

Technical Feasibility of Flat Plate Collector Water Heating System with Auto Tilting Mechanism

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ABSTRACT

Solar energy is the basic source of all the energy needs of the human kind. Solar energy, in its various forms is used by human civilization for fulfilling its needs. Water heating system is one of them. Conventionally, Flat Plate Collector (FPC) solar water heating system was used for this purpose. However, with technological development, new and more advanced systems, which are much more efficient and cost effective, replaced the FPC market. The developed pilot scale system in the current paper tries to evaluate the performance of the FPC by inclusion of an auto tilting mechanism for utilizing maximum incident solar radiation throughout the day. Changes in the temperature with respect to time, and comparison of the temperature variations of the tilting panel and a fixed panel were recorded, and further, a suitable mathematical correlation was developed for prediction of theoretical temperatures.

Keywords— Civilization, FPC, Solar Energy, Temperature

I. INTRODUCTION

FPC solar water heater (SWH) systems are one of the oldest devices used for water heating. The estimated number of FPCs in India accounts for more than 1,375,500 i.e. 2.635 million m² (Greentech Knowledge Solutions Pvt. Ltd, 2009). Recently developed technologies like ETC offer a better efficiency at lower costs. Due to the less efficiency and cost, the FPC systems are not very much popular. However, discarding the old systems may result in unnecessary wastage of the available technology as well as incur excess monetary costs. In order to reduce this, new techniques to enhance the available technologies with limited cost becomes vital.

It was revealed from the literature review, many efforts are directed towards intelligent sun tracking systems, specially designed for PV panels. However, no effort was made reflecting the utility of the same technique for thermal solar energy utilization. Also, some efforts

have been directed study toward the modification of the existent flat plate collection system for efficiency enhancement by different methods. The concept of solar tracking is not applied to the flat plate solar water heaters. The FPC panel can be rotated according to the sun path and its performance can be assessed. If there is increase in the efficiency of the flat plate solar water heaters, it will enhance the efficiency of the system.

In this paper, an attempt is made to design and modify the existing FPC system by application of auto tilting mechanism and also to carry out performance evaluation and cost economics of the same with system without auto tilting mechanism.

It has been observed that, solar tracking is related to the positioning the panel perpendicular to the solar rays, so that, the solar radiations can be utilized efficiently. In general, for a period of 12 hours (from sunrise to sunset), the sun will travel through 180° (East to West). This means, if the panel is rotated through 180° during the period of 12 hours, it will follow the sun path. In order to track the sun path maintaining perpendicularity between sunrays and the panel of SWH, rotational speed of the panel should be in accordance with the period for which solar radiations are available.

The experimental setup has been designed with a driving force of 12 V Direct Current (DC) motor of speed 75 rpm. In general, for a period of 12 hours, the panel is required to be rotated through 180° and hence the required rotational speed of the panel comes to be 0.00069 rpm. The required velocity (VR) ratio becomes 0.000009. Hence, to have a such large VR, an epicyclic gear box with VR of 0.00001 is used for the setup. The little difference between the required VR and available VR was adjusted by varying the speed of the motor. Also, the time for which solar radiations are available changes day-by-day and hence the rotational speed of the panel also changes. Hence, in order to match the required and actual VR and also to match the required rotational speed of the

motor, an electronic speed controller was assembled. The speed of the motor was varied by varying the voltage supplied to the motor. The relation between the voltage supplied and the speed of motor was developed by measuring the voltage by multimeter and speed of the motor by mechanical rpm.



Figure 1 Position of the panel at 3.00 pm

II. EXPERIMENTAL SETUP

Fig. 1 shows the experimental setup for tilting panel. At the time of sunrise, the panel was set so that it faces the East and locked in the position. This was done manually and the required rpm of the motor is set by using the electronic controller. The motor was switched on and the panel is allowed to rotate at the designed speed. In order to avoid over movement of the panel, a limit switch is provided on West side, so that the panel will stop automatically. In the next morning, the same procedure was repeated.

III. METHODOLOGY

Positioning the panel:

At the time of sunrise, the tilting panel is required to be kept facing towards East. The panel is rotated automatically so that it will be facing East and it is then locked in the position using the chain and sprocket arrangement. By using a plumb bob, the correct required position of the panel is permanently marked on the support stand and the panel is locked at this mark.

Setting up the speed of the motor:

In order to rotate the panel according to the sun path, it is required to set the speed of the motor as per the calculations. From the data collected for sunrise and sunset timings for the study area, the required voltage for corresponding speed is noted and the voltage of the motor is set to the required value.

Recording the temperatures:

The temperature of the water in both the tanks (fixed and tilting panel) is measured with the same thermometer. In order to measure the temperature of the water, a water sample is collected directly from the tank. For this, bibcocks were provided at the hot water outlet of the tank. At the same time, ambient air temperature has been recorded every hour.

Emptying the tanks:

After sunset, the hot water in both the tanks is stored in separate tank of capacity 200 lit. The hot water stored in a separate tank was used in the next morning. After emptying, both the tanks were filled with fresh cold water. In the next morning all steps were repeated.

IV. RESULTS AND DISCUSSIONS

Performance of both panels before experimentation:

In order to assess the performance evaluation of the panels with and without auto tilting, it was necessary to know the performance of both the panels at fixed position. Both the panels are kept at fixed position and their performance is observed. The hourly observations were recorded for a period of one week. The results showed that, there is no change in the temperatures of both the panels. The efficiency of both the panels was observed to be same.

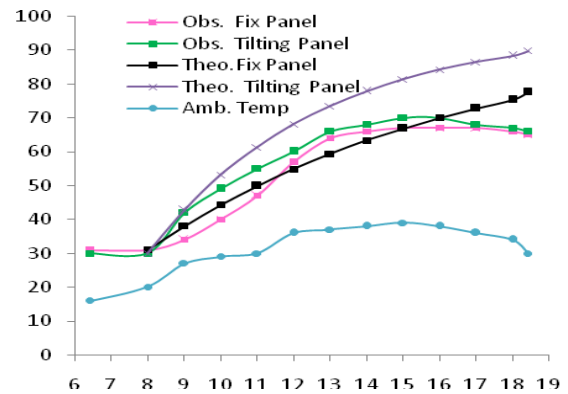


Figure 2(A): Variations in Temperature With Time

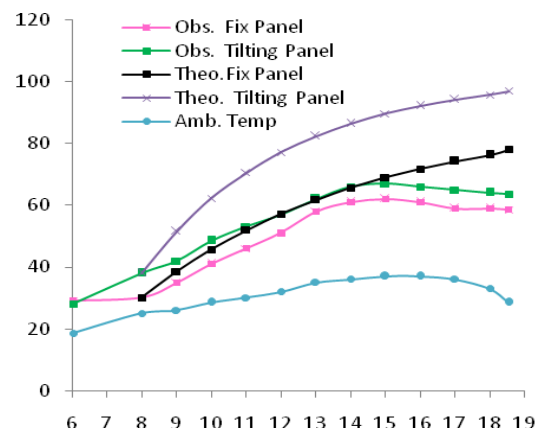


Figure 3(B): Variations in Temperature with Time

Performance of both panels during experimentation:

During a period from sunrise to sunset, it was observed that, the rate of increase in temperature in tilting panel is proportional to the rate of increase in the ambient air temperature, whereas this was not the case for fixed panel. It can be observed that, there is a difference in observed and theoretical temperatures for both the panels.

This may be due to the various factors like wind, climate of the day and losses in the temperatures. However, the difference between observed and theoretical temperatures is more in tilting panel because of the loss in temperature due to long length of the flexible pipes.

From the mathematical corelations, it was observed that, as compared to the fixed panel, there is an average increase of 61% in the temperature rate coefficient for tilting panel. The results indicate that, upto 8.00 am for all the days, there is no change in the temperature of water for both the panels. This is due to the less intensity of the solar radiations and the cold climate in the morning.

Time	Average Temperature (⁰ C)	
	Fixed Panel	Tilting Panel
09.00 am	35.6	40.9
10.00 am	40.6	46.4
11.00 am	47.0	51.8
12.00 noon	52.8	57.5
01.00 pm	58.5	61.9
02.00 pm	62.9	65.7
03.00 pm	64.7	66.9
04.00 pm	63.4	65.9
05.00 pm	62.2	64.6
06.00 pm	61.5	63.5
Sunset	60.6	62.4

Table 1 – Average Temperatures recorded during study period

From Table 1, it can be seen that, as compared to the difference in the temperatures upto 10.00 am, the difference in temperatures at 11.00 to 01.00 pm is less. It can also be seen that, as compared to the difference in the temperatures at 11.00 to 01.00 pm, the difference between the temperatures at 2.00 pm is more. It can be seen that, the difference in the temperatures between 03.00 pm to sunset, is more than the difference between the temperatures at 2.00 pm. At 2.00 to 3.00, depending on the climate of the day, temperature of waters for both the panels reaches their maximum limit. Depending on the climate of the day, for the tilting panel, the maximum temperature (corresponding to fixed panel) is achieved 1 to 2 hours earlier than fixed panel. For maximum temperatures, average marginal difference of 3⁰C have been observed.

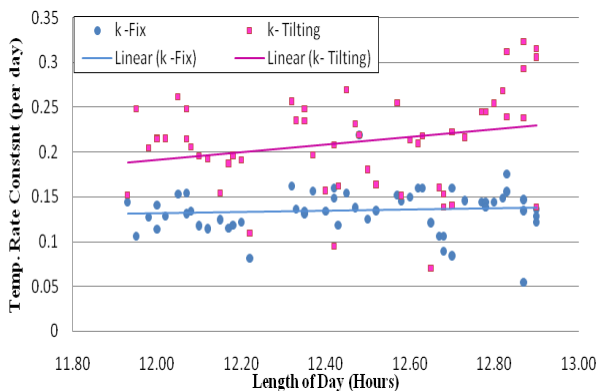


Figure 4: Variation in temperature rate constant with length of day

From Fig. 3, it was also observed that, the temperature rate constant for tilting panel varies with the length of the day. As the length of the day increases, the temperature rate constant increases. Due to the longer length of the day, the solar panel is exposed to the solar radiations for a longer period and hence the temperature rate constant increases. For the fixed panel, the solar panel is exposed to the sun, but the radiations are not falling perpendicular to the panel and hence the temperature rate constant is not increased.

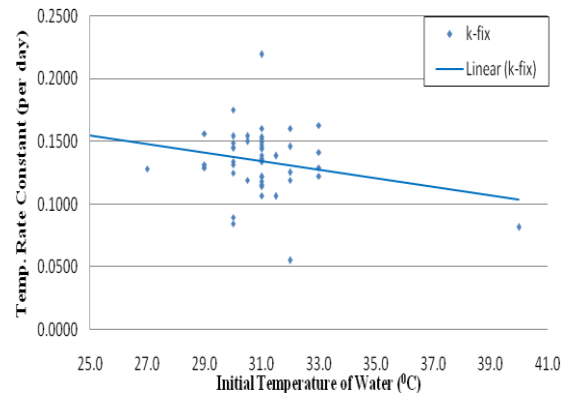


Figure 5: Variation of temperature rate constant with initial temperature of water for fixed panel

From Fig. 4 and Fig.5, it was observed that, the reaction rate constant varies with the initial temperature of the water in the tank. For the fixed panel, the temperature rate constant decreases with the increase in initial temperature of the water. In case of fixed panel, during the morning session, the heat collected by the solar collector is not sufficient to maintain the temperature of the water and hence the decrease in the temperature rate constant has been observed. However, for the tilting panel, the temperature rate constant increases with the increase in the initial temperature of water in the tank. From the sunrise, the tilting panel is always facing the sun and hence the heating of water starts earlier than the fixed panel, as a result of which the temperature rate constant increases.

It was observed that, as the length of day increases, the maximum temperature achieved decreases. A similar phenomenon has been observed for both the panels. It was also observed that, as the length of day increases, the loss in the temperature increases. A similar observation has been recorded for both the panels. This is due to the more time lapsed after achieving the maximum temperature, because after achieving the maximum temperatures, for both the panels, loss in temperature has been observed. Loss in temperature is due to the less intensity of the solar radiations and long length of flexible pipes.

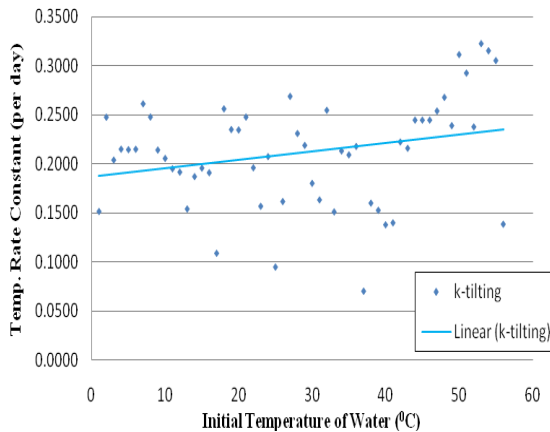


Figure 6: Variation of temperature rate constant with initial temperature of water for tilting panel

Results indicate that, after reaching the maximum limit, for both the panels, loss of temperature was observed. The rate of loss of the temperature for tilting panel was more than the fixed panel. The loss of temperature was mainly due to the following reasons:

1. The length of flexible pipes:- In order to tilt the panel, it was necessary to provide these flexible pipes to carry hot and cold water. However, an attempt was made to reduce the loss of temperature by providing Asbestos insulation to these pipes. In case of fixed panel, the length of flexible pipe is very short and hence, the loss of temperature was less.

2. Intensity of solar radiations: After 3.00 pm, the intensity of solar radiations decreases. The heat collected by the solar collector is not sufficient to maintain the temperature of the water circulated in the pipes and thus loss of temperature was observed.

Cost economics of the auto tilting system:

At site, the total cost incurred to convert the fixed panel to auto tilting panel was approximately ₹16200.00 (excluding the insulated water tanks). The insulated water tank are supplied by the manufacturer along with the system. If an existing FPC system is to be converted to auto tilting system, the stand supplied by the manufacturer has to be replaced by a new stand. The cost of the new stand is ₹1000.00. The stand used during the experimental study was designed as per the requirements of the site. At site, the upper stand was fitted on the wall. Hence the stand supplied by the manufacturer has to be replaced with the new stand. Thus, the total cost incurred shall be about Rs. 17200.00

If the 61% increase in the temperature rate coefficient is considered, the conversion of a fixed FPC to auto tilting FPC proves to be economical.

V. CONCLUSION

The tilting of the FPC solar panel was observed to be working as per the design concept.

The reaction rate constant for auto tilting panel is nearly 61% more than that of fixed panel. The average increase in temperature of water due to auto tilting was observed to be 3°C. In the tilting panel the maximum

temperature is achieved at 2.00 pm. After 2.00 pm the tank can be refilled with fresh water to gain the maximum utilization of solar energy. After 3.00 pm, more loss of temperature was observed in auto tilting mechanism. This is due to the long length of the hot and cold water pipes fitted to auto tilting panel. This can be avoided by providing more insulation to the pipes. As the reaction rate constant was increased for auto tilting panel, more quantity of water can be heated by using same panel. The difference in the observed temperature and theoretical temperature was due to the loss of temperature due to poor insulation and intensity of solar radiations. From the cost economics, it can be concluded that, the auto tilting mechanism proves to be economical and energy efficient.

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