ISSN (online): 2349-6010

Powerless Air Conditioning with Integrated Water Heating

Nishin Asharaf
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottukulam Hills, Pathamuttom P.O, Kottayam-686532, Kerala, India

Nicku Abhraham
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottukulam Hills, Pathamuttom P.O, Kottayam-686532, Kerala, India

Sajin Chacko
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottukulam Hills, Pathamuttom P.O, Kottayam-686532, Kerala, India

Shijo George
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottukulam Hills, Pathamuttom P.O, Kottayam-686532, Kerala, India

Tom Mathew
Assistant Professor
Department of Mechanical Engineering
Saintgits College of Engineering, Kottukulam Hills, Pathamuttom P.O, Kottayam-686532, Kerala, India

Abstract

The planet is progressively marching towards a serious electric energy crisis, owing to an escalating desire of electric energy becoming greater than its supply. We have always accepted that the energy we make use of each day is not unrestricted, still we take it for granted. So it is better to utilize the available resources. Among these solar energy is the most abundant and cheap resource available. So here we use only solar energy for the cooling of buildings and also for water heating. In this project, we utilize only solar power for the cooling process and also for water heating. The cooling process proceeds as the temperature of atmosphere increases by sun rays. This can also be used as a room heater in winter condition by proper adjustment. The main highlight of our project is that only solar energy is utilized for the cooling and heating process. No other external power sources are used. Our product is eco-friendly and pollution less. This can also installed at remote areas where electricity is not available and in regions where atmospheric temperature is high e.g. Rajasthan. It is well suited for middle class family as it requires only initial investment and less maintenance cost. No separate water heater is required for domestic purpose.

Keywords: Photovoltaic (PV) system, Evaporative Cooling System

---

I. INTRODUCTION

Space cooling and refrigeration are highly energy-intensive processes. Cooling demands in various sectors are maximum mainly during day time when solar energy is also prevalent; this is more so in the hot summer season. Most parts of India get abundant sunshine throughout the year. Solar cooling/refrigeration is, therefore, the most relevant application for our country, especially in view of the rapidly increasing demand for energy and shortage of electric power. It is estimated that cooling consumes about 35,000 MW of electricity for various end-uses. Part of this is from conventional power plants in areas where electricity is easily available and the rest is being generated through DG sets which consume a significant amount of highly subsidized diesel leading to noise and air pollution, besides heavy CO2 emissions.

Apart from this, in rural areas, where such options are not available, 30–40% of agricultural produce is being destroyed due to lack of proper post-harvest cooling facilities. Thus, resorting to solar cooling not only mitigates energy shortage and environmental pollution, but also contributes to the reduction of food spoilage. The applications of cooling include domestic refrigeration, comfort/ space cooling in various sectors, industrial refrigeration and process cooling, cold storages with deep freezing, etc. The capacity range of systems varies from a few Watts to thousands of kilo Watts. Solar cooling/air-conditioning systems have the potential to catering to all the above sectors. However, this is an emerging technology and faces many growth barriers, which are different from other heating and cooling technologies.

The demand of air conditioning is increasing due to the effect of climate change and global warming. If we still rely on the conventional electric air conditioning but electricity is generated from fossil fuels, the greenhouse gas emission would continuously worsen global warming; in turn the demand of air conditioning would be further increasing. In subtropical cities, air conditioning is a standard provision for buildings. However, air conditioning would commonly take up half of building electricity consumption.

The development of renewable energy is on the rise worldwide because of the growing demand on energy, high oil prices, and concerns of environmental impacts. In recent years, progress on solar-powered air conditioning has increased as nowadays, air conditioning system is almost a must in every building if we want to have a good indoor comfort inside the building. Therefore, this project focuses in the design and construction of a direct current (DC) air conditioning system integrated with solar parabolic focusing collector using angularly placed mirrors and photovoltaic (PV) system with mechanized sun-tracking system which consists of PV panels, solar charger and batteries. The air conditioning system can be operated on solar and can be used in non-electrified areas. As we all known, solar energy is cost effective, renewable and environmentally friendly.

Air conditioning is defined as the simultaneous processing of temperature, humidity, purification and distribution of air current in compliance with the requirement of space needing air conditioning. In general, air conditioning which also can be known as refrigeration is defined as any process of heat removal. To produce the process, it requires energy where the sources are commonly gas and electricity. With increasing gas and electricity tariffs, solar energy becomes attractive once the system has been installed. As one of the sources of renewable energy, solar energy is likely the most suitable system for installation in sub-tropical countries.

The most common globally, preferred type of thermally driven technology is evaporative cooling. The system, which has simpler capacity control, mechanism, easier implementation, high reliability, silent operation, long life and low maintenance cost was a genuine candidate for efficient and economic use of solar energy for cooling applications. But in this project concentrates on development and improvement of a normal air conditioner unit using steam condensation and evaporative cooling sidewisely using solar energy and electricity generated from the PV system. Utilizing solar energy to run the air conditioning system is a practical technique to replace conventional electricity. In order to obtain a feasibility of the air conditioning system using solar, a lot research and testing have been initiated to learn and discover the design and operation of the air conditioning and solar water heating system which is consist of PV system.

D.M. Whaley describes the design, construction and initial experimental performance testing of a novel integrated solar thermal system prototype for the provision of space cooling and dehumidification, space heating and domestic water heating.[1]. Luis Carlos Herrera Sosa research found that in arid climates, evaporating water is the best cooling technique possible.[2].Morgado Baca I. evaluates Evaporative Cooling (EC) strategy efficiency, in which water is used as coolant.[3].

Concentrated solar power technology constitute an interesting option to meet a part of future energy demand, especially when considering the high levels of solar radiation and clearness index that are available particularly in India. In this work, we study a medium temperature parabolic trough solar collector used to drive a cooling and water heating installation. Solar steam generating systems using parabolic trough concentrators have been in use for the past decade in several countries in the world. During the past years, various R & D efforts have been put into use to improve the performance.

Parabolic-trough solar water heating is a well-proven technology that directly substitutes renewable energy for conventional energy in water heating. Parabolic-trough collectors can also drive absorption cooling systems or other equipment that runs off a thermal load. There is considerable potential for using these technologies in India.

II. PROJECT OBJECTIVES

The demand of air conditioning is increasing due to the effect of climate change and global warming. If we still rely on the conventional electric air conditioning but electricity is generated from fossil fuels, the greenhouse gas emission would continuously worsen global warming; in turn the demand of air conditioning would be further increasing. However, air conditioning would commonly take up half of building electricity consumption. So we aimed to develop a new hybrid power-less air conditioning system and an in built water heating system attached to it by utilizing free energy source. Also we aimed to develop an environment friendly and low cost air conditioning and water heating system.

III. THEORY

A. Evaporative Cooling System:

Evaporative cooling involves heat and mass transfer, which occurs when water and the unsaturated air water mixture of the incoming air are in contact. This transfer is a function of the differences in temperatures and vapor pressures between the air and water. Heat and mass transfer are both operative in the evaporative cooler because heat transfer from the air to the water evaporates water, and the water evaporating into the air constitutes mass transfer. Heat inflow can be described as either latent or sensible heat. Whichever term is used depends on the effect. If the effect is only to raise or lower temperature, it is sensible heat. Latent heat, on the other hand, produces a change of state, e.g., freezing, melting, condensing, or vaporizing.

In evaporative cooling, sensible heat from the air is transferred to the water, becoming latent heat as the water evaporates. The water vapour becomes part of the air and carries the latent heat with it. The air dry-bulb temperature (DBT) is decreased because it gives up sensible heat. The air wet-bulb temperature (WBT) is not affected by the absorption of latent heat in the water vapour because the water vapour enters the air at the air wet-bulb temperature. Theoretically, the incoming air and the water in the evaporative cooler may be considered an isolated system. Because no heat is added to or removed from the system, the process of exchanging the sensible heat of the air for latent heat of evaporation from the water is adiabatic. Evaporative cooler performance, therefore, is based on the concept of an adiabatic process. The minimum temperature that can be reached is the wet bulb temperature of the incoming air. Wet pads provide a large water surface in which the air is moistened and the pad is wetted by dripping water.

The direct evaporative cooling process works essentially with the conversion of sensible heat in latent heat. The surrounding ambient air is cooled by evaporation of the water from the wet surface of the panel to the air. The addition of water vapour to the air increases its latent heat and relative humidity. If the process is adiabatic, this increase of the latent heat is compensated by a reduction of the sensible heat and consequent reduction of the dry bulb temperature of air.

IV. LAYOUT OF THE SYSTEM

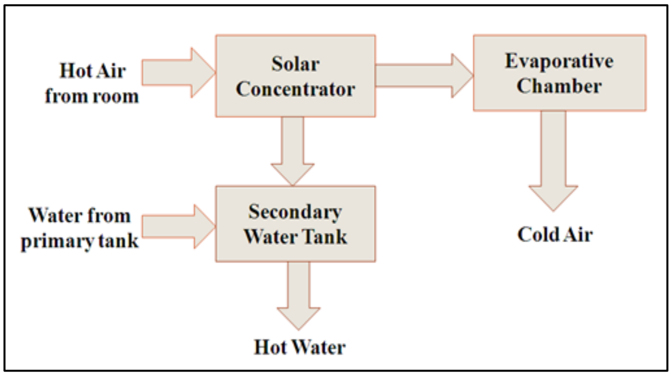

Fig. : Layout of the System

V. WORKING OF THE SYSTEM

In this project, we utilize only solar power for the cooling process and also for water heating. The cooling process proceeds as the temperature of atmosphere increases by sun rays. A solar parabolic concentrator with a mechanized sun tracking is used for heating of water inside a copper pipe which is placed at the focus of the concentrator. The mirrors of the concentrator are correctively positioned, so that the sun rays falling on the concentrator is directed towards the focus of the concentrator. This causes the heating of water inside the copper tube to a temperature of more than 350 degree Celsius and produces superheated steam which is mixed with the air from the room. This mixture is then expanded through a duct which condenses the steam. The high pressure mixture is then passed to an evaporative cooler which consist of moist fibers which causes the cooling of the mixture.

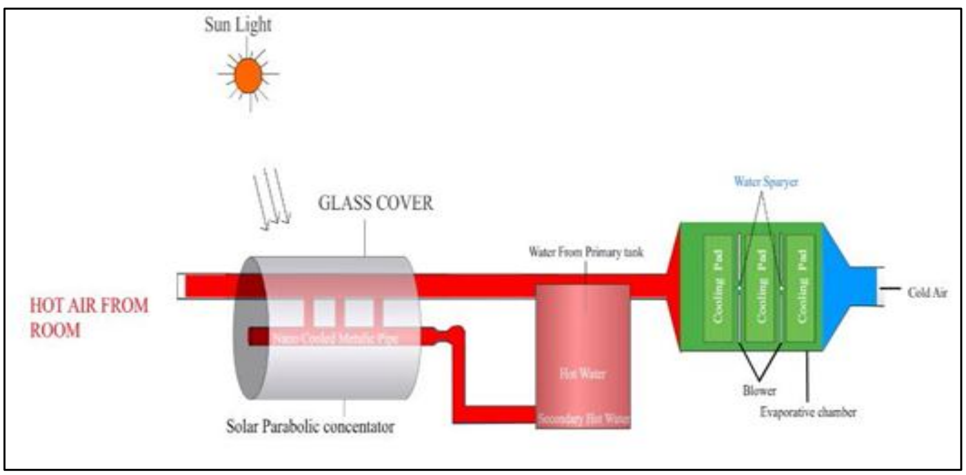

Fig. : Cooling Solar Power System

The passage to the evaporator is coated with coolant material which lowers the temperature of the incoming air without affecting its pressure. This cooled air is then passed to the room which is at a lower pressure. The vents of the evaporator are coated with dehumidifiers such as silica gel and a sheet coated with lithium chloride or lithium bromides is rolled inside the evaporator chamber. In this system cooling effect is produced by both steam condensation and evaporative cooling. This is how the cooling effect is produced. This can also be used as a room heater in winter condition by proper adjustment.

The required level of water inside the concentrator is maintained by a reservoir which is attached to concentrator pipe (copper). A metallic pipe is used to connect the concentrator and reservoir. As the temperature of water in the concentrator increases, the temperature of water in the reservoir also increases by convection. This hot water can be utilized for domestic purposes.

VI. COMPONENTS OF THE SYSTEM

A. Solar Parabolic Concentrator:

The Parabolic Trough Concentrator (PTC) is a solar concentration technology that converts solar beam radiation into thermal energy in their linear focus receiver. This type of concentrator is commonly provided with one-axis solar tracking to ensure that the solar beam falls parallel to its axis.

In our system a medium range concentrator ranging from about 85 to 250 °C is used. It consists of about 16 mirrors equally spaced along the circumference of the solar concentrator. Each mirror so angled so that the light incident on it is reflected towards the focus. Each mirror is properly angled by using a laser reflection process. The sides of the concentrator are covered by Aluminum foil so that light transmitted through the mirrors are again reflected towards the center. A copper tube of about 50mm diameter is placed at focus of the concentrator. The sides and top surfaces of the concentrator are covered by a reflective film so that light incident is reflected back and so heat loss by convection can be reduced. The concentrator is properly directioned by using a mechanized sun tracking system.

- Length of the concentrator = 1000 cm
- Diameter of the concentrator = 55 cm
- Diameter of the copper tube = 50 mm
- Width of mirrors = 5 cm
- Length of the mirrors = 100 cm
- Reflectivity of the mirrors = 0.73

Fig. 1: Orientations of mirrors in the concentrator

The orientation of mirrors in the concentrator is shown in figure 1. It consists of about 16 mirrors equally spaced along the circumference of the solar concentrator. Each mirror so angled so that the light incident on it is reflected towards the focus. Each mirror is properly angled by using a laser reflection process. The fabricated model of the solar concentrator with mechanized sun tracking systems is as shown in figure 2

Fig. 2: Solar Parabolic concentrator

B. Evaporative Cooling Chamber:

It consist of layers of cooling pad, a sheet coated with lithium bromide and water sprayer. The cooling pad is made of coconut fiber and cotton due to its good water holding capacity. The cooling pad is timely sprayed with water by using a sprayer. A sheet coated with lithium bromide / lithium chloride is rolled in and out of the chamber .The sheet rolled so that water absorbed by the sheet is regularly dried outside by using the heat from sunlight**.**

Fig. 3: Evaporative Chamber

The fabricated model of the evaporative cooling chamber is as shown in the figure 3.The dimensions of the chamber designed is .05×.05×.05 m. It mainly consist of evaporative cooling pad which is regularly water sprayed by using a sprayer. The chamber has two ducts on its either sides. The duct at the inlet of the chamber is designed for steam condensation and the other duct at the outlet is for proper air flow to the cooling space. The shape of the duct designed at the inlet of the evaporative chamber is as shown in figure 4.

Fig. 4: Inlet duct of the Evaporative chamber

The evaporative chamber is filled with layers of cooling pad which is regularly sprayed with water by a sprayer. The cooling pad is made of coconut fibre and cotton due to their high water holding capacity .the dimension of the layer of cooling pad used is about 45×45×45 cm. The cooling pad used in the proposed system is as shown in figure 5.

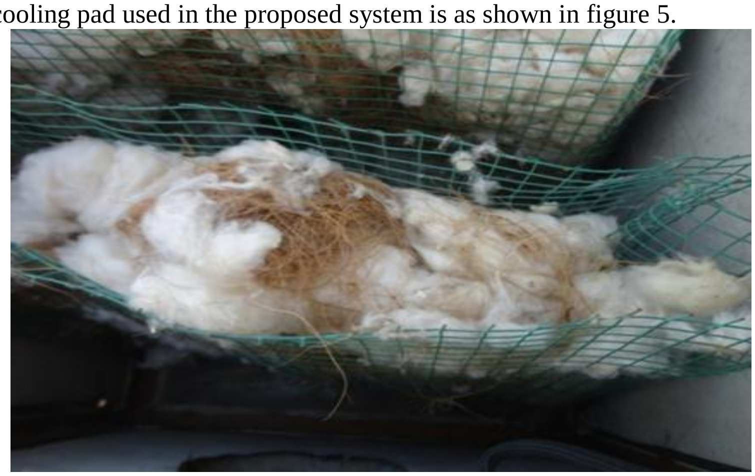

Fig. 5: Cooling pad used in the fabricated system

C. Primary Water Tank:
Primary tank is the main tank of the house. It is connected to the secondary tank and the evaporative chamber.

D. Secondary Water Tank:
It is the tank containing the hot water. It is connected directly to copper pipe of the concentrator. The water for secondary tank is from the primary tank. The level of water in the concentrator is maintained by maintaining the water level in the secondary tank by using a float valve. The dimension of the secondary tank used is 25×25×50 cm. the fabricated secondary tank is as shown in the figure 6.

Fig. 6: Fabricated secondary hot water tank

E. Solar Photovoltaic Panel:
The solar photovoltaic panel used in the system is 100 W panel. The solar panel is only power source used in the system to drive the blower, sun tracking system motors and motors used to roll the lithium bromide coated sheets.

VII. CALCULATIONS

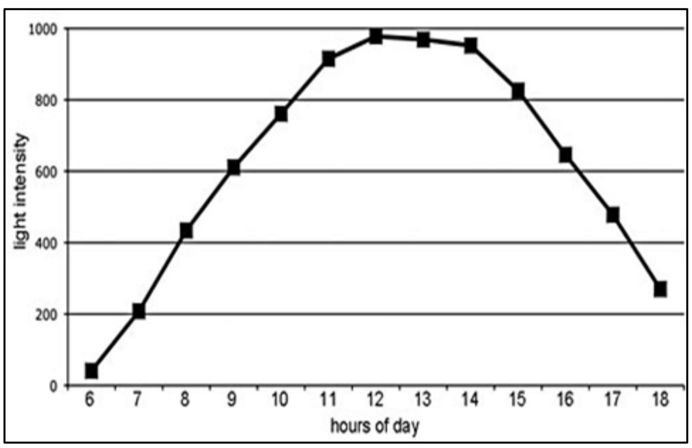

Fig. 7: The variation of solar intensity in a day

- Average solar radiation intensity =500W/m^2
- Area of each mirror of concentrator =.05*1=.05 m^2
- Total area of the mirror =16*0.05=0.8 m^2
- Reflectivity of the glass used =0.73
- Intensity of solar radiation at peak time =900W/m^2
- Total solar energy incident on the mirror=900*.8=720W
- Total solar energy reflected by mirror =720*0.73=525.6W
- Absorptivity of copper =0.94
- Total heat generated in the concentrator pipe =0.94*525.6 = 495W =495J/s

Temperature at the exit T2=23 deg. celsius

- Total heat transfer across the system =-mCp(T2-T1) =.03*1.004*(30-23) = 211.09 J

Total heat transfer through the cooling pad

- Q*.45 = 211.09
- Q=0.46899
- Heat transfer through the cooling pad = q*0.45*0.45 = Q
- q=2.316 kJ/m^2
- Heat transfer rate of the cooling pad material per unit area =2.316 kJ/m^2
- Rational cooling efficiency= $\dfrac{\text{Total Cooling effect}}{\text{Total heat input}}$

$$= \frac{211.09}{495} = 0.43$$

- Rational cooling efficiency =0.43

VIII. RESULTS AND DISCUSSIONS

Fig. 8: Fabricated model of the system

The fabricated model of the proposed system is as shown in the figure 8. A cabin of size about 3×3×5.5 ft was fabricated as the cooling space. The side wall of the model shows the blower which is used for the suction and flow of the hot air from the room to the system. Two pipes are provided inside the cabin for getting the hot and cold water.

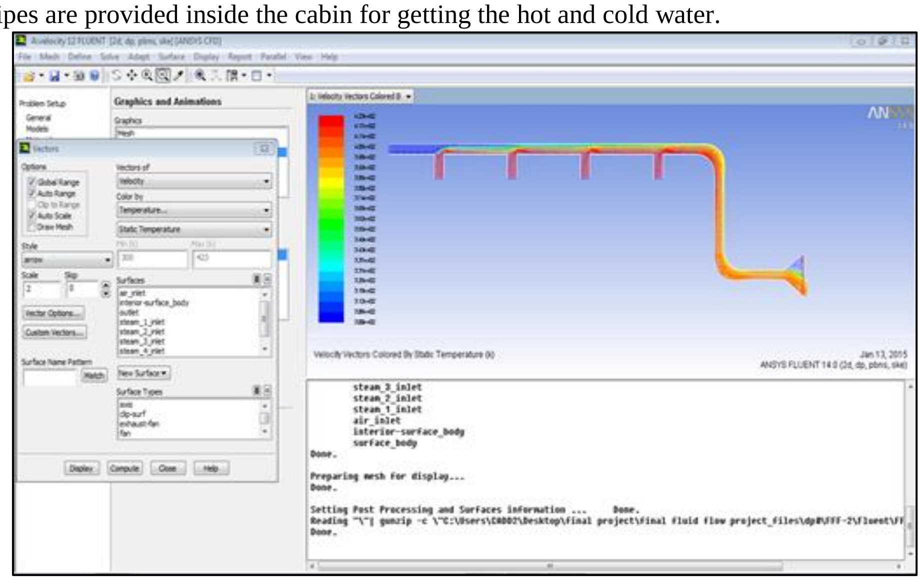

Fig. 9: CFD analysis of the air and steam flow through the pipe

It is clear from the figure 9 that the steam air superheated mixture condenses at the exit of the duct. The design and analysis of the proposed system was done and designed system is fabricated and the analysis of the fabricated model was conducted. In the analysis part it was found that the steam condenses at the inlet of the evaporative chamber. Also from calculations it was found that rational cooling efficiency was about 0.43. From the analysis of the fabricated model it was found that the temperature of the cabin was reduced to about 25 degree Celsius and the temperature of the hot water was about 50 degree Celsius.

IX. CONCLUSIONS

A constant temperature about 25℃ is obtained in the cabin which is almost human comfort temperature. And for water heating about 50℃ is obtained at the hot water tank. Rational cooling efficiency of 0.43 is obtained and is greater when compared to the existing system whose rational cooling efficiency is about 0.3 to 0.4. This can also be used as a room heater in winter condition by proper adjustment.

The main highlight of our project is that only solar energy is utilized for the cooling and heating process. No other external power sources are used. Our product is eco-friendly and pollution less. This can also installed at remote areas where electricity is not available and in regions where atmospheric temperature is high e.g. Rajasthan. It is well suited for middle class family as it requires only initial investment and less maintenance cost. No separate water heater is required for domestic purpose.

X. FUTURE SCOPE

Keeping in view the present status and cost of electricity/diesel and other fossil fuels fuel and also the available solar technologies, there seems to be a vast potential of solar cooling as per following factors:

- Solar cooling systems with intermittent heat storage for institutions and other establishments working during day time
- Integrated hybrid solar systems both for heating and cooling to work in all seasons
- High heat storage air conditioning and water heating systems
- Increasing cost of electricity and its non-availability on a 24×7 hour basis at many places
- Decreasing cost of solar electricity through photovoltaic which has come down to around Rs 8/- per unit from the earlier price of Rs 18/- per unit about 3 years back.

REFERENCES

[1] D.M. Whaleya, W.Y. Samana, A.T. Alemua, "Integrated Solar Thermal System for Water and Space Heating, Dehumidification and Cooling", Energy Procedia, vol.57, 2014, pp. 2590 – 2599
[2] Luis Carlos Herrera Sosa, Gabriel Gómez-Azpeitiab, "Cooling Average Potential of Evaporative Cooling System in Dry Warm Climate", Energy Procedia, vol. 57, 2014 , pp. 2554 – 2563
[3] Morgado Baca I.a, Melero Tur S.a, Neila Gonzalez J.a, Acha Román C.a , "Evaporative cooling efficiency according to climate conditions" , Procedia Engineering, vol.21 ,2011, pp. 283 – 290
[4] José Roberto García Chávez, "Application of Combined Passive Cooling and Passive Heating Techniques to Achieve Thermal Comfort in a Hot Dry Climate", Energy Procedia, vol. 57, 2014, pp. 1669 – 1676