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Thermoelectric Refrigeration by Using Solar Energy for Domestic Appliance

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Abstract- Design and developmental methodology of thermoelectric refrigeration has been explained in detail also the theoretical physical characteristics of thermoelectric cooling module used in this research work have been investigated. Authors have been designed and developed an experimental prototype of thermoelectric refrigeration system working on solar photo voltaic cells generated DC voltage. The developed experimental prototype having a refrigeration space of 1liter capacity is refrigerated by using four numbers of Peltier module (Supercool : PE-063-10-13, Qmax=19W) and a heat sink fan assembly used (Model No: TDEX6015/TH/12/G, Rth=1.157 oC/W) to increase heat dissipation rate from hot side of Peltier module. The experimental result shows a temperature reduction of 11oC without any heat load and 9oC with 100 ml water kept inside refrigeration space in 30 minute with respect to 23oC ambient temperature. Also the COP of refrigeration cabinet has been calculated and it is 0.1. The developed thermoelectric refrigeration system is having potential application of storage and transportation of life saving drugs and biological materials at remote areas of our country where grid power is unavailable.

Index Terms- ***Peltier effect, Thermoelectric module, Coefficient of Performance, P V cells.***

1. INTRODUCTION

Conventional refrigeration systems use ChloroFluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs) as heat carrier fluids. Use of such fluids in conventional refrigeration systems has a great concern of environmental degradation and resulted in extensive research into development of novel refrigeration technologies. The current tendency of the world is to look at renewable energy resources as a source of energy. This is done for the following two reasons; firstly, the lower quality of life due to air pollution and secondly, due to the pressure of the ever increasing world population puts on our natural energy resources. From these two facts comes the realization that the natural energy resources available will not last indefinitely. Therefore, the ideal solution would be to use some type of renewable energy resource to provide these houses with energy without an expensive electrical grid connection. One solution is a RAPS (Remote Area Power Supply) using an alternative form of energy. [2]

Thermoelectric refrigeration system powered by solar photo voltaic (PV) cell generated DC voltage is suitable for Indian climate conditions and applicable for rural health centers. For utilizing solar energy efficiently and cost effectively, proper design of reliable solar devices and system have to be attempted to suit the radiation climate and socioeconomic conditions. From this perspective, sizing of PV system involves finding the cheapest combination of array size and storage capacity that will meet the anticipated load requirement with the minimum acceptable level of security. The information required is including the daily or hourly load requirement, peak current and voltage characteristics of the solar module, the number of autonomous days, the estimated percentage of energy losses in the battery and power conditioning equipment, and the estimated losses in the array due to module mismatch, cable, dust and shading.

2. REFRIGERATION

An American society of refrigeration engineer has defined refrigeration as “the science of providing and maintaining temperature below that surrounding atmosphere.”

2.1. *Necessity of Refrigeration*

For normal functioning of human beings sufficient, protein, carbohydrate, vitamin and salts are requires which accomplish by balance diet or pills. The people with normal health and their peculiar habits prefer tasteful diet to fulfill the normal functioning of body organs requirement. Another necessity of refrigeration is in the developing of certain scientific equipment and their operation under controlled environment to get reliable results. Many industries like chemical, milk dairy, oil refinery, etc. require low temperature to carry various processes.

2.2. *Methods of refrigeration*

Methods of refrigeration can be classified as non-cyclic, cyclic, thermoelectric and

i. Cyclic refrigeration

ii. Thermoelectric refrigeration

iii. Magnetic refrigeration

3. THERMOELECTRIC REFRIGEARTION BY USING SOLAR ENERGY:

3.1 Experimental Setup:

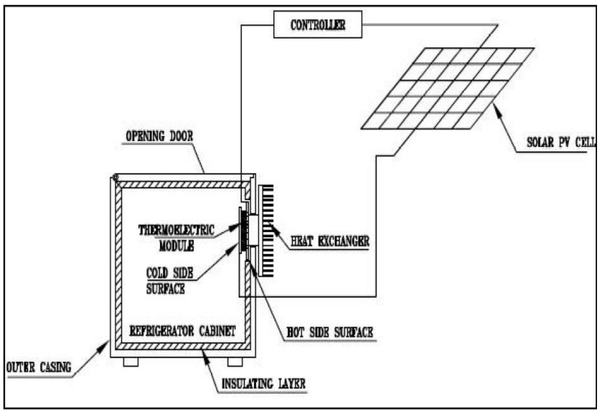


Figure 3.1 Experimental Setup Diagram

The construction set up for this system require following parts:-

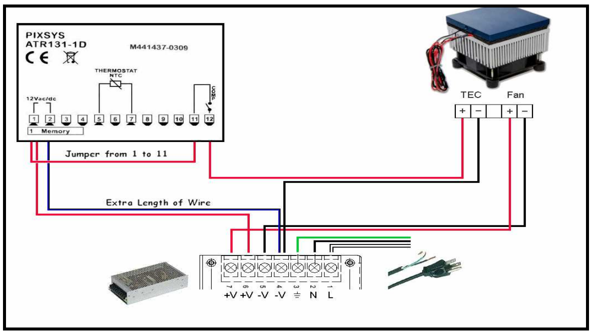
1. Solar panel
2. Charge controller
3. Thermoelectric module
4. Exhaust fan
5. Cabinet
6. Battery bank
7. Relay switch

3.2 Working:

Figure 3.2 Project setup

The principle of power generation behind the solar cells consists of the utilization of the photovoltaic effect of semiconductors. When such a cell is exposed to light, electron-hole pairs are generated in proportion to the intensity of the light. Solar cells are made by bonding together p-type and n-type semiconductors. The negatively charged electrons move to the n-type semiconductor while the positively charged holes move to the p-type semiconductor. They collect at both electrodes to form a potential. When the two electrodes are connected by a wire, a current flows and the electric power thus generated is transferred to battery banks connected to it. Solar charge controller is used to supply constant current to batteries. From battery the supply is given to the thermoelectric module which produces refrigeration effect in the cabinet using peltier effect. So required refrigeration effect can be obtained by supplying voltage from battery. [5]

3.3 Electrical Connections of Thermoelectric Refrigeration:



` **Fig.3.3 Electric connections of thermoelectric cooler**

4. COEFFICIENT OF PERFORMANCE CALCULATIONS

i.THEORETICAL COP:

The performances equations (1-3) of a thermoelectric cooler are expressed as follows and are described in many handbooks and papers [2,3,6]

$$Qc = \propto m \times Tc \times I - \frac{1}{2}(I^2 Rm) - Km \times (Th - Tc) \quad \ldots(1)$$

$$W = \propto m \times I \times (Th - Tc) + I^2 Rm \quad \ldots\ldots\ldots.. (2)$$

$$COP = \frac{Qc}{W} \quad \ldots\ldots\ldots(3)$$

$$Rm = \frac{2\rho tnN}{G} \quad \ldots\ldots\ldots..(4)$$

$$\propto m = 2 \propto N \quad \ldots\ldots\ldots..(5)$$

$$Km = 2NKG \quad \ldots\ldots\ldots(6)$$

In the above equations the αm, Km, Rm are the device Seeback voltage, device thermal conductance and device electrical resistance under the assumption of all identical couple and the unidirectional heat flow. These device parameters can be calculated from manufacturer's datasheet by using following equations as given below [7],

$$\propto m = \frac{Vmax}{Th} \quad \text{........(7)}$$

..............(8)

$$Rm = \frac{(Th - \Delta Th)}{Th} \times \frac{Vmax}{Imax}$$

$$Km = \frac{(Th-\Delta Tmax)}{2\Delta Tmax} \times \frac{(Vmax \times Imax)}{Th} \quad \text{..... (9)}$$

$$Z = \frac{2 \times \Delta Tmax}{(Th - \Delta Tmax)2}$$

.... (10)

Where Imax is the maximum input current at Qc=0, Vmax is maximum DC voltage at Qc=0 and ΔTmax is the maximum temperature difference at Imax, Vmax and Qc=0.

For module,
TEC1-12706
T_h=25
T_c=10
Q_{max}=50W
ΔT_{max}=66K
I_{max}=6.4A
V_{max}=14.4V

$$\propto m = \frac{Vmax}{Th}$$

$$=14.8/298$$

$$\mathbf{=0.04832\ V/{}^{\circ}K}$$

$$Rm = \frac{(Th-\Delta Th)}{Th} \times \frac{Vmax}{Imax}$$

$$= \frac{(298-66)}{298} \times \frac{14.4}{6.4}$$

$$= 1.75\Omega$$

$$Km = \frac{(Th-\Delta Tmax)}{2\Delta Tmax} \times \frac{(Vmax \times Imax)}{Th}$$

$$= \frac{(298-66)}{2 \times 66} \times \frac{(14.4 \times 6.4)}{298}$$

$$\mathbf{=0.5435/{}^{\circ}K}$$

$$Z = \frac{2 \times \Delta Tmax}{(Th - \Delta Tmax)2}$$

$$= \frac{2 \times 66}{(298-66)2}$$

$$= 0.00245/{}^{\circ}K$$

$$Qc = \propto m \times Tc \times I - \frac{1}{2}(I^2 Rm) - Km \times (Th - Tc)$$

$$= 0.04832 \times 283 \times 6.4 - \frac{1}{2}(6.4^2 \times 1.75) - 0.4535 \times (25 - 10)$$

$$= 43.99W$$

$$W = \propto m \times I \times (Th - Tc) + I^2 Rm$$

$$= 0.04832 \times 6.4 \times (25 - 10) + 6.4^2 \times 1.75$$

$$= 76.31w$$

$$COP = \frac{Qc}{W} = \frac{43.99}{76.31}$$

$$COP = 0.6$$

ii. ACTUAL COP:

$$RE = \frac{mCp\Delta T}{t}$$

Given:

m= 1kg

Cp=4.187

$$\Delta T = 10°C$$

t=20min

W=76.31W

$$RE = \frac{mCp\Delta T}{t}$$

$$= \frac{1 \times 4.187 \times (29 - 10)}{20 \times 60}$$

$$RE = 0.0348KW$$

$$RE = 0.0348 \times 1000W$$

$$COP = \frac{\text{Refrigerent Effect}}{W}$$

$$= \frac{0.03489 \times 1000}{76.31}$$

$$COP = 0.45$$

Table1;COST ESTIMATION

SR. NO	PART NAME	QTY.	PRICE
1.	Battery (EXIDE CS7-12)	2	1560/-
2.	Solar Panel 20watt	1	1400/-
3.	Solar Charge Controller	1	850/-
4.	Temperature Controller	1	1495/-
5.	Thermoelectric Cooler Peltier Module	1	925/-
6.	DigitalHydroThermometer With Clock	1	682/-
7.	Thermoelectric Cooler Set	1	4799/-
8.	Switch	1	20/-
9.	Wire	1	150/-
10.	LCD	1	70/-
11.	Fridge Switch	1	20/-
12.	Cello Ice Box	1	2400/-
13.	Ply	1	480/-
14.	Lug	1	40/-

Total cost (Rs.): 14891/-

5. APPLICATIONS

Commercial devices based on thermoelectric materials have come up in a big way recently. In addition to the benefits thermoelectric offer over the conventional devices, commercial factors like decrease in production costs and significant opening of consumer markets have helped it in a big way and the use of T.E. devices is increasing day by day.

6. CONCLUSION

Thermoelectrics and thermoelectric cooling are being studied exhaustively for the past several years and various conclusions have been conceived regarding the efficient functioning of thermoelectric refrigerators.

Thermoelectric refrigerators are greatly needed, particularly for developing countries, where long life, low maintenance and clean environment are needed. In this aspect thermoelectrics cannot be challenged in spite of the fact that it has some disadvantages like low coefficient of performance and high cost. These contentious issues are the frontal factors hampering the large scale commercialization of thermoelectric cooling devices.

The solution to above problems can only be resolved with the development of new techniques. There is a lot of scope for developing materials specefically suited for TE cooling purpose and these can greatly improve the C.O.P. of these devices. Development of new methods to improve efficiency catering to changes in the basic design of the thermoelectric set up like better heat transfer, miniaturization etc. can give very effective enhancement in the overall performance of thermoelectric refrigerators. Finally, there is a general need for more studies that combine several techniques, exploiting the best of each and using these practically.

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