Design fabrication and performance of hybrid active PV/T double slope solar still

[1]Chirag j Patel, [2]Kuldip dodiya, [3]Ashvin suthar
[1]M.E Thermal Engineering, [2]Asistant professor, [3]M.E Thermal Engineering
[1]Department of Mechanical Engineering,
[1]Gandhinagar Institute of Technology, Gandhinagar, Gujarat, India

***Abstract* - Solar is the most promising and reliable source since millions of years. Solar energy is abundant, inexhaustible and available everywhere free of cost without political hindrances. It is found form the critical literature survey that, the hybrid technology is to be developed for the water distillation which is acceptable and convinced to the society That results to get continuous getting of distillate output of solar still. The aim of this research has been to study the effect of various parameters on performance of double slope solar still to improve efficiency and output of distill water.In this paper a modified photovoltaic thermal (PVT) double slope solar still was designed and fabricated for remote locations this system has been installed at the campus of Gandhinagar Institute of Techanology, motibhoyan In Photovoltaic operated DC water pump has been used between solar still and photovoltaic integrated flat plate collector to rotate the water through collector and pass it to the solar still. In this paper comparision between active and passive solar still with same water level depth 0.025m and compare the experimental readings. Maximum distillate output of 3.123 L/m^2/day was obtained by active solar still and passive solar still maximum distillate output of 2.817 L/m^2/day with a water depth of 0.025m on both side of solar still.**

***Index Terms* - Hybrid Photovoltaic thermal, double slope solar still active and passive**

I. INTRODUCTION

Potable water is a human birthright - as much a birthright as clean air. Out of the total earth's surface, 70% is covered by water, but most of it is salty. However, much of the world's population does not have access to safe drinking water. Out of 6 billion people, more than one sixth, lack access to safe drinking water. Fresh water covers only 3% of the earth's surface. Humans consume fresh water available from rivers, lakes, underground sources and aquifers. Jointly, these sources account only for 1% of available water on the earth. After a generation, the world's population will grow up about 8 billion people and the amount of water will remain the same or may be less. The challenge is as clear and compelling as pristine water cascading down a mountain stream. Hence, we must find new and reasonable ways of saving, using and recycling the water.

Some people have a misconception that distilled drinking water is not good for health. In fact, distilled water is quite beneficial as also stated by Dr. Andrew Weil from the University of Arizona: I meet people who object to drinking distilled and purified water because it has been 'robbed' of its mineral content. We get trace minerals from foods, especially fruits and vegetables, not from water and the benefits of purifying drinking water are myriad. It is your best protection against ingesting a host of toxins and pollutants that are serious threats to health.

The solar distillation method is an easy, small-scale and cost effective technique for providing safe water at homes or in small communities. Distillation is one of many processes that can be used for water purification. This requires an energy input as heat and the solar radiation can be the source of energy. In this process, water is evaporated, thus, separating water vapour from dissolved matter. The vapours get condensed as pure water. A conceptual plants discussed earlier are energy-intensive and require scarce electric power or fossil fuel for operation. But solar energy, despite being much lower grade energy, is ideally suited. The technology involved in distillation of saline or brackish water using solar energy is relatively simple and semiskilled/unskilled operators can carry out its operation and maintenance.

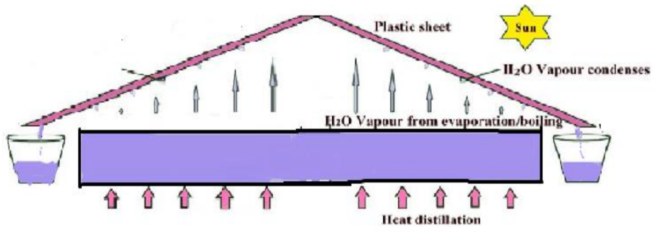

Fig 1 Diagram explaining the process of solar distillation

Liquids, followed by transport of vapours by winds, and then cooling of air-vapors mixture, condensation and precipitation. This natural process is copied on a small scale in basin-type solar stills. A solar still operates using the basic principles of evaporation and condensation. The impure saline feed water goes into the solar still and the sun's rays penetrate a glass surface causing the water to heat up through the greenhouse effect and, consequently, evaporate. When the water evaporates inside the solar still, it leaves all contaminants and microbes behind in the basin. The evaporated and now purified water condenses on the underside of the glass and runs into a collection trough and then into an enclosed container. In this method the salts and microbes that were present in the original feed water to the solar still, are left behind. Additional water fed into the solar still flushes out concentrated waste from the basin of solar still to avoid excessive salt deposition in the basin.

A solar still effectively eliminates all water-borne pathogens, salts and heavy metals that other huge methods cannot do. Solar still technologies bring immediate benefits to users by reducing health problems associated with water-borne diseases. For solar still users, there is also a sense of satisfaction in having their own trusted and easy to use water treatment plant on-site at home. As a thumb rule, solar still production is a function of solar energy (insulation) and ambient temperature.

The average adult consumes about 10 cups of water daily. Adults should drink six to eight cups of liquid per day. Although most of this liquid should come from beverages, food also supplies some water. Water can be hard or soft, natural or modified, bottled or tap, carbonated or still. About 50% of water comes from underground water tables, i.e. ground water and the other 50% from surface water, i.e. rivers, lakes and reservoirs.

II. A REVIEW OF DOUBLE SLOPE SOLAR STILL

V.K. Dwivedi [1] Developed the thermal modeling for the double slope solar still. He has been carried out on the basis of energy balance of east and west glass covers, water mass and basin liner under natural circulation mode. The different Characteristics of the system are studied and compare with the different water depth for the validation of the model. The following parameters are evaluated by thermal modeling for the validation of model. The energy efficiency of double slope active solar still is higher than the exergy efficiency of double slope passive solar still. The double slope active solar still under natural modes gives 51% higher yield in comparison to the double slope passive solar still The hourly thermal and exergy efficiency of active solar still have also been evaluated for 0.03m water depth.

Shiv Kumar[2] Study the effect of life cycle cost analysis of the single slope passive solar stills based on the 0.05m water depth. He observed that the various parameters like interest rate, life of the system and maintenance cost have been taken into account. Hybrid active solar still is 3.5 times higher than the passive solar stillThe distilled water cost obtained from the hybrid (PV/T) active solar still is found to be 2.8 times higher than the passive solar still. The cost of production and energy pay back periods can further be reduce for higher solar radiation, longer sun-shine hours and number of clear days in a year.

M.R. Rajamanickam [3] studied the effect of water depth on the internal heat and mass transfer in the single basin double slope solar still. In that experimental he made cover from a transparent glass of 3mm thickness. He used both environmental and operational parameter like solar intensity,ambient air ,wind speed ,feed water quality, water depth, and orientation.Distillate output of 2.760 L/m2/day was obtained with a water depth of 0.02mMaximum distillate output of 3.07 L/m2/day was obtained with a water depth of 0.01m Increase in water depth resulted with decreasing in productivity of the solar still.Radiation heat transfer co-efficient is higher than the convective heat transfer co-efficient.

K. Kalidasa Murugavel [4] one of these methods used for increase the productivity is by decreasing the volumetric efficiency heat capacity of the basin. He used a layer of water with wick material in the basin it will increase the evaporation area and enhance the production. Double slope solar still designed and fabricated with minimum mass of water and different wick material like cotton cloth sponge sheet coir mate and waste cotton pieces the basin. Theoretical values of water and glass temperature using proposed model were compared with theoretical values obtained by dunkle model and actual experimentation values. The still with light black cotton cloth is the effective wick material. It was found that theoretic production rate using proposed model were close to the experimental.The maximum values of production rate, water temperature and glass temperature are varying inversely with heat capacity of basin water and other materials used in the basin The production rate depends on water, glass and atmospheric temperatures, water–glass temperature difference and glass temperature difference.

M.K. Gaur [5] Number of collectors are placed in series for PV/T Hybrid active solar still with the basin by the researcher to optimize no of collators for different heat capacity. Computed value of daily result is approx. 7.9 kg for 50 kg water and 0.055 kg/s, which is higher than that the daily result obtained from passive solar still. On the basis of daily exergy efficiency, the optimum number of collectors increases with an increase in the mass of water in the basin of the hybrid active solar still. V.K.Dwivedi[6] An experiment is performed to see the effect of life cycle cost analysis of single and double slope passive solar still .The analysis based on energy and exergy of both solar still. by the researcher observed that water produced by proposed double slope solar still is cheaper than proposed single slope solar still.The daily thermal and exergy efficiency of double slope solar still is higher as compared with single slope solar still.Double slope solar still (Rs 0.28 L^{-1}) is more economical than single slope solar still (Rs 0.33 L^{-1})Energy payback period (EPBP) for proposed double slope solar still (1.6 years)is lower than proposed single slope solar still.

A.E. Kabeel[7] In this paper the review showed that by the researcher; the basin water depth is considered the main parameters that affect the solar still performance. Also showed that the solar productivity also increase with decrease the cover thickness and increase its thermal conductivity. The researcher coupled that things like solar colletor,hot water tank, external tank internal condenser and greenhouse with increased the productivity.The solar still productivity and efficiency depended on parameters like Location solar radiation intensity, Temperature, basin water depth, glass cover material, thickness and its inclination,, wind velocity and ,the heat capacity of the still The cover with inclination equal to latitude angle will receive the sun rays close to normal throughout the year. The productivity of solar still decrease with an increase in depth of water during daylight. Rubber is the best basin material to improve absorption, storage and evaporation effects. The coupling with a solar still with hot water tank generally doubles the distill water. The coupling with solar collector with a still has increase the productivity by 24-36% Hanana.aburideh [8]in this paper the researcher interested in the internal parameters on a double slope solar still .he was conceived and realized by our team of research. In the researcher had found that influenced by the present of wind and the climate condition changes which decrease the amount of diffuse solar energy received by the brackish water. The experimental study permits to examine the influence of some internal and external parameter evaluation. Related to the evaluation of global efficiency such as the global losses factor obtained experimentally $U_L = 2.76W/m^2{}^\circ C$ The independent solar radiation and deposits decrease relative the rate of and distilled water production.

Rahul dev[9] In this paper new approach has been made to obtain the characteristic equation of double slope passive solar still based on experimental observations. The performance of double slope passive solar still has been analyzed for the composition climate condition .It have been Non-linear characteristic curves have been found more accurate than linear characteristic curves.

Kalidasa Murugavel[10] In this paper a single basin double slope solar still with an inner size2.08m×0.84m×0.075m and that of outer basin area 2.3m×1m×0.25m has been fabricated with mild steel plate. He found that the still 3/4 in sized quartzite rock is the effective material. The production rate depends on water ,glass and atmospheric temp, water –glass temp difference and glass atmosphere temp difference.

III. Experimental Set Up

Fig 2 Experimental set up of the system

Force circulation mode

In system the flat plat colleter supplied an additional thermal energy via circulating water by help of pump so this system is called forced circulation mode.The two flat plat collectors are coupled with double slope solar still connected in series. In below table specification of fabricated of double slope solar still and flat plat collector.

PV Module

In PV module ,from total solar radiation absorber by PV cell is not fully converted into the electicity ,remaining of excees air which is converted into the electricity is incresed the temperature of PV cell.

Experimental setup description

Experiments have been performed to evaluate the performance of the solar still under the field conditions of GIT College, Moti-Bhoyan. Before the commencement of test, the basin was filled with brackish water to a desired level (0.025 m) to bring the water in steady state. All the glass covers were cleaned for the dust/dirt particles before the experimentation. The tests started at 10:00 a.m. and continued till 5:00 p.m. on the same day. During experiment the following parameters were measured hourly.

- Solar intensities on E-W glass covers
- Solar intensities on collector panels
- Ambient air temperature
- Basin liner temperature
- Water temperature inside still
- Inner surface temperature of glass covers
- Outer surface temperature of glass covers
- Hourly yields from E-W cover sides

Table 1 The parameter for the double slope solar still

Component	Specification
Length	1m
Width	1m
Lower height	0.11m

Higher height	0.24m
Thickness of glass cover	0.004m
Inclination angle	14°
Basin area	1m^2
Material of paint	Fiber reinforce plastic(FRP)
Material	M .S
No of glasses	2

Table 2 The parameter for the collector box

Length	1.4m
Width	0.56m
Height	0.10m
Spacing between absorber and cover	0.08m
Spacing between absorber and bottom plate	0.08m
Inlet port diameter	0.04m
Outlet port diameter	0.04m
Area of each collector	0.784m^2
No of collector	2
Tube material	Copper tubes
Tube diameter	10mm

IV. RESULT DISCUSSION

Table 3 Solar insolation of present system

Time	Is(t)E	Is(t)W	Is(t)C
9:00AM	656	490	451
10:00AM	880	532	536
11:00 AM	1048	855	806
12:00 AM	1059	992	844
1:00 AM	973	1040	890
2:00 AM	847	1008	879
3:00 AM	662	882	805
4:00 AM	354	616	580
5:00 AM	247	479	392

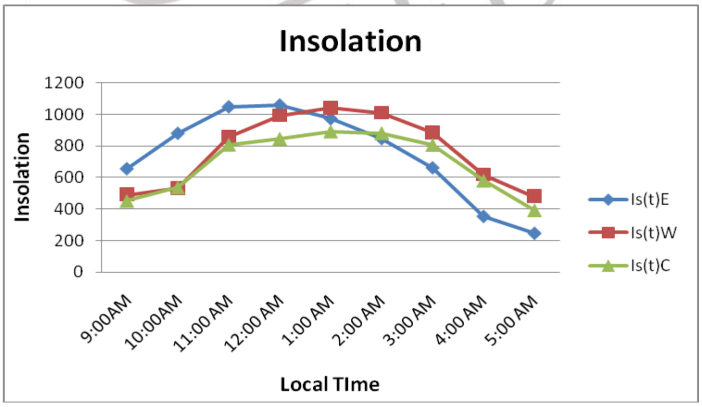

Fig 3 solar insolation Vs Time

The graph shown in figure is drawn the solar insolation with respect to time on the project with the solar power meter . The isolation is increasing while the sun radiation in between 1.00PM to 2.00PM. The solar isolation in morning time it continuously increases up to 1.00PM then it suddenly decreases the solar radiation. In to the experiment in morning the east side isolation is higher and then afternoon the west side afternoon isolation is high.

Table 4 Various temperature of solar still

Time	Ta	Tw	Tb	Tgie	Tgiw
9:00AM	40	41	40	46	38

10:00AM	48	49	48	58	50
11:00 AM	52	52	51	61	54
12:00 AM	60	71	66	63	59
1:00 AM	68	76	75	44	68
2:00 AM	68	80	79	49	71
3:00 AM	68	80	79	58	72
4:00 AM	62	62	74	45	70
5:00 AM	60	61	71	43	68

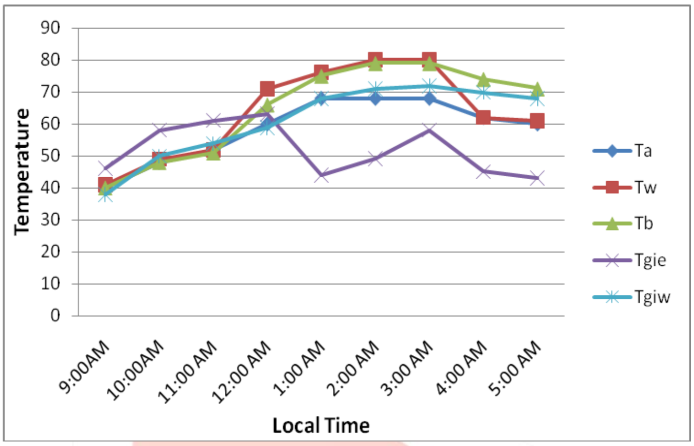

Fig 4 Different temperature Vs time

The above graphs for performance of ambient temperature, water temperature, basin temperature, glass cover inner temperature on both east and west side in water depth 0.025. The water temperature is marginally increasing with through the system and basin temperature parallel increase with water temperature. In east side glass cover temperature in morning section is higher and then afternoon at 2:00pm then decrease the temperature and reverse procedure in west side in morning section temp is lower than east side and then after at 2:00pm the temperature is continuously increase that shown in fig.5

Table 5 Distillate output of active solar still

Time	Mewe	Meww
9:00AM	0.014	0.030
10:00AM	0.025	0.075
11:00 AM	0.055	0.079
12:00 AM	0.040	0.120
1:00 AM	0.375	0.275
2:00 AM	0.300	0.320
3:00 AM	0.270	0.250
4:00 AM	0.255	0.260
5:00 AM	0.200	0.180

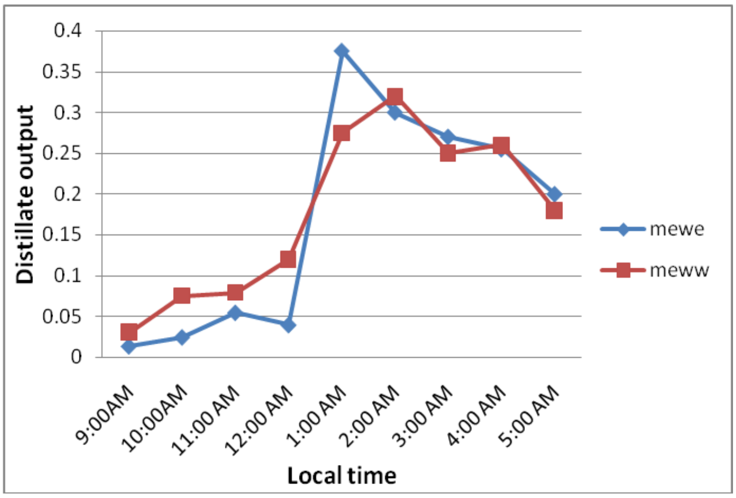

Fig 5 distilate output with active solar still Vs time

The graph shown in figure that mass flow rate on both side east and west side with respect to time . The graph indicate the east side has more distillate out put then west side.The maximum distillate output has been on between 1;00 pm and 2:00pm. Maximum distillate output of active solar still is 3.123 L/m2/day was obtained with a water depth of 0.025m on both side of solar still.

Table 6 distillate output of passive solar still

Time	Mewe	Meww
9:00AM	0.014	0.030
10:00AM	0.059	0.100
11:00 AM	0.058	0.120
12:00 AM	0.150	0.170
1:00 AM	0.205	0.210
2:00 AM	0.290	0.280
3:00 AM	0.280	0.260
4:00 AM	0.180	0.185
5:00 AM	0.126	0.100

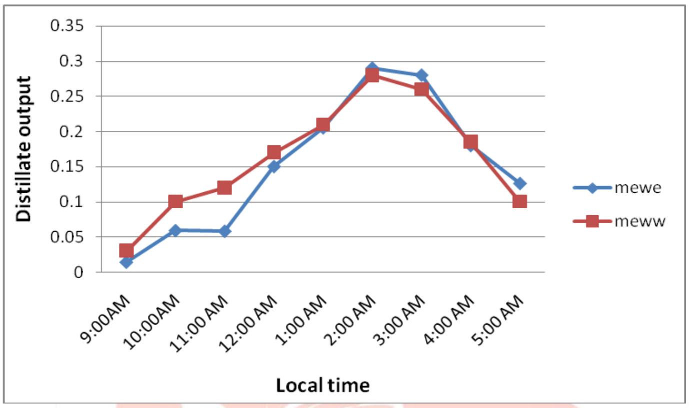

Fig 6 distilate output with passive solar still Vs time

The graph shown in figure that mass flow rate on both side east and west side with respect to time in passive solar still . The graph indicate the east side has more distillate out put then west side.The maximum distillate output has been on between 1;00 pm and 2:00pm and distillate output is 2.817 L/m2/day was obtained with a water depth of 0.025m on both side of solar still.

V. Conclusions

- The double slope active solar still under natural modes gives 51% higher result in comparison to the double slope passive solar still.
- Hybrid active solar still is 3.5 times higher than the passive solar still
- Maximum distillate output of active solar still is 3.123 L/m^2/day was obtained with a water depth of 0.025m on both side of solar still.
- Maximum distillate output of passive solar still is 2.817 L/m^2/day was obtained with a water depth of 0.025m on both side of solar still.
- The production rate depends on water, glass and atmospheric temperatures, water–glass temperature difference and glass temperature difference
- Exergy efficiency of double slope active solar still is higher than the exergy efficiency of double slope passive solar still
- The yield of water is high in hybrid photovoltaic/thermal active solar still compared to the passive solar still.

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