Performance Enhancement of Solar Still by Modified Design and Different Techniques: A Review

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Abstract— Solar energy is a kind of renewable energy available in abundant quantity on our planet. Portable water availability for mankind is the matter of concern in this era. Purification of water using solar energy is getting popularity day by day. It is method in which one can obtain fresh water from saline as well as polluted water without any running cost. In this paper various methods applied for desalination are reviewed. Various modifications applied in solar still for performance enhancement are discussed in this paper.

Key words: Solar Energy, Passive Solar Still, Active Solar Still, Water Depth, Inclination Angle

I. INTRODUCTION

More than 97% of the earth's water is salty and rest around 2.6% is fresh water. Out of which, less than 1% fresh water is within human reach [1]. This 1% water is not distributed evenly on the earth. Increasing water pollution is making the situation more severe. To make portable water accessible to human population new technologies are taking step ahead. Purification of water using solar energy is one such method in which we get pure drinking water at low cost. Solar still is a set up used for solar water purification. In solar still impure or saline water is kept in a basin which is covered by glass at an inclination. Sidewalls are painted in black to absorb more and more solar energy. Water get evaporated by using this solar energy and vapour moves upward. Vapour get condensed beneath glass inner surface and released the heat to environment.

II. CLASSIFICATION OF SOLAR STILL

Solar stills are classified into two types. In first type of solar still external devices (solar collector, motor, condenser, etc.) are coupled with solar still and they called active solar still (Fig.1) while still without external devices are passive solar still (Fig.2). The active solar distillation is mainly classified as follows [2]:

1) High temperature distillation—Hot water will be fed into the basin from a solar collector panel.
2) Pre-heated water application—Hot water will be fed into the basin at a constant flow rate.
3) Nocturnal production—Hot water will be fed into the basin once in a day.

Passive solar still are also classified by various researchers on the basis of slope as single slope and double slope passive solar still. They can be further categorized as single effect, double effect and multi effect solar stills. In this paper various modifications applied in solar still for performance enhancement has been reviewed. An extra thermal energy is supplied to the basin through an external mode to increase the evaporation rate and in turn improve its productivity.

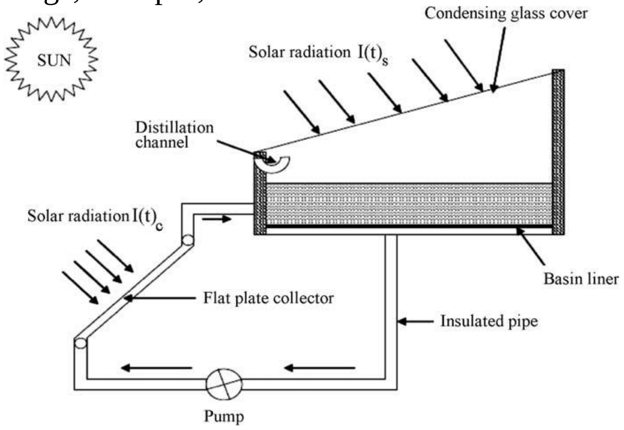

Fig. 1: Layout of active solar still

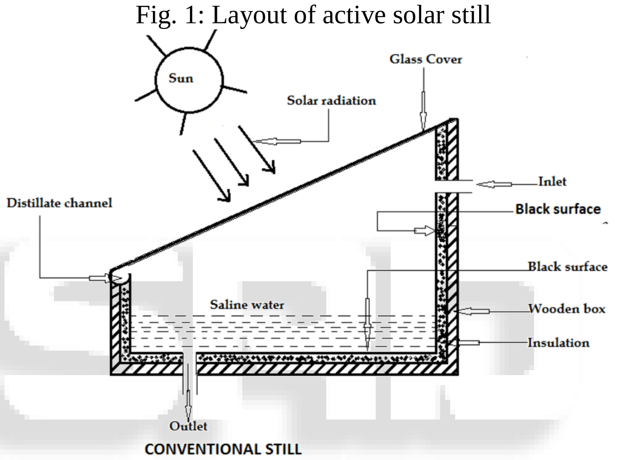

Fig. 2: Layout of active solar still

III. MODIFICATIONS IN PASSIVE SOLAR STILL

Dev and Tiwari [3] fabricated new kind of stills and experimented in winter and summer conditions both, the different angles of inclination of condensing cover (15°, 30°, 45°) have been chosen (Fig.3) and It has been observed that both in winter and summer the passive solar still with inclination of 45° gives better performance respectively. Solar still with 30° inclination angle, for summer weather condition, different water depths (0.04, 0.08, 0.12, and 0.16 m) have also been taken. They concluded that efficiency was observed better for lower water depth.

Fig. 3: Solar stills with different inclinations

Gnanadason et al. [4] have fabricated a single basin vacuum solar still made up of copper sheet. The distilled water production rate of a single basin copper solar still with and without nanofluids in basin has been compared.

Addition of nanofluids in the basin water increases heat transfer rate and consequently the evaporation rate. They concluded that copper still with nanofluids in basin water yields up to 7.5 l/day.

Kumar and Bai [5] have designed and built a basin type solar still (0.5 m^2) with improved condensation technique, in which, an additional condensation surface was provided on the sidewalls for improving daily output of the still. The maximum daily production of the solar still was about 1.4 L/m^2 with the efficiency about 30%. They have applied solar still with different samples such as tap water, seawater and dairy industry effluent.

Suneesh et al. [6] have designed and fabricated a “V” type solar still (Fig.4) with a Cotton Gauze Top Cover Cooling (CGTCC) and experiment with and without air flow over the glass cover. Over bare glass cover water flows unevenly over the width of the glass cover. In this new design solar stil,l distribution is even due to CGTCC and increased distillate output was recorded. The water production rate due to water flowing over bare glass was 3300 ml/(m^2-day). Use of CGTCC without air flow over glass plate increases production to 4300 ml/(m^2-day), and with CGTCC and air flow, it further increased to 4600 ml/(m^2-day).

Fig. 4: V Type Solar Still

Panitapu et al. [7] have used Titanium oxide as a nano-material in solar distillation for improving the productivity and efficiency of solar still and have reported the variations in temperatures of basin water, glass inner surface, glass outer surface due to presence of titanium oxide in basin water.

Tenthani et al. [8] have studied two conventional stills with an identical geometry but the internal surfaces of their walls were different. One in black and other in white (Fig.5). Distillate output was measured for both stills during experimentation. It was found that the average daily distillate outputs were 2.55 kg/m^2 and 2.38 kg/m^2 for the white painted still and conventional black painted still. the efficiency of white painted still was also 6.8% greater than other still.

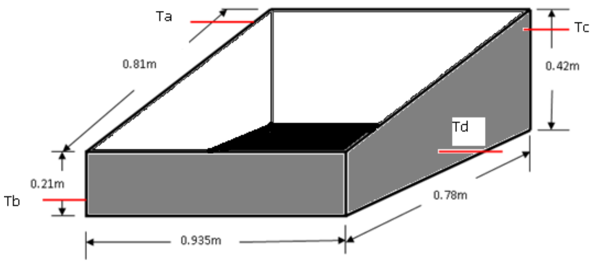

Fig. 5: White painted solar still

Singh et al. [9] have designed, fabricated and tested a new type of multi-stage solar still of low inertia for decreasing the thermal inertia of the water (Fig.6). It consists of three main parts namely: bottom tray, upper trays and collecting channels made from galvanized iron sheet. It has two diagonally opposite pipes in its opposite sides for the circulation of hot water of externally added solar collector through it. Gauss-seidel iteration method was used to solve energy balance equations for various parts of the still. Computer model was made to predict the performance of the still and to estimate the annual performance and payback period of the still. At optimum combination of absorption area of solar water heater and evaporation area, the annual distillate yield was 2223 liters/m^2 assuming 300 clear days. The payback period of the still was estimated to be three years.

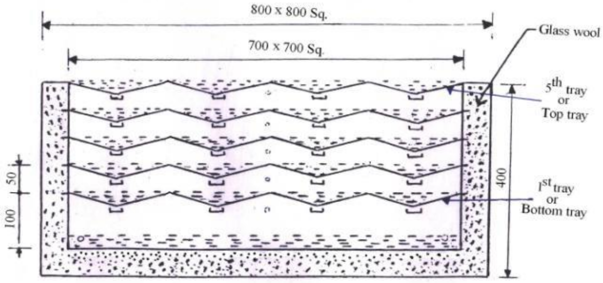

Fig. 6: Multistage Solar Still

Kumar et al. [10] have carried out performance analysis of solar still by developing MATLAB model and result obtained is verified by experimental setup. They have taken basin water depth of 5cm, 10 cm and 15 cm for inclination of glass cover at angle of 23^0 and 30^0 respectively. They concluded that in both case yield was greater for low water depth at angle of inclination of 30^0.

Sharma et al. [11] have evaluated performance of a single slope solar still using water film cooling over the glass cover and in combination with CuO In their experimental work. They concluded that conventional solar still yield 1906 ml/ (m^2-day) and solar still fitted with sprinkler to reduce glass temperature, yields 2765 ml/ (m^2-day). Finally, production of Experimental solar still with sprinkler & nano particle increased to 3485 ml/ (m^2-day).

Sharma et al. [12] have reviewed a number of methods to increase the condensation in solar still. Using external condenser as well as integrating the still with solar sprinkler to impinge water on glass surface are most popular and effective methods of increasing condensation and consequently the yield of the still.

IV. MODIFICATIONS IN ACTIVE SOLAR STILL

Kabeel et al. [13] have designed and modified a single basin solar still and investigated the solar still performance. They have used nanofluids in basin water and also integrate the external condenser to the basin (Fig.7). The suspended nanosized solid particles of aluminum-oxide were used as nanofluids in this experiment. Nanofluids change the transport properties, heat transfer characteristics and evaporative properties of the water. External condenser to the still basin decreased the heat loss by convection from water to glass and increases the condensation simultaneously. The experiments were performed for various operating conditions of fan at different speed. for continuous running fan, productivity of modified still is 53.22% higher than the productivity of the conventional still at 1350 rpm while for corrupted running fan productivity of modified still is 50.24% higher than the productivity of the conventional still at speed of 1350 rpm operating through 11 am to 3 pm. Using nanofluids improves the solar still water productivity by about 116% and 76% with and without operating the vacuum fan respectively.

Mathioulakis and Belessiotis [14] have experimented with solar still coupled with thermal solar system (the tank of which is thermally coupled with the still basin) and concluded that productivity of coupled system was about the double from that of the still only system for days with similar climatic conditions. In night productivity of coupled system is triple than still only system. The presence of a tank acting as thermal buffer gives the ability to use the still for the simultaneous production of distilled and usage hot water.

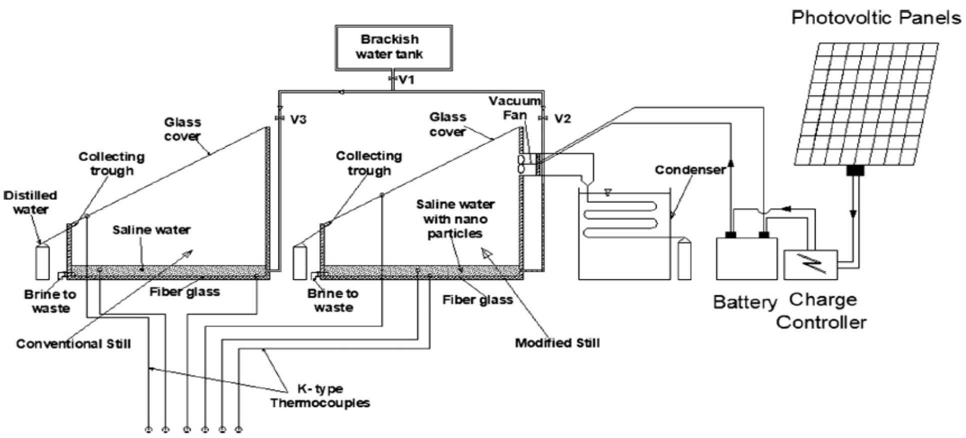

Fig. 7: Solar Still Integrated With External Condenser

Prasad and Tiwari [15] presented an analysis of a double effect, solar distillation unit coupled with parabolic concentration collector (Fig.8).they concluded that due to the reduced upward heat losses the temperature of the water in the lower basin was increased in comparison with single effect distillation. In the lower basin the hourly output was reduced due to the reduced temperature difference between the water and glass temperatures. However, due to reutilization of the latent heat of evaporation, the overall output is increased in the second effect. They also concluded that evaporative heat transfer coefficient is a strong function of the operating temperature range.

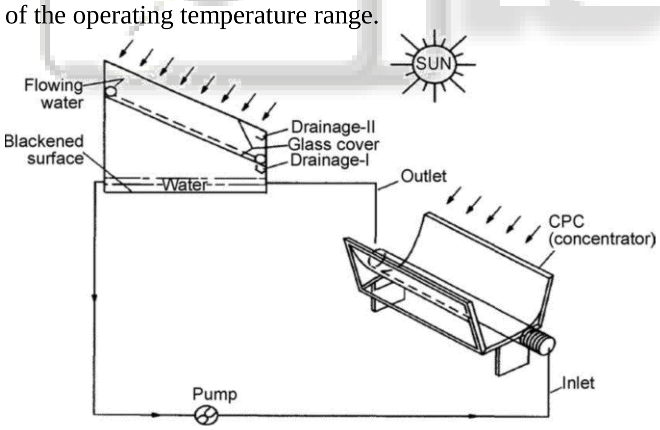

Fig. 8: Solar still integrated with CPC concentrator

Aybar et al. [16] have developed an inclined solar water distillation system (Fig.9) and tested under actual environmental conditions.In this type of still the feed water falls down on the solar absorber plate and get evaporated. The system produces fresh water and hot water simultaneously. The system was tested with bare plate, black-cloth wick, and black-fleece wick. The wicks increased the fresh water generation by two or three times of a bare plate. The hot water temperature was good enough for domestic use.

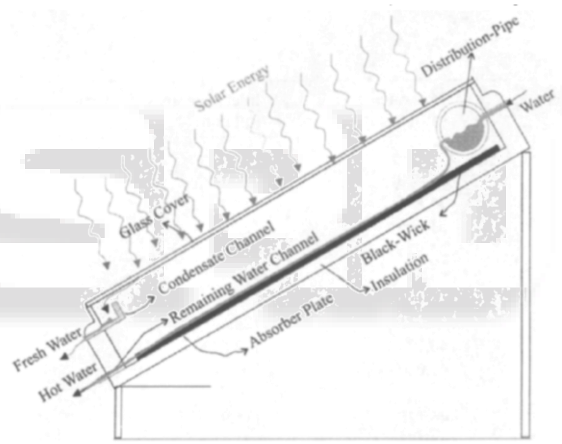

Fig. 9: Inclined solar water distillation system

Abdullah [17] has experimented on a stepped solar still coupled with a solar air-heater (Fig…) and investigated the performance of new still with comparison to conventional still. The hot air from the solar air heater passes near the base of stepped still and increases the temperature of saline water. The higher saline water temperature and use of aluminum filling as thermal storage material beneath the absorber plate increases rate of evaporation and ultimately productivity gets improved. It was concluded that, water productivity increased by 112% over conventional still, when the system was coupled with a solar air-heater and the productivity of the stepped still is increased by integrating aluminum filling by about 53% over conventional still.

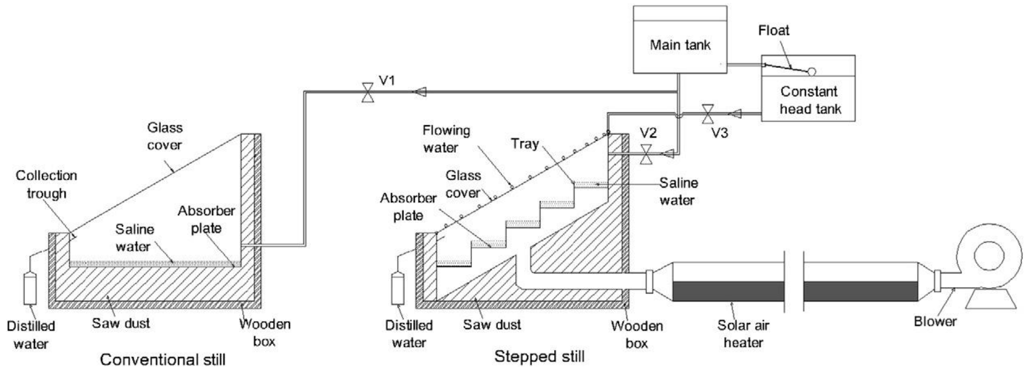

Fig. 10: Stepped solar still coupled with a solar air-heater.

V. CONCLUSION

A number of modifications have been applied to passive as well active solar stills for performance enhancement. In passive solar still, painting of sidewalls in white and adding nanoparticles to basin water are the methods which can be applied for the increase in the productivity. Water at glass surface is another method which increases the condensation and finally the productivity of the still. In active solar still, integration of external condenser is an important method to increase the condensation and consequently the yield. Pre heating of feed water by solar collector and CPC concentrator are other modifications which can increase the yield up to large extent.

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