International Journal of Research in Engineering, Science and Management
Volume-3, Issue-2, February-2020
www.ijresm.com | ISSN (Online): 2581-5792

Peltier Effect based Thermoelectric Refrigeration System

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***Abstract*: The refrigerator could be used to store perishable items and facilitate the transportation of medications as well as biological material that must be stored at low temperatures to maintain effectiveness. The design of the solar-powered refrigerator is based on the principles of a Peltier effect to create a hot side and a cold side. In developing countries and remote areas where an electric supply is not available, a thermo-electric refrigerator is often needed for food and medical drugs storage. Such a refrigerator, which requires a direct current supply is suitable for matching with a photo-voltaic collector (PV). This paper theoretically analyses and experimentally investigates the performance of Solar Photovoltaic driven thermoelectric cooler system for cold storage application. Thermoelectric cooling provides a promising alternative R&AC technology due to their distinct advantages. Thermoelectric solid-state air conditioners can be a cost-effective solution for cooling electronic and electrical equipment and devices housed in enclosures and cabinets. With relatively low energy requirements and the ability to provide both cooling and heating from the same device when needed. The research and development work carried out by different researchers on development of novel thermoelectric R&AC system has been thoroughly reviewed in this paper. Use of Thermoelectric effect to increase the COP of existing cooling system has been also reviewed in this paper.**

***Keywords*: Thermoelectric refrigerator, Thermoelectric Module, Peltier Effect.**

1. Introduction

In the current situation the energy demand is increasing with increasing in the population and improvement in the living standard. Energy is the crucial input to the social, economical, industrial and technological development of any country. A rational use of energy brings both economic and environmental benefits, by reducing consumption of fossil fuels, electricity and pollutant emissions. The International Institute of Refrigeration in Paris (IIF/IIR) has estimated that approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air-conditioning processes. In a tropical country, like India, refrigeration is most widely used and generally the most energy consuming process.

A study done by the University of Cape Town's Energy Development Research Centre came up with interesting facts that can be used to support the application of PV systems to Third World housing. The study found that once households received electricity, they still relied on multiple fuel use for cooking, heating etc. The electrical energy is usually used for lighting, because of its low energy consumption and the substantial increase it makes to living standards. In these houses, the most sought after appliances are a television, radio and (despite the cost), refrigerators. The TEC cooler will utilize the power from the PV panels when the battery is fully charged, and at night, will use a small amount of power to maintain the temperature in the cooler box.

In other words, if the battery of the system is fully charged, and there is no appliance to absorb the power generated from the PV panel, it would be wasted, resulting in a 'poor efficiency factor for the whole PV system. The cooler box integrated in RAPS would allow for a very efficient system utilizing all the excess generated power from the sun. Conventional cooling systems such as those used in refrigerators utilize a compressor and a working fluid to transfer heat. Thermal energy is absorbed and released as the working Fluid undergoes expansion and compression and changes phase from liquid to vapor and back, respectively. Semiconductor thermoelectric coolers (also known as peltier coolers) offer several advantages over conventional systems. They are entirely solid-state devices, with no moving parts, reliable, and quiet. They use no ozone depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to conventional refrigeration. They can be extremely compact, much more so than compressor-based systems. The applications of thermoelectric coolers are increasing with an ever increasing demand of cooling in every sector for the past forty years. The TE coolers convert electrical energy into a temperature gradient which is also known as peltier effect. In 1821, the first important discovery relating to thermoelectricity occurred by German scientist Thomas See beck who 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. Later, in 1834, while investigating the See beck Effect, a French watchmaker and part-time physicist, Jean Peltier found that there was an opposite phenomenon where by thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flows within the closed circuit. After studying some of the earlier thermoelectric work, Russian scientists in 1930s, inspired the development of practical thermoelectric modules based on modern semiconductor technology by replacing dissimilar metals with doped semiconductor material used in early experiments.

2. Related work

1) Solar Panel

A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output - an 8% efficient 230-watt module will have twice the area of a 16% efficient 230-watt module. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

Fig. 1. Solar panel

2) Charge Controller

The series design improves charging accuracy. In PWM, series switching becomes self-correcting for temperature and system voltage drops.

- Extremely High Reliability and full continuous current ratings at 60° ambient temperatures.
- Advanced lightning and transient overvoltage protection. Reverse polarity protection.
- High quality surface-mount components and Series switching design for improved safety and protection.
- Outstanding PWM Battery Charge Control and confirmed increase in battery capacities and operating life.
- PWM Pulse charging for highest charge acceptance and standard temperature compensation.
- Approved for use in Hazardous Locations: Class 1, Div. 2, and Groups A-D. Built in a world class ISO 9002 certified facility.

Fig. 2. Charge controller

3) Thermoelectric Module

Thermoelectric devices are solid-state heat pumps. They take advantage of the Peltier effect, in which heat is either evolved or absorbed at the junction of two dissimilar electrical conductors when an electric current flows through the junction.

Fig. 3. Thermoelectric module and module number

- TEC1-12709 Thermoelectric Cooler Peltier 12V 90W.
- Model number: TEC1-12709.
- Voltage (V): 12V Umax (V): 15.4V Imax (A): 9A.
- QMax (W): 138.6W.
- Dimensions: 40mm x 40mm x 3.6mm.

3. Construction of Thermoelectric Refrigerator

The heat pumping of a single p-n junction is very low, typically in the millewatt range. This problem was overcome, depending on the amount of heat required to pump, by connecting a series of p-n junctions in series and thermally in parallel. it can be seen that the p-n junction is split into a p-n block and electrically connected using a copper bar. The copper bar will also act as the surface where the heat is absorbed or rejected. H more than one junction is used; they are connected in series with the copper bars.

The basic construction of the TEC

1. The p-n semiconductor legs
2. Copper bar contacts
3. Series electrical connection

Due to the different voltages at the copper bars (because they are connected in series), the copper bars have to be isolated from the body that has to be cooled, to prevent any short circuit conditions. This is done using a heat conducting ceramic, which has no electrical conduction but proves to be an excellent heat conductor. (To conduct the heat from the copper bars).

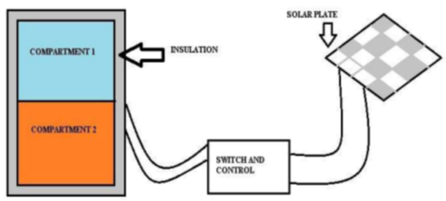

Fig. 4. Line Diagram of thermoelectric refrigerator

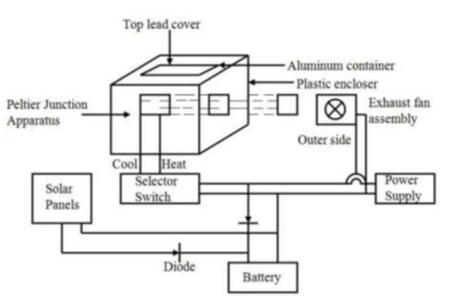

Fig. 5. Assembly of thermoelectric cooler

1) Couple design

A couple as already explained in the previous sections, a couple consists of a p-type semiconductor, n-type semiconductor, copper and a ceramic. The ceramic is an electric insulator while the copper acts as a conductor of electricity. The junction where the copper is soldered to the leg has a material that has an electric contact resistance. This contact resistance plays an important role while calculating the cooling power of a module. This electrical contact resistance especially is very important when the leg length of the element is below 0.5mm. The effect these resistances is explained in detail in the next chapter. The figure below shows the modeling of this design.

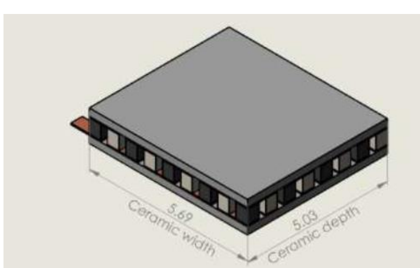

Fig. 6. Couple design

2) Module Design

A module in the current study has 36couples. Like the couple study, the dimensions in the module varies from 0.1mm to 0.5mm in a miniature module while the leg length varies from 1mm to 1.5mm in a macro module. The figure below shows the design of a 36 couple module.

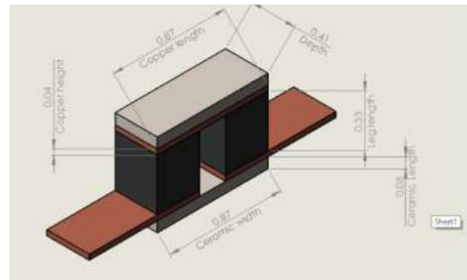

Fig. 7. Module design

Thermoelectric devices are solid-state heat pumps. They take advantage of the Peltier effect, in which heat is either evolved or absorbed at the junction of two dissimilar electrical conductors when an electric current flows through the junction. In a Peltier cooler, the rate of heat absorption is linearly proportional to the electric current and the difference between the Peltier coefficients of the two conductors. Thus, increasing the current increases the rate of heat pumping. The amount of current in conductor represent the quantity of electron flowing in conductor, therefore it can be said that cooling effect in thermoelectric heat pump is directly proportional to the current flowing through the device.

3) Calculations:

Testing the Co-Efficient of Performance of the Solar Thermoelectric

Refrigerator: When the designed solar thermoelectric refrigerator was tested, it was found that the inner temperature of the refrigeration area was reduced from 32 ^{0}C to 12.3 ^{0}C in approximately 35 min; a difference of 19.7 ^{0}C. Below is an example, which shows how the co-efficient of performance of the refrigeration (COPR) was calculated. It was assumed that the refrigerator used to cool a 0.5 l can drink from 330C to 130C in 40 min .in these calculation, it was assumed that the properties of canned drinks are the same as those of water (density = 1kg/l and c=4.18 kj/kg).

V=0.5 l canned drink.

Cools from 330C to 130C in 40 min.

Calculation of COPR:

COPR =Qcooling/ Win

m = 0.5 kg.

Qcooling= mCΔT = 0.5 x 4180 x (33-13) =41,800 J.

Qcooling = Qcooling = 41,800/60x40 = 17.41667 W.

Win = IV = 9.5x2+4×2 = 27 J.

COPR=17.41667/27 = 0.64506

Calculation of the Power: Calculation of the Power consumed by the 2 modules used in the Assembly.

Each module takes a maximum of 2.5 A and 3.8V.

The power needed to give maximum cooling efficiency = 3.8x

2.5x 2 =19W.
Calculation of the power consumed by the fans
Each fan consumed 4W.
Two fans consumed 8W.
Total power needed from solar cells.
Total power = power consumed by the modules+ power consumed by fan
Total power= 19+8=27W.
Number of solar cells needed
Ideally, each solar cells generate 1.8W (0.5 V and 3.6 A).
So the number of cells needed =27/1.8=15+2extra cells
Cells =17 solar cells.

4. Conclusion

After having focused on problems related to Peltier cooling, let's not forget about their biggest advantage: They allow cooling below ambient temperature, but unlike other cooling systems that allow this (vapor phase refrigeration), they are less expensive and more compact. Peltier elements are solid-state devices with no moving parts; they are extremely reliable and do not require any maintenance. This is completely eco-friendly project. Multipurpose and portable. This will help in reducing electricity consumption.

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