Solar Air-Conditioning: Design for a Compressor-Less System using Peltier Effect

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Abstract

Air-conditioning is one of the major consumers of electrical energy in many parts of the world today and already today air-conditioning causes energy shortage in for example China. The demand can be expected to increase because of changing working times, increased comfort expectations and global warming. Air-conditioning systems in use are most often built around a vapour compression system driven by grid-electricity. However, most ways of generating the electricity today, as well as the refrigerants being used in traditional vapour compression systems, have negative impact on the environment. Solar air-conditioning might be a way to reduce the demand for electricity. In addition many solar air-conditioning systems are constructed in ways that eliminate the need for CFC, HCFC or HFC refrigerants. This research work is based on the Peltier effect with which we can cool a specific area without using compressor which take a huge consumption of electricity. And this system is driven by solar energy using solar plates, battery, transformer peltier module and heat sink. This paper deals with a wide range of components, from room air-conditioners to solar.Conventional compressor run cooling devices have many drawbacks pertaining to energy efficiency and the use of CFC refrigerants. Both these factors indirectly point to the impending scenario of global warming. As most of the electricity generation relies on the coal power plants, which add greenhouse gases to the atmosphere is the major cause of global warming. Although researches are going on, better alternatives for the CFC refrigerants is still on the hunt. So instead of using conventional air conditioning systems, other products which can efficiently cool a person are to be devised. By using other efficient cooling mechanisms we can save the electricity bills and also control the greenhouse gases that are currently released into the atmosphere .Air-conditioning is one of the major. Collectors, which can be used as subcomponents in a solar air-conditioning system. However, most of the components and subsystems covered are not only suitable for solar air-conditioning. Some components are used for electrically, mechanically or heat driven air-conditioning. And of course other sources of mechanical energy or heat could be used for powering these components. Other components are used for solar energy collection and storage, which can be used in solar energy system with other purposes than just driving a solar air-conditioning system. In this research work the idea was to build an alternative for AC and to provide Air conditioning effect. The research aims to design and build a miniature prototype of thermoelectric cooling system for a conventional air conditioned to provide air conditioning to reduce the consumption of electricity and to reduce the pollution.

1. Introduction

Consumers of electrical energy in many parts of the world today. For example about 40 % of the summer electricity used by commercial buildings in the United States is used for air-conditioning, and in Egypt at least 32 % of the electrical energy used by the domestic sector is for air-conditioning. Furthermore, the demand is growing, and this trend is expected to continue as traditional working times in many locations with midday siesta are changed to the rhythm typical to Central Europe (Lamp 1998). The demand is also growing due to increasing comfort expectations and cooling loads & the average temperature worldwide is also expected to rise because of the global warming and this might already have begun. Nearly all air-conditioning systems in use are built around vapour compression systems driven by grid-electricity.

Others components are for solar energy collection and storage, which can be used also in solar energy system with other purposes than driving a solar air-conditioning system. The word air-conditioning is used in this paper it refers to dehumidification and cooling. Likewise solar air-conditioning refers to active solar cooling. And CTSAC refer as compressor less thermo electric solar air conditioning which works without help of any compressor,

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which works on the peltier effect of heating and cooling of air

2. Methodology Adopted And Components Used

The Components of Compressor less thermoelectric solar AC are.

- Solar Plate(solar cell)
- Rectifier
- Battery
- Thermoelectric module
- Heat Sink
- Cooling Fan

3. Basic Principle And Working

A semiconductor (called a pellet) is used because they can be optimized for pumping heat and because the type of charge carriers within them can be chosen. The semiconductor in this examples N type (doped with electrons) therefore, the electrons move towards the positive end of the battery. The semiconductor is soldered to two conductive materials, like copper. When the voltage is applied heat is transported in the direction of current flow.

When a p type semiconductor (doped with holes) is used instead, the holes move in a direction opposite the current flow. The heat is also transported in a direction opposite the current flow and in the direction of the holes. Essentially, the charge carriers dictate the direction of heat flow.

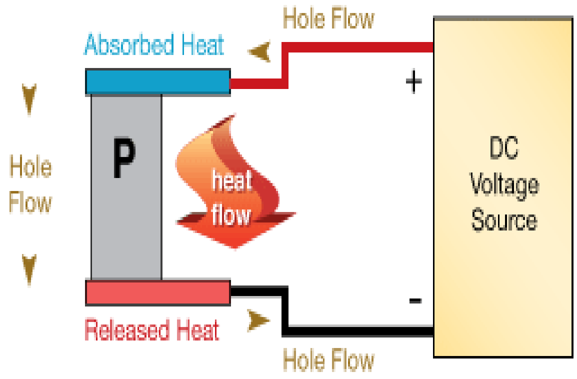

Fig: 1. Supply in P-Type Semiconductor

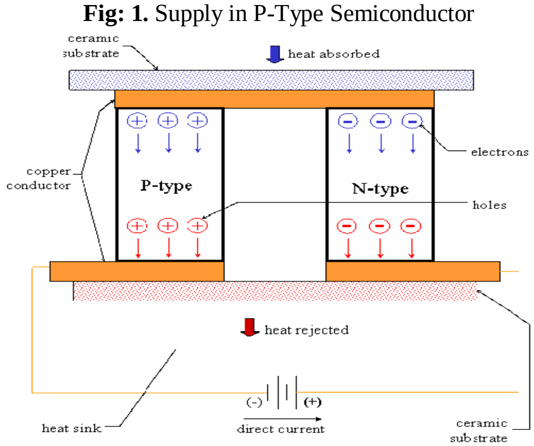

Fig: 2. Current Flow in P-N Junction

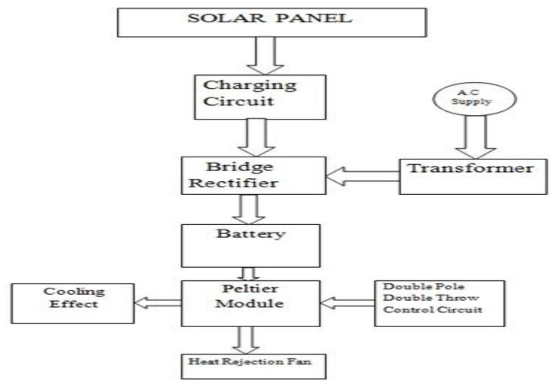

Fig: 3. Block diagram of the solar AC

4. Applications of Solar Cells

A solar cell or photovoltaic cell is a device that converts solar energy into electricity by the photovoltaic effect. Photo voltaic is the field of technology and research related to the application of solar cells as solar energy. Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight, while the term photovoltaic cell is used when the source is unspecified.

Assemblies of cells are used to make solar modules, which may in turn be linked in photovoltaic arrays.

Solar cells have many applications. Individual cells are used for powering small devices such as electronic calculators. Photovoltaic arrays generate a form of renewable electricity, particularly useful in situations where electrical power from the grid is unavailable such as in remote area power systems, Earth-orbiting satellites and space probes, remote radiotelephones and water pumping applications. Photovoltaic electricity is also increasingly deployed in grid-tied electrical systems.

5. Design & Fabrication of Model

To design a cooling system using thermoelectric cooler (TEC) one has to know the basics of thermoelectric effect, thermoelectric materials and thermoelectric cooling. Thermoelectric effect can be defined as the direct conversion of temperature difference to electric voltage and vice versa. Thermoelectric effect covers three different identified effects namely, the See back effect, Peltier effect and the Thomson effect

a. Peltier effect

The Peltier effect bears the name of Jean-Charles Peltier, a French physicist who in 1834 discovered the calorific effect of an electrical current at the junction of two different metals.When a current I is made to flow through the circuit, heat is evolved at the upper junction (at T_2), and absorbed at the lower junction (at T_1). The Peltier heat absorbed by the lower junction per unit time, is equal to

$$\dot{Q} = \Pi_{AB} I = (\Pi_B - \Pi_A)\, I$$

Where π is the Peltier coefficient Π_{AB} of the entire thermocouple, and Π_A and Π_B are the coefficients of each material. P - Type silicon typically has a positive Peltier coefficient (though not above ~550 K), and n-type silicon is typically negative. The Peltier coefficients represent how much heat current is carried per unit charge through a given material. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if Π_A and Π_B are different. This causes a non-zero divergence at the junction and so heat must accumulate or deplete there, depending on the sign of the current. Another way to understand how this effect could cool a junction is to note that when electrons flow from a region of high density to a region of low density, this "expansion" causes cooling (as with an ideal gas).A thermoelectric device will create a voltage when there is temperature difference on each side of the device. On the other hand when a when a voltage is applied to it, a temperature difference is created.

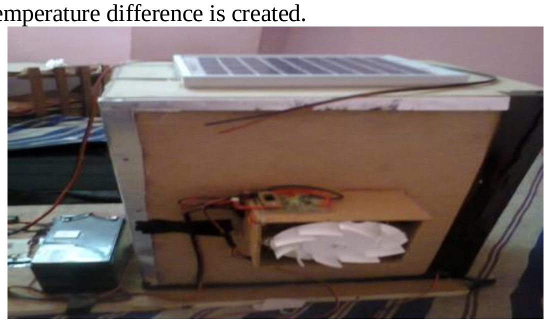

Fig: 4. Working Model of a Compressor less Solar AC

The temperature difference is also known as Peltier effect. Thus TEC operates by the Peltier effect, which stimulates a difference in temperature when an electric current flows through a junction of two dissimilar materials.

To create a Peltier cooler, the hot junction is placed outside the refrigerator, and the cold junction is placed inside. Normally, you create a module containing many junctions to amplify the effect. See the links at the end of this article for details on the Peltier effect. If the temperature difference ΔT between the two ends of a material is small, then the thermo power of a material is defined (approximately) as:

$$S = \frac{\Delta V}{\Delta T}$$

and a thermoelectric voltage ΔV is seen at the terminals. In practice one rarely measures the absolute thermo power of the material of interest. This is because electrodes attached to a voltmeter must be placed onto the material in order to measure the thermoelectric voltage. The temperature gradient then also typically induces a thermoelectric voltage across one leg of the measurement electrodes. Therefore the measured thermo power includes a contribution from the thermo power of the material of interest and the material of the measurement electrodes. The measured thermo power is then a contribution from both and can be written as:

$$S_{AB} = S_B - S_A = \frac{\Delta V_B}{\Delta T} - \frac{\Delta V_A}{\Delta T}.$$

Superconductors have zero thermo power since the charged carriers produce no entropy. This allows a direct measurement of the absolute thermo power of the material of interest, since it is the thermo power of the entire thermocouple as well. In addition, a measurement of the Thomson coefficient, μ, of a material can also yield the thermo power through the relation:

$$S = \int \frac{\mu}{T} dT.$$

The thermo power is an important material parameter that determines the efficiency of a thermoelectric material.

6. Parameters Of Thermoelectric Module

Once it is decided that thermoelectric cooler is to be considered for cooling system, the next step is to select the thermoelectric module or cooler that can satisfy a particular set of requirements. Modules are available in great variety of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity. The minimum specifications for finding an appropriate TEC by the designer must be based on the following parameters. The cutaway of a TEC is shown in Figure

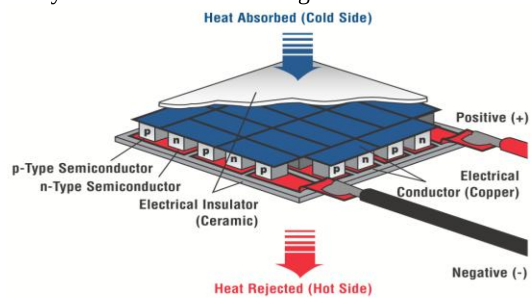

Fig: 5. A Cutaway of Thermoelectric Module

- Cold side temperature (T_c)
- Hot side temperature (T_h)
- Operating temperature difference (ΔT), which is the temperature difference between T_h and T_c.
- Amount of heat to be absorbed at the TEC's cold surface. This can also be termed as heat load. It is represented as (Q_c) and the unit is Watts
- Operating current (I) and operating voltage (V) of the TEC.

1. Cold side temperature

If the object to be cooled is in direct contact with the cold surface of the TEC, the required temperature can be considered the temperature of the cold side of TEC (T_c).Here in this project the object is air, which has to be cooled when passed through a cluster of four Aluminium heat sinks. It is discussed in detail in the next chapter. The aim is to cool the air flowing through the heat sinks. When this type of system is employed the cold side temperature of the TEC is needed to be several time colder than the ultimate desired temperature of the air.

2. Hot side temperature

The hot side temperature (T_h) is mainly based on the two factors. First parameter is the temperature of the ambient air in environment to which the heat is been rejected. Second factor is the efficiency of the heat sink that is between the hot side of TEC and the ambient.

3. Temperature difference

The two temperatures T_c and T_h and the difference between them ΔT is a very important factor. ΔT has to be accurately determined if the cooling system is expected to be operating as desired. The following equation shows the actual ΔT.

$$\Delta T = T_h - T_c$$

Actual ΔT is not same as the system ΔT. Actual ΔT is the difference between the hot and cold side of the TEC. On the other hand system ΔT is the temperature difference between the ambient temperature and temperature of the load to be cooled

4. Cooling Load

The most difficult and important factor to be accurately calculated for a TEC is the amount of heat to be removed or absorbed (Q_c) by the cold side of the TEC. In this project Q_c was calculated by finding the product of finding the product of mass flow rate of air, specific heat of air and temperature difference. Here the temperature difference system ΔT in the difference between the inlet temperature and outlet temperature of the cooling system. The mathematical equation for Q_c is as shown below.

$$Q_c = \dot{m} C_p \Delta T$$

5. Coefficient of Performance

The Coefficient of performance (COP) of a thermoelectric module which is the thermal efficiency must be considered for a TE system. The selection of TEC will also be based on the COP factor. COP is the ratio of the thermal output power and the electrical input power of the TEC. COP can be calculated by dividing the amount of heat absorbed at the cold side to the input power. The COP of current commercial thermoelectric refrigerators ranges from 0.3 to 0.6, only about one-sixth the value of traditional vapour-compression refrigerators.

7. Thermoelectric Materials

All materials have a nonzero thermoelectric effect; in most materials it is too small to be useful. However, low cost materials that have a sufficiently strong thermoelectric effect (and other required properties) could be used for applications including power generation, refrigeration and a variety of other applications. A commonly used thermoelectric material in such applications is Bismuth telluride (Bi_2Te_3), Skutterudite thermo electrics, Bismuth chalcogenides

8. Results and Discussion

With the help of this air-conditioning system we can get the cooling effect without help of compressor. A TE module must not be operated without a sufficient heat rejection from the hot side. Peltier devices are commonly used in camping and portable coolers and for cooling electronic components and small instruments. Some electronic equipment intended for military use in the field is thermoelectrically cooled. The cooling effect of Peltier heat pumps can also be used to extract water from the air in dehumidifiers. Peltier elements are a common component in thermal cyclers, used for the synthesis by polymerase chain reaction (PCR) a common molecular biological technique which requires the rapid heating and cooling of the reaction mixture for denaturation, primer annealing and enzymatic synthesis cycles. With the help of this research we can cool 1*1*1 feet area by using 6*6 inch solar plate.

9. Conclusions

The system was targeted as an AC and temperature of the cooled air should be lowered from ambient temperature. Secondary objective of the project includes design of a dc power supply and a temperature controller circuit. The idea of AC is based on Peltier effect, as when a dc current flows through TE modules it generates a heat transfer and temperature difference across the ceramic substrates causing one side of the module to be cold and the other side to be hot. The analysis shows that for the prevalent conditions in Eliath, the compressor less AC is significantly more economical to own and operate then the conventional AC. In spite of a slightly higher initial cost, the thermoelectric AC proves to be more economical, mainly due to its significantly lower operating cost.

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