve as a housing and electrical insulation for P-type and N-type (typically Bismuth Telluride) elements between the substrates. Heat is absorbed at the cold junction by electrons as they pass from a low energy level in the p-type element, to a higher energy level in the n-type element. At the hot junction, energy is expelled to a thermal sink as electrons move from a high energy element to a lower energy element. A module contains several P-N couples that are connected electrically in series and thermally in parallel.

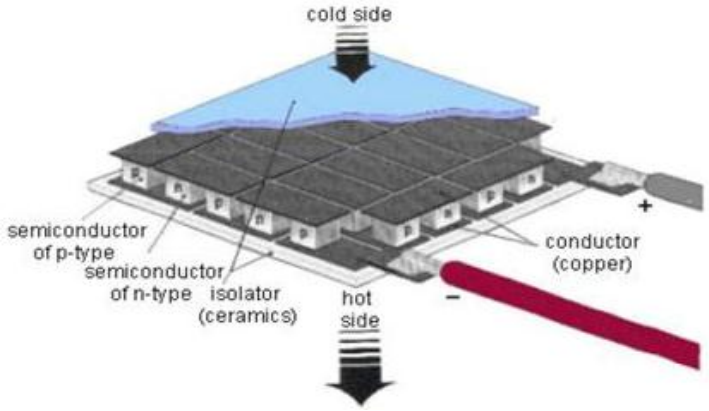

Fig. 1.1: Peltier Module

The peltier module usually rated according to its capacity on heat removal, waste heat and maximum system temperature difference for a specified DC voltage and applied current. Another important characteristic of peltier module is the polarity of the heat removal changes when the direction of applied current changes, thus it is potential to cool or warm an object within same configuration, with respect to the polarity of the current. When considering usage of these peltier modules, it is necessary to analyze the performance of the module over the heat removal rate. From a manufacturer data sheet of peltier module known as TE Technology, Inc, It is necessary to maintain the system temperature difference with respect to required heat removal in order to maintain the COP performance of the peltier module. Thus, in this project the development of the heat sinks must be considered to fulfill performance requirement. In the context of heat sink resistance, the leading materials that possess high thermal conductivity is copper and aluminum.

When considering peltier cooling with copper or aluminum heat sinks, of course it will cost in high price for the fabrication of the prototype but since this manner of cooling could overcome some disadvantages of existing compressor-based cooling, it is still worth of the price.

Previously, thermoelectric devices were used in for medical devices, sensor technology, cooling integrated circuits.

A. Components and Discripton:

When the car is parked during sunny days, the car cabinet get heated up. The thermoelectric module is powered using a solar panel. The battery is recharged by solar panels and the power is consumed by thermoelectric module from the battery. The temperature sensor is provided in the cabinet to measure the temperature inside the cabinet. A relay circuit is provided along with a microcontroller to cut off the supply from battery to thermoelectric module as the temperature goes below a certain value in the cabinet, thus maintaining a definite temperature.

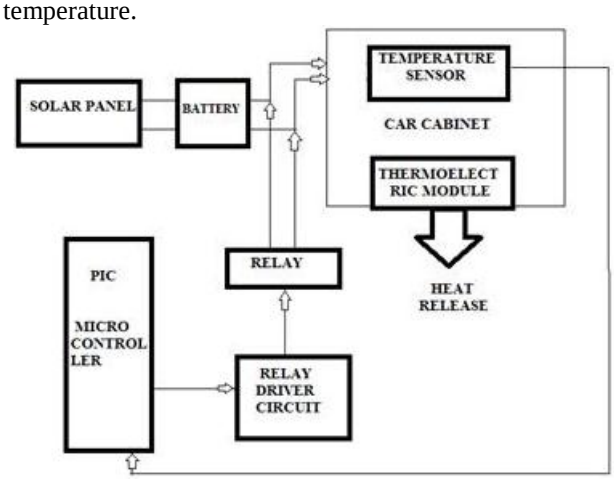

Fig. 1.2: Schematic Layout

The major components are,

1) Battery
2) Temperature sensor
3) Microcontroller unit
4) Solar panel
5) Thermo electric cooler
6) Relay drive

1) Battery:

We use lead acid battery for storing the electrical energy from the solar panel for lighting the street. Where high values of load current are necessary, the lead-acid cell is the type most commonly used. The lead acid cell type is a secondary cell or storage cell, which can be recharged. The charge and discharge cycle can be repeated many times to restore the output voltage, as long as the cell is in good physical condition. However, heat with excessive charge and discharge currents shortens the useful life to about 3 to 5 years for an automobile battery. Of the different types of secondary cells, the lead-acid type has the highest output voltage, which allows fewer cells for a specified battery voltage.

a) Advantages:

- Low cost
- Long life
- High reliability
- High overall efficiency
- Low discharge
- Minimum maintenance

2) Temperature Sensor:

Temperature is the most-measured process variable in industrial automation.Most commonly, a temperature sensor is used to convert temperature value to an electrical value. Temperature Sensors are the key to read temperatures correctly and to control temperature in industrials applications.

A large distinction can be made between temperature sensor types. Sensors differ a lot in properties such as contact-way, temperature range, calibrating method and sensing element. The temperature sensors contain a sensing element enclosed in housings of plastic or metal. With the help of conditioning circuits, the sensor will reflect the change of environmental temperature.

In the temperature functional module we developed, we use the LM34 series of temperature sensors. The LM34 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Fahrenheit temperature. The LM34 thus has an advantage over linear temperature sensors calibrated in degrees Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Fahrenheit scaling.

3) Microcontroller Unit:

The alcohol sensor senses the alcohol contents of the particular room/vehicle. This sensing signal is given to the microcontroller unit. When the current voltage is below the setted voltage, the output from the microcontroller activates the relay to function the alarm unit.

4) Solar Panel:

The most useful way of harnessing solar energy is by directly converting it into electricity by means of solar photo-voltaic cells. Sunshine is incident on Solar cells, in this system of energy Conversion that is direct conversion of solar radiation into electricity.

5) Thermo Electric Cooler:

Using a combination of the Seebeck, Thomson and Peltier effects, cooling occurs when electricity flows through materials and specific junctions. Classic thermoelectric work, but with very low efficiency. The reason is simple. Heat will flow through any material, and does not require electrons to do so. So as soon as one side becomes colder than the other, then natural conduction will seek to equilibrate the two sides.

Thermoelectric coolers (TECs) employ the Peltier effect, acting as small, solid-state heat pumps. The TECs are ideally suited to a wide variety of applications where space limitations and reliability are paramount. The TECs operate on DC current and may be used for heating and cooling by simply reversing the direction of the DC current. Thermoelectric coolers (TECs) are solid-state heat pumps that have no moving parts and do not require the use of harmful chemicals.

6) Relay Drive:

A relay is an electro-magnetic switch which is useful if you want to use a low voltage circuit to switch on and off a light bulb (or anything else) connected to the 220v mains supply.

B. Working Principle:

A Thermoelectric Air cooling for car prototype was designed and built which can be used for personal cooling inside the car. Six TECs were used for achieving the cooling with a DC power supply through car battery. It had been shown from testing results that the cooling system is capable of cooling the air when recirculating the air inside the car with the help of blower. TEC cooling designed was able to cool an ambient air temperature from 32°C to 25.8°C. Cooling stabilizes within three minutes once the blower is turned ON. The system can attain a temperature difference of set target which was 7°C. Accomplishing the set target establish the success of the project. All the components in the project had been tested individually and the results were found to be positive.

The prototype can be made compact by selecting as single TEC of higher power (.i.e. of 200W or more). It can be done by choosing a better cold side heat sink that has twisted channels or pipes for circulating the air for a longer time. As an alternative for normal axial fan used in this project, if a blower fans is selected, the cooling system would provide better airflow. Even as shown in the appended figure we can mount no of TEC cooling in Roof, Floor, Seat, Door, front dashboard with proper

insulation. Well-known TEC brands (.i.e. Melcor, FerroTECetc) must be chosen if there is only one high power TEC selected for the cooling system. Bigger hot side heat sinks have to be selected accurately based its calculated thermal resistances for best cooling efficiency. With a single TEC, one hot side and a cold side heat sink a smaller personal TEC cooler which gives comfort can be fabricated and can be installed on roof for individual cooling by changing the airflow and some mechanical or electronics section modification, the TEC air cooling for car can be used for heating applications too.

1) *Advantages:*
   - Simple in construction
   - Compact and reliable
   - This system is noiseless in operation
   - Its operate in battery
   - Maintenance cost is low

II. MODELLING AND FABRICATION

A solid works model is designed using the above heat load calculation,
The size of windshield=18cm×38cm
The size of back glass=10cm×18cm
The area of side glass= 4(10cm×15cm)

Fig. 2.1: Front View

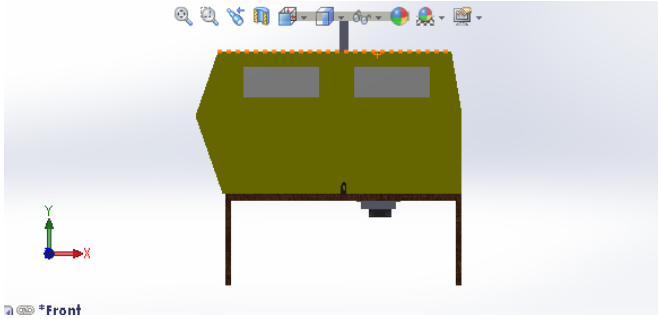

Fig. 2.2: Side View

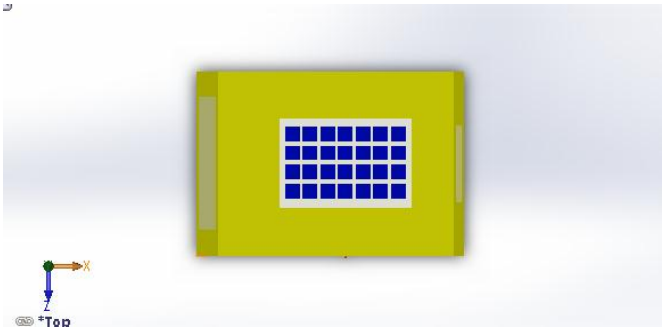

Fig. 2.3: Top View

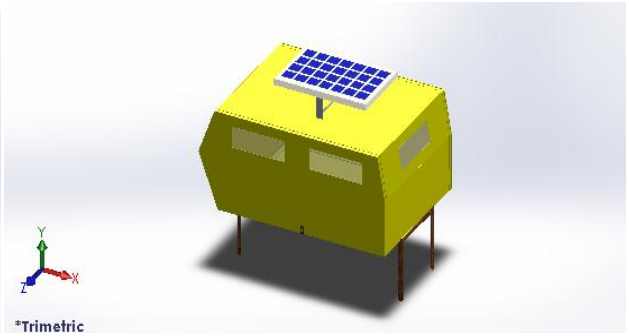

Fig. 2.4: Isometric View

A. Fabrication:

Based on design model the outer frame was designed using an angle bar. Then a sheet metal of 20 gauge was used to cover the frame made from mild steel. To make the structure arc welding was used. A glass of 4mm thickness with the dimension windshield=18cm×38cm, back glass=10cm×18cm, side glass= 4(10cm×15cm) was incorporated. Then for insulation, the inside of the cabin was covered with 12mm thick thermocole. A 60 Watts Peltier module was placed on the lower part of the cabin such that the hot side lies outside the cabin and the cold side lies inside it. Heat sinks with fan are attached to both hot side and cold side.


Fig. 2.5: Main Frame


Fig. 2.6: Body with Glass Windows

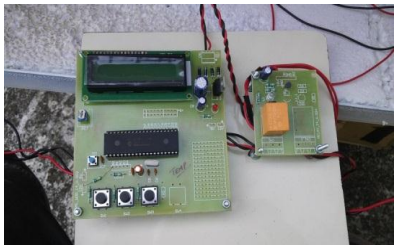
Fig. 2.7: Peltier Module (Cold Side)


Fig. 2.8: Temperature Sensor and Relay


Fig. 2.9: Solar Panels


Fig. 2.10: Peltier Module(Hot Side)


Fig. 2.11: Fabricated Model

III. EXPERIMENTS AND RESULTS

A. Experiments:

The scale down model of cabin was placed under direct sunlight with absence of refrigeration system and measured the amount of heat accumulated between 12:00 pm to 1:00 pm for each 15 minutes in the cabin using temperature sensor.
Then the thermoelectric module was switched on and the relay circuit temperature was set to 28˚C. Then using temperature sensor, reading for each 15 minutes was taken between 2:00 pm to 3:00 pm in order to obtain the rate of cooling.
Then the temperature change with respect to time was plotted.

B. Results:

From the first experiment conducted without using refrigeration system it can be seen that the temperature inside the cabin begins to rise slowly with time since the entire volume of air inside the cabin gets heated up. After a certain period of time the temperature increases rapidly because of the accumulation of heat due to the thermal insulation of the cabin. Towards the end of the experiment the rate of increase in temperature becomes fairly constant. The graph was plotted for the temperature variation for 15 minutes intervals as shown in Fig. 3.1.

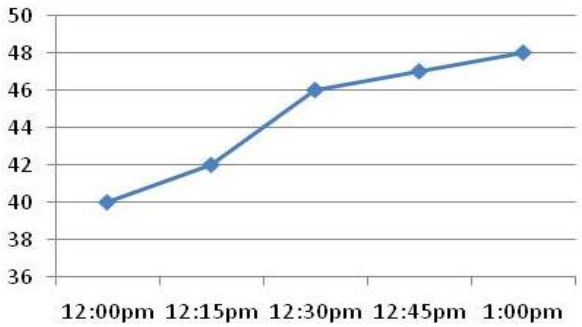

Fig. 3.1: Without Refrigeration System

From the second experiment conducted using the thermoelectric refrigeration system it can be seen that the temperature inside the cabin begins to fall slowly with time since the entire volume of air inside the cabin needs to be cooled. After a certain period of time the rate of cooling slightly increases and as a result the temperature inside the cabin is maintained at ambient condition. The graph was plotted for the temperature variation for 15 minutes intervals as shown in Fig. 3.2.

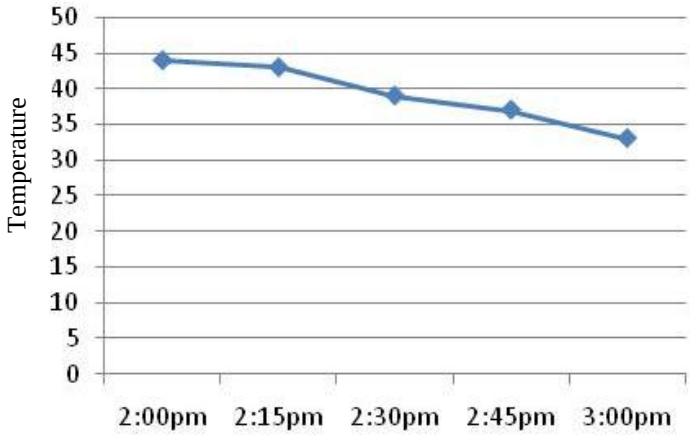

Fig. 3.2: With Refrigeration System

IV. CONCLUSION

The scaled down version of the car cabin was fabricated from the design calculation. Experiments with and without using the refrigeration system was conducted on the model and the results were compared. Heat load accumulated in the cabin was reduced using this refrigeration method. The temperature inside the cabin was brought down to ambient condition and maintained by means of a relay drive. The thermoelectric system being compact gives a low maintenance cost. The energy used to run the refrigeration system is provided by non-conventional method i.e., using solar energy. As the system contains no moving parts it is reliable and produces no noise.

REFERENCES

[1] "ASHRAE Handbook of Fundamental, American Society of Heating", Refrigerating, and Air Conditioning, Atlanta, GA, 1988.
[2] Mohammad A.F., and Majid B., "Comprehensive Modeling of Vehicle Air Conditioning Loads Using Heat Balance Method", SAE Technical Paper 2013-01-1507, 2013, doi:10.4271/2013-01-1507.
[3] Khurmi R.S. and Gupta J.K., "Refrigeration and Air conditioning", Eurasia Publishing house Ltd.