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STUDYING OF PERFORMANCE ENHANCEMENT FOR CLASSIC SOLAR STILL USING SOLAR CONCENTRATOR BY FRESNEL LENS TECHNIQUE WITH HOT WATER PRODUCTION

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ABSTRACT

In this study, Fresnel lens has been used with two axes tracking to improve the desalination system and increase its production, where it has been specified the main components of the solar concentrator, using a Fresnel lens and specified the main components of the classical solar still. The theoretical calculations for Thermal energy have been accomplished, the energy extracted from solar radiation using the solar concentrator, as well as the energy extracted by classic solar still, without using the concentrator, the production amount of distilled water extracted under standard condition of 1000 w/m^{2}and ambient temperature (25 ^{o}C), without using concentrator was (4.7liter / day) and the distilled water with using concentrator was (7.14liter / day), in addition to get amount of hot water wash (52.98 liter/ day) at temperature (42.52^{o}C).

KEYWORDS: Solar Energy**,** Classic Solar Still, Solar Concentrator, Fresnel lens

INTRODUCTION

The main principles to distillate the water using solar energy is simple and active, distillation is similar copy to make droplets of rain, where the solar energy warms water to a temperature of evaporation, so the water vapor rises and condensation on the glass of solar still and then collected. This process removes impurities such as salts and heavy metals, as well as eliminate the microorganisms and the final result was that distilled water, which is obtained by solar distillation is cleaner and purer than rain water and (passive solar distiller) only needs sunlight to work. The distilled water produced from these distillates does not acquire a taste distilled commercial water because it does not boil (i.e. Lowers pH) and this distillation use evaporation and natural condensation of any similar operations rain and this allows for the degree of natural acidity which produces an excellent taste compared with the distillation of steam.

Solar desalination Systems can easily provide drinking water and cooking needs by the family, can be used to remove impurities effectively and many of the salts and microorganisms and even used to produce drinking water from sea water and these distillates still used by many users, both in the countryside and urban around the world can be successfully used in any place where the sun shines.

It has been the practice of the solar distillation for many generations because of all the desalination require fossil fuels or electricity, but solar distillation is one of the many processes that can be used to produce fresh water by using the heat of the sun directly in a simple water purification equipment and called on the devices solar distillation [1 -2].

Solar distillation is a tried and true technology. The first known use of stills dates back to 1551 when it was used by Arab alchemists. Other scientists and naturalists used stills over the coming centuries, including Della Porta (1589), Lavoisier (1862), and Mauchot (1869).

The first "conventional" solar still plant was built in 1872 by the Swedish engineer Charles Wilson in the mining community of Las Salinas in what is now northern Chile (Region II). This still was a large basin-type still used for supplying fresh water using brackish feed water to a nitrate mining community. The plant used wooden base which had blackened bottoms using logwood dye and alum. The total area of the distillation plant was 4,700 square meters. On a typical summer day this plant produced 4.9 kg of distilled water per square meter of steel surface, or more than 23,000 liters per day. This first stills plant was in operation for 40 years. Over the past century, literally hundreds of solar still plants and thousands of individual stills have been built around the world.

There have been many research studies on the design of solar distillates and improve their performance and get a high output of distilled water and in order to increase the efficiency and productivity of these distillates made various attempts were the effect of changing the geometry of the distillates Test (type and thickness of the upper covers, tilt angle, a number of basins, and the use of double effect) to improve the distillate output [3-7].It was also testing the use of materials that absorb radiation , such as blacking , depth of the water in the tub , use a sponge cubes , black coal and black steel cubes in the water all of these factors affect the production [8-10] .

Solar distillation systems are classified mainly to negative Systems (passive Solar Still) and positive (Active Solar Still), these systems are effective until the present time. And factors affecting the productivity of solar distillation are: the depth of detailed basin, the materials used in the construction of detailed, wind speed, solar radiation, the degree of external ambient temperature, inclination angle. Since the productivity of any kind is determined by the difference in temperature between the water in the distilled Basin and the inner surface of the cover glass, In the negative solar distillation systems are receiving solar radiation directly by the basin water is the only source of energy for raising the basin water temperature then evaporation of water and this leads to low productivity and this is a major drawback of negative solar distillers [11].

At present, research activities focused to increase distillate yield and increased reliability and low primary cost solar distillers. This research includes new designs for solar distillation systems that improve production by increasing the temperature of the water in the solar still. This can be achieved through heat recovery by reducing the impact of factors affecting the productivity of the solar distillers or by engaging solar still with a thermal tank heated by the solar source [12].

In the current study will be a solar concentrator use by using the Fresnel lens to get the necessary energy to deliver it to the classic solar still then water is ready to vaporize thin distillates directly while water in the solar still basin without the concentrator was vaporized by direct solar radiation after a period of time.

SOLAR STILLSYSTEM

The solar still system consists of the main units as in figure (1).

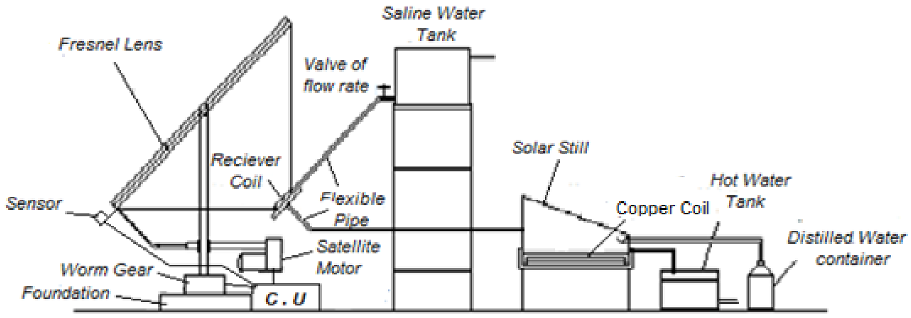

Figure 1: Schematic Diagram of the Solar Still System

SOLAR CONCENTRATOR UNIT

It consists of the following units:

Fresnel lens

It is optical elements with surfaces of graded form used in the application of capacitors, light, enlargement, as concentrator elements for the optical detectors.

The optical lens can be made from: glass, acrylic, (within the visible and short infrared ranges), polycarbonate (for the long infrared). The concept of the concentrator lens is shown in figure (2), as a Plano convex lens. The lens was segmented into several rings with the same center; all the rings are a lens which refracts the falling rays to common focus as known in formula no. (1)

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad \textbf{(1)}$$

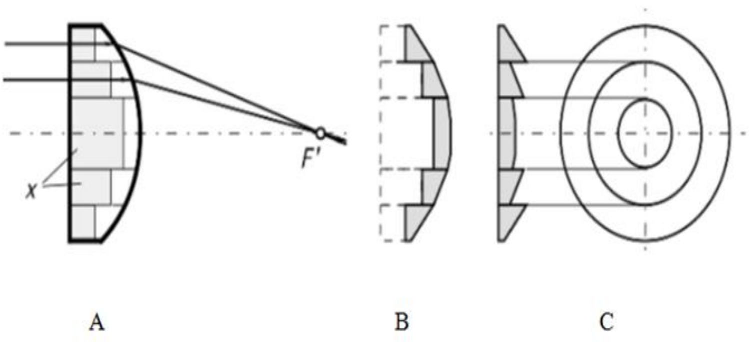

Figure 2: Fresnel lens Principle

Where:

f: is the focal length.

n: is coefficient of refraction for the lens material.

R_1, $R_{2:}$ are the radiuses of the balling of the lens.

Fresnel lens has more advantages than the conventional lens like low weight, thin size, ability to be convex or any other form, low loss absorption of the flow of light, the last advantage for the manufacturing of the lenses for the long and medium ranges of the infrared rays, as the absorption is high in the material. [13]

The mixing between the semispherical surface which eliminates the longitudinal spherical aberration and thinnest of the lens (which decrease a largely the losses of absorption in the materials and through the lens form) this should allow the Fresnel lenses to have accepted performance then to be made with very large diameters [14]

The aperture area of the concentrator can be calculated by the following equation [15]

$$A_a = \pi \frac{d^2}{4} \quad \textbf{(2)}$$

The power value of the solar radiation (q_{inc}) falling on the lens, can be given by the following equation [15]

$$q_{inc} = I.\ A_a.\ T \qquad (W) \quad \textbf{(3)}$$

Where

T: the transmittance of the lens

I: the solar radiation. (W/m^2)

a: .The aperture area (m^2)

Mechanical Unit

It consists of two parts:

- The fixed part that represents the main base of the solar concentrator and it is made of (I-Beam 100x50) structural steel.
- The moving part that accomplishes the lens movement into two axes.

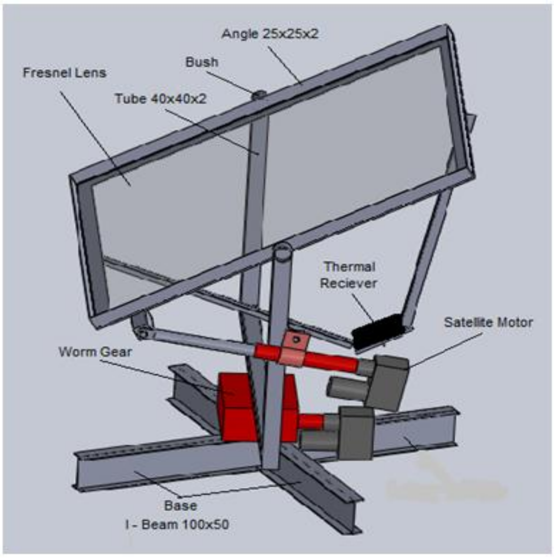

Figure 3: Design Photograph for the Mechanical Unit

- The first is the rotational axes which are done with worm gear through the metal structure made of (Tube 40x40x2) which has flexible join with the metal frame of the lens made of (Angle 25x25x2).
- The second is for the straight movement which is done by DC. Motor, 12 volts, which are fixed on the metal structure for the rotational movement and the moving part to connect the iron frame of the lens in order to move the lens.

The mechanical movement was done according to the signal coming from the control unit.

CONTROL UNIT (TRACKING SYSTEM)

Optical group

It consists of silicon sensor type (PIN); their response to spectral is (700-1100) μm. It can be assembled on mechanical base with pyramidal form with the angle of 45^o with horizon to ensure the fall of the solar rays on the fourth sensors then the unit can sensitive the solar rays and translate the electrical signal to control unit in order to get continuous instantaneous tracking for the sun position.

Control Box

It considers the main part of translating the electrical signal from the four sensors to the mechanical motors to conduct the required movement. This part was built to ensure the movement and the instantaneous tracking completely and efficiently.

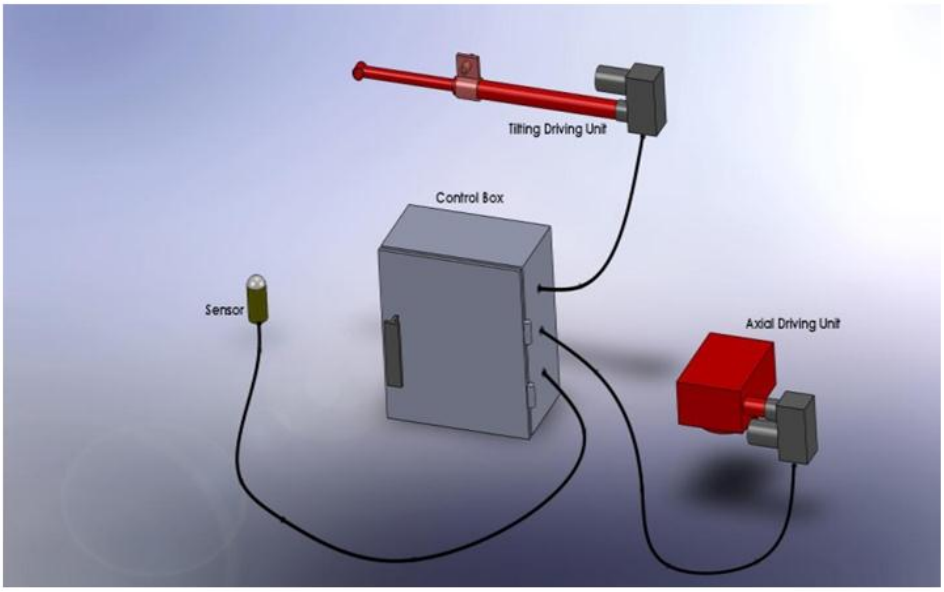

Figure 4: Control and Tracking System

SOLAR STILL UNIT

The cellar still work on the principle of the rain water cycle, which consists of two steps are the evaporation and condensation, as the water was heated by the solar energy to the evaporation case and then condensed on the glass surface.

This study will use Fresnel lens as a solar concentrator, to follow the sun with two axes, to conduct the steam inside the solar still, as additional energy to the direct energy entering the still through the glass, to cover the steam that will condense at the inner surface of the glass, which is fixed with tilt angle of (20^o), for sliding the condensed drops easily to the assembly channel, this way it will remove the salts, heavy materials and end the micro – organisms. The basin of the still must be coated with black coating to improve the absorptivity of the solar radiation .The glass has Transmittance to sunlight (Ultraviolet, Visible light ,Near infrared) as it absorb some of them by the black surface of the basin (still basin) in which the water temperature in it will increase, there is also emission of energy in the form of (far infrared wave) it will be reflected by the glass and bounce to the still basin and this will cause greenhouse effect and this will lead to increasing the water temperature , the evaporation rate and the moisture content for the air trapped between the water surface and inner surface of the glass ,as a result, this will lead to increase the water vapor, which condense at the inner surface of the glass as a small drops.

The condensation will take place between of temperature reduction of the outer surface of glass because of the ambient temperature, then the condensed drops will slide and pass to the distilled water channel, the remaining impurities and Microbiology will remove, as the distilled water will bring together in the glass containers or plastic.

Note that the longitudinal axis is placed on the line (west – east) then the class must be toward the south.

The Components of Classic Solar Still and their Properties

The various components of Classic solar still and their properties as shown in figure (5) and can be listed in the table (1) below:

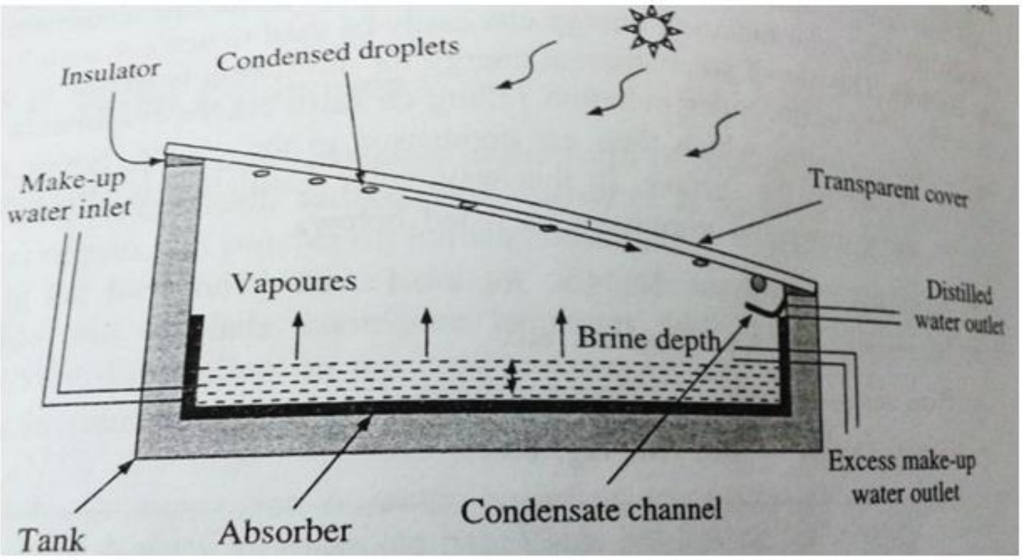

Figure 5: Schematic Diagram of the Classic Solar Still

Table 1: The Basic Component of the Solar Still

No.	Steel Components	Material	The Purpose
1	Container of salty water	Galvanized Iron Sheet	Must be insulated at the base and sides to prevent the heat losses
2	Insulator	Glass wool	To decrease the heat losses
3	Glass Cover (Transparent cover)	Glass	To allow the solar radiation to pass into the water inside the basin and its inner surface helps to condense the steam and slide it to the distilled water channel.
4	Absorptive Surface (Absorber)	Black Nitrocililose	To absorb the Solar radiation and must be able to withstand the high temperatures.
5	Distilled Water channel (Condensate channel)	Galvanized Iron Sheet	To assemble condensed water drops.
6	Water Supply Pipe (Make-up water inlet)	PVC	To provide salty water (raw water)
7	Excess Water Pipe(Make-up water outlet)	PVC	To clean up and take out the excess water from still basin.
8	Distilled Water Container	Glass	To store the distilled water output.
9	External container (Tank)	Galvanized Iron Sheet	The main container

THE THEORETICAL CALCULATIONS

The important factor is the value of required distilled water product per day, and then the total required solar collector area can be found. But, we can improve solar collector performance through use other solar thermal source and here used solar concentrator by Fresnel technique, to the enhancement of the performance classic solar still, with hot water production and the following theoretical calculations will show this:

Standard Data used in the Calculations

- Potential energy for water evaporation λ_w = 2260 (KJ/Kg).

- Water density ρ = 1 (Kg/litter).

- The efficiency of solar still η = 30% (this can be changed according to the design).

- Solar radiation rate I = 500 (W/m^2).

- The number of daylight hours = 10 hours.

- Optical efficiency for the Fresnel lens η_o = (0.6-0.75)

- Thermal receive absorptive α = 0.9.

Energy Produced Account of the Solar Concentrator and the Productivity of Distilled Water

The produced energy at the receiver of the concentrator can be found by the following equations:

$$Q = I * A_a * \eta_o * \alpha \quad (4)$$

$$A_a = \frac{\pi}{4} * D^2 \quad (5)$$

Where:

A_a: the aperture area of the lens (m^2).

D: the diameter of the Fresnel lens (m).

$$Q = \dot{m} * C_P * \Delta T \quad (6)$$

$$\dot{m} = \frac{Q_1}{(C_P * \Delta T)}$$

Where:

$\dot{m}$:The water flow rate (Kg/s).

C_p:The specific heat for water = 4.2 (KJ/Kg.℃).

ΔT:The temperature difference between entry and exit the water for the receiver

$$Q_{loss} = U * A_s * \Delta T_1 \quad (7)$$

Where:

q_{Loss}: The heat losses at the outer surface of the pipe (Watt).

A_s:The outer surface area of the pipe (m^2)

ΔT_1:The temperature difference of water between the outer surface of the pipe and the ambient (℃)

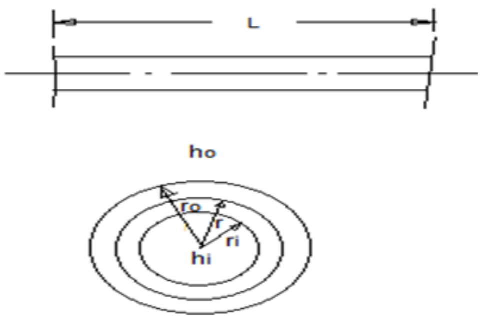

Figure 6: Pipe Details

$$U = \frac{1}{R} = \frac{1}{\frac{1}{h_i} + \frac{\ln\frac{r}{r_i}}{2\pi KL} + \frac{\ln\frac{r_o}{r}}{2\pi KL} + \frac{1}{h_o}} \quad (8)$$

$$Q_{Loos} = \dot{m} * C_p * \Delta T_2$$

$$\Delta T_2 = (T_i - T_o)$$

$$T_o = T_i - \frac{Q_{Loos}}{\dot{m} * C_p}$$

ΔT_2: The temperature difference between entry and exit water for the pipe

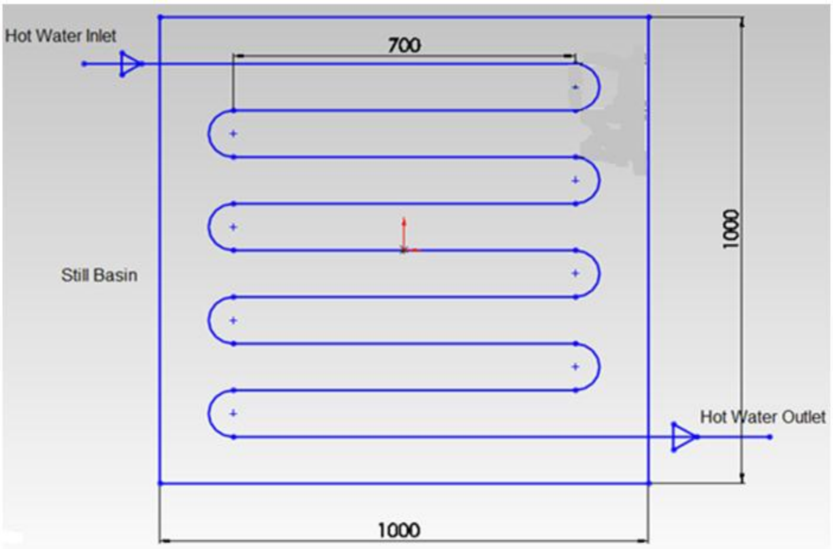

Figure 7: The Copper Coil in the Solar Still Basin

$$Q_1 = \dot{m} * C_P * \Delta T_3$$

ΔT_3: The temperature difference of the water for the copper coil in the solar still basin

$$Number\ of\ liters(1) = \frac{Q_1 * Sun\ hours\ in\ day * \frac{3600}{hour}}{latent\ heat\ of\ vaporization\ for\ water}$$

Direct Energy Reached Account to the Solar Still and the Productivity of the Distilled Water:

$$Q_2 = I * \eta \quad (9)$$

Where:

Q_2: the direct energy reached by solar still (Watt).

$$Number\ of\ liters(2) = \frac{Q_2 * Sun\ hours\ in\ day * \frac{3600}{hour}}{latent\ heat\ of\ vaporization\ for\ water}$$

Total liters = $Number\ of\ liters(1) + Number\ of\ liters(2)$

The Hot Water Production in Addition to Enhancement of Classic Solar Still Performance:

In addition to improve the classic solar still production the solar concentrator will provide amount of the hot water and this can calculated by equation:

$$m = \dot{m}\ x\ 3600 \quad (10)$$

m: the amount of hot water (liter/h).

DISCUSSIONS AND ANALYSIS

The calculation of amount the distilled water by the classic solar still is enhanced by using the solar concentrator, that increase the amount as shown in figure (8), where under standard condition of (1000 W/m^2) and ambient temperature

(25 °C) it is noted that, the amount of distilled water was (0.236 liter/h) and this represents only solar concentrator energy contribution productivity, while the classic solar still productivity, the amount of distilled water was (0.477 liter/h) that shown in figure (9), the whole amount of productivity that produced by both classic solar still and the solar concentrator contribution was (0.714 liter/h) as shown in figure (10). The solar concentrator also contributes in hot water productivity that was (5.29 liter/h), as shown in figure (11).

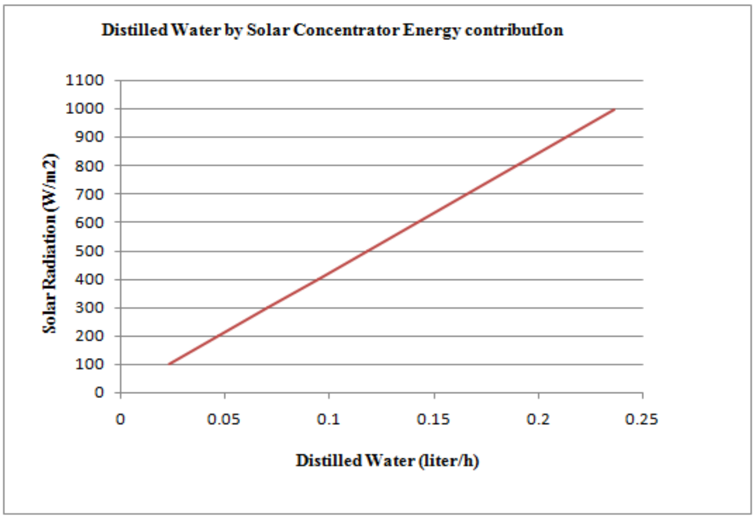

Figure 8: Distilled Water per Hour Depending on Solar Radiation Value by Solar Concentration Contribution

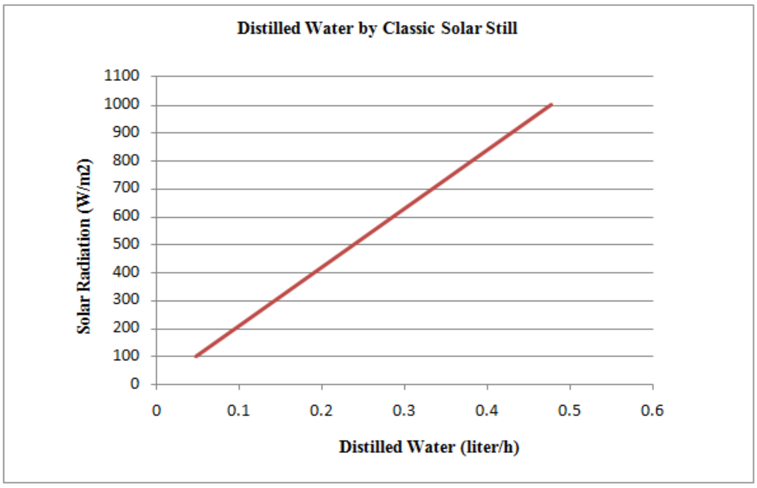

Figure 9: Distilled Water Production per Hour Depending on Solar Radiation Value by Classic Solar Still

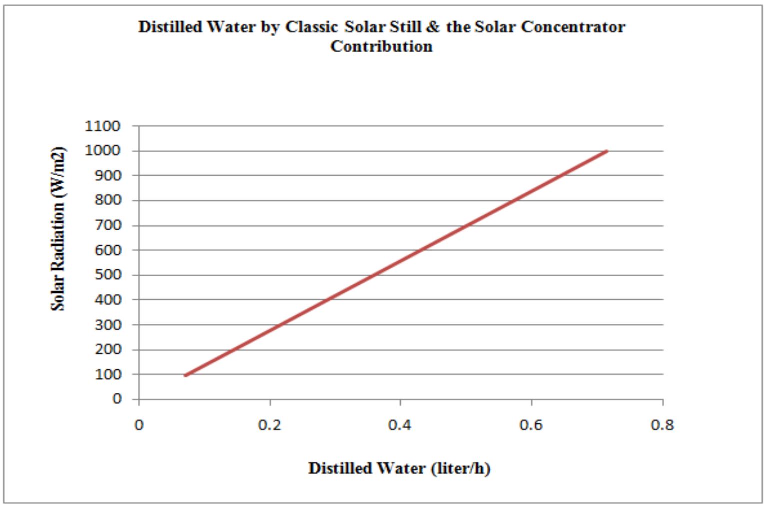

Figure 10: Distilled Water Production per Hour Depending on Solar Radiation Value by Classic Solar Still &Solar Concentrator Contribution

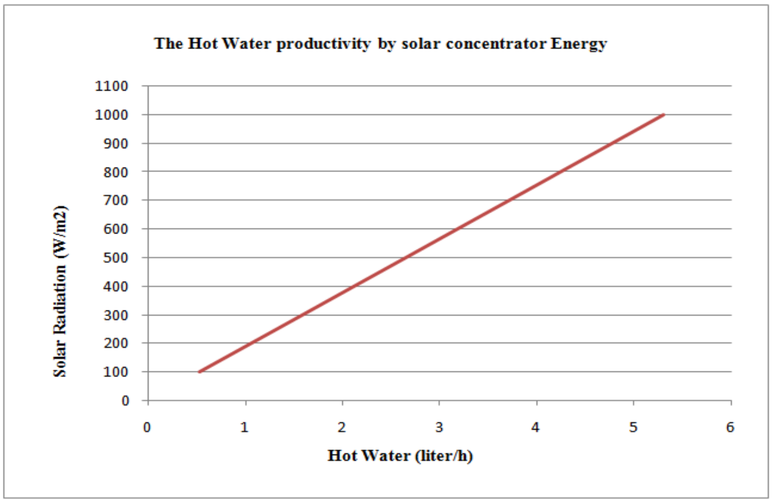

Figure 11: The Hot Water Production by Solar Concentrator Depending on Solar Radiation Value

CONCLUSIONS

In the present study, through the theoretical calculation has been proved the use of solar concentrator, by Fresnel lens technique increased the energy, that receive by the classic solar still by heat transfer and cause enhancement its performance, in addition to get the amount of hot water by solar concentrator for home use, but it is worth mentioning there is additional cost, because of using Fresnel lens as solar concentrator and solar tracking system, this cost will compensate after period from the profit of the additional production for distilled water and hot water.

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