The Single Basin Solar Still Productivity Enhancement Using Flat-Plate Collector

Ridha CHERRAYE
Laboratory of New and Renewable Energy in Arid Zones (LENREZA), University Kasdi Merbah Ouargla, 30000, Algeria
Department of process engineering, Kasdi Merbah University, Ouargla 30000, Algeria
E-Mails cherrayeridha@yahoo.fr

Bachir BOUCHEKIMA
Laboratory of New and Renewable Energy in Arid Zones (LENREZA), University Kasdi Merbah Ouargla, 30000, Algeria
Department of renewable energy, Kasdi Merbah University, Ouargla 30000, Algeria.
E-Mails boubachir@yahoo.fr

Abstract —In this experimental study, single basin solar still (SBSS) has a low productivity, to solve this problem some techniques have been used, these techniques consist of using a flat plate collector. The main objective of this research was to effectively utilizing the flat plate collector (FPC) for solar still productivity enhancement and it is working as a hybrid system. The flat plat collector (FPC) model solar water heater was coupled with a solar still, and the experiments were repeated in 3 to 5 winter days, and the results were measured in the same manner for each day. The results revealed that the productivity of the still was increased 87% when it was coupled with one and was decreased 20% and 50% when it was coupled with two and three flat plate collector respectively under winter condition (5-20/01/2016) in Ouargla (31.95°N, 5.4°E), south of Algeria.

Keyword: ***Solar energy; Solar desalination; Distillation; Single basin solar still; Flat plate collector; Coupled; Productivity; Enhancement.***

I. INTRODUCTION

There are new solutions were proposed for the water supply to counterbalance emerging challenges related to the availability of water posed by population growth and climate change. Conventional desalination technologies are available for purifying the water, but due to high energy intensive and dependent on fossils fuels, carbon emission to the environment degrade ecology and natural habitats [1-3].

Therefore, finding renewable and sustainable energy technology, which is cost–effective, safe, environmentally friendly to produce potable water from unkempt or toxic water for its optimal use in drinking and other purposes is utmost necessary.

Solar still is a device used in solar distillation process to produce potable water. This device is a cheap unit and can be designed from abundant and cheap materials. There are different types of solar stills including pit, cone, and domo solar stills. However, the most common type is the basin still. It has many different variations, the use of solar still is not popular due to its low productivity. A number of works have been undertaken to improve the productivity of these stills. The most effecting parameters on the still productivity and efficiency are location, solar intensity, ambient temperature, glass cover material and its thickness, basin water depth and wind velocity.

For most cases, even under optimized operating conditions, the reported efficiency of the single basin solar still was less than 5 $l.m^{-2}day^{-1}$ of fresh water production. This low efficiency is mainly due to the complete loss of latent heat of condensation of water vapor on the solar still glass cover, To improve the performance of conventional solar stills, several other designs have been developed, such as adding flat plate solar collector. On integrating flat plate collectors to the solar still, there was a significant increase in the temperature of the brine solution for the better improvement in the yield and efficiency [4,5]. Fig. 1 show the schematic diagram of a single slope solar still coupled to a flat plate collector. As per Rajaseenivasan et al. [6], the increase in temperature of brine solution depends on parameters such as mass flow, solar intensity, absorber material. Experimental results showed that, two different materials (Jute cloth and dyed jute cloth knitted with wool) in a thermosyphon mode was improved the yield by 48.15% than the simple one for minimum water mass of 20 kg. Further increase in the water mass has decreased the yield and temperature of water in the basin as it was not evenly distributed. The average distillate increases with an increase in water mass up to 6 kg and thereafter decreases. Also, it was reported that the yield depends on mass flow in FPC, and it was observed that there was an improvement in yield when the flow rate was increased from 1to 3 $kg.min^{-1}$. It was recommended to cool glass cover as it was improved the condensation rate. The effect of coupling a flat plate collector to a solar still for improving the yield of fresh water was experimentally investigated by Badran et al. [7], Experimental investigations were carried out, and parameters like water depth, orientation and solar radiation are the important parameter for enhancing the yield. It was found that coupling flat plate collector increased the yield by 36% (3.5 kg/day of distilled water) while the yield of conventional still was found as 2.24 $kg.day^{-1}$. Hitesh N Panchal [5] made an experiment with solar still with flat plate collector in climate conditions of Mehsana, Gujarat. They proved 29% increase in efficiency of solar still by coupling of flat plate. Panchal et al. [4] experimental results show that, connecting evacuated tubes with the lower side of the inner basin increases daily distillate output of 56% and is increased by 60, 63 and 67%. in climate conditions of Mehsana, Gujarat. Eltawil et al. [8] The solar still coupled with water solar collector showed better performance over conventional basin solar still by: 104% and 141% in case of sprayed hot water (passive and active circulations). Rajaseenivasanet al. [9] Result indicates that the FPCB still has higher evaporation rate than the conventional basin still. Raju et al. [10] The results show that solar still, with two FPCs connected in series, provides 41% more distillate yield when compared to still with single FPC. Sampathkumar et al. [11] The results revealed that the productivity of the still was doubled when it was coupled with a 24-hour period. Alharahsheh et al. [12] The external solar collector improved the productivity of the system by complementing the energy required to operate the unit continuously. Sathyamurthy et al. [13] The integration of solar stills with solar collectors increases the yield of fresh water by 36%.

The aim of the present paper is to conduct an experimental work for the solar still in active mode under the south east Algerian climate. The active still with different operational techniques have been proposed to improve its productivity. All the results were compared together to reach to the best operating technique that can be used in future for solar still augmentation for production of drinking water to population of arid regions in the Algerian desert.

II. EXPERIMENTAL INVESTIGATIONS

Figure 2 shows four identical stills were constructed from a large variety of local materials to reduce the overall cost and ease of construction. Solar stills coupled with 3 different number of FPCs, namely single collector, two collectors and three collectors, collector inclination of 30° is fixed for all experiments. The experiments were conducted in 4 phases, witness still, still with one FPC, still with two FPCs connected in series and still with 3 FPCs connected in series. The parameters, outer glass temperature, inner glass temperature, vapor temperature, water temperature, ambient temperature, incident radiation on glass cover and collector/collectors, inlet and outlet temperatures of collector/collectors and distillate output are measured on 12 h basis for all the four experiments.

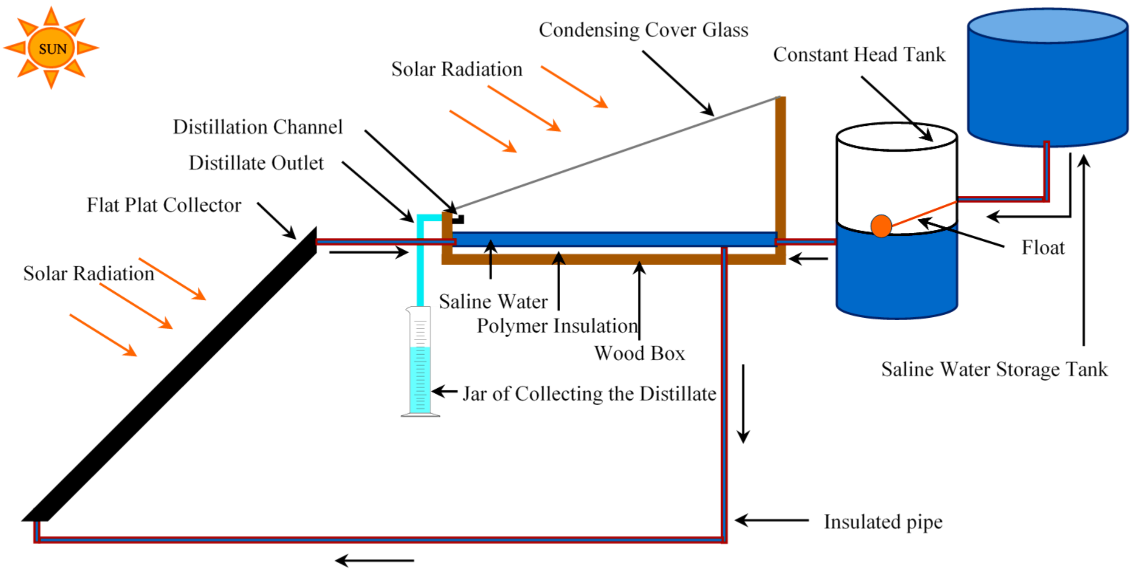

Fig. 1 Line diagram of an active solar still coupled with flat-plate collector.

The equipment used in the experiment. The basin liner is made of galvanized iron sheet of 40 x 60 cm2 with maximum height of 5 cm, and 1.4 mm thickness. The galvanized basin was painted by by matt-type black paint. the glass cover has 40x70 cm^2 and 3mm thickness , Glass covers have been sealed with silicon rubber which plays an important role to promote efficient operation as it can accommodate the expansion and contraction between dissimilar materials. polymere of 5 cm thickness with thermal conductivity of 0.045 $W.m^{-1}$ $.K^{-1}$ is used as an insulating material to reduce the heat losses from the bottom and the side walls of the solar still. A small tank is installed in the system as a constant head tank which is used to control the level of water inside the still (maintain the water level in the basin constant along time) by a floating ball.


Fig.2 Photograph of the still with three FPC arrangements.

A Pyranometer is used to measure the solar radiation. This device measures the instantaneous intensity of radiation in ($kW.m^{-2}$) with a range from 0 to 1.2 $kW.m^{-2}$. Six thermocouples (type-k) coupled to digital thermometer with a range from 0 to 99.9 °C with ±1°C accuracy are used to measure the temperatures of the various components of the still system. A digital anemometer is used to measure wind speed. The distillation efficiency (η_D) of the solar still has been defined as the ratio of distilled water produced to the total solar radiation energy received. Integration over a given period of time results in following distillation efficiency: For the passive solar still,

$$\eta_D = \frac{\sum m_{ew} L}{A_g \sum I(t)} \times 100 \quad (1)$$

For the active solar still,

$$\eta_D = \frac{\sum m_{ew} L}{A_g \sum I(t) + A_c \sum I_c(t)} \times 100 \quad (2)$$

Where mew is yield, L is latent heat, A_g and A_c are areas of glass cover and collector and I(t) and $I_c(t)$ are incident radiations on still and collector.

III. RESULTS AND DISCUSSION

In the present work, the comparative performance of a single slope and single basin active solar still with 30 condensing cover inclination with one FPC and two different numbers of FPCs connected in series is reported. Three different collector inclinations and tilte angle of solar still were fixed of 30° (local latitude).

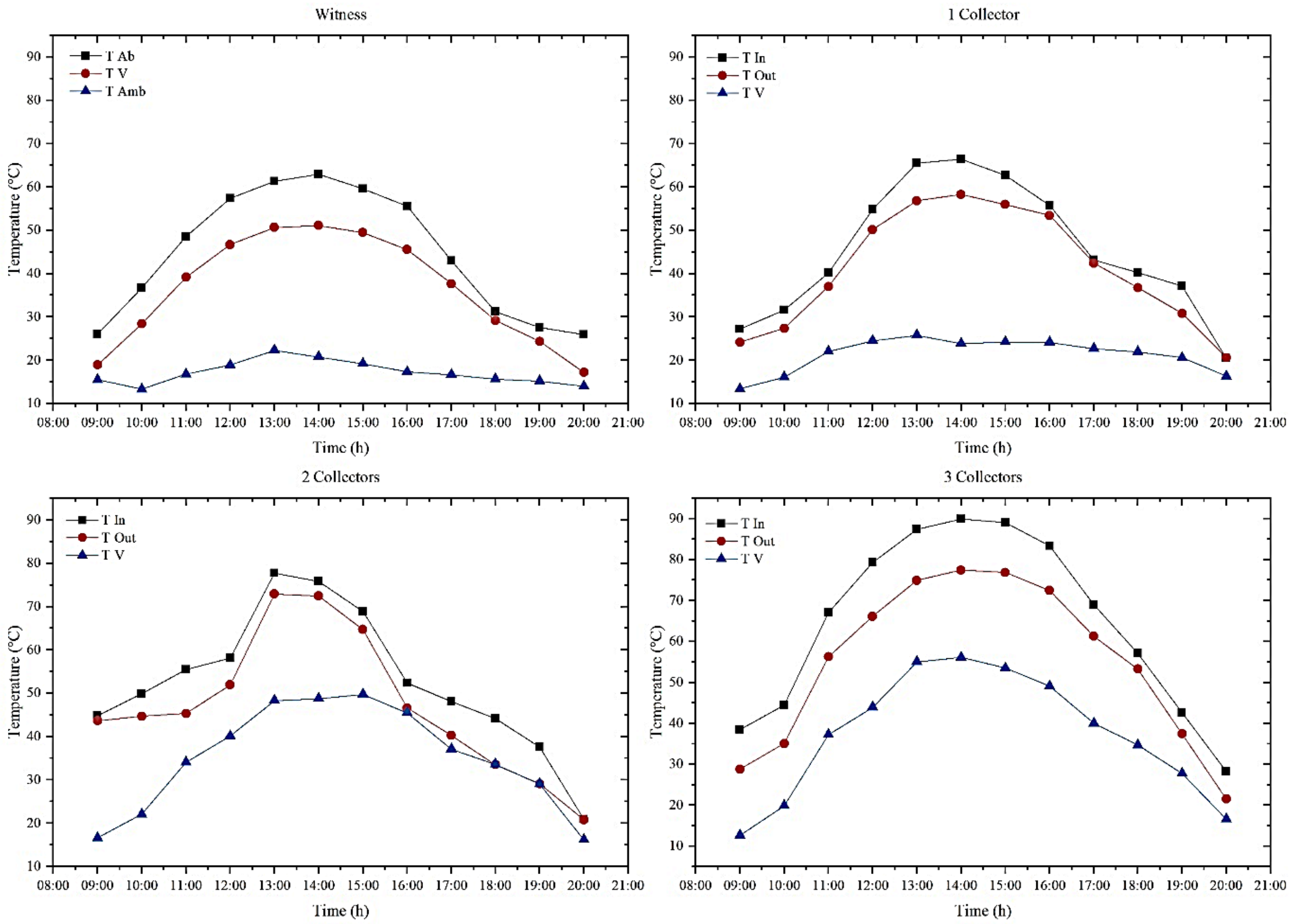

Fig 3. Hourly variation of temperatures

The hourly water and condensing cover inside temperatures for still coupled with different numbers of FPCs in series are shown in Fig. 3 and b respectively. Maximum temperatures are obtained for the still with 3 FPCs connected in series when compared with witness, 2 FPCs and 1 FPC. This is because of more added area with 3 FPCs for solar radiation. It was observed that water and condensing cover inside temperatures, there is no significant increase for the still with 1 FPC to 2 FPC. This is because during experimentation with 1 FPC, the local solar irradiation was very high.

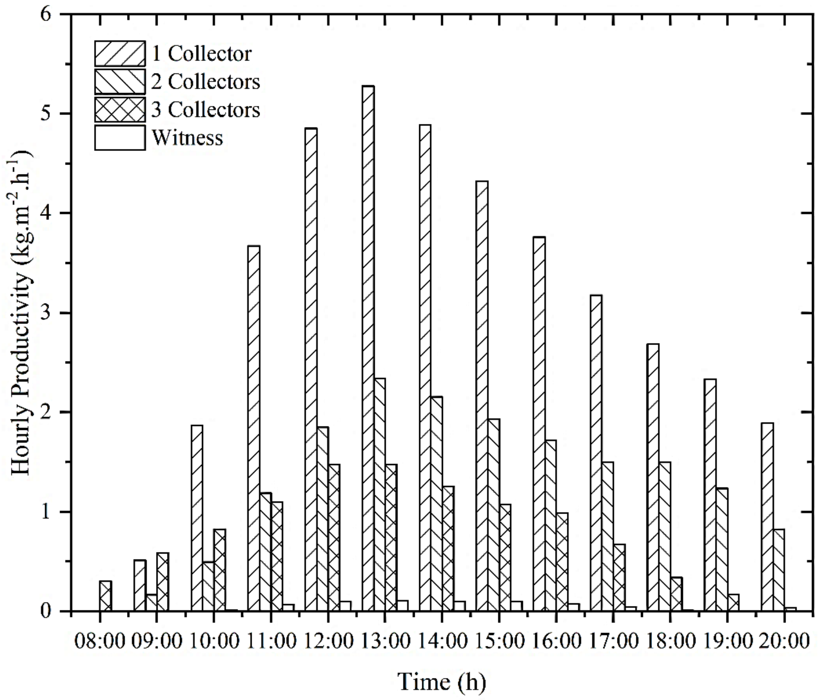

Fig.4 Hourly variation of productivity

High yields are obtained, as shown in Fig. 4, for the still coupled with FPCs in series compared to the still with one FPC for the entire period of 12 h. Fig. 5 shows the daily yield and distillation efficiency for the still coupled with three different FPC arrangements. A maximum yield of 6.669 kg and 2.87 kg are obtained for the still with 1 FPC and 2 FPCs in series respectively, whereas the yield for the still with 3 FPC is 1.75 kg and 0.606 kg for witness solar still. It is clear from the above that the still with single FPC gives more yield than FPCs connected in series. This is due to that the still with one FPC has an increased area for solar radiation and maintain positive ΔT for more time.

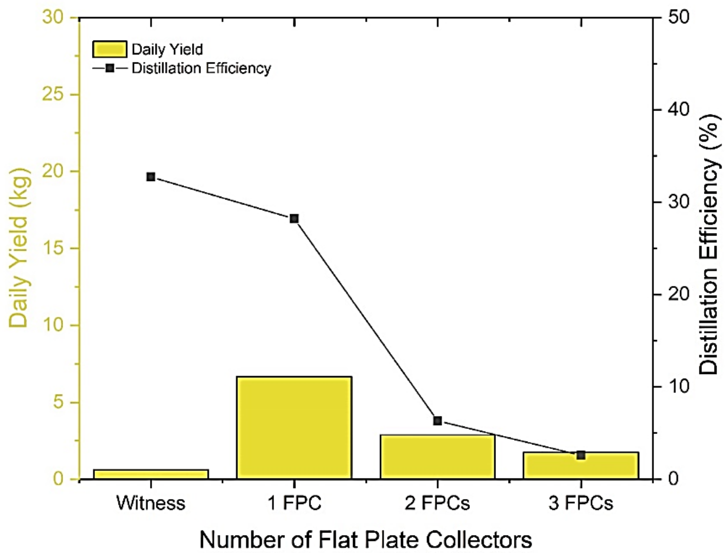

Fig.5 The average daily production for different configurations

The daily productivity of the still with 1 FPC is greater by 500%, compared to that with tow FPCs, whereas the still efficiency with 3 FPCs in series is 600% less when compared to that with single FPC. With the increase in ΔT, the yield and still efficiency will increase and this tendency is observed for the still with one FPC as well as for the still with 2 FPCs in series. However, as the increase in area off sets the advantage of increase in yield for the still with 3 FPCs in series, the efficiency has decreased compared to other two cases.

However, the distillation efficiency is optimum for the witness still compared to other arrangements and the efficiency is found to decrease for the still with 3 FPCs in series due to the increase in collector area.

IV. CONCLUSIONS

(1) More yields are obtained for the still with 1 and 2 FPCs connected in series compared to that with one FPC. Hence the one FPC is found to be more suitable to enhance the distillate yield. The partial pressure difference between water temperature and condensing cover temperature is found to be high, which directly influences the yield.

(2) The distillation efficiencies of the still with 2 FPC and 3 FPCs connected in series are 6% and 2% respectively. A distillate efficiency of 28% is obtained for the still with single FPC. Hence the witness solar still with produces the optimum performance.

(3) A maximum yield of 6.669 kg is obtained for the still with single FPC, whereas the yield is 2.87 kg for the still with 2 FPCs in series and 1.75 kg for 3 FPCs respectively.

(4) The average daily yield is 500% and 600% more for the still with 2 and 3 FPCs in series respectively, when compared to still with single FPC. The distillate efficiencies are 0.47% more and 0.48% less for the still with 2 and 3 FPCs in series respectively, when compared to that with single FPC. The study will be useful for designing efficient active solar distillation systems for the winter climatic conditions with 31.95°N, 5.4°E.

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