Performance Analysis of Non-Concentrating Solar Collector- A Review

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Abstract— Solar energy becomes an alternative for the limited fossil fuel resources. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Flat plate solar collectors are the most common thermal collectors used among the various solar collectors for domestic and industrial purposes. Solar drying is one of the promising methods of reducing post-harvest losses in rural areas. The performance of any solar collector is largely affected by various parameters such as glazing, absorber plate, top covers and heating pipes. The absorber plate of the flat plate collector transfers solar energy to liquid flowing in the tubes. The collector efficiency is dependent on the temperature of the plate which in turn is dependent on the nature of the flow of the fluid inside the tube, solar insulation, ambient temperature, top loss coefficient, the emissivity of the plate and glass cover, slope. This paper discusses the factors affecting the performance of the solar collector.

Keywords— Flat plate solar collector, Solar energy, Heat, Efficiency, Absorber plate

I. INTRODUCTION

Currently 80% of the world’s energy is produced from fossil fuels imposing a real threat to the environment, mainly through global warming and acidification of water cycle. The distribution of fossil fuels around the world is equally uneven. Middle-East possesses more than half of the known oil reserves. This fact leads to economical instabilities around the world, which affect the whole geopolitical system as it cannot be maintained. There is also the danger arising from the increase of the energy usage from the countries of the third world. These countries are expected to try to increase their standard of living, which has been at the minimum level for decades. As a result, this will increase the depletion of the limited stock, creating an even more logical problem. These countries even today cannot afford the cost of protecting the environment consequently and will increase the rate of combustion of oil and coal, will accelerate deforestation or they will turn to nuclear energy.

Keeping the above in mind as well as the fact the oil is running out fast, alternatives should be adopted. Renewable energy is one of the most promising alternatives to the above sources. Renewable energy sources are larger than even the traditional fossil fuels and in theory can easily supply the world's energy needs. Completely 89 PW of solar power falls on the planet's surface. While it is not possible to capture all, or even most of this energy, capturing less than 0.02% would be enough to meet the current energy needs. Solar collectors are commonly used for active conversion of solar energy to heat.

II. ANALYSIS

A. Flat Plate Collector

A typical flat-plate collector made up of an absorber which is in an insulated box together with transparent cover sheets is taken up. The absorber is usually made up of a metal sheet of high thermal conductivity such as copper or aluminum, with integrated or attached tubes. Its surface is coated with a special selective material for maximizing radiant energy absorption while minimizing radiant energy emission. The insulated box reduces heat losses from the back and sides of the collector. These collectors are used for heating a liquid or air to a temperature less than 680°C. Flat-plate collectors are in wide use for domestic household hot-water heating and for space heating, where the demand temperature is low. Solar flat plate collectors are used for water heating applications. The efficiency of these systems is around 70% which is very high compared to solar direct energy conversion systems which have efficiency around 17%. The five components associated with the flat plate collector namely, absorber plate, top covers, heating pipes, heat insulating backing and heat-transport fluid which is clearly shown in Fig. 1. The absorber plate is selectively coated to have high absorption. It receives heat by solar radiation and, by conduction; heat is transferred to the flowing liquid...
through the heating pipes. The fluid flow through the collector pipes is by natural or by forced circulation. Natural circulation is used for fluid flow for small water heating system.

Fig. 1. Cross-Section of a Typical Liquid Flat Plate Collector

Conventionally, absorbers of all flat plate collectors are straight copper/aluminum sheets, which, however limits the heat collection surface transfer area.

B. Concentrator

In order to overcome the drawback of the conventional solar collectors arising out of low water temperature or even freezing, a new design of solar collectors is presented. This is based on a combination of a curved surface concentrator and an aluminum concentric solar receiver contained in a double-skin glass evacuated tube. Overall thermal performance of solar water heating systems reduces due to non uniform flow in riser tubes. The overall thermal performance and efficiency is higher in variable header system due to uniform velocity.

C. Flow Pattern

By changing the air flow pattern inside the collector the collector efficiency of single duct front pass, double duct front pass and double duct counter flow were observed as 30.6, 36.1 and 38.2% respectively which means design with double duct counter flow can improve collector performance for up to 8.3% compared to single duct front pass and the efficiency of flat plate collector is found to increase with increasing ambient temperature with a single glass cover.

D. Coating

A coated solar flat plate collector was analyzed by introducing a new heating system at low cost has been conducted by using different material as header and riser tubes. It results in copper, aluminum and stainless giving the same performance despite cost of stainless tube with epoxy-polyether and aluminum with copper oxide being less than that of copper tube. Minimization of cost in fabricating solar flat plate collector using ceramic coated panel is being investigated. The solar flat plate collector performance characteristics are analyzed with three types of surface coatings. It found maximum temperature of hot water in the storage tank obtained for black chrome coating when compared to other two coatings. Performance of solar thermal absorber can be improved by change of absorber materials and coating thickness. Use of phase change material can improve the temperature of water compared to simple flat plate collector and easy to install in remote areas.

E. Performance

Thermal performance of flat plate solar air heater with various designs, namely, plane absorber, transverse V-porous ribs and inclined V-porous ribs of absorber are fabricated and tested with artificial solar radiation and in natural convection. The Performances are compared on the basis of overall thermal efficiency and thermal gradient along normal to the base. The overall thermal efficiencies of these designs have been found as 14.91%, 17.24% and 20.04% respectively. Thermal gradient is seen trending to reduce with increase in efficiency. The performance of the solar flat plate collector was increased using semi circular cross sectional tube below the absorber plate, as the area of intimate contact increases between fluid and absorber plate and resistance due to adhesive decreasing too. The performance of the conventional absorber plate is compared with that of the newly proposed absorber plate having concavities. In which the heat transfer rate is increased by 5.12%. It shows the increase in outlet temperature due to the provision of concavities which increase the diffusion area for radiation reducing the reflection losses. Performance of the variations of top loss heat transfer coefficient with absorber plate emittance and air gap spacing between the absorber plate and the cover plate has been evaluated. High plate emission was seen tending to dissipate more heat to the atmosphere and consequently resulting in increase in top loss heat transfer coefficient leading to reduced system performance. Thermal performance analysis of a glazed solar flat plate collector system was analyzed with heat storage tanks. Special attention was focused on the influence of the system parameters such as the capacity of thermal storage and thermal load of the collector system. Results show the variation of temperature inside the storage tank becoming smaller as the capacity of the tanks increases and the final temperature decreases with increasing the heat load.

F. Absorber

Productivity of the flat plate solar collector system has been estimated by using the present method of average monthly and annual productivity. The performance of flat plate collector with different geometric absorber configuration has been analyzed. The efficiency variation in given collector with their given parameter was found as also variation in cost, area, and its storage outlet temperature. A huge scope for reduction in the collector area, cost and minimizing the number of tubes was also seen and it results at same outlet temperature by changing its geometric shape of flat plate collector. Efficiency and performance of flat plate collector has
been improved by increasing the transmissivity of the glazing using highly transmissive polymer films or low iron glass, and using a very absorptive absorber, which is inexpensively accomplished by including a carbon black coating, would have the largest impact on performance of flat plate collector. The solar water heater has been tested with an absorber made of 2 sheets of 1mm thickness GI material with integrated canals painted in silica based black paint. This system can reach satisfactory levels of efficiency and prove to be inexpensive and easier to manufacture. Theoretical and experimental analysis of the emissivity of absorber plate has been investigated with a single glass cover. This shows a significant impact on loss coefficient and efficiency of the flat plate collector found to increase with increasing ambient temperature.

G. Medium

Thermal efficiency of flat plate solar air heater has been analyzed in a single and double pass with and without Porous Media. Smooth plate double pass solar air heater is 3-4% more efficient than the single pass solar air heater. The presence of porous media in double pass solar air heater, increases the air heater efficiency to 5% efficient than air heater in a single pass, and 2-3% higher than a double pass without porous media. The effect of different nano particle concentrations of TiO₂ in water as base fluid was studied. Adding nano particles to water brought about an improvement of initial efficiency of flat plate solar collector between 3.5 and 10.5% and the index of collector total efficiency between 2.6 and 7% relative to base fluid. The heat transfer rate of enhanced flat-plate solar collectors has been improved by inserting wire-coil devices within the flow tubes. The effect of mass flow rate, flow channel depth and collector length on the system has been investigated on the basis of the thermal performance and pressure drop through the collector with and without porous medium. Results show that the collectors obtained high efficiency when the collector operates at relatively high flow rates, and at relatively low collector temperature since the collector losses will be less in low temperature difference.

H. Tracking System

An efficient and low power Programmable System on Chip based sun tracker device has been built. The solar energy based street light with auto tracking system to increase the conversion efficiency of the solar power generator was analyzed. Design and implementation of energy efficient continuous solar tracking system from a normal mechanical single axis to a hybrid dual axis is discussed. A dual-axis solar tracking controller has been fabricated and installed to increase the performance of solar panel. An automatic solar-tracking mechanism using embedded system design with minimum cost and reliable structure was designed and implemented. The solar cell array system with sun tracking system was analyzed to get maximum output from the available solar energy. Efficiencies of Single-Axis Tracking System are compared with Dual-Axis Tracking System with Fixed Mount solar system. The analysis of a solar tracking system driven by PIC 18F452 micro controller was performed. An 8051 micro controller based solar panel tracking system was developed to increase the amount of power generated by the solar panel as the sun traverses across the sky. Solar tracking with Atmel 8051 micro controller to perform an approximate 3-dimensional hemispherical rotation to track movement of sun and to increase the overall electricity generation has been implemented. A prototype of micro controller based automatic solar tracking system with Light dependent resistors for tracking the sun both in normal and bad weather condition is fabricated. A single axis solar tracker system for PV conversion panels to properly orienting the PV panel in accordance with the real position of the sun for maximizing the output of solar energy produced by the PV panel for sufficient values of light signal intensity has been designed and implemented.

III. CONCLUSION

The conclusion from the above review is that the performance of flat plate solar collector varies with respect to design, coated surface material and process parameters including atmospheric temperature. In most of the cases, the collector efficiency has improved with respect to the application. Thermal efficiency of collector should be monitored by controlling process parameters and avoiding thermal losses for obtaining higher energy efficiency with minimum cost.

REFERENCES


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