Experimental Study of the Performance of Low Cost Solar Water Heater in Najaf City

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***Abstract*--** **The Integrated Collector Storage Solar Water Heater (ICS-SWH) designed and manufactured in the Alternative and Renewable Energy Research unit, at Technical Engineering College of Najaf. Its consist of a collector box that works as container of receiver cylinder having a length of 1.3m, width 0.83m , short height 0.32 m, and long height 0.81m and receiver cylinder work as the receiver of solar energy to heat the water flows have outer diameter 0.4 m and length 1.1 m. The thermal performance was evaluated extensively throughout the month of March 2015; a maximum temperature difference of 36.3 ^{o}C between inlet and outlet of the solar water heater at a mass flow rate of 9 kg/h was achieved. The efficiency of the integrated collector storage solar water heater was calculated. The maximum value during the experimental period was found to be 52%. This reveals a good capability of the system to convert solar energy to heat which can be used for heating water. The objectives of this work are construction solar water heater with minimum law cost and work in Iraq weather.**

***Index Term*--** **Solar energy, solar heater, Integrated Collector Storage, Efficiency.**

1. INTRODUCTION

Hot water is an essential requirement in industry as well as in the domestic sector. In Iraq, water is generally heated by electric heaters. The electric energy required to run heaters is produced from thermal power stations by burning fossil fuel. The average electric energy consumption in the winter months in Iraq about 2200 watt the electric energy consumption in the winter months in Iraq goes for the domestic use.

Iraq has a clear sky most of the year. Cloud formation occurs in some limited periods only, throughout the year. In addition, the geographical position of Iraq could be another reason to have relatively high solar radiation values, as compared to many parts of the world, for most days throughout the year.

C. Garnier and et al (2009) [1], they analyzed of the temperature stratification inside an Integrated Collector Storage Solar Water Heater (ICS-SWH) was carried out. The system takes the form of a rectangular-shaped box incorporating the solar collector and storage tank into a single unit and was optimized for simulation in Scottish weather conditions. A 3-month experimental study on the ICS-SWH was undertaken in order to provide empirical data for comparison with the computed results. Using a previously developed macro model; a number of improvements were made. The new model was able to compute the bulk water temperature variation in different SWH collectors for a given aspect ratio and the water temperature along the height of the collector (temperature stratification).

Hussain Al-Madani (2006) [2], designed and manufactured of A cylindrical solar water heater. It consists of a cylindrical tube made from high quality glass having a length of 0.8, 0.14m outer diameter and a thickness of 6 mm. A copper coil tube in the shape of spiral rings, with the tube inner diameter of 2mm and outer diameter of 3.175 mm, painted black, serves as a collector to the incident solar energy on the cylinder wall. The thermal performance was evaluated throughout the months of March and April 2002; a maximum temperature difference of 27.8 1C between inlet and outlet of the solar water heater at a mass flow rate of 9 kg/h was achieved. The maximum efficiency calculated value during the experimental period was found to be 41.8%.

E. Ekramian and et al (2014) [3], they were used the numerical analysis to investigate the effect of different parameters on thermal efficiency of flat plate solar collectors such as absorber thickness, riser position, shape of tube cross section, absorber material, absorber absorptivity, glass transmissivity, and mass flow rate have been investigated. Results show that the efficiency of collector with risers on top of the absorber plate is 4.2% more than that of the collector with risers on bottom. Also the tube cross-sectional geometry shows strong effect on the efficiency e.g. the efficiency of collectors with circular tubes is 38.4% more than that of collectors with triangular cross sections. Thermal efficiency of solar collectors increases with increasing the fluid flow rate, plate absorptivity, absorber thickness, and glass transmissivity.

Y. Tripanagnostopoulos and M. Souliotis (2004) [4], they compare ICS solar systems with cylindrical water storage tank and different mountings of it in a symmetric CPC or involute reflector trough. The design, construction and experimental results from four ICS systems regarding water temperature profile, mean daily efficiency and thermal losses during night are presented and discussed. During tests they have recorded solar radiation, ambient temperature, water temperature in different locations inside the storage tank and also wind speed. The results show that during the day the ICS systems with a horizontal tank present a satisfactory performance in water temperature rise and heat preservation in water storage tank during night. Regarding reflector types, the ICS models with CPC reflectors achieve higher mean daily efficiency, while models with involute reflectors present high efficiency only in low operating temperatures.

Y. Tripanagnostopoulos and M. Souliotis (2004) [5], they are designed the new types of ICS solar systems and outdoor tests of experimental models were performed. The systems consist of single cylindrical horizontal water storage tanks placed inside stationary truncated asymmetric CPC reflector troughs of different design. We used high emittance absorber surface, low cost curved reflectors, iron oxide glazing and thermal insulation at the non-illuminated tank surfaces, aiming towards cost effective ICS systems with satisfactory heat preservation during the night. Four experimental models of different designs were constructed and tested to determine their performance regarding their mean daily efficiency and thermal losses during the night. The new ICS systems were compared to an ICS system with symmetric CPC reflectors of similar construction and dimensions and also to a typical Flat Plate Thermosiphonic Unit (FPTU). Test results showed that the ICS systems with asymmetric CPC reflectors present almost the same mean daily efficiency and better preservation of hot water temperature during the night, compared to the ICS system with the symmetric CPC reflectors. The comparison with the FPTU system confirmed the satisfied daily operation of all ICS systems and their moderate storage heat preservation during the night. Theoretical results showed acceptable thermal performance of all ICS systems regarding annual operation.

The aim of the present work is to assess the performance of the Integrated Collector Storage Solar Water Heater (ICS-SWH) designed and manufactured in the Alternative and Renewable Energy Research unit, at the Technical Engineering College of Najaf. Where the collector box has a trapezoidal shape and the upper face is covered by glass and it is inclined horizontally by a slope of 30^0 and it is oriented to the south of Najaf city. Many researchers have discussed using different shapes and orientations of collectors. For instance, [3,4,5] have investigated the improvement of solar collector to enhance heat transfer in water, however, our work mainly aims to minimize the cost by using second hand materials and reduce or eliminating the manufacturing cost of the storage tank. For example, in our work we used an old electrical water boiler tank which is relatively cheap and significantly effective and appropriate to be implemented in weather in Iraq.

The results demonstrate the utilization of the solar energy for domestic purposes and encourage the public to use similar systems. In spite of the fact that Iraq is very suitable for utilizing solar energy to heat water, it is not yet widely applied. This is due to two reasons, namely the availability and low cost of the conventional energy sources, and the lack of knowledge among the public of the application of solar energy, its technology and advantages.

2. EXPERIMENTAL

2.1. Description of The Passive Water Heater Integral-Collector Storage Systems

The solar water heater used in this work has been designed and construction as Integral-collector storage systems (ICS-SWH) (batch type design) as shown in figure 1 by using old used material with law cost. Where consist of a collector box that works as container of receiver cylinder and a cylinder work as the receiver of solar energy to heat the water flows. The cylindrical water tank is made of steel and it is placed inside the collector box and acts as the collector. The objectives of this work are construction solar water heater with minimum law cost and work in Iraq weather.

2.2. The Instruments Used To Test the ICS-SWH

We used six channels Digital thermometer in six locations (inlet of water, outlet of water, class cover, two on the surface of tank, and outside ambient temperature) to measure the temperature as shown in figure 2, as well as measure the volume flow rate of water out. Also used the data recorded of solar radiation and ambient temperature by weather station in alternative and renewable research unit in technical Engineering College of Najaf. All this experimental data used to study the performance and calculation efficiency of solar water heater.

3. THE COST OF CONSTRUCTION OF THE ICS-SWH

The total cost of construction of integral-collector storage - solar water heater (ICS-SWH) a little than the other types of solar water heat design, where the cost about (62000 ID = 50$ USA) by using old used material (second hand). We would recommend it as an excellent source of hot water or as a supplement to conventional water heating systems and very cheap can be used in Iraqi home.

4. CALCULATION OF THE PERFORMANCE

To evaluate the performance of the cylindrical solar water heater the instantaneous efficiency will be calculated to determine the useful energy gained and hourly beam radiation. The detail of the procedure used here is reported as following:

4.1. Instantaneous Efficiency

The instantaneous efficiency of the Integral-collector storage system (ICS) water heater is defined as the ratio of useful energy gain to the solar energy received by the wall of the glass surface (collector). It can be obtained from the following equation:[3]

$$\eta_i = \frac{Q_u}{A_c I_b} \quad (1)$$

Where:

Q_u is energy gain (W)

A_c is the collector area (m^2)

I_b is solar radiation (W/m^2)

In the present work the equivalent collector area of the glass surface solar water heater is $1.2784 m^2$.

4.2. Useful Energy Gained, Q_u

At steady state, the Integral-collector storage system (ICS) can be described by an energy balance equation that relates useful energy gain, Qu can be calculated from the following equation:

$$Q_u = m^{\cdot} cp(T_o - T_i) \tag{2}$$

Where:

$m^{\cdot}$ is mass flow rate (kg/s)

cp is specific heat at constant pressure (J/kg*K)

T_o is outlet water temperature (K)

T_i is inlet water temperature (K)

5. RESULTS AND DISCUSSIONS

Performance and testing of the Integral-collector storage system (ICS) solar water heater has been carried out throughout the months of March 2015 for five days are (13/3, 14/3, 24/3, 27/3, and 28/3). The global solar radiation variation for five days for year 2015 based on day time only is shown in Figs. 3, 4, 5, 6, and 7. This is the measurable amount of solar energy that reaches the ground. Data given here are taken from Weather station in alternative and renewable energy research unit in technical Engineering college of Najaf. Hence, solar energy has great potential for use even during winter time. The maximum solar radiation is 890 W/m^2 at 12:30 am, while Fig. 5 shows fluctuation in solar energy because this day is cloudy.

5.1. Experimental Measurements of the Temperature

During the experimental period, the following measurements were carried out on daily basis: the data of days 13,14,24,27, and 28 March 2015only are reported. Figs. 8-12 show the variation of the ambient temperature (Tamb), water inlet temperatures (Tin), water outlet temperatures(Tout), water tank wall temperature near inlet (Ts2), water tank wall temperature near outlet (Ts1), and class cover (collector surface) temperature(Tg) with time from morning 8:00 am to afternoon 5:00 pm. As time progresses, the temperature increases to reach the maximum temperature between 11 am and 12:00 pm, for the days 13,14,24,27, and 28 March, respectively.

Then for all days the ambient temperatures drop as the time passes. Ambient temperature has a strong effect on water inlet temperature because inlet temperature increases with the rise of ambient temperature. This effect will increase the useful energy gained so the efficiency of the solar water heater will also increase.

5.2. Temperature Difference of Solar Water Heater

The measurements of the temperatures difference (Tout–Tin) between inlet and outlet of water are shown in Fig. 13, which represents the temperature rise through the solar water heater versus time. The figure indicates that water temperature rise reaches maximum temperature of 36.3 ^{0}C during the day at about 1:30 pm for the 27 March 2015, 32.9 ^{0}C during the day at about 2:00 pm for the 28 March 2015, 20.6 ^{0}C during the day at about 2:00 pm for the 24 March 2015, 31.1 ^{0}C during the day at about 3:00 pm for the 14 March 2015 and 11.3 ^{0}C during the day at about 1:30 pm for the 13 March 2015. It should be mentioned here that the mass flow of the water in all the days are shown in table 1.

This could be a reason for this difference between the all days. It is clear from the figure 4.11 that water temperature increases as time proceeds. If it is assumed that inlet temperature is fixed during the day, then temperature difference reaches maximum value between 12:30 am and 2:30 pm because it is the hottest period of the day during which the experimental work was carried out.

5.3. The Efficiency of ICS Solar Water

The efficiency of the ICS solar water heater versus time is unsteady as shown in Figs 14-18. The maximum value of the efficiency for time (12:00am to 1:30pm) for the day of 27 March 2015 is 52% while for the day of 13 March 2015 is 10%. In the morning small amount of solar energy arrive the collector so that the efficiency is very low and then will be increases after 10:30 am, also the efficiency depending upon the mass flow rate of water and ambient temperature.

6. Conclusions

Today, hundreds of thousands of modern solar water heaters are in use throughout the world. While the initial purchase and installation cost of a solar water heater is higher than an equivalent conventional water heater this extra cost can be recovered over a period of time through lower energy bills.

Solar energy can reduce the national demand for conventional fuels, reduce the damage to the environment, as it is a non-polluting free energy, and reduce the need to build new power stations which require huge investment.

The Integrated Collector Storage solar water heater has been designed and its performance evaluated. A maximum temperature difference of 36.3 ^{o}C between inlet and outlet at water mass flow rate of 9 kg/h was observed. The efficiency of the integrated collector storage solar water heater was calculated. The maximum value during the experimental period was found to be 52%. This strongly suggests a good capability of the system to convert the solar energy to heat which can be used for heating water.

A major advantage of this system is used old material (second hand). The cost of manufacturing the integrated collector storage water heater is 60000 ID (50$) while a flat plate collector with similar capacity of flowing water (9–15.6 kg/h) costs 450000 ID (358$).

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Fig. 1. Assembling of solar water heater

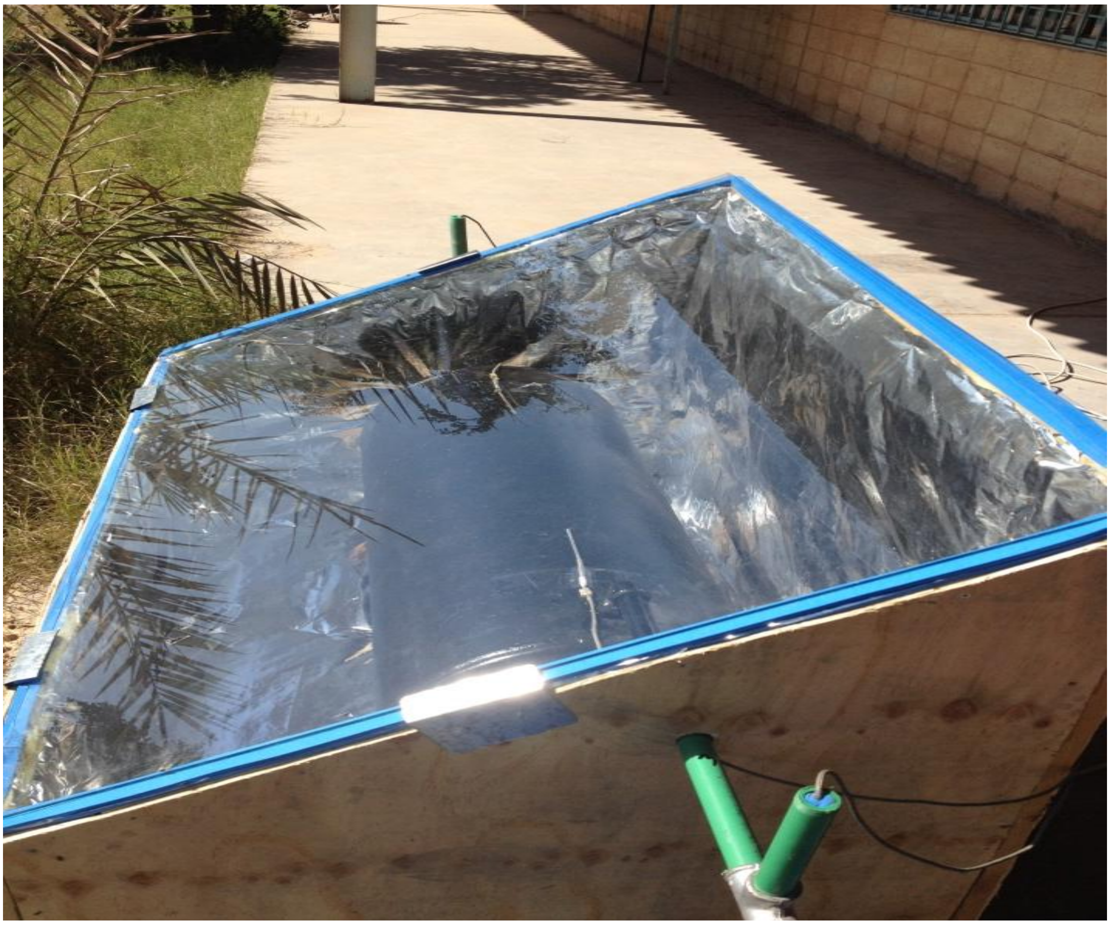

Fig. 2. The solar water heater during operation

Table I
The mass flow rate of Water variation with time

Time	Mass flow rate (kg/s) 13/3/2015	Mass flow rate (kg/s) 14/3/2015	Mass flow rate (kg/s) 24/3/2015	Mass flow rate (kg/s) 27/3/2015	Mass flow rate (kg/s) 28/3/2015
8	**0**	**0**	**0**	**0**	**0**
8.5	**0**	**0**	**0**	**0**	**0**
9	**0**	**0**	**0**	**0**	**0**
9.5	**0**	**0**	**0**	**0**	**0**
10	**0.00166**	**0.00166**	**0**	**0**	**0**
10.5	**0.00166**	**0.00166**	**0**	**0.00194**	**0.00194**
11	**0.00166**	**0**	**0.00305**	**0.00194**	**0.00222**
11.5	**0.00166**	**0.002222**	**0.003611**	**0**	**0**
12	**0.00166**	**0.002777**	**0.003611**	**0**	**0**
12.5	**0.00166**	**0**	**0.003611**	**0.00305**	**0.0025**
13	**0.00166**	**0**	**0.003611**	**0.003611**	**0.0025**
13.5	**0.00166**	**0.0025**	**0.003611**	**0**	**0**
14	**0.00166**	**0.002777**	**0.003611**	**0.00277**	**0**
14.5	**0.00166**	**0**	**0.003611**	**0.00277**	**0.00305**
15	**0.00166**	**0.001388**	**0.003611**	**0**	**0**
15.5	**0.00166**	**0.001388**	**0.003611**	**0**	**0**
16	**0.00166**	**0.001388**	**0**	**0.001388**	**0**
16.5	**0.00166**	**0.001388**	**0**	**0**	**0.00222**
17	**0.00166**	**0.001388**	**0**	**0**	**0**

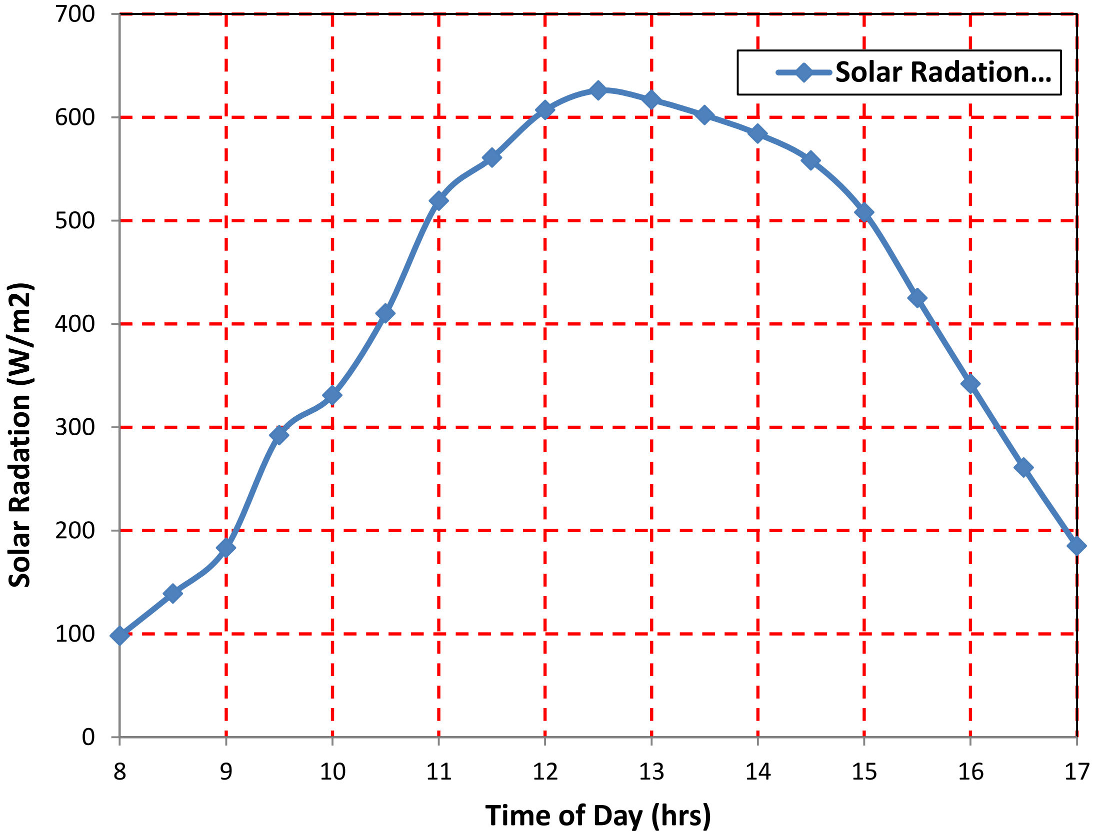

Fig. 3. The global solar radiation (13/3/2015)

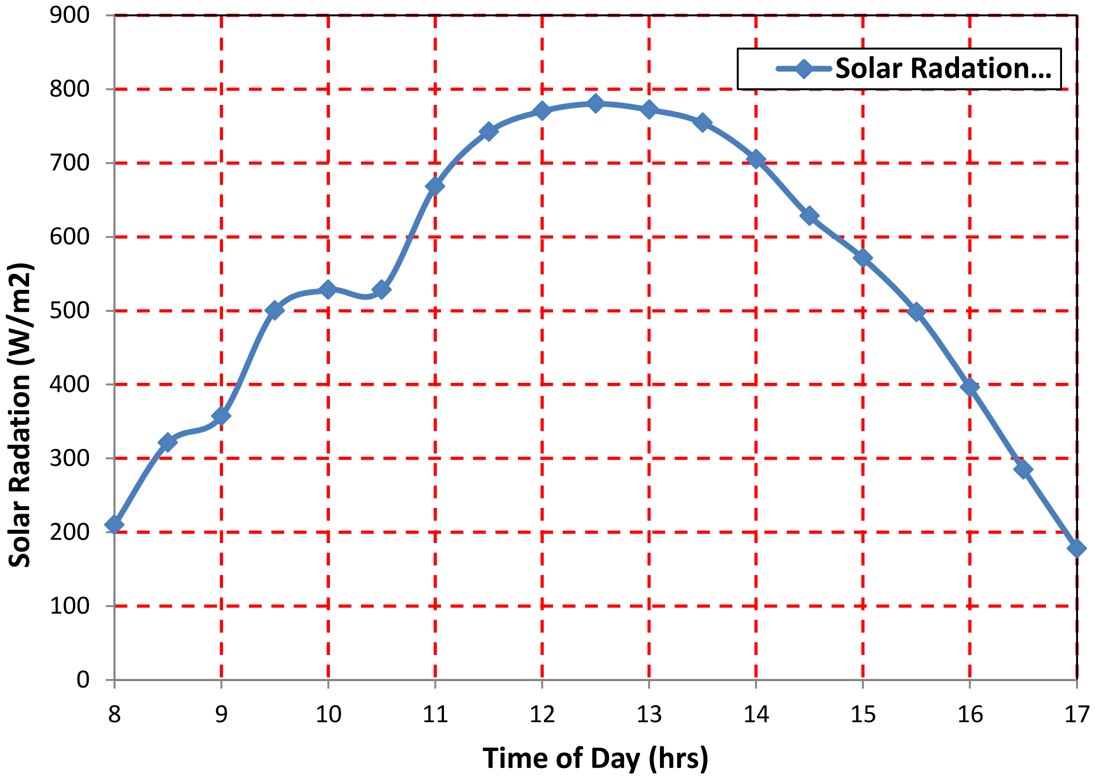

Fig. 4. The global solar radiation (14/3/2015)

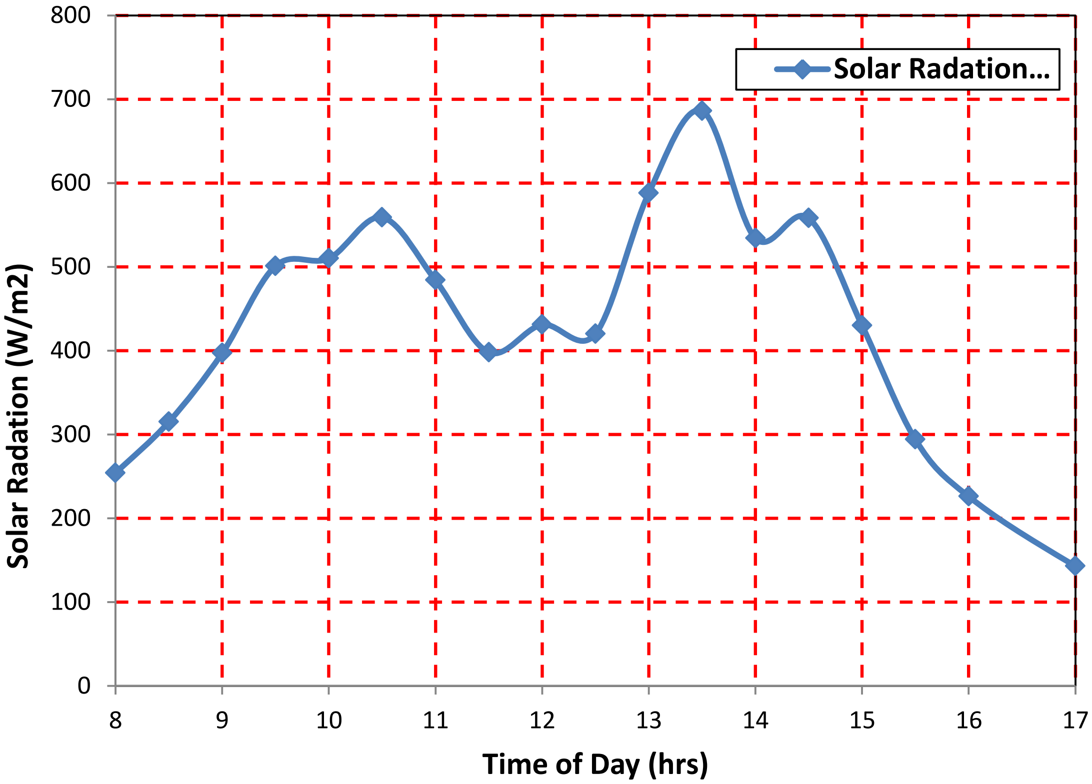

Fig. 5. The global solar radiation (24/3/2015)

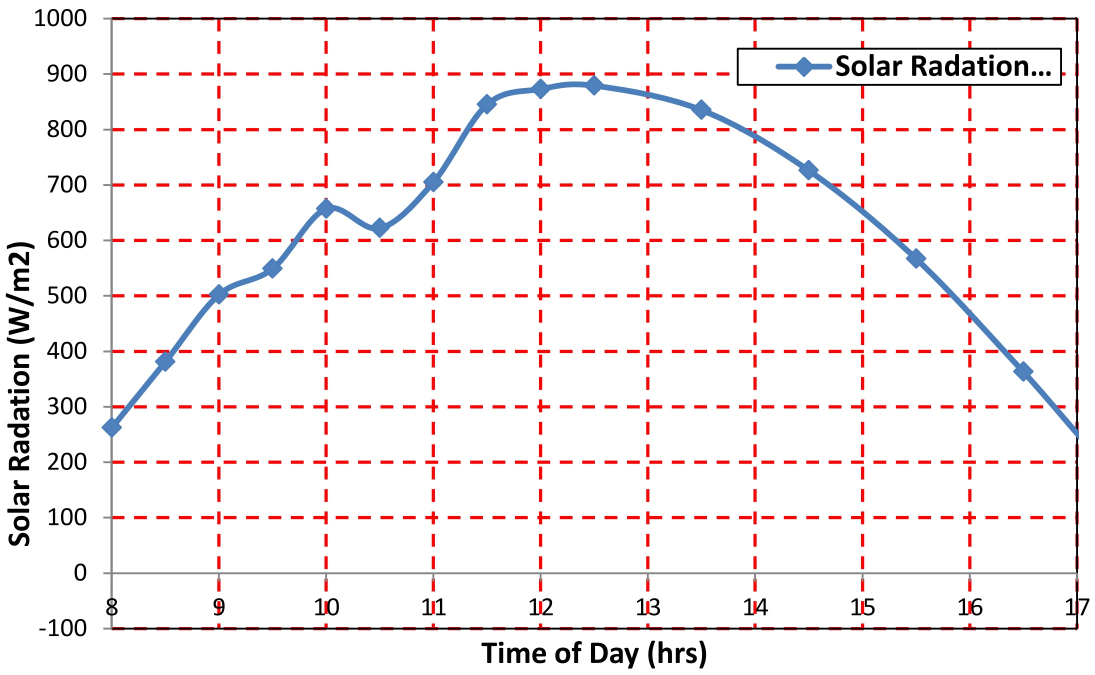

Fig. 6. The global solar radiation (27/3/2015)

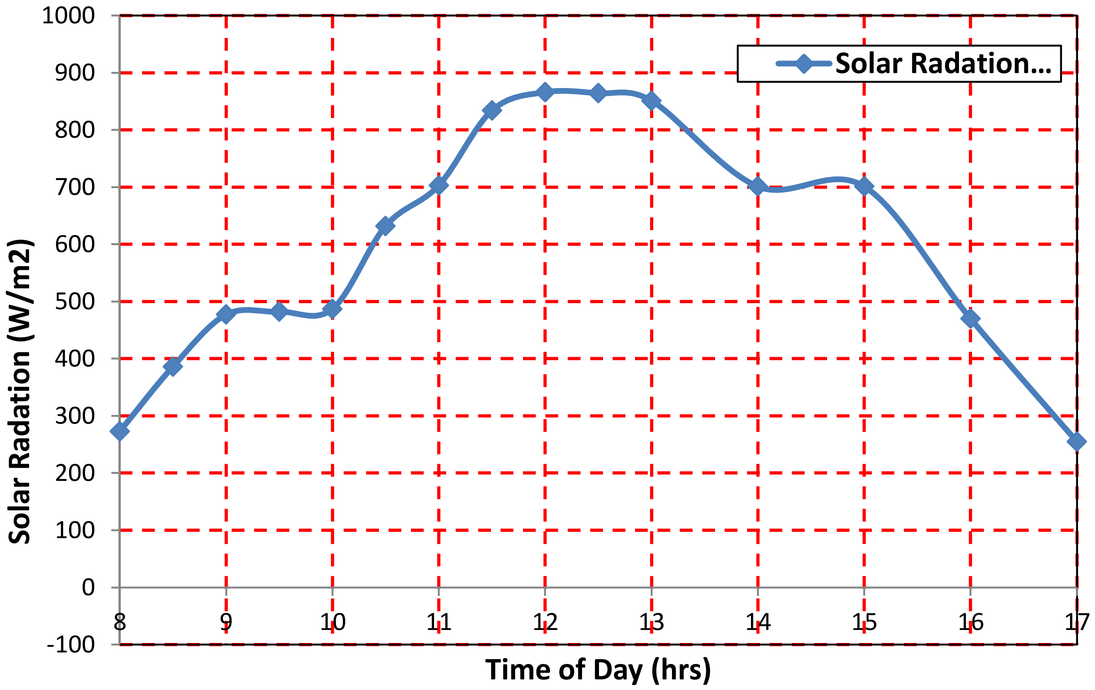

Fig. 7. The global solar radiation (28/3/2015)

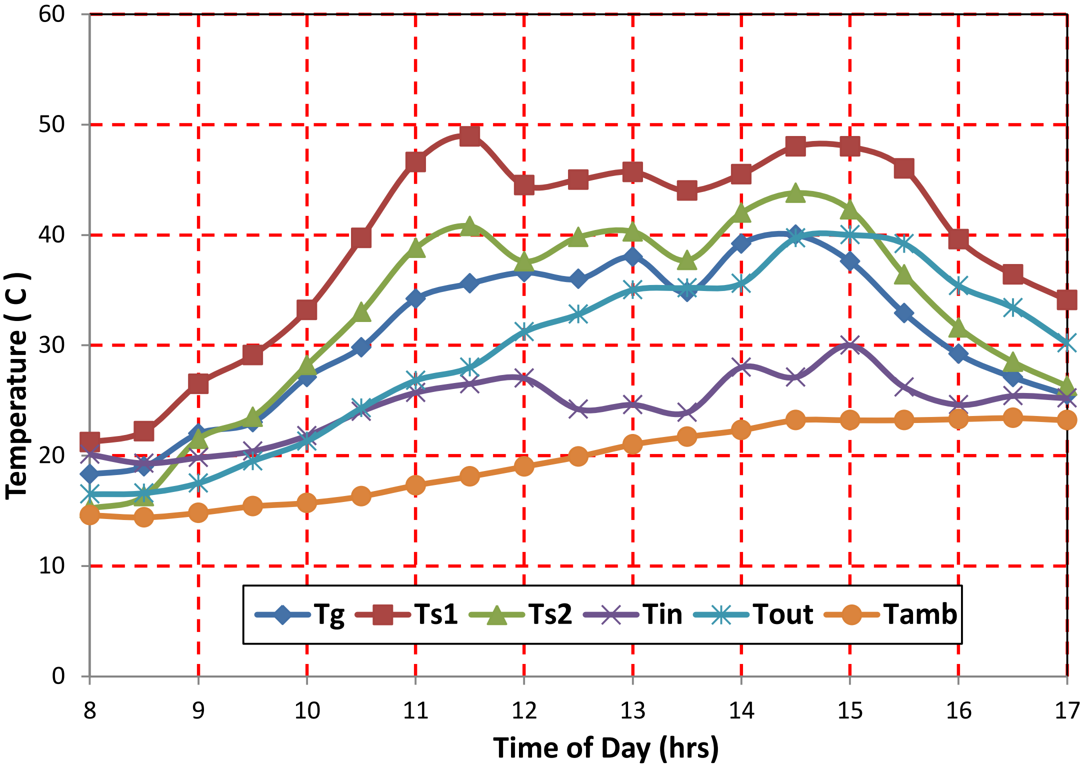

Fig. 8. The Temperatures variations (13/3/2015)

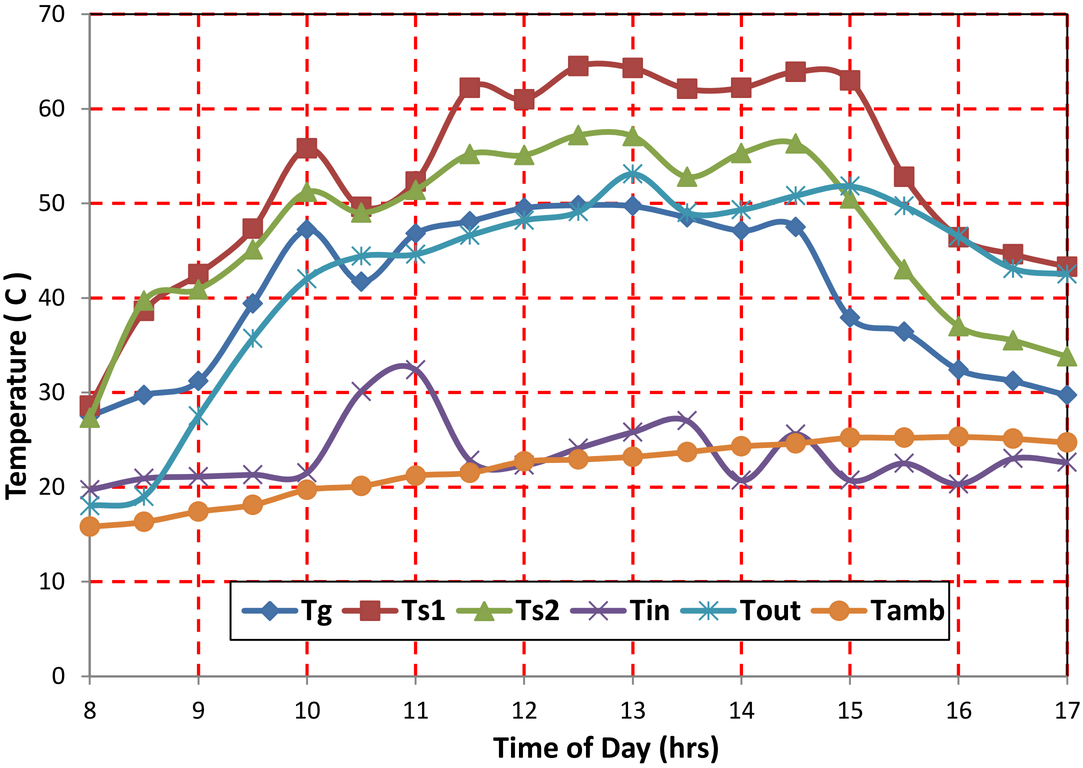

Fig. 9. The Temperatures variations (14/3/2015)

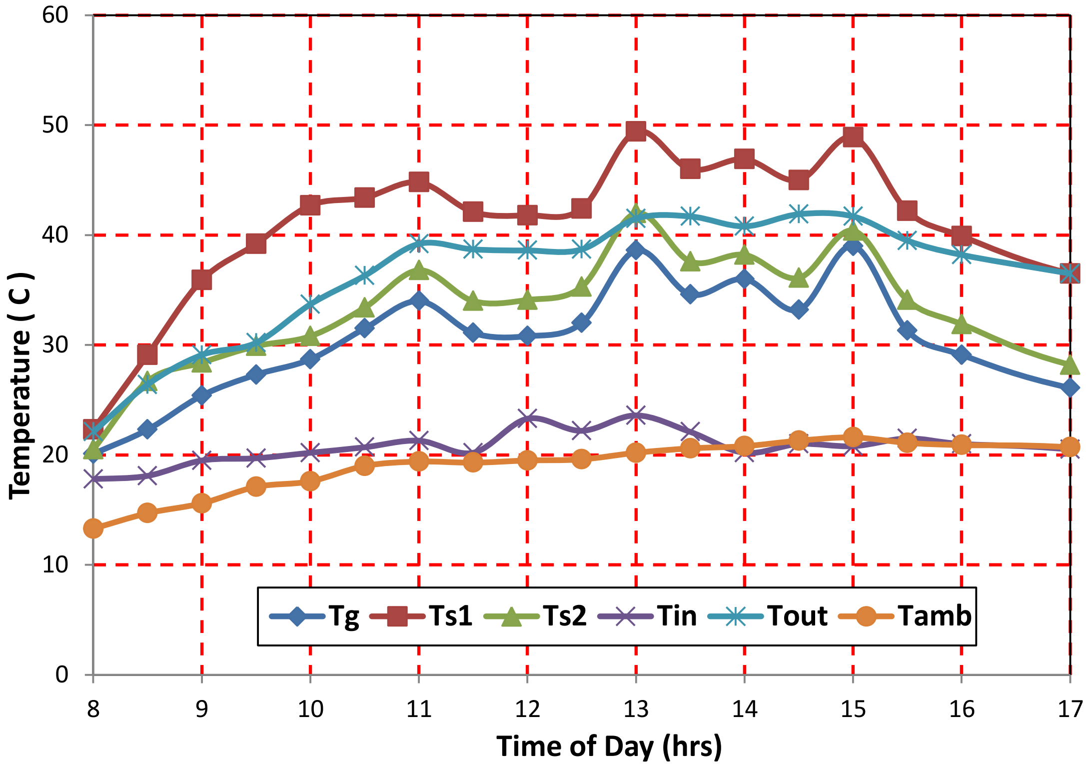

Fig. 10. The Temperatures variations (24/3/2015)

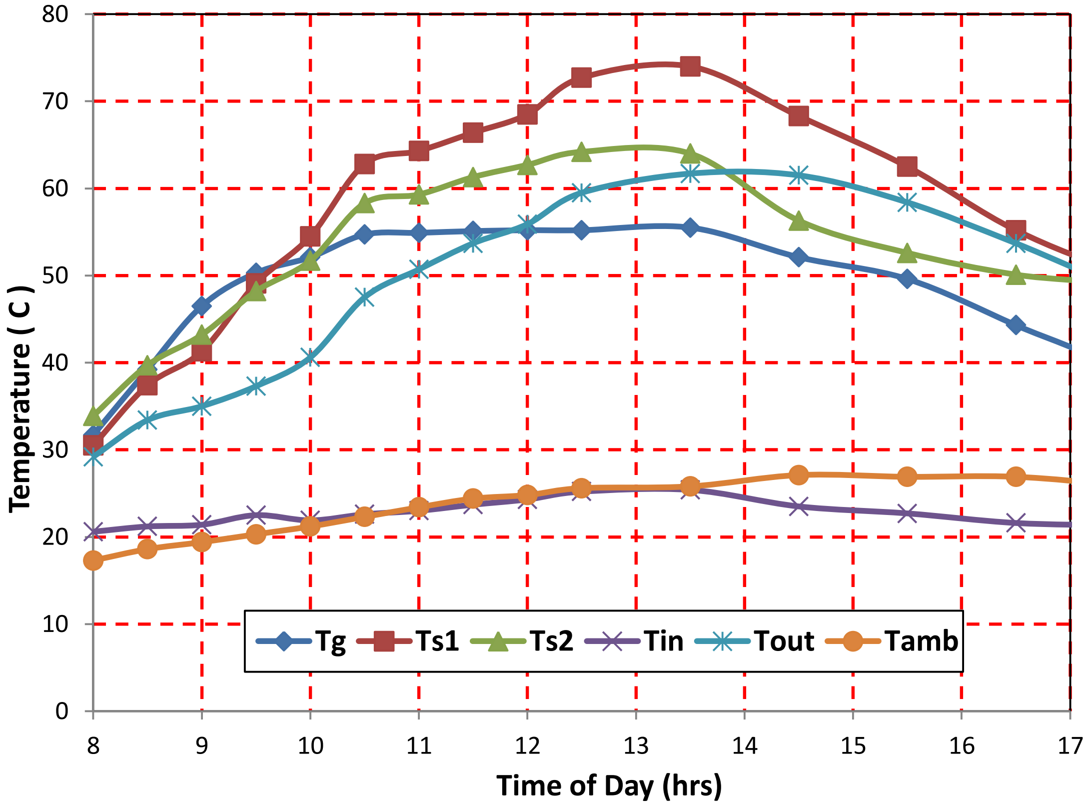

Fig. 11. The Temperatures variations (27/3/2015)

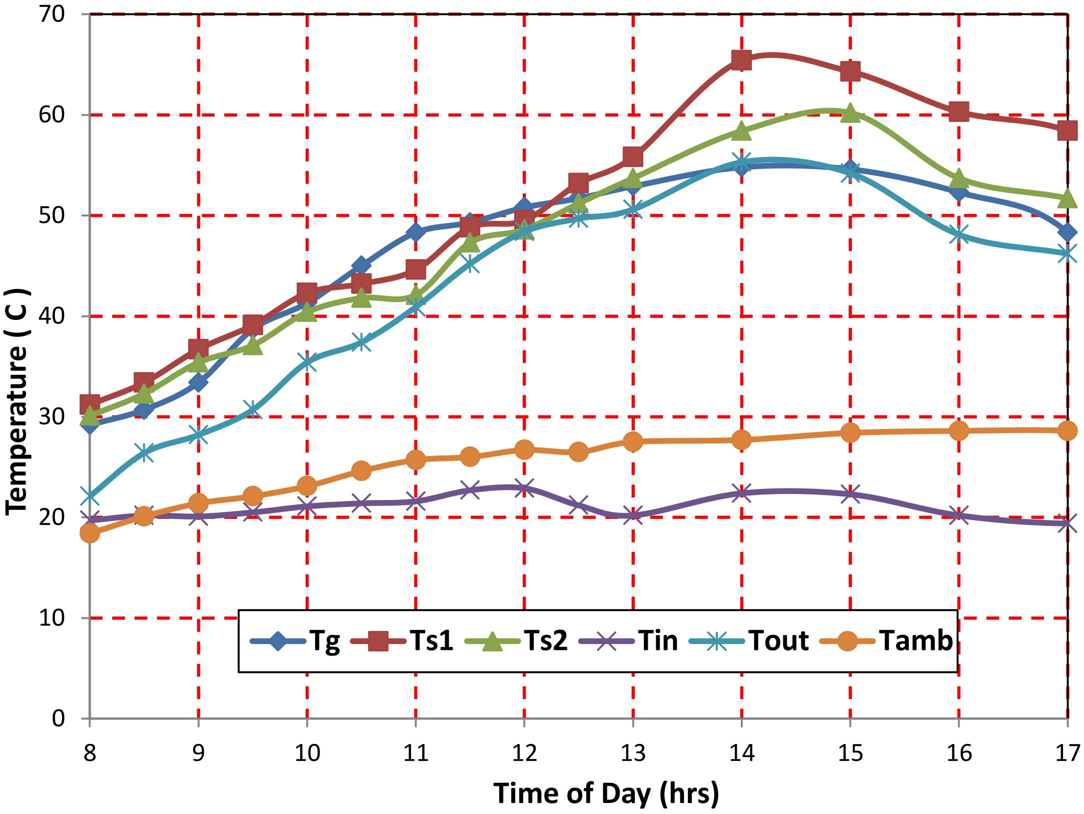

Fig. 12. The Temperatures variations (28/3/2015)

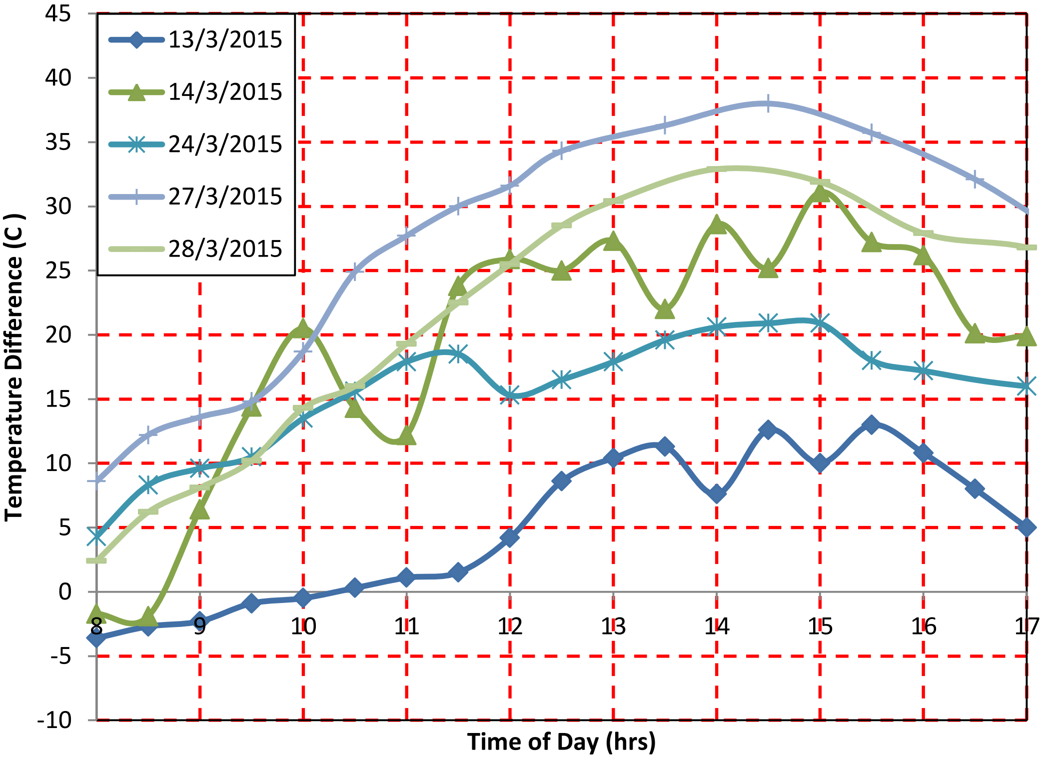

Fig. 13. Temperature difference between input and output of the solar water heater.

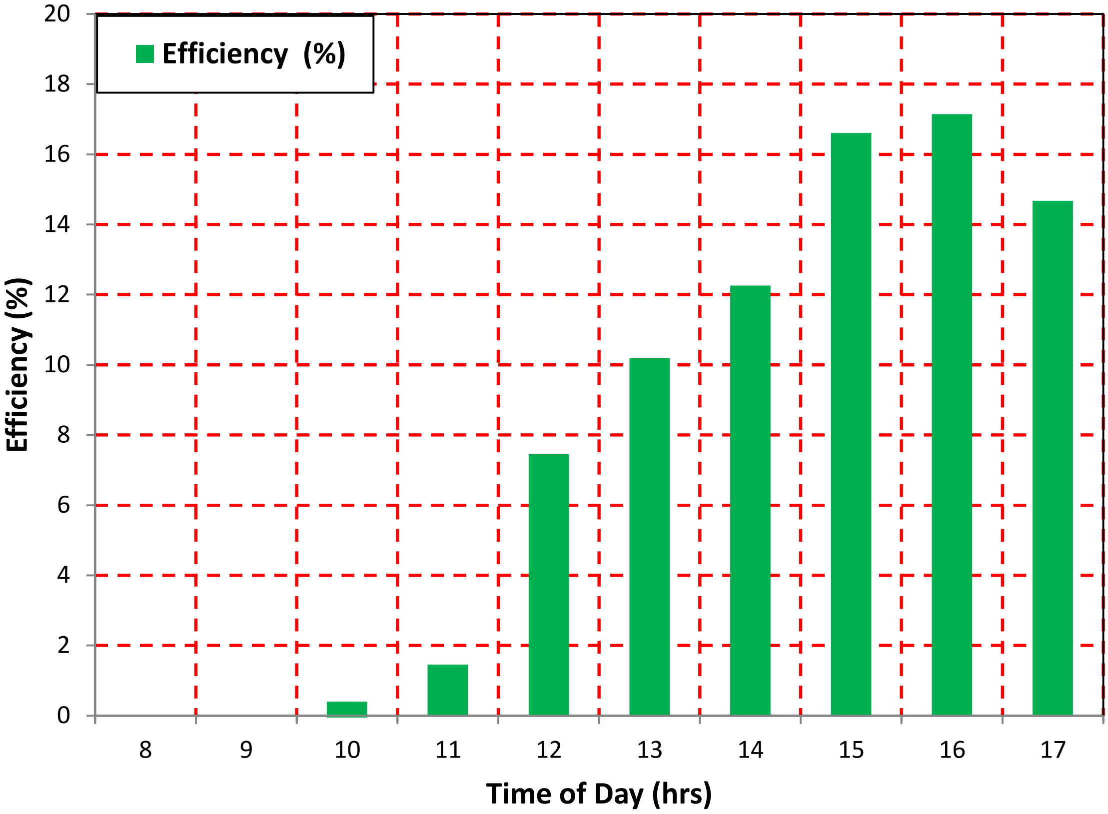

Fig. 14. The instantaneous efficiency of the Integral-collector storage system (13/3/2015)

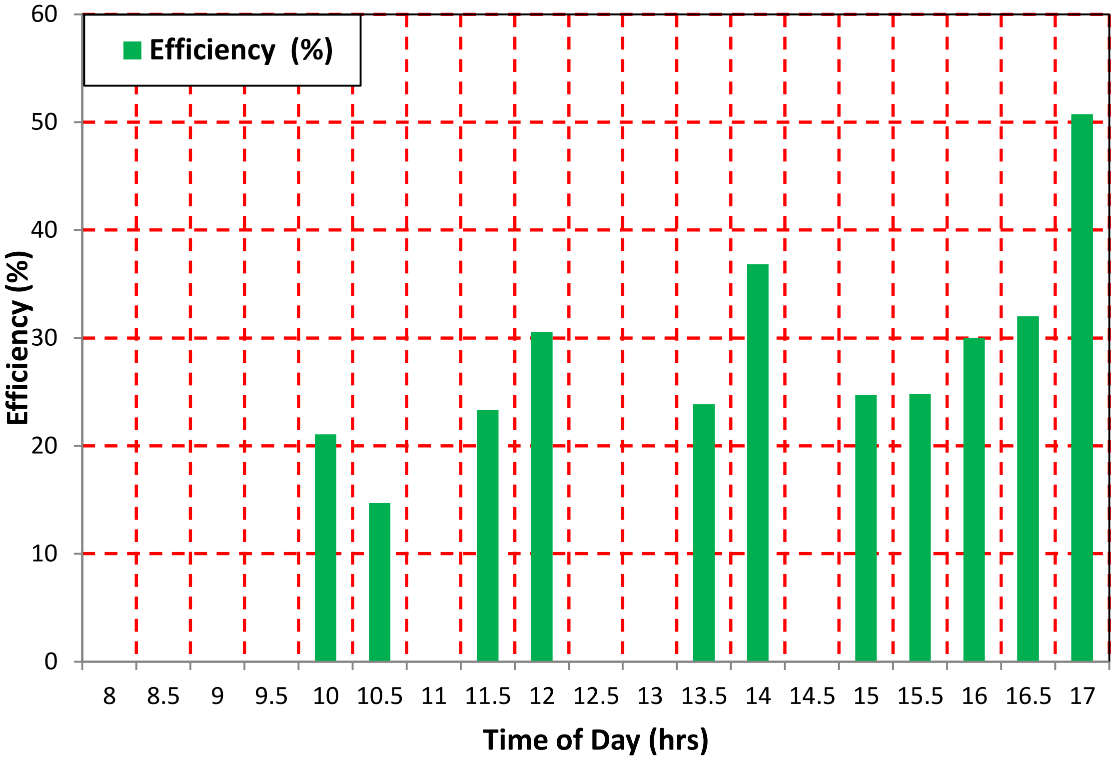

Fig. 15. The instantaneous efficiency of the Integral-collector storage system (14/3/2015)

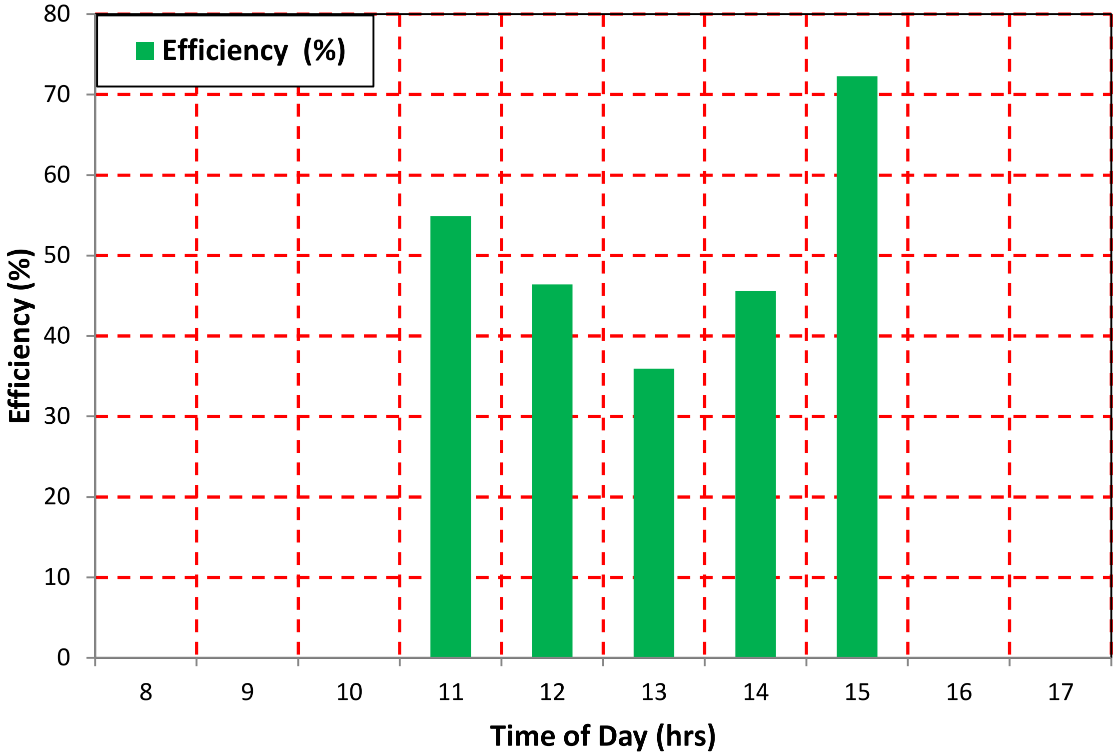

Fig. 16. The instantaneous efficiency of the Integral-collector storage system (24/3/2015)

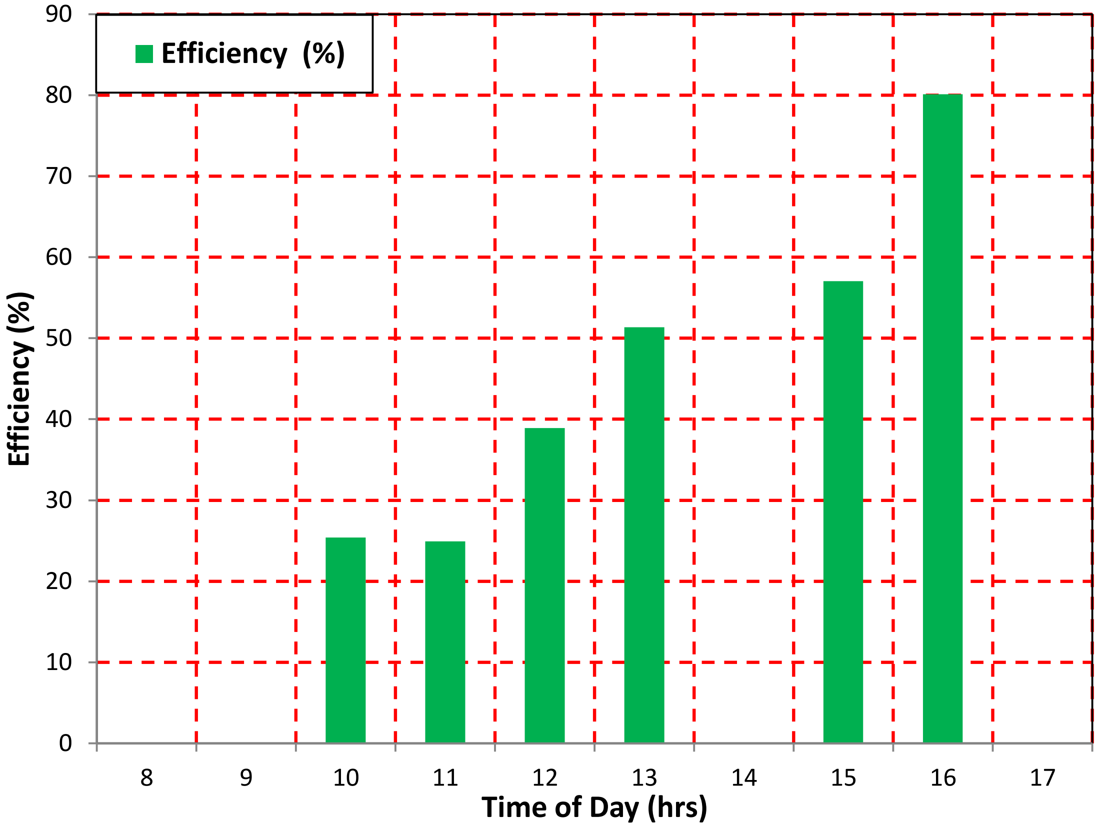

Fig. 17. The instantaneous efficiency of the Integral-collector storage system (27/3/2015)

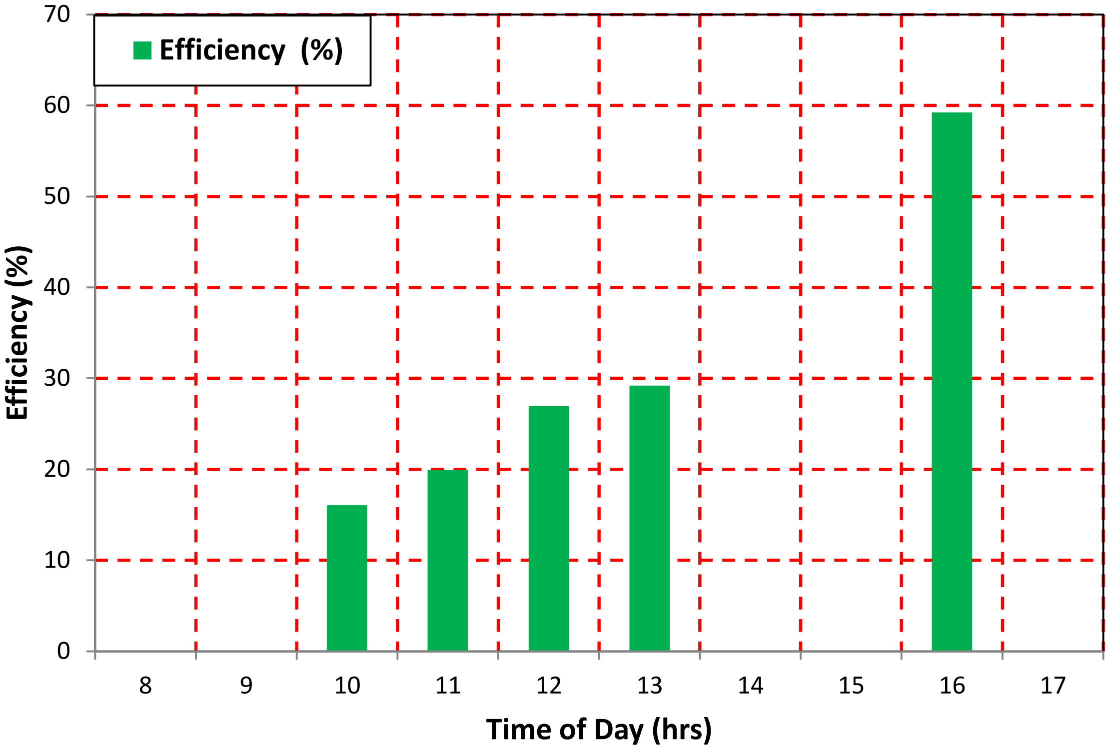

Fig. 18. The instantaneous efficiency of the Integral-collector storage system (28/3/2015)