UTILIZATION OF PELTIER TECHNOLOGY AS COOLING SYSTEM

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Abstract: **The objective of this paper is to provide a cooling technology that is ecofriendly and portable. Refrigeration is the need of present time in various fields as medical field, vegetables storage and food products etc. In present scenario, this is performed by Chlorofluorocarbons as refrigerant in various cooling systems but it is harmful for environment as well as for health. In this work a cooling technology is furnished without use of harmful refrigerants.**

This paper focuses on developing a solar photovoltaic cell based on thermoelectric cooling system which can function as the refrigerator. In doing so, in this work Peltier technology is applied for the cooling of a box. A number of researches have also been done in the field of cooling usingPeltier technology. The main feature of this box is that solar energy is used to feed power to the Peltier device which improves portability of the box and makes it eco-friendly.

Introduction

The characteristics of the cooling box are its simple application, maintenance, safe performance with autonomous power supply, convenient energy storage, no environmental pollution etc. In addition, comparing Peltier'srefrigeration system to the conventional refrigerationsystem, it makes the use of Peltier effect that doesn't require pumps, compressors and other moving parts and so there is no noise in the operation. A number of researches have been investigated to provide different cooling systems without use of chlorofluorocarbons as refrigerants. Jugsujindaet al. [1] conducted a study on analyzing thermoelectric refrigerator performance. The strengths of Peltier technology lie in the scalability of the cooling elements, their location independence, reliability and precision control.Peltier effect also used in application of thermoelectric devices to enhance the performance of air-cooled heat exchanger et al. [2].Thermoelectric coolers are solid state heat pumps used in applications where temperature stabilization, temperature cycling, or cooling below ambient are required. There are many products using thermoelectric coolers, including CCD cameras (charge coupled device), laser diodes, microprocessors, blood analyzers, portable picnic coolers, vaccine storage and food preservation etc. Artificial Neural Networks can also be used with thermo coolers to improve working of it [3]. The concrete realization form of power are "heat - electric - cold", "light - electric - cold", "light - heat - electric - cold". The working principle mainly is the combination of both photovoltaic effect and the Peltier effect.

At present days, the world faces Global warming and CFCs plays the key role for further temperature increase by 1.4-4.5 K up to 2100 [4].In order to avoid these unfavorable impacts, we need to reduce the harmful emission resulting from burning fossil fuel. Among various renewable sources, solar energy universal abundance with unlimited capacity unlike many other renewable energy sources [5]. Solar energy is easy to collect unlike the extraction of fossil fuel. In reference [6], different technologies are discussed to economize the electricity.

Various Solar Cooling Technologies

Solar Cooling technologies can be classified in three main categories: solar electrical, thermal and combined power/cooling cycles.The solar cooling system can be divided into three major components; solar energy collecting element, refrigeration cycles and the application at different temperature ranges.

1. Solar Electrical Cooling

The solar electrical cooling box consists of photovoltaic panel and electrical refrigeration device. Photovoltaic cells transform solar light into electricity through photoelectric effect.

2. Thermo-electric Cooling (Peltier Cooling System)

Thermo-electric device utilizes the Peltier effect to make a temperature gradient of two types of semiconductors materials. Peltier effect can be defined as presence of heating or cooling at junction of two different conductors due to electricity flow [7].

When a DC current is passed through one (or more pairs) of n-type and p-type semiconductor materials, the temperature of one conductor decreases and absorb the heat from its surrounding space. When electrons pass from p-type material to n-type material (from low energy level to high energy level),heat is absorbed from inner space between p type and n type material.
When a temperature gradient is achieved between the hot and cold ends of the conductor, adverse voltage is created [8].

If the direction of the current is reversed, the direction of the heat flow is also get reversed and air conditioning system operates in the heating mode [9]. The use of thermo-electric cooling is less efficient compare to vapor compression cycle in the market.

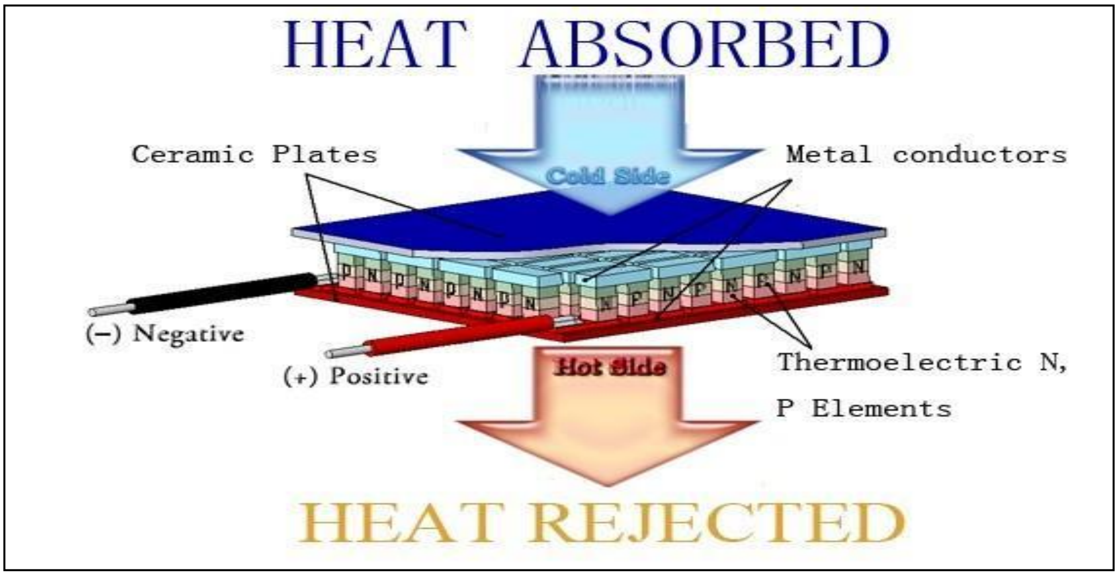

fig.1: thermo electric cooling

3. Solar Powered Vapor Compression Cooling System

PV panel converts solar radiation to DC power which is supplied to a conventional **vapor compression** system. The Coefficient of performance of the system depends on the efficiency of the PV panel.

Klein and Reindl [10] investigated the electrical characteristics that produced from Photovoltaic cells and compared it with required characteristics of compressor motor.

4. Stirling Refrigeration System

The Stirling Cycle engine was invented by the Reverend Robert Stirling of Kilmarnock in 1812.A Stirling system is suitable for specific applications requiring low temperatures, Stirling refrigerator can be used for cooling at very low temperatures of about 3 K.

The stirling refrigerator has been used in the application that require low temperature on a relatively small scale such as producing liquid nitrogen and liquid oxygen from atmospheric air.

Stirling **refrigeration** cycle principle is based on the volume changes caused by pistons, thus inducing changes in pressure and temperature of a gas (no phase change). On the other hand, it yields very good performance at large temperature increases [11].

Ewert et al. [12] discussed the test result of 100 watts Stirling refrigerator that showed decreasing of COP from 1.5 to 0.8 for temperature variation 13-33 K with outdoor temperature from 23- 28°C.

Berchovitz et al. [13] discussed the test result of similar machine of Ewert et.al. 1998 with 40 Watts capacity, the results showed COP decreasing from 1.65 to 1.17 with variation temperature of cold side from -1.4 to -19.1°C and temperature of hot side from 28.4 to 30.3°C.

Raine et al. [14] reported test result from the Heat pump stirling cycle development programmed which showed high performance at specific condition compared to conventional vapor compression cycle.

There is many challenges in designing efficient Stirling refrigerator as low COP due to poor heat transfer between working fluid and ambient air [15].

5. Solar Thermal Cooling

Solar energy conversion system can be used to transform solar thermal energy into cooling or heating through chemical or physical Processes. In the solar thermal system thecompression chiller is replaced by a sorption chiller, modeled according to the performance of single stage LiBr/water absorption chillers [16].

6. Open Sorption Cycle Solar Cooling

It represents desiccant systems that are used in air conditioning applications for humidification or dehumidification which basically transfer moisture from one air stream to another one. These cycles can be used as pre-cooling of other system and can be used to provide cooling for specific application with special requirement.

7. Liquid Desiccant System

A detailed description of the desiccant cycle, design considerations that led to the various choices and an experimental investigation of this system is given elsewhere [17]. The system consists of a conditioner and regenerator, the principle operation of the system as follow:

7.1 Conditioner

The liquid desiccant is pumped and passes through nozzle that will spray the desiccant in the air to absorb the moisture from air due to difference in surface vapor pressure of the desiccant and air.

The liquid desiccant falls to the basin of conditioner and spray back in air, the desiccant temperature and pressure has increased.

The water content increased due to absorption of moisture and in order to increase the concentration of desiccant small amount of the mixture of water and liquid desiccant is pumped from conditioner basin to regenerator basin.

7.2 Regenerator

The desiccant is sprayed in the air and should be heated before spraying; so its

partial pressure get increased, therefore the moisture had absorbed by regenerator's air and leave it in hot and humid condition.

The concentration of liquid desiccant increased in the basin of regenerator and its temperature and pressure increased as well.

A small amount of desiccant return to conditioner to sprayed again. Finally, before spraying the liquid desiccant, it must be cooled by cold water from chiller or other cooling sources.

Lithium chloride, calcium chloride, and lithium bromide are main materials used in liquid desiccant systems [18].

Gommed and Grossman [19] investigated solar assisted liquid desiccant cooling system using Lithium chloride and water as working fluid, outside temperature was the influencing factor that is having high effect on the dehumidification process.

The result showed that the system supplied 16 kW of dehumidification capacity with 0.8 coefficient of performance.

Davies et al. [20] developed the liquid desiccant system based on Abu Dhabi data weather with the solar collector for regenerative heating coil and the adiabatic cooler to reduce inside condition in greenhouses. The result revealed clearly the possibility of lower outside temperature by 5°C as cooling effect.

8. Solid Desiccant System

Henning et al. [21], Simulated a solar assisted solid desiccant system with solar collector (20 m^2 Area) and storage tank (2 m^3volume). The results showed that a 54% collector efficiency, 0.6 COP and 76% solar fraction (auxiliary energy supplied).

Henning et al. [22] Investigated a solid desiccant cooling system, the result showed that the maximum COP was about 0.7.

The solid desiccant system used to provide air conditioned air through basic process as shown in the below:

8.1. Working Principle

i. Dehumidification process by adsorption the water in the desiccant wheel, the air enter the wheel is Warm and humid, so the humidity ratio decreases and dry bulb temperature increase.
ii. Sensible cooling of the supply air in sensible wheel.
iii. The air is humidified and further cooled by evaporative cooler, the required room temperature and humidity can be set by using controller on supply air stream.
iv. The exhaust air stream from the air conditioned space is humidified by evaporative cooling to achieve the full cooling potential needed in sensible wheel.
v. The exhaust air is heated up in sensible wheel, the cold side of the wheel moved to supply air side to achieve the required cooling. (5-6) the air pass through the regenerative heat coil and air temperature increased. The hot water received from dedicated solar collector in a comparatively low temperature around 70°C.
vi. The desiccant wheel has to be regenerated to keep the system operate continuously for dehumidification process, so the humidity ratio increased and dry bulb temperature decreases of the exhausted air.

9. Closed Solar Cooling Sorption Cycle

Closed cycles are divided in two categories based on the sorption material as follow:

9.1 Solar Cooling Absorption system

Absorption refrigeration cycles require hot water from waste heat source, solar collector or boiler to separate a water refrigerant from a mixture of LiBr/Water in the generator.

It is used to produce ice by an evaporation of pure water from a vessel placed within an evacuated container with sulfuric acid [23-25].

9.2 Chemical and Physical Adsorption

Adsorption and chemical reaction adsorption cycles are similar to each other. The difference between these cycle is the process which occur in cycle. The force causing the adsorption process is a physical adsorption force; and the causing the chemical adsorption process is a chemical adsorption force.

No moving parts and low evaporation temperatures during operation is the main advantage of chemical reaction cooling system. While as low COP, high weight of adsorbent makes it not sufficient for large application.

Methodology

This consist the working process of solar cooling box with the information and technology which is implemented.

Peltier

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctionsof two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a **Peltier device**, **Peltier heat pump**, **solid state refrigerator**or **thermoelectric cooler** (**TEC**).

It can be used either for heating or for cooling [26] although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools [27]. The primary advantages of a Peltier cooler compared to a vapor-compression refrigerator are its lack of moving parts or circulating liquid, very long life, invulnerability to leaks, small size, and flexible shape.

A Peltier cooler can also be used as a thermoelectric generator. When operated as a cooler, a voltage is applied across the deviceand as a result, a difference in temperature will build up between the two sides.When operated as a generator, one side of the device is heated to a temperature greater than the other side and as a result, a difference in voltage will build up between the two sides (the Seebeck effect).

Parameters

I	Operating Current to the TEC module (in Amps)
$\mathbf{I_{max}}$	Operating Current that make the maximum temperature difference ΔT_{max} (in Amps)
$\mathbf{Q_c}$	Amount of heat that can be absorbed at the cold side face of the TEC (in Watts)
$\mathbf{Q_{max}}$	Maximum amount of heat that can be absorbed at the cold side. This occurs at $I = I_{max}$ and when Delta T = 0. (in Watts)
$\mathbf{T_{hot}}$	Temperature of the hot side face when the TEC module operatiing (in °C)
$\mathbf{T_{cold}}$	Temperature of the cold side face when the TEC module operating (in °C)
$\mathbf{\Delta T}$	Difference in temperature between the hot side (T_h) and the cold side (T_c). Delta $T = T_h - T_c$ (in °C)
$\mathbf{\Delta T_{max}}$	Maximum difference in temperature a TEC module can achieve between the hot side (T_h) and the cold side (T_c). This occurrs (Maximum cooling capacity) at $I = I_{max}$ and $Q_c = 0$. (in °C)
$\mathbf{U_{max}}$	Voltage supply at $I = I_{max}$ (in Volts)
ε	TEC module cooling efficiency (%)
α	Seebeck coefficient of thermoelectric material (V/°C)
σ	Electrical coefficient of thermoelectric material (1/cm·ohm)
κ	Thermo conductivity of thermoelectric material (W/CM·°C)
N	Number of thermoelectric element
Iεmax	Current attached when the hot side and old side temperature of TEC module is a specified value and it required getting the Maximum efficiency (in Amps)

Introduction of application Formulae to TEC module

$Q_c = 2N[\alpha(T_{c+}\ 273)\text{-}L\ I^2/2\sigma S\text{-}\kappa s/Lx(T_h - T_c)\ ]$

$\Delta T = [\ I\alpha(T_{c+}\ 273)\text{-}L\ I/^2 2\sigma S]\ /\ (\kappa S/L + I\ \alpha]$

$U = 2\ N\ [\ I\ L\ /\sigma S + \alpha(T_h - T_c\ )]$

$\varepsilon = Q_c\ /U\ I$

$Q_h = Q_{c\ +}\ I\ U$

$\Delta T_{max} = T_h + 273 + \kappa/\sigma\alpha^2\ x\ [\ 1\text{-}\sqrt{}2\sigma\alpha^2/\kappa x\ (T_{h+}\ 273) + 1]$

$I_{max\ =}\kappa S/\ L\alpha x\ [\sqrt{}2\sigma\alpha^2/\kappa x\ (T_{h+}\ 273) + 1\text{-}1]$

Iεmax = $\alpha\sigma S\ (T_h - T_c\ )\ /\ L\ (\sqrt{}1+0.5\sigma\alpha^2(546+ T_h - T_{c)}\ /\ \kappa\text{-}1)$

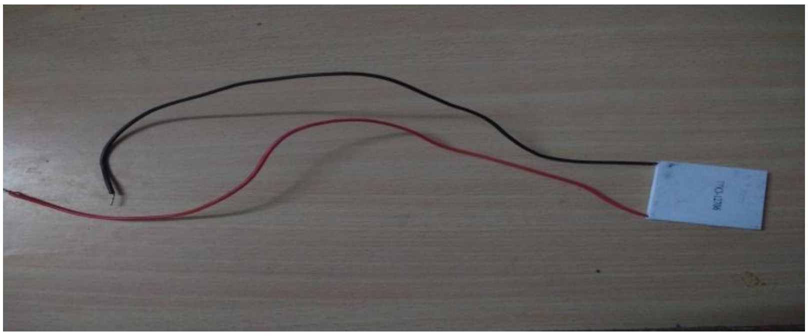

fig 2 peltier module

Operating Principle

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides and when a DC electric current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The "hot" side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature.

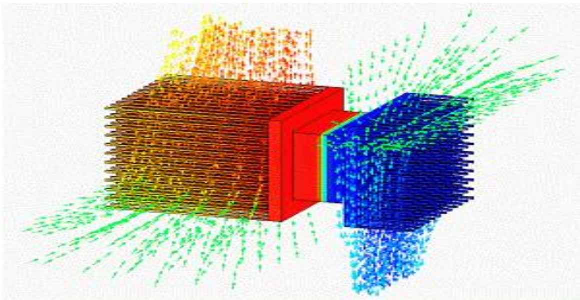

fig 3 operating principle

Construction

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. Thermoelectric Coolers, also abbreviated to TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it.

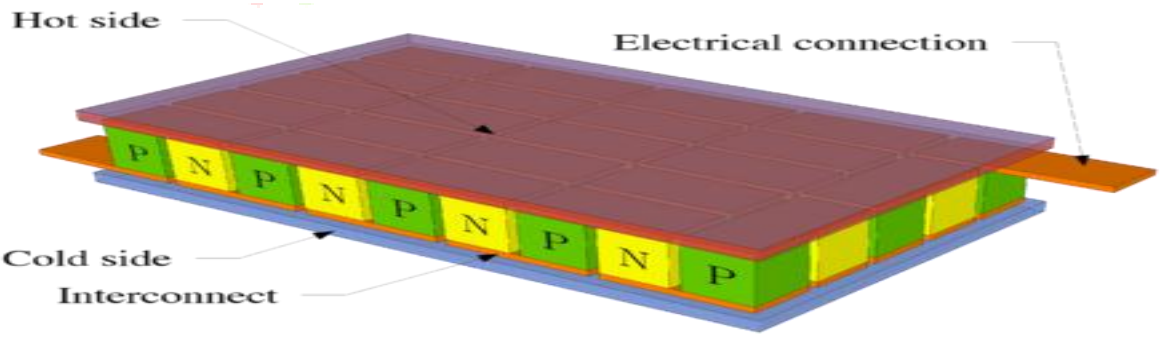

fig4 construction of peltier

Heat Sink with Cooling Fan

It is used to increase heat transfer rate. The cooling fan is having 12 volt motor and is 200 mA rating. A heat sink (also commonly spelled heat sink) is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium often air or a liquid coolant, where it is dissipated away from the device, therebyallowing regulation of the device's temperature at optimal levels.

A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of aheatsink

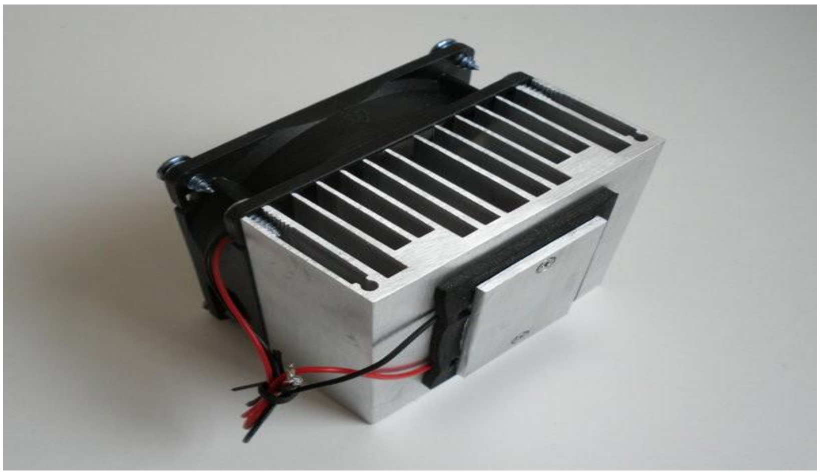

fig 5 heat sink with cooling fan

Performance objectives(Efficiency)

The performance of solar cooling box depends upon the folloeing factors

- The temperature of the cold and hot sides.
- Thermal and electrical conductivities of the device's material.
- Contact resistance between the TE device and heat source/heat sink.
- Thermal resistance of the heat sink.

AtMega8 Microcontroller

A monitoring and protection circuit for 1-cell and 2-cell Li-ion applications that require high security and authentication, accurate monitoring, low cost and high utilization of the cell energy. The microcontroller includes 8KB self-programming flash program memory, 512-Bytes SRAM, 256-Bytes EEPROM, 1 or 2 cells in series, over-current, high-current and short-circuit protection, 12-bit voltage A/D converter, 18-bit coulomb counter current A/D converter and debug Wire interface for on-chip debug.

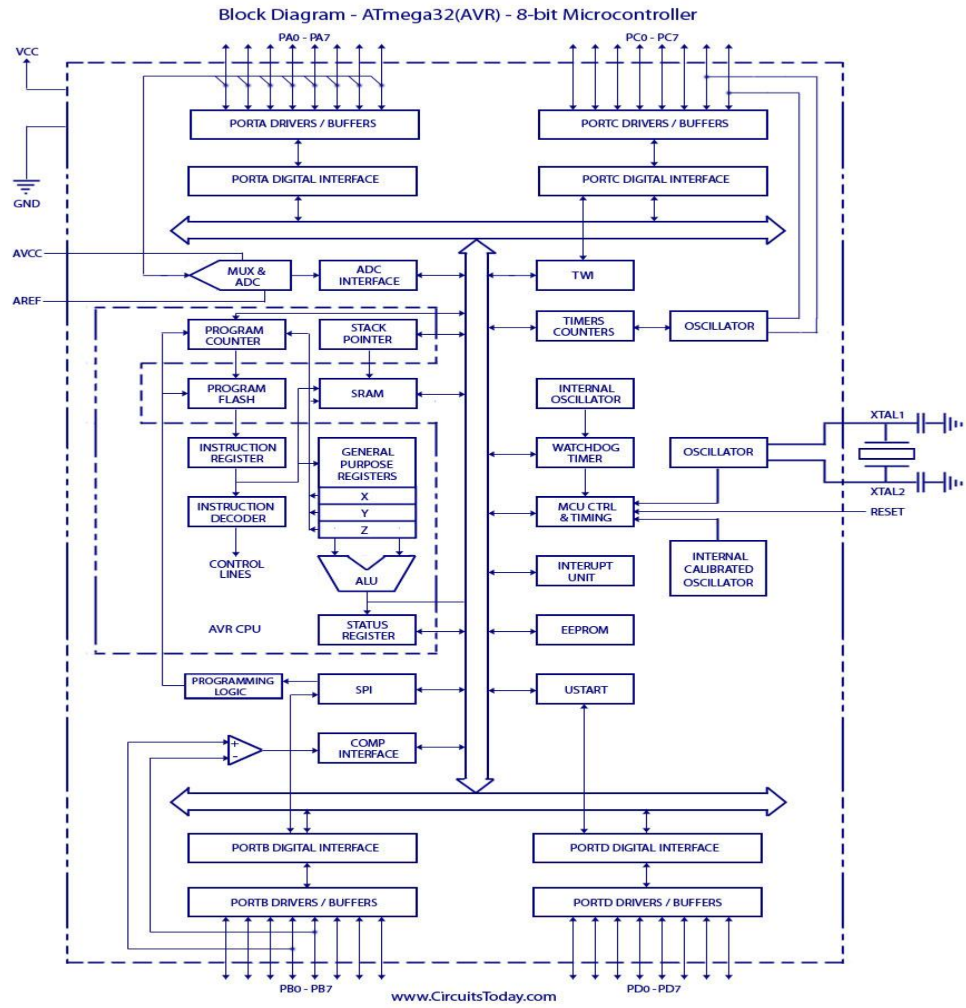

fig6 block diagram of atmega8 microcontroller

Working of cooling box

In the solar cooling box, a solar plate is used for the production of the electricity. When there is availability of the sun rays it produced electricity. A chargeable battery is connected with the solar panel. When the electricity is produced by the solar panel then this electricity is used to charge the battery. A microcontroller is used in the control circuit of the solar cooling box. Microcontroller consists of two terminals; one is connected to the temperature sensing device and another one is connected to battery. Due to which the temperature sensing device starts charging till the temperature of the cooling bucket reaches upto 15 degree.

As once the temperature of the bucket approaches up to 15 degrees, the control circuit cut the supply from the temperature sensing device and starts charging the battery. A manual switch is connected between the battery and the peltier (cooling module), so that we can operate this manually during night too.

We used temperature sensing device to sense the temperature and if the temperature does not fluctuate between the predefined inequality constraints i.e. $T_{min} < T < T_{max}$, then control circuit automatically cut the supply and starts to charge the battery.

Control circuit operates the whole circuit ofcooling box on its operational value, if any discontinuity is occurred then it will turn off the circuit.

Control circuit here consists of microcontroller and switching devices as well which will operate our circuit accordingly.

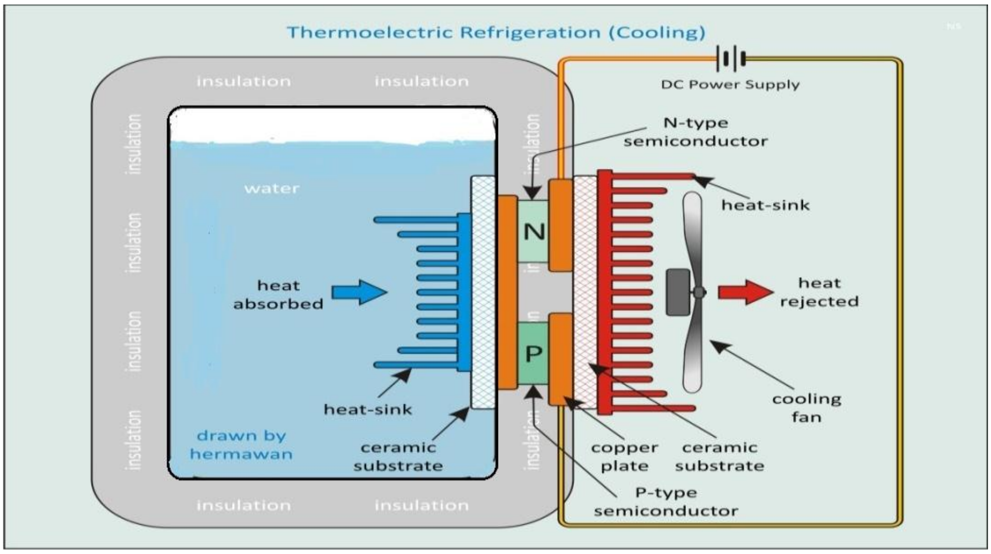

fig.4: working of solar cooling box

Conclusion & Future Scope

Exploitation of solar thermal energy for cooling is an efficient, intelligent and environmentally friendly way to use renewable energy sources to meet our air conditioning needs. The study suggests by utilizing the waste heat and storing power from solar cells, the system becomes highly efficient compared to its traditional counterpart. In this work, an approach is provided to design a cooling system which contains a combination of PV cells and Peltier. This is eco-friendly system and doesn't make any harm to health like there is no use of chlorofluorocarbons as refrigerants. Its portability, easy use and cheap cost make it ideal. The purpose of this project has been to investigate the possibility of designing a solar driven air-toair heat pump by connectingPeltier elements to a PV panel and evaluate its potential.

Solar cooling box is a cooling system that is life-changing and life-saving as the system is based on a law of nature, appliances using it, are reliable and robust even in the harshest environments. This work provides an idea regarding use of Peltier technology for applications of cooling in different areas. In future the various combinations of cooling technologies can be further implemented to get an efficient, reliable and smart cooling system for cooling a wide volume with its impeccable outcomes.

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