IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 3 Ser. III (May – June 2021), PP 56-62
www.iosrjournals.org

A short review on utility of solar energy in refrigeration and fabrication of a mini solar fridge

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Abstract
Background*: Solar-powered refrigerators are able to keep perishable goods such as meat and dairy products cool in hot climates and are used to keep much needed vaccines at appropriate temperature to avoid spoilage. Solar-powered refrigerators may be most commonly used in the developing world to control pollution and help mitigate climate change. In developed countries, plug-in refrigerators with backup generators store vaccines safely, but in developing countries, where electricity supplies can be unreliable, alternative refrigeration technologies are required. Solar fridges are therefore introduced in the developing world.*
Review on solar refrigeration*: A short review has been conducted on various types of methods that are available for utilizing solar energy in refrigeration purposes. Solar refrigeration methods such as solar electric system, solar mechanical system and solar thermal system have been touched upon. In solar thermal system, various methods like desiccant refrigeration, absorption refrigeration and adsorption refrigeration are discussed. The results of the review reveal solar electric method as the most promising one for solar refrigeration over other methods. A mini fridge is fabricated that is based on solar electric method. Peltier unit and cooling fan are operated by the battery that is charged with the help of a solar panel.*
Results*: The fabricated solar fridge is tested and positive cooling effect is confirmed.*
Conclusion: *A short review on various methods that are available for utilizing solar energy for refrigeration purposes has been presented. A mini fridge based on solar electric system is fabricated. Peltier unit and cooling fan are operated by the battery that is charged by a solar panel. The fridge is tested and positive cooling effect is confirmed.*
Key Word*: Solar energy; Solar Refrigeration; Mini Fridge; Solar panel; Peltier unit*

Date of Submission: 08-06-2021 Date of Acceptance: 21-06-2021

I. Introduction

A solar refrigerator runs on electricity provided by solar energy. There are three systems by which solar energy can be utilized for refrigeration purposes. They are as follows:- Solar Electric System, Solar Mechanical System and Solar Thermal System. These systems are reviewed in the paper. The results of the review reveal solar electric method as the most promising method for solar refrigeration over other methods. A mini fridge is fabricated that is based on solar electric system. Peltier unit and cooling fan are powered by battery that is charged by a solar panel.

II. Review on solar refrigeration

Solar Electric System

Refer Fig. 1. In Solar Electric Method, Photovoltaic (PV) panel transforms the solar energy to DC current with the help of a group of solar cells known as Photovoltaic Cells. Portion of this current is stored by lead acid battery while the rest is used to drive the compressor of the refrigerator. This DC current can be either used to run a DC motor connected to compressor or an inverter can be used to change the DC current to AC current for operating the compressor. A solar charge controller comprising the capacitor, sensors etc. is needed to stabilize the current.

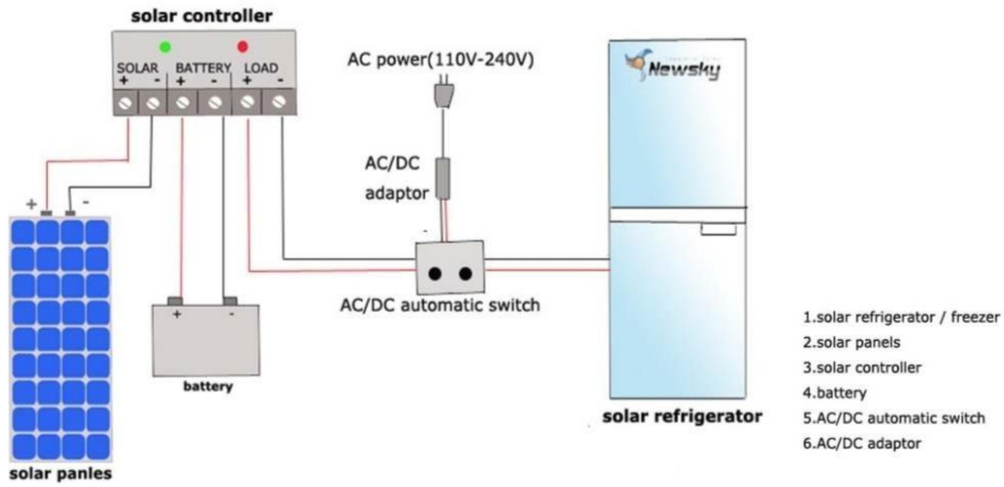

Fig. 1 A typical Solar Electric PV system

Solar electric PV system includes different components that should be chosen according to the system type, site location and applications. The major components of solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances).

- PV module – converts sunlight into DC electricity.
- Solar charge controller – regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
- Inverter – converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line.
- Battery – stores energy for supplying to electrical appliances when there is a demand.
- Load – is electrical appliances that connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.
- Auxiliary energy sources **-** is diesel generator or other renewable energy sources.

Solar Mechanical System

Refer Fig. 2. In Solar Mechanical Method, solar driven heat power cycle generates the mechanical power required to drive the compressor of the refrigerator. Rankine cycle is the heat power cycle considered for this process. In Rankine cycle, fluid is vaporized at an elevated pressure by heat exchange with a fluid heated by solar collectors. A storage tank can be included in this process to provide some high temperature thermal storage. The vapor flows through a turbine or piston expander to produce mechanical power. The fluid exiting the expander is condensed and pumped back to the boiler pressure where it is again vaporized. The efficiency of the Rankine cycle increases with increasing temperature of the vaporized fluid entering the expander whereas, the efficiency of a solar collector decreases with increasing temperature of the delivered energy. High temperatures can be obtained by employing concentrating solar collectors that track the sun's position in one or two dimensions.

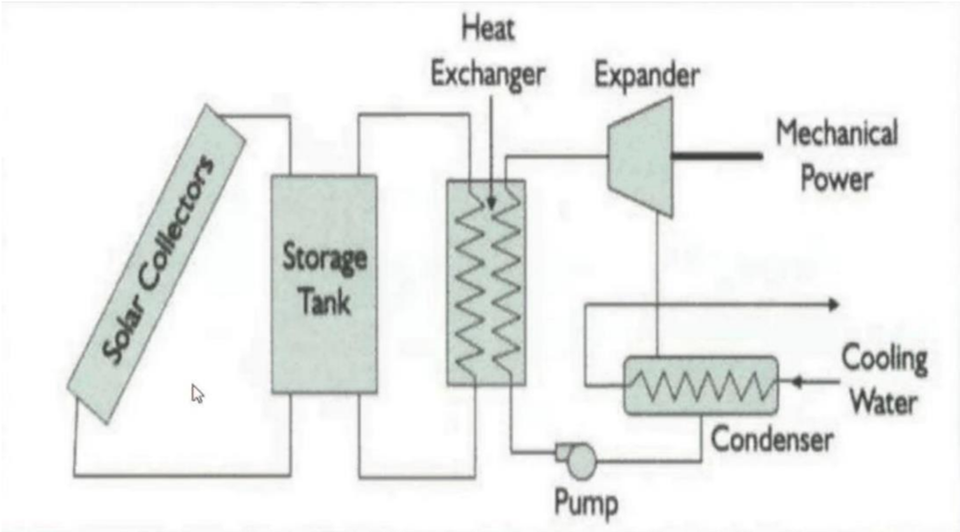

Fig. 2 Solar Mechanical Method

Solar Thermal System[1,2,3]

The main advantage of using Solar Thermal Method is that they can utilize more of the incoming sunlight than photovoltaic systems. But all of the absorbed energy is not converted to useful energy due to inefficiencies and losses. A typical solar thermal refrigeration system consists of four basic components - a solar collector array, a thermal storage tank, a thermal refrigeration unit and a heat exchange system to transfer energy between components and the refrigerated space.

Desiccant

A desiccant system is usually an open cycle where two wheels turn together – a desiccant wheel containing a material which can effectively absorb water, and a thermal wheel which heats and cools inward and outward flows. Warm, humid, outside air enters the desiccant wheel where it is dried by the desiccant material. Next, it goes to the thermal wheel which pre-cools this dry, warm air. Next, the air is cooled further by being re-humidified. When leaving, cool, conditioned air is humidified to saturation and is used to cool off the thermal wheel. After the thermal wheel, the now warm humid air is heated further by solar heat in the regenerator. Lastly, this hot air passes through the desiccant wheel so that it can dry the desiccant material on its way out of the cycle. Some commonly used desiccants are silica gel, activated charcoal, calcium sulfate, calcium chloride, montmorillonite clay, and molecular sieves.

Absorption

Refer Fig.3. An absorption refrigerator is a refrigerator that uses a heat source (e.g., solar, kerosene-fueled flame, waste heat from factories or district heating systems) to provide the energy needed to drive the cooling system. Absorption refrigerators are a popular alternative to regular compressor refrigerators where electricity is unreliable, costly, or unavailable, where noise from the compressor is problematic, or where surplus heat is available (e.g., from turbine exhausts or industrial processes, or from solar plants). In absorption, two mainly used cycles are- LiBr (Lithium Bromide) and NH3 (Ammonia Hydrogen). In a LiBr system, LiBr is the absorbent and water is the refrigerant. In an NH3 absorption system, water is now the absorbent and NH3 is the refrigerant. In both cases, the job of the compressor (in a conventional vapor compression system) is replaced by an absorber and a generator. Concentrated absorbent enters the absorber, which is connected to the evaporator. When refrigerant is boiled off in the evaporator (removing heat from the refrigerated space), vapor (of relatively high pressure) then moves to the LiBr/water absorber where it is absorbed. Next, the mixture moves to the generator where solar heat is supplied to boil off the refrigerant High-pressure refrigerant vapor then travels to the condenser where heat is rejected to the surroundings to condense the refrigerant back to liquid. Liquid refrigerant goes back into the evaporator, where it can be used again to take in heat from the refrigerated space, which completes the loop.

Adsorption

In this cycle, solar heat is directed to a sealed container containing solid adsorbent saturated with refrigerant. Once this reaches the proper temperature/pressure the refrigerant desorbs and leaves this container as pressurized vapor. That is, the vapor has been compressed with thermal energy. This vapor then travels to a condenser where it turns to liquid by rejecting heat to the surroundings. Expanded, low-pressure liquid refrigerant then flows over the evaporator which pulls heat from the conditioned space to boil off the refrigerant. The refrigerant vapor can then be adsorbed again by the cool adsorbent material easily at night. Although there are similarities between absorption and adsorption refrigeration, the latter is based on the interaction between gases and solids. The adsorption chamber of the chiller is filled with a solid material (for example zeolite, silica gel, alumina, active carbon and certain types of metal salts), which in its neutral state has adsorbed the refrigerant.

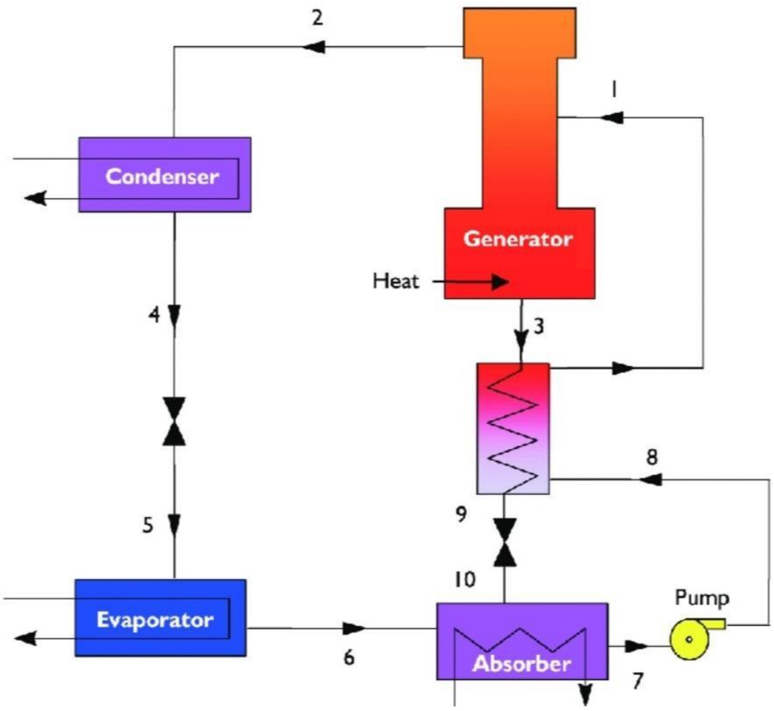

Fig. 3 Ammonia-water absorption refrigeration system

III Fabrication of a mini-fridge[4,5]

Components

Peltier unit (Refer Fig. 4)

Fig. 4 Peltier Unit

This unit enables the cooling effect in the fridge. The Peltier cooler effect occurs whenever electrical current flows through two dissimilar conductors; depending on the direction of current flow, the junction of the two conductors will either absorb or release heat. In the world of thermoelectric technology, semiconductors (usually Bismuth Telluride) are the material of choice for producing the Peltier effect because they can be more easily optimized for pumping heat. Using this type of material, a Peltier device (i.e., thermoelectric module) can be constructed in its simplest form around a single semiconductor "pellet" which is soldered to electrically-conductive material on each end (usually plated copper). In this configuration, the second dissimilar material required for the Peltier effect, is actually the copper connection paths to the power supply. It is important to note that the heat will be moved in the direction of charge carrier movement throughout the circuit (actually, it is the charge carriers that transfer the heat).

The Peltier unit used in the fridge is of specification TIC 12073. This unit works on 5 volts DC and takes maximum current of 4 amps at full load. The power rating of this unit is 20 watts.

Cooling fan (Refer Fig. 5)

Fig. 5 Cooling fan

Cooling fans in the refrigerator are mounted on one heat sink each. The main purpose of a cooling fan is to dissipate heat from the heat sink by taking in fresh air. The fans used in this fridge work on 12 volts DC and draw 0.18 amps. The power consumption of fan is 2.16 watts. The speed of fan is 2500 rpm

Heat sink (Refer Fig. 6)

Fig. 6 Heat sink

The heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. The heat sink is made up of aluminum. The heat sink used in this fridge is of the dimension 7.5cm x 8cm x 4.5cm (L x B x H).

Battery (Refer Fig.7)

Fig. 7 Battery

The battery used in this fridge has following specifications:

- 6-volt DC
- 4.5 ampere hour

One battery is used at a time for the working of the fridge. Also the extra connection for the second battery in the fridge is provided if more cooling is required. The battery receives charging power from solar panel. Output from battery is used to operate the cooling fan and the Peltier unit.

Thermocol (Refer Fig. 8)

Fig. 8 Thermocol

Thermocol is known for its economic value 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.

Solar panel (Refer Fig. 9.)

Fig. 9 Solar Panel

Portable 10 watts-12-volt solar panel is used to charge the battery. This solar panel is power-efficient, lightweight, and easily portable. It has 36 PV cells.

Construction (Refer Fig. 10)

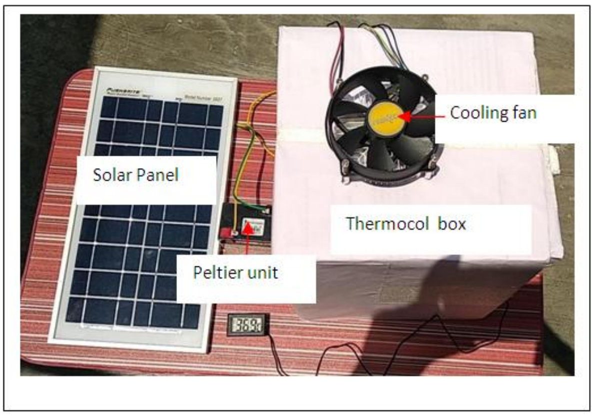

Fig. 10 Solar fridge

1 Firstly, a box of thermocol of given dimensions is made and the outer walls is prepared by the chart paper.
2 The taping of the box from outer side is done so as to provide mechanical support and blocking of air.
3 The Peltier unit is well placed in the holes made in the box and kept on the heat sink with hot side attached to the heat sink surface and cold side inside the box.
4 The heat sink is linked with a fan which is used to dissipate the heat of heat sink into the outer atmosphere i.e., out of the thermocol box. So, the hot side of Peltier unit is unable to affect the temperature inside the box.
5 All the electrical connections are made putting a switch for on/off. Battery of 6 volts DC, 4.5 Ah is connected in parallel with the Peltier unit and connected in series with the cooling fan.
6 All the electrical connections are made strong and all the wires are arranged properly so as to avoid any inconvenience for the user.

IV Results

The solar fridge is tested and the data is recorded as shown in Table 1.

Table.1 Readings

Reading	Start temperature (deg. C)	Duration time	End temperature (deg. C)
1	33.9	35 min	25.7
2	25.7	32 min	21.3
3	21.3	31min	19.5
4	19.5	28min	16.8

The following observations are made:-

- Starting temperature: 33.9 deg. C
- Starting time: 00
- Final stable temperature: 16.8 deg. C
- Final time: 2 hours 6minutes

Electrical measurements

- Voltage supply(V): 6volts DC
- Voltage across peltier unit(V1): 6 volts DC
- Current drawn from the battery (I): 2.2Ah
- Power of peltier unit(p1): V1 x I = 6 x 2.2 = 13.2 watts
- Total power of fridge: 13.2 watts

V. Conclusion

A short review on various methods that are available for utilizing solar energy for refrigeration purposes has been presented. A mini fridge based on solar electric system is fabricated. Peltier unit and cooling fan are operated by the battery that is charged by a solar panel. The fridge is tested and positive cooling effect is confirmed.

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Sunil Bhat, et. al. "A short review on utility of solar energy in refrigeration and fabrication of a mini solar fridge." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(3), 2021, pp. 56-62.