Solar Powered Thermoelectric Refrigerator

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Abstract- *Conventional cooling systems like those utilized in refrigerators utilize a compressor and a working fluid to transfer heat. Thermal energy is absorbed and released because the working Fluid undergoes expansion and compression and changes phase from liquid to vapor and back, respectively. Semiconductor thermoelectric coolers (also referred to as Peltier coolers) offer several advantages over conventional systems. They're entirely solid-state devices, with no moving parts; this makes them rugged, reliable, and quiet. They use no ozone depleting chlorofluorocarbons, potentially offering a more environmentally responsible alternative to standard refrigeration. They will be extremely compact, far more so than compressor based systems. Precise temperature control (< ± 0.1 °C) are often achieved with Peltier coolers. However, their efficiency is low compared to standard refrigerators. Thus, they're utilized in niche applications where their unique advantages outweigh their low efficiency. Although some large-scale applications are considered (on submarines and surface vessels), Peltier coolers are generally utilized in applications where small size is required and therefore the cooling demands aren't too great, like for cooling electronic components (Astrain and Vian, 2005). Objective of this project is to style thermoelectric refrigerator utilize Peltier effect to refrigerate and maintain a specified temperature, perform temperature control within the range 5 °C to 25 °C. Interior cooled volume of 1Litre and Retention for next half hour.*

Keywords- Peltier effect, solar power, thermoelectric cooler, thermoelectric refrigeration

I. INTRODUCTION

Solar powered refrigerators could also be most normally consumed within the evaluative world to assist reduce poverty and environment change. By solar power, these refrigerators are ready to keep perishable goods like meat and dairy cool in hot season and are wont to keep much needed vaccines at their appropriate temperature to avoid spoilage. The portable devices are often caused with simple components and are refrigerator beneficial for areas of the developing world electricity is unreliable or non-existent. Solar refrigerator supported the thermoelectric cooling technology it's differ from the refrigerator mainly utilized in times .In this sort of refrigerator don't have any requirement of compressor, evaporator ,condenser, and not any pump also .in this refrigerator solar array in used for power supply. Thermoelectric cooler (TEC) is sort of cooler or heater which is a combination of two different material to get hot and cold junction at its end by use of electric potential or voltage. TEC works on the principal of Peltier effect which is conversion of electrical applied voltage into thermal gradient. Thermoelectric effect can be observed when direct current is applied across the P and N type semiconductor materials. Heating and cooling effect depends on direction of current flow; electron carries energy from cold to hot junction. TEC is a versatile compact component which is very reliable, long life and silent as it does not contain any moving parts. Despite having so many advantages TEC have low COP, as heat absorb at cold junction is less than energy supplied. Performance of a TEC depends on material's thermal conductivity, electrical conductivity, and Seebeck coefficient, and Peliter coefficient, figure of merit, applied voltage and temperature difference across hot and cold junction. In later section will discuss how these parameters affect the performance of TEC.

II. METHODS OF REFRIGERATION

Methods of refrigeration can be classified as non-cyclic, cyclic, thermoelectric and magnetic.

Non-Cyclic Refrigeration:-

This refrigeration method cools a contained area by melting ice, or by sublimating solid. Perhaps the only example of this is often a transportable cooler, where items are put in it, then ice is poured over the highest. Regular ice can maintain temperatures near, but not below the melting point, unless salt is employed to chill the ice down further (as during a traditional ice-cream maker). Dry ice can reliably bring the temperature well below water melting point.

Cyclic Refrigeration:-

This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work, and its inverse, the thermodynamic power cycle. In the power cycle, heat is supplied from a high-temperature source to the engine, a part of the warmth getting used to supply work and therefore the rest being rejected to a low-temperature sink. This satisfies the second law of thermodynamics.

Thermoelectric refrigeration:-

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two types of material. This effect is commonly used in camping and portable coolers and for cooling electronic components and small instruments. Peltier coolers are often used where a traditional vapor-compression cycle refrigerator would be impractical or take up too much space, and in cooled image sensors as an easy, compact and lightweight, if inefficient, thanks to achieve very low temperatures, using 2 or more stage peltier coolers arranged during a cascade refrigeration configuration, meaning that 2 or more peltier elements are stacked on top of each other, with each stage being larger than the one before it, in order to extract more heat and waste heat generated by the previous stages. Peltier cooling features a low COP (efficiency) in comparison thereupon of the vapor-compression cycle so it emits more waste heat (heat generated by the peltier element or cooling mechanism) and consumes more power for a given cooling capacity.

Magnetic refrigeration:-

Magnetic refrigeration, or adiabatic demagnetization, may be a cooling technology supported the magneto caloric effect, an intrinsic property of magnetic solids. The refrigerant is usually a paramagnetic salt, like cerium magnesium nitrate. The active magnetic dipoles during this case are those of the electron shells of the paramagnetic atoms. A strong magnetic flux is applied to the refrigerant, forcing its various magnetic dipoles to align and putting these degrees of freedom of the refrigerant into a state of lowered entropy. A conductor then absorbs the warmth released by the refrigerant thanks to its loss of entropy. Thermal contact with the warmth sink is then broken in order that the system is insulated, and therefore the magnetic flux is transitioned. This increases the warmth capacity of the refrigerant, thus decreasing its temperature below the temperature of the warmth sink. Because few materials exhibit the needed properties at temperature, applications have thus far been limited to cryogenics and research

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III. THERMOELECTRIC DEVICES

A Peltier element may be a thermoelectric cooler, or TEC, which is just a little apparatus. In 1821 J.T Seebeck discovered that two dissimilar metals connected at two different junctions create a micro voltage between them if held at two different temperatures. If two wires are connected, for instance iron and copper, and therefore the other ends applied to the terminals of a galvanometer a voltage are often recorded if the junction between the wires is heated. The wires are called a thermocouple J. Peltier realized, in 1834, that the inverse effect is feasible also. If a voltage is applied to a thermocouple a temperature difference are going to be initiated between the junctions. This is known as the Peltier effect. A heating or cooling effect of the junction is made counting on the direction of the present.

Peltier Effect:-

If direct current is passed through two dissimilar metals then a potential difference will be developed across the two dissimilar metals. There will be cooling at one junction and heating at another junction. Peltier says that charge is directly proportional to current which means when voltage is applied to the Peltier device then current will be developed and due to the current, charge will be generated and due to charge a potential difference will be developed between two dissimilar metal. The effect of Peltier may be a crucial concept during this study. The thermoelectric effect may be a direct exchange of temperature differences to electric voltage and vice-versa. A thermoelectric device produces a voltage once there's an altered temperature on all sides. The heat will eliminate from one of the metals and shifted to the other since the electrical current applied across the junction of two different metals. Thermoelectric coolers operate by Peltier effect which also goes by general name thermoelectric effect. However, the device has two sides when a DC current passes over the Peltier; it generates heat from all sides which one side gets cooler while the opposite hotter (Figure 3.1). The hot side is attached to the heat sink which remains at atmospheric temperature. On the opposite hand, the cold runs below the space temperature.

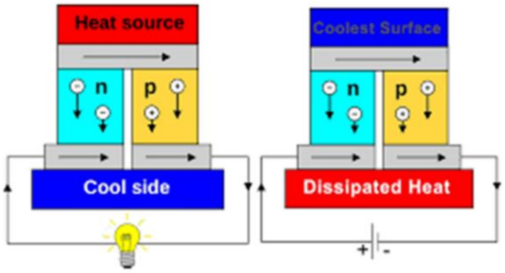

Fig. 3.1: Peltier Effect

Seebeck Effect:-

The Seebeck effect is that the conversion of warmth directly into electricity at the junction of various sorts of wire. It is named for the Baltic German physicist Thomas Johann Seebeck, who in 1821 discovered that a compass needle would be deflected by a closed-loop system formed by two different metals joined in two places, with a temperature difference between the joints. This was because the electron energy levels in each metal shifted differently and a voltage difference between the junctions created an electrical current and thus a magnetic flux round the wires. Seebeck didn't recognize there was an electrical current involved, so he called the phenomenon "thermomagnetic effect". Danish physicist Hans Christian Ørsted rectified the oversight and coined the term "thermoelectricity". The Seebeck effect may be a classic example of voltage (emf) and results in measurable currents or voltages within the same way as the other emf. Electromotive forces modify Ohm's law by generating currents even within the absence of voltage differences (or vice versa); the local current density is given by $J = \sigma(-\nabla V+E_{emf})$ where V is that the local voltage and σ is that the local conductivity. In general, the Seebeck effect is described locally by the creation of an electromotive field: $E = -S\nabla T$ Where S is the Seebeck coefficient (also known as thermopower), a property of the local material, and ∇T is the gradient in temperature T.

Seebeck Coefficient:-

The Seebeck coefficient (also referred to as thermopower, thermoelectric power, and thermoelectric sensitivity) of a cloth may be a measure of the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material, as induced by the Seebeck effect. The SI unit of the Seebeck coefficient is volts per kelvin (V/K), although it's more often given in microvolts per kelvin (μV/K). The use of materials with a high Seebeck coefficient is one among many important factors for the efficient behavior of thermoelectric generators and thermoelectric coolers. More information about high-performance thermoelectric materials are often found within the thermoelectric materials article. In thermocouples the Seebeck effect is used to measure temperatures, and for accuracy it is desirable to use materials with a Seebeck coefficient that is stable over time. $S = -\Delta V/\Delta T$ Where ΔV is the thermoelectric voltage seen at the terminals. The Seebeck coefficient is defined in terms of the portion of electric current driven by temperature gradients, as in the vector differential equation: $J = -\sigma\nabla V - \sigma S\nabla T$

Thomson Effect:-

In different materials, the Seebeck coefficient is not constant in temperature, and so a spatial gradient in temperature can result in a gradient in the Seebeck coefficient. If a current is driven through this gradient then endless version of the Peltier effect will occur. This Thomson effect was predicted and subsequently observed by Lord Kelvin in 1851. It describes the heating or cooling of a current-carrying conductor with a gradient. If a current density J is skilled a homogeneous conductor, the Thomson effect predicts a heat production rate q per unit volume of:

$q = kJ.\nabla T$

IV. DESIGN AND MODELLING

4.2 Design:-

4.1.1 Selection of materials:-

Aluminium sheets with thermal conductivity of 52 W/mK were used as outer wall. MDF slabs with 6 mm thickness having a density of 30 kg/m3 and thermal conductivity of 0.33W/mK were used to give the required thermal insulation. Typical values range from 0.032 to 0.038 W/mK counting on the density of the MDF board. The value of 0.038 W/mK was obtained at 15 kg/m3 while the worth of 0.032 W/mK was obtained at 40 kg/m3.

4.1.2 TEC Selection:-

It is required to choose a TEC module that not only has sufficient cooling capacity to maintain the proper temperature, but also meet the dimensional requirements imposed by the housing. A module is arbitrarily chosen by considering the geometrical constrain imposed thanks to the dimensions of cabin and also appears to possess appropriate performance characteristics. The performance data is presented graphically and referenced to a selected conductor base temperature. Most performance graphs are normally standardized at a heat sink temperature (TH) +50°C and the resultant data is usable over a range of around 40°C to 60°C with only a slight error. ΔT is that the governing parameter required for arbitrarily selecting the module. To derive relevant parameters for making mathematical calculations the performance graphs for this TE module is usually considered. In order to begin the design process we must first evaluate the heat sink and make an estimate of the worst case module hot side temperature (TH) and module temperature differential, ΔT. The TEC module was selected by considering few factors such as dimensions, QC, power supply etc. The model number of the module is TEC1-12706. It is decided to select a TEC module which has a cooling power greater than the calculated cooling load. TEC1-12706 operates with an optimum voltage value of 12V. It has a maximum voltage of 15.4V. At 12V it draws and maximum DC current of 6 A. The nominal power rating or the cooling power is 60 W. It has a maximum operating temperature of 200ºC. ΔT of the TEC is 68ºC when hot side temperature is 25ºC.

4.1.3 Heat sink selection:-

The values obtained within the preceding analysis are wont to assess overall system feasibility. We want to qualify our assumption of 15°C temperature rise across conductor. The efficiency of the warmth sink features a significant influence on the warmth pumping capability of the thermoelectric module. The hot side of the module must interface with an efficient heat removal system in order to achieve a useful temperature differential across the thermoelectric module. Natural convection type, forced convection type, and liquid cooled are three of the most common variety of heat sinks. Thermal resistance varies among the various types and sizes of sinks during which natural convection being the smallest amount efficient and liquid cooled the foremost efficient. Most of thermoelectric cooling applications use forced convection heat sinks with thermal resistance values (Rht) starting from 0.10 0C/W to 0.50 0C/W. The size of Heat Sink used in our project are 85.4 × 85.4 × 41.5 mm.

4.1.4 Blower Selection:-

The blower performs the function of dissipating the heat removed by the heat sink to the surrounding atmosphere. For the purpose of portability we selected the normal Computer CPU blower which is very small in size. The specifications of it are tabulated in table 1 as given below.

Table 4.1: Specification of Blower

Size	70 x70mm
Bearing Type	Rifle Bearing
Voltage DC	12V
Current	0.28A
Noise	19±3 dBA
Speed	3300 RPM±10%

4.1.5 Peltier Module:-

Thermoelectric device are pair of two dissimilar metal semiconductors or conductor with semiconductor. In this system the device is formed of extrinsic semiconductor having contact serial with required no of cells. The energy difference of conduction band of fabric should be high for higher refrigeration.

Table 4.2: Specification of Peltier Module

Model Number	TEC1-12706
Operating Voltage	12V
Maximum Voltage	15.4V
Maximum Current	6A
Maximum Power	92W
Maximum Temperature	138°C

Fig. 4.1: Peltier Module

4.1.6 Solar Panel:-

Photovoltaic solar panels absorb sunlight as a source of energy to get electricity. A photovoltaic (PV) module may be a packaged, connected assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. The most common application of solar power collection outside agriculture is solar water heating systems. Solar panel refers either to a photovoltaic module, a solar hot water heater, or to a set of solar photovoltaic (PV) modules electrically connected and mounted on a supporting structure. A PV module may be a packaged, connected assembly of solar cells. Solar panels can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated.

Table 4.3: Specification of Solar Panel

Panel Size	1 ¼'' — x 1''
Cost of Panel	Rs.700-Rs.1000
Weight of Panel	1 Kg
Voltage	12V
Current	5A
Power	12W

Fig. 4.2: Solar Panel

4.1.7 Lead Acid Battery:-

Negative plate reaction

$Pb(s) + HSO^-_4(aq) \rightarrow PbSO_4(s) + H^+(aq) + 2e^-$

the release of two conducting electrons gives the lead electrode a charge. As electrons accumulate they create an electrical field which attracts hydrogen ions and repels sulfate ions, resulting in a double-layer near the surface. The hydrogen ions screen the charged electrode from the answer which limits further reaction unless charge is allowed to effuse of electrode.

Positive plate reaction

$PbO_2(s) + HSO^-_4(aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Taking advantage of the metallic conductivity of PbO_2. The total reaction are often written as

$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ $E^o_{cell} = 2.05$ V

The net energy released per mol (207 g) of Pb(s) converted to $PbSO_4(s)$, or per 36 g of water formed, is ca. 400 kJ. The sum of the molecular masses of the reactants is 642.6 g/mol, so theoretically a cell can produce two faradays of charge (192,971 coulombs) from 642.6 g of reactants, or 83.4 ampere-hours per kilogram (or 13.9 ampere-hours per kilogram for a 12-volt battery). For a 2 volts cell, this involves 167 watt-hours per kilogram of reactants, but a lead– acid cell in practice gives only 30–40 watt-hours per kilogram of battery, due to the mass of the water and other constituent parts.

4.2 Modelling:-

For the modeling we used CATIA V5 software. The main parts that were modeled are shown below.

4.2.1 Outer Cover:-

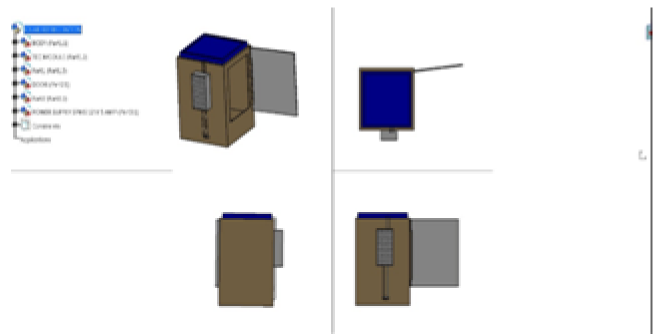

Fig. 4.3: CATIA Model of Outer Cover

4.2.2 Assembly of Model:-

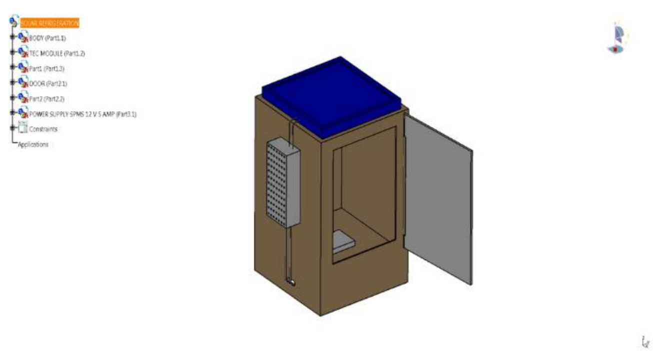

Fig. 4.4: CATIA Model Final Assembly

V. FABRICATION

Fabrication incudes the manufacturing processes which we utilized in our project to manufacture the ultimate Assembly. The manufacturing processes that were used are as follows:

5.1 Sheet Cutting:-

Punching is a cutting process in which material is removed from a piece of sheet metal by applying a great enough shearing force. Punching is extremely almost like blanking except that the removed material, called the slug, is scrap and leaves behind the specified internal feature within the sheet, such as a hole or slot.

5.2 Sheet Bending:-

Bending is a manufacturing process that produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials, most commonly sheet metal. Commonly used equipment include box and pan brakes, brake presses, and other specialized machine presses. In press brake forming, a piece is positioned over the die block and therefore the die block presses the sheet to make a shape. Usually bending has got to overcome both tensile stresses and compressive stresses. When bending is completed, the residual stresses cause the fabric to spring back towards its original position, therefore the sheet must be over-bent to realize the right bend angle. The amount of spring back depends on the fabric, and therefore the sort of forming. When sheet is bent, it stretches long. The bend deduction is the amount the sheet metal will stretch when bent as measured from the outside edges of the bend. The bend radius refers to the within radius. The formed bend radius depends upon the dies used, the fabric properties, and therefore the material thickness.

5.3 Brazing:-

Brazing is a metal joining process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a lower melting point than the adjoining metal. Brazing differs from welding in that it does not involve melting the work pieces and from soldering in using higher temperatures for a similar process, while also requiring much more closely fitted parts than when soldering. The filler metal flows into the gap between closefitting parts by capillary action. The filler metal is brought slightly above its melting (liquids) temperature while protected by an appropriate atmosphere, usually a flux. It then flows over the bottom metal (known as wetting) and is then cooled to hitch the work pieces together. A major advantage of brazing is that the ability to hitch an equivalent or different metals with considerable strength.

5.4 Insulating Material Cutting:-

Wood-machining has largely remained an art for a scarcity of scientific investigation during this field. An Analysis of the Wood-Cutting Process was prepared to supply a basic understanding of wood-cutting and especially of parallel-grain wood-cutting.

5.5 Drilling:-

Drilling may be a cutting process that uses a drilling bit to chop a hole of circular cross-section in solid materials. The drilling bit is typically a rotary cutter, often multi-point. The bit is pressed against the work-piece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work-piece, cutting off chips (swarf) from the hole as it is drilled. Drilling may affect the mechanical properties of the work piece by creating low residual stresses round the whole opening and a really thin layer of highly stressed and disturbed material on the newly formed surface. This causes the work piece to become more vulnerable to corrosion and crack propagation at the stressed surface. A finish operation could also be done to avoid these detrimental conditions. Cutting fluid is usually wont to cool the drilling bit, increase tool life, increase speeds and feeds, increase the surface finish, and aid in ejecting chips. Application of those fluids is typically done by flooding the work piece with coolant and lubricant or by applying a sprig.

5.6 Electrical Connections:-

For electrical connections we use battery of 12 V and 7.3 Ampere. Battery has two terminals that is red and black red terminal is connected to each switch. Second connection of each switch is given to one terminal of TEC, second terminal of each TEC is connected to blue terminal of a battery. When we switch ON the switches respective TEC's will work. This electrical connection has been made on the basis of polarities of TEC's according to their ratings. It has used all basics of electrical systems so that each TEC could have been perform under same operating loads. This electrical connection incorporates load distribution to each TEC as well as blowers.

VI. RESULT

For the results of our project, after assembling all the parts, we had taken trials for medium load (normal water) and cold water. The results obtained are given below.

1) Trial on Cold Water:

Time vs Temperature Drop:

In this trial, it was concluded that as time commences, the temperature drop decreases up to certain limit and thereafter it was increases.

2) Trial on Normal Water:

The calculation of COP for thermoelectric module can be done by taking the ratio of amount of heat absorbed at the cold side to the I/P power.

The conclusion which will be drawn is that the COP of refrigerators ranges from 0.3 to 0.6, which is about the 1/6th value of traditional VCR refrigerators.

• Qrej = 22W

• Pinput = 80W

• COP actual = 0.3

• COPth = 5.4

VII. CONCLUSION

TEC is a versatile component which is very small in size as compared to compressor which works on peltier effect. Performance of TEC depends on peltier coefficient, applied current, seebeck coefficient and temperature difference between two junctions. Optimization of Conventional pyramid-styled and cuboid-styled multi-stage cooler deals with determining the optimum ratio of the number of TE modules and optimum ratio of electric current between stages respectively.

Also we can conclude that the reliability of the peltier module available in India is less with unsatisfactory level of cooling. Thus more research is required within the cooling module design with top quality Peltier modules to be made available from U.S or Europe. If such changes are made than the speed of satisfactory results will surely increase with reliability. The general system is simple to design yet performance of the entire system is yet to be realized.

Thus, Thermoelectric Cooling is very Cost-effective, Non – Polluting, Non – hazardable and emerging concept of replacing the typical Mechanical Compressor based refrigeration system. It can be commercially used in various industries for medical, chemical, dairy and water chilling plants.

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