Review Paper on Solar Powered Thermoelectric Refrigerator Using Peltier Modules

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Abstract-*The global increasing demand for refrigeration in field of refrigeration air-conditioning, food preservation, medical services, and cooling of electronic devices, led to production of more electricity and consequently more release of CO2 all over the world which it is contributing factor of global warming on climate change. In recent years, with the increase awareness towards environmental degradation due to use of ChloroFluoro Carbons (CFCs) and Hydro Chlorofluorocarbons (HCFCs) as heat carrier fluids in conventional refrigeration and air conditioning systems has become a subject of great concern and resulted in extensive research into development of novel refrigeration and space conditioning technologies. Thermoelectric refrigeration is new alternative because it can convert waste electricity into useful cooling. Thermoelectric refrigeration (TEC) exhibits several advantages compared to vapour-compression, since this technology presents accurate temperature control systems and higher levels of compactness, Robustness and noiselessness. However, its low efficiency is acting as a deterrent for it to spread in the refrigeration market. The research and development work carried out by different researchers on development of thermoelectric R&AC system has been reviewed in this paper.*

Keywords-COP, TER, Seebeck effect, Seebeck effect, Thomson effect

I. INTRODUCTION

The physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800‟sThe first important discovery relating to thermoelectricity occurred in 1821 when a German Scientist, Thomas Seebeck, found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals maintained at two different temperatures. 12 years later French watchmaker, Jean Charles Athanase Peltier, discovered thermoelectric cooling effect, also known as Peltier cooling effect, Peltier discovered that the passage of acurrent through a junction formed by two dissimilar conductors caused a temperature change. The true nature of Peltier effect was made clear by Emil Lenz in 1838, Lenz demonstrated that water could be frozen when placed on a bismuth-antimony junction by passage of an electric current through the junction.

He also observed that if the current was reversed the ice could be melted. Shortly after the development of practical semiconductors in 1950's, Bismuth Telluride began to be the primary material used in the thermoelectric cooling. Thermoelectric refrigerator sometimes called a thermoelectric cooler module or Peltier cooler is a semi conductor based electric component that functions as a small heat pump. By applying a low voltage direct current (DC) power source to a thermoelectric cooler module, heat will be moved through the module from one side to the other In a thermoelectric cooling system, a doped semi-conductor material essentially takes the place of the refrigerant, the condenser is replaced by a finned heat sink, and the compressor is replaced by a Direct Current (DC) power source. The application of Direct Current (DC) power to the thermoelectric cooler modules causes electrons to move through the semi-conductor material. At the cold end of the semi-conductor material, heat is absorbed by the electron movement, moved through the material, and expelled at the hot end. Since the hot end of the material is physically attached to a heat sink, the heat is passed from the material to the heat sink and then in turn, transferred to the environment.

II. DEVELOPMENTS IN THERMOELECTRIC REFRIGERATION AND AIR CONDITIONING SYSTEMS

Irjet Template Dai et al. [1] developed a prototype which consists of a thermoelectric module, array of solar cell, controller, storage battery and rectifier. The system with solar cells and thermoelectric refrigerator is used for outside purpose in daytime and system with storage battery, AC rectifier and TER is used in night time when AC power is available. Experimental analysis on the unit was conducted mainly under sunshine conditions. The studied refrigerator can maintain the temperature in refrigerated space at 5–10°C and has a COP about 0.3 under given conditions. Min et al. [2] developed a number of prototype thermoelectric domestic-refrigerators with different heat exchanger combination and evaluated their cooling performances in terms of the COP, heat pumping capacity, cooling down rate and temperature stability. The COP of a thermoelectric refrigerator is found to be 0.3-0.5 for a typical operating temperature of 5°C with ambient at 25°C. The potential improvement in the cooling performance of a thermoelectric refrigerator is also investigated employing a realistic model, with experimental data obtained from this work. The results show that an increase in its COP is possible through improvements in module contact resistances, thermal interfaces and the effectiveness of heat exchangers. Wahab et al. [3] has designed and devloped thermoelectric refrigerator powered by solar cells for the desert people living in Oman where electricity is not available. In this study the researchers used 10 nos. of thermoelectric module in design of refrigerator. Author achieved temperature difference upto 26.6°C at current 2.5 A and voltage 3.7 V. The coefficient of performance of the refrigerator was calculated and found to be about 0.16. Christian J et al [4] the refrigeration systems were experimentally evaluated in a climatized chamber with controlled temperature and humidity. Tests were carried out at two different ambient temperatures (21°C and 32°C) in order to obtain key performance parameters of the systems (e.g., power consumption, cooling capacity, internal air temperature, and the hot end and cold end temperatures). D. Astrain et al [5] this paper discusses the results of an experimental study of different types of heat exchangers for thethermoelectric module hot side: a water–air system comprising a cold plate, pump and fan coil; a finned heat sink with fan; a heat pipe with fan. Expressions of thermal resistance have been obtained for these three types as a function of the air and water mass flows and the number of TEMs per unit of surface area of heat exchanger (occupancy ratio, d), as well as expressions of the power consumed by the fans and the pump. MingjianLiao et al [6] has studied The open-circuit voltage, internal resistance, and output power by numerical simulation. All calculation results are in good agreement with the experimental results, and the maximum deviation is less than 6%. Due to the influence of Peltier effect, both heat flow and equivalent thermal conductivity increases by 30.2% when temperature difference between the hot and cold side is 170 °C Onoroh Francis et al[7] has done research focused on simulation of a thermoelectric refrigerator maintained at 4°C . The performance of the refrigerator was simulated using Matlab under varying operating conditions. The system consisted of the refrigeration chamber, thermoelectric modules, heat source and heat sink. Results show that the coefficient of performance (C.O.P) which is a criterion of performance of suchdevice is a function of the temperature between the source and sink. For maximum efficiency the temperature difference is to be kept to the barest minimum. Mayank Awasthi1 et al [8]has designed and developed a working thermoelectric refrigeratorinterior cooling volume of 5L that utilizes the Peltier effect to refrigerate and maintain a selected temperature from 5 °C to 25 °C . The design requirements are to cool this volume to temperature within a time period of 6 hrs and provide retention of at least next half an hour Umesh V. sangale et al [9] 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 and a heat sink fan assembly used to increase heat dissipation rate from hot side of Peltier module. The experimental result shows a temperature reduction of 11°C without any heat load and 9°C with 100 ml water kept inside refrigeration space in 30 minute with respect to 23°C ambient temperature. Also the COP of refrigeration cabinet has been calculated and it is 0.1. SuwitJugsujinda et al [10] has fabricated a thermoelectric cooler and tempreature was reduced from 30 to -4.2°C and COP obtained was 0.3

III. REFRIGERATION AND NECESSECITY OF REFRIGERATION

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

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.

IV. THERMORLRCTRIC EFFECTS

Whenever direct current passes through a pair of thermocouples with junctions maintained at different temperatures, three important effects are observed: Seebeck effect, Peltier effect, Thomson effect.

4.1 Seebeck effect

When the two junctions of a pair of dissimilar metals are maintained at different temperatures, there is the generation of emf (electromotive force).He conducteda series of tests by varying the temperatures of the junctions of various combinations of a set of materials. The emf output was found to be:

$$\Delta E \ \alpha \ \Delta T \quad (1)$$

Where ΔE and ΔT are the emf output and the temperature difference of the junctions. The phenomenon of generation of emf is called Seebeck effect

The proportionality constant of Eq.1is denoted by:

$$\alpha_{ab}= \Delta E / \Delta T \quad (2)$$

and is called Seebeck coefficient or the thermoelectric power. It is to be noted that $\alpha ab(\alpha a - \alpha b)$ is the coefficient for a pair of different metals (A and B or P and N or p and n).

4.2 Seebeck effect

If direct current is passed through a pair of dissimilar metals, there is heating at one junction, cooling at the other depending upon material combinations. Peltiervaried the current and observed the heating and cooling rate for different sets of elements. He found that:

$$q \ F \ I \quad (3)$$

Where q is the cooling or heating rate. The proportionality constant of Eq. (3) is called as Peltier coefficient, Πab (= volt) i.e.

$$q= \Pi_{ab} \ I \quad (4)$$

Where $\Pi_{ab} = \Pi_a - \Pi_b$, is the coefficient for two different metals

4.3 Thomson effect

When an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or rejected from the conductor. Whether heat is absorbed or rejected depends upon the direction of both the electric current and temperature gradient. This phenomenon, known as Thomson effect is of interest in respect to the principles involved but plays a negligible role in the operation of practical thermoelectric models.

V. THERMOELECTRIC MATERIALS

The common Thermoelctric Material used in Different applications are Bismuth sulfide(Bi_2S_3), Lead Telluride(PbTe), Antimony Telluride(Sb_2Te_3), Cesium Sulfide(CeS), Bismuth telluride(Bi_2Te_3), and Germanium Telluride(GeTe). The seeback coefficient for different material are given in table below

Table -1: Seeback Coefficient for Different Material

Material	$\alpha(K^{-1})$
Germanium Telluride	1.5×10^{-3}
Cesium Sulfide	1×10^{-3}
Bismuth Telluride	41×10^{-3}
Lead Telluride	1.5×10^{-3}

VI. CONFIGURATION OF SOLAR THERMOELECRIC REFRIGERATOR

Prototype of a solar cell driven, thermoelectric refrigerator, which is mainly configured by the array of solar cells, controller, storage battery, rectifier and thermoelectric refrigerator, is shown in Fig. 1. In daytime, solar cells receive solar energy and turn it into electric power supplied to thermoelectric refrigerator by means of photovoltaic effect. If the amount of electric power production is large enough, the power surplus can be accumulated in storage battery besides driving the refrigerator. If the solar cells can not produce enough electric power, for example, incloudy or rainy days, the storage battery may offer a makeup.

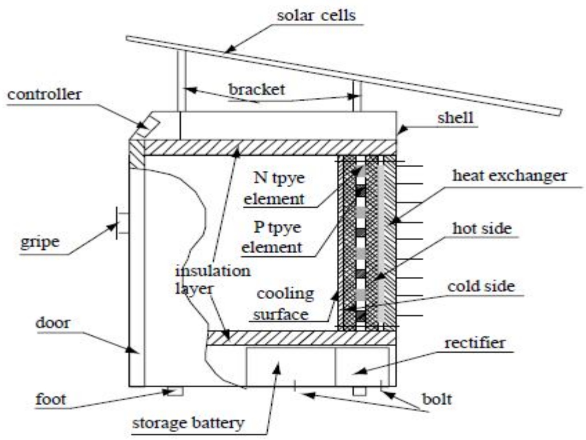

Fig -1: Schematic of solar cell driven, thermoelectric refrigerator (prototype).

The controller, also an auto-switcher, plays a role to maintain the energy conversion process in most optimized way. In nighttime, the storage battery, as well as a backup AC rectifier is used to power the refrigerator. The thermoelectric refrigerator consists of a thermoelectric cooling module. The cold side of the module is set inside the refrigerator and the hot side is set outside. A fin-type heat exchanger is tied with the hot side in order to release heat more efficiently. In the module, the electric current flows from N type element to P type element at cold junction, whilst the current flows from P type element to N type one at hot junction, the heat is rejected to the outside at the same time. This is the so called Peltier effect. [10]

VII. ANALYSIS

The various equations used for calculating the parameters under the study are given below.

Heat pumped by the module or the cooling effect achived is given by:

$$Qc = \alpha\, ITc - 0.5I^2\, R - K\,(Th - Tc)$$

Input electric power is written as:

$$P = \alpha\, I(Th - Tc) + I^2\, R$$

Coefficient of performance (C.O.P) can be calculated as:

$$COP = \frac{Q_C}{P}$$

Where,

I Electric current (A)
Qc Peltier pellet cold side heat flow (W)
P Electric power supplied
R Thermal resistance (K/W)
Tc Cold side temperature (K)
Th Hot side temperature (K)
K Total thermal conductance(w^0c^{-1})
α Seeback coefficient (v^0c^{-1})

VIII. CONCLUSIONS

The literature regarding the of Thermoelectric refrigerator using different modules and research efforts made by different researchers for design and development of thermoelectric refrigeration has been reviewed in this paper .From the review of the pertinent literature presented above, it can be inferred that thermoelectric technology using different modules used for cooling as well as heating application has considerable attention and future scope. Also compatibility of thermoelectric refrigerator with solar energy made them more useful and appropriate for environment protection

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