TRNSYS Simulation of Solar Water Heating System in Iraq


Abstract—The objective of this work is to model and verify a direct solar water heating system in Baghdad, Iraq using TRNSYS software to meet the demand of hot water for 25 persons. This is achieved by using 10 m$^2$ of a flat plate collector and 600 liters storage tank. This system is analyzed with an auxiliary electric heater. Performance is simulated by TRNSYS with the weather data of TMY file for Baghdad, Iraq. The annual solar fraction obtained was 69% and the system cover the hot water needs during the cold months with the help of auxiliary electric heater. The maximum auxiliary energy was needed during the months of December (about 1025 MJ/month) and February (about 1000 MJ/month).

Keywords—Solar, water heating, TRNSYS, Baghdad-Iraq

I. INTRODUCTION

The history of solar energy begins with “hot box” which is the first solar energy collector in the world invented In 1767 by Swiss scientist Horace de Saussure [1]. In the late 1830s, Edmond Becquerel wrote a research on how to convert light to energy [2]. At the same time John Herschel who is a British astronomer used a hot box to cook food [2]. In 1891 Clarence Kemp made a new invention when he used metal tanks as a hot box to collect and retain the heat [1]. In 1968 Gupta and Garg developed a solar hot water with a natural circulation and without load [3]. At 1976 Ong made a first thermosyphon system [4]. At 1985 Kudish made a directly measurement of the flow rate of thermosyphon system [5]. In 1997 Shariah and Shalabi used TRNSYS for optimizing the SWH in Jordan [6]. In 1986 Swartman studied the effect of the temperature of hot water load on the performance of SWH by using TRNSYS [10]. In 2002, a new SHW had been modeled using TRNSYS by Carrilo Andres and Cejudo Lopez [11]. In 1999 Shariah made an investigation on the absorber plate thermal conductivity and its effect on the performance of SHW by using TRNSYS software [12]. In 2002 Jim Salasovich et.al used TRNSYS and weather data for 30 years in the USA for SDWH system to make a pipe-freeze model [13]. In this research, the process of hot water in the cold winter days by using solar energy in Baghdad is going to be studied using TRNSYS software to overcome some techno-economic issues for possible promoting of this idea in Iraq.

The study area is on the country capital of Iraq, Baghdad situated at an elevation point of 40 meters from the sea level. The city is located at 33° 20' 19" North latitude and 44° 23' 38" East longitude. According to the weather of Baghdad in winter, the water is cold and cannot be used without heater. The objective of this work is to model a solar water heating system with intends to verify the solar water heating system in Iraq by using TRNSYS software:

- Predicted monthly and yearly contribution of the solar water heater. Predicted monthly auxiliary energy needed by the system. Variations of the temperature coming out of collector and temperature coming out of storage tank.

The direct solar hot water system is as shown in Fig 1.

![Fig.1 Direct solar hot water system](image_url)
components whose collective performance describes the performance of the system. The mathematical models of the components which used in the system are formulated as equations by using the FORTRAN code to determine the performance of the system and to describe its physical behavior. A more attractive feature of the TRNSYS program is the possibility to create a user-friendly input file called a TRNSED file. This is the case if outside conditions that influence the system behavior change, such as weather conditions, or if the system components themselves go through conditions that vary with time. In developing countries such as Iraq, due to absence or malfunction of measuring instruments, reliable solar radiation data is not available. Global solar radiation data on horizontal surface is recorded at Baghdad, Basra and Mosul only [14-16].

The TMY2 Reader (Type109) used to provide reading of weather data of the given region such as to determine the temperature of the cold water source which gives the mains water temperature model. The forcing function (Type 14) which gives the pattern of the forcing function and prescribe the hot water draw profile. The Divider (Type11) pipe or duct tee-pieces, mixers, and diverters which are subject to external control are often necessary in thermal systems. The Equation component in TRNSYS has the ability to define equations within the input file which are not in a component and can be function for output file like: solar fraction and daily load. The instance of the (Type2) controller is used for controlling the value of signal which is chosen as a function of the difference between upper and lower temperatures. The pump of fluid (Type3) is used for simulating the circulation pumps of the SDHW systems which compute a mass flow rate using a variable control function. The (Type1) flat-plate solar collector which modeled as the thermal performance and the coefficients of the function are supplied by an ASHRAE or equivalent test. The Integrator (Type24) used to prescribe the integrated series of quantities over a period of time. The Tee piece (Type11) is a pipe or duct tee-pieces, mixers, and diverters with two inlet liquid streams are mixed together into single outlet water. (Type25) is similar to (Type65) for printing simulation information as a readable output file in TXT extension [17].

III. RESULTS

Fig’s 2 and 3 show the monthly average daily ambient temperature and solar radiation on horizontal surface respectively of Baghdad during a year.

![Fig.2 monthly average daily ambient temperature](image)

![Fig.3 Solar radiation on horizontal surface](image)

The results from TRNSYS and the weather data of Baghdad is assumed at 1st of January and are shown in Fig’s (4-6) below. Fig.4 shows the daily hot water consumption profile based on human needs during 24 hours of a day.

![Fig.4 Daily hot water consumption profile (600 l/day).](image)

The trend of water flow rate and incident solar radiation as a function of time is shown in Fig.4. It can be seen that the water flow rate is assumed to be constant due to using (active) water pump to circulate the water. As the water pump is started at about 7:30am, the flow rate is designed to be 200 kg/h. Also from Fig.5 it can be seen that the incident solar radiation increases from morning hours to reach 557w/m² as a maximum at about 12:30 pm and then starts to decline until sunset.

![Fig.5 Variations of incident solar radiation and water flow with time](image)
Fig. 6 shows the variations of the temperature coming-out of collector and temperature coming out of storage tank. The temperature coming-out of collector increases during the morning hours to reach 68 °C as a maximum at 3pm and then starts to decline until sunset. The temperature coming out of storage tank fluctuated between 60 °C to 67 °C. It increases during the morning hours to reach a maximum value at 3pm and then starts to decrease until 60 °C.

![Fig.6 Variations of the temperature coming out of collector and storage tank](image)

The monthly solar fraction is shown in Fig. 7. In this figure solar fraction values are fluctuating from 65% in Feb to reach 72% in Jul. The annual solar fraction is found to be 69%.

![Fig.7: Predicted monthly solar contribution of the solar water heater](image)

Fig. 8 shows the auxiliary energy needed per month. It is important to note that during the months of winter the requirements of heating are much bigger than in summer. The minimum auxiliary energy was needed during July nearly 300 MJ/month while the maximum auxiliary energy was needed during February nearly 1025 MJ/month and December 1000 MJ/month.

![Fig.8 Predicted monthly auxiliary energy needed by the system](image)

Fig. 9 shows the effect of collector area on solar fraction. Solar fraction increased from 69% to 75.5% as collector area increased from 10 to 40 m² respectively. At collector area of 40m² to 80m², the solar fraction shows maximum/constant value of 75.5%.

![Fig.9: Annual solar fraction as a function of collector area](image)

IV. CONCLUSION

An optimal SDHW direct system for 25 persons in Baghdad was identified. The system would use one-storage tank (600 liter) design with a collector area of 10 m² with an annual solar fraction of about 69%. The minimum auxiliary energy was needed during July nearly 300 MJ/month while the maximum auxiliary energy was needed during February nearly 1025 MJ/month and December 1000 MJ/month. Solar energy research is vital and should be always adopted for the future plan in Iraq due to environmental challenges and future oil/gas depletion.

REFERENCES


