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Research Paper

PERFORMANCE AND ECONOMIC STUDY OF DESALINATION IN TUBULAR SOLAR STILL

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Tubular Solar still is a very simple solar device used for converting the available brackish or waste water into fresh distilled water. The tubular solar still can be fabricated easily with available materials. This device can be suitable solution to solve fresh distilled water production problem. Here comparison is made between simple tubular solar still and green net covered tubular solar still. Experimental study shows that solar still covered with green net increases the productivity. Lower the water depth in the tray increases the productivity of solar still and solar radiation can also produce considerable effect on productivity.

Keywords: Tubular Solar Still, Solarimeter, Thermocouples, Green net

INTRODUCTION

As a matter of fact 97% of water in the world is in an ocean and approximately 2% of the water in the world is present as ice stored in the polar region, and mere 1% is fresh water available for plants, animals and human life. There is an important need for clean, pure drinking water in developing countries. Often water sources are brackish (i.e., Contains dissolved salts) and contains harmful bacteria's and therefore cannot be used for drinking. Distillation is one of many processes that can be used for water purification. This requires energy input in the form of solar radiation. The process involves separation of water vapor from dissolved matter, which further condenses as pure water. Therefore solar still is used for removal of dissolved salts from water. The physics of solar stills is mainly a superposition of heat and mass transfer by radiated heat exchange between the surrounding surfaces. Free convection accompanied by evaporative mass transfer and radiation are modes of heat transfer between the water surface and the PVC cover inside the still.

According to Mowla and Karimi (1995) Conventional techniques for desalting water can broadly be classified on the basis of energy input, and these conventional techniques are not cost

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effective for low demands of clean water. According to Bouchekima *et al*. (1998), improvements in solar distillation technology makes it ideal for desalinating water in remote areas with water demands below 50 L per day. Shukla *et al.* (2010), in order to measure the effect of the inner and outer glass cover temperature on various internal heat transfer processes in a solar still, an indoor simulation has been carried over a typical operating temperature ranges. The condensing surface has been maintained at three different environmental conditions: (a) by exposing it to ambient air temperature, (b) by exposing it to air conditioned surroundings; and (c) by keeping ice on it.

OBJECTIVE

The objective of this work is to study a tubular solar still and determinate a relation for distillate output in simple a tubular solar still and tubular a solar still covered with green house. To perform cost analysis of still, and determine a mathematical model for performance analysis of output in simple tubular solar still and tubular solar still covered with green house.

Setup Description of TSS

This paper presents an experimental work conducted on a Tubular Solar Still installed at "Institute of Tool Room Training U.P" (ITTUP) Lucknow, Uttar Pradesh, India. Analysis of performance and economic study of desalination in tubular solar still has been carried out.

COVER AND TROUGH MATERIALS

Table shows the materials of cover and tray for the TSS.

FABRICATION COST OF TSS

The PVC sheet of 3.18 m^2 was brought at the rate of Rs. 592/m^2 for the tubular structure. Totalcost of sheet is Rs. 1882.56.

Two rings were at the rate Rs. 200 each. So the total cost of the ring is Rs. 400. For the side wall two discs each of area 0.7853 m^2 is brought at the rate of Rs. 592/m^2. So thetotal cost of the sheet is Rs. 930.

Table 1: Specification of Tubular Solar Still

S.No.	Items	Particulars	Specifications
1.	Cover	Shape	Tubular
		Lentgth of Cover	1 M
		Diameter of Cover	.80 M
2.	Tray	Shape	Rectangular
		Length	1 M
		Breath	0.74 M
3.	TSS	Frame of TSS Tubular	
		Assemble & Set Up of TSS	Easy

Table 2: Material of Cover And Tray For Tss

S.No.	Items	Particulars	Specifications
1.	Cover	Cover	PVC
		Thickness	1 Mm
		Transmissibility	80%
2.	Tray	Material	Gi*
		Thickness Of Tray	0.5 Mm

Note: * Galvanized Iron

Twenty M-seal packets were brought at the rate of Rs. 15/pack. So the total cost of the M-sealis Rs. 300.

Galvanized iron sheet of area 1.5 m^2 was brought at the rate of Rs 254/ m^2. So total cost of thebasin is Rs 400.PVC solution was brought which cost about Rs. 50.

2 m PVC pipe is brought at the rate of Rs. 10/ m. so the total cost of is pipe is Rs. 20.

About 7.32 m of L bar was brought at the rate of Rs. 100/m. so the total cost of L bar is Rs. 732.

About 3.44 m of flat iron strip was brought at the rate of Rs. 50/m. so the total cost of flat strip is Rs. 172.

2.4 m of square rod is brought at the rate of Rs. 75. So the total cost of square rod is Rs. 180.

So the total fabrication cost comes to Rs. 5500.

EXPERIMENTAL PROCEDURE

The incident solar radiation is transmitted through PVC tubular cover to the water in the tray. Thus, the water in the tray gets heated up and evaporates. The evaporated water particles condense in the inside layer of PVC cover. This condensed water flows down the cover due to tubular shape of the cover and is collected in the lower portion of the tubular structure. There is a gap between the tray and the walls of the tubular structure. Through this gap the water coming down is collected in the lower portion of the tube. This is collected towards one side due to 10 inclination of the TSS. There is a hole in this portion which allows the water to come out of TSS. The water coming out of TSS is collected in al closed vessel.

The experiment is commenced on the existing setup. So as to enable the set to reach the steady state condition. For each experiment, the tubular PVC cover is cleaned in the morning to avoid the dust deposition over the outer layer of PVC cover. The experiment was conducted on the sunny day of May and June. The readings were taken from 9:00 am to 5:00 pm at an interval of half an hour. The variables measured in this experiment are as follows:

Water temperature (Tw)

Tube surface temperature (Tt)

Solar intensity (Si)

OBSERVATION (FOR SIMPLE TSS)

The following reading was taken on 31st May 2014 for simple TSS:

*455 mL of distillate output which is measured during 16.45 pm to 9.15 am is also added in grand

Table 3: Observation for Simple TSS

Time	Time Step	Solar Intensity	Water Temperature	Tube Temperature	Diff Temp	Distilled Water
9.15	0	740	38	35	3	0
9.45	30	850	44	35	9	80
10.15	60	920	48	35	13	100
10.45	90	990	52	37	15	90
11.15	120	1060	53	37	16	110
11.45	150	1070	53	38	15	170
12.15	180	1040	54	38	16	180
12.45	210	1040	55	40	15	190
13.15	240	910	55	39	16	180
13.45	270	810	53	39	14	210
14.15	300	760	53	38	15	150
14.45	330	750	52	37	15	180
15.15	360	500	50	37	13	135
15.45	390	400	49	37	12	125
16.15	420	350	48	36	12	110
16.45	450	300	44	36	8	110
Grand Total Of Distilled Water (24 Hours) (Ml) = 2120+455=2575						

total of 24 h output.

OBSERVATIONS (WHEN TUBULAR SOLAR STILL WAS COVERED WITH GREEN NET)

The following reading was taken on 2nd June 2014:

*1170 mL of distillate output which is measured during 16.45 pm to 9.15 am is also added in grand total of 24 h output.

FRESH WATER PRODUCTION COST

The most important factor is the cost of fresh water production for commercialization of the new TSS.

The amount of daily production = 3.2 L

Cost of water per litre = Rs. 12

Cost of water produced daily = Rs. 38.4

Operating Cost

Net profit = cost of water produced – operating cost- maintenance cost

= 38.4 - 0.0 - 0.0

= Rs. 38.4

Payback Period = 5500/ 38.4=144 days

If the system is used for production of water cost of per litre will be:

Total life = 30 years

=30 x 300 = 9000 days

Total quantity of water produced = 9000 x 3.2

Cost of water perL = 5500/28800

= 20 paise/ L

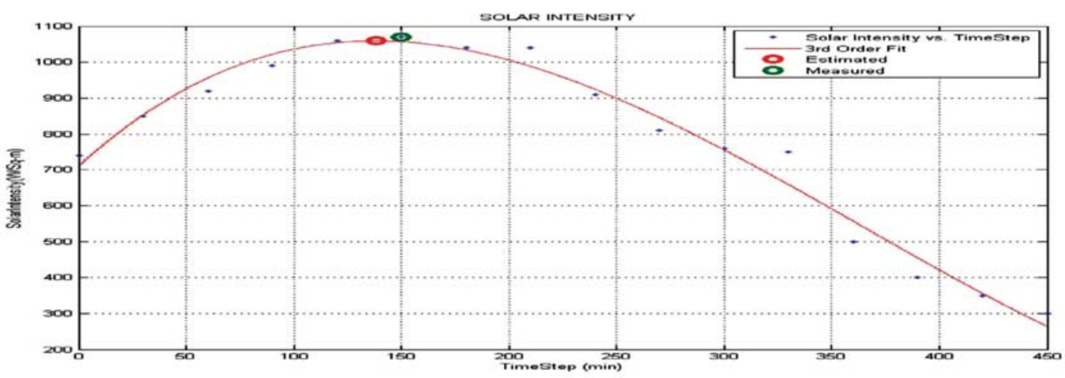
Performance Analysis of Solar Tubular Still

Table 4: Observation for Modified TSS

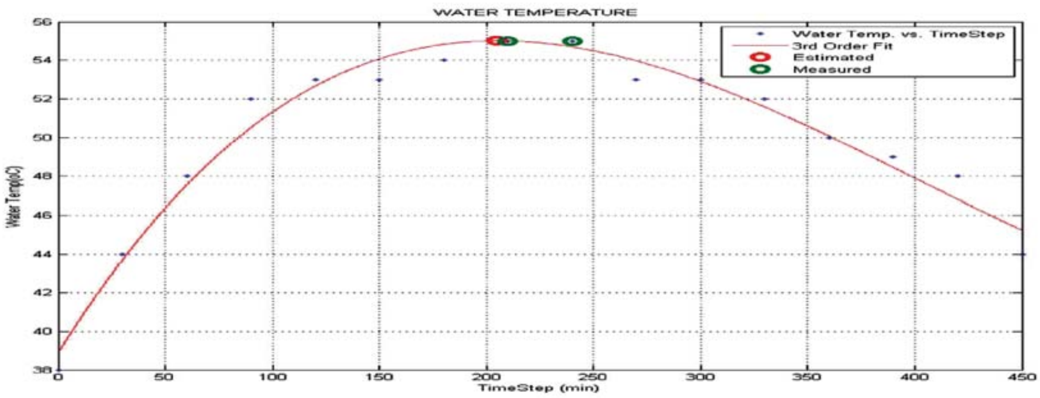
Time	Time Step	Solar Intensity	Water Temperature	Tube Temperature	Diff Temp	Distilled Water
9.15	0	800	38	35	3	0
9.45	30	880	44	35	9	80
10.15	60	1050	49	36	13	90
10.45	90	1120	52	37	15	120
11.15	120	1120	54	37	17	150
11.45	150	1140	55	38	17	190
12.15	180	1140	55	38	17	210
12.45	210	1160	56	39	17	220
13.15	240	1180	56	39	17	240
13.45	270	1190	57	40	17	250
14.15	300	920	53	39	14	270
14.45	330	770	52	39	13	225
15.15	360	610	50	38	12	225
15.45	390	530	49	37	12	170
16.15	420	380	49	36	13	140
16.45	450	280	45	35	10	120
Grand Total Of Distilled Water (24 Hours) (Ml) = 2700+1170=3870						

SECTION A: EXPERIMENT WITHOUT GREEN-NET

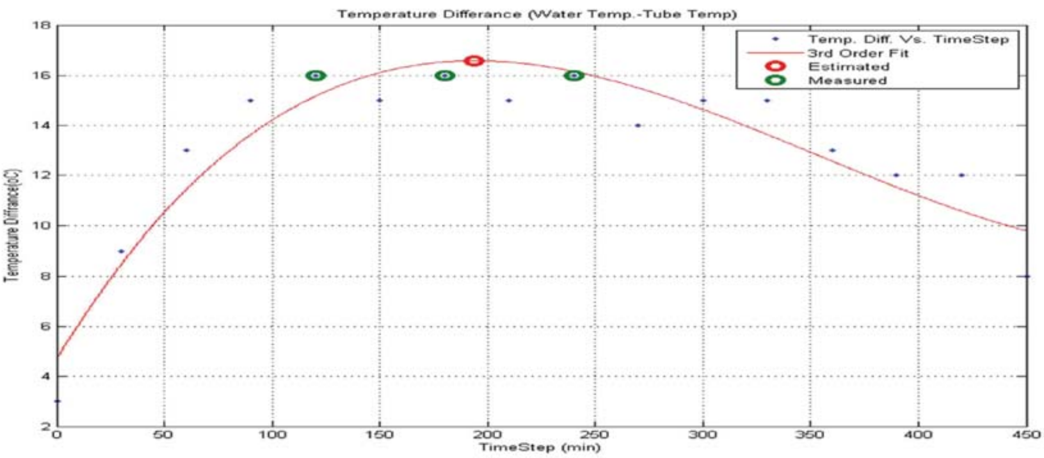
Estimation of Solar Intensity From 3rd Order Polynomial Curve Fitting



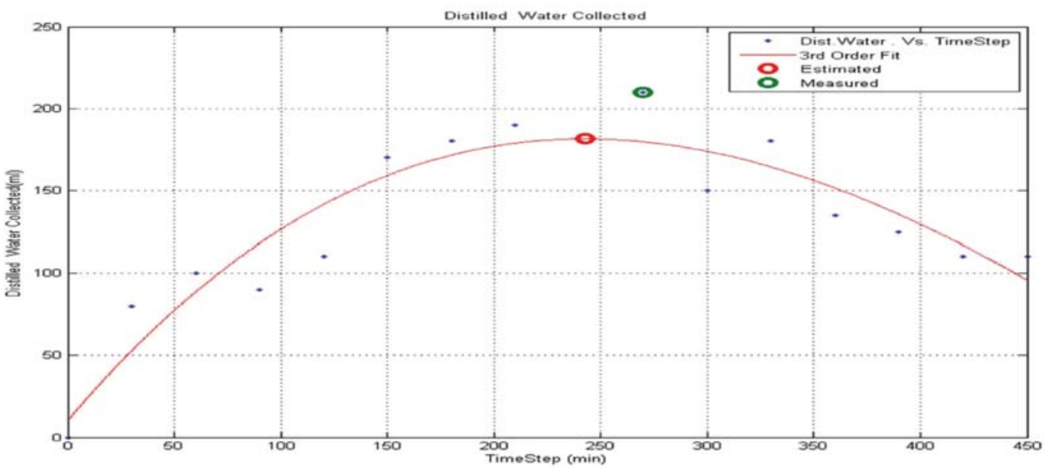
Estimation of Water temperature From 3rd Order Polynomial Curve Fitting



Estimation of Temperature Difference From 3rd Order Polynomial Curve Fitting

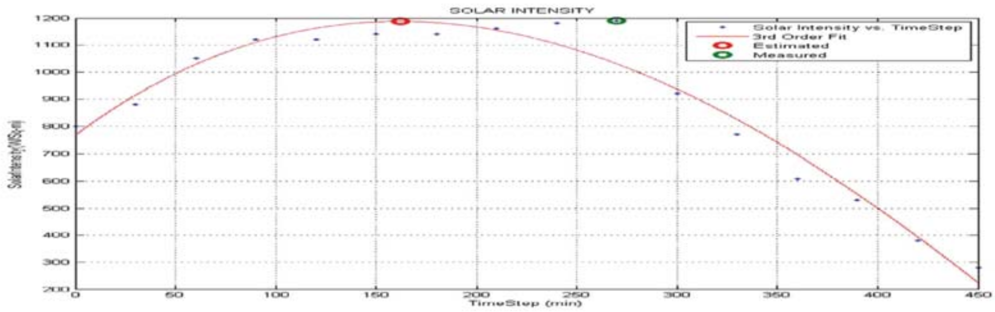


Estimation of Distilled Water From 3rd Order Polynomial Curve Fitting

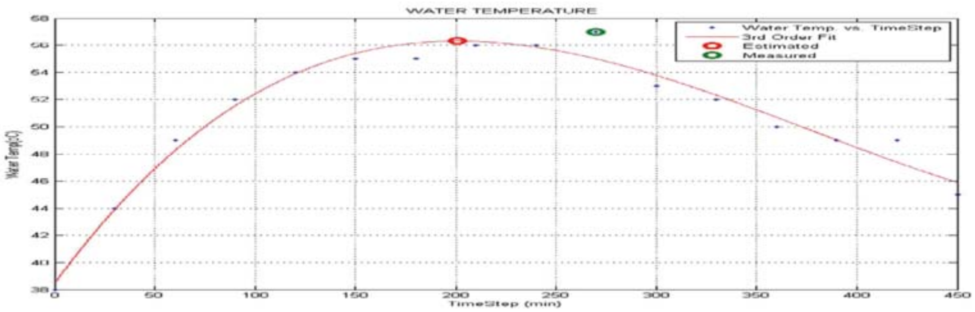


SECTION B: EXPERIMENT WITH GREEN-NET

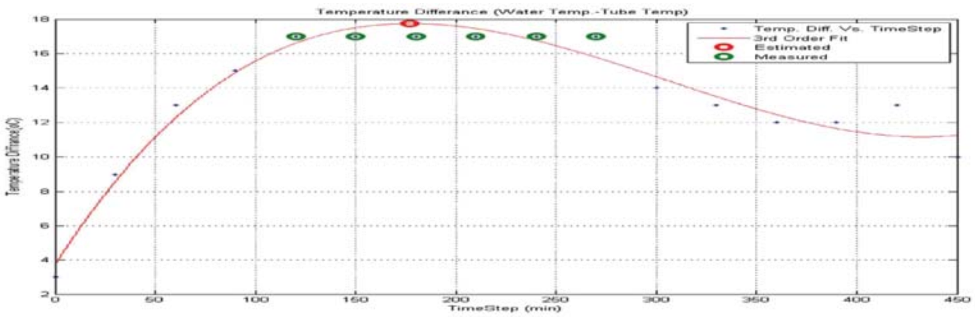
Estimation of Solar Intensity From 3rd Order Polynomial Curve Fitting



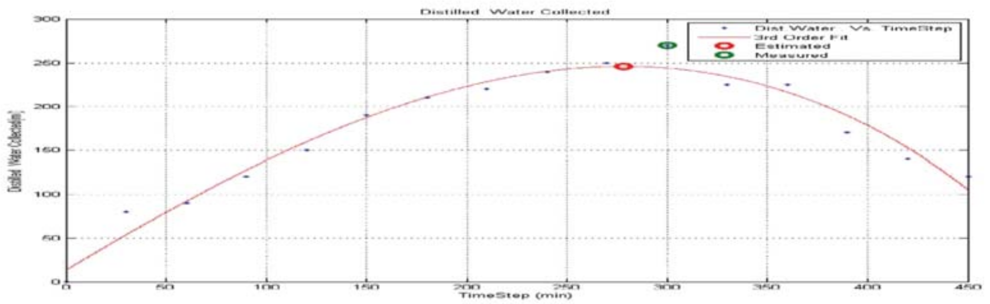
Estimation of Water temperature From 3rd Order Polynomial Curve Fitting



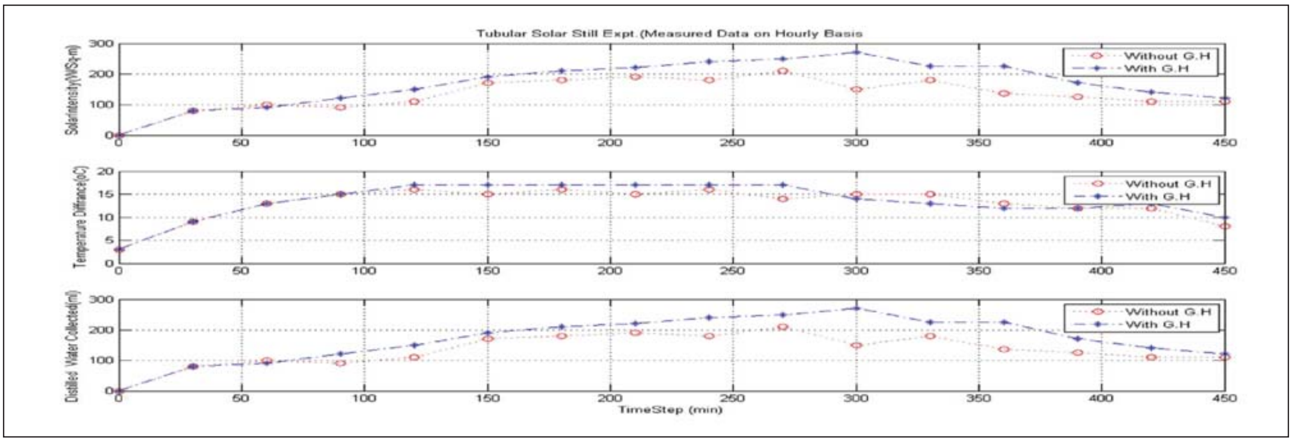
Estimation of Temperature Difference From 3rd Order Polynomial Curve Fitting



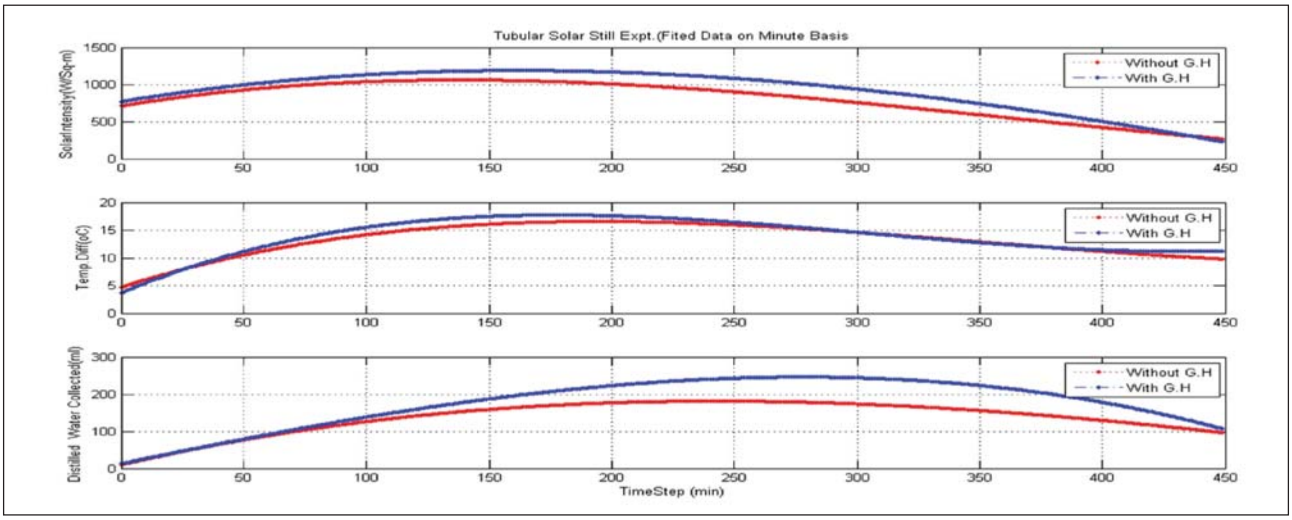
Estimation of Distilled Water From 3rd Order Polynomial Curve Fitting



RESULTS AND DISCUSSION



ANALYSIS OF EXPERIMENTAL RESULT (MEASURED DATA ON HOURLY BASIS)



ANALYSIS OF EXPERIMENTAL DATA (3RD ORDER POLYNOMIAL FITTED DATA ON MINUTE BASIS)

Result for Simple TSS (without green net)

Experimental constant	p1	p2	p3	p4
'SolarInt'	2.2579e-05	-2.4549e-02	5.4833e+00	7.1050e+02
'DiffTemp'	4.6810e-07	-4.9629e-04	1.3979e-01	4.7270e+00
'DistWater'	2.0434e-06	-3.8984e-03	1.5303e+00	1.0435e+01

This model follows the mathematical equation as given below, having value of constants shown above

$$f(x) = p_1x^3 + p_2x^2 + p_3x + p_4$$

Result for Modified TSS (Covered with green net)

This model follows the mathematical equation as

Experimental constant	p1	p2	p3	p4
'SolarInt'	1.0030e-05	-1.9330e-02	5.4599e+00	7.6797e+02
'DiffTemp'	7.9531e-07	-7.2747e-04	1.8306e-01	3.7257e+00
'DistWater'	-3.8724e-06	-8.6028e-04	1.3760e+00	1.3255e+01

given below, having value of constants shown above

$$f(x) = p_1x^3 + p_2x^2 + p_3x + p_4$$

DISCUSSION

Based on the modified model (Covered with Green Net), the results obtained were in better agreement. From the results, the output of simple model is slightly more initially than modified model but as time passes the output of modified model increases due to the effect of green house.

1st, 2nd, 3|, and 4th order polynomial is fitted to the experimental data and from analysis using MATLAB Curve fitting it is concluded that, the 3rd order polynomial curve is best suited for this model having equation as follows:

$$f(x) = p_1x^3 + p_2x^2 + p_3x + p_4$$

where p_1, p_2, p_3, p_4 are constant having different values for system with green net and without green net. This equation can be used to find solar intensity, difference temperature and output at particular time, by using the values of constant obtained through curve fitting. The values obtained through the above equation shows minimum and maximum error of ±0.35

It can be calculated that the productivity of the water varies with solar radiation and temperature. The output of still is maximum at noon. Production also depends upon the temperature difference between the tray water and PVC temperature. As the temperature difference increases productivity of the system also increases, the productivity of system also varies with the depth of water in the tray.

CONCLUSION AND FUTURE SCOPE

The present model of the tubular still is based on the process of solar distillation. The device is very useful in rural areas to remove the shortage of fresh water. The PVC sheet is used for tubular structure having transmissibility of 80%. In testing water temperature, tube temperature, solar intensity and distillate output are measured at an interval of half an hour.During testing readings were also taken by varying the depth of water in tray. As depth of water decreases distillate output increases it was also found that productivity of system increases with the increase in the solar intensity and temperature. On the whole it could be concluded that it is very useful system for purification of water in rural areas. Based on modified model (Covered with Green Net), the result obtained for modified model the output was in better agreement. It can be utilized in remote places where there is no electricity and fuels. The present model can use for different design of condensing cover without any limitation of cavity volume.Fan and blower can be used for fast condensation.

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