REVIEW ON SOLAR POWERED REFRIGERATOR

R. Sharavanan[1], Manish kumar[2], Kumar Gaurav [3], Lakshman kumar[4], K. Ananth[5]

[1]Professor, [2,3,4,5] student, Department of Mechanical Engineering, Bharath Institute of Higher Education and Research, Chennai, India.
Email:-kumargaurav9860@gmail.com

Abstract:-

Solar energy is proved to be an ideal source for low temperature heating applications. Three known approaches that use solar energy to provide refrigeration at temperature below 0 degrees include photovoltaic (PV) operated refrigeration, solar mechanical, and absorption refrigeration. In this paper, a review has been conducted on various types of methods which are available for utilizing solar energy for refrigeration purposes. Solar refrigeration methods such as Solar Electric Method, Solar Mechanical Method and Solar Thermal Methods have been discussed. In solar thermal methods, various methods like Desiccant Refrigeration, Absorption Refrigeration and Adsorption Refrigeration has been discussed. All the methods have been assessed economically and environmentally and their operating characteristics have been compared to establish the best possible method for solar refrigeration. Also, innovators at NASA's Johnson Space Center have patented a proven, solar-powered refrigeration system that eliminates reliance on an electric grid, requires no batteries, and stores thermal energy for efficient use when sunlight is absent.

Keywords: Solar powered refrigeration, Solar Electric Method, Solar Mechanical Method, Solar Thermal Method, etc.

Introduction

A solar-powered refrigerator is a refrigerator which runs on electricity provided by solar energy. Solar-powered refrigerator are able to keep perishable goods such as meat and dairy cool in hot climates, and are used to keep much needed vaccines at their appropriate temperature to avoid spoilage. Solar-powered refrigerator may be most commonly used in the developing world to help mitigate poverty and 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 were introduced in the developing world to cut down on the use of kerosene or gas powered absorption refrigerated coolers which are the most common alternatives. They are used for both vaccine storage and household applications in areas without reliable electrical supply because they have poor or no grid electricity at all.

Types of Solar Refrigeration:

1. PV Operated Refrigeration Cycle.
2. Solar Electrical Refrigerator.
3. Absorption Refrigerator.

Photovoltaic Operated Refrigerator Cycle

Photovoltaics (PV) involve the direct conversion of solar radiation to direct current (dc) electricity using semiconducting materials. In concept, the operation of a PV-powered solar refrigeration cycle is simple. Solar photovoltaic panels produce dc electrical power that can be used to operate a dc motor, which is coupled to the compressor of a vapour compression refrigeration system. The major considerations in designing a PV-refrigeration cycle involve appropriately matching the electrical characteristics of the motor driving the compressor with the available current and voltage being produced by the PV array.

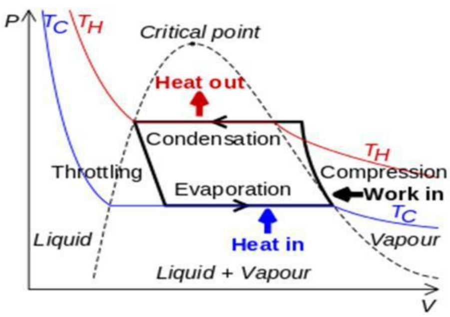
The rate of electrical power capable of being generated by a PV system is typically provided by manufacturers of PV modules for standard rating conditions, i.e., incident solar radiation of 1,000 W/m^2 (10 800 W/ft^2) and a module temperature of 25°C (77°F). Unfortunately, PV modules will operate over a wide range of conditions that are rarely as favorable as the rating condition. In addition, the power produced by a PV array is as variable as the solar resource from which it is derived. The performance of a PV module, expressed in terms of its current voltage and power-voltage Voltage characteristics, principally depends on the solar radiation and module temperature.

At any level of solar radiation and module temperature, a single operating voltage will result in maximum electrical power production from the module. The module represented in 2 shows the voltage that yields maximum power ranges between 30 and 35 volts for this PV array.

The efficiency of the solar panels, defined as the ratio of the electrical power produced to the incident radiation is between 8% to 10% at maximum power conditions for the PV array represented in Figure 2. If the PV refrigeration system is to operate at high efficiency, it is essential that the voltage imposed on the PV array be close to the voltage that provides maximum power.

This requirement can be met in several ways. First, a maximum power tracker can be used which, in effect, continuously transforms the voltage required by the load to the maximum power voltage. If the system includes a battery, the battery voltage will control the operating voltage of the PV module. PV panels can then be chosen so that their maximum power voltage is close to the voltage for the battery system.

The battery also provides electrical storage so that the system can operate at times when solar radiation is unavailable. However, the addition of a battery increases the weight of the system and reduces its steady-state efficiency. Electrical storage may not be needed in a solar refrigeration system as thermal storage, e.g., ice or other low temperature phase storage medium, may be more efficient and less expensive.



A final option for systems that do not use a maximum power tracker or a battery is to select an electric motor having current-voltage characteristics closely matched to the maximum power output of the module.

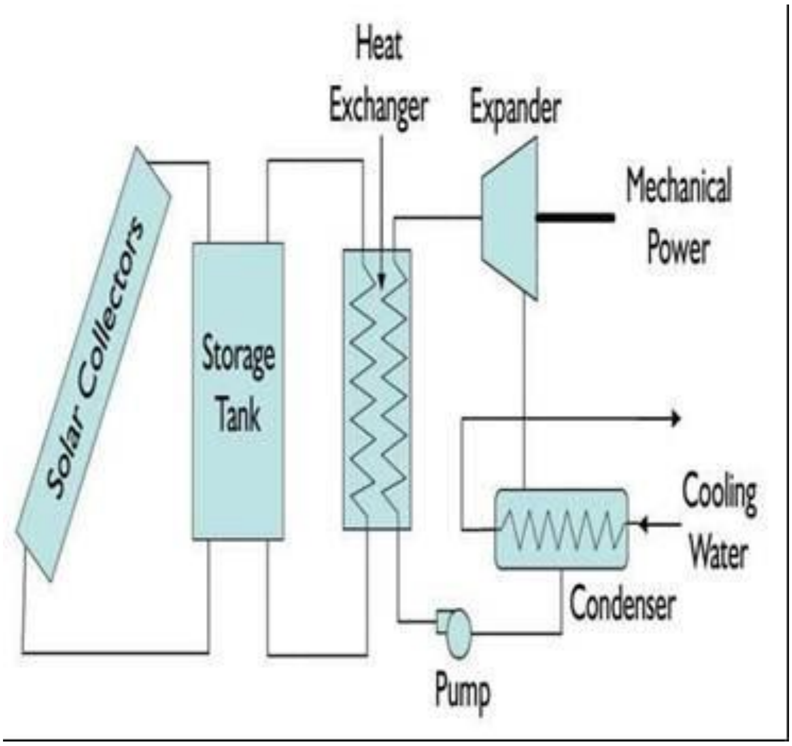
Figure 3 superimposes the current-voltage characteristics of a series dc motor and separately excited motor on the photovoltaic module. In this case, the separately excited motor would provide more efficient operation because it more closely matches the maximum power curve for the photovoltaic module. However, neither motor type represented in Figure 3 is well matched to the characteristics of the PV module over the entire range of incident solar radiation. Studies of solar-powered motors have shown that permanent magnet or separately excited dc motors are always a better choice than series excited dc motors in direct-coupled systems that are not equipped with a maximum power tracker.

Solar Electric Method

In Solar Electric Method, the solar energy is directly converted to DC current by an array of solar cells known as Photovoltaic (PV) panel. Photovoltaic Cells are nothing but semiconductors which allow direct conversion of solar energy to direct current. A part of this current is

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

The disadvantages of using solar trackers are cost, weight and complexity of the system. If tracking is to be avoided, evacuated tubular, compound parabolic or advanced multi-cover flat plate collectors can be used to produce fluid temperatures ranging between 100°C



200°C. Both intensity of solar radiation as well as difference of temperature between entering fluid and ambient govern the efficiency of solar collector. The efficiency of such a system is lower than solar electric method using non-concentrating PV modules. Solar Mechanical is advantageous only when solar trackers are used but, the use of such systems is limited to large refrigeration systems only i.e. at least 1000 tons.

Desiccant

A desiccant system is usually an open cycle where two wheels turn in tandem – 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. Pre-packaged desiccant is most commonly used to remove excessive humidity that would normally

Cooling Thermal Energy Storage (CTES) System

The most important use of CTES systems is to shift the power consumption from peak to off peak periods. For this reason these systems are also known as "off-peak cooling" systems. The performance of a TES system is described by its co-efficient of performance (COP). The COP of a system during peak and off-peak hours is defined by the chiller and compressor design. CTES systems are generally classified into three types-chilled water, ice storage and eutectic salt TES systems. Among these techniques, the Chilled Water Storage (CWS) and the Ice Thermal Storage (ITS) systems are the most promising ones in case of the normal applications. The ITS system has the advantages of larger storage volume in comparison with two other systems. However, the COP of the ITS system is much lower than other techniques. In sensible CTES, the storage medium is usually water-based whereas in latent CTES systems, eutectic salts with phase change materials is generally preferred as storage medium. Sensible CTES systems account for most cold TES applications presently. Thermochemical TES may prove.

Chilled Water Storage (CWS)

It is a famous strategy adopted in many countries to save energy by shifting power consumption from peak hours in the daytime to off-peak hours during the night times by employing chilled water to store cool thermal energy. In the past, prior to the successful evolution of thermally stratified systems, many different types of CWS designs have been developed and employed. Designs of CWS were such in order to primarily avoid temperature mixing of chilled water with return water. However, they often require complex tank configurations or piping systems that are expensive and difficult to operate. The CWS systems currently in use can be classified as (a) labyrinth, (b) baffle, (c) tank series, (d) membrane tank.

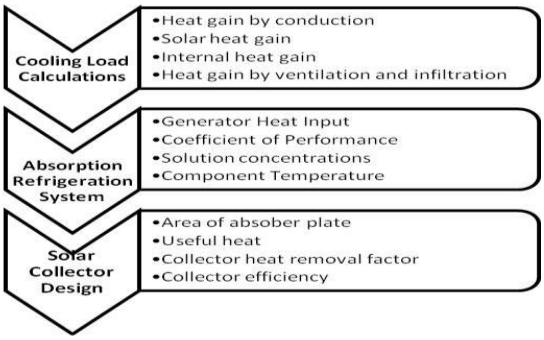
Ice Harvesters

This technique is a dynamic type of ITS system consisting of an open insulated storage tank and vertical plate surface positioned above the tank. A circulating pump brings the water at a temperature of 00C on the outer surface of the evaporator, which is fed internally with liquid refrigerant. Normally, thickness of the produced ice varies between 8 mm and 10 mm depending on the length of the freezing cycle.

Design methodology:

Design methodology has been explained in brief in section 1 of which flowchart is shown in Fig.

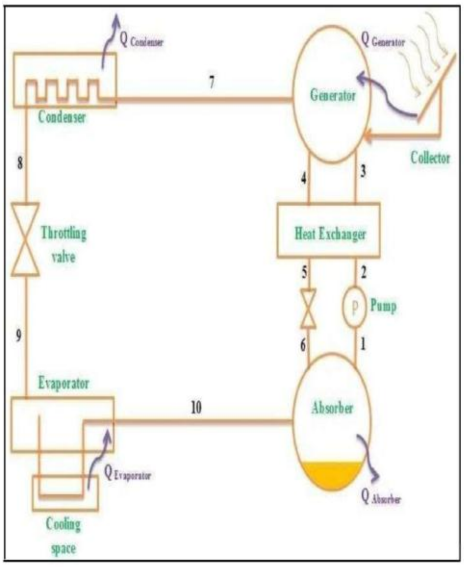
1. This section also presents detailed design procedure.



Cooling load calculations:

To propose a suitable air conditioning system for this classroom building, it is essential to compute cooling loads on it. Based on these cooling loads, design parameters such as capacity of air conditioning system, heat input to the generator, mass flow rates, collector area etc. were calculated. Several methods to estimate the building cooling loads due to various heat sources have been developed over the years [11-13]. Apart from the standard methods established by

ASHRAE, researchers have proposed various approaches to calculate building cooling loads [14,15]. There are also software packages and simulation tools such as TRNSYS [16], Design Builder [17], and Autodesk Ecotect [18] which are being used to estimate cooling load. In this study, cooling load temperature difference (CLTD) method has been employed to calculate the cooling loads on the classroom. This method is very widely used for manual calculations and estimation of building cooling loads. Definition of various cooling loads according to CLTD method is presented in Table 2.



Complete information about the methodology, applicability and limitations of CLTD method can be found in ASHRAE fundamental handbooks [12, 13]. Parameters that have been measured in order to perform cooling load calculations are room's specifications, ambient and room's temperature and relative humidity.

It should be noted here that an absorption refrigeration system is similar to that of a conventional vapour compression refrigeration system during process 7-8-9-10. However after the evaporator, vaporized refrigerant is absorbed by the absorbent thus resulting in a liquid solution which is then pumped to the generator. In generator, heat is given to this absorbent-refrigerant mixture to separate the two. Refrigerant vapour is then brought to condenser which is condensed to saturated liquid while absorbent is brought back to absorber. Since, the refrigerant is water the minimum evaporator temperature must not go below 5°C to avoid problems in operation of the refrigeration system. To design such system, basic assumptions and input values must be considered. Mass balance and energy balance across various components constitutes the basic equations needed to calculate the unknown. These equations are presented in Table 3. It should be mentioned here that the mass balance equations are valid for refrigerant, absorbent and for refrigerant-absorbent mixture as well. However, enthalpies are taken at state points. During state points 7, 8, 9 and 10, enthalpy must be taken for water while for other state points; enthalpy of the mixture has to be taken. Some of the enthalpy values can be obtained from the known conditions of pressure, temperature and/or concentration while the unknown enthalpies are calculated using conservation equations. Similarly, mass flow across evaporator is easily known by knowing evaporator capacity and enthalpy drop across evaporator which is generally known as evaporator temperature is fixed.

Conclusion

Based on this cooling load, a vapour absorption refrigeration system was designed using lithium-bromide water as the working pair. To support the operation of this system, a solar collector was designed to provide the necessary heat to this air-conditioning system. It can be concluded from the results that if the strong and weak solution concentrations are hold to their maximum and minimum values respectively, then COP is expected to have maximum value. Such refrigeration systems can be used in places where there is abundance of solar energy and/or scarcity of electrical energy which is needed for traditional refrigeration systems

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