Int. J. of Thermal & Environmental Engineering
Volume 3, No. 1 (2011) 47-51

Design, Construction and Operation of Solar Heating Coil

R. Abu-Mallouh[a,]*, O. Badran[b], S. Abdallah[a], Y. Abdellatif[a]

[a] *Applied Sciences University, Amman 11931, Jordan*
[b] *Al-Balqa Applied University, Amman, Jordan*

Abstract

In this work a novel design of a solar heating system is suggested, which is the solar heating coil. A computerized sun tracking system was used for rotating the solar heating coil with the movement of the sun. An experimental study was conducted to investigate the performance of the solar heating coil with two axes tracking and without tracking. The results indicate that in the case of exposing the SHC to the sun for 30 minutes, the heating coil with two axes tracking can increase water temperature from 24 ºC to 91 ºC, while the heating system without tracking can increase water temperature from 24 ºC to 57 ºC.

Keywords: *solar heating coil, sun tracking*

1. Introduction

Jordan is a developing country located in the Middle East, but it suffers from a scarcity of oil and gas resources. The significant increase in global demand for energy has driven the cost of energy to unprecedented levels. The ramifications of this large increase in energy cost, will present serious challenges to personal, and institutional budgets. In addition Jordan has an excellent mean solar radiation on horizontal surfaces of 5.5-6 Kwh/m2/day as compared to Europe and most of North America which amounts to 3.5 Kwh/m2/day.
The solar water heating industry in Jordan is well developed. By 1999, about 25% of homes (i.e., 2.3 x 105 homes) had been fitted with solar water heaters, leading to savings of approximately 2% of the total oil imports, estimated to worth about US $12 million annually [2].
Abdallah and Nijmeh [2] designed a one axis sun tracking system with programmable logic controller in three modes of operation: rotation about east-west, north-south and vertical axes. There was an increase in the daily measured solar energy of up to 19.7%, 23.3% and 24.5% for the north-south, vertical and east-west tracking, respectively, as compared to a 32o inclined surface to the south. Mamlook et al [4] used fuzzy set methodology to perform comparisons between different solar systems for various applications in Jordan. Neville [5] presented a theoretical comparative study between the energy available to a two axes tracker, an east-west tracker and a fixed surface. Hession and Bonwick [6] presented a sun tracking system for use with various collectors. The system used both analog and digital techniques with sun sensing phototransistors which resolved the sun's position to a precision of better than 0.10. Baltas et al [7] made a comparative study between continuous, and stepwise tracking. They showed that unlike concentrating systems, FPPV arrays yielded almost the same energy when tracking in a stepwise fashion. Tracking motors could be idle for one or two hours, yet obtain more than 98% of the energy obtained from a continuous tracking array. Bruntte et al [8] presented a prototype two-stage photovoltaic concentrator with concentration ratios up to 300X one axis tracking. Khalifa and Al-mutwalli [9] performed an experimental study to investigate the effect of using a two axes sun tracking system on the thermal performance of compound parabolic concentrators. This work presents a novel design of water solar heating system, which consists of a spiral circular tube, which in turn is made of a blackened copper pipe with an automatic two axes system.

2. Mechanical design of solar heating coil

Fig. 1 shows a schematic diagram of the proposed solar heating coil. The solar heating coil consists of a copper pipe, which is black painted and formed into a circular spiral shape. The coil is placed in a dish which serves as a base that carries the copper pipe. The pipe is approximately 40 meters in length, with a diameter of 10 mm and a separation of 2mm between adjacent loops. This modified design of the solar collector which replaces the common flat plate collector will provide an extra contact surface with solar radiation, and will definitely provide more heat and mass transfer area. Fig. 2 shows the front and rear views of the solar heating coil with a two axes tracking system. The proposed SHC operates in the following manner: A pump, driven by a 12 VDC motor is used to pump cold water from the source tank into the solar heating coil. In this design, the DC motor is powered by a photovoltaic system.

[*] Corresponding author.
E-mail: riad_abumlwah@asu.edu.jo

DOI:10.5383/ijtee.03.01.008

The pumped water will remain in the SHC for 30 minutes, after this time the pump will operate again to drain the hot water through the hot water outlet and into the collection tank. The mechanical design of the proposed SHC applies the following principles:

1) Converting light into heat, directly through the huge contact area of the circular spiral tube which absorbs almost all of the incident sunlight and turns it into heat.
2) Trapping heat, by using a glass cover to protect the SHC from heat removing wind.
3) Isolation is used for the backside of SHC.

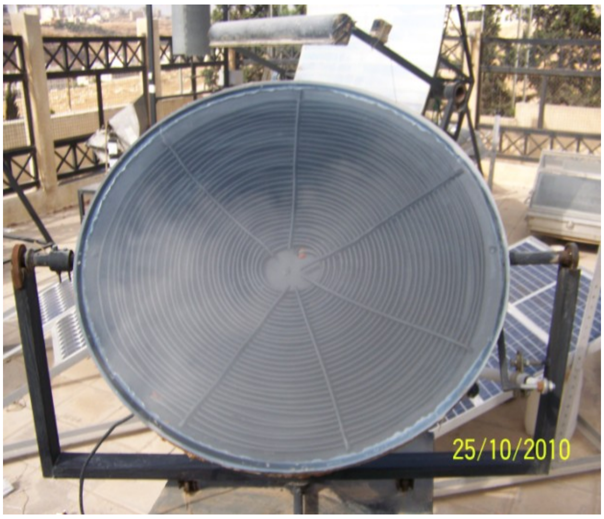

Figure 1. A two-axes tracking system, is used to maximize the incident solar radiation into the SHC.

Figure 2 (a). Rear view of the constructed system

Figure 2 (b). Front view of the constructed system

3. Electromechanical system of the SCH

The electromechanical system consists of two drivers as shown in Fig. 3. The first uses the drive motor (M1) for the joint rotating around the vertical axis to track the solar azimuth angle (γ_s) and the second uses the drive motor (M2) for the joint rotating around the horizontal axis to track the solar altitude angle (α_s).

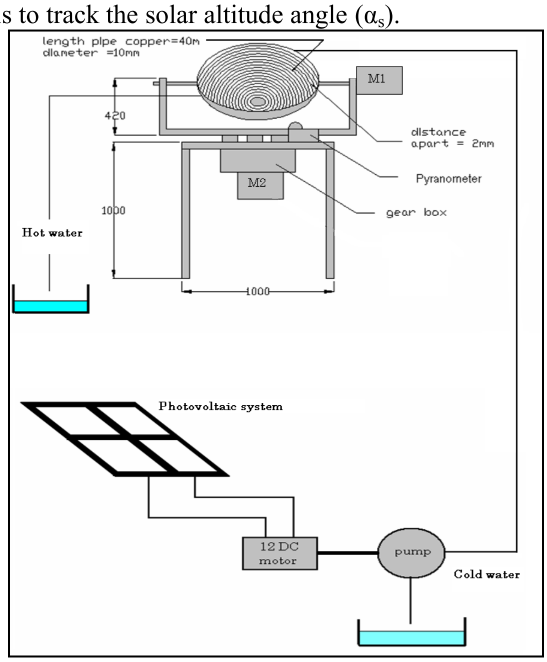

Fig. 3. The solar heating coil with a two axes tracking system

The system has two power supplies (PS1 and PS2). PS1 converts the 220 VAC of the supply network into 24 VDC to power the PLC, while PS2 converts the 220 VAC of the supply network into 24 VDC to provide the motor M2 with 24 VDC. The frequency inverter (FI) is used to provide the motor M1 with the regulated voltage and regulated frequency. The frequency inverter will work as an electrical gear to increase or reduce the speed of the electrical motor M1 to the desired speed of rotation. In this system the (LOGO 24 RC) PLC is used as a controller. This type of PLC has eight inputs and four outputs. In this system a programming method to control the dish alignment as a function of time is used. This method works in all conditions regardless of the presence of dust or clouds. To implement the programming method, the solar Azimuth angle γ_s and Zenith angle θ_z must be calculated and programmed into the PLC system.

The PLC will actuate the motor M1 through the FI and the motor M2 through the power supply PS2 so that the SHC will track the sun's position. The position of the SHC is defined by two angles β as the slope of the SHC surface and γ as the surface azimuth angle of the SHC surface. For two axes tacking , the surface positions are determined as follows: $\beta = \theta_z$ and $\gamma = \gamma_s$.

4. Experimentation and results

A continuous test during the 25th and the 27th of April 2010 from 8:40 AM to 4:40 PM local time was performed at the Renewable Energy Laboratory of the Applied Science University, Amman, Jordan. Two identical SHCs were constructed, one was mounted on a fixed surface with a 32^o tilting to the south, the other was mounted on a two axes tracking surface.

The electronic measurement instruments and devices were tested and calibrated before being used. The global solar radiation on the horizontal surface was measured using Kipp and Zonen pyranometer. Calibrated thermocouples (type-K) coupled to a digital thermometer were used to measure the temperature.

The proposed SHC operates in the following manner: The cold water is pumped into the SHC through the cold inlet of the circular tube, where the cold water will be exposed to solar radiation for 30 minutes. After that the heated water will be pumped out through the hot water outlet of the circular tube. The volume of the water inside the SHC is approximately 3.14 liters.

The electrical voltage and electrical current generated by the photovoltaic system at the input of the DC motor drives the water pump as shown in Fig. 4 and Fig. 5. Current measurement is accomplished with an ammeter (A), and voltage measurement is accomplished with a voltmeter (V). Fig. 6 presents the electrical power generated by the photovoltaic system, which is found by the multiplication of current by voltage.

Fig. 7 shows the ambient temperature measured at the site during the test period for the two days in which the experimental part was conducted. Hourly variation of solar intensity measured during the test period, is exhibited in Fig. 8. Figures 9, 10 and 11 show the measured hourly variation of inlet cold water temperature values, the hourly variation of outlet hot water temperature values and the hourly variation the SHC surface temperature values.

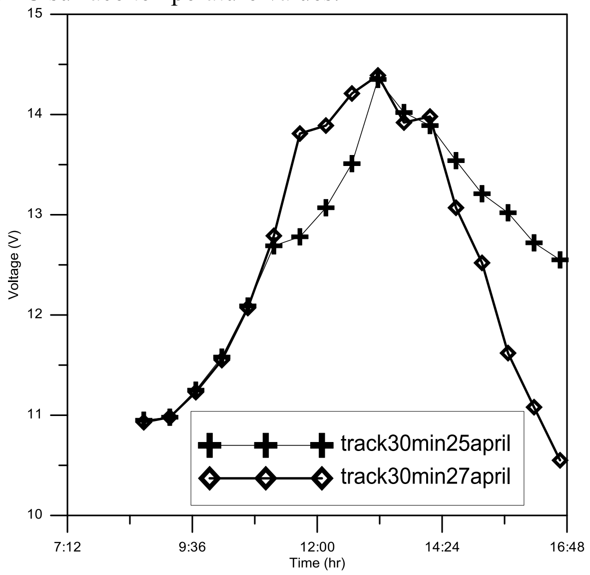

Fig.4. Variation of voltage as a function of time

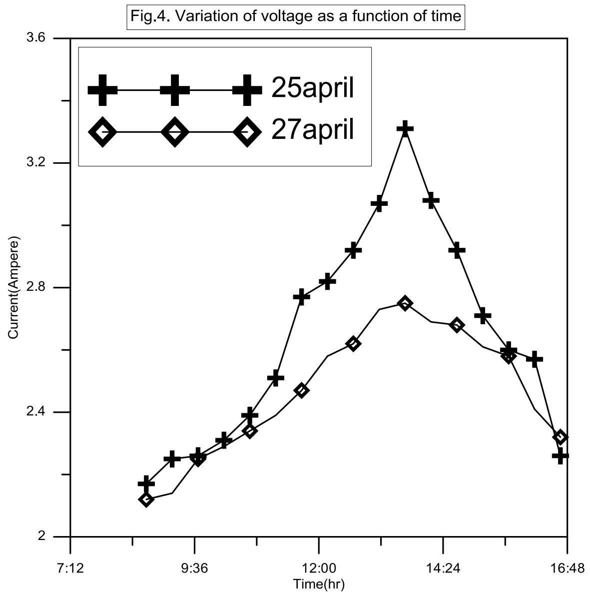

Fig.5. Variation of Current as a function of time

5. Conclusions

A novel suggested design of water solar heating system was constructed and tested under actual environmental conditions of Jordan. The solar heating coil consists of a copper pipe, black painted, in the form of circular spiral. A sun tracking system was used for rotating the SHC with the movement of the sun. The results of the experimentation indicate that in case of the exposure of the SHC to the sun for 30 minutes, that SHC with a two axes tracking system can increase the water temperature from 24 C to 91 C. While SHC without tracking can increase the water temperature from 24 C to 57 C.

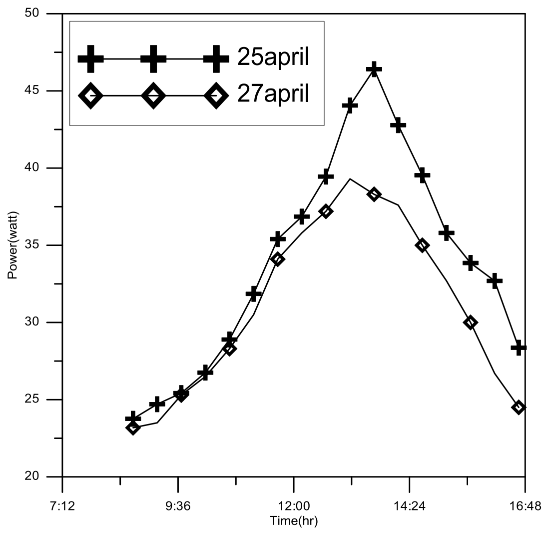

Fig.6. Variation of electrical power as a function of time

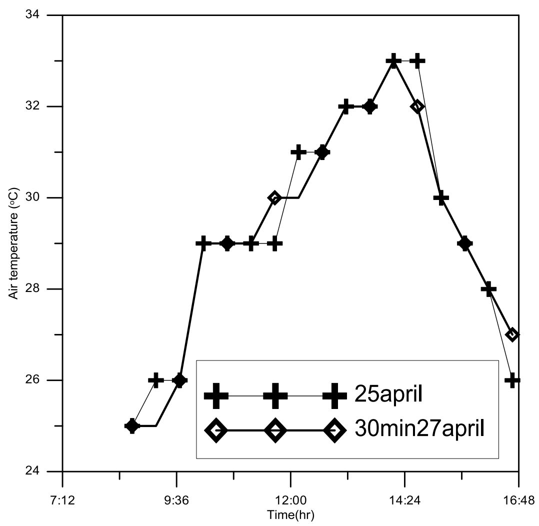

Fig.7. Variation of air temperature as a function of time

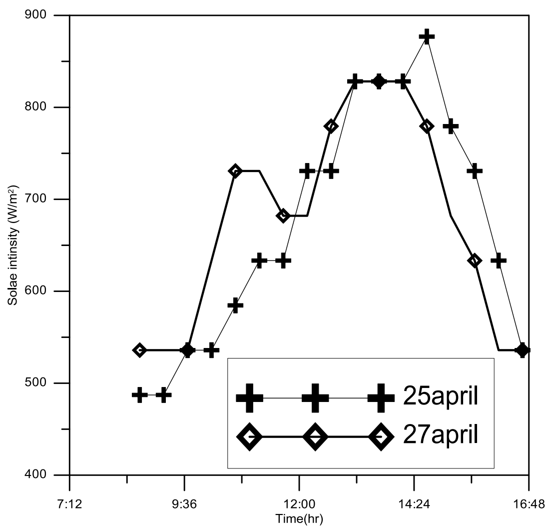

Fig.8. Variation of solar intinsity as a function of time

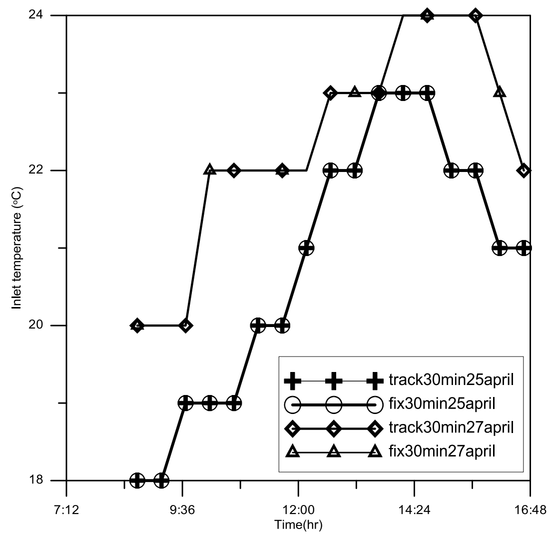

Fig.9. Variation of the inlet cold water temperature as a function of time

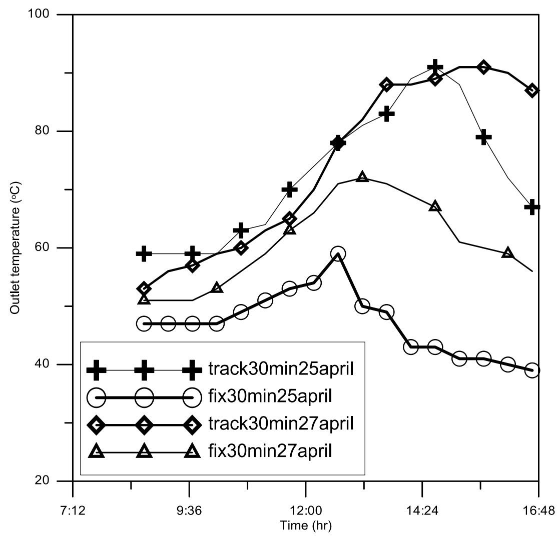

Fig.10. Variation of outlet hot water temperature as a function of time

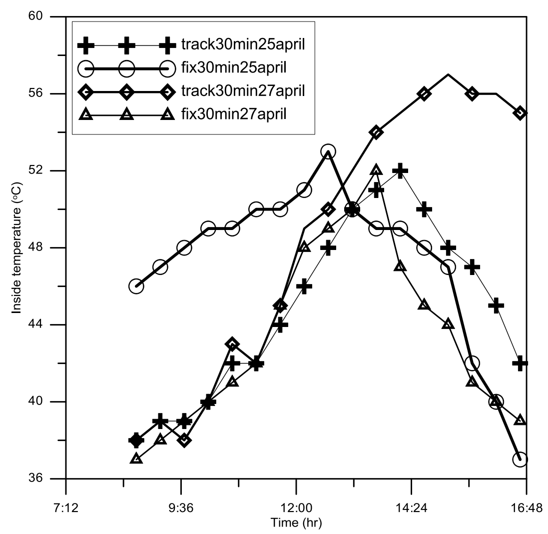

Fig.11. Variation of SHC surface temperature as a function of time

References

[1] H.El-Mulki.1986, Solar and wind energy potentials in Jordan. Proceedings of the international seminar on appropriate technology in the fields of solar and wind energy applications. Royal Scientific Society in Jordan.

[2] M. Mohsen, J. Jaber. A photovoltaic-powered system for water desalination. Desalination 138(2001)129-136. http.dx.doi.org/10.1016/S0011-9164(01)00254-5

[3] S. Abdallah, S. Nijmeh, (2002), Design construction and operation of one axis sun tracking system with PLC control. J. J. Sci. (Jordan, 4(2):45-53.

[4] R. Mamlook, B. Akash, S. Nijmeh.(2001). Fuzzy sets programming to perform evaluation of solar systems in Jordan. Energy Conversion and Management, 42:1717-1726. http.dx.doi.org/10.1016/S0196-8904(00)00152-7

[5] R. Neville (1978) Solar energy collector orientation and tracking mode, Solar Energy, 20:7-11. http.dx.doi.org/10.1016/0038-092X(78)90134-2

[6] P. Hession and W. Bonwick (1984) Experience with a sun tracker system. Solar energy, 23:3-11. http.dx.doi.org/10.1016/0038-092X(84)90042-2

[7] P. Baltas. Tortoreli and P. Russel (1986) Evaluation of power output for fixed and step tracking photovoltaic arrays, Solar Energy, 37(2):147-163. http.dx.doi.org/10.1016/0038-092X(86)90072-1

[8] M. Brunotte A. Goetzberger and U. Blieske (1996) Two stage concentrator permitting concentration factors up to 300X with one axis tracking, Solar Energy, 56(3):285-300. http.dx.doi.org/10.1016/0038-092X(95)00107-3

[9] A. Khalifa and S Al-Mutawali (1998) Effect of two axes sun tracking system on the performance of compound parabolic concentrators, Energy Conversion and Management, 39:1073-1079. http.dx.doi.org/10.1016/S0196-8904(97)10020-6