

Absorbing Solar Thermal Cooling System, an Evaluation Study of the Environmental Effects on the Interior Space, A New Mid-Rise Housing Project in Cairo

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ABSTRACT: This research addresses measuring the efficiency of solar energy production using Absorption Solar Thermal Cooling Technology in the residential buildings and integrating them with the external case design, suitable for residential units and designed based on standards and recommendations of the Egyptian Energy Code of residential buildings and the consumed energy quantum and savings and rationalization quantum required monthly and annually. The research aims to practically analyze the bio-simulation results using TRNSYS program, developing a methodology for comparison and analysis, then the research presents the most important results and explain the purposes of increasing renewable energy efficiency within residential units in the New Medium-Rise Housing Project In Cairo and concludes the Academic recommendations calls for further research studies on energy and sustainable environmental design.

The Absorption Solar Thermal Cooling System was designed to cover the thermal loads in the southwest residential unit on roof, as this unit is the most exposed residential unit for external and internal thermal loads. Consequently, this system is the most suitable for testing and checking performance efficiency of the Absorption Solar Thermal Cooling System. The simulation results were intended to be read on 19 June, as, according to the TRNSYS simulation program, the date on which the summer season simulation results were recorded the highest temperature in Cairo, place of the practical study.

The evaluation study proved that the Absorption Solar Thermal Cooling System is efficient at saving percent of 86% of the monthly electricity consumption percent.

KEYWORDS: Renewable Energy - Solar Thermal Cooling - Absorption Cooling Technique – Medium-Rise Housing -simulation – TRNSYS.

I. INTRODUCTION

Energy is the main motive and basis to achieve sustainable development in its all economic, social and especially, environmental aspects which is the cornerstone of sustainable development but due to depletion of conventional resources upon which most building operation is based, causing CO₂ emissions and consequently greenhouse effect and global warming, which leads to climate variability and environmental pollution spread. Therefore, renewable energy orientation must be adopted, as it never depletes and enable to ensure the global current rate of energyconsumption as much again in case of proper utilization. Indicators show that electricity consumption in Egypt is increasing significantly, especially in the residential sector, which represents 45% of total electricity consumption of conventional energy resources, according to the Ministry of Electricity and Energy statistics in 2018. [1].

II. RELATED WORK

The dynamic simulation was conducted for the Absorption Solar Thermal Cooling System using (TRNSYS) program, then entering the residential unit model, subject of the study, and integrating it with the Absorption Solar Thermal Cooling System by simulation program. The next step is to set the simulation hypotheses and enter all thermal, structural and climatic inputs which is required to complete the concerned multiple mimiries. The simulation results were intended to be read on 19 June as the date on which the simulation results were recorded the highest temperature throughout the year upon conducting TRNSYS simulation program after determining the climatic inputs of the practical study case site. To ensure achieving the maximum efficiency and operational capacity testing and check of the Absorption Solar Thermal Cooling System, subject of the study, it was tested in

the hottest day in the year which is 19 June. The Absorption Solar Thermal Cooling System has been integrated into the residential units, place of the practical study. The southwest residential unit on roof was selected to be the case of the study, as this unit is the most exposed residential unit for external and internal thermal loads, for testing and checking performance efficiency of the Absorption Solar Thermal Cooling System in covering the maximum thermal loads in case of using frequently the best and most economically appropriate alternative to the external case of the roof and residential units, which annually saves 40% of the conventional consumption, which was concluded and adopted based on the Egyptian Energy Code of Residential buildings. [2].

III. SOLAR THERMAL COOLING SYSTEMS

Definition of solar thermal cooling systems:-

The thermal cooling system runs by heat instead of electricity to operate the compressor in the conventional cooling system, and it is better to install the thermal cooling system when the amount of wasted thermal power is huge especially in hot areas with a large solar amplitude such as Egypt which located at the Sunbelt area, in this case it is better to use the solar power in the cooling and air-conditioning systems at this areas. (3)

Types used in the solar thermal cooling systems:-

The solar thermal cooling systems are divided into open system and closed system as follows:-

1- Cooling Systems with Open Cooling Ring:-

- Solid Desiccant System.
- Liquid Desiccant System.

2- Cooling Systems with closed Cooling Ring:-

- Absorption System.
- Adsorption System

Reasons for Selecting Absorptive Solar Thermal Cooling System to be applied in the Case Study:-

Absorption System is selected as the best system of the case study for cooling and air conditioning in the residential buildings, it also one of the most important types used in thermal cooling systems, and it is the most efficient one and the biggest in coefficient of performance ranging from (0.7-0.8).

Absorption cooling Unite

Absorption Definition:

Absorption is a process in which two substances are mixed, each in a different physical state. For example, one is gaseous and the other is liquid, When these substances are mixed, we get a mixture (dilute solution).

The substances commonly used in the absorption cooling process (water-lithium bromide) (H₂O-LiBr), and water is the absorbed chiller and lithium bromide is the absorber due to lithium bromide absorption glut in liquid state of water vapor in gaseous state.

Absorption Chiller Unite Components:

Absorption Chiller Unite consists of four main components, as shown in figure(1):

- Generator
- Condenser
- Evaporator
- Absorber

In addition to the other components of Solar Thermal Cooling System as follows:

Components of Absorption Solar Thermal Cooling System:

The actual components required for designing and operating the Absorption Solar Thermal Cooling System:

- Absorption chiller Unite
- Storage Heater Tank
- Solar Collector
- Cooling tower
- Cooling Coil

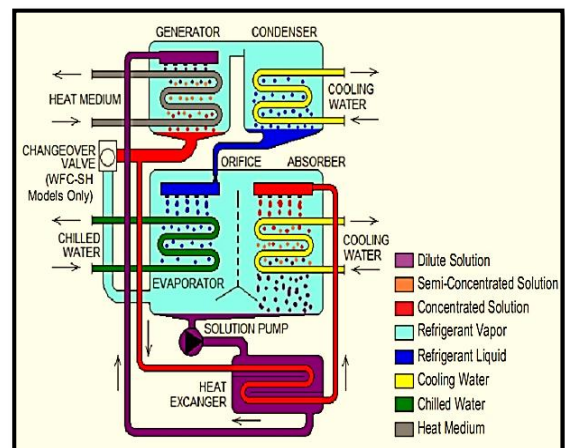


Figure (1), showing the internal main components of Absorption Chiller Unite.

- Heat exchanger Auxiliary
- Pumps
- Valve Extension.
- Controller

When the components are inserted into the simulation, the climate inputs of the area, place of the study:

1. Data Weather

Methodology of Absorption Solar Thermal Cooling System:

Working steps:

- 1- Within the experiment, the absorption cooling cycle bases upon two substances (water- lithium bromide) ($H_2O-LiBr$), as the water is the absorbed chiller and lithium bromide is absorber at 65% of lithium bromide and 35% of water, which means that the absorption cooling cycle contains coolant (water- lithium bromide).
- 2- The diluted solution (water- lithium bromide) included in the Chiller Unite absorber and the diluted solution is pumped to the generator through coil. The generator heats the diluted solution it includes by the heat from the solar collector connected to it.
- 3- As a result of the high heating inside the generator, the lithium bromide becomes separated from water which evaporates to the top of the generator. The remaining concentrated solution (lithium bromide) is lowered to the bottom of the generator and returned through the coil to the absorber.
- 4- The steam moves from the generator towards the condenser and since the steam of the generator is hot, the condenser temperature becomes high, it needs to be cooled in order to condense. Consequently, the cooling tower should be installed to the condenser and the coil containing $32^\circ C$ water should be connected to the condenser. The steam in the condenser condenses and turns into $10^\circ C$. chilled water and accumulates in the bottom of the condenser, then transmits to the evaporator through coil and expansion valve.
- 5- Since the atmospheric pressure is under the pressure of a vacuum in the evaporator by the expansion valve, water temperature becomes $4^\circ C$, then the chilled water evaporates and turns into a chilled water vapor passing through the cooling coils, which is the air conditioning internal unit of the building and connected to the evaporator and containing the chilled water at $7^\circ C$. When the external air contacts these chilled coils, the air temperature lowers and enters the building, in its cool state, and thus the air conditioning is achieved.

System Advantages:

- 1- Highest efficiency and COP largest value; ranging from (0.7 – 0. 8) and thus it is the most suitable cooling system for buildings.
- 2- Safe use without risk.
- 3- Less initial and maintenance costs.
- 4- The system is environmentally friendly and does not cause pollution.
- 5- Low electricity consumption.

System Disadvantages:

- 1- Needing more regular development and improvement.

IV. APPLIED STUDY SAMPLE (MEDIUM HOUSING PROJECT (NEW CAIRO))

Characterization of the applied study sample:

Among the projects of the Ministry of Housing, Utilities and Urban Communities - New Urban Communities Authority and Mediterranean Housing Project in New Cairo City for middle-income with areas ranging from 100 to 116 m^2 . The project includes 132 housing buildings consisting of four floors by 16 residential units in the building with a total of 2112 residential units, which is a number of typical housing models inside an integrated services community.

Applied study sample site:

Mediterranean Housing Project (Egypt Housing) in New Cairo City, the application of the study was selected on the city of New Cairo as in Figure (2), this is because the TRNSYS simulation program supports climate input and its own weather data.

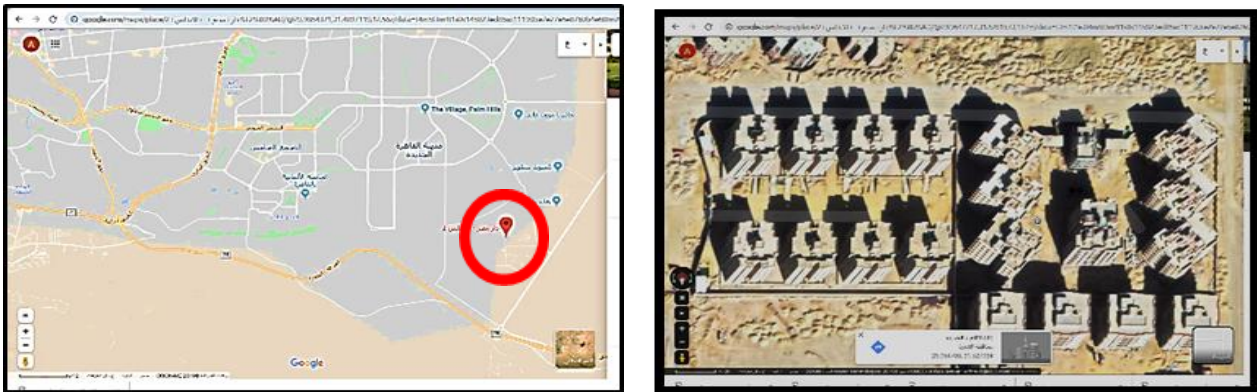


Figure (2): The applied study sample illustrates: Mediterranean Housing Project (Egypt Housing) in New Cairo City
Source: 7/ 11/ 2019 <https://www.google.com/maps/place>

Reasons for choosing the practical study sample:

One of the most important bases on which to choose the sample of applied study (Project of the Ministry of Housing, Utilities and Urban Communities for Medium Housing) the following:

- 1- The National House Project is one of the most important projects adopted by the State and its concerned institutions to provide suitable housing, especially for middle income groups.
- 2- The Egyptian state is moving towards providing clean energy from safe and sustainable energy sources and reducing dependence on traditional energy sources.
- 3- Ensure that the support provided by the Egyptian state for this type of project be in the correct position.
- 4- The residential unit in middle housing projects is characterized by repeatability modules, when saving and rationalization in electrical consumption is achieved and the renewable solar energy production is increasing, the savings multiply and repeat as the number and frequency of these residential units increases.
- 5- Due to the state replication to construction such projects continuously to cover the housing deficit for this segment of the population, this empirical research study can be considered as curriculum for physical completion application currently and in the future at large scale, it provides optimum thermal comfort within the residential unit at reasonable economic costs.

Models of residential units in the applied study sample:

The project consists of two typical housing models, figure (3) illustrates the typical model chosen for the analytical study, it consists of typical residential unit with four units per floor and the height of the housing building from the ground floor and three floors repeated.



Figure (3): the typical model chosen for the analytical study, Source: (brochure of the conditions of the middle housing project (SAKAN Egypt) in New Cairo), 2018

Building the model in the program (TRNSYS):

The model has four residential units per floor as in Figure (4), the analytical study was conducted on the residential unit (4) with guidance: southern simulation as the most residential unit exposed to external and internal thermal loads.

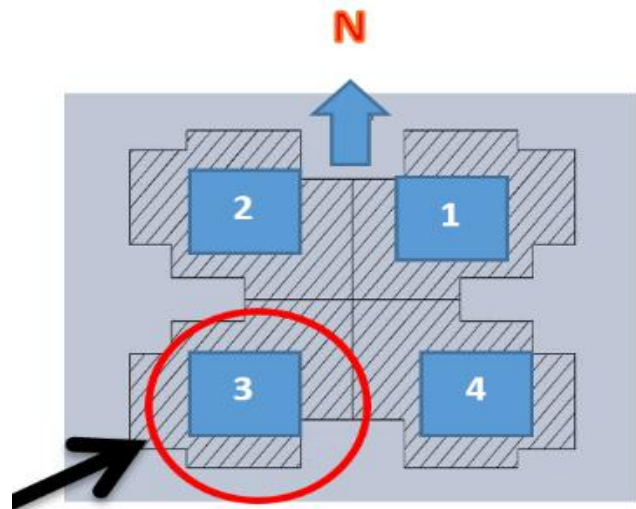


Figure No. (4): Selection of Southwest Unit No. (4) on roof for the research study, Source: (Researcher, 2019).

The external case of the southwestern residential units at the roof:

The external case of the residential units is designed and inserted on the TRNSYS program according to the external case of the roof most economically suitable for the residential units, which provides 40% annually of the traditional consumption, which was extracted and adopted based on the standards and recommendations of the Egyptian Energy Code in the housing premises used by the Urban Communities Authority in the medium housing project as shown in Table (1):

Table No. (1): Components of the external case of the South West residential units of the roof:

| | |
|----------|--|
| Ceilings | reinforced concrete ceiling 20 cm / moisture insulation / sand and mortar 8 cm / tile 2 cm |
| Walls | Exterior walls thickness of 12 cm hollow clay bricks |
| Windows | Aluminum and 6mm transparent glass |

Source: (Researcher, 2019).

V. SOLAR THERMAL COOLING SYSTEM DESIGN IN TRNSYS ENERGY SIMULATION PROGRAM TRNSYS

Analytical Study Hypotheses (simulation):

A fixed set of hypotheses inserted on the program's natural simulations throughout the duration of the experiment, it is as follows:

- Specifying the period of time applied to the simulation is four months i.e. summer season (June-September). June 19 was selected to read the results of the simulation because it was recorded the highest temperature in the summer season of the Cairo “Applied study place “.
- Thermal comfort at a temperature of 24 degrees Celsius.
- There are no internal devices working other than the typical devices for each housing.
- Working to achieve thermal comfort by cooling only (during the summer season)
- The work of the space for 24 hours a day (assuming the existence of users of the space throughout the day).
- Air conditioning works for the reception and bedrooms only and there is no air conditioning works in the bathroom, kitchen and the main staircase of the housing building.
- Occupancy rate according to the average number of family members (5 members per each family).
- Climate data used for Cairo, provided by TRNSYS program.
- The thermal properties of the materials used determined according to the Egyptian code of thermal insulation items specifications.

Solar Cooling Simulation System:

To conduct the dynamic simulation of the Absorption Solar Thermal Cooling System, it was designed using (TRNSYS) program which provide us with several components and elements required for designing cooling and heating systems of several renewable energies, such as Absorption Solar Thermal Cooling System, subject of the practical study. The mentioned-above Cooling System components were imported in addition to climatic inputs of the area, place of the practical study and printer icon to extract readings and results of the program library to conduct a bio-simulation of the system methodology. The Cooling System has been designed cooling system using the above-mentioned elements, as shown in Figure (5), knowing that the simulation is conducted in the southwest unit on roof after merging and integrating the Cooling System.

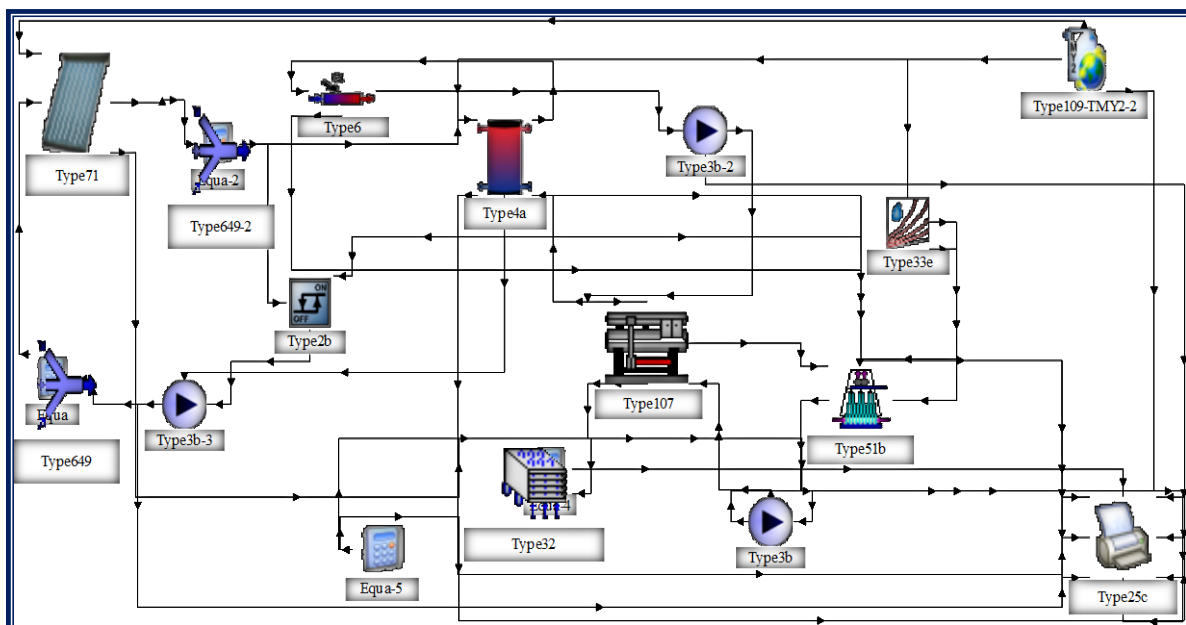
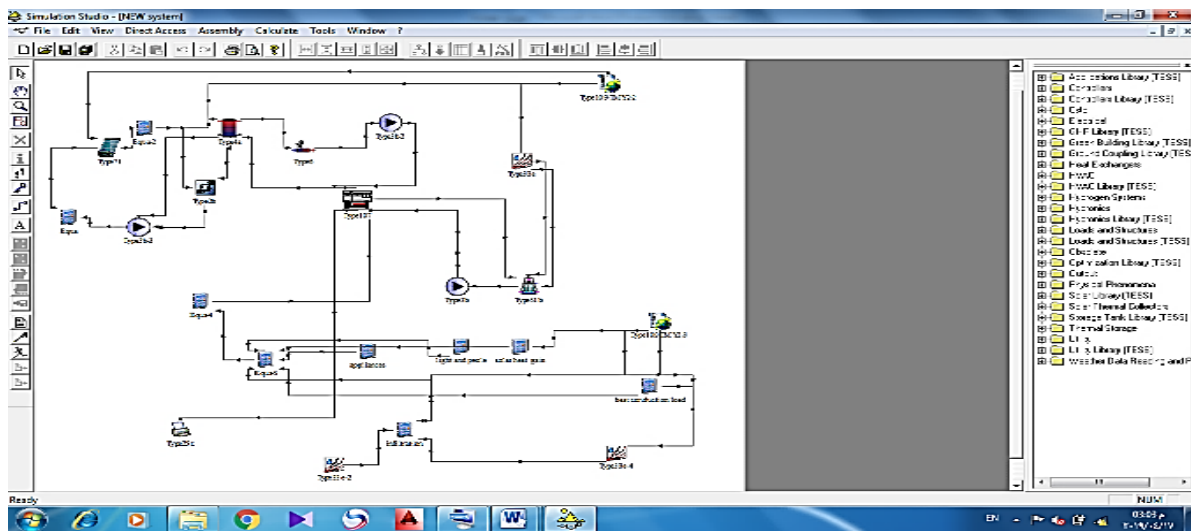


Figure (5) shows the design model of the Absorption Solar Thermal Cooling System for cooling the residential unit and water flow directions within the system cycle and replication in the simulation program to cover the normal cooling loads during the summer season (June, July, August, September) in TRNSYS program. Source: (Researcher, 2019, using the program TRNSYS)).

V. READINGS AND RESULTS OF THE NATURAL SIMULATION FOR SOLAR THERMAL COOLING SYSTEM INTEGRATION IN THE RESIDENTIAL UNIT (SOUTH/ WEST) ON ROOF FLOOR

1- Solar radiant intensity on Cairo solar collector on June 19:

The roof with the most economically suitable alternative for the external case of the residential unit (South/ West), Fig. 6:

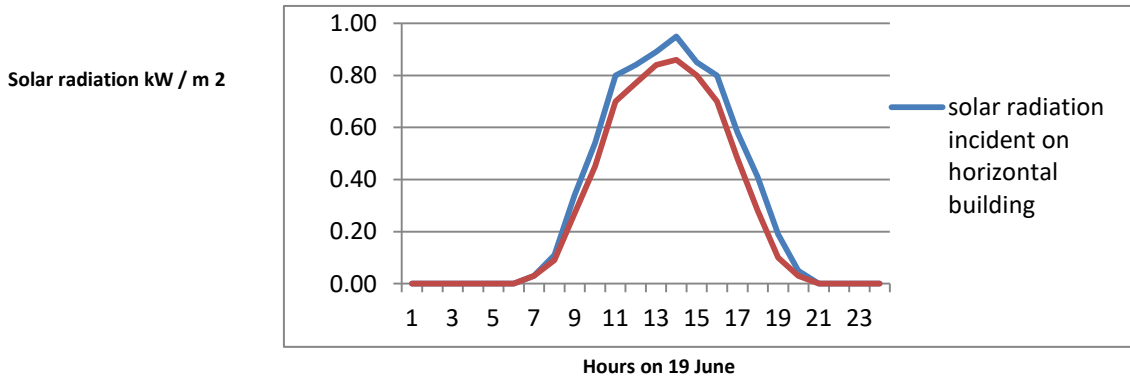


Figure (6), Total solar radiation on the horizontal and inclined surface of the solar collector in kilowatt / m2 in the (southwest) unit on roof which is better on June 19 , Source: (Researcher, 2019).

Analytical Observations:

- Changing the external case of the residential unit in on roof does not affect the quantum and percentage of solar radiation incident either on horizontal building roof or inclined solar collector surface in use.
- On June 19, the solar radiation in Cairo reaches 82% for the (south/ west) unit and 95% for the (north/ east) unit, which urges to use solar energy in Egypt.
- To simulate the system dynamically, the solar radiation data of the place of the study must be collected. The weather and Cairo solar radiation data were used within the simulation databases (TRNSYS) program. Solar radiation incident on the horizontal building roof during 19 June, where the curves are asymptotic significantly in the solar radiation quantum incident on them, which indicates the intensity of solar radiation used in the Cooling System of the solar energy collection at 95% as a maximum in the (south/ west) unit on the hottest day within the year in Cairo, and the best inclination angle for the solar collector is 35 ° C, so the solar collectors angles inclination in Egyptian solar energy projects are 35 ° C to the south.

2- Temperature of solar collector water inflow/ outflow on June 19:

The roof with the most economically suitable alternative for the external case of the residential unit (South/ West), Fig. 7:

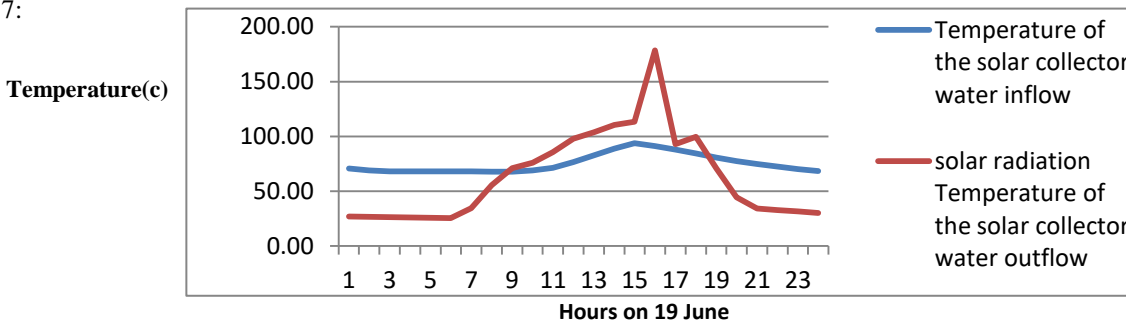


Figure (7), Temperatures of solar collector water inflow/ outflow on the (south/ west) unit floor which is better on June 19, Source: (Researcher, 2019).

Analytical Observations:

- Temperature of solar collector water inflow ranges (55 - 65) °C and (55) °C in the best alternative, which is almost constant throughout the day (with a uptick in the midday).
- Temperature of solar collector water inflow of the chiller absorption unite in the best alternative is lower than that of the basic temperature because the better external case shell has decrease the temperature inside the residential

unit at (20%) than the basic alternative. Therefore, the extra water temperatures returning back to the solar collector are lower than in the basic temperature.

- Temperature of solar collector water outflow decreases at night ranges (25-30) °C and increases gradually with the first daylight hours from 7:00 am until it reaches its maximum at 2:00 pm, ranging (100 - 220) °C, then they decrease gradually by evening again.
- We observe that the temperature results of solar collector water inflow/ outflow of the southern orientation on the roof of the residential unit.
- In hours the Cooling System stops working at night, the temperature of the water in the solar collector is the same temperature as the surrounding environment.
- Then since sunrise, temperature of solar collector water increases before the Cooling System starts.
- With the start of operation of the system begins the temperature of solar collector water inflow/ with variance the temperature of the water outflow reaches its maximum after midday at 2:00 pm (220 ° C), so for the power and intensity of solar radiation at that time.

3- Average temperatures inside the tank heat for June 19:

The roof with the most economically suitable alternative for the external case of the residential unit (South/ West), Fig.

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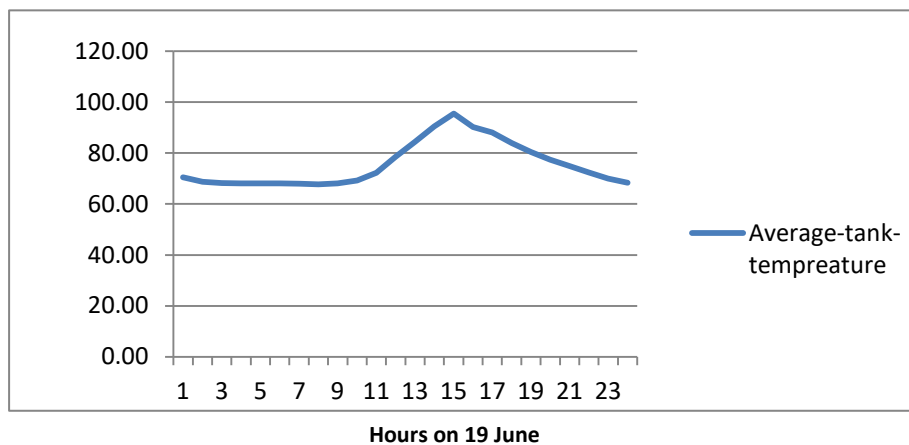


Figure (8) The average temperature inside the thermal tank of the unit (south / west) of the surface with the most suitable outer shell on 19 June, Source: (Researcher, 2019)

Analytical observations:

- We observe that on the roof that the temperature inside the heat tank decreases at the start-up phase of the cooling system and is 70 ° C, lower than the water temperature required when inserting on the system (not less than 80° C) to complete the cooling. Due to the low water temperature coming from the heat exchanger. Gradually, increase with the increasing solar radiation falling on the solar collector during the day. Water temperatures inside the thermal tank begins to rise significantly and reach the highest value of 80 degrees Celsius at the maximum solar radiation in the roof.
- After the hot water exiting the solar collector, it goes through an auxiliary heat exchanger to maintain the water temperature and as an auxiliary heater in case of cloudy days or in case of weak solar radiation. The heat transferred through it to the thermal tank. Figure (8) shows the average temperature of the thermal tank during the day chosen June 19, the following was observed:
 - When hours of cooling system stopped working, we find that the water temperature within the thermal tank begins to decrease slightly relative without significant loss of heat as a result of good insulation of the thermal tank.
 - The temperature of the tank also decreases at the start-up stage of the cooling system, due to the decrease temperature of the water exiting the heat exchanger.
 - And gradually increase with the increase of solar radiation falling on the solar collector during the day, water temperatures within the thermal tank begins to increases significantly and reach the highest value at the maximum solar radiation.

- At the beginning of the cooling system work, we note the decrease of thermal energy within the thermal tank and compensate for that decrease in heat with the heat exchanger and auxiliary heat connected to the thermal tank, so that the system is operating at full efficiency and the required cooling cycle.

4- Hot water entry and exit temperatures from the generator within the absorption chiller unit for June 19:

The roof with the appropriate alternative economically for the external case of the residential unit (south/west) in figure (9):

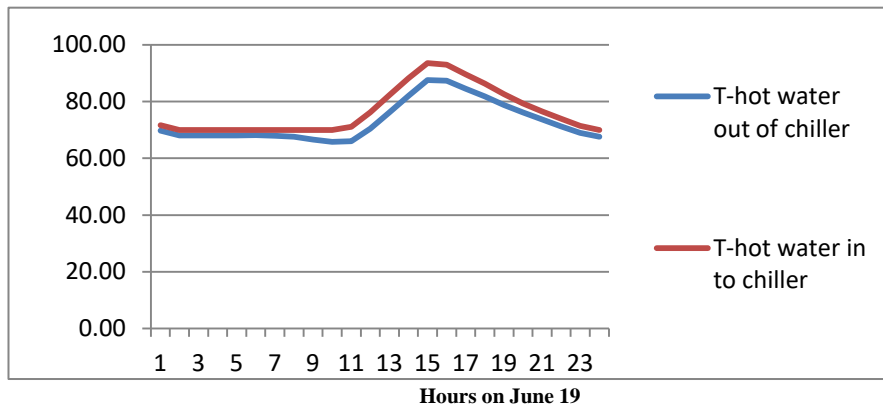


Figure (9) The temperature of hot water entering and exiting the generator to the unit (c / g) for the best floor on June 19
Source: (Researcher, 2019)

Analytical observations

- The temperature of hot water entering and exiting the generator ranging between (69-72 ° C), 69 ° hot water entering the generator, and 72 ° hot water exiting the generator in the surface of the southwest unit.
- The temperature also starts to increase gradually with the first hours of the day from seven in the morning until it reaches its peak in the second and third at noon, ranging between (68-79) degrees. 68 degrees of hot water entering the generator, 79 degrees of hot water exiting the generator, and after It begins to decreases gradually by the evening again.
- When hours of cooling system stopped working at night, there is a gradual decrease in the temperature of the hot water exiting the solar collector to the generator and out of it towards the condenser inside the absorption chiller unite.

5- Temperature of chilled water inflow/ outflow of the evaporator in the Absorption Chiller Unit on 19 June:

The roof with the appropriate alternative economically for the external case of the residential unit (south/west) in figure (10):

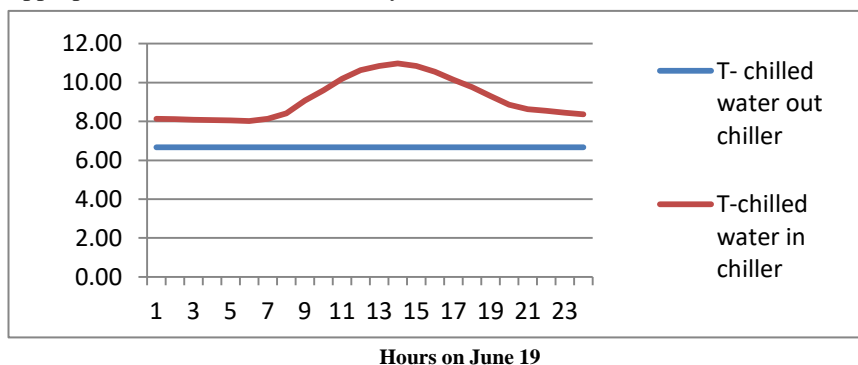


Figure (10) the temperature of the chilled water inflow/ outflow of the evaporator for unit (south/west) on roof which is better on 19 June). Source: (Researcher, 2019)

Analytical Observations:

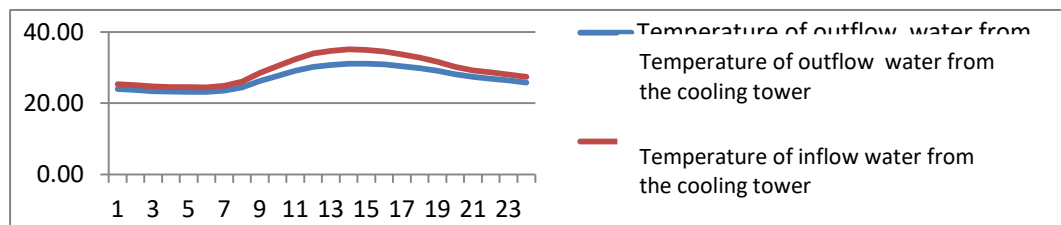
- In the on roof and in the unit (south/ west), we find that the temperature of the chilled water coming from the coils and connected to the evaporator in the Absorption Chiller at 7 ° C is constant, while increasing in the temperature of the chilled water entering the evaporator is still ranging until it reaches 14 ° C.
- It reaches 12° C in the appropriate alternative and then declines again.
- The direction of the residential unit does not affect the outcomes.



- Simulation of the temperature of chilled water coming from the Absorption Chiller Unit is an important variable and a key indicator in measuring the success of the system performance; and chilled water temperature reaches 7 ° C as we have mentioned above when we identified how the system works. Therefore, when conducting the simulation and the chilled water temperature was (7°C) most of the hours of the day with the possibility of minor changes at some times of the day but at the rate level, this indicates the success of the simulation process. In the case of great differences about the known temperature of the chilled water, this demonstrates that an error occurred in the simulation process of the cooling system.
- Upon operating the system, the chilled water which is connected to the Absorption Chiller Unit at 7°C comes out from cooling coil and it absorbs part of the thermal load and returns back to the evaporator from the condenser at 12 ° C, as the temperature of the returned water does not rise so much due to the high flow rate.

6- Temperatures of Cooling Tower Water Inflow/ Outflow on 19 June:

The roof with the appropriate alternative economically for the external case of the residential unit (south/west) in figure (11):



Hours on June 19

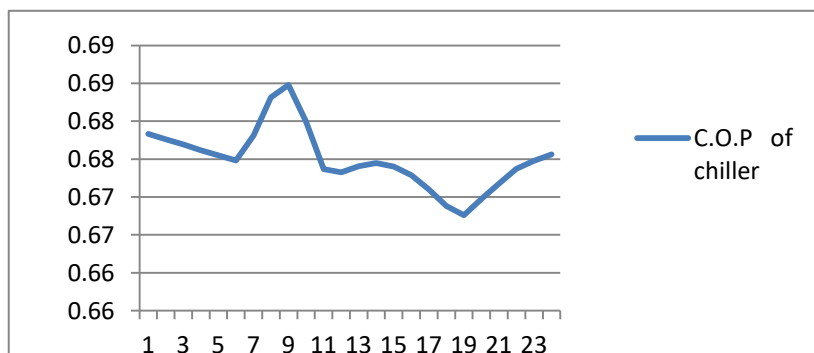
Figure (11) Temperatures of inflow/ outflow water from the cooling tower of the unit in the (southwest) unit on roof which is better on June 19 ,Source: (Researcher, 2019)

Analytical Observations:

- Temperature of cooling tower water inflow/ outflow converges at night and varies with the early hours of the day. Temperature gradually increases until reaching its maximum values at two o'clock in the afternoon. The temperature gradually decreases again by evening.
- The Temperature of the cooling tower water inflow increases as a result of the increased cooling load resulting from the high temperature inside the condenser inside the cooling unit. Temperature reaches its maximum at noon (40 ° C) on roof of the unit (Southwest).
- The temperature of the cooling tower water outflow is lower than the water inflow and the water towards the evaporator. The water reaches its maximum temperature (32 ° C) in the on roof of the housing unit (Southwest).

7- Absorption Chiller Unit Coefficient of Performance on 19 June:

The roof with the appropriate alternative economically for the external case of the residential unit (south/west) in figure (12):



Hours on June 19

Figure (12) Coefficient of Performance of the cooling system of in the (southwest) unit on roof which is better on June 19.Source: (Researcher, 2019)

Analytical Observations:

Through simulating the work of the Solar Thermal Cooling System during the summer season (June- September), it was found that the Coefficient of Performance of the Absorption Cooling Unit in the on roof of the unit (Southwest)

ranges 0.70 to 0.68 during the hours of the day. This is an acceptable range for the efficiency of the performance of the Absorption Cooling Unit.

8- Energies inflow and outflow curves of thermal storage tank on 19 June:

The thermal storage tank is the key cornerstone and source of energy that operates the Absorption Chiller Unit, thus operates Solar Thermal Cooling System as a whole, the following Figure 13 shows Energies inflow and outflow curves of thermal storage tank, which are the four types of energy flowing as follows:

- 1- Added energy by Auxiliary electric water heater “Q Auxiliary”.
- 2- Flowing energy from “Q thermal store tank to solar collector”.
- 3- Flowing energy from “Q thermal store tank to Chiller”.
- 4- Flowing energy from “Q solar collector to store tank”.

Roof with the economically better alternative of the residential (southwest) unit external case:

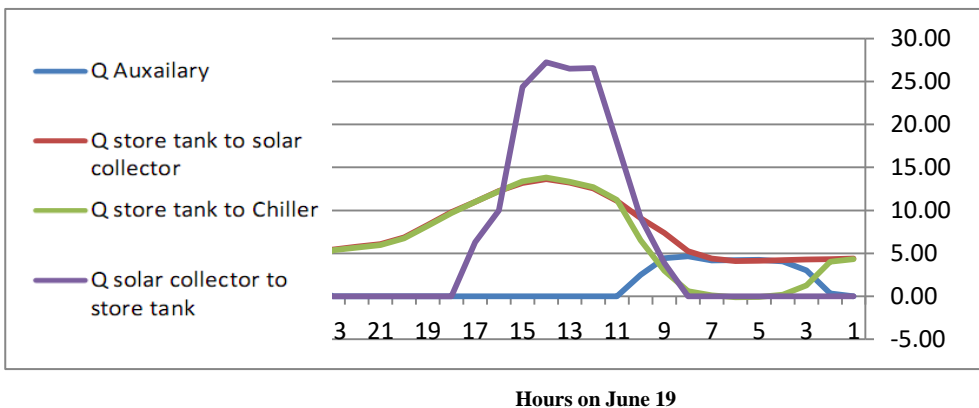


Fig. (13) The energy flow within thermal storage tank of the unit (southwest), which is better on June 19 Source: (Researcher, 2019)

Analytical Observations:

- The rate of energy flow added by the auxiliary electric water heater is inversely proportional to the rate of energy flow from the solar collector toward the thermal storage tank, and that makes sense because, the auxiliary electric water heater operates only when the solar radiation intensity is low, on cloudy days, or when the system is desired to operate at night.
- The rate of energy flow of the thermal storage tank toward the Absorption Chiller Unit and the rate of energy flow from the thermal storage tank toward the solar collector is proportional to the system's working hours.
- The highest proportion of the energy flowing from solar collector toward thermal storage tank, reaching 30 kw/ m2 at its highest degree on June 19.
- There is an increase in the energy flow, south, due to the intensity of solar radiation on the south of the residential block.

9- Curve of the average temperature in the residential unit before the cooling system is integrated and after the cooling system was integrated on June 19.

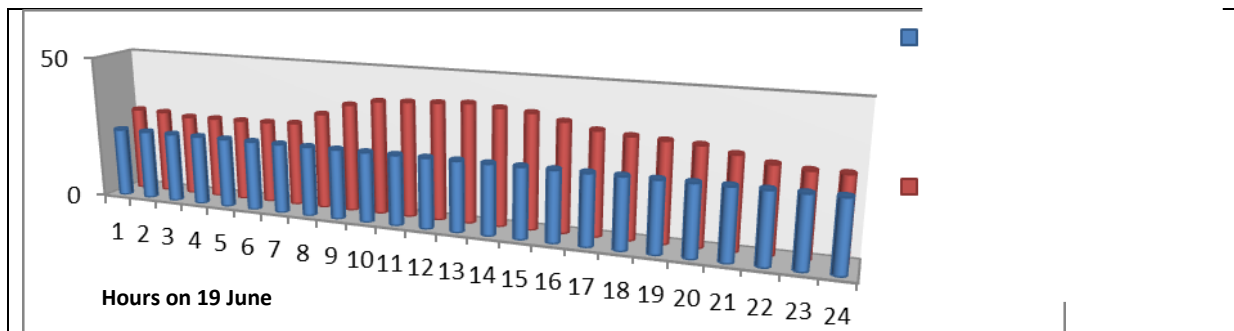


Figure (14) the average temperature shows, through hours in the day June 19 of the unit (southwest) on roof. Source: (Researcher, 2019)

Analytical Observations:-

- The temperature of the spaces inside the residential unit was simulated before integrating the cooling system during the hottest hours in the summer season for the Cairo city on 19 June on the roof of the southwestern unit. It



noticed when practical the best alternative for the external case of the residential unit, the average of the thermal loads are decreased by only 20%. Where, the average temperature was calculated during the day’s hours and was found to range from (28 ° C) at least to (40 ° C) maximum. Therefore, it is necessary to install and integrate the Solar Thermal Cooling System in the residential unit to fully cover the thermal loads.

- Then, the temperature of the spaces inside the residential unit was simulated before integrating the cooling system during the same day 19 June, we found that the solar thermal cooling system has covered the thermal loads of the entire housing unit and reached the temperature inside the spaces to Thermal comfort degree required at (24 ° C).
- The Solar thermal cooling system is succeeded and verified its efficiency in the required task in its integration with the external case is the best in providing thermal comfort within residential spaces.

10- Calculation of the value of saving in electrical consumption after the integration and of solar thermal cooling system in the residential unit (South/ West) with the best external case in the roof during the summer months: According to the readings and the important outcomes of the solar cooling system is the value and quantity of solar energy produced by the system in electricity in kilowatts / hours of the usual electrical consumption of the residential unit which is necessary for air conditioning though the summer. This is determined by simulation program “TRNSYS” according to the following points:

- Calculations were made for the electrical consumption required for air conditioning in residential units, assuming air conditioning 24 hours a day for four months of summer (June – September) , that means testing the maximum operating capacity of the cooling system which allows to verify and ensure its efficiency and performance in covering the conventional electrical loads required for air conditioning during the summer season.
- The value of electrical consumption was calculated in Egyptian pounds according to the prices of electricity stripe approved by Ministry of Electricity and Energy of (2019-2020).
- The calculations were made , considering the operation of air condition to cool an area of about 85 square meters (three bedrooms + hall) for each residential unit by running force a 1.5 H consuming about 1.5 kw / hr) for four months per 16 square meters, with conventional electric power ,and comparing it with the same Area of the housing unit. In the case of internal air conditioning by solar thermal cooling system and calculate the value of saving electricity (kw/h- percentage- Egyptian Pound).

The calculations were done and the results were obtained in Table (2) considering the following inputs and data:-

- 1- Total electricity consumption before solar cooling for summer season measured by (Q Generator) (KW/hr.).
- 2- Total solar energy produced from solar cooling for summer season measured by (Q solar) (KW/hr.).
- 1- Monthly Electricity consumption before solar cooling (Q1 generator) measured by (KW/hr.).
- 2- Solar energy produced monthly by cooling system (Q2 solar) measured by (KW/hr.).
- 3- Monthly Electricity consumption after solar cooling (Qg1-Qs2) measured by (KW/hr.).
- 4- Monthly Electricity consumption before solar cooling in US dollars.
- 5- Monthly Electricity consumption after solar cooling in US dollars.
- 6- Saving’s percentage (%).
- 7- The value of monthly savings in US dollars.

Table (2) shows the quantity and value of electricity consumption (kWh - percentage - Egyptian pound) after the integration of solar thermal cooling system in the housing units (c / g) with the best outer shell of the roof during the summer months (from June - September):

| Housing units | Total electricity consumption before solar cooling for summer season (Q generator) and measured .(KW/ hr | Total solar energy produced from cooling system for summer season (Q solar) and measured (KW / hr) | Monthly electricity consumption before solar cooling Q1 generator KW/hr | Monthly solar energy produced from cooling system for | Monthly electricity consumption after Qg1-) solar cooling (Qs2) (KW/hr) | Monthly electricity consumption before solar cooling in US dollars | Monthly electricity consumption after solar cooling in US dollars | Saving percentage (%) | Monthly savings in US dollars |
|--|--|--|---|---|---|--|---|-----------------------|-------------------------------|
| Roof units West-south A better alternative | 27925 | 24015 | 6981 | 6003 | 978 | 422.75 | 59.16 | 86% | 363.59 |

Source: (Researcher, 2019).

Analytical Observations:

We find that the usual electrical consumption required for air conditioning in the roof before the integration of solar thermal absorption system is higher than the electricity consumption after the process of integration and so as rational, because the solar energy produced by the cooling system for housing units in the roof covers about 86%, indicating the success and efficiency of performance Solar thermal cooling system, and the amount of solar energy produced (Qs) is directly proportional to the traditional electrical consumption Q g).

VII. CONCLUSION

- To cover the usual thermal loads in the housing unit and its rationalize with solar energy instead of electric power. The air conditioning system designed according to the stages of solar energy absorption to achieve thermal comfort in the housing units by an area of 100 square meters. The dynamic simulation program TRNSYS was used to calculate cooling loads seeking for the summer season (June - September) and culminated in the basic alternative to the housing unit (25 kW / Hr) at on 19 June in Cairo “the place of study applied” has been the application and conducting repeated simulations after the integration of solar thermal cooling system with the most suitable external alternative to the housing units southwest of the roof.
- The absorption thermal cooling system was selected to apply to the case study and to return to the products available in Egypt in the markets of solar thermal cooling systems. Absorption Chiller Unite was selected with a design capacity of about 15 kilowatts and the unit works with water as an absorption refrigerator and lithium bromide as absorbers. The cooling unit is water cooled at 7 ° C 'and the design (two solar collectors vacuum tubes with an area of 16 square meters respectively connected to provide hot water at 85 ° C to a thermal tank with a capacity of 2 cubic meters. Also connected to the cooling tower and cooling pipes and an auxiliary heat exchanger, pumps, valves, expansion) for the design and operation of the solar thermal cooling system previously mentioned.
- The cooling system achieved a solar participation rate of 95%
- The average performance coefficient of the cooling unit c. o. p. About 0.7
- The efficiency of solar collectors 88%
- The success of the solar thermal cooling system and verification of its efficiency with the task required in its integration with the best outer shell of the roof of the southwestern unit in providing thermal comfort within the blanks 24 ° C and also rationalize the consumption of electricity by the usual 86%.
- The research study recommends after the success and efficiency of the solar thermal absorption cooling technology to generalize and activate its usage on a large scale and at the level of various projects.

REFERENCES

1. Ministry of Electricity and Renewable Energy, available at <http://www.nrea.gov.eg/Technology/SolarIntro> 3-11-2019.
2. Standing Committee for the preparation of the Egyptian code, the Egyptian code for the improvement of energy efficiency in the two parts (residential and commercial), the National Center for Housing and Building Research,2008.
3. http://www.moee.gov.eg/test_new/home.aspx 6-12-2019.
4. Mugnier, D., Solar Cooling Position Paper, Operating Agent of Task 48: Quality Assurance and Support Measures for Solar Cooling of the IEA Solar Heating & Cooling Programme, September 2015.
5. Pridasaws,W., Solar-Driven Refrigeration Systems with Focus on the Ejector Cycle, Doctoral Thesis, Royal Institute of Technology, KTH, Denmar, 2006.
6. Lorincz, J., Bule I., and Kapov, M., Performance Analyses of Renewable and Fuel Power Supply Systems for Different Base Station Sites, Energies 7, 2014 ,pp 7816-7846.
7. <http://www.yazakienergy.com/waterfired.htm> 7/9/2019
8. http://www.aosua.com.cn/company_profile.html _ 2/10/2019
9. <http://www.nrea.gov.eg/Technology/SolarIntro> 3-11-2019
10. <https://www.syr-res.com/article/7824.htm> 7-11-2019
11. <https://www.carriermaintenance.com/963/Components-Air-Conditioner> on 7-11-2019
12. Otanicar, Todd, Robert A Taylor and Patrick E Phelan. ,Prospects for solar cooling– An economic and environmental assessment. Solar Energy,2012
13. Best, R and W Rivera, A review of thermal cooling systems. Applied Thermal Engineering,2015.



14. Sarbu, Ioan and CalinSebarchievici, Review of solar refrigeration and cooling systems. Energy and Buildings, 2013.
15. Ghafoor, Abdul and AnjumMunir, Worldwide overview of solar thermal cooling technologies. Renewable and Sustainable Energy Reviews, 2015
16. Ullah, Kr, R Saidur, Hw Ping, RkAkikur, and NhShuvo, A review of solar thermal refrigeration and cooling methods. Renewable and Sustainable Energy Reviews, 2013
17. Bent Sorensen, Solar Power, in Renewable Energy Focus Handbook, Academic press: USA,2009.