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Hybrid Solar Steam Generator using Fresnel lens for Desalination and Application in small scale laundry system

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Abstract— This paper demonstrates experiments for hybrid solar water desalination and small scale laundry system (drying process) by using Fresnel lens (non electric) and Photovoltaic panel (electric). The work was done in two stages each of them is of equal importance. The aim is to heat the water using solar energy. The acrylic based Fresnel lens is the next generation technology in the conversion of solar energy. By focusing the solar energy through the lens, the light energy is concentrated and focused into the focal point of the lens, results in the heating of water using Fresnel lens. Here the lens is focused into the vessel with water; the thermocouple is used to measure the temperature. This project is hybrid solar Photovoltaic panels also used for additional heating facility. The water temperature rises up to 135 degree Celsius. So that water gets boiled, evaporated and gets desalinated. It can be installed in remote areas where electricity supply is not available and the fresh water is scarce. The result for water desalination experiment showed a maximum water production of 102 cubic centimetre per hour for each liter of saline water. The energy consumption 46.3 kilo Watt hour per cubic metre could be obtained if we involve photovoltaic cell. Also, water production could be further improved if we utilize the saline water in a subsequent desalination stage.

Keywords— Solar Energy; Fresnel lens; Steam Generator; Desalination; Laundry system; Drying System

I. INTRODUCTION

Water has always been earth's most valuable resource. All ecosystems and every field of human activity depend on Water. The World's supply of fresh Water is running out. Already one person out of five has no access to safe drinking Water [1]. The amount of Water in the World is limited. The human race, and the other species which share the Planet, cannot expect an infinite supply. Restricted resources of fresh water are always considered inadequate in future due to population increase as well as expansion of Urban and industrial developments. The Reverse Osmosis (RO) process can be used to Supply the future needs of fresh water; however the energy requirement will be the Stumbling block. While the world fights to reduce the Carbon-di-oxide output for future. Environment, the production of fresh water with current methods ought to increase the Carbon-di-oxide. Development and implementation of new technologies for small capacity Plants are highly enviable. Tamil Nadu is relatively modest in its water resources. Kaveri water quota is put at 5.5 Billion cubic metre, which represents 50% of the Tamil Nadu State water resources and covers around 60 % of its current needs [2]. Now the current water desalination production in Egypt is 0.06 X 10^9 cubic metre which is targeted to be to 0.14X 10^9 cubic metre by 2017 especially by Using the low cost techniques. At present, the desalination industry is almost equally divided between the RO and Multi Stage Flashing (MSF) processes. A much smaller market share of water Desalination is generated by the multiple effect evaporation (MEE) process Evaporation and

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condensation process is an attractive Desalination process because of its simple layout and it can be combined with solar Energy. Also, it can be designed to minimize the amount of energy discarded to the Surroundings. Solar water desalination with EC processes has proven to be an efficient means of production of fresh water in remote and sunny regions. Numerous Solar desalination installations concerned with small and medium production have been developed and studied.

The EC process is based on the fact that water is evaporated by solar energy. On the other hand, the distilled water is recovered by maintaining humid air at contact with the cooling surface, causing the condensation of part of vapor mixed with air. Generally the condensation occurs in exchanger in which salt water is preheated by latent heat recovery. An external heat contribution is thus necessary to compensate for the sensible heat loss. Energy consumption is represented by this heat and by the mechanical energy required for the pumps and the Blowers. Many researchers investigated the desalination processes. Among them, the EC process seems to be potentially a useful method, especially in arid regions and isolated islands. Goosen et al. reviewed various layouts of the Evaporation and Condensation desalination systems as well as single and multiple effect solar desalination. They stressed the fact that many of units are limited to theoretical evaluation or prototype scale; however , increase in future demand for fresh water might make several of these processes viable for fresh water production. Younis et al. [1] investigated a seawater desalination process in which brackish water was pre-heated by using solar collectors and then brought into contact with inlet air in an evaporation column followed by a condensation stack for dehumidification. They presented a theoretical design procedure for this process and conclude that by increasing inlet air flow rate, the production of fresh water increasing. Most investigations on the EC desalination process have focused on productivity and efficiency improvement [7-9].In 1999, Farid and AI-hallaj [2] constructed a EC desalination unit in Basrah, south of Iraq. However, very high pressure drop in the condenser and humidifier increased the electrical power consumption of the blower to a level which makes the process uneconomical. Then, two units of different sizes were constructed and operated in Jordan reported by Farid et al. [8]. They found that the effect of water flow rate on heat and mass transfer coefficients is more significant than air flow rate. Another unit was built in Malaysia by Newayseh et al.[4]. They developed a simulation program to correlate with experimental results and studied the effect of dehumidifier, humidifier and solar collector surface on daily production of the unit. The effect of feed water flow rate on production was also studied, showing the existence of maximum desalination production. In a study made by Amara et al. [5] they presented experimentally the principal operating parameters of a new desalination process working with an air multiple-effect HD method. The experimental work resulted in the optimization of the ratio of water to dry air mass flow rates by 45%. The Fresnel lens (FL) is a flat optical solar concentrator; the surface is made up of many small concentric grooves. Each groove is approximated by a flat surface that reflects the curvature at that position of the conventional lens, theatre focus, slide projectors, rear windows of cars, photographic flash, etc. Fresnel lens can act as collimators, collectors, condensers, field lenses magnifiers, for imaging, thermometry and solar energy collection. Solar energy concentrated by Fresnel lens is a cheap and environmentally friendly energy source suitable for many applications such as surface materials treatments. The advantages of the Fresnel installation make it a serious alternative to some conventional techniques used in this field [11]. In this paper, we report experiments for

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utilization of Fresnel Lens in developing a solar of water desalination by Evaporation and Condensation Method.

II. METHODOLOGY

Figure 1. illustrates a schematic diagram of the experimental setup. The Fresnel Lens made of acrylic sheet with concentric grooves with focal length of 0.5m. The lens was fixed facing south with a tilt angle of 28 degree in summer season. The saline water passes thorough pipe of 0.3m length and internal diameter 15 milimetre. The water storage tank is made from steel and sealed by glass wool in order to reduce the heat loss; also it is supplied with electrical heater to adjust the temperature of hot saline water to the desired feed temperature. As indicted in Fig. 2, water pass with a different flow rates once through the heating pipe where it is heated by the focused solar energy. Once the water temperature reaches the desired starting temperature, water is directed to the humidification unit.

The arrangement of Evaporation and condensation unit is Constructed of Stainless steel of 0.001metre thickness. The air is inserted to the unit by fan with 0.25 metre diameter mounted on one face of the tank.

$$\Delta H = H_{out} - H_{in}$$

Equation 1.

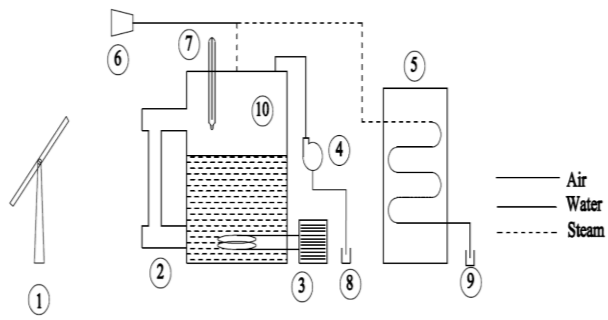
Where H_{in}, H_{out} are the inlet outlet humidity of the unit.

On the opposite face, a condenser is fixed with length, width and thickness of 0.3, 0.6 and 0.3 metre respectively. The fresh water resulting from treatment process is collected through a header channel mounted below the condenser. The unit has discharge weir for recycling of miscarried water to the storage tank, and is covered by transparent plastic cover to keep the air inside.

The concentration of salt was measured by AZ 86555 laboratory bench top meter supplied by AZ Instrument Corp. The heavy metal concentration was measured by atomic absorption spectrophotometer (ELICO SL 176) at 324.7 nanometre wave length for copper. The temperature of hot feed water and air and the humidity at the inlet and the outlet of each part of the unit and water and air mass flow rates are measured.

Figure 1. Line Diagram for Solar Desalination Plant

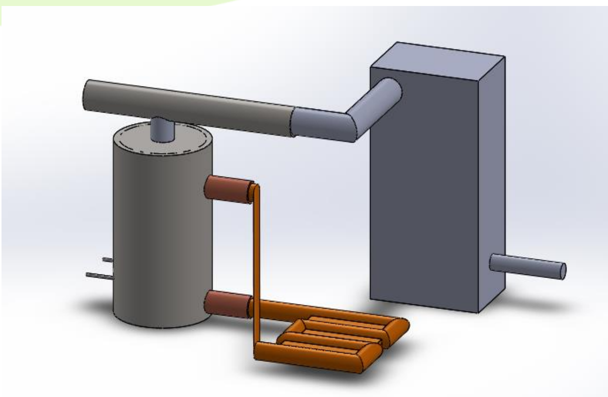
The Figure 1. shows the line diagram for solar desalination plant and the components are discussed here. 1. Fresnel Lens, 2. Absorber Plate, 3. DC Heating filament with PV Panel, 4. DC Pump, 5. Laundry, 6.DC Compressor, 7. Thermometer, 8. Raw Water Tank, 9. Desalinated Water, 10. Stainless Steel Tank



III. BLOCK DIAGRAM

The three dimensional drawing is developed in order to better understand the working principle of solar desalination system as shown in Figure 2.

Figure 2. Block Diagram for Solar Desalination Plant



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IV. EXPERIMENTAL SETUP

Fresnel lens used here is in size of 275 X 275 X 3 (Length X Width X Diameter) in milimetre. It weights around 0.6 kilogram. The absorber plate is designed and fabricated to absorb more heat through direct sunlight and through Fresnel lens. The low voltage water heating element is used as there are more possibilities for diversion load. Instead of condenser for converting steam into water the heat drop is used for Laundry applications, such as for drying of cloths.

Figure 3. Experimental Setup

V. RESULTS AND DISCUSSION

Table 1 shows the variation of temperature with flow rate for heating water by Fresnel Lens solar collector. The solar heating system was almost insufficient to supply enough water continuously to the Evaporation and Condensation experiment with the desired temperature. That was mainly referred to the poor heat transfer from the hot pipe to reflection and inside it, also there are uncertainties about the power loss due to reflection and radiation, moreover, there are other unaccounted solar intensity losses such as the manual solar tracking system of the Fresnel Lens solar collector available for this experiment was relatively small. In order to heat water to the desired temperature for EC experiment.

It was necessary to use electric heater However, the solar water heating could be further improved by increasing the area of solar water heating system or utilization of more efficient scheme to heat water such as linear Fresnel lens.

Table 1. Variation of Temperature

Feed water Temperature, ºC.	Pipe preheating Period, minutes	Temp. of water after Heating pipe, ºC
30	30	80
32	30	81
33	30	83
34	30	84
34	30	84
35	30	85
35	45	86

In the second stage, water desalination process was investigated. In order to check the quality of the fresh water, a preliminary experiment was made; the feed saline water has temperature of 60 degree Celsius and average flow rate of 100 litre per hour. The initial concentration of salt in water was 35 gram per litre relatively close to the value of average water salinity in the sea. The result showed fresh water with salinity of 0.5 gram per litre, similar to corresponding value of the water quality standards. Next, the possibility of heavy metal removal was checked. Copper ion was chosen to represent heavy metal contaminant in water. The feed saline water,

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with the same temperature and flow rate as aforementioned, was prepared with initial copper sulfate concentration of 100 miligram per litre. From these data, it is evident that method could be used for production of water with acceptable quality. Theoretically, the more dominant parameter is inlet water temperature. Figure 2. shows the effect of inlet water temperature on both percentage humidity of carrier air and outlet water flow rate. It was evident that increasing water temperature increases both the air humidity and outlet water flow rate. The maximum water flow rate obtained was 2.65 litre per hour at inlet water temperature of 85 degree Celsius. If initial Saline water of 25 litre and average experiment duration of 15 minutes, the maximum water production will be 106 cubic centimetre per hour for each liter of saline water.

VI. CONCLUSION

This study presented the possibilities of using Fresnel lenses in the development of water desalination system by Evaporation and condensation technique. The results for water heating by Fresnel lens showed that the theoretical yield was not accomplished due to energy loss by radiation; also the experiment showed that hot water yield depends on water flow rate. The results for water desalination experiment showed that water with initial concentration of salt of 40 gram per litre gave fresh water with salinity of 0.7 gram per litre also. The maximum water flow rate obtained was 2.65 litre per hour at inlet water temperature of 35 degree Celsius. The temperature of miscarried water is high enough to be introduced to a second stage of the Evaporation system [15690 kilo Joules per hour with miscarried water in case of T =54 degree Celsius]. Also, the consider efficiency is 25% and additional condensation steps are required to maximize the field of fresh water from this unit. Here, the heat recovery is done in the condensation unit by setting up small laundry system.

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