Performance Analysis of Solar Absorption Cooling Systems in Iraq

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Abstract- The energy requirements and demands of air conditioning systems is steadily increasing. The use of solar assisted Single Effect Absorption Chillers (SEAC) can alleviate energy losses and reduce CO_2 emissions. The needs to customize such systems is crucial. Hence, the feasibleness of using a absorption solar cycle in Najaf, Iraq is evaluated in this study. In the system proposed, a 105,6kW SEAC is powered by Evacuated Tube Collectors (ETC). TRNSYS (version 18) simulation is performed to select the various system parameters and optimize them to increase solar system efficiency, and this simulation develops a solar cooling model that simulates reality and is used effectively for cooling service buildings. According to the results, the optimum solar air-conditioner for a building consists of a 35 m2 collector area with 8 collectors connected in series and at a tilt angle of 32° for Najaf, Iraq, from the horizontal and 1.5 m3 HWST. Moreover, it has been found that in effect, the solar absorption cycle reduces the annual electricity consumption where the solar fraction is high, reaching 77% at Najaf, Iraq. Also Utilizing solar energy can provide further benefits to the governments in the form of CO_2 reduction, as the thermal energy generated by solar evacuated tube can reduce the energy used when the greatest percentage of CO_2 reduction moreover 70.33 tons of CO_2 for Tehran and 68.88 tons of CO_2 in work period in each year.

Keywords Solar Air Conditioning, Evacuated Tube Collectors, TRNSYS 18, Single Effect Absorption Chiller, Parametric Analysis.

1. Introduction

In the past few decades, energy demand for refrigeration and air-conditioning equipment has steadily increased. World demand for energy and CO_2 is predicted to rise by about 60% by 2030 with regard to this century [1-2]. The cooling load has a majority share from this demand especially in Middle East during summer. In this connection, conventional chillers for vapor compression require high energy quality, electricity generated from original energy resources. In addition, chlorofluorocarbons (CFCs) and fluorochlorocarbons (HCFCs) as working fluids are used with vapor compression cooling systems. global warming affected in these substances and causes ozone depletion. Various studies on solar thermal and solar photovoltaic systems have been introduced to deal with this energy issue [3-7]. To overcome these challenges, it is noteworthy to mention that the cooling load in summer is associated with high solar energy, which offers a suitable opportunity to utilize this energy for the chiller. For instance, thermal AC systems use heat as motive energy to supply AC electricity. These systems may be categorized as absorption systems [8-9], adsorption systems [10-11], duplex rankine [12-13], cooling desiccants [14-15] and cooling ejector systems [16-18]. The heat could be generated from waste heat sources or from solar energy [19-20].

Many of the theoretical work and reported studies on the cycle solar cooling system examined the parameters affect the performance [21], design [22], and optimization [23]. Many theoretical works and reported studies on the cycle solar cooling system examined the parameters affect the performance, optimization, and design. Shirazi et al. [24] conducted a parametric, systematic, and feasibility study of SHC absorption systems. These systems utilize single-, double-, and triple- effect LiBr-H2O absorption chillers combined with solar thermal collectors such as Evacuated

Tube Collector (ETC), Parabolic Trough Collector (PTC), Micro-concentrating Collector (MCT), and Evacuated Flat Plate Collector (EFPC). The simulation was performed using TRNSYS 18 software. In addition, a unique and complete perspective is provided by studying the impact on technical and economic performances of proposed SHC plants in a variety of weathers throughout the world of characteristic solar radiation. A parameter HWST volume for system SHC1 about 70 l / m2 is a perfect option, and for other systems, SHC2 into SHC5, 40–50 l / m2 HWST volume is enough. Djelloul et al. [25] developed a computational model that allows the simulation on an hourly basis for a SEACLiBr as solution working fluid - system assisted by solar energy and CNG in the hot and dry climate of Algeria as an auxiliary fuel combined with the housing building. This modelling of the demand for AC has used the TRNbuild module of TRNSYS 18, which allows simulating in a dynamic way the AC requirements for the building. The simulation results of the SEACLiBr system with 10 KW assisted by a solar source with the COP is 73%, indicate that with an area of 28 m2 of FPC with an inclination of 35° and 800L of HWST is achieved to cover the demand of air conditioning of the house of 120m2 located in Biskra.

In brief, many past studies were performed to simulate the international solar absorption system. However, the need for customization to find the optimal system design is crucial. The gap in this research topic can be observed in Iraq. Hence, there is a need for more research into solar cooling system's performance in Iraq. However, the SEAC for the weather in Najaf town has not yet been investigated, to the best of the authors knowledge. Furthermore, just a small number of studies have considered the impact on parameters system performance such as ambient conditions and HWST size. This paper shows the design of SEAC in an office building using TRNSYS 18 software and its simulations are dynamic. Weather data in the standard meteorological year TIMY2 format should be used to predict the cooling system performance in Najaf, Iraq. Meteonorm version 7.1 software could generate this format for Najaf, Iraq at a location with longitude 44.32 E and the latitude 31.98 E. The data weather of Meteonorm are generated data between 2011-2020 for the entire 20 average years. Moreover, the impact of HWST size, ETC area, and slope were investigated and presented. While a sensitivity analyses was carried out to optimize the effectiveness of SEAC, by identifying the SEAC system parameters.

2. Methodology

Characterization and modelling of the SEAC in the TRNSYS 18 program

A simplified summary and process of flow diagram involved in the simulated SEAC is obvious in Fig. 1 and explained here. It should be noted that lines in the diagram represent logical connections in the TRNSYS 18 simulation rather than physical pipes etc.

The process of SEAC starts from the ETC Type71. The cold water from a stratified HWST Type4a bottom is pumped to the ETC and hot water returns to the top of the HWST. The type3d pump is controlled by a timer controller and work during the day if the energy is available. Because of solar radiation is unpredictable, back-up heat sources (Auxiliary heat) are occasionally employed in solar cooling systems to ensure that there is always enough heat available to satisfy loads of cooling. hot water is being pumped from the top of HWST into Auxiliary heat Type 6 after that this water is being pumped into chiller Type107 and returns into the bottom of the HWST through a pump Type3d-2. The chiller absorbs the heat from the cooling coil Type52 by circulating chilled water. The chilled water returned and exchanges heat from the cooling coil with the absorption solution inside the chiller. The absorption solution is cooled by cooling water from a cooling tower Type510. The hot cooling water from the chiller is circulated by a pump Type3d-3 to the cooling tower Type510. It cools hot water by exchanging heat with ambient air. The cooled water is returned to the chiller for heat absorption.

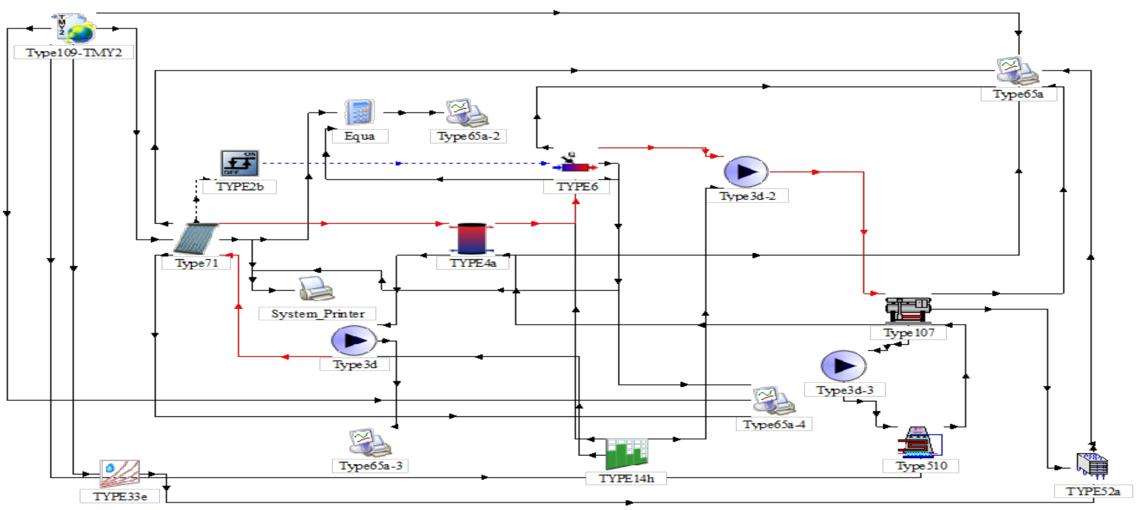

Fig. 1. Schema of SEAC in TRNSYS 18.

System Components

The computer simulation for SEAC was using TRNSYS 18 program. The project of TRNSYS 18 is usually configured through the graphical connection of the elements in TRNSYS 18 Studio. TRNSYS 18 engine describes all elements types by mathematical prototypes and includes in TRNSYS 18 studio a series of initial matches. The initial matches describe elements in a black box: inputs, outputs and parameters etc. The relation between TRNSYS 18 elements in the studio act as information streams between elements. The connection of the elements in the TRNSYS 18 studio operations as the flow of information. The first elements outputs are the second element input [26]. The schema of SEAC in TRNSYS 18 for the entire system is generated as described previously in Fig. 1.

1. ETC Type71: The collector was designed with the typical library of TRNSYS 18 for ETC model, as described in Fig. 1. This type of ETC demands different models of inputs, the ETC input in this simulation was: a collector ETC of 35 m2. number of ETC in series is 8, fluid specific heat is 4.19 kJ/kg.K, Collector's tested flow rate is 40 Kg/hr.m2, intercept efficiency 0.75, efficiency of slope is 6.15 W/ m2.K, efficiency curvature is 0.03 W/ m2.K2 and azimuth angle is 0°.

2. HWST Type 4a: The storage tank is used to Type 4a model. This type is suitable for HWST models with constant inlets and constant losses. This system also had an AHP to provide the chiller system with a minimal water temperature outlet (80° C in the current work).

3. SEAC Type 107: For modelling SEAC, the TRNSYS 18 integrated Type 107 utilizes an external chiller absorption data file to predict chiller performance in hot water, the cooling water input temperature under predominant conditions. There has been a model of a 30 TR absorptive chiller that has been purchased from the YAZAKISC30 manufacturer. The parameters are: The capacity of cooling is 105.6 kW, Inlet and outlet temperature for chilled water with flow rate are equal to 12.5 °C, 7 °C, and 16.5 m3/hr, respectively. While, for a flow rate of 55.1 m3/hr the inlet and outlet cooling water temperature are equal to 31 °C and 35 °C, respectively, Hot inlet and outlet water temperature are equal to 88 °C and 83 °C, respectively with inlet temperature ranging between 70 °C and 95 °C.

4. Weather data Type 109- TMY2: This component is mainly designed for reading the weather data from a regular data file, generate direct and diffuse radiation outputs with numbers of arbitrary oriented and inclined surfaces, and convert it to the desired unit system to do the simulation in TRNSYS 18. Type 109 reads a standard meteorological year TMY2 file. The National radiation information Base (USA) uses the TMY2 kind, TMY2 weather information files will be generated from many programs like Meteonorm program.

Parametric Analysis

ETS slope

The effectiveness of the ETS tilt angle facing southern has been studied. The latitude of the ETS region should, in theory, be the optimal value of the ETS slope for ETS without a tracking system. In Fig. 2, the ETS slope was varied in the vary of 5° to 45°. The outcomes indicated that the best possible collector energy acquires the angle of slope to be equivalent to the latitude in the area. Therefore, the collector's optimal slope is 32 °N in Najaf 31.98 °N latitude.

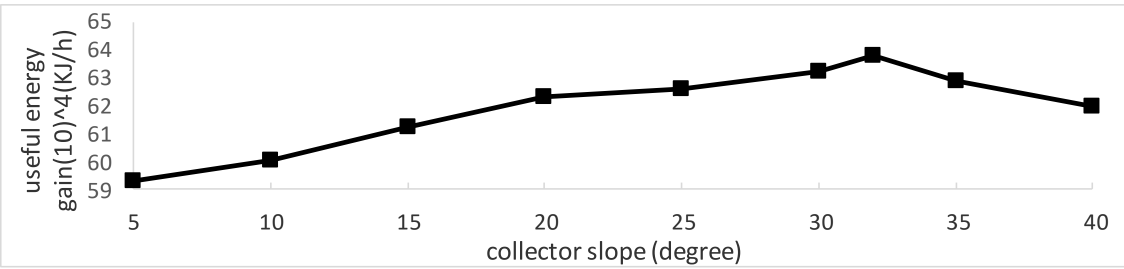

Fig. 2. ETC slope vs. UEG

Storage tank volume flow rate

By looking at the impact of VFR storage on system performance, the optimal HWST is determined. For this purpose, HWST with VFR is various from zero m3/s to 3 m3/s. An optimal VFR of HWST would be at which maximum is achieved the trend solar fraction and the trend of annual UEG on the analysis of parameters of HWST with VFR. This result was proven in Fig. 3 by monitoring the trend.

The SF computes the thermal energy fraction delivered to the SEAC generator load from UEG. SF = (UEG)/ (Generator load), Fig. 3 elucidate Najaf data. The HWST with VFR of 1.5 m3/s was achieved minimum trend of annual AHP with highest SF and UEG.

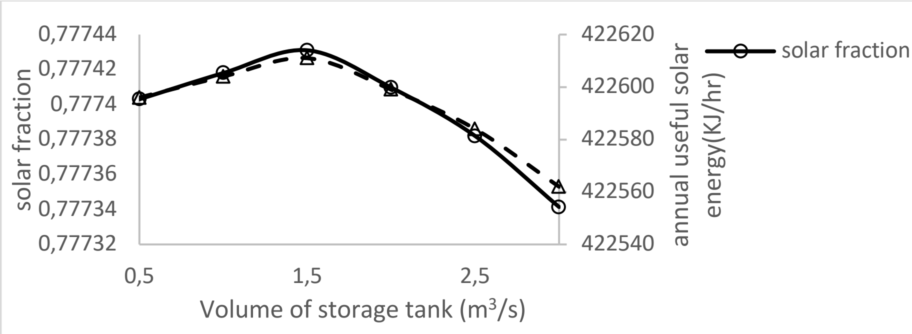

Fig. 3 SF and Annual useful solar power vs. VFR of HWST

By monitoring the trend this result was confirmed in Fig. 4, where it was concluded that the optimum HWST with VFR is 1.5 m3/s for Najaf because by the parameter analysis of the storage tank VFR, which minimum is achieved by the required AHP annual trend can be obtained.

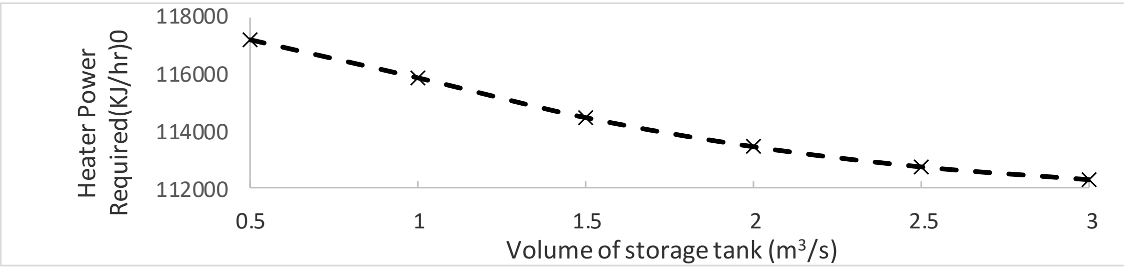

Fig. 4 Annual heater power required vs. VFR of HWST

ETC area

The certain area of ETC was varied with range 0 to 50 m2. The difference between the yearly solar fraction and UEG with varying ETC areas is shown in Fig. 5. There was a rise in the SF in the ETC area, but a considerable 35 m2 impact of the rising ETC area was observed. This is the reason to take the area of this project into account for the produced energy so that the area of the project is not a barrier to benefit from it. With this area (35 m2) the project can be implemented in the roof of a multi-story building with the high solar fraction. A similar trend is noted for UEG.

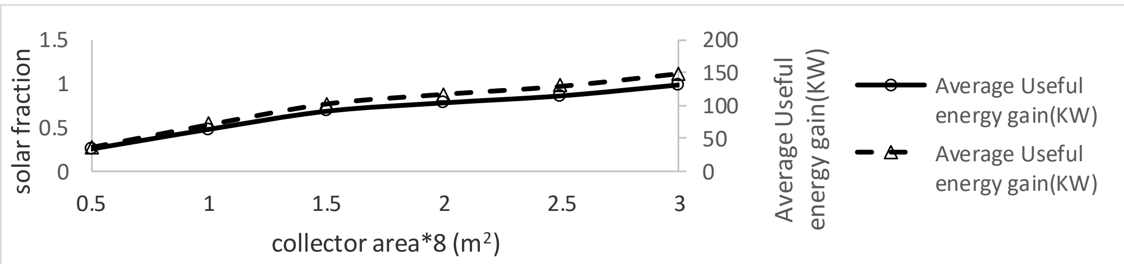

Fig. 5 SF and Average UEG vs. ETC area

Fig. 6 shows this as expected that necessary AHP shows a different trend into that of UEG and SF. AHP required decreases with raise in ETC area until 35 m2. Otherwise, useful ETC heat increases with raise in ETC area.

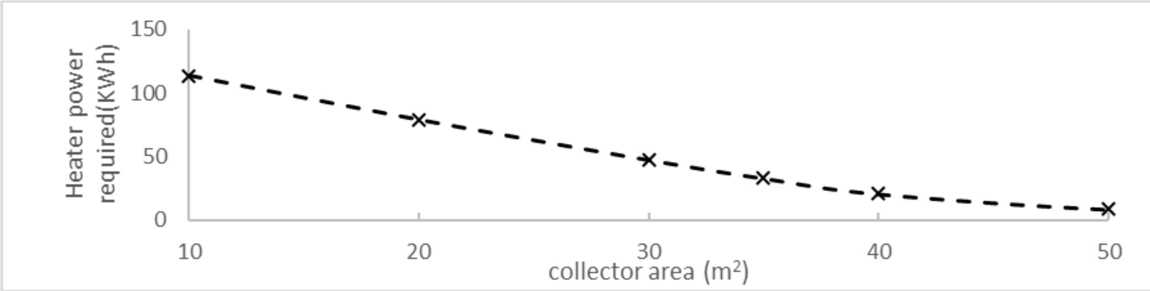

Fig. 6 Average AHP required vs. ETC area for Najaf, Iraq.

Mass flow rate

The effectiveness of changing the MFR of ETC is examined, MFR of ETC of 500 to 5000 kg / h has been changed. It is shown in Fig. 7. MFR of ETC of 1000 kg / h optimizes the SF of Najaf up to 0.77.

In this optimize, it was considered as the ultimate suitable amount. while it is remarkable to indicate that a change in the MFR with range 500 to 5000 kg/h was not a big change in the annual SF, It's been in diversity with range 63% into 77% for Najaf. The ultimate system requirements for the Najaf optimising study, this system consisted of a 35 m^2 ETC area and number ETC in series 8 tilted at 32^0 for Najaf from the horizontal and with 1000 kg/h MFR and a 1.5 m^3 HWST. The efficient Building requires 30 Ton of refrigeration (TR).

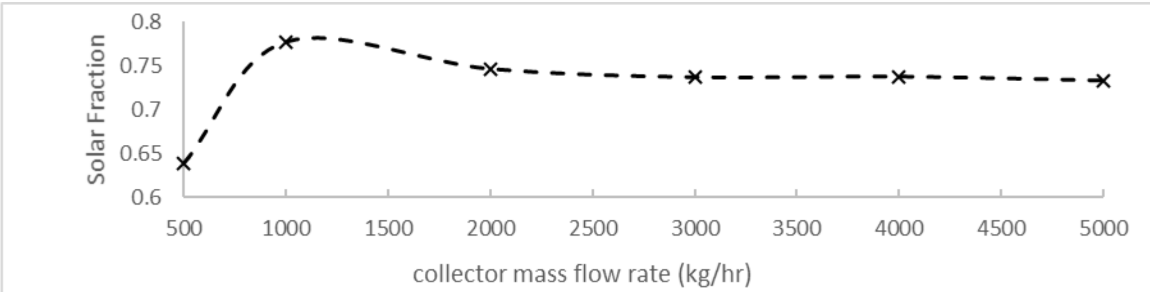

Fig. 7 SF vs. MFR of ETC.

3. Results and discussion

Energy Analysis

The simulation is performed for the six months (APR to Sep), i.e., with a simulation time step of 1 hr. The first parameter to be considered was the ETC outlet hot water temperature. In starting, it takes a while to warm up the system. Hence, the curve is flat as can be seen from the bottom left side of Fig. 8. At around 8:00 am, when the intensity of radiation is high, around 96.87 °C was obtained. at a certain point in the high solar time, for instance, at 13:00, round 131.6 /°C had the top temperature. Another observation is that the system collected energy efficiently for a period of nine hours that is from about 8 a.m. to 5 p.m.

Fig. 9 shows that the energy given by the heater is the highest possible at the beginning of operation of the system between 8 am and 9 am as well as at the end of the working of SEAC between 4 pm to 5 pm. It has been noted that HWST maintains the non-fluctuation energy of the solar collector, which goes through HWST to the electric heater and then to the absorption cooling. Hence, 1.5 m3 HWST stable temperature can supply.

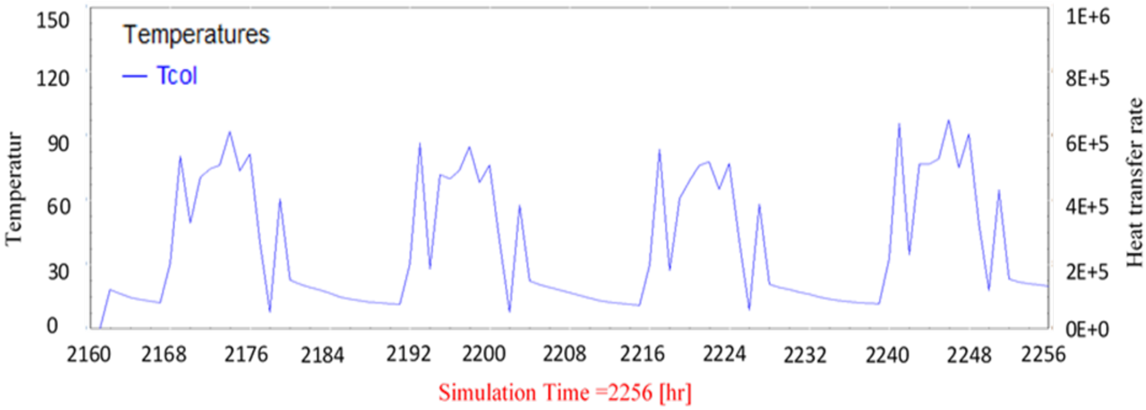

Fig. 8 Temperature outlet for the Najaf collector plot.

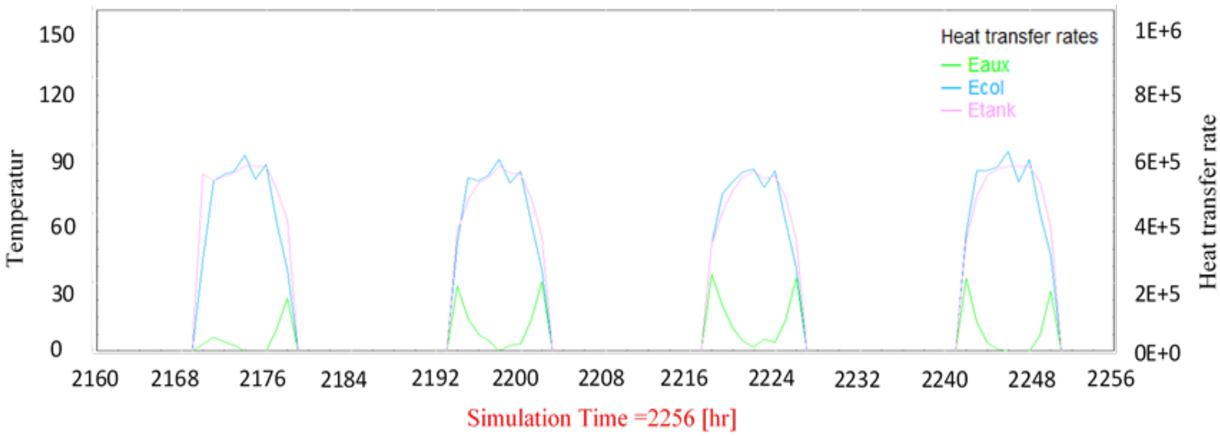

Fig. 9 Outlet energy for Najaf plot.

The outlet temperature of the chilled water is the following important parameter. The HWST warm water is supplied to the SEAC generator and released as chilled water. The SEAC remainder in running during the working period of the system from 8 am to 5 pm Because there are hot water and chilled water demand. Fig. 10 shows that the temperature of constantly chilled water is six months at 6.6 °C.

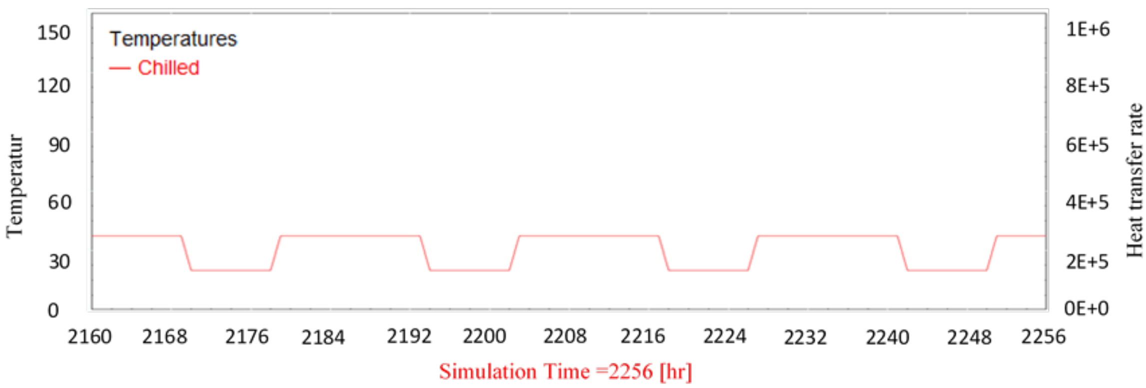

Fig. 10 Chiller water outlet temperature for Najaf plot.

Fig. 11 illustrates the energy produced by the ETC and the energy consumed from the electric heater each month from April to September at a rate of nine hours a day. The proposed solar AC system can achieve an average SF of 77 % for Najaf, which is quite high.

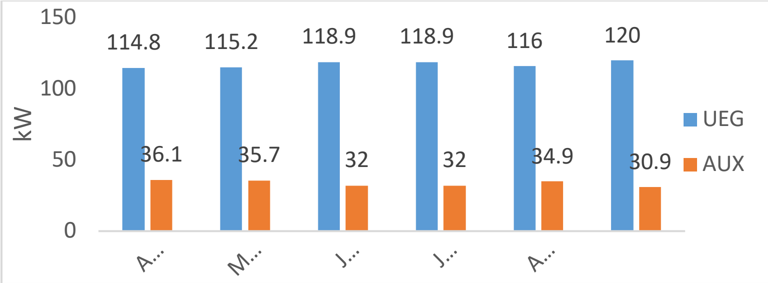

Fig. 11 UEG and AHP for every month in Najaf, Iraq

Economic Analysis

Costs to design, deliver, install and operate the hot solar water to 30-ton SEAC (YAZAKISC30) equal 32,182.4 USD (Manufacturer Quotation), Maintenance and operation cost equal 15,601.3 USD [27].

Net cost = 32,182.4 USD + 15,601.3 USD = 47783.7 USD

Number of office working days = 135, Day hours of work = 9 hours.

Saving energy for Najaf for six months = 117.3*135 * 9 = 142602.2 kWh

Cost of electricity per kWh (2018) = 0.096 $/kWh, 120 Dinar/kw.

Savings in energy bill per six months = 142602.2 kWh*0.096 $/kWh= 13689.8 $

Simple payback period = (47783.7 $)/13689.8$ = 3.49 years.

Environmental impact

Environmental impact can be found by multiplying the saving solar energy with the efficiency of power stations, where the efficiency of power stations is 0.483 ton CO_2/MWh [28], reductions of generated CO_2 from power stations are around 68.88645 tons of CO_2.

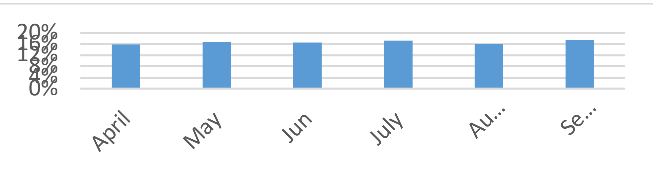

Fig. 12 CO_2 reduction

The bar-chart Fig. 12 illustrates the changes in the power stations of CO_2 reduction over six months from April to September which it around 16% for each month.

4. Conclusion

TRNSYS 18 was used to model the solar SEAC system using input ETC model parameters taken from an ETC performance measurement data. The final optimal system consisted of a 35 m2 ETC area and number ETC in series eight tilted at 32° for Najaf from the horizontal and a 1.5 m3 HWST. The efficient Building, as estimated before, requires 30 Ton of refrigeration (TR) for a Building of 1000 m2 located in Najaf, Iraq. This yearly load has met by achieving the annual average solar fraction of 77% at Najaf. The annual average collector energy yield is only 117.36 kW at Najaf, Iraq. This reduction in an electrical draw could hence reduce the emissions from greenhouse gas-intensive height demand energy sources. These results affirmed the feasibility and environmental benefits of using a solar absorption cooling system for space cooling in Najaf, Iraq. Moreover, the length of payback in Najaf is 3 years. The results of the research attest to the potential use for solar absorption cooling in Iraq climate, while also providing motivation for further research into the application and reduction of barriers of solar air conditioning systems.

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