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Design and Fabrication of Portable Solar Thermoelectric Refrigerator

PremRitesh Kumar[1], M.Vikram Raj[2], N Shiva Prasad[3], B Kalyani[4], Dr. M Sreeramulu[5]
[1,2,3,4]Students, *Mechanical Engineering, HITAM college, Affiliated to JNTU, Hyderabad*
[5]*Professor, Head of Mechanical Department, HITAM college, Affiliated to JNTU, Hyderabad*
Email: Prem.ritesh96@gmail.com[1], vikramrajmaska@gmail.com[2], sreeramulum.mech@hitam.org[5]

Abstract-A large distribution of people living in developing countries irrespective of areas where the major problem at present is lack of electrification to provide refrigeration. Grid power is presently unavailable and is not imagined in the divine future. Refrigeration systems driven by the thermal combustible organic material haveefficiency about 35% in average and leads emission of greenhouse gas . Since, conventional electrically powered refrigeration system may not be much use in those areas, for basic applications such as food and drug preservation, alternative refrigeration system isrequired. Solar energy is confirmed to be an ideal source for a low temperature heating applications. Three known sound outthat use solar energy to produce refrigeration at temperature below 0^0C include solar i.e photovoltaic (PV) operated refrigeration, absorption refrigeration and solar mechanical. Among these approaches, the photovoltaic(PV) system or solar thermal energy by using Thermoelectric Technology , the most feasible and appropriate means for portable systems irrespective to any location , can call as freezer on wheels. Thus the refrigerator is eco-friendly, without fluorine pollution ,small volume, and absence of moving parts in system. Solar-powered refrigerators are typically used in off-grid locations where utilities provided AC power is not available, but we can implement these irrespective to several conditions to meet the future and utilize the conventional sources in vast possible ways. By this project we have archived the instance cooling and adequate coefficient of performance of the system is 3.5 which can be carried out to any locations easily.

Index Terms-Peltier effect, thermoelectric module, solar energy, multi power supply option

1. INTRODUCTION

Refrigeration means removing the heat from the subject or space to lower temperature than of the surroundings. Thermoelectric cooling is on the way to eliminate heat from a medium or device by allowing an voltage of unchanged polarity to the junction between two dissimilar semiconductors or electrical conductors. Thermoelectric Refrigeration produce cooling effect by using thermoelectric effect (Peltier effect) rather than a common conventional methods.

Conventional cooling systems used in refrigerators works by a compressor or by working fluid to transfer heat. But here we are avoiding all these methods to absorb Thermal energy. Semiconductor i.e thermoelectric cooler (also called as Peltier cooler) offer Several proffer advantages over the conventional systems. These are completely solid state devices, eleminating moving parts, this makes them uneven, quiet and reliable.

There is no way for ozone depletion of CFCs chlorofluorocarbons, offering more ecologically responsible alternative to conventional refrigeration. They will be ultimate compact, than the compressor based systems. Explicit temperature (< ±0.1°C) are achieved by Peltier coolers. However, its efficiency is lower then the conventional regular refrigerators. Thus, these are used in suitable applications where their unique advantages override its low efficiency. But still some large scale applications are considered (on submarines and aircrafts), Peltier coolers aregenerally utilize where small size is needed and the cooling exact not too great, such as for cooling electronic devices.

Thermoelectric refrigeration is also used in a aerospace to control an extreme thermal energy that generates in components on the sunlit side and the heated components on the other side. In other scientific applications like digital photo cameras and charge coupled devices TER also used to lower thermal noise, to optimize the sensitivity along with image contrast.

In compression refrigerators the coefficient of performance(COP) degrades with the decrease in the capacity. Therefore, it is required to design a low capacity of refrigerator, TER is preferable. even it has better control on the open space temperature which is the major advantage of the TER. Hence, TER is the better preference for food preservation & storing the insulin.

The thermoelectric cooler will use the power from solar panels When battery is charged fully, and at the time sun is absent then to maintain the temperature in the cool box we use less amount of power.

2. LITERATURE SURVEY

MatthieuCosnier[1] he conducted the experimental and numerical study on thermoelectric air-cooling. They have archived a cooling power at 50Watt per module, with a COP between 1.5 and 2, by allowing current of 4Amps and maintaining the 5°C temperature variance between both the hot and the cold sides. SuwitJugsujinda[2] performed a study

report on thermoelectric refrigerator performance. This TER system is designed by using thermoelectric cooler and applied 40 Watt power. The TER has decreased from 30 ºC to 21 ºC within 1 hour and then slowly temperature was decreasing for 24 hours. The max COP of TEC and TER are 3.0 and 0.65 respectively. Wei He[3] has Conducted Numerical study on both Theoretical and experimental exploration of a TEC and heating systems driven by solar power. Minimum temperature was 17^0C he achieved, with COP 0.45. Then compared with simulation result with experimental data. Qiu and Riffat[5] have compared the performances of thermoelectric and vapour compression air conditioners. Results have show that actual COP of vapour compression (VC) and (TEAC) are in the range of 2.6 to 3.0 and 0.38 to 0.45, respectively. Dominguez, Astrain& Vian[6] have conducted an investigation on the COP of TER by optimizing the heat dissipation. Xiao et al[7] has investigated a novel on thermoelectric radiant air conditioning system (TE-RAC). This system engages with thermoelectric modules. Based on this analysis, a commercial TE module have obtained the max cooling COP- 1.77 when 1.2A current is applied and at cold side temperature was maintained at 20°C. International Journal of Modern Trends in Engineering and Research (IJMTER) Volume 02, Issue 07, [July– 2015]Review on Thermoelectric Refrigeration: Applications and Technology By Kiran D and Sagar D. Patil. Devade Indira College of Engineering & Management, Pune.

3. WORKING SET UP

Main requirement for solar power solid state refrigeration is solar panel, then comes the battery which stores electric current switches, copper wires of required length (more in number).Switch mode power supply (SMPS), charge controller, AC adapters, on/off switch, with respective required. Then comes peltier cells fins hot sink, cold sink, thermal paste, temperature indicator.

In our project, we used various components for proper functioning and the performance of refrigerator for the body we used thermocol (Polystyrene)box.

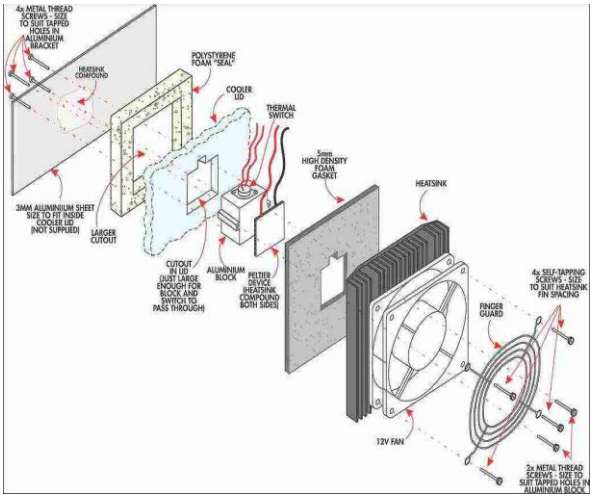

Fig. 1 - Explode view of peltier setup

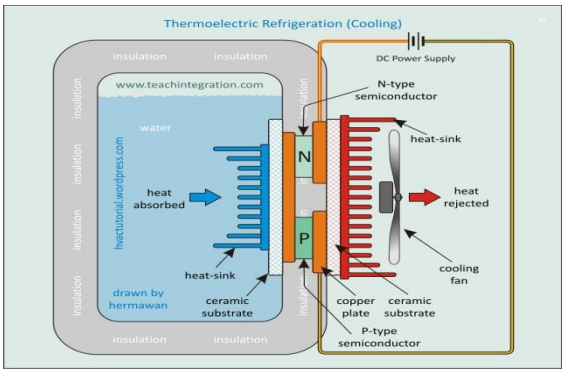

Fig. 2 - model setup of system

List of components are as follows:-

3.1 Peltier device

Two Peltier modules are used here in this the refrigerator i.e TEC1-12706 having 127 p-n junction couples. It requires 12V DC, power rating of 60W and current 6A load, each.

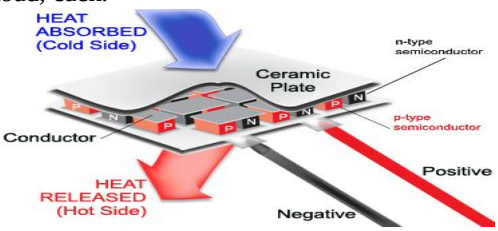

Fig. 3- Peltir device

3.2 Solar panel& charge controller

Device which absorbs the sun's energy in the form of photons, hence here we used two solar panel as a source and to charge the battery.

Fig. 4 - Solar panel& charge controller

3.3 Battery

Battery of (17 amp 12V) is used to give power for both the peltier device and the cooling fans. battery is connected to solar charge controller and to the panel which tends the battery to charge from solar.

3.4 Temperature indicator

It Indicates temperature and humidity present in the box and sensor is placed inside the cold chamber

Fig. 5 - Temperature indicator

3.5 Switch mode

Switch is used for special purpose, to switch the directional flow of current. Here we can operate the refrigerator by 3 modes of power supply they are solar , AC power , and car battery (car cigarette lighter) using various power supply adapters we can use any of them with respective to the availability and conditions.

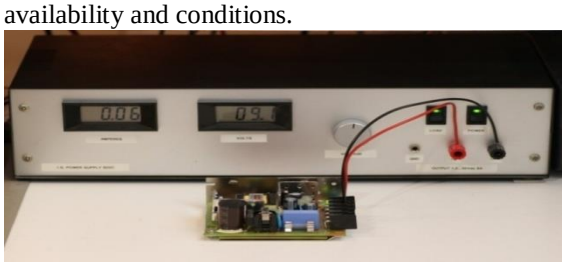

Fig. 6 - Switch mode

3.6 Heat Sink with cooling fan

Heat sinks are generally used to transfer the thermal energy from the component i.e. Peltier device.we have used 3 cooling fans mounted on heat sink in either sides. The cooling fans in this refrigerator works on 12 V.

Fig. 7 - Heat Sink with cooling fan

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3.7 AC adaptor and car cigarette lighter

An AC-adapter a type of external power supply often used as same as an AC plug. Adapters for charging the battery are generally described as chargers or rechargers.

Fig. 8 – AC adaptor

3.8 Body of refrigerator

By taking the thermocol (polystyrene) box of 26 liters, we will coat the complete outer body with the wooden lamination sheet for strengthening of polystyrene box. By applying the synthetic resin adhesive to the lamination sheet and polystyrene they are pasted together. For the texture and finishing for outer body we will use the green craft eco textured sheet to cover the outer body. The cap and the box will be joined using door hinges and screws, this will help the refrigerator to easy closing and opening of fridge door, for easy closing of door we will fit the magnets in alignment so that it can close the door easily. For opening the door we used door handle. At the bottom of the refrigerator 5 foot rests are used.

Connections:-

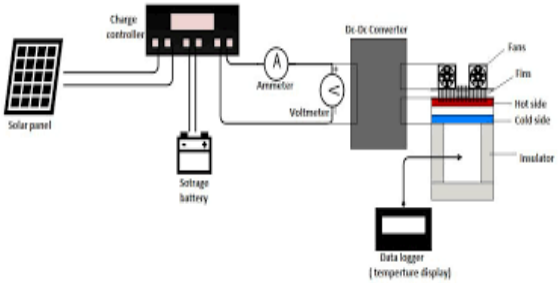

Fig. 9 – Connection

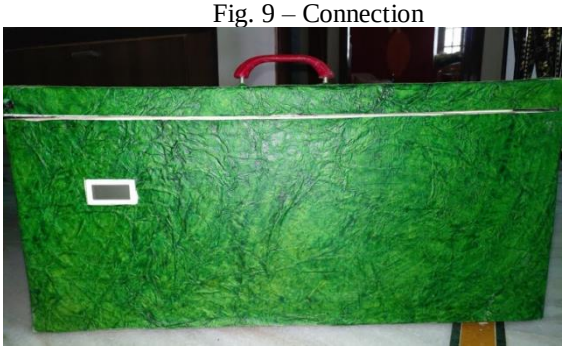

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Fig. 10 - Iinsulation box with digital temperature sensor

Fig. 11 - In side setup

4. DESIGN ANALYSIS and METHODOLOGY

4.1 Working

The Refrigerator is provided power supply from a 12V DC 17 Ah battery which is charged by 12V Solar panel by converting solar energy into electrical energy. To start the Refrigerator, the power switch is turned on. Depending upon your position and requirement power supply will be decided i.e solar , AC power supply , or adapter/car lighter.

Now the Peltier Devices (TEC1-12706) generates cooling effect on inner side and heat is distributed on outer side. On the hot side of the Peltier device, heat sink along with cooling fan on both sides works to dissipate the heat from the peltier unit. The peltier module is arranged in proper insulation box and heat sink for get sufficient cooling effect. The cooling effect is created by the Peltier module is automatically sensed by Temperature sensor placed near the cooling side of the peltier device, and then the cooling rate along with humidity is digitally shown on the screen of Digital-meter. The battery of 12V DC 17 Ah is used to supply power to cooling fans and peltier device. To turn OFF the refrigerator, the switch can be turned off, which stops the refrigerator.

Fig. 12 – Peltier device

4.2 Advantages

- Solid state heat pumps have no moving parts.
- No Freon's or other liquid or gaseous refrigerants required.
- Noiseless operation.
- Compact size and light weight
- High reliability, guarantee 200,000 hours of life span
- Precise temperature control.
- Relatively low cost and high effectiveness.
- Operation in any orientation.
- Easy to maintain
- Eco-friendly C-pentane. CFC free insulation.
- gives fast temperature response.
- It is portable, easy to carry while travelling .

4.3 Applications

- Medical field and ambulance- Pharmaceutical industry.
- In Military, rural area, etc.
- Dairy (milk) industry.
- Mechanical industry.
- Scientific and research Laboratory.
- Restaurant and hotel.
- Vegetable, fish, fruit, beverage storage. Etc.
- Electronic cooling units.

4.4 Limitations

In rainy season it cannot be possible to charge battery due to irregular atmospheric condition our project has solar energy, The only limitation of our project. And has less COP compared to other systems But problem can be solved by giving direct electric supply.

4.5 Calculations

The refrigeration chamber of (TER: 25 × 25 × 34cm³)
Thermoelectric cooler i.e peltier (TEC; 4 × 4 cm²) (TEC1-12706) of each

- Imax**:** 6.4A
- Vmax**:** 15.4V
- Qmax**:** (ΔT =0) 63 W
- ΔT max. = 68°C
- Max temp =138^{0}C
- P-N Junction = 127 couples
- Module resistance (ohms) =2.12**Ω**

Solar panel of (66x42x4 cm³)
And we have used 2 panels of each

- Maximum power (Pmax): 40W
- Voltage at (Vmax) : 16.4V
- Current at (Imax) : 2.45A
- Open circuit voltage : 21V
- Short circuit current : 2.7A
- System voltage : 1000 V DC
- Power : 80 W
- Battery of 12V 17A capacity

As per observation
TEC cold side temperature (**Tc**) was decreased from 32 ºC to –3.2 ºC in 1 hour and continuously decreasing to –6.4 ºC in 24 hours and 96 ºC for hot side temperature (**Th**). The TER temperature was decreased from 36 ºC to 18 ºC in 1 hour and slowly temperature is decreasing for 24hrs

We know, The general forms of heat absorption and heat rejection are presented as
Heat absorption
$Qc= \alpha I Tc – 0.5I^2 R – Kt(Th- Tc)$ ----------(eq1)
Heat rejection
$Qh = \alpha I Th+ 0.5I^2 R – Kt(Th- Tc)$ ---------(eq2)

Where,
α - Seebeck coefficient (V $k^{-}1$),
I - electric current,
Tc -TEC cold side temp ^{0}C,
Th -TEC hot side temp ^{0}C,
R - electrical resistant of the TEC material (**Ω**),
And *Kt* is the thermoelectric element thermal conductivity (W $m^{-}1K^{-}1$).

COP = Qc / Qh-Qc = Tc / Th –Tc ---------- (eq3)

By using these values and formulas we can determine the COP of TEC and TER from fabricated TER.

COP of Thermoelectric cooler (peltier)

COP of TEC (TEC1-12705) is taken from measured values compose of Voltage, Amps and temperature etc, where TEC performance specifications are as mentioned above.
The Qc of TEC is calculated by Eq. (1),
Where
$\alpha = 0.053$ V $K^{-}1$, or 53mV k-1
$R = 1.8\Omega$
And $Kt = 0.495$ Wm–1K–1
COP of peltier cooler is 3.5

COP of Thermoelectric refrigerator

TER has dimension of (25 × 25 × 34 cm^3) approx 22L capacity
The TER temperature is decreased from 36 ºC to 18ºC within 1 hour
the COP of refrigerator we achieved is 1.1

Actual efficiency : COP = Q/P
Q=MCpΔT/tx60
P= VX I
Efficiency = actual/theoretical

Table 1 - Analysis

Parameters	VCAC	AAC	TER
Cooling/heating capacity	medium	High	Less
Electricity consumption	medium	Low	High
COP	2.6-3.0	0.6-0.7	0.38-0.45
Noise level	noisy	Noisy	Quiet
Total cost(initial &operating)	medium	lowest	highest

5. CONCLUSION

These days, solar energy is greatly used to meet the energy requirement of the country. Growing at a very fast rate, its applications have also been explored in many areas. This Refrigerator is intended to go all over the world and is efficient and economical to the areas where there is no Electricity and cooling is required.
The main objective is to introduce the non-conventional Compressor less Solar Refrigerator and we have successfully reached. The application of this Refrigerator can be vast used in various places for different operations.

6. FUTURE SCOPE

Though refrigerator is working successfully to its full capacity, still there are many changes and improvements to be made so that it is more user-friendly and cultivated in nature. Some changes are as follows:

- By increasing the number of Peltier modules and keeping the size of refrigerator unchanged and decrease the temperature inside the box.
- similar process can be used for heating purpose also , if we add the heating side of the refrigerator chamber inside system.
- by increasing the volume of refrigerator the capacity can be varied
- efficiency can be increased by choosing better insulation material.
- The use of this refrigerator can also impliment in Four Wheeler by installing it at the time of manufacturing of vehicle

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