# Thermoelectric air conditioning system using solar cells

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**Abstract**— This Study is investigated the possibility of heating and cooling air by connecting thermoelectric Elements to a PV panel. The idea is to reverse the direction of heat flow in Room wall. In hot season the cold side for thermoelectric element will be inside the room and the hot side will be outside the room and vise versa in winter, hot side will be inside the room and cold side will be outside the room, using switch as shown in fig. 1 .A relatively new method to reverse heat transmission through wall is to use thermoelectric (TE) devices when two dissimilar materials form a junction. If a voltage is applied, heat will flow from one end of the junction to the other, resulting in one side becoming colder (inside the room) and the other side warmer (outside the room) this will be for summer season, but in winter season warmer (inside the room) and the other side colder (outside the room) . Connecting to Solar Panel energy will help in system integration, so that we don't have to use any other electricity source. Moreover if charging system has been applied, cooling and heating will be possible in the absence of sun. Also extra power can be used for other purposes.

**Index Terms**— solar Air Conditioning ☐Heat Pump wall ☐Solar cells ☐Thermoelectric paper☐revers heat direction☐solar cells with thermoelectric clooer☐forced and natural cooling for thermoelectric.

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## 1 INTRODUCTION LITERATURE REVIEW

THERMOELECTRIC coolers are heat pumps solid state devices without any moving parts, fluids or any gasses. The basic laws of thermodynamics apply to these devices just as they do to conventional heat pumps, absorption refrigerators and other devices involving the transfer of heat energy. TEC couples are made from two elements of semiconductor, primarily Bismuth Telluride, heavily doped to create either an excess (n-type) or deficiency (p-type) of electrons. When heat absorbed at the cold junction it will be pumped to the hot junction at a rate proportional to current passing through the circuit and the number of couples. A conventional cooling system contains three fundamental parts-the evaporator, compressor and condenser. At the cold junction, energy (heat) is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element, so that the energy required to move the electrons through the system. At the hot junction, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type).

Parameters Required for Device Selection: In practical use, couples are combined in a module where they are connected electrically in series and thermally in parallel. Modules are available in a great variety of sizes, shape operating Current, operating voltages and ranges of heat pumping capacity. The present trend, however, is toward a larger number of couples operating at lower currents. Three specific system parameters must be determined before device selection can begin. These are:

- TC Cold Surface Temperature
- TH Hot Surface Temperature
- QC The amount of heat to be absorbed at the Cold Surface of the TE.

Generally, if the object to be cooled is in direct intimate contact with the cold surface of the thermoelectric, the desired temperature of the object can be considered the temperature of the cold surface of the TE (TC).

The hot surface temperature TH is defined by two major parameters:

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- The temperature of the ambient environment to which the heat is being rejected.
- The efficiency of the heat exchanger that is between the hot surface of the TE and ambient.

These two temperatures (TC and TH) and the difference between them (ΔT) are very important Parameters and therefore must be accurately determined if the design is to operate as desired.

One additional criteria that is often used to pick the "best" module(s) is the product of the performance (COP) which is the heat absorbed at the cold junction, divided by the input power (QC / P). The maximum COP case has the advantages of minimum input power and therefore, minimum total heat to be rejected by the heat exchanger (QH = QC +P). It naturally follows that the major advantage of the minimum COP case is the lowest initial cost. Single stage thermoelectric devices are capable of producing a "no load" temperature differential of approximately 67°C. Temperature differentials greater than this can be achieved by stacking one thermoelectric on top of another. This practice is often referred to as cascading. The design of a cascaded device is much more complex than that of a single stage device [2].

Another important two parameters for TE devices are the maximum allowed electrical current Imax through the device (exceeding the current will damage the TEC) and the geometry factor (G). The number of thermocouples and the geometry factor help to describe the size of the device; more thermocouples mean more pathways to pump heat. One thing about G is that it is related to the density of thermocouples per square area and it is also related to the thickness of the TEC. More widespread use of TE requires not only improving the intrinsic energy-conversion efficiency of the materials but also implementing recent advancements in system architecture [3]. Using nanotechnology, the researchers at BC and MIT produced a big increase in the thermoelectric efficiency of bismuth antimony telluride in bulk form [4].

Specifically, the team realized a 40 percent increase in the alloy's figure of merit. The achievement marks the first such gain in a half-century using the cost effective material that functions at room temperatures and up to 250°C. The success using the relatively inexpensive and environmentally friendly alloy means the discovery can quickly be applied to a range of uses, leading to higher cooling and power generation efficiency. Power supply and temperature controller are additional items that must be considered for a successful TE system. Regardless of method, the easiest device parameter to detect and measure is the temperature. Therefore, the cold junction is used as a basis of control. The controlled temperature is compared to some reference temperature, usually the ambient or opposite face of the TE. The various control circuits are numerous, complex and constantly being upgraded [5]. Suffice it to say that the degree of control and consequent cost, varies considerably with the application.

Solar-driven Thermoelectric Air Condition:

primarily for the cold chain project of the World Health Organization and the international Health Organizations specifically for rural areas [10, 11]. Solar cells were used to power small TE operated fridges [6]. Experimental investigation and relevant analysis on a solar cell driven, thermoelectric refrigerator has been conducted [12,13]. The main components of the solar PV battery thermoelectric Air Condition system are the PV cell (including the PV array, the storage battery and the controller), the thermoelectric refrigeration system and the cooled object (e.g., a

cooling box). The PV array is installed outdoors and the storage battery stores the excess electricity produced during sunshine periods. This stored energy is used for running the system during the night. There are specially designed lead-acid batteries suitable for deep discharge cycles occurring in PV systems. The controller is an electronic device, which controls the system operation according to the state of charge of the battery. Its main duty is to protect the battery against excessive charging or discharging. For the solar-driven thermoelectric systems, the performance of whole system is the COP of the thermoelectric refrigeration system and the PV efficiency. [9] proposed an effective heat rejection method for the hot side of thermoelectric modules to enhance the performance of a laboratory thermoelectric refrigerator and its solar power supply. Compared with thermoelectric refrigerators and solar driven thermoelectric refrigerators, fewer thermoelectric air-conditionings and solar-driven thermoelectric dehumidifiers are reported. The service temperature is generally IS-20°C for an air-conditioner system and 2-6°C for the a dehumidifier so the cooling capacity required is higher than a refrigerator system and energy removed from the cooling side has a low potential to convert to a useful energy. The reported solar-driven thermoelectric dehumidifiers were all applied in the cases in which the cooling capacity required is low, or the expense is not the main consideration (such as military or aerospace applications).

System Assembly: The technique used in the assembly of a TE system is as important as the selection of the proper device. It is imperative to keep in mind the purpose of the assembly, namely to move heat. All of the mechanical interfaces between the objects to be cooled and ambient are also thermal interfaces. Similarly all thermal interfaces tend to inhibit the flow of heat or add thermal resistance. Again, when considering assembly techniques every reasonable effort should be made to minimize thermal resistance. Mechanical tolerances for heat exchanger surfaces should not exceed 0.001 in/in with a maximum of 0.003" Total Indicated Reading. If it is necessary to use more than one module between common plates, then the height variation between modules should not exceed 0.001" (request tolerance lapped modules when ordering). Most TE assemblies utilize one or more "thermal grease" interfaces. The grease thickness should be held to 0.001 ± 0.0005". When these types of tolerances are to be held, a certain level of cleanliness must be maintained. Dirt, grit and grime should be minimized; this is very important when "grease" joints are utilized due to their affinity for these types of contaminants. The solar cell unit used in this system has a 12 V rating output voltage with the maximum output power of 120 W, which is able to supply enough power for three 40 W Peltier coolers connected in parallel. Each Peltier cooler has a dimension of 4x4x0.8 cm, temperature difference ΔT of 87°C. The heat sink for each Peltier element is made of aluminum alloy and has a dimension of 15x15 cm making the total heat exchange area to be 45x15 cm on each side of the Peltier elements.

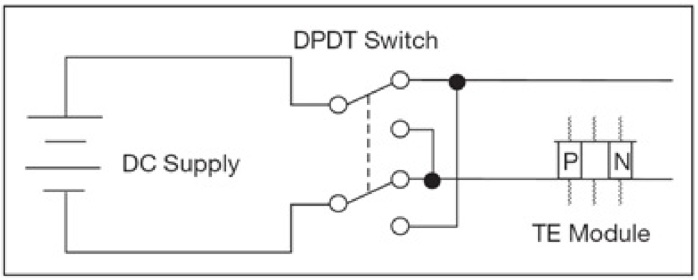

Fig. 1.1 Controller switch

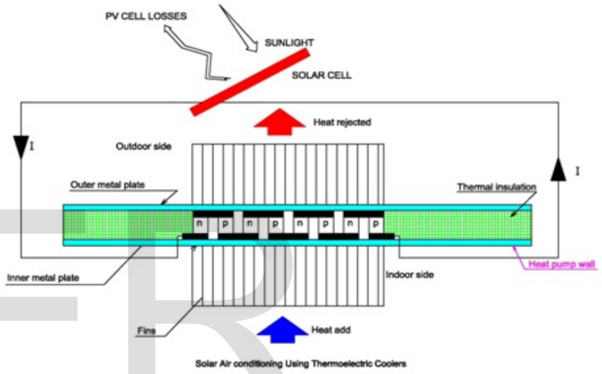

Fig. 1.2 Heat Pump Wall

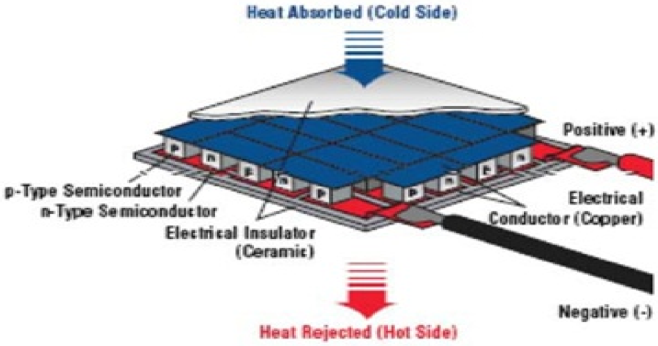

Fig. 1.3 overview of the thermoelectric cooler

## 2 EXPERIMENTAL TEST RIG

The idea is to use array of TEC installed in the Room walls (Heat Pump wall). If a voltage is applied, heat will be flow from one end of the junction to the other, resulting in one side becoming colder and the other side warmer. Connecting to Solar Panel energy will help in system integration, so that we don’t have to use any other electricity source. Moreover if charging system has been applied, cooling and heating will be possible in the absence of sun. Also extra power can be used for other purposes.

### 2.1 Experimental test rig.

Figure (2.1) shows the schematic diagram of the experimental test rig , Fig. (4) shows its photo. Its basic pars consists of an electrical power supply, thermoelectric module and heat sink.

1- PV panel which has Maximum power = 100 W ,at Max. volt = 17.6 V and Max. current= 5.68 A.
2- TEC Module with power= 55 watt at 12 volt, and ventilation fan with power = 3 Watt.
3- AVO meter for recording Voltage and current.
4- Temperature measurement device as described below.
5- Room model which fabricated from 20 mm Polyethylene insulation.
6- Computer for receding and analysis of data.
7- Battery charger/load regulator which will charge the battery from PV Electrical source and feed the required DC -12 V to TEC- and ventilation fan.
8- Battery will be charged from PV panel during day and provide the required power at the absence of the solar energy.

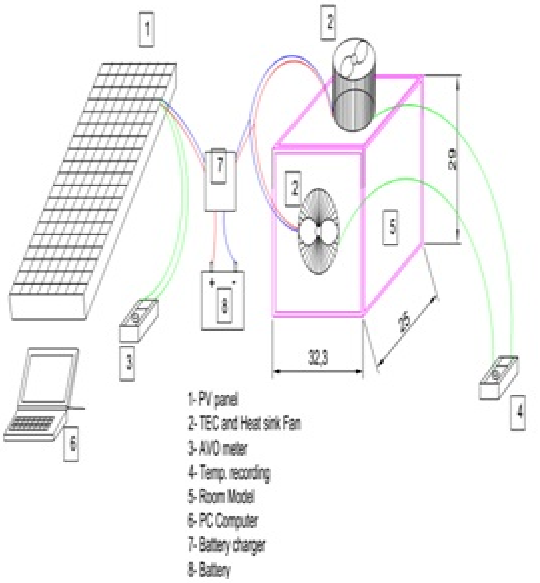

Fig. 2.1 .Exp. test rig.

### 2.2 Experimental test cases

| | | |
|---|---|---|
| Case-1 | Single Module | Fan at cold side (off) |
| | | Fan at hot side (off) |
| | | (natural convection) |
| Case-2 | Single Module | Fan at cold side (on) |
| | | Fan at hot side (on) |
| | | (forced convection) |
| Case-3 | Two Module Connected in parallel | Fan at cold side (on) |
| | | Fan at hot side (on) |
| | | (forced convection) |
| Case-4 | Two Module Connected in Series | Fan at cold side (on) |
| | | Fan at hot side (on) |
| | | (forced convection) |

### 2.3 Analysis:

In order to evaluate the performance of the thermoelectric cooling system, cooling capacity and the COP should be calculated as following;

$$Q_c = a\, IT_c - 0.5I^2 R - K\,(T_h - T_c)$$

Where; α: is the average Seebeck coefficient of the thermoelectric material; R is the electric resistance of the TEC module, K is the thermal conductivity of the TEC module, I is the input electric current and Th and Tcare the hot and the cold sides temperatures; the previous equation consists of three parts called heat sources, these heat sources are described in the following sections.

Figure (1) Schematic diagram of the thermoelectric cooler

Thermoelectric heat pumping (Peltier effect) at the cold end of the TEC module, which is given by;

$$Qab = a\, IT_c$$

Joule heat: When the electric current flow it generates what is called Joule heating ($Q_J$) in the thermoelectric material. 50 percent of the Joule heat goes to the hot end and 50 percent goes to the cold end. The Joule heating is given by;

$$Q_J = I^2 R$$

Conducted heat: The heat is conducted from the hot end to the cold end of the TEM through the thermoelectric material during the operation process. This conduction heat rate is given by;

$$Q_{cd} = K\,(T_h - T_c)$$

The above equation shows that Qcd increases across the TEM with the temperature difference.

The electrical energy consumption of the TEM is given by;

$$P = a\,I\,\Delta T + I^2 R$$

The COP of the TEM for cooling is given by;

$$COP = Q_c / P = [a\,I\,T_c - 0.5\,I2\,R - K(T_h - T_c)]/[a\,I\,\Delta T - I^2 R]$$

From the previous equation it seems that the COP is a function of the material dimension property of thermoelectric material, hot and cold sides temperatures Th ; Tc and input current.

α; Seebeck coefficient; $a = V_{MAX}/T_h$

Rm; Resistance of module; $R_m = [(T_h - \Delta T_{max}) x V]/IT_h$

k – Thermal conductivity;$K = [(T_h - \Delta T_{max}) xIV]/[\,\Delta T_{max}\ x\ T_h]$

Where the values of the variables are taken from handbook and various data

## 3 RESULTS AND DISCUSSION

In this section the experimental results are in case-1 curve (Fig. 5-1) represented the performance of TEC module with natural convection heat transfer for both cold and hot sides for one TEC module, it is observed that the temperature of cold and hot side has ranges higher than 25 oC and 38 oC respectively, and the Electrical current reached 1.3 A.

Case-2 curve (Fig. 5-2) represented the performance of TEC module with forced convection heat transfer for both cold and hot sides for one TEC module, it is observed that the temperature of cold and hot side has ranges lower than 23 oC and 36.5 oC respectively, and the Electrical current reached 0.4 A. which indicates that forced convection is more effective than natural convection for cooling mode, and vice versa in heating mode, natural convection is more effective than forced convection for heating mode.

Case-3 curve (Fig. 5-3) represented the performance of TEC modules with parallel connection for two TEC modules, it is observed that the temperature of cold side has a ranges lower than 19 oC and the temperature of hot side has a ranges higher than 36$^o$C, and the Electrical current reached 2.5 A. which indicates that the parallel connection decrease the temperature of cold side which means more efficiency for cooling mode.

Case-4 curve (Fig. 5-4) represented the performance of TEC modules with Series connection for two TEC modules, it is observed that the temperature of cold side has a ranges higher than 35 oC and the temperature of hot side has a ranges higher than 80 oC, and the Electrical current reached 4.9 A. which indicates that the Series connection increase the temperature of hot side which means more efficiency for heating mode.

COP curve (Fig. 5-5) represented the performance of TEC modules with Cooling mode, it is observed that COP of

- cooling is the highest at case three i.e. connecting several TEC modules in parallel connection and forced convection will be the optimum for cooling mode.
- COP curve (Fig. 5-6) represented the performance of TEC modules with heating mode, it is observed that COP of heating is the highest at case FOUR i.e. connecting several TEC modules in series connection and forced convection will be the optimum for heating mode.

Natural convection leads to high range temperature in both cold and hot sides, but using of forced convection will leads to lower temperature ranges.

Connecting of TE modules in parallel suitable for cooling purpose, and connecting TE modules in series suitable for heating purpose.

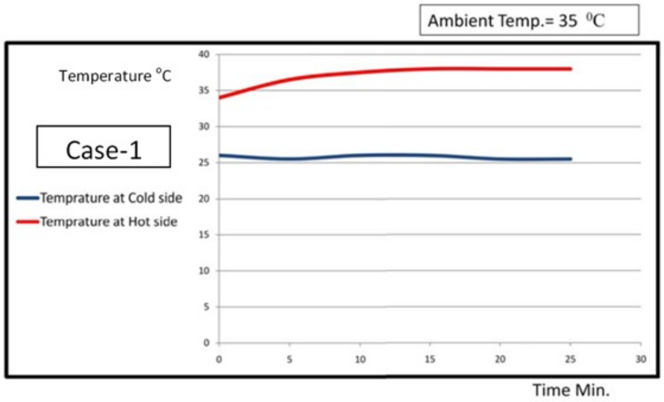

Fig. 5.1, Temperature at cold side and hot side with time.

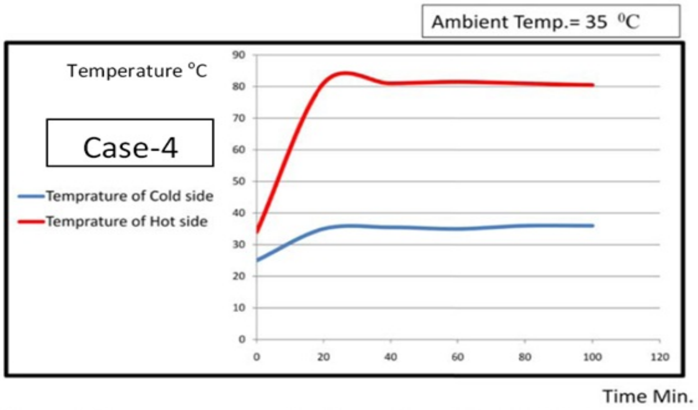

Fig. 5.4, Temperature at cold side and hot side with time.

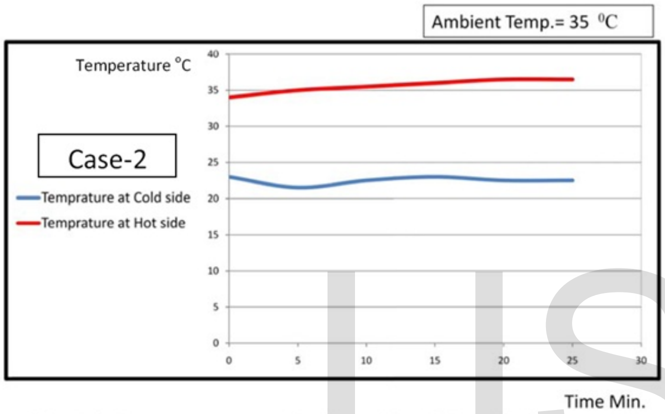

Fig. 5.2, Temperature at cold side and hot side with time.

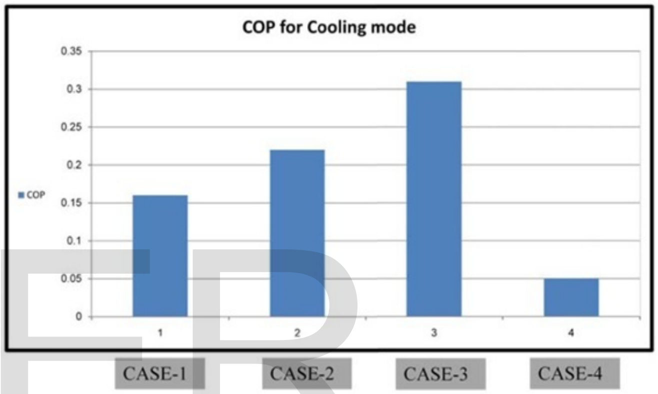

Fig. 5.5, COP for different for cases of cooling mode

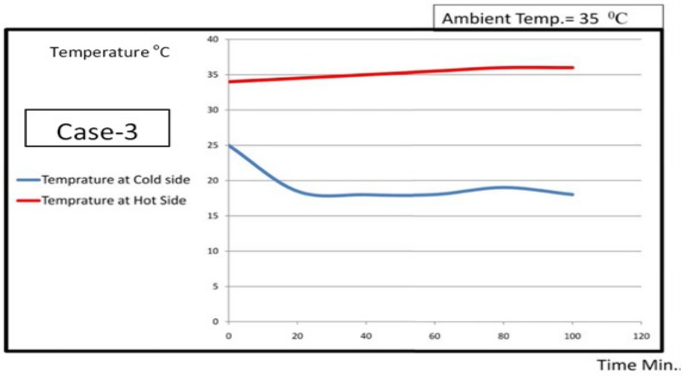

Fig. 5.3, Temperature at cold side and hot side with time.

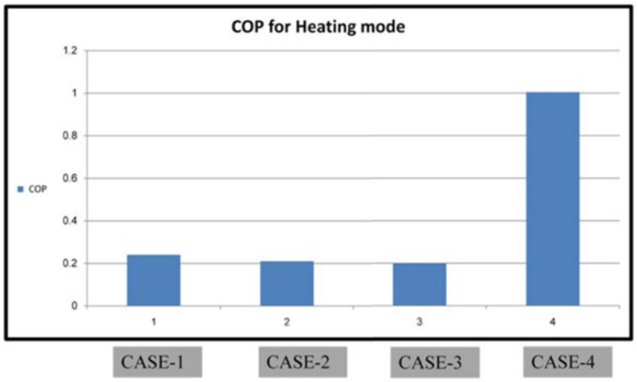

Fig. 5.6, COP for different for cases of heating mode.

## 4 CONCLUSIONS

1- HAP calculations help in selecting of TEC/PV panel selection indicating The steps for Designing and selection of TEC/PV air conditioning System.

2- COP in Forced convection air system is better than natural convection air system.

3- COP when connecting TEC Modules in Parallel is better than in series connection.

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