International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 07 | July 2018 www.irjet.net p-ISSN: 2395-0072

Development of a Hybrid Thermoelectric Refrigerator for Applications in Rural Area

Smrithi.U.S[1], Swathi.S[2], Akhil.M[3]

[1]Assistant Professor, Dept. of Electrical and Electronics Engineering, ACE College of Engineering, Kerala, India
[2]B.Tech Scholar, Dept. of Electrical and Electronics Engineering, ACE College of Engineering, Kerala, India
[3]B.Tech Scholar, Dept. of Electrical and Electronics Engineering, ACE College of Engineering, Kerala, India

---

Abstract - *This paper illustrates the development of a simple alternative to conventional refrigeration system which is eco-friendly in all aspects. The increased requirement of simplified and cost effective refrigeration/warming in rural areas especially for vaccine storage and other hospital purposes during natural calamities has forced to develop a cooling system which possess simple usage and portability, decentralized power supply, provision for energy storage, no environmental hazards etc. The system adopts thermoelectric principle namely Peltier Effect to cool a space. In order to achieve the purpose of cooling, solar cells generate electricity to drive the thermocouple. A micro controller based smart charge controller is also developed for protection and working status indication. The cooling or warming based on thermoelectricity may play an important role due to its immense advantages despite a lower cooling performance compared to conventional refrigeration. The proposed model is verified using appropriated hardware, where the results are found to be satisfactory.*

***Keywords*: Solar Energy, Peltier Effect, Thermocouple, Charge Controller**

1. Introduction

The globally increasing demand in refrigeration and air-conditioning calls for increased usage of conventional refrigerators and other cooling systems, which triggers high usage of electricity as well as uncontrolled release of green house gases like CFCs, CO2 etc to the atmosphere. A conventional refrigerator utilizes a compressor, evaporator, condenser and a working fluid called refrigerant to transfer heat. Heat is absorbed and released as the refrigerant undergoes expansion and compression and transforms its state from liquid to vapour and vice versa in a cyclic manner. This process involves heavy consumption of electricity which may not be affordable for people living in remote areas.

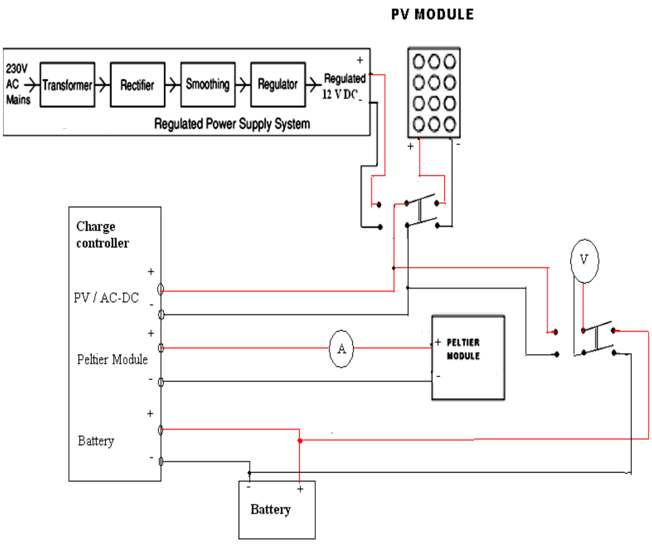
An efficient alternative to this is an eco-friendly refrigerator which works on the principle of 'Thermo-electric effect' [1]. Thermoelectric devices are based on Peltier, Seebeck and Thomson effect which has gained major developments in recent period [2]. Semiconductor thermoelectric/peltier coolers possess several advantages over conventional Refrigeration systems. They are solid-state devices which are rugged and silent since there are no moving parts. They are very much environment friendly as no release of ozone depleting gases occurs during their working. Accurate temperature control (< ± 0.1 °C) can be achieved with Peltier coolers. Another important feature is its mobility, which increases its reliability in remote areas, especially during natural calamities. The device 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.[3] However, they have low efficiency compared to conventional refrigerators. Hence they are used in specific and crucial applications where their advantages overrule efficiency. Peltier coolers are mostly used in applications where small size is needed and the cooling demands are not too great, such as for cooling electronic components, preserving medicines etc [4]

A Solar thermoelectric cooler is a special type of cooler which utilizes solar energy instead of conventional electrical energy to power the thermoelectric module that has been used to cool the refrigeration space. In this current scenario of energy crisis, the use of renewable solar energy source will increase the impact of peltier cooler as an apt environmentally responsible alternative towards the conventional means.[5]

This paper aims at developing a prototype of an eco friendly solar powered peltier cooler with the help of thermocouple and other necessary accessories like battery, heat sink, fan etc. In order to ensure continuity of service during night or cloudy days, provision for accessing conventional power is also incorporated which makes the entire cooling system, a hybrid one. A micro controller based smart charge controller has been designed and developed to detect and control the power flow in the system. This paper includes 6 chapters. A simple block diagram of the 'hybrid thermo-electric refrigeration system' is included in Chapter 1. Chapter 2 includes the working principle. While chapter 3 explains about the design and selection of components of the system, chapter 4 includes the Charge Controller design. Chapter 5 focuses on the prototype development. The conclusion and future scope of the work is discussed in chapter 6.

2. Block Diagram of Hybrid Thermo-electric Refrigeration System

Fig-1 represents the block diagram of solar powered



thermoelectric refrigeration system with additional conventional power backup.

Fig-1: Block Diagram of Thermoelectric Refrigeration System

2.1 Block Diagram Description

- **SOLAR MODULE**

As a part of making the system eco-friendly, a solar panel of 10 watts to meet the power requirements of the system is used here.

- **CHARGE CONTROLLER**

Charge controller is included in the circuitry to protect the battery from overcharging. It also ensures that under low voltage condition, the load is disconnected and the battery is charged according to its requirement. Here, microcontroller-based smart charge controller is used.

- **BATTERY**

A sealed maintenance-free type Lead Acid battery of 26 Ah, 12 V is used here.

- **PELTIER MODULE**

A peltier module works based on the principle that 'if direct current is passed through two dissimilar metals then a potential difference will be developed across them and there will be cooling at one surface and heating at the opposite surface[6]. A typical thermoelectric module consists of an array of Bismuth Telluride semiconductor pellets that have been "doped" so that one type of charge carrier either positive or negative carries the majority of current. The pairs of P/N pellets are configured so that they are connected electrically in series, but thermally in parallel. When DC voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The surface where heat energy is absorbed becomes cold; the opposite surface where heat energy released becomes hot. Its operating voltage is about 12 V.

- **CHARGER**

This is an AC-DC converter which is used as an alternative power supply, in case the solar power is unavailable.

3. Working Principle

The Peltier Effect is the basis on which a thermoelectric module operates: it involves the generation of a temperature difference due to an electric current passing through a non homogeneous conductor.. Thermoelectric modules are made of two materials called p-type and n-type and are often made from a Bismuth Telluride semiconductor. When a DC voltage is applied to the module, one side absorbs heat (becomes cold) and the other side rejects heat (becomes hot) as shown in Fig-2. The cold side of a thermoelectric module can be used for cooling in a refrigerator and the hot side for warming. The rate of heat transfer through the module is directly related to the temperature difference across the two sides of the module and the temperature of the hot side of the module. Less heat will be transferred when the temperature difference across the module is high or the hot side temperature is relatively low. It is most desirable to have a low temperature difference across the two sides of the module and to have a high temperature on the hot side of the module. However, in order to freeze water, the temperatures of the hot and cold sides must be kept at extremes, which severely limit the amount of heat transfer that can occur through the thermoelectric module.

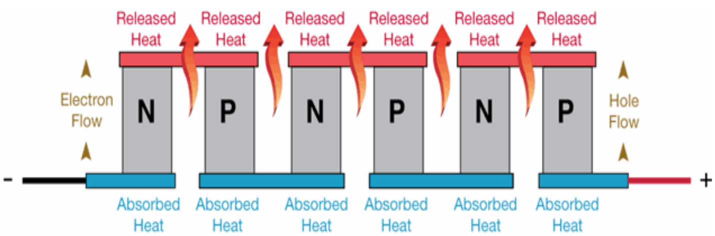


Fig-2: Heat flow in Thermocouple

The electricity needed for the module is provided by the sealed maintenance type lead acid battery charged by solar energy through the solar panel. The PV cells produce direct voltage from light that can be used to power everyday equipment.

The charge controller connected between the panel and battery monitors the battery's state-of-charge to ensure that when the battery needs charge-current it gets it, and also ensures the battery isn't over-charged. It also cuts out the battery from the load when the lead acid battery is depleted to prevent damage to the battery [8]. A charger which consists of a rectifier, filter and voltage regulator is incorporated to charge the battery incase the solar supply fails. Fig-3 shows the schematic diagram of thermo electric cooling.

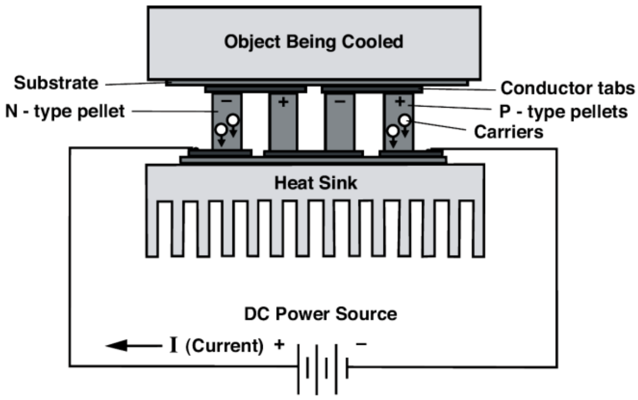


Fig-3: Thermo-electric Cooling

4. SYSTEM DESIGN

Based on the load requirement of the prototype, the following estimation and design has been done.[7]

4.1 Load Estimation

Peltier module power rating = 40 watts
Voltage rating = 12 volts
Operating period = 2 hours
Total watt-hour rating of module
= 40x2
= 80 watt-hours

4.2 Battery

Voltage rating =12 V
Ampere hour requirement = 80 Wh /12 V
=6.67 Ah
Considering the battery efficiency to be 80%,
Ah rating =6.67/0.8
=8.33 Ah
$\simeq$10 Ah

Since the battery should retain at least 20% of total charge at all times, it should be sized at least 20% larger than this amount. So, we select a 26 Ah battery.

It is important to match the solar panel's current rating to the battery's amp-hour rating (C). A typical maximum battery charging current is C/10, so a 26 Ah battery should have a solar panel rating of no greater than 3 ampere.

4.3 Solar Photo Voltaic Module

Total energy to be supplied by solar cells
= 80 Wh
Average charging time = 7 hrs
So, wattage rating of solar module
= 80/7
= 11.43 watts
i.e., 1 solar module of 12W, 18 V.
Ideally, each solar cell generates 0.5V.
So, number of solar cells = 18/0.5
= 36 cells.

4.4 Charge Controller

Charge controllers rating is based on the solar panel ampere rating. Hence, a 12V, 3A charge controller is selected.

4.5 Charger

A 12V, 5A power supply is used. For an input voltage of 15 V for the regulator, plus 10% of this value for ripple, plus 1.4 voltage drop across the bridge rectifier,
Voltage at secondary of transformer
=15+1.5+1.4
=18.9 V
$\simeq$18V, 5 A.
Hence, 230/18V transformer is selected. A current limiting resistor of 1 ohm, 1 W is used.

The rating of components of Thermoelectric Cooler is listed in table 1.

Table- 1: Component Ratings

Sl .No	Component	Rating
1	Peltier Module	80 Wh
2	Battery	10Ah
3	Solar Panel	12 W, 18 V
4	Charge Controller	12 V, 3A
5	Transformer	230/18 V

5. COMPONENTS OF CHARGE CONTROLLER

The function of a charge controller is to regulate the power flowing from a photovoltaic panel into a rechargeable battery. A charge controller monitors the battery's state-of-charge to insure that when the battery needs charge-current it gets it, and also insures the battery isn't over-charged.

Microcontroller based charge controller design is feasible for performing complex task and hence to expand the utility of the project to a wide scale. **Atmel 89C51** microcontroller used in this charge controller is the central of coordinating all system's activity.

5.1 Features of Charge Controller

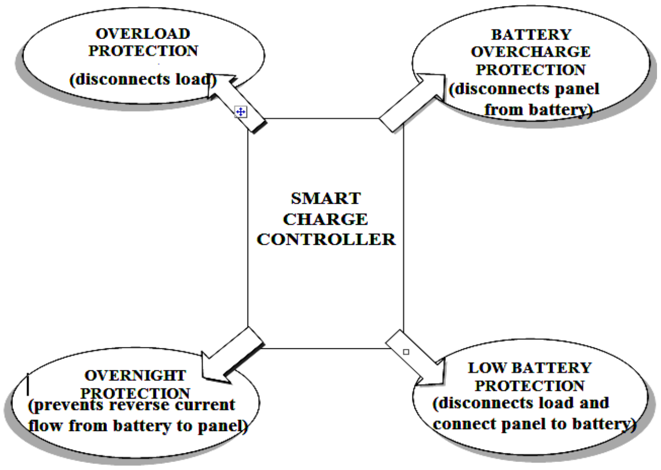


Fig-4: Charge Controller features

The main design features of the charge controller are shown in Fig -4. 5 LED indicators are added to show the status of the charge controller which are charging indication, battery low condition, battery high condition, overload condition, trickle charging condition. Charge controller controls the charging condition of the battery in both solar charging method as well as conventional electric charging method.

5.2 Charge Controller Components

- Microcontroller-Atmel 89C51
- Voltage Regulator IC 7805 – to get 5 V dc for powering the chip.
- MOSFET– IRF9530
- Comparator – LM324, LM358
- Transistor – BC547
- Diodes
- Resistors
- Capacitors
- Cartridge fuse
- LEDs

The PCB mounted Charge Controller incorporating the programmed micro controller is shown in Fig -5

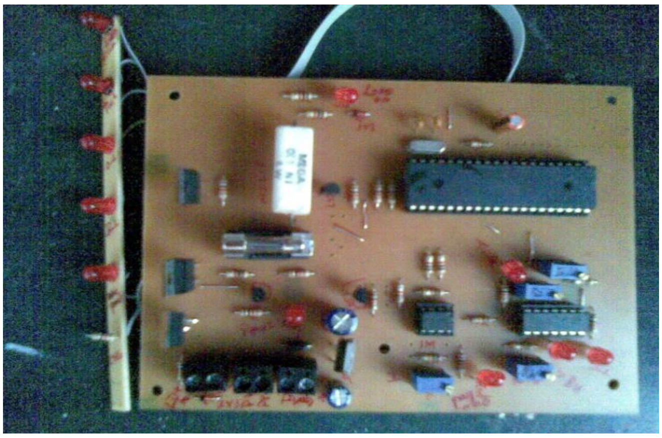


Fig-5: Charge Controller

6. DEVELOPMENT OF PROTOTYPE

6.1 The Peltier Module Assembly

Several methods for installing thermoelectric modules have been considered including: mechanical clamping, epoxy bonding, and direct solder bonding [9][10]. Mechanical clamping is adopted here. The assembly of peltier module, heat sink etc are shown in Fig -6. Special care must be taken to insure that uniform pressure is applied during installation.

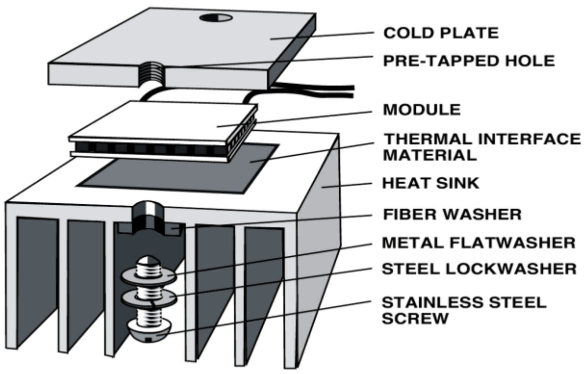


Fig-6: The Module Assembly

6.2 Casing Dimension

The dimension of the complete prototype is as shown in Fig -7

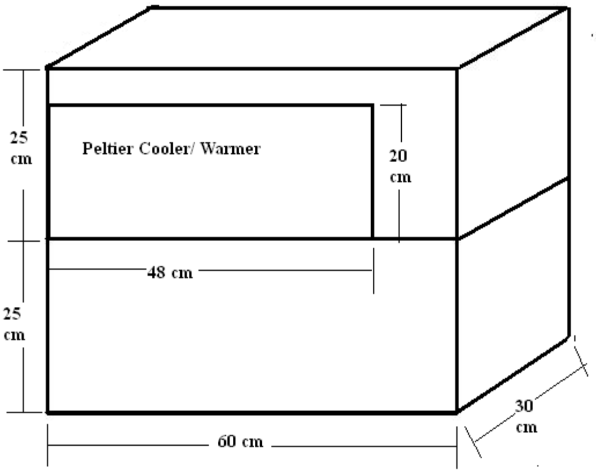


Fig -7: Planned dimension of the prototype

6.3 Selection of Vacuum Insulated Cabinet

Fig-8: Insulated Chamber of Peltier Cooler

Fig-8 shows the insulated chamber of our cooler/warmer. The cabinet shown is made of ABS material with Aura vacuum panels sandwiched between the inner and outer shells. The top part of the cabinet is insulated with foam and was designed to house a thermoelectric device and allow for air heat exchange.

6.4 The Complete Prototype

The front view, top view and side view of the developed prototype are shown in Fig -9-11

Fig- 9: The front View

Fig- 10: The top view showing the solar panel

Fig-11: The bottom half view showing the meters, switches &LEDs

6.5 The Initial Conditions

Before the actual working was checked, the following were the readings obtained:

Battery Voltage	--- 12.8 V
Charger Output Voltage	--- 15.3 V
Charger Current	--- 1.08 A
Peltier Module Current	--- 1.6 A
Panel Voltage	--- 14.16 V

7. CONCLUSION & FUTURE SCOPE

The paper demonstrates the use of a novel and innovative technology for the implementation of a cooling system. The cooling system is employed using a Peltier module and powered by solar energy. It is seen that reasonable cooling can be achieved using the prototype developed. The temperature variations achieved using our prototype is of the order of 10-55 degree Celsius. This eco-friendly initiative can be used for local refrigeration, cooling in remote areas, preservation of vaccines and medicines etc. Although the prototype works well in small enclosed space, a more versatile version may be developed for general purpose applications. The prototype can be modified according to specific requirements by changing the Peltier element by a series-parallel combination to achieve greater degree of temperature variations. Further, the prototype can be made an intelligent system by incorporating signal processing and signal conditioning elements.

REFERENCES

[1] C J Mole, D V Foster, R A Feranchak, "Thermoelectric Cooling Technology," in IEEE Transactions on Industry Applications, vol. IA-8, no. 2, pp. 108-125, March 1972

[2] R. Sharma, "Peltier Effect Based Solar Powered Air Conditioning System," International Conference on Computational Intelligence, Modelling and Simulation, pp. 288-292, 2009

[3] Gastelo-Roque, José & Morales-Acevedo, Arturo, "Design of a photovoltaic system using thermoelectric Peltier cooling for vaccines refrigeration", IEEE MIT Undergraduate Research Technology Conference , 2017.

[4] Linlin Cao, Jitian Han, Lian Duan, and Chong H, "Design and Experiment Study of a New Thermoelectric Cooling Helmet," In Proceedings of the 10th International Symposium on Heating, Ventilation and Air Conditioning, pp.1426–1432, 2017, China

[5] Ajeet Gared, Abdurrahman, Babita K Varghese, Amit Jain, "Thermoelectric Refrigerator: A Novel Potential Green Technology," International Journal of Engineering Trends and Technology , Vol 35, No 14, 2016

[6] A. Jose, A. D'souza, S. Dandekar, J. Karamchandani and P. Kulkarni, "Air conditioner using Peltier module," International Conference on Technologies for Sustainable Development (ICTSD), Mumbai, pp. 1-4. 2015

[7] Shuwang Chen, Jun Zuo and Dan Xie, "Design of solar power semiconductor refrigerator," 2010 8th World Congress on Intelligent Control and Automation, Jinan, pp. 419-423, 2010

[8] N. B. Totala, Prof. V. P. Desai, Rahul K. N. Singh, Debarshi Gangopadhyay, Mohd. Salman Mohd. Yaqub, Nikhil Sharad Jane, "Study and Fabrication of Thermoelectric Air Cooling and Heating System", International Journal of Engineering Inventions pp. 2319-6491 Volume 4, Issue 2, 2014

[9] Palash Nakhate , Niraj Pawaskar , Purva Vatamwar , Saurabh Kalambe, "Ecofriendly refrigerator using peltier effect", International Journal of Research In Science & Engineering pp 2394-8280, 2017

[10] Sabah A. Abdul-Wahab , Ali Elkamel b, Ali M. Al-Damkhi , Hilal S. Al-Rubai'ey, Abdulaziz K. Al-Battashi , Muhammad U. Chutani, "Design and experimental investigation of portable solar thermoelectric refrigerator", International Journal for Renewable Energy, Volume 34, Issue 1, pp 30-34, 2009