Transient Numerical Model for the Thermal Performance of Solar Receiver in Indian Condition

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Abstract— To counter the energy crisis due to over dependence on conventional fossil fuels Test are working on solar energy based systems. In domestic and industrial sector dependence of evacuated water heaters is increasing for ensuring uninterrupted supply of low temperature hot water. In this work the performance of ETC was evaluated following standard test procedure in the IMSEC CAMPUS. At this location adequate amount of solar radiation are available throughout year. The result obtained from the test predicts that the maximum efficiency of the system, is 46.7%.

Keywords: Transient Numerical Model, ETC

Nomenclature

- m= Mass flow rate of the heat transfer fluid kg/s
- I= solar irradiation t = Time in sec.
- A = Aperture area of collector T_a=Ambient air Temp. °C
- T_m=Cold water temp. from mains, °C T_s=Temp. of water in storage tank, °C
- T_i= Temperature of fluid entering the collector, °C T_o=outlet temperature at specified time t, °C
- T_{ad}= Average air temp. during day-test, °C T_{sfd}=Water Temp. at the end of day test, °C T_{sid}=Water Temp. at the beginning of the day test, °C

I. Introduction

Presently, the energy crisis is predominant as conventional sources of power such as fossil fuels are depleting at a quicker rate. Also, the utilization of these fuels, adversely have an effect on our environment ensuing in global warming, ozone layer depletion, acid rain etc. Hence, there is a necessity to shift the center of attention closer to different non-conventional and renewable electricity sources. Solar power finds its utility over various fields.

The world market for solar water heaters has increased substantially in the last decade. As a result, there have been large- scale trends of new-technology and improved-quality products. The evacuated tube solar collectors operate better in comparison to flat plate solar collectors, in unique for high temperature operations. However, previously, it provided no actual competition for flat plate solar collectors, due to the fact of difficulties in manufacturing and maintenance of the vacuum seal.

The supply of thermal energy required by using most of the water heating processes can range from 70-120°C. [7] which can ideally be produced by using evacuated tube collectors which can without difficulty obtain this range and have the delivered gain of a excessive performance. With the recent advances in vacuum technology, evacuated tube collectors can be reliably mass produced. it was identified that the creation of vacuum between the absorber and the cover of a solar collector would end result in a considerable improvement in collector efficiency due to reduction in heat loss via convection and conduction.

Each evacuated tube consists of two glass tubes. The outer tube is made of extremely sturdy transparent borosilicate glass that is in a position to resist impact from hail up to 37 mm in diameter. The internal tube is additionally made of borosilicate glass, but lined with a one-of-a-kind selective coating (ALN/AIN-SS/CU).

II. Site Details

The experiment will carried out at IMS ENGINEERING COLLEGE, GHAZIABAD which had Sunny day, partially cloudy and scattered cloud day some times. During the testing time, the collector at a tilt angle equal to latitude of IMSEC CAMPUS GHAZIABAD.

A. Specifications of ETC:

The evacuated tube collector containing five tubes was selected with tube length 0f 1500 mm having outer diameter is 47 mm for this study. The collector is of direct flow type and inner is 37 mm having three layer coating. The detail specifications of the ETC are follows:

Type of collector	Evacuated Tube Collector, direst flow
Tube length	1500 mm
Inner diameter of each tube	37 mm
Outer diameter of each tube	47 mm
Number of tubes	5
Details of selective coating	Graded AL-N with Copper

Table 1. Evacuated Test Collector's Specifications

B. Testing Procedure for ETC:

The standard specifies that the collector shall be tested under clear sky conditions in order to determine efficiency. On any given day data is recorded under steady state conditions for fixed As per standard test procedure the data was recorded for four inlet temperatures on different days and total sixteen data sets were obtained,. The efficiency of the ETC was calculated using the standard Hottelier equation and the calculated values of the efficiency are shown in Table 2. Further, while values of mass flow rate 'm' and inlet water temperature 'Ti'. For each set of fixed values, it is specified that an equal number of tests be conducted symmetrically before and after solar noon. For eg. If data of five set is recorded then the time of recording should be 11:00 am, 11:30 am 2 noon, 12:31 pm and 13:00 pm, Theses set of testing the collector is considered to be operating under steady state conditions, if the deviations in the experimental parameters is within permissible limits the experimental parameters recorded during the test are shown in experimental parameters recorded during the test are shown in Table 3 and were within permissible limit.

Date of Test	Tsid °C	Tsfd °C	Average Ambient Temp. Tad °C	Average Solar Radiation, GT W/m²	(1+2)/2	ΔT	X	η	% η
05.04.2019	42.9	66.3	33.6	635	54.60	21.00	0.03	0.47	46.7
06.04.2019	46.5	68.2	34.0	626	57.35	23.35	0.04	0.44	44.0
08.04.2019	53.2	74.4	33.2	646	63.80	30.60	0.05	0.42	41.6
10.04.2019	59.5	80.2	34.6	630	69.85	35.25	0.06	0.42	41.7
11.04.2019	64.2	85.6	35.1	652	74.9	39.8	0.07	0.42	41.6

Table 2: Test Results

Sr. No.	Time	Ambient Temp.	Average Temp. of water in tank
	Hrs.	°C	°C
1	8:40	33.1	42.9
2	9:10	34.3	43.9
3	9:40	34.6	45.2
4	10:10	33.2	44.7
5	10:40	32.8	46.4
6	11:10	34.4	47.8
7	11:40	34	51.2
8	12:10	34.2	52.5
9	12:40	33.3	53.1
10	13:10	34.7	54.9
11	13:40	35.9	56.0
12	14:10	35.2	58.1
13	14:40	34.5	58.2
14	15:10	34.5	59.3
15	15:40	33.6	60.1

Table 3: Experimental Parameters.

III. RESULTS AND DISCUSSIONS

Figure 1 show the thermal efficiency of the evacuated tube collector. The efficiency curve shows the negative slope indicating that as the temperature of the inlet water increases the thermal efficiency of the collector decreases. If the thermal efficiency curve is extended towards the left and it touches the vertical axis then the pint of intersection shows the point of maximum efficiency for the given collector.

Extending the curve on right side and the point where it touches the horizontal axes then point of coincide at horizontal axes indicates zero thermal performance. The point of zero thermal performance depends on the slope of the curve. Greater the slope of the curve earlier it will coincide the horizontal axes. Therefore, it is concluded from the discussions that for larger range of efficiency the slope of the curve should be gentle.
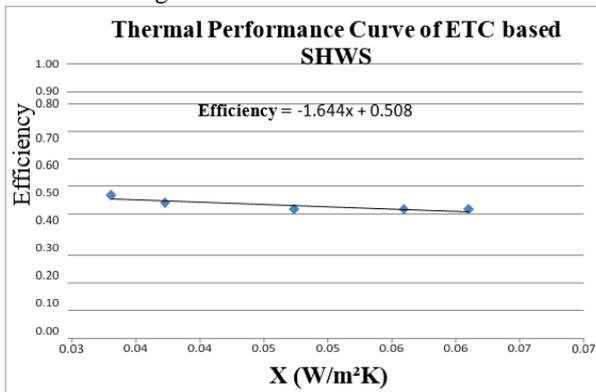

Fig. 1: Efficiency curve for a commercial evacuated tube collector

The test results obtained are summerised below:
- Efficiency, ηc of the collector is found equal to 46.7%
- Percentage system efficiency at standard test conditions Ts = 50°C, Tad = 25°C) is found 0.43 as calculated above.
- Average amount of energy collected (Q) during the period of day time test corresponding to standard test conditions (Kwh) is 2.76.

IV. CONCLUSIONS

Prescribed standards worldwide for testing the solar thermal collectors are unique and very precise in predicting the thermal performance of the solar collectors. The results obtained from the tests can be used for further designing and improvements in the evacuated collectors for any location globally and also for particular applications.

REFERENCES

[1] ASHARE standards, 93-86: 1986. "Methods of testing to determine thermal performance of solar collectors", American Society of Heating, Refrigeration and Air-conditioning Engineers, Atlanta USA.

[2] Duffie, J.A. and Beckman. W.A., "Solar Energy Thermal Processes"' John Willey, New York..

[3] S. Hasan Saeed and D.K. Sharma, Non-Conventional Energy Resources, 1st Edition, S.K.Kataria & Sons, 2006-2007

[4] Internet, 2004, http://webarsiv.hurriyet.com.tr/ 2004/02/24/418098.asp

[5] H.P.Garg, D.S.Hrishikesan, "Enhancement of solar energy on flat-plate collector by plane booster mirrors". Solar Energy 1998;40(4):295–307.

[6] Berwal Anil K., Kumar S, Kumari N, Kumar V, Haleem Abid, "Design and analysis of rooftop grid tied 50 kW capacity Solar Photovoltaic (SPV) power

[7] Internet Source