

Efficient Designing and Qualitative 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 lab 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 34.940 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 0.52-0.75 in the considered city and collector areas. The primary energy savings reaches up to 52%.

Keywords: ACH-Air change per hour, TCP Variant, Router, Bandwidth, Simulation Time

Introduction

Because of global warming, increased energy need, limited elements 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.

H₂O-LiBr and NH₃-H₂O are the two major working pairs used in the absorption system. In the water lithium bromide pair H₂O works as the refrigerant and other is the absorbent while in the ammonia H₂O pair ammonia works as the refrigerant and water is the absorbent.

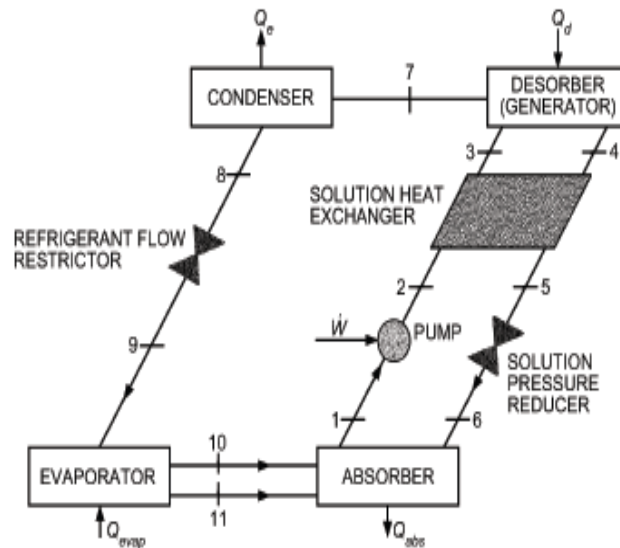


Fig. 1 Vapour Absorption System

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 expansive collectors can be used for single effect LiBr-water absorption machine.

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.

Table I: Building Dimensions & Other Parameters

Parameter	Value
Length	15.690 m
Width	12.655 m
Height	3.64 m
South wall glass window	1.65 x 1.5 m
West wall glass window	1.65 x 1.5 m
North wall door	2.55 x 1.5 m
Total floor area	198.55 m ²
Wall brick thickness	0.3556 m
Cement plaster thickness	12 mm
Wall thickness	0.3796 m
Wall U-value	1.105 W/m ² -K
Roof thickness	0.3048 m
Roof U-value	1.154 W/m ² -K
Infiltration rate	0.2 ACH
Fresh air	0.3 m ³ /min/person
Sensible heat load	60 W
Latent heat load	40 W

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

Table II: Calculated Values of Sensible Heat Gain

Source	Sensible Heat Gain (W)
North wall	883.29
South wall	741.58
East wall	725.07
West wall	558.06
Roof	3436.90
Floor	458.25
Door - 1	127.94
Door - 2	77.53
Windows	1225.12
Persons	1980

Outside Air	3029.40
Lighting	8400
South Glass	1237.5
West Glass	618.75

Table III: Calculated Values of Latent Heat Gain

Source	Latent Heat Gain (W)
Persons	1320
Outside Air	8118

Total room sensible heat = $1.115 \times$ total sensible heat gain from all sources = 24.93 kW

Total room latent heat = $1.06 \times$ total latent heat gain from all sources = 10.01 kW

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

Simulation Setup

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 $80\text{-}120\text{ m}^2$ is taken with an interval of 10 m^2 .

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.

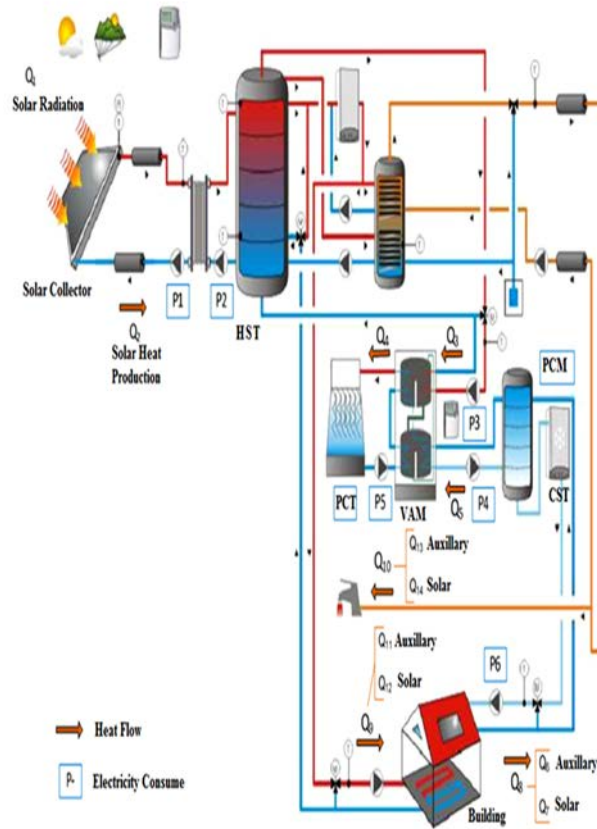


Fig. 2 Solar Thermal Cooling System

Table IV: Solar Collector Parameters used in TRANSOL

S.N	Parameters	Flat Plate Collector	Evacuated Tube Collector	Compound Collector	Parabolic
1	Manufactured	Yazaki	Sungeosetz	Rittor Solar	
2	Product	Y-2000	Sungeoset-SER	21 Star azzuro	
3	Laboratory	CSTB	CSTB	CSTB	
4	Conversion factor η_0	0.733	0.710	0.550	
5	Loss coefficient a_1 W/m ² -K	3.606	2.010	0.920	
6	Loss coefficient a_2 W/m ² -K	0.120	0.0175	0.000	

7	IAM	0.90	0.90	0.90
8	Height meter	1.730	1.935	2070
9	Unitary Area m ²	2.390	2.250	2.330
10	Qt l/h-m ²	72	72	72
11	Capacitance kJ/m ² -K	10.78	10.78	10.78

Table V: Pump Parameters

Pump	Flow Rate (Kg/hr)	Power (W)
P1	4300	215
P2	4300	215
P3	4300	215
P4	18400	920
P5	5500	270
P6	8600	430

Table VI: Climatic Condition of Bharatpur

S.N	Parameters	Value
1	Lat-Long	27.21, 77.48
2	Average RH	55 %

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. Simulation results are as follows:

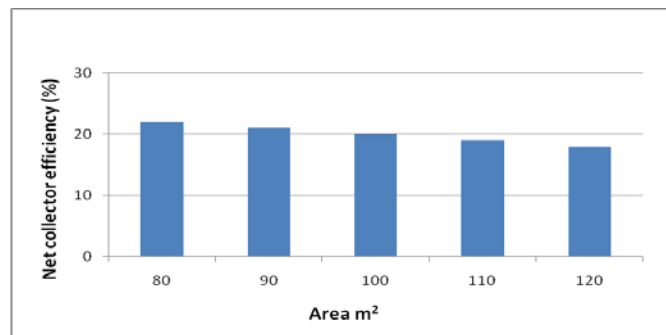


Fig. 3 Net Collector Efficiency for FPC

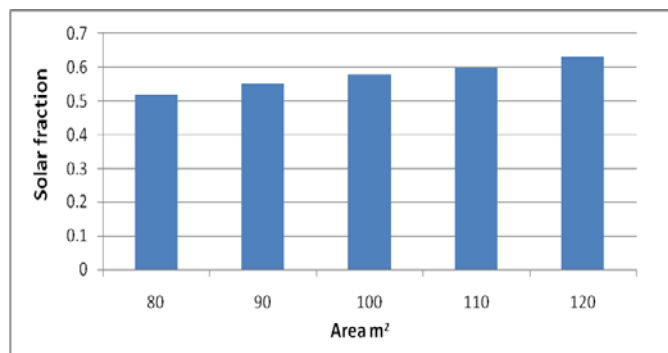


Fig. 4 Solar Fraction for FPC

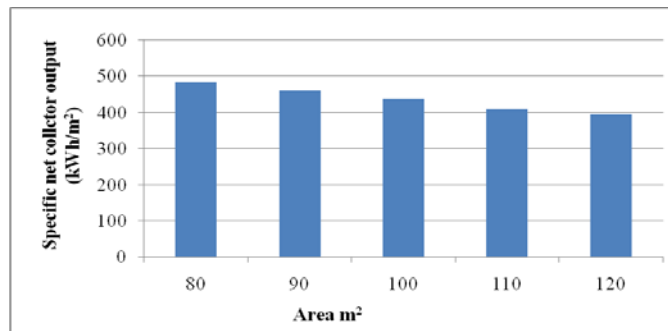


Fig. 5 Specific Net Collector Output for FPC

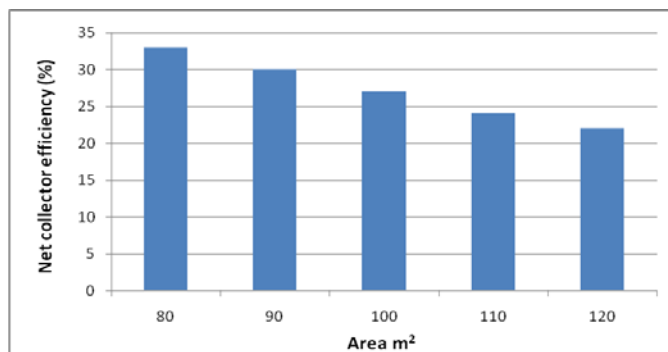


Fig. 6 Net Collector Efficiency for ETC

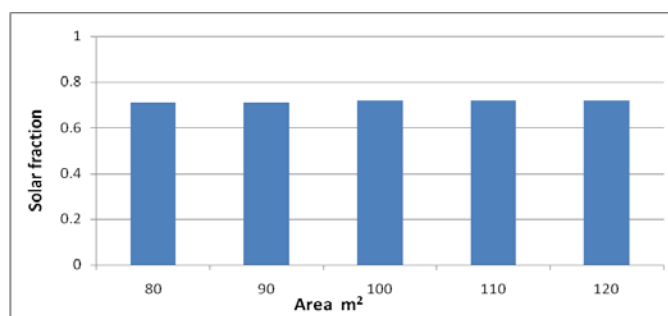


Fig. 7 Solar Fraction for ETC

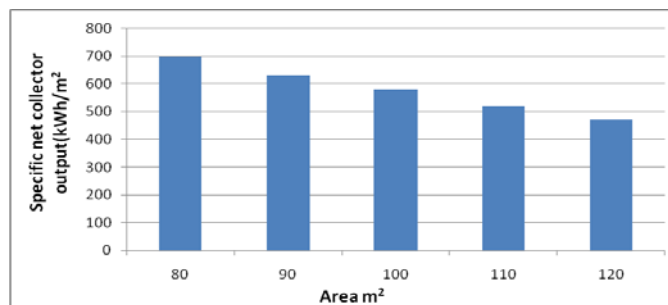


Fig. 8 Specific Net Collector Output for ETC

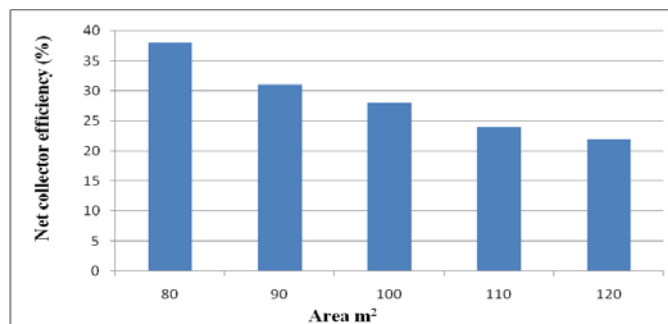


Fig. 9 Net Collector Efficiency for CPC

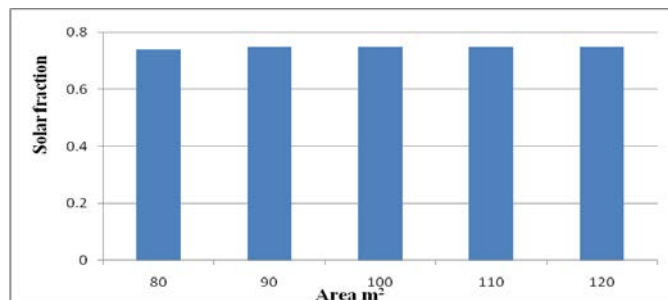


Fig. 10 Solar Fraction for CPC

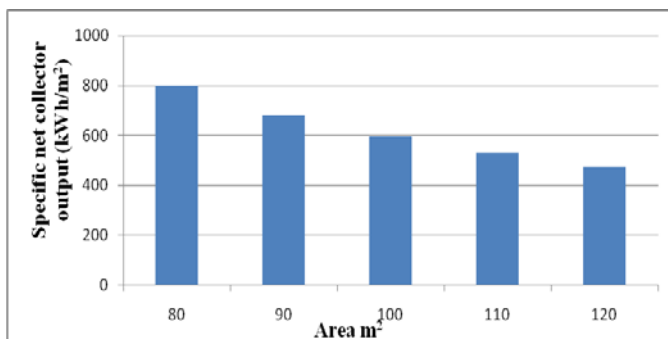


Fig. 11 Specific Net Collector Output for CPC

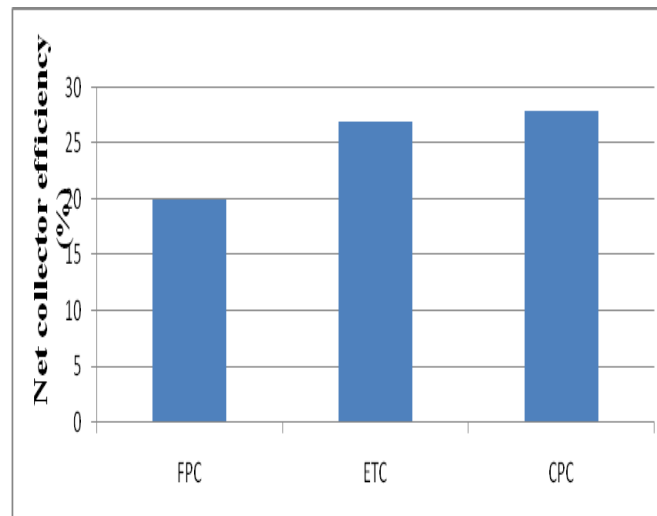


Fig. 12 Comparison of Net collector efficiency for each collector

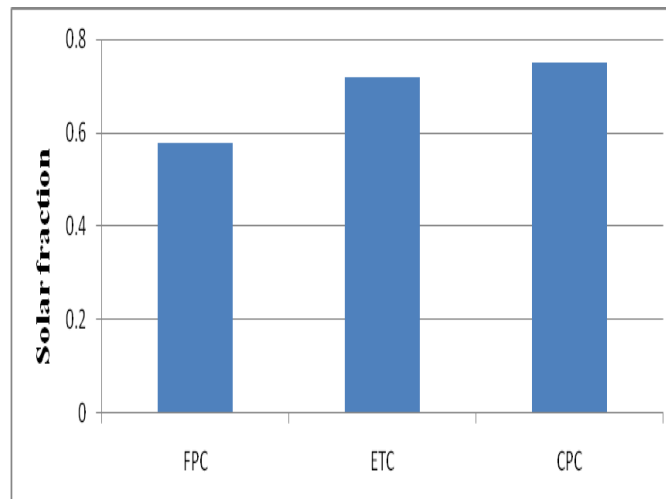


Fig. 13 Comparison of Solar fraction for each collector

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 m^2 . 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 $80\text{-}120 \text{ m}^2$. 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 $80\text{-}120 \text{ m}^2$. 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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