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Estimation Of The Production Of A Solar Still

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ABSTRACT

A set of operating parameters of a solar still such as outer glass temperature T_o, inner glass temperature T_g, ambience temperature T_a and water temperature T_w can be regarded as signals. The transfer function of the solar still can then be obtained using Discrete Fourier transform. The performance of the still is estimated by convolution of another set of operating conditions. The result gives a good prediction as compared with the measured value for day 1 and day 2.

KEY WORDS; *Solar still, Discrete Fourier transform, Operating Parameters*

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I. INTRODUCTION

Solar still distillation comes very handy in the production of portable water which has posed a serious problem in the rural areas and in the mangrove swamps. This problem has been further compounded by toxic waste and severe water pollution from industries like the oil and gas industries. Both the passive and active solar distillation unit can produce this water so desired despite the intermittent supply of solar energy (incident radiation). The effective distillation of water from solar still depends on a number of factors like the construction materials, the orientation, the tilt angle of the cover glass, climatic conditions, tightness, operating conditions and thermo-physical properties [1]. Hence all these were taken into consideration.

In order to understand the mechanism of the production of these stills, quite a number of numerical analysis has been carried out [2, 3, 4]. The distillation process looks simple but there are operating variables that affect the performance of this common configuration as, for example. heat losses through the glass cover and the base, solar radiation intensity, water depth and ambient temperature [5]. The link between these operating variables needed for the proper estimation of a solar still is complex and making the mathematical model of a solar still is still too complicated. Hence research using numerical analysis is underway in order to understand the mechanism of the solar still and to estimate and improve the yield from stills. It is well known that highly erratic wind speed resulting in heat loss because of convection can pose a challenge to the computation of the yield of a solar still. Another factor is the intermittent nature of solar radiation despite its abundance in our part of the world.

The purpose of this work is to present a method that can be used to estimate the yield from solar stills regardless of these challenges. To effectively do this, solar reading was taken for two days in Edo state. We will consider the operating variables [5] which are actually the operating temperatures generated by incident solar radiation and will take them as inputs. To do so we regard the solar still as a system. The inputs into the system include the temperature difference of the cover glass, that is the temperature of the outer glass T_0 and the temperature of the inner glass T_g, the water temperature T_w and the ambient temperature T_a. The rest of inputs correspond to

$T_{oa} = T_o – T_a$
$T_{go} = T_g – T_o$
$T_{wa} = T_w – T_a$
$T_{ga} = T_g – T_a$

The output from the system is basically the hourly yield. An alternative provided in this work as regards the heat transfer processes taking place inside the solar still was to measure the different input temperature parameters with an average of three measurements taken and the still production was estimated by convolution because the input parameters were taken at discrete times. The atmospheric temperature was taken into consideration to ensure proper monitoring of the still production using s thermometer.

A short discrete Fourier analysis theory of systems approach is presented for the effective estimation of the yield from the operation of a solar still followed by discussion of the results of the analysis present here.

II. SYSTEM APPROACH TO OPERATION OF A SOLAR STILL UNIT

In what follows, the system approach in [6] is adopted in this paper. A solar still can be viewed as a continuous system represented by;

$$\mathbf{x(t)} \rightarrow \boxed{\text{Continuous Time}} \rightarrow \mathbf{y(t)} \tag{1}$$

where x(t) is the input and y(t) is the output. For averaged input and output over time intervals, Equation (1) becomes

$$\mathbf{x[n]} \rightarrow \boxed{\text{Discrete Time}} \rightarrow \mathbf{y[n]} \tag{2}$$

Here it is assumed that the distillation unit is causal, linear and time-invariant, (LTI). The model simply provides insight into the intricate relationship between the aforementioned operating temperatures and the yield. In Equation (2), n represents hours which in this work runs from 0 to 23 hours. This simple representation of the solar still is possible because this model can describe other physical systems. This includes many systems being conceived for renewable energy.

In general we can rewrite Equation (2) as

$$\sum_k a_k x_k[n] \rightarrow \sum_k a_k y_k[n]. \tag{3}$$

If we regard the solar still as an LTI system and the unit sample response h[n] as a system characteristic transfer function, then

$\delta[n] \rightarrow h[n] \Rightarrow \delta[n\text{-}k] \rightarrow h[n\text{-}k]$, where $\delta[n]$ describes the time factor by time-invariance.

Then from LTI:

$$x[n] = \sum_{k=-\infty}^{\infty} x_k[n]\delta[n-k] \rightarrow \underbrace{y[n] = \sum_{k=-\infty}^{\infty} x_k[n]h[n-k]}_{Convolution\ sum}$$

Thus, y[n] can be written as a convolution of the input x[n] and the system characteristic transfer function h[n];

$$x[n] \rightarrow \boxed{\text{Discrete Time}} \rightarrow y[n] = h[n] * x[n] \tag{4}$$

or simply as $Y(e^{j\omega}) = H(e^{j\omega})\, X(e^{j\omega})$ (5)

where $Y(e^{j\omega})$, $X(e^{j\omega})$ and $H(e^{j\omega})$ are the corresponding Discrete Fourier transform (DFT) of the output, transfer function and the input respectively.

The transfer function of a distillation unit can be derived from the DFT of set of input and output. It should then be possible to predict the output for another set of inputs by convolution. This principle is routinely employed for design of advanced optical systems (see [4]). Thus the set of operating temperatures T_a, T_o, T_g, T_w, T_{oa}, T_{ga}, T_{wg}, T_{wa} and the hourly yield for a passive distillation was measured. In this work, we used values for two different days, denoted by day 1 and day 2, for the same still to test this principle.

III. RESULTS AND DISCUSSION

a. Temperature measurements

Results presented here are typical hourly averages as usual in a work of this nature. Table 1 shows the temperature difference cycle for day 1. Notice that between 8 hours and 18.00 hours of day 1 during which the still receives solar insolation, T_{oa}, T_{ga}, T_{go}, T_{wo}, and

T_{wa} are positive, while T_{wg}, which is the difference between the water and glass temperature is negative between 8.00 hours and 12.00 noon. One equation that is often used to estimate still production is a function of the difference between water and glass temperatures (see [7]).

Time (hour)	T_{oa}(°C)	T_{ga}(°C)	T_{go}(°C)	T_{wg}(°C)	T_{wo}(°C)	T_{wa}(°C)	Op
0	0.45	0.45	0	1	1	1.45	0
1	-0.5	-0.5	0	1.5	1.5	1	14.3
2	0.4	0.4	0	1.1	1.1	1.5	0
3	0.4	0.4	0	1.1	1.1	1.5	0
4	0	0	0	1.5	1.5	1.5	0
5	-0.5	-0.5	0	0	0	-0.5	0
6	0.2	-0.5	-0.7	0.5	-0.2	0	14.3
7	3	5.5	2.5	-5	-2.5	0.5	0
8	1.5	8.5	7	-5.5	1.5	3	14.3
9	6	22	16	-15	1	7	0
10	7	16	9	-1	8	15	42.9
11	10	30	20	-11	9	19	57.2
12	16	35	19	-5	14	30	214.5
13	17.5	22.5	5	9	14	31.5	171.6
14	16	23	7	4.5	11.5	27.5	143
15	13	19.5	6.5	6	12.5	25.5	114.4
16	9	12	3	9	12	21	114.4
17	7.5	7.5	0	11	11	18.5	71.5
18	3.5	3.5	0	10	10	13.5	71.5
19	3	2	-1	7.5	6.5	9.5	28.6
20	1	0.5	-0.5	4	3.5	4.5	10
21	0.5	0	-0.5	2.5	2	2.5	4.3
22	-0.5	-1.5	-1	3	2	1.5	0
23	0	-1	-1	3	2	2	0

Table 1:
Temperature Differences between the ambient temperature, T_a, outer glass temperature, T_o, inner glass temperature, T_g, and water temperature, T_w for Day 1. ($T_{oa}= T_o – T_a$, $T_{ga}= T_g - T_a$, $T_{wa}= T_w – T_a$, $T_{go}= T_g - T_o$ and $T_{wa}= T_w – T_a$)

$$\dot{m}_{ew} = \frac{h_{ew}(T_w - T_g)*3600}{L} kg/m^2 - h \qquad (6)$$

Where $\dot{m}_{ew}$ Is the hourly production, L is the latent heat of vaporization of water and h_{ew} is evaporative heat transfer coefficient from the water surface to the glass cover. Furthermore, it can be observed, that T_g is higher than T_w before 13.00 hours and the reverse is the case thereafter. The still starts producing well before this time and peaks when T_{wg} is at a minimum. Thus, Equation (6) may give incorrect estimates of still output during this period. It may be more appropriate to use T_{wa} or T_{oa} since these inputs follow the same trend as the output as shown in Figure 1. Evidently, Figure 2 shows good match between predicted and actual output using T_{wa}. It needs to be stated here that data from a passive solar still has been employed in this work.

The analysis can be extended to other types of stills as well, especially active solar stills, if detailed temperature measurements are made. Such studies will give a better understanding of the inner workings of solar devices in general for improved designs.

b. Predicted output

Of all the set of operating temperatures T_a, T_o, T_g, T_w, T_{oa}, T_{ga}, T_{wg}, and T_{wa}. Only the input temperatures T_{oa} and T_{wa} allowed us to predict still output with reasonable accuracy, as can be seen in Table 2.
Table 2: Predicted daily yield

Input	Predicted Yield $l/m^2/day$	Measured output $l/m^2/day$	Pecentage error (%)
T_{wg}	0.841	2.308	-63.560
T_{oa}	2.316	2.308	0.346
T_{ga}	3.202	2.308	38.73
T_{wa}	2.316	2.308	0.346

IV. CONCLUSIONS

The different temperature components of a passive solar still were employed to investigate the still performance. The difference T_{oa} between outer glass temperature and ambient temperature can be used as input to drive the transfer function of a still for good estimates of the yield. This technique was used to predict the output of a passive solar still output as 2.316 $l/m^2/day$ which is very close to the actual value of 2.308 $l/m^2/day$. Note that T_{wg} underestimates the yield while T_{ga} gives an overestimate. In addition, other temperature components give unrealistic estimates.

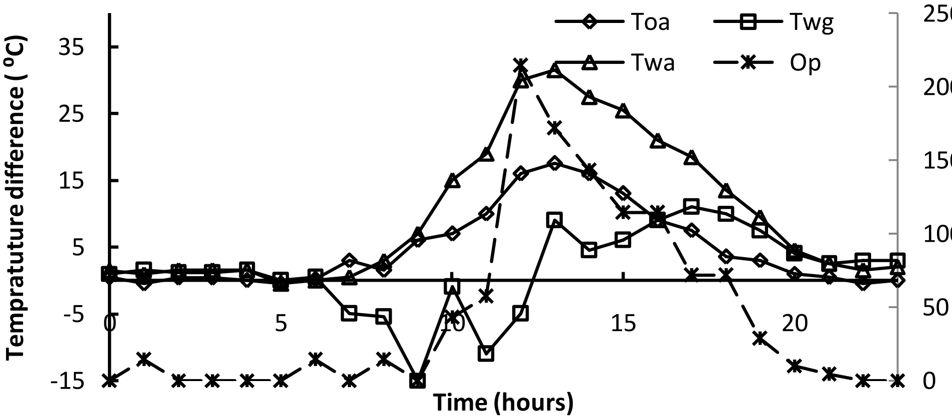

Figure 1: Plot of T_{oa}, T_{wg}, T_{wa} and Op for the solar still on Day 1

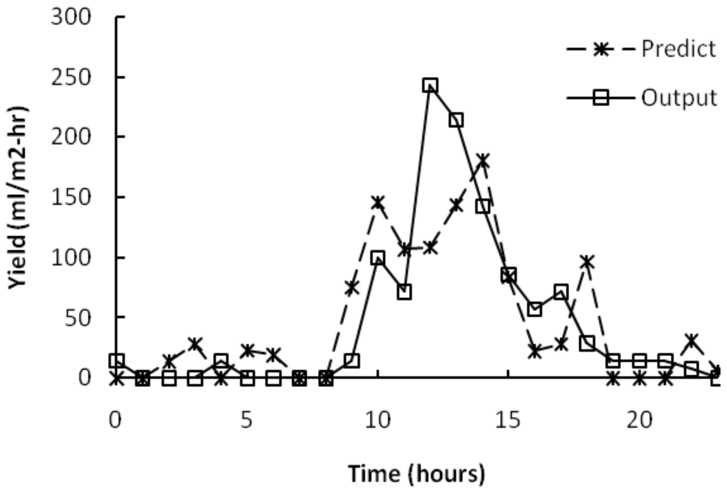

Figure 2 Predicted yield for solar still on Day 2

REFERENCES

[1] Boukar, M. and Harmim, A., 2004, Parametric study of a vertical solar still under desert climatic conditions, Desalination, 168, pp. 21–28.

[2] Dunkle, R.V., 1976, Solar distillation and combined distillation and water heating for tropical areas. Conf. Application of Solar Energy, pp. 148–172.

[3] Fahema, K., Jabrallahb, S. B., Belghitha, A., and Corriou, J, P., 2006, Numerical simulation of the behavior of a distillation cell with influence of the characteristics of the heating wall, Desalination 201, pp. 185–197

[4] Hecht, E. and Zajac, A. 1979, Optics, McGraw Hill, New Jersey

[5] Singh, H.N. and Tiwari, G.N., 2004, Monthly performance of passive and active solar stills for different Indian climatic conditions, Desalination 168, pp 145–150

[6] Azi, S.O., Aghemenloh, E. and Jegede, S.I., 2006, Prediction of the Yield of a Passive Solar Still, Nig. J. of Appl. Science 24, pp. 204-210

[7] Kumar, S. Tiwari, G.N. and Singh, H.N., 2000, Annual performance of an active solar distillation system, Desalination 127, pp.79-88.