Vol.2 pp. 19-23 International Journal of Renewable Energy and Sustainability (RES)

Efficiency of a Solar Still with Dual Slope

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Abstract **Solar distillation is a simple method for producing fresh water. The theoretical model is based on the resolution of the heat transfer equations and mass dependent time for the glass, and the water film. A verification of theoretical results using the applied model is achieved, in comparison with an experiment Performs on solar still with dual slope in Ouargla in Algeria; the testes perform during the day of 19 February 2009. The daily yield of the still is 2.5 (L / D), for an absorber area is 0.63 m^2, the results found are in agreement with the experimental results.**

***Keywords*— Desalination, solar radiation, temperature, water, arid zone, greenhouse effect**

I. I Introduction

Water is essential element to all life on earth since the creation of the universe, despite it represents 71% of the earth's surface, but more than one billion people haven't sufficient access to good quality of water. Groundwater has always been considered as a better source of potable water of sufficient quantity. However, in the vast regions of the world, groundwater is unsuitable for human consumption and other domestic uses because of the high concentration of salts as in [1].

Several methods exist for the production of potable water from saline water. The process for obtaining potable water of saline water with the aid of solar energy is called the solar distillation.

Solar distillation plays an important role in obtaining potable water in the arid and desert zones. The study of solar still of greenhouse is rendered difficult by the complexity of thermals and masses exchanges inside and outside of the still, several models have been proposed for studying and modelling of heat transfer phenomena and mass in the passive solar still.

Our study consists in a comparison between theoretical and experimental results of the global illumination, the temperature of the various components, and daily production in order of improving the production of still.

II. DESCRIPTION AND PRINCIPLE OF FUNCTION

The still used in this study is a solar still with dual slope. It is composed of an aluminium basin, has thickness of 0.03 m, and surface 0.63 m^2 (0.9m long by 0.7m wide). The bottom and sides of the basin are isolated by the polystyrene's thickness 6cm and galvanized material 5 mm in thickness to reduce the heat loss. Every surface is covered by ordinary glass thickness of 4 mm, 0.94 m in length and 0.4 m in width, the two sides are inclined by an angle of 31.0° (Latitude Ouargla), an angle much greater than the minimum of inclination (100 or 150).The thickness of water film is 1.5 cm.

The solar distillation is a technique that uses solar radiation to heat brackish water in a tray covered by a sloping glass. The water in the tray will be heated (especially faster than the basin is black), and with the increase in temperature a part of the water evaporates and the steam is liquefied on the inner surface of the cover's transparent glass, then it is recovered in a recovery.

III. The calculation of solar radiation

The global solar radiation is estimated by the model Diffus –Beckmen that is based on the experimental estimation of coefficient K_t , during the year for considered place.

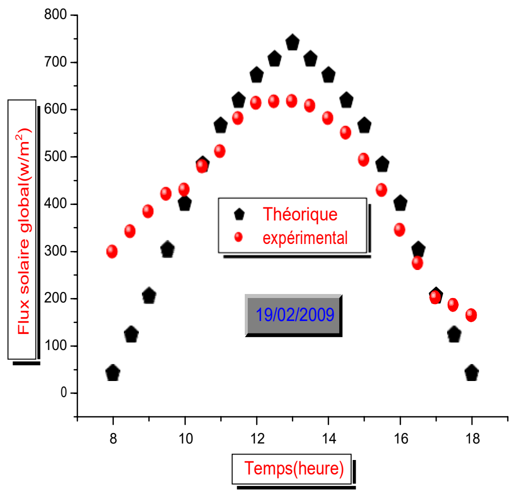

Fig. 1 The variation of global solar flux

ISSN: 2961-6603

IV. THE THERMAL ASSESSMENT

The theory of a simple solar still in the shape of greenhouse, it is presented by Mousa Abu-Arabi and al (e.g. [2], [3]) and Yousef H. as in [4]. Figure 3 illustrates the various heat exchanges that occur in a solar distiller. It bases on three assessment .

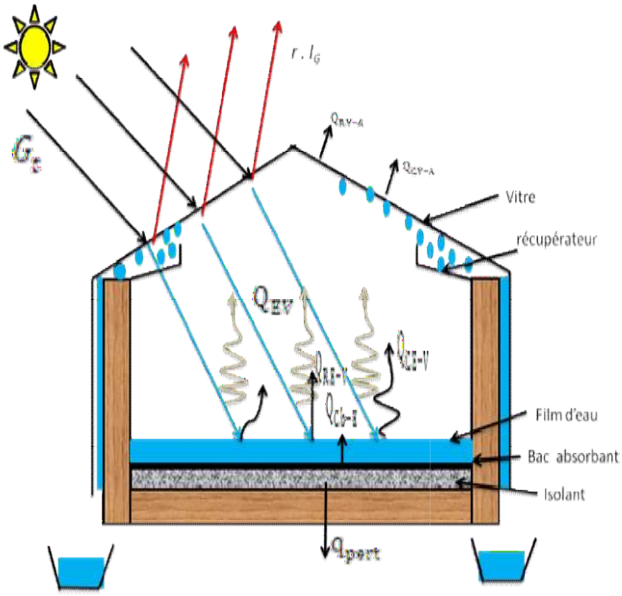

Fig. 2 The energetic assessment of a solar still with dual slope

Like all greenhouse still apparatuses, solar still with dual slope is a system that exchanges the heat with the ambient environment. The heat's transfer between the outside and the still is done at the level of the glass cover by radiation and convection.

At the water's level, the transmitted incident solar radiation is used to heat water. It evaporates and exchanges heat with the glass cover by convection, radiation and evaporation. The interior-exterior exchange is done by conduction through the glass cover.

A. The thermal assessment of glass

$$m_v C_{Pv} \frac{dT_v}{dt} = Q_V + Q_{C.E-V} + Q_{R.E-V} + Q_{EV} - Q_{C.V-A} - Q_{R.V-A}$$

$$Q_{C.E-v} = h_{C.E-V} \left(T_E - T_V\right), avec$$

$$h_{C.E-V} = 0.884 \left[(T_E - T_V) + \frac{(P_e - P_v).(T_e + 273.15)}{268.9.10^3 - P_e}\right]^{1/3}$$

$h_{C.E-V}$: Heat transfer coefficient by convection between the water film and the glazing as in [2].

$$Q_{R.E-v} = h_{R.E-V} \left(T_E - T_V\right)$$

$$avec : h_{R.E-V} = \frac{\varepsilon_{eff} * \zeta 1 * [(T_e + 273.15)^4 - \left(T_v + 273.15\right)^4]}{T_e - T_v}$$

$h_{R.E-V}$: Heat transfer coefficient by radiation between the water film and the glass.

$$\varepsilon_{eff} = \left(\frac{1}{\varepsilon_e} + \frac{1}{\varepsilon_v} - 1\right)^{-1}$$

ε_{eff} : Effective emissivity.

ε_e: Emissivity of water.

ε_v : Emissivity of glass.

$$Q_{EV} = h_{EV} \left(T_E - T_V\right)$$

$$h_{EV} = 16.273.10^{-3} h_{C.E-V} \frac{(P_E - P_V)}{(T_E - T_V)}$$

Avec:

h_{EV} : Heat transfer coefficient by evaporation-condensation between the water film and the glazing.

P_E ,et P_v : Saturation pressure of humid air to the brine temperatures and the glazing [5].

$$P_i = exp\left(25.317 - \frac{5144}{T_i + 273.15}\right)$$

$$Q_{R.V-A} = h_{R.V-Ciel} \left(T_V - T_A\right)$$

Avec:

$$h_{R.V-Ciel} = \frac{\varepsilon_v * \zeta 1 * [(T_v + 273.15)^4 - \left(T_{ciel} + 273.15\right)^4]}{T_e - T_v}$$

$h_{R.V-Ciel}$: Heat transfer coefficient by radiation through the glass cover to the outside. The sky temperature is given by the following equation as in [3]:

$$T_{ciel} = T_{air} - 6$$

$$h_{C.V-A} = 5.7 + 3.8v$$

$$P_V = \alpha_v G_t$$

B. The thermal assessment of water's mass

$$m_e C_{pe} \frac{dT_e}{dt} = Q_E - Q_{C.E-V} - Q_{R.E-V} - Q_{EV} + Q_{C.b-E}$$

$$Q_{C.b-E} = h_{C.b-E} \left(T_V - T_A\right)$$

$$avec : h_{C.b-E} = \left(Nu\lambda_E\right) / L$$

$h_{C.b-E}$: Heat transfer coefficient by convection between the tray bottom and the water film.

λ_E: Thermal conductivity of water.

$$P_E = \tau_V (1 - \alpha_V) \alpha_E G_t$$

ISSN: 2961-6603

C. The thermal assessment of the absorbent tray

$$m_b C_{pb} \frac{dT_b}{dt} = Q_b - Q_{C.b-E} - q_{pert}$$

$$P_b = \eta_V (1 - \alpha_V)(1 - \alpha_E)\alpha_b G_t$$

$$q_{pert} = U_b (T_b - T_A)$$

The thermal loss of the tray to the ambient air is given as follows [6]:

$$U_b = \left(\frac{1}{h_b} + \frac{\delta}{e} \right)^{-1}$$

The overall efficiency is given by:

$$\eta_g = \left(\frac{m_d * L_v}{G * A_v} \right).$$

$$\eta_i = \left(\frac{Q_{ev}}{Q_{eau}} \right).$$

V. RESULTS AND DISCUSSION

A. The variation of production in function of the time

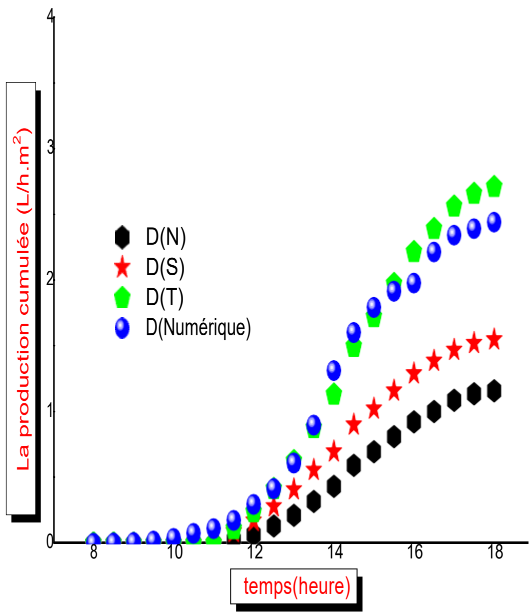

Fig. 3 The variation of the cumulated production in function of the time

The representation production's variation of the both theoretical and experimental accumulated according to the time, shown a good connection between the two resulting.

A value of distilled water production is 2.43 L, that is found at the end of the day with the code of the calculation performed. Against the value of real calculation is 2.7 L, which represents a relative error of 0.1% in the estimation of the amount of distilled product water.

One of the parameters leads to the existence of a gap between the theoretical and real production, that is the temperature of the glass cover which is the average temperature, against the condensation of water is carried out at the inside temperature of the glass cover.

The representation of the amount of water produced by the two faces of the distiller, which is oriented to the south or the north facing, showed the existence of some difference between the two amounts, this difference can be interpreted by that always the face having a low temperature produce a large amount of water distilled, because the process of drainage of droplets water is very rapid on this face.

B. The overall effectiveness in function of the time

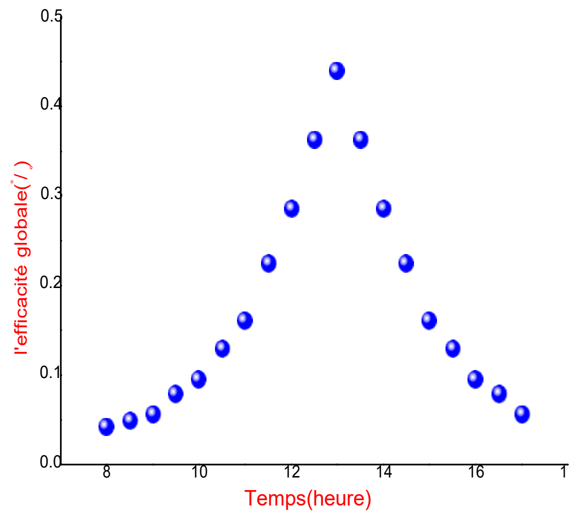

Fig. 4 The overall effectiveness in function of the time

The variation in the overall efficiency of solar desalination system also varies in the same way as a solar radiation, the overall efficiency of the distiller during the day of the experiment is 44 %, which really represent the weakness performance of this system of production distilled water, the theoretical overall efficiency during the day of the experiment.

C. The variation of the performance factor in function of the time

According to the graph presented in figure 5 below relative to the variation of the performance factor of the distiller studied, we noticed that the values the performance factor are very low, so the maximum value of this characteristic is achieved at solar midday is 7, 10^{-4} as shown in figure 5. The low values of this character is a response to the purple energy conversions by the solar still is leading to low production of distilled water.

ISSN: 2961-6603

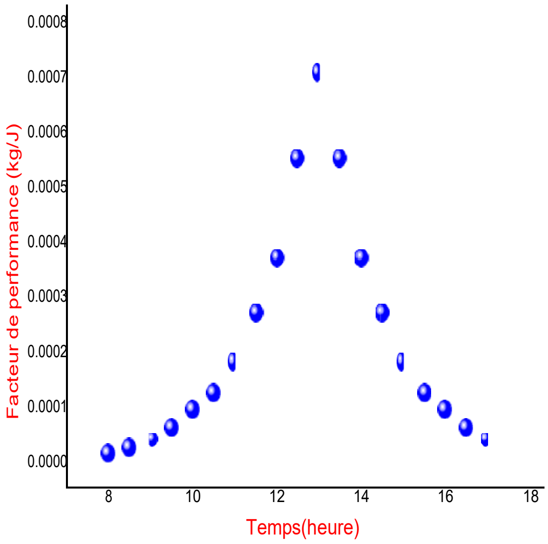

Fig. 5 The variation of the performance factor in function of the time

IV. Conclusion

Through the results achieved, we are noticed a good concordance between the results of numerical simulation and those of the experiment. The small differences are probably due firstly to the accuracy of the measure and secondly to the assumptions used in the numerical simulation. The variations efficiencies suggest us to say that the production of distilled water obviously depends on the incident solar energy and also the absorbent surface. A volume of 2.7 litters of high quality distillate water was recovered in the end of the day.

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ISSN: 2961-6603