Analysis and Design of Thermoelectric Solar Air Conditioning System

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ABSTRACT : The conventional air-conditioning system uses refrigerant that harms the environment and depletes the ozone layer. The commonly used refrigerants are CFC's and HFC's. Though HFC's has less effect over the ozone layer as compared to the CFC's but it still plays a role in depletion of ozone layer. A huge time would be required to make the complete system eco-friendly Moreover the other factors like extra power consumption, maintenance, service etc. lead to find an alternative for existing air-conditioning system. Thermoelectric Hybrid air-conditioning system has a solution to these advantages. In our project main use of solar power which is nature's free gift is used to drive the thermoelectric module. The solar energy is converted into electrical energy through solar panel which is then given to the thermoelectric module. In case of insufficient solar energy, electrical energy can be used to charge the battery. As the electric current is given to the thermoelectric module due to Peltier effect temperature difference occurs. The blowers extract the heat from the cold side and the cold air is circulated in the conditioned space by changing the polarity hot air can be circulated in the conditioned space. So basically this is a year round air-conditioning which can be used for many purposes.

Keywords – Air Conditioning, Thermoelectric Module.

I. INTRODUCTION

The sun is probably the most important source of renewable energy available today. Scientists and engineers today seek to utilize solar radiation directly by converting it into useful heat or electricity. This Electric energy provided by the sun can be used for various purposes like cooking, comfort, various home appliances etc. Among these comfort is gaining importance in today's century.

Air conditioning today is no longer a luxury it is necessity. When one hears the term air conditioning, usually the first thing that comes to mind is cold air. Actually, a true air conditioning system automatically controls the temperature, humidity, purity and air circulation of the air. In automotive application, air conditioning is any system that cools and dehumidifies the air.

Today's present AC system is very efficient and reliable but it has some demerits. HFC used in this system is hazardous for environment, human body and responsible for the global warming. Maintenance cost and repairing cost of this system is very high. This system requires very large space .In this system, if any component fails to perform well then the whole system will either will not function properly or not function at all.

As a Mechanical engineer we must try to overcome these problems. We come up with the new innovation and technology as the Solar thermoelectric Air condition System.

II.   COMPONENTS

Components of the solar thermoelectric air cooling system

- ✓ Peltier Module
- ✓ Solar Panel
- ✓ Battery
- ✓ DC fan
- ✓ Heat Sink
- ✓ Charge Controller

- **Peltier Module**

A thermoelectric module consists of arrangements of number of P-type and N-type semiconductor which are heavenly doped with electron carrier and sandwiched between two ceramic substrates.

These elements are arranged in a way that is electrically connected in series but thermally connected in parallel. In this Project, We have used the Peltier module model **TEC1-12706**.

- **Solar Panel**

Solar photovoltaic module is the array of number of electrically connected solar cell mounted on a frame. Modules are designed to supply the electricity at certain voltage. The efficiency of the module and current supply by it is totally depend upon the amount of solar radiation fall on the surface of the PV module.

- **Battery**

Battery used is having the following specification

- ✓ 12 Volt DC
- ✓ 40 Ampere hour

- **DC Fan and Heat Sink**
- ✓ Cooling fan works on 12V DC at 3000 rpm been used here to remove the heat from the hot side.
- ✓ Heat sink is a passive heat exchanger that cools a device by dissipating the heat into surrounding medium, it consists of fin blade due to which the surface area for cooling increase and hence the cooling effect obtained

- **Charge Controller**

A charge controller, charge regulator or battery regulator controls the rate at which the current is been added or drawn from the electric batteries. It protect the battery from been overcharged during the charging from the PV module and hence acts as battery safety device.

III. WORKING PRINCIPLE

A thermoelectric (TE) cooler, sometimes called a thermoelectric module or Peltier cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low voltage DC power source to a TE module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. It is important to note that this phenomenon may be reversed whereby a change in the polarity (plus and minus) of the applied DC voltage will cause heat to be moved in the opposite direction.

Peltier Effect : When electric current is passed through a circuit consisting of two different conductors, a cooling effect is observed in one junction whereas another junction experiences a rise in temperature. This change in temperatures at the junctions is called the Peltier effect. The effect is found to be even stronger when two different semiconductors are used in place of conductors in the circuit.

This effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.
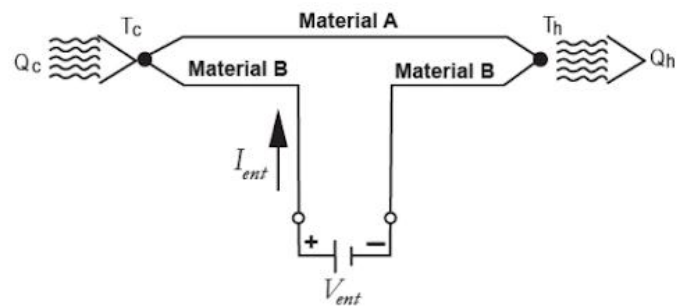
IV. CONSTRUCTION & WORKING

The Solar thermoelectric Air conditioning system consist of

- ✓ Thermo-electric plate
- ✓ Solar panel
- ✓ Battery
- ✓ Heat sink
- ✓ Electric blower

Solar Panel- Solar power is a renewable energy. A photovoltaic or PV module is a packaged; connect assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules use light energy called photons from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or back layer. Each module is rated by its DC output power under standard test conditions or STC.

Thermoelectric plate is sandwiched between two heat sink made up of aluminium with a suitable pressure depending upon the material of thermo electric plate. The various types of material available are bismuth, potassium, platinum, rhodium nichrome etc.

By applying a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. At the hot junction, energy is expelled to a heat sink as electrons move from an n-type to a p-type.

The two blowers are mounted on the either side of the heat sinks. When the voltage is applied to the thermoelectric plate through the battery one side of thermo electric plate gets hot and other side gets cold. The blower that is mounted on cold side takes the air from atmosphere and that air passes over the heat sink which in turn becomes cold and is supplied to the conditioning area. The blower mounted on the other side takes away the heat from the hotter side and releases into the atmosphere. And if the polarity of the thermoelectric plate is changed with the help of electric switch the hot side becomes cold and vice-versa. With the help of this heating effect can be obtained in the passenger compartment.

V.   CALCULATIONS

Couples = 127

Current = 6 A

Dimensions = 40×40 mm

$I = 3.9$ A

$T_C = 22°C = 295K$

$T_H = 32°C = 305K$

- **TEMPERATURE-DEPENDENT   MATERIAL PROPERTIES:**

There are a number of parameters associated with thermoelectric materials and modules that are considered Seebeck coefficient (S_M), Electrical Resistance (R_M), and Thermal Conductance (K_M).

1. **SEEBECK COEFFICIENT:** When a temperature differential is maintained across a thermoelectric device, a voltage can be detected at the input terminals. The magnitude of the resultant voltage, called the Seebeck emf, is proportional to the magnitude of the temperature difference. The Seebeck coefficient, as a function of temperature, can be expressed as a third order polynomial:

$$S_M = S_1 + S_2T + S_3T^2 + S_4T^3$$

Where:

S_M is the Seebeck coefficient of the module in volts/°K
T is the average module temperature in °K
Coefficients for a 71- couple, 6-amp module
$S_1 = 1.33450 \times 10^{-2}$

$S_2 = -5.37574 \times 10^{-5}$

$S_3 = 7.42731 \times 10^{-7}$

$S_4 = -1.27141 \times 10^{-9}$

The above polynomial expression represent the Seebeck coefficient when the temperature difference across the module is zero ($\Delta T = T_h - T_c = 0$). When $\Delta T > 0$, the Seebeck coefficient must be evaluated at both temperatures T_h and T_c using the expressions:

$$S_{MTh} \text{ or } S_{MTc} = S_1T + \frac{S_2T^2}{2} + \frac{S_3T^3}{3} + \frac{S_4T^4}{4}$$

$$S_M = (S_{MTh} - S_{MTc}) / \Delta T$$

$$S_M = 0.0292$$

Where:

S_{MTh} is the module's Seebeck coefficient at the hot side temperature T_h
S_{MTc} is the module's Seebeck coefficient at the cold side temperature T_c

2. **MODULE RESISTANCE:** The electrical resistance of a thermoelectric module, as a function of temperature, can be expressed as third order polynomials for the two conditions (a) and (b):

(a) when $\Delta T = 0$: $R_M = r_1 + r_2T + r_3T^2 + r_4T^3$

(b) when $\Delta T > 0$:

$$R_{MTh} \text{ or } R_{MTc} = r_1T + \frac{r_2T^2}{2} + \frac{r_3T^3}{3} + \frac{r_4T^4}{4}$$

$$R_M = \frac{(R_{MTh} - R_{MTc})}{\Delta T}$$

$$R_M = 1.349$$

Where:

R_M is the module's resistance in ohms
R_{MTh} is the module's resistance at the hot side temperature T_h

R_{MTc} is the module's resistance at the cold side temperature T_c

T is the average module temperature in °K
Coefficients for a 71- couple, 6-amp module
$r_1 = 2.08317$

$r_2 = -1.98763 \times 10^{-2}$ **$K_{new} = 0.5210$**

$r_3 = 8.53832 \times 10^{-5}$

$r_4 = -9.03143 \times 10^{-8}$

3. MODULE THERMAL CONDUCTANCE: The thermal conductance of a thermoelectric module, as a function of temperature, can be expressed as third order polynomials for the two conditions (a) and (b):

$K_M = 0.2913$

Where:

K is the module's thermal conductance in watts/°K
K_{MTh} is the thermal conductance at the hot side temperature T_h

K_{MTc} is the thermal conductance at the cold side temperature T_c

T is the average module temperature in °K coefficients for a 71- couple, 6-amp module

$k_1 = 4.76218 \times 10^{-1}$

$k_2 = -3.89821 \times 10^{-6}$

$k_3 = -8.64864 \times 10^{-6}$

$k_4 = 2.20869 \times 10^{-8}$

4. PARAMETER CONVERSIONS FOR OTHER MODULE CONFIGURATIONS: The S_M, R_M, and K_M parameters shown are calculated for a 71-couple, 6-ampere thermoelectric module. If a new or different module configuration is to be modeled, it is necessary to apply a conversion factor to each of these parameters, as follows:

$$S_{new} = S_M \times \frac{N_{new}}{71}$$

$$R_{new} = R_M \times \frac{6}{I_{new}} \times \frac{N_{new}}{71}$$

$$K_{new} = K_M \times \frac{I_{new}}{6} \times \frac{N_{new}}{71}$$

Where:

S_{new} is the Seebeck coefficient for the new module
R_{new} is the electrical resistance of the new module
K_{new} is the thermal conductance of the new module
N_{new} is the number of couples in the new module
I_{new} is the optimum or maximum current of the new module

(a) when ΔT = 0: $K_M = k_1 + k_2T + k_3T^2 + k_4T^3$

$$K_{MTh} \text{ or } K_{MTc} = k_1T + \frac{k_2T^2}{2} + \frac{k_3T^3}{3} + \frac{k_4T^4}{4}$$

(b) when ΔT > 0:

$$K_M = \frac{K_{MTh} - K_{MTc}}{\Delta T}$$

- **SINGLE-STAGE MODULE CALCULATIONS :**

Calculations of the various parameters should be performed in the order:

a) The temperature difference (ΔT) across the module in °K or °C is:

$\Delta T = T_h - T_c = 10°C$

b) Heat pumped (Q_c) by the module in watts is:

$Q_c = (S_M \times T_c \times I) - (0.5 \times I^2 \times R_M) - (K_M \times \Delta T)$

$Q_c = 33.5946 - 10.2591 - 2.913 = 20.4225$

c) The input voltage (V_{in}) to the module in volts is:

$V_{in} = (S_M \times \Delta T) + (I \times R_M)$

$V_{in} = 0.292 + 5.2611 = 5.5531$

d) The electrical input power (P_{in}) to the module in watts is:

$P_{in} = V_{in} \times I$

$P_{in} = 21.6570$

e) The heat rejected by the module (Q_h) in watts is:

$Q_h = P_{in} + Q_c = 42.0795$

f) The practical coefficient of performance (C.O.P.) of the module is:

C.O.P. = Q_c / P_{in}

C.O.P. = 0.9429

VI. APPLICATIONS

- ✓ Good for use in the remote areas where unavailability of electricity is there.
- ✓ Medical and pharmaceutical industry
- ✓ Military application
- ✓ Science Laboratory, computers, video cameras for cooling.

VII. ADVANTAGES

The advantages of thermoelectric module are as follows:

- ✓ Direction of thermoelectric heating pump is reversible by changing the polarity of current, so it can work as cooler and heater too.
- ✓ Thermoelectric module does not have moving part to wear and tear; therefore there is no need of any maintenance.
- ✓ It has capacity to work for more than 200,000 hours in steady state.
- ✓ It resists shock and vibration.
- ✓ It can work in too severe or sensitive environment.
- ✓ It does not contain any harmful material like chlorofluorocarbons (CFCs) which can damage environment.
- ✓ It does not dependent on gravity. Thus, it can be placed in any direction.
- ✓ Temperature can be maintained in fraction of degree, even below ambient temperature using thermoelectric module by controlling the power load provided to the module.
- ✓ Temperature can work between 100°C to - 100°C of heat sink temperature
- ✓ It can work at extremely low acoustic level by choosing proper heat sink and fan.
- ✓ It can be tailored to any size as per the requirement of application.

VIII. DISADVANTAGES

- ✓ The main disadvantage of thermoelectric module is lower efficiency when compare to non-thermoelectric modules when working as power generator.
- ✓ Also it has lower co-efficient of performance (COP) with range of 0.4 to 1.1

IX. FUTURE SCOPE

In future the time can be reduced; even temperature can be reduced corresponding to time. As the technology advances, thermo electric module is emerging as a truly viable method that can be advantageous in the handling of certain small-to-medium applications. As the efficiency and effectiveness of thermoelectric cooling/heating steadily increases, the benefits that it provides includes self-contained, solid-state construction that eliminates the drawbacks of HVAC systems, superior flexibility and reduced maintenance costs through higher reliability will increase as well.

X. RESULTS

The above designed system is cooling the desired space from the ambient temperature of 32°C to final temperature of 22°C.Thus the designed system attains the temperature difference of 10°C, which can be further improved by using more number of peltier module. As we observed the heat pump by the module equal to 20.4225W and the electrical power input to the module is 21.657W. So, we got the Practical Coefficient of Performance of the Module equal to 0.9429

XI. CONCLUSION

A solar thermoelectric air cooling system is designed which can be better for use in remote areas where unavailability of electricity is there and also the designed system is good for cooling small area with good efficiency. As the system is eco-friendly it can be better alternatives for the future use as considering the depleting of non-renewable sources.

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