

Analysis of Solar Thermal Cooling System Using TRANSOL

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Abstract: This paper covers the performance analysis of solar thermal cooling system for a computer laboratory situated in Government Engineering College Bharatpur using Flat Plate Collector, Evacuated Tube Collector and Compound Parabolic Collector. The computer lab has the floor and roof area 198.55 m^2 . The peak cooling load is calculated and it is 34.94 kW , accordingly 10TR vapor absorption cooling system was adopted. The 10 TR vapour absorption system was operated by a field of collector area varying from $80\text{--}120 \text{ m}^2$. The other parameters like hot storage tank, cold storage tank, pump, cooling tower etc are used. The simulation was carried out on TRANSOL Program for Bharatpur city situated in east of Rajasthan (INDIA). It can be conclude that solar thermal cooling system is technically feasible because it offers good solar fraction in the range of $0.52\text{--}0.75$. The primary energy savings reaches up to 52% .

Keywords—*Solar Thermal System, TRANSOL, Solar Fraction, Primary Energy ,*

1.Introduction

Because of global warming, increased energy need, limited resources and environmental pollution there is dire need for development of such technologies that can offer decrease in energy consumption, peak electrical demand, and energy costs without lowering the desired level of comfort. That can also significantly reduce the emission of CO_2 because buildings use around 50% of the total energy consumption in developed countries. In place of the use of electricity in conventional cooling systems, solar thermal cooling systems use solar heat to produce refrigerating effect. In such systems the phenomenon of sorption: the process by absorption liquid-gas and the process by adsorption solid gas are utilized to produce the refrigeration effect.

A solar electric refrigeration system consists mainly of photovoltaic panels and an electric refrigeration device based on vapor compression system. Photovoltaic panels consist of solar cells which are basically made of semiconductor materials that convert the incident solar radiation into direct current. This direct current may be directly used to drive the DC compressor or may be converted into AC to drive the

conventionally used AC compressor. Using solar panels for refrigeration has many advantages. They are simple, compact in size, high power to weight ratio and have no moving parts. In this system solar panel drive the DC motor of the compressor for producing the cooling effect in the evaporator by absorbing heat and rejecting heat to the ambient by the condenser. In the vapour absorption systems, a pair of substances having the strong affinity to form a solution is utilized. Among the pair of substances, the substance having lower boiling temperature is called refrigerant and the other is called absorbent. Solar thermal collector is used to supply low grade heat input in the generator. Cooling is produced in the evaporator and heat is rejected from the condenser and the absorber. $\text{H}_2\text{O-LiBr}$ and $\text{NH}_3\text{-H}_2\text{O}$ are the two major working pairs used in the absorption system. In the water lithium bromide pair H_2O works as the refrigerant and other is the absorbent while in the ammonia H_2O pair ammonia works as the refrigerant and water is the absorbent.

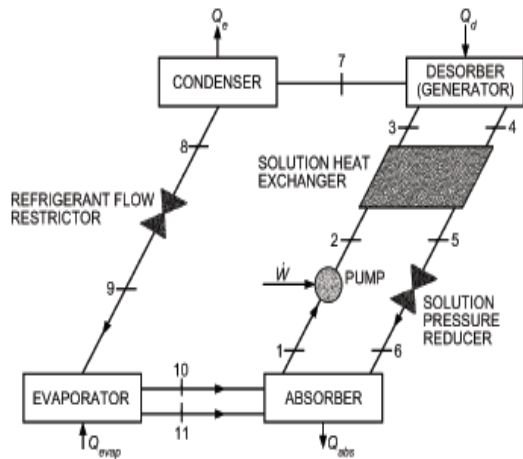


Fig. 1 Vapour Absorption System [ASHRAE]

Currently, various absorption machines with COPs ranging from 0.3 to 1.2 are available. For double-effect LiBr-water chillers with COPs around 1.2 are available for air conditioning which use solar collector capable of working at 150°C but the costs of these systems are high. Less expensive collectors can be used for single effect LiBr-water absorption machine.

2. Methodology Adopted:

The whole work is divided into three phases. First phase is related to defining a building for carrying out the analysis. The building has a floor area of 198.55 square meters. Parameters such as construction detail, occupancy, lighting load, ventilation, infiltration are defined as per utilization of existing building of computer lab situated at Govt. engineering college Bharatpur. The cooling load of the building is determined by using calculation for sensible cooling load and latent cooling load. Details of heat gain, with respect to source, such as wall conduction, reflection, direct solar heat gain etc are taken.

In the second phase according to the cooling load of the building the component sizing for

solar thermal cooling system is carried out. The building simulation of solar thermal cooling system is done in the program TRANSOL 3.1 (software for simulating thermal solar cooling systems) by taking suitable component and their size. Based on the results given by the program's key parameters, solar fraction, primary energy savings, electrical (Grid) COP and paybacks are calculated for solar thermal cooling systems. Finally in the last phase conclusion is made on the behalf of paybacks whether the system was adopted for the existing building or not.

Laboratory is scheduled from 9 AM to 6 PM from Monday to Saturday and Sunday is holiday.

Total Room Sensible Heat = 1.115 x total sensible heat gain from all sources = 24.93 kW

Total Room Latent Heat = 1.06 x total latent heat gain from all sources = 10.01 kW

Therefore total cooling load = 10.01 + 24.93 = 34.94 kW.

3 Modelling and Simulation

In the present work modelling and simulation of small scale solar cooling systems is carried out using TRANSOL program. The program TRANSOL EDU 3.1 is used for the simulation of a solar thermal cooling system. The simulation is carried out for a computer lab used in day time only and which is considered to be in situated at Govt. engineering college Bharatpur in India an Asian country.

The solar analyzed thermal cooling system is composed of a solar collector field (Solar collector), hot storage tank (HST), cold storage tank (CST) and vapour absorption chiller (VAC). Three different types of collectors are considered in this study flat plate, evacuated tube and compound

parabolic. The solar collector captures the energy from the sun and supplies energy to a hot storage tank through an external heat exchanger.

A 35 kW capacity vapour absorption chiller (VAC) is selected which have the COP 0.7 and pump power consumption of 210W. A cooling tower of 90 kW capacities is selected because the generator capacity of VAC is 50 kW and heat rejection in the condenser is 90 kW.

A hot storage tank of 5000 litres and a cold storage tank of 1000 litres are used. The wide variance of collector area 80-120 m² is taken with an interval of 10 m².

Two pumps are used in the solar collector loop, one is to circulate hot working fluid from solar collector to heat exchanger, and another to circulate fluid between heat exchanger and hot storage tank. These pumps (P1, P2) are known as primary and secondary pump respectively and operated by control strategy depending on solar radiation intensity. The flow rate of pump is constant. The system stops the pumps if the temperature in the hot storage tank exceeds the maximum security value.

A vapour absorption machine (VAM) is directly connected to the hot storage tank, this machine is turned on when cooling is required and the temperature of the solar tank is over a set point temperature. The heat coming from the absorber and condenser is released by cooling tower controlled by a variable frequency drive that increases energy efficiency and reduces electrical energy consumption. The cold water coming out from the evaporator of vapour absorption machine is stored in the cold storage tank (CST).

An electrical operated compression cooling machine is used as a backup in order to

cover complete cooling demand of the building. This compression based cooling machine is operated only when the cooling demand is in building and the temperature of the cold storage tank is below than the specified set point temperature.

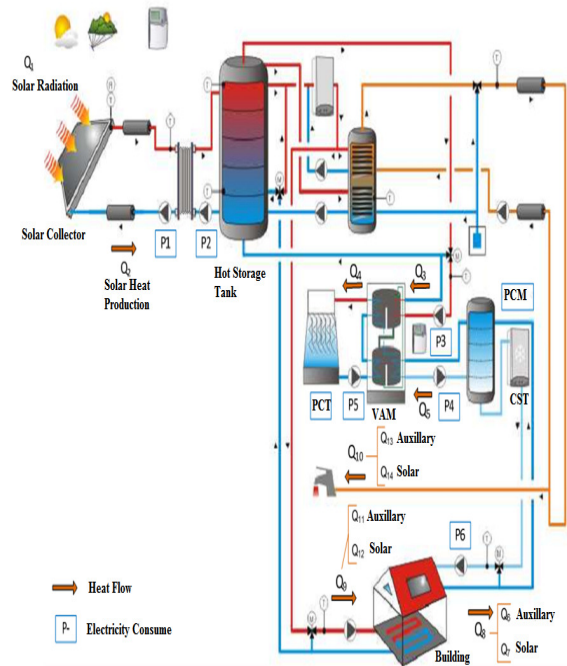


Fig. 2 Solar Thermal Cooling System

4. Simulation Results:

In this paper we have analyzed and compared performance of solar thermal cooling system using 3 types of solar collector. These collectors are: Flat plate collector (FPC), Evacuated tube collector (ETC) and Compound parabolic collector (CPC). Simulation is performed to find out some performance metrics like Annual net collector efficiency, solar fraction and Specific net collector output for each collector. Fig.3-7 shows the simulation results in graphical format. It is clear that solar fraction is increase as the collector area increases.

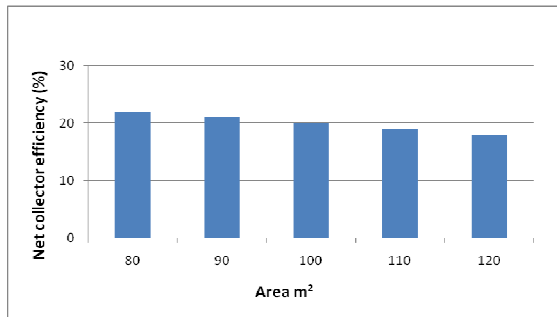


Fig. 3 Net Collector Efficiency for FPC

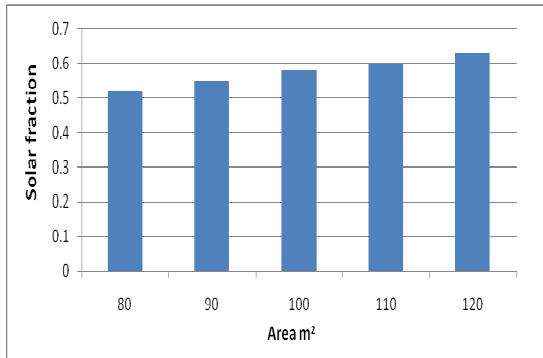


Fig. 4 Solar Fraction for FPC

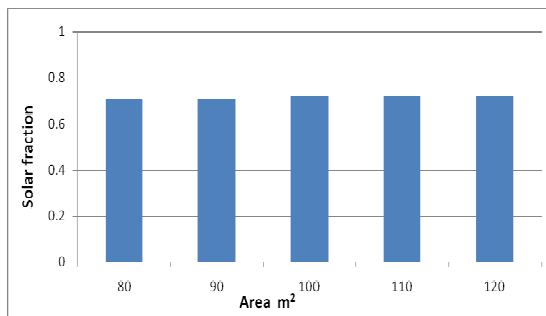


Fig. 5 Solar Fraction for ETC

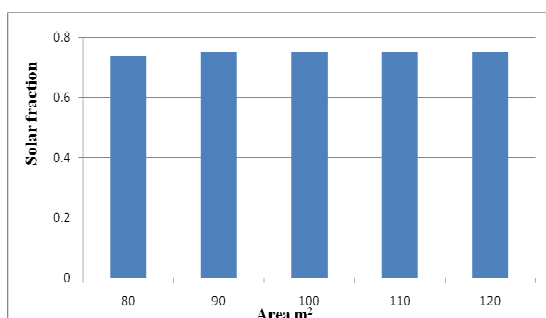


Fig. 6 Solar Fraction for CPC

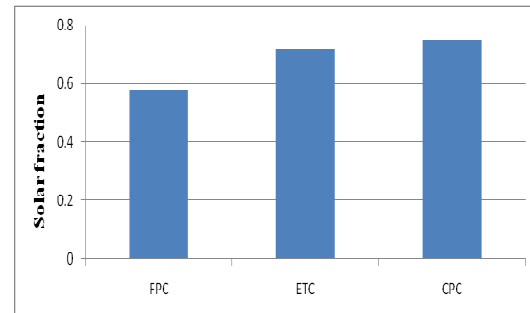


Fig. 7 Comparison of Solar fraction for each collector

Fig. 7 shows that comparison of solar fraction for different three types of collector i.e FPC/ETC/CPC and shows that the using CPC solar fraction is highest.

5. Conclusion:

This study covers the performance analysis of solar thermal cooling system for a computer lab situated in government engineering college Bharatpur using FPC, ETC and CPC. The computer lab has the area 198.55 m². The peak cooling load is 34.94 kW accordingly 10TR vapour absorption cooling system was adopted. The 10 TR vapour absorption system was operated by a field of collector area varying from 80-120 m². The solar fraction is highest for the CPC type collector and lowest for the FPC. The highest solar fraction has been observed as 0.63, 0.72, 0.73 for FPC/ETC/CPC for the collector area range in 80-120 m². At high collector area the collected heat is increased in all the type of collector but in the case of ETC and CPC the heat losses also increase.

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