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An Experimental Investigation of an Inclined Solar Distillation and Domestic Water Heating System in Cogeneration

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Abstract

Solar distillation system works on the simple principle of evaporation and condensation process .Unlike other types of distillation system which works either by consuming electrical energy or by burning fossil fuels; it works simply on thermal energy provided by the sun which is free in nature. The hot waste brackish water is cogenerated. It takes brackish or impure water as an input to the system and clean wateras well as hot brackish water as an output. The simplicity of the system makes it ideal for disaster situations mainly flood, where the water is plenty but unsafe to drink .Test run on the performance of the system on daily day basis in the month of April,2015 location : National Institute of Solar Energy (Latitude: $28^0 25' N$,Longitude:$77^0 9' E$) ,GwalPahari Haryana(India) by taking reading of daily clean water production corresponding to variation of temperature ,wind speed,solar radiation and ambient temperature during daytime for every 10 minutes from hour:min. (9.3a.m. to 5.00 p.m.)

Keywords : Brackish and saline water; Solar Distillation; Solar energy; Distilled Water; Low cost; Humidfication-Dehumidification process

1. Introduction

In the developing countries, unsafe drinking water, poor sanitary environment, malnutrition, and poverty are largely responsible for epidemic and deadly diseases. Half of the World's hospital beds are occupied by people suffering from water borne diseases.

In India, water-borne diseases alone are said to claim 73 million workdays every year. The cost in terms of medical treatment and lost of production is around Rs. 24,000 million (US $ 600 million) per year. More than 70 percent of Indian population lives in rural and sub-rural areas. India has nearly 559,553 villages out of which about 28% are reported to have unsafe drinking water due to chemical or biological contamination as reported by World Health Organisation(WHO).

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Now apart from consuming water intelligently and spreading awareness of shortages of fresh water supply,there are various solution proposed like the Desalination Plants to produce fresh water andthere are nearly 15000 Desalination Plants worldwide so far but the drawback with this kind of technologies : powered by fossil fuels, high cost if backed by Solar Photovoltaic System and thirdly hot Brine released into the river.

Still the Desalination Plants are widely popular in the developed world but most of the people who are suffering from unsafe drinking water are living in rural areas or underdeveloped countries having a bright sunshine day where we can provide this kind of low cost design of Solar Distillation System solely work on thermal energy, i.e. Solar Energy as there is limited scope of electricity and shortages of investment in rural areas.

Xing li et al.(2014) have performed the solar humidification and dehumidification using a new sort of solar air heater with evacuated tubes and optimization by mathematical design method and found that higher outlet air temperature and relative humidity effectively increased fresh water production under same air temperature and cooling condition.CihanYildirim and Ismail Solmus (2014) have given the mathematical analysis by using the fourth order Ranga- Kutta method for humidification and dehumidification desalination system.J. Orfi et al.(2007) discussed dependency on the ratio between the salt water and the air mass flow rates and shown that, if ratio put to optimum level, it is possible to produce more than 40 L of fresh water daily per square meter of solar collector surface on a typical July day in Tunisia. ShaoboHou et al. (2005) have used the pinch technology which focussed on the ratio of mass flow rate of water to the dry air at a different spraying water temperature for performance optimization of solar humidification and dehumidification desalination system.Hikmet S. Aybar et al.(2005) have tested with variants : bare plate, black cloth-wick and black fleece wick and found that the fresh water production rate was increased two to three times when wick were used instead of bare plate. Margarita Castillo-Tellez et al.(2015) performed experiment on a forced convective double slope solar still and found that the thermal efficiency and production increment when the air velocity increases up to the value limit around 5.5 m/s and it then decreases at higher velocities and the velocity of 3.5 m/s is considered to be the optimum.Ahmad Ghazy (2002) showed the influence of environmental and design parameters. He also explains that the flow rate of feed water is insignificant on solar desalination system.

2. System description

Solar water distillation system (SWDS)consist of a galvanized steel absorber plate which is painted black and is covered with Teflon sheet formed a box of length ,breath and height are 0.5m,0.5m,and0.1m respectively.A black cloth is laid on the absorber plate to flow the water evenly on the plate and to increase the exposure time to solar radiation. The system is inclined to an angle of 45 degree in order to run the water down effectively and easily.

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fig.1. SWDS with black cloth and without Teflon sheet cover

2.1 Working : Feed water flow at the rate of (7.317ml per min) from a separate tank of brackish water through a pipe which is connected to distribution pipe on the top of absorber plate and its inlet is shown on the top right side fig.1. Now the water falls through the distribution pipe onto black cloth and can see the layer of water spreaded all over the absorber plate. Solarradiation warms the absorber plate and water on plate starts evaporating and finally condenses when it touches the cool Teflon sheet. The condensate water is collected at bottom in separate channel and the remaining hot water which is brackish in nature is also collected in separate channel and can used for heating purpose.

2.2 Instruments and its Specification

Solar irradiation measurement :Pyranometer

Manufacturer : the Eppley laboratory Inc. USA

Impedence : 650 ohm approx.

Receiver : Circular 1 cm^2, coated with Parson's black optical lacquer.

Temperature Dependence : ±1 % over ambient temperature -20 to 40 degree centigrade

Linearity : ±0.5 % from 0 to 2800 W/m^2

Response time : 1s

Anemometer

- Combined wind speed and direction sensor with 10 meter cable.
- ABS cups with retainer nut.
- Wiring details & test report copy.

Thermocouple

To measure the temperature of water and air inside the box (in degree centigrade) during the day.

3. Results of tests and discussions

The experiment was conducted during daytime between the hours of 10:15 am and 4:55 pm through the(21th of April ,2015 to 21th of May,2015) to study the performance of the system. In the test, amount of fresh water produced every 10 minutes during day and measured in measuring cylinder glass of 0.02m diameter corresponding to parameters like air temperature, solar radiation and wind speed.

In this paper ,the performance of the data taken for a day of the month(i.e. 22nd ,April) from hour:min 10:15am to 4:45pm when experienced maximum production of fresh or distilled water.

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3.1 From the table 1, the maximum rate of production of water increases in the time interval hour (11:25am to 1:55pm)

Table 1. Experimental data performed during day hours :

TIME	HEIGHT (m)	RADIUS (m)	VOLUME (m^3)
10.15	0	0	0
10.25	0.038	0.01	0.000011932
10.35	0.043	0.01	0.000013502
10.45	0.048	0.01	0.000015072
10.55	0.041	0.01	0.000012874
11.05	0.035	0.01	0.00001099
11.15	0.043	0.01	0.000013502
11.25	0.073	0.01	0.000022922
11.35	0.094	0.01	0.000029516
11.45	0.098	0.01	0.000030772
11.55	0.098	0.01	0.000030772
12.05	0.097	0.01	0.000030458
12.15	0.091	0.01	0.000028574
12.25	0.089	0.01	0.000027946
12.35	0.087	0.01	0.000027318
12.45	0.082	0.01	0.000025748
12.55	0.089	0.01	0.000027946
1.05	0.077	0.01	0.000024178
1.15	0.065	0.01	0.00002041
1.25	0.085	0.01	0.00002669
1.35	0.082	0.01	0.000025748
1.45	0.076	0.01	0.000023864
1.55	0.072	0.01	0.000022608
2.05	0.058	0.01	0.000018212
2.15	0.081	0.01	0.000025434
2.25	0.071	0.01	0.000022294
2.35	0.055	0.01	0.00001727
2.45	0.055	0.01	0.00001727
2.55	0.073	0.01	0.000022922
3.05	0.051	0.01	0.000016014
3.15	0.058	0.01	0.000018212
3.25	0.053	0.01	0.000016642
3.35	0.064	0.01	0.000020096
3.45	0.045	0.01	0.00001413
3.55	0.065	0.01	0.00002041
4.05	0.059	0.01	0.000018526
4.15	0.046	0.01	0.000014444

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4.25	0.06	0.01	0.00001884
4.35	0.058	0.01	0.000018212
4.45	0.075	0.01	0.00002355
4.55	0.05	0.01	0.0000157
total volume calculated			0.00084152

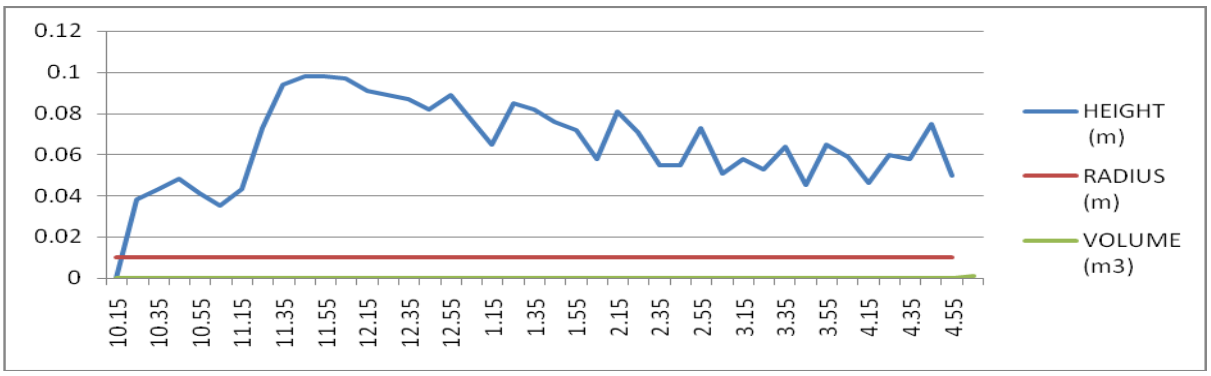

Fig.2. Distilled water production w.r.t time

From fig.2, the maximum production of fresh water (i.e 30.772ml) correspond to hr:min is 11:55 am. In order to analyse this, from Table 2.,the meteorological parameters has been recorded : Air temperature, pyrometer reading ,wind speed, wind direction and solar collector box inlet temperature(T5). The fresh water production is maximum corresponding inlet solar collector temperature is 66.354 ^{0}C,wind speed 3.9m/s ,air temperature 34.7106 ^{0}C and solar radiation 921.054 W/m^2.

3.2 Table 2: Meteorological data recorded from Data Logger :

time	temp1 (degC)	Temp2 (degC)	AIR TEMP (degC)	PYRO METER (W/m2)	WS (m/s)	WD (Degree)	T3 (degC)	T4 (degC)	T5 (degC)
10:15	33.78861	33.8882	29.8927	541.14594	1.88313	118.1248	30.0144	30.48	35.54249
10:25	33.9341	34.0004	29.96057	545.03229	2.15729	97.60529	30.05725	30.85	35.61501
10:35	34.90558	35.0084	30.61044	589.52234	1.95883	116.003	30.85876	31.667	36.50262
10:45	36.00957	36.0162	31.0697	643.61914	1.95172	154.2658	31.4642	32.185	37.03705
10:55	36.86571	37.0077	31.42282	694.56989	1.84056	89.50345	32.14376	32.54	37.75714
11:05	38.08306	38.0138	31.69995	741.89789	1.36393	117.6334	32.71545	32.722	38.94351
11:15	38.95967	39.009	32.23706	781.91296	1.85249	110.4459	33.61333	33.809	41.23521
11:25	40.60209	40.0161	33.29367	831.13922	1.83428	100.7608	34.25116	34.643	65.61723
11:35	41.63382	41.0042	33.79935	883.70862	1.65898	101.7789	34.77362	35.574	69.20994
11:45	42.55773	42.0204	34.392	893.20911	0.50497	162.9566	36.39042	36.48	71.51034
11:55	43.50193	43.0016	34.7106	921.05444	1.00125	73.80317	35.22845	36.282	70.35488
12:05	44.47609	44.0093	34.91736	909.86108	0.6694	21.11337	34.95366	36.955	66.9752
12:15	45.32588	45.0009	35.46741	912.48956	1.25101	92.90931	34.78605	37.045	68.42149
12:25	46.37498	46.0081	35.53302	932.89685	1.41436	95.51188	35.41653	36.831	68.59917
12:35	47.35219	47.0023	35.90735	943.24719	2.6885	104.1674	36.44224	37.893	68.60278

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12:45	48.35826	48.0092	36.04449	958.48962	2.20258	121.3044	36.12099	37.793	65.73474
12:55	49.57172	49.0052	36.20966	955.29773	2.86037	136.6818	36.50063	37.796	66.08283
01:05	50.29916	50.0255	36.34119	936.83911	4.66657	124.4062	37.58397	37.697	61.32798
01:15	51.38716	51.0032	36.49152	919.15845	2.92175	82.54091	39.224	37.371	67.1693
01:25	52.41565	52.0033	36.86224	913.48065	1.3644	122.8205	40.41548	38.33	72.41452
01:35	53.38478	53.0023	37.06778	908.12927	3.85273	88.72533	40.33407	38.248	68.41525
01:45	54.42944	54.0349	37.22272	904.24567	3.6735	143.4742	40.58913	38.364	66.13335
01:55	55.35653	55.008	37.39844	869.04797	2.77114	131.5803	40.62518	38.474	66.70116
02:05	56.29489	56.002	37.74207	822.99017	2.14046	80.10082	41.16352	38.675	69.61749
02:15	57.36283	57.0047	37.9613	779.71265	2.67609	97.51392	41.51331	39.22	67.95692
02:25	58.51859	58.0358	37.87704	745.0238	3.38106	111.0911	40.89417	38.899	68.16682
02:35	59.31875	59.0232	37.90701	724.5542	1.89685	106.8765	40.85691	38.776	70.05106
02:45	59.97492	60.0294	38.05267	658.28625	1.98353	105.3899	41.35727	38.908	70.35123
02:55	61.22981	61.0093	37.94922	568.77582	3.16288	108.8289	40.19754	38.71	67.6013
03:05	62.63996	62.0447	38.06628	555.69757	5.01703	57.3861	40.22823	39.947	67.5098
03:15	62.6053	63.0239	38.25403	461.75482	2.50974	113.1402	39.38255	40.135	67.5126
03:25	63.71277	64.0187	38.16672	330.62814	1.33304	122.4717	38.73515	40.462	60.24274
03:35	64.46634	65.0065	37.61102	179.88354	4.55981	124.3973	37.54161	39.315	56.26941

Fig. 3 shows the trend of meteorological data recorded every 10 sec .on 22nd April by Data Logger :

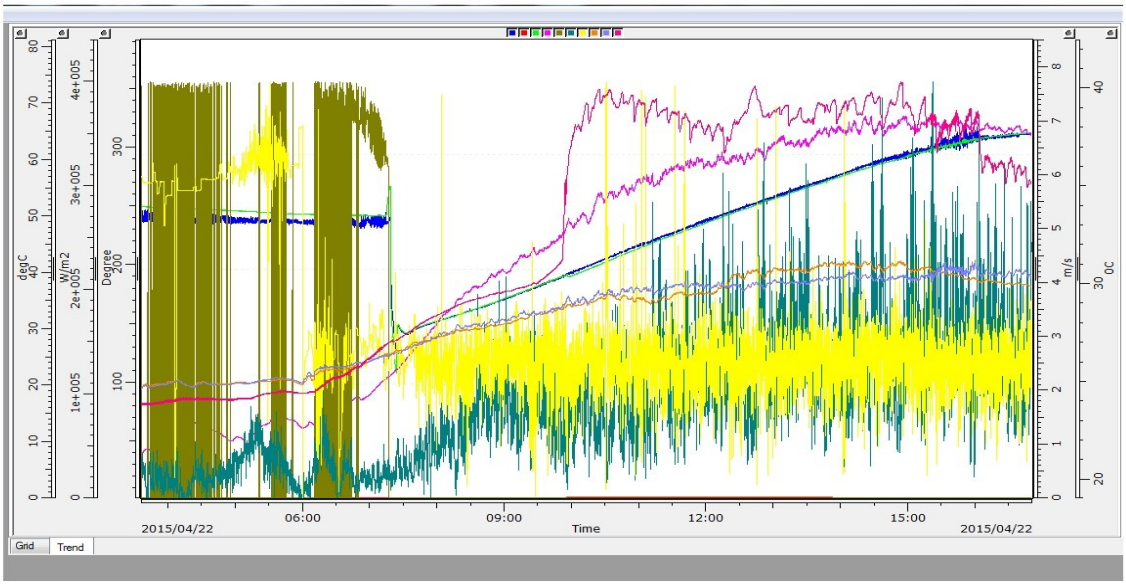

Fig3. The trend graph of the meterological data recorded

4. Conclusion

The production of the fresh water is maximum during a day in the month of22nd April, corresponding to Average air temperature(35.398^{0}C),Average wind speed (i.e. 2.333m/s),Average Solar Radiation (756.281W/m2) and Average solar collector box temperature (60.944^{0}C).The average maximum production of fresh water during the whole month is available at daytime hour (i.e.11.05 am to 2.55pm) of a day. Wind

speed plays a major role in the production of fresh water as it reaches to maximum value i.e30.772ml corresponding parameters (inlet solar collector temperature is 66.354 0C,wind speed 3.9m/s ,air temperature 34.7106 0C and solar radiation 921.054 W/m2) from Table 1 and Table 2. Now during the same daytime, at hour:min12:55 pm corresponding values of parameters (system inlet temperature 66.08280C, air temperature 36 .209 0C and solar radiation 955.297 W/m and wind speed 1.860 m/s) is higher though except wind speed yet produce less amount of fresh water i.e27.94 ml. Therefore wind speed accelerates the rate of evaporation and condensation process inside the system and hence produced more fresh water. Solar Water Distillation system(SWDS) is simple ,require less maintenance and low installation cost makes it ideal for the larger rural population safe drinking water as other options of Desalination Technologies is not feasible because of high cost and no electrification in rural areas.

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References

[1]CihanYildirim and Ismail Solmus(2014), "a parametric study on a HDH desalination unit powered by solar air and water heaters", Energy Conversion and Management,vol.86,pp.568-575.

[2]G.N.Tiwari and N.K.Dhiman,(1991) "performance study high temperature solar distillation system" ,Energy Convers.&Mgmt,vol.32,pp.283-291.

[3]GN Tiwari and Hriday Narayan Singh, "Solar Energy Conversion and Photoenergy Systems-Solar Distillation-Vol.II

[4]Hikmet S. Aybar,FautEgelioglu,U.Atikol(2005), "an experimental study on an inclined solar water distillation system", Desalination,vol. 180,pp.285-289.

[5]Hassan ES Fath,AhmadGhazy(2002), "solar desalination using humidification – dehumidificationtechnology",Desalination142,pp.119-133.

[6]IDSA. (2010). Water Security for India: External dynamics. IDSA Task Force Report.

[7]J.Orfi,N.Galanis,M.Laplante(2007),"Air humidification–dehumidification for a water desalination system using solar energy",Desalination,vol.203,pp.471-481.

[8]Margarita Castillo-ellez,Issac Pilatowsky-Figuera,Aaron SanchezJuarez,Luiz Fernandez-Zayas(2015), "experimental study on the air velocity effect on the efficiency and fresh water production in a forced convective double slope solar still",Applied Thermal Engineering-vol.75,pp.1192-1200.

[9]ShaoboHou,ShengquamYe,Hefei Zhang(2005), "performance optimization of solar HDH desalination process using Pinch technology",Desalination183,pp.143-149.

[10]Rosegrant, M.W., Cai, X. and Clire, S.A. (2002). Global water outlook to 2025: Averting an impending crisis. Food Policy Report, IWMI. 36 pp.

[11]XingLi,GuofengYuan,ZhifangWang,HongyongLi, ZhibinXu(2014) , "experimental study on humidification and dehumidification desalination system of solar air heater with evacuated tubes",Desalination ,Vol .351,pp. 1-8