Solar Operated Cooling Using Thermo-Electric Module

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Abstract— In the recent year, energy crises and environment degradation due to the increasing CO2 emission and ozone layer depletion has become the primarily concern to both developed and developing countries. Our project utilizes the solar energy for its operation. Solar refrigeration using thermo-electric module is going to be one of the most cost effective, clean and environment friendly system. Both heating and cooling can be done in a single system which is possible due to the thermoelectric module. This project does not need any kind of refrigerant and mechanical device like compressor, prime mover etc for its operation. The main purpose of this project is to provide refrigeration system to the remote areas where power supply is not possible and also to study the cooling effect on DC as well as AC supply and compare the results coming out and determining the Coefficient of Performance of the system.

Key words: Refrigeration, Peltier effect, Thermo-electric module, Solar energy

I. Introduction

From last century till now refrigeration has been one of the most important factors of our day to day life. The current tendency of the first 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.

The basic idea is implementation of photovoltaic driven refrigerating system powered from direct current source or solar panel (when needed) with a battery bank.

II. Concept

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature.

The Seebeck coefficient is the ratio between the electric field and the temperature gradient or the ratio between the voltage difference and temperature difference between the ends of the sample.

The Peltier coefficient of the junction is a property depending on both materials and is the ratio of the power evolved at the junction to the current flowing through it.

The Thomson coefficient is the ratio of the Power evolved per unit volume in the sample to the applied current and temperature gradient.

III. Construction

The construction setup of the refrigerator is as follows,

a) Thermo-electric module
b) Refrigeration chamber
c) Battery
d) Solar cell
e) Frame

A. Thermo-electric module (Model no. – TEC1-12706)

A thermo-electric module (TEM) is a solid state current device, which, if power is applied, move heat from the cold side to the hot side, acting as a heat exchanger. This direction of heat travel will be reversed if the current is reversed. Combination of many pairs of p and n semiconductors allows creating cooling units - Peltier modules of relatively high power. As shown in the model no. there are 127 number of p–n coupling Specification,

1) Material used- Silicon - Bismuth
2) A = 0.04 x 0.04 = 0.0016 m^2

B. Refrigeration chamber

The chamber used is same as that of the chambers used in conventional refrigeration. The chamber can be of any volume, shape and size. We have used 7.8 L capacity cooler box. For experimentation purposes the volume of the chambers is kept low. Insulation provided to the chamber is done by polystyrene. And aluminium casing is done in the inner side of insulation to provide better cooling.

C. Battery

The battery is an electrochemical converting chemical energy into electrical energy. The main purpose of the battery is to provide a supply of current for operating the cranking motor and other electrical units.
Specification,

1) Voltage 12 V
2) Current 7.2Ah

D. Solar cell

The direct conversion of solar energy is carried out into electrical energy by conversion of light or other electromagnetic radiation into electricity.

1) Voltage – 17 V dc
2) Current – 1.16amp
3) Power - 20 W
4) Solar irradiation – 1000 W/m2
5) No. of subcells - 72

IV. Working of Thermo-electric cooler

It is an equipment, which work on principle of conversion of solar energy into electrical energy. A solar cell is used to develop 17 V & 1.16 amps current DC supply and 20W. This electrical energy is stored in a battery which is of 12 volts DC supply which then supplies the power to transformers.The transformer control three fan out of which two-fan work as exhaust fan & remove heat from heat sink plate. The third in side fan work as heat extractor, this fan remove heat from system and add to heat sink. During operation, DC current flows through the TEM causing heat to be transferred from one side of the TEC to the other, creating a cold and hot side.The COP for heating and cooling are different, because the heat reservoir of interest is different. The COP is the ratio of the heat removed from the cold reservoir to input work. However, for heating, the COP is the ratio of the heat removed from the cold reservoir plus the input work to the input work:

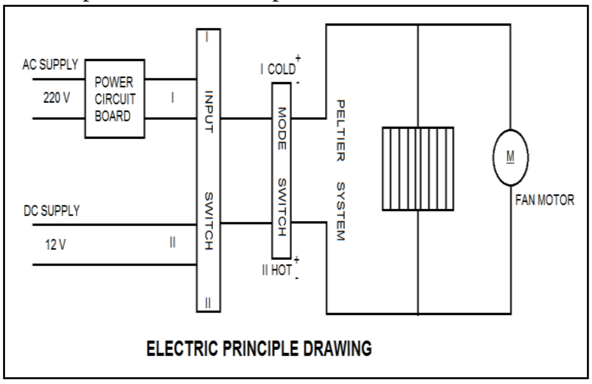

Fig. 1: Electric principle drawing

A. *Working design*

As project is based on peltier effect our first main step is selection of right peltier module. For selection of module following factors should be consider, which is taken from previous data.

1) Its operating temperature must be within required limits.
2) Heat rejected by hot side of module should be less than its total power capacity.
3) For desired cooling proper heat sink should be provided on hotter side.
4) Peltier module should be selected according to the volume which has to be cooled.

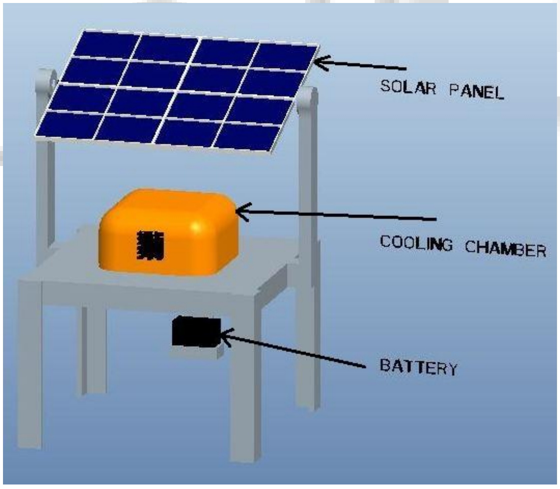

Fig. 2: cad model of solar refrigerator using peltier effect in pro- e

V. OBSERVATION

Based on the AC and DC supply we carried out some experimentation and got following observations.

A. *AC supply cooling at corner of chamber*

NO.	TIME (min)	TEMPERATURE (°C)	NO.	TIME (min)	TEMPERATURE (°C)
1	0	27	16	15	19.1
2	1	26.8	17	16	18.8
3	2	26.4	18	17	18.4
4	3	25.7	19	18	18.2
5	4	25.1	20	19	17.9
6	5	24.3	21	20	17.7
7	6	23.6	22	21	17.6
8	7	22.9	23	22	17.4
9	8	22.2	24	23	17.2
10	9	21.6	25	24	17.1
11	10	21.1	26	25	16.9
12	11	20.6	27	26	16.8
13	12	20.2	28	27	16.7
14	13	19.7	29	28	16.5
15	14	19.4	30	29	16.5
			31	30	16.4

Fig. 3:

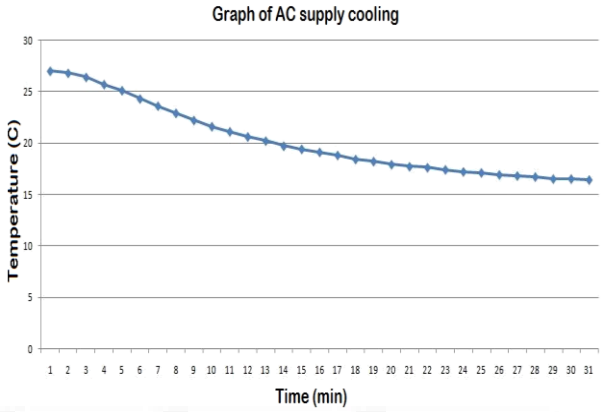

Fig. 4:

B. *DC supply cooling at corner of chamber*

NO.	TIME (min)	TEMPERATURE (°C)	NO.	TIME (min)	TEMPERATURE (°C)
1	0	28.8	16	15	20.1
2	1	28.5	17	16	19.8
3	2	28.1	18	17	19.5
4	3	27.4	19	18	19.2
5	4	26.5	20	19	19
6	5	25.6	21	20	18.8
7	6	24.9	22	21	18.4
8	7	24.1	23	22	18.3
9	8	23.4	24	23	18
10	9	22.8	25	24	17.9
11	10	22.2	26	25	17.7
12	11	21.7	27	26	17.5
13	12	21.2	28	27	17.4
14	13	20.9	29	28	17.3
15	14	20.5	30	29	17.2
			31	30	17.1

Fig. 5:

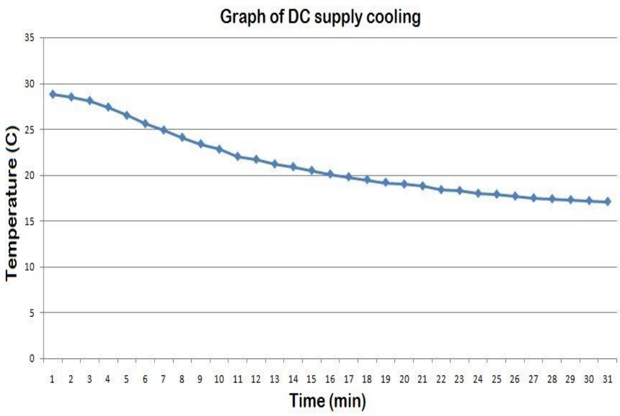

Fig. 6:

C. AC supply cooling of 250 ml water

NO.	TIME (min)	TEMPERATURE (°C)	NO.	TIME (min)	TEMPERATURE (°C)
1	0	26.3	16	15	25.6
2	1	26.3	17	16	25.6
3	2	26.3	18	17	25.6
4	3	26.3	19	18	25.4
5	4	26.2	20	19	25.4
6	5	26.2	21	20	25.3
7	6	26.1	22	21	25.3
8	7	26.1	23	22	25.2
9	8	26	24	23	25.2
10	9	26	25	24	25.1
11	10	25.9	26	25	25
12	11	25.8	27	26	24.9
13	12	25.8	28	27	24.9
14	13	25.8	29	28	24.8
15	14	25.7	30	29	24.7
			31	30	24.6

Fig. 7:

D. AC supply heating at corner of chamber

NO.	TIME (min)	TEMPERATURE (°C)	NO.	TIME (min)	TEMPERATURE (°C)
1	0	27	16	15	45.4
2	1	27	17	16	46.2
3	2	27.2	18	17	47.1
4	3	28.5	19	18	47.8
5	4	29.9	20	19	48.3
6	5	31.9	21	20	48.7
7	6	33.7	22	21	49.2
8	7	35.4	23	22	49.7
9	8	37.1	24	23	50
10	9	38.5	25	24	50.3
11	10	40	26	25	50.7
12	11	41.3	27	26	51
13	12	42.4	28	27	51.2
14	13	43.4	29	28	51.4
15	14	44.5	30	29	51.8
			31	30	51.9

Fig. 8:

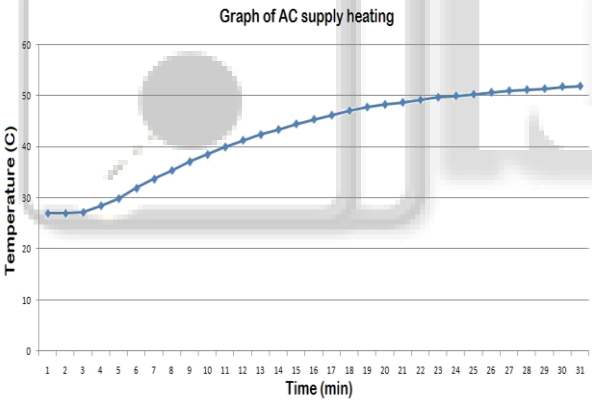

Fig. 9:

During the experimentation the different temperatures achieved by the thermoelectric module after 30 minutes is as follows-

1) AC supply cooling – 17.3°C
2) DC supply cooling – 16.5°C
3) AC supply cooling of 250 ml water – 17.2°C
4) AC supply heating – 63.6°C

Temperature differences achieved during the experimentation are as follows-

1) AC supply cooling – 27 – 16.4 = 10.6°C
2) DC supply cooling – 28.8 – 17.1 = 11.7°C
3) AC supply cooling of 250 ml water –
a. 26.3 – 24.6 = 1.7°C
4) AC supply heating – 51.9 – 27 = 24.9°C

VI. CALCULATION

1) Theoretical Coefficient of performance –

COP = Q/P_{input}

where,

$Q = \alpha I T_c - 0.5(I^2 R_m) - k(T_h - T_c)$,

$P_{input} = \alpha I(T_h - T_c) + I^2 R_m$

where the values of the variables are taken from handbook and various data book for module TEC1-12706 which are as follows-

T_h – Hot side temperature - 25°C = 298K,

T_c – Cold side temperature - 10°C = 283K,

Delta maximum temperature – (ΔT_{max}) = 66K,

V_{max} = 14.4 V, I = 6.4 A,

α-Seebeck coefficient = V_{max}/T_h = 14.4/298

α = 0.04832 V/K,

R_m–Resistance of module= $[(T_h - \Delta T_{max}) * V]/[T_h * I]$

= [(298 – 66) * 14.4]/[298 * 6.4] = 1.75Ω,

k – thermal conductivity = $[(T_h - \Delta T_{max}) * V * I] / [2(\Delta T_{max} * T_h]$

= [(298-66)*14.4*6.4] / [2(66*298)]

= 0.5435 W/m

Now calculating Q and P_{input},

$Q = \alpha I T_c - 0.5(I^2 R_m) - k(T_h - T_c)$

= (0.04832*6.4*283) – [0.5(6.4^2*1.75)] - [0.5435*(298-283)]

Q = 44.8746 W

$P_{input} = \alpha I(T_h - T_c) + I^2 R_m$

= [0.04832*6.4*(298 – 283)] + (6.4^2*1.75)

P_{input} = 76.31872 W

Now, COP = Q/P_{input}

COP = 44.8746/76.31872

COP = 0.5879

2. Actual Coefficient of performance

COP = Q/P_{input}

Where Q = Refrigeration effect

$Q = (m * C_p * \Delta T)/(t * 60)$

Where $\Delta T = T_{initial} - T_{final}$

$C_p = 4.187 * 10^3$ KJ/KgK

After experimentation of the refrigeration system we have calculated the actual COP for several interval of time by using above formula and on the basis of several COP we have plotted a graph of Time vs COP.

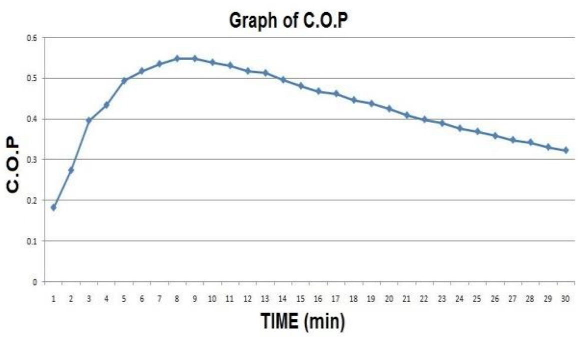

Fig. 10:

Fig. 11: Actual photo of project

VII. ADVANTAGES OF MACHINE

1) Light weight and compact for very small heat loads.
2) No moving parts, eliminating vibration, noise, and problems of wear.
3) Reversing the direction of current transforms the cooling unit into a heater.
4) Very low cost device for cooling in small appliances.
5) No use of refrigerant.

VIII. DISADVANTAGES OF MACHINE

1) Limited to very small refrigeration volume.
2) Compared to conventional refrigerators cooling achieved is less.
3) Heat sinks required to conduct heat to and from the thermoelectric modules become very heavy and bulky as the refrigeration capacity increases.

IX. APPLICATIONS OF MACHINE

1) Medical field- Pharmaceutical industry, medicine and medical equipment storage, etc.
2) Military- storing of consumable goods in war affected zones, rural area, etc.
3) Dairy (milk) industry.
4) Mechanical industry.
5) Restaurant and hotel.
6) Vegetable, fish, fruit, beverage, etc. storage.
7) Electronic— miniature cooling units for incoming stages of highly sensitive receivers and amplifiers; coolers for high power generators, CCD cameras, vacuum and solid-state photo detectors and CPU coolers, etc.

X. CONCLUSION

After conducting experiments on the project we have found that the temperature difference with respect to time, which is important in determining the performance of the refrigerator, comes out more in the case of DC supply as compared to AC supply. Similarly like current variation load is also responsible for variation in the performance of the refrigeration system. While observing the graph of Time vs actual COP we have found that the COP rises with positive slope till it reaches to its peak point and then it starts declining in the negative slope.

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