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DESIGN ANDCHARACTERISTICS OF SOLAR THERMO ELECTRIC REFRIGERATOR

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ABSTRACT

In this automation scenario when everyone is serious about glaciers melting & ozone layer depletion so it's important to do which helps in overcoming his problem. Many type of refrigerator are made using refrigerant which to extent affect our environment. Then it strikes to make a refrigerating system in which there is no use of refrigerant so there is an option of vapour absorption system. Now the problem occurs about its shape refrigeration system with absorption system is heavy & bulky. This leads our project to thermo-electric cooling using concept of See beck effect.

With reference to various research papers published in various scientific journals it has been evident that a lot of work is done in the field of thermoelectric cooling while some of the research papers and books depicts that the efficiency of this thermoelectric refrigeration system is not more. To increase the efficiency of this thermoelectric cooling refrigeration system a Peltier junction is used with fin and a forced convection process to increase the heat dissipation from the outsource of Peltier junction. The total arrangement is studied, fabricated &analysed. The result hence obtained shows that this refrigeration system is useful in journey period, carrying medicines and making the temperature of the food stuff stable at what they were kept. Without any harm to our environment.

1. INTRODUCTION

As before invention of the thermo electric cooler or module, conventional vapour compression refrigeration system plays an important role in the society but the vapour compression system release CFC, HFC and some global warming gases causes to greenhouse effect. And also vapour compression refrigeration system occupies very large space and It has more components. Those are compressor, condenser, expansion valve and evaporator. Those mechanical components are plays main role on vapour compression refrigeration system but some draw backs occurs at that time researches are going on better alternative for the CFC refrigerants still on the hunt. Although thermo electric property was discovered, thermo electric module working based on peltier effect. The applications of thermo electric module vary from small refrigerator and electronic package cooling, water chillers, cold plates, portable insulin cooling, portable beverage containers etc

Thermo electric module consists of two junctions those are P-N type semiconductors. Thermo electric module working on the principle of peltier effect. When Dc supplied to the thermo electric module there will be temperature difference. By using this module we can generate the electricity based on the principle of see beck effect. When we are giving to the heat to the module we can generate the voltage. See beck effect is the reversible of peltier effect to produce current up to 12 volts.

Types of refrigerator

Non cyclic process.Cyclic process.Magnetic Refrigeration.Thermo electric Refrigeration

Non cyclic: Ice kept on a thermal insulated box which provides cooling effect inside the box. It is the non-cyclic process. It is used before invention of the cyclic process.

Cyclic process: This is a continuous process, where a process fluid flows through to achieve continuous heat exchange from low to hot temperature reservoirs creating a cooling effect to provide refrigeration. It also has certain types those are three types. a) Gas cycle or Air refrigeration system. b) Vapour compression refrigeration system. c) Vapour absorption refrigeration system

Thermoelectric phenomenon was discovered nearly two hundred years ago. Since last sixty years the practical applications from thermoelectric had been exploited

The first breakthrough that would eventually be used to form the thermoelectric effect was discovered in 1820. Several other breakthroughs in the field were discovered over the next few decades but their relationship was not realized for a full 38 years. William Thomson discovered that heat is absorbed or produced when current flows in material with a certain temperature gradient and that the heat is proportional to both the electric current and the temperature gradient. His publication linked all the discoveries from the preceding decades**.** Kryotherm, (2007 Thermoelectric coolers which is also known as thermoelectric module or Peltier cooler is widely used in the market for several cooling applications. Use of TE modules often gives an answer to many critical thermal management problems, where low to moderate amount of heat is concerned. Certain advantages of TE coolers are it works electrically without any moving parts, thus it becomes maintenance free and silent. They are able to cool or heat within the same module depending on the polarity

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of the applied DC power. Traditional refrigeration systems are almost impossible to be manufactured without using chlorofluorocarbons or other chemicals that harmful to the environment. TE devices do not use or generate gases of any kind. TE modules are noted when there is a need to cool one specific component or area only.
Koetzsch and Madden (2009) examined on thermoelectric cooling versus conventional cooling in industrial enclosures. Conventional cooling systems such as air conditioners and air-to-water heat exchangers rely on chemical refrigerants or water to cool, or remove heat from, enclosures. Besides that refrigerants, air conditioners use compressors, evaporators, condensers and fans to provide cooling.

McStravick, et.al (2009) had invented a medical travel pack with cooling system. The invention has helped people suffering from chronic disease to travel with proper supply of medicine kept at proper temperature. These insulated container using TE modules comprises of a cold plate, heat sink, fan and a temperature sensor. A microcontroller is in electrical communication with the TE modules and the sensor. The device maintained a temperature of 2°C to 8°C. Thus it shows that TE cooler helps for low temperature cooling.Several studies related on TE coolers with regards to vehicles and are utilized well. They can be integrated into several designs. Hyeung, et.al (2007) have done a research on thermoelectric device to control the temperature of car- seat surface. The device helped when the temperature is warm in summer and cold in winter. Thermoelectric property was also implemented in pick up refrigerated trucks. Studies based on thermoelectric cooling unit for thermostatic body on refrigerated trucks were conducted by Bulat and Nekhoroshev (2003). In this study a comparison between the thermoelectric cooling units with vapour-compression installations was also made, where it showed that cost price of thermoelectric unit is four-five times cheaper than vapour-compression cooling units. The cooling power obtained for TE cooling was same when compared to compression cooling units.

These are excellent examples for spot cooling property of a TE module. Once such prototype was made by Bartlett and Sukuse (2007). They have built an air-conditioned cooling helmet which used thermoelectric device. The product was designed to give comfort for the user. The idea of cooling helmet was also discussed by Buist and Streitwieser (1988)**.** The 12 volt personal cooling system worked well to cool the head of a race driver. The 225 grams helmet cooling system reduced 5 to 6 degree Celsius form ambient.

TECs are more utilized in personal cooling and Harvie (2005) invented a personal cooling and heating system specifically designed to provide many hours of efficiency cooling or heating when worn by an a user. It was a durable light weight cooling specifically for harsh climatic conditions. Lauwers and Angleo (2009) had conducted a study and development of personal cooling vest which catered to maintain a core body temperature even at extreme conditions. So this was an admirable example, where they made use the property of TEC to benefit for their country's armed forces. Several others also tried examining TEC in air cooling. One such innovative is a thermoelectric air cooling device which is powered up by a jack that is to inserted in to a cigarette lighter socket in a vehicle. It was studied by Harrington (2009) and the device provided comfort cooling to a person's head and face in a vehicle. The device also removed the heat with help of a heat sink and exhausted away to the ambient from the user.
Tan and Fok (2008) have conducted an analytical study on method of selecting a TEC from different manufacturers before designing a cooling system. Their purpose of study was to assist the designers to help on developing an optimised thermoelectric cooling system design in minimum amount of time. The designers will be benefited from this study to implement a cooling system with TEC.

Many of the previous studies discussed above ensure that TEC is a reliable product to be used in a cooling system for personal use. The author is confident that anyone who has a keen interest to design TEC cooling system and if they are willing to trail certain methodology and sizing this report will set as good example.

2. Principle of Thermo electric module

Thermo electric cooling module basis on peltier effect and thermo electric cooling mainly working based on peltier effect in 1834French watch makers and jean peltier found that an electrical current would produce a temperature gradient at a junction of two dissimilar metals.

The thermo electric module gives the instantaneous cooling effect when dc applied it gives low efficiency as compared to vapour compression refrigeration system but it has portable and control the temperature at certain places. In thermo electric module two dissimilar materials are there those are made with bismuth telluride or any other materials one is for heat absorbing and other is for heat rejecting, p-type semiconductors are sandwiched between the two dissimilar materials and coated with ceramic material at outside of the module. And the module is electrically connected then the dc applied to that module, one side of the module cold and other side is hot because of properties of materials and passage of electron on the P&N type semiconductors.

Seebeck effect

The THOMAS SEEBECK was found this method in 1821.By using this module we can generate the power generation when we maintain temperature difference ΔT=700c. then we can get 12v power with help of thermo electric cooling when the difference between the two temperature the EMF will generate that causes to power generation on the see beck effect .

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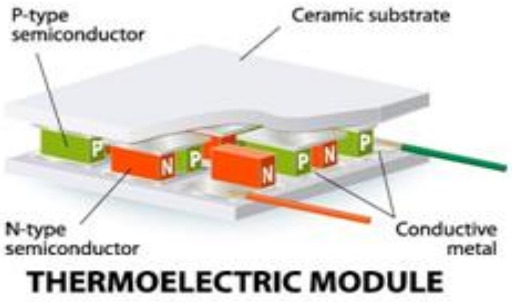

Fig 1 : Thermoelectric module Schematic of TEC

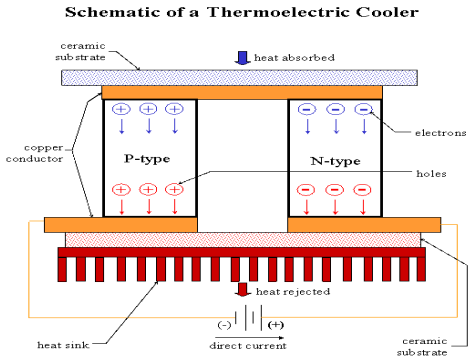

Fig 2: Schematic of TEC

Generally when the two conductors are in electrically contact, electrons flow from one in which they are less bound, into the other one where electrons are more bound. This phenomenon is due to the Fermi level difference in the two conductors. Fermi level denotes the difference in the energy levels occupied by electrons to that of un occupied of a metal conduction band. When the two different Fermi level conductors make contact, electrons flow from higher level to the lower level until the change in electrostatic potential brings the two Fermi levels to the same level. Current passes through the junction resulting a temperature gradient in any one of forward or reverse bias. If we maintain the heat sink at low temperature by removing the generated heat, the temperature at the cold plate side can be cooled by tens of degrees.

2.1 ASPECTS OF THERMOELECTRIC MODULE

Some of the attractive specifications of thermoelectric modules are:

Thermoelectric modules works without any moving parts i.e. they works electrically so less maintenance.

Thermoelectric cooling systems are smaller in structure and lighter in weight than the mechanical systems. Wide standards and special sizes and configurations are present in market to meet the requirements.Conventional heat sinks where the temperature is necessarily must above the ambient, if we attach thermoelectric device to the same heat sink to reduce the temperature beyond ambient value. Temperature control should be precise due to the closed-loop temperature control circuit. Due to their solid state construction they are highly reliable. This reliability factor is application dependent.Unlike a mechanical refrigeration system, thermoelectric modules generate no electrical noise. They can be used along with sensitive electronic sensors. They are silent and efficient.

Thermoelectric modules are working in zero gravity environments so they are popular in many aerospace applications. Thermoelectric devices are operating directly from DC power source.

With the thermoelectric devices we can able to achieve spot cooling In fraction of time to the conventional systems in automobiles.When the utilisation is reverse in order that is by applying temperature difference across it is responsible to generate DC power Conventional refrigeration systems are utilising chemical and CFCs which are harmful to environment. But thermoelectric devices does not use of any kind.One more benefit of thermoelectric device is due to the direct conversion of thermal energy to electrical energy, direct conversion eliminates the losses associated. Conversion done in solid state of the device as such there is no moving parts and no wear.

2.2. COMPONENTS REQUIRED

- Thermo electric module
- Heat sinks
- Air blowers
- Rectangle closed thermo coal box
- Battery(12v,7amps)

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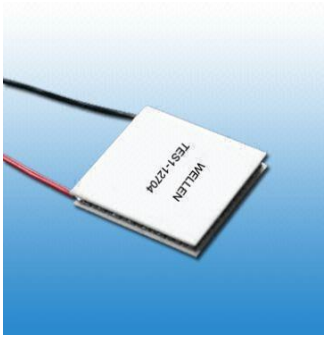

Fig 3:Thermo Electric Module

Fig 4:Heat sink

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Fig 5:Air Blower

A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates. By applying a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. Cooling capacity varies from fractions of Watts up to many hundreds.

A heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. The heat sink is generally made up of aluminium. The heat sink used in this fridge is of the dimension 7.5 x 8cm x 4.5cm (L x B x H) Air blower are the one type of fans, those are used for the transferring the heating air or cooling air from the thermo electric module through the heat sinks by using air blowers we can get the temperature difference

2.3. Insulation material

Thermocol have been used as insulator in constructing the body of refrigerator. For preventing air leakage proper fixing has been done. The material used is given as follows:

Fig 6. Thermocol

Fig 7..Battery

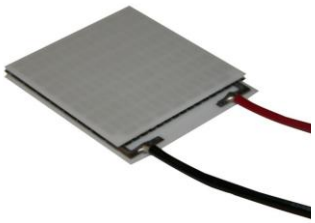

Figure 8: A typical single stage thermoelectric module.

As we know the ice vendors take advantage of thermocol for its economic valve and good insulation property as it does not allow the inner temperature of cooling medium to go down. Hence it is also an economic source of insulation.
The battery used in this fridge has following specifications:

- 12 volt DC
- 7 ampere hour

In this fridge one battery is used as a time for the working of the fridge. Also the extra connections for the second battery in the fridge are also provided if more cooling is required.

3. TYPES OF MODULES

Different types of TEC modules are single stage, two stage, three stage, four stage, center hole modules etc. Single stage will be suitable for a wide range of cooling applications with low to high heat pumping capacities.

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3.1Considerations of the TEC module

Before starting to design a TEC cooling system the designer have to take note the following into consideration.

1. Temperature to be maintained for the object that is to be cooled.
2. Heat to be removed from the cooled object.
3. Time required to attain the cooling after a DC power is applied.
4. Expected ambient temperature.
5. Space available for the module and hot side heat sink.
6. Expected temperature of hot side heat sink.
7. Power available for the TEC.
8. Controlling the temperature of the cooled object if necessary

3.2. Parameters of a 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.

Cold side temperature Tc, and 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 WattsOperating current (I) and operating voltage (V) of the TEC.

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 TcHere 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.

The hot side temperature Th 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. The two temperatures Tc and Th 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. Figure 6 illustrates a relationship of a classic temperature summary across a thermoelectric system.

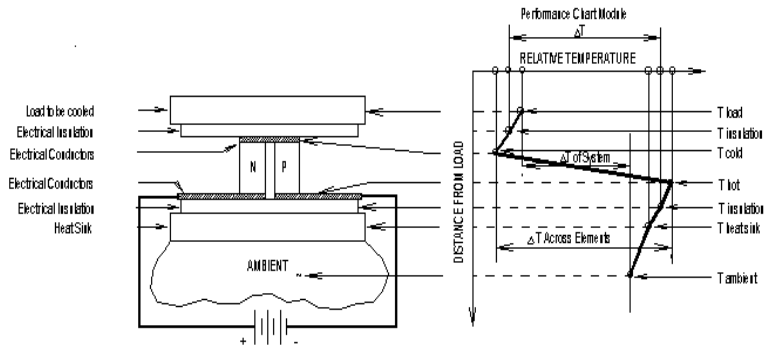

Figure 9: Characteristics temperature of relationship in a TEC

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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.

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

Thermoelectric Assemblies (TEAs) are cooling or heating systems attached to the hot side of the TEC to transfer heat by air, liquid or conduction. TEAs which dissipate heat from the hot side use heat exchangers. TEC requires heat exchangers or heat sinks and will be damaged if operated without one. The two ΔTs, actual ΔT and system ΔT depend on the heat sinks fitted at the hot sides or cold sides of TEC. The thermal resistances of the heat sinks could vary the ΔT across the TEC for a set ambient temperature and cooling load temperature. Therefore the thermal resistance of the heat sinks could increase the current flowing through the TEC. The three basic types of heat sinks are: forced convective, natural convective and liquid cooled, where liquid cooled is the most effective. The typical allowances for ΔT at the hot side heat sink of a TEC are

There are several different types of heat exchangers available in the market. As far this project is concerned a forced convection type of heat sink was be used based on the ΔT. Figure 7 shows a forced convection hot side heat sink attached with a fan. The air blows towards the heat sink from the fan will cool down the temperature of heat sink.

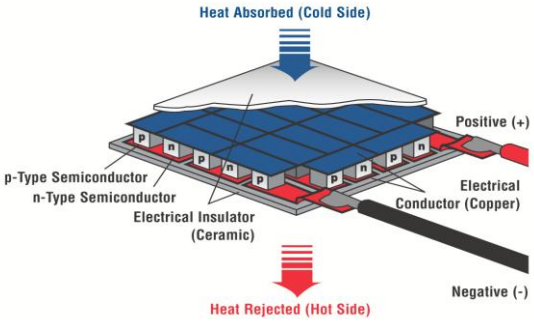

Fig 10 :The cutaway of a TEC

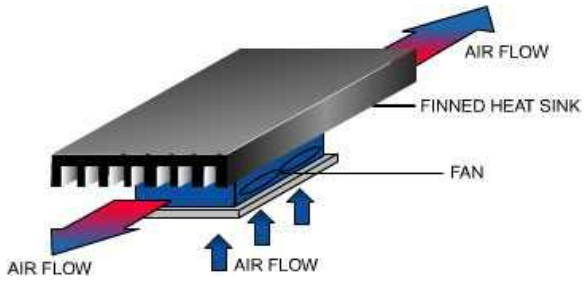

Figure 11 : Forced convection heat sink system

The main heat sink parameter for the selection process is its thermal resistance. Heat sink resistance can be termed as the measure of the capability of the sink to dissipate the applied heat. The equation is as follows.

$$R = \frac{T_h - T_\infty}{Q_h} \qquad Q_h = Q_c + P_e$$

R is the thermal resistance (in ^{0}C/W or K/W) and T_h, T∞ is the hot side temperature and ambient temperature respectively. Q_h is the heat load into the heat sink which is the sum of TEC power P_e and heat absorbed.

The goal of a heat sink design is to lessen the thermal resistance. It can be attained through exposed surface area of the heat sink. It may also require forced air or liquid cooling. The following Figure shows a simple thermal schematic of a forced convective heat sink.

Typical values of heat sink thermal resistance for natural convection range is from 0.5°C/W to 5°C/W, where as for forced convection is from 0.02°C/W to 0.5°C/W, and water cooled is from 0.005°C/W to 0.15°C/W. Most of the thermoelectric cooling requires forced convection or water cooled heat sinks. In this project force convective heat sink is used for the design of the cooling system.

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.

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

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3.3Power Supply and Temperature Control

Power supply and temperature control are two added items that must be considered wisely for a successful TE system. TEC is a direct current device. The quality of the DC current is important. Current and voltage of a TEC can be determined by the charts provided by the manufacturer. TEC's power is the product of required voltage and current. (P = IV).

Temperature control is generally categorized into two groups. One is open loop or manual and the other is closed loop or automatic. For cooling systems normally cold side is used as basis of control. The controlled temperature is compared to the ambient temperature. An on-off or a control using thermostat is the simplest and easiest techniques to control the temperature of a TEC. Thermo electric refrigeration works on Battery, Electricity & Solar energy.

Specifications of battery

1. Volts 12V
2. Ampere 7 amp
3. Model number 12 AVL007
4. Net quantity 1N

By using battery energy, to supply to the Thermo electric module we can generate the temperature difference. In the Thermo electric module the 12 v dc supply through the P-N type semiconductors. Thos e are causes to the heat absorption in one side and heat rejection in another side. The Thermo electric module generate the cooling effect and also generate the electricity when heat is applied to the TEC module up to 12 v is produced through the see beck effect.

Case i. When the 12V dc is applied to the TEC module, we can generate the temperature difference (one side is cooling effect and other side is heating effect). This is works on the peltier effect.

Case.ii. when the heat is applied to the TEC module, we can generate the voltage up to 12V heat is applied in one side the cooling effect generate opposite side, and voltage produced through the P-N type semiconductors. This is works on the see beck effect.

From 230 volts to 12 volts by using 12-0-12-12 v 1 amp step down transformer we can convert the 12v DC. In this conversion diodes and rectifiers are used for the charging the battery for duration of charging the battery it will take much time because of we are used in this project 12v, 7.2 amp battery, here we are used 12-0-12 1 amp step down transformer so time taken much if you use 12-0-12 3 amp step-down transformer we can reduce the duration of charging time.

Our main Moto of 230v to 12 is to charge the battery and supply the 12v DC to the thermo electric module for producing the temperature difference in the refrigerator cabin.

At firstly the 12-0-12 v step down transformer connected with the 230 v. Then to form a bridge rectifier with using the 4diodes, 1 rectifier, 1 resistor and connect with the transformer from the bridge rectifier connection reconnected to battery, then after switch on the 230v supply the conversion is happening and at the same time battery is charging slowly. At the same time we can use the 12v DC supplying to the TEC module then we can get the temperature difference.

Conversion of electricity of 230v to 12v DC

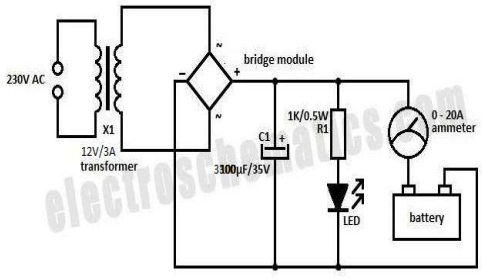

Fig.12.Circuit diagram of electrical conversion

Components are used for this conversion

Transformer (step down) , 4007 type diodes , 25v rectifier

Resistor

LED bulb.

3.4 Solar energy conversion

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Solar panel used for the converting the light energy to electrical energy that electrical energy transformed through the charge controller or regulator we can store on the battery. Here we are using 17 volts and 100 watts solar panel but we need 12 volts and 75 watts, so storage is possible in the battery. By using charge controller or regulator we can drop the17volts to 12 volts and 100 watts to 75 watts .This is the process of solar conversion and electricity store on the battery.

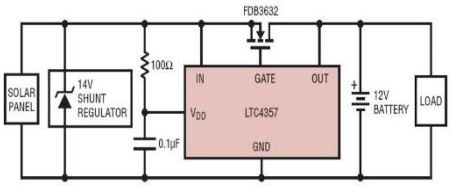

Fig. 13. Circuit diagram of solar conversion

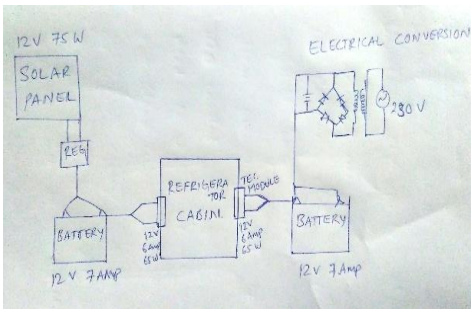

Fig.14. Block diagram

Solar panel specifications

1. Rated peak power = 75 W
2. Rated voltage = 17.3 V
3. Rated circuit = 4.33 A
4. Open circuit voltage = 21.72 V
5. Short circuit = 4.6 A
6. Fuse rating = 10 A
7. Application class = class A

3.5 WORKING PRINCIPLE OF TEC IN PELTIER EFFECT

Case i**.** From battery output is 12volts 7amperes it will be used for supplying to the thermo electric cooler to generate temperature difference.

Case ii. From electricity output is 12 volts, it is stored into the battery then after we can supply from the battery to the thermo electric cooler module.

Case iii. From solar panel output is 12 volts it is stored on to the battery then after we can supply to the thermo electric cooler module and generates the temperature difference on the refrigerator cabin.

Purpose of these three alternative sources on one refrigerator is when we are going outside if there is no electricity near to our surroundings then we can use solar energy, when we are in home at that time we can use direct electricity.When there is no current, no sunlight at that time battery energy can be used for refrigeration. This is the main purpose of usage of three alternative sources.

4. RESULTS&DISCUSSIONS

The aim of the development of the fridge is to provide efficient and effective cooling in the designated locations and places. As observed from the data above, this fridge is capable of maintaining an inner temperature of – after 20minutes of continuous power supply and is maintaining it at a constant rate. Also when the battery will be fully charged. Fridge will remain operational for the time period of 3.2hrs after which the battery will be discharged and the temperature inside the fridge will increase at a very slow rate due to the insulation provided.

On the basis of the above data it can be said that the above fridge can be easily used for the small chilling operations where cooling is required in a small time.

This system is provided with a solar panel charge controller which can be easily used to charge the battery from the solar panels. In addition the battery charger which runs on normal 220 volt ac supply is provided which can be used to charge the batteries.

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4.1. Refrigeration graph

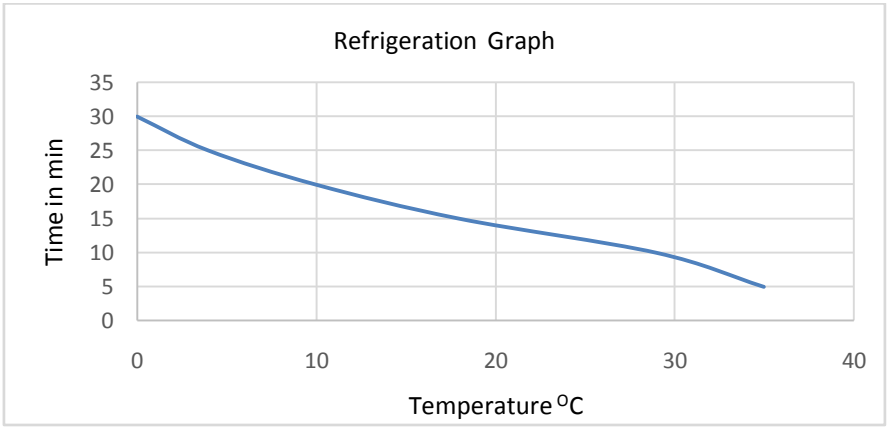

Fig.15. comparison between time in minutes &temperature

In this graph we are going to know about the how much time required to produce the chillness on the cabin considering every five minutes, in 15 to 20 minutes it will reach 20^0 to 22^0, and for reaching the 00c the minimum time we need one hour.

Here we are going to discuss about the results and graphs of the thermo electric cooling system

4.2 EMF Graph

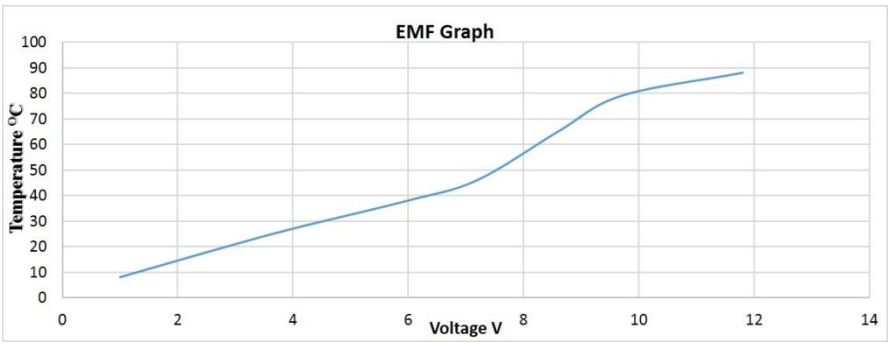

Fig.16. comparison between temperature& voltage

Here we are going to be calculating the amount of EMF induced on the system in this system must be observe the temperature difference between hot and cold junctions. The temperature difference of minimum of 70^0c, maximum of 12v we can produce thorough the system. Where the temperature difference increasing, voltage production also increasing when up to 12v.

4.3. Applications

Used As a power generator due to the temperature difference, the thermal energy is converted in to the electrical energy which is a solid state device. It works on the seebeck effect. It is used in industries, defence, aerospace etc.Solar energy is a un conventional source and clean source. By using solar thermal collector and thermo electrical generator will produce electrical energy.

It is quality different than vapour compression refrigerator system. In this one no pipe, no joints & no mechanical components. It has only direct supply of voltage to the device, the device will give chillness is one side and hot is another side. It is used as mini refrigerator.

By using this device we can produce water in desert places. In deserts less water and high humidity is there by using this device. We can produce water less maintenance less cost also.

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5. CONCLUSION

This project is describing the experimental analysis of thermoelectric refrigeration system with different Alternative sources along with the applications of the thermoelectric cooling in the different sectors, which are

1) Thermoelectric devices are using practically in many areas like defence, aerospace, medical sciences and commercial products which are named as coolers generators and sensors depends on the application.
2) Due to the weak coupling between electrical and heat currents of many materials thermo electrical technology is not widely popular. And one more disadvantage of weak coupling is low efficiency. So the invention of more P and N-type semiconductors will be the good solution for this drawback.
3) For the future purpose this model is very useful because of no mechanical components and no refrigerants are used.
4) It can be carried to anywhere and at any situation at any time. It may useful for further generation for cooling purpose for the human needs and less cost for purchasing of the Thermo electric refrigeration.
5) On further it can become popular, convenient, reliable eco-friendly alternative -refrigeration system.

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