Study of a solar water heater in Algeria

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***Abstract:* To satisfy the requirements of hot water, the use of clean and inexhaustible renewable energy, due to their availability is a necessary and urgent need.**
Specifically, the study depends on a variety of parameters attached to the operation of a solar water heater, taking into account the thickness of the absorber or insulation as well as the rate cover and even the daily consumption to put in place mechanisms to improve the performance of this system. For example, the numerical results obtained by using Matlab, enabled us to find the best surfaces for implantation, as well as the total annual load heating.

Keywords-Solar water heater, solar collector, coverage, storage efficiency, thermal efficiency.

I. INTRODUCTION

Provide clean energy in sufficient quantity and at a good price, is today a major imperative for the development of any nation. Indeed, the increase in energy demand, accelerated environmental degradation related to residues of energy resources used, pose serious problems on a global scale. After the crisis of 1973, all states have decided to set up a strategy to develop the various applications of renewable energy. Algeria adhered to this universal process while putting in place and equipping with the data-gathering in relation to this intention.

The domestic hot water represents a significant shutter in the search of comfort, however its obtaining asks for a considerable quantity of energy. We will thus adopt the solution of solar heating water taking into account these environmental advantages rather than the systems thermodynamics hoping that it is an economic solution.

Many studies aim to study economic and technical feasibility of solar systems, among which we can mention: Bouzidi et al, have adopted a method based on the determination of total discounted cost per cubic meter (m^3) of water based on the daily flow, total head (Hmt) and sunshine at the installation site. From this analysis, will rise the choice on the investment to consider because to take first into account, the analysis of the costs and of profitabilites is a precondition impossible to circumvent before any decision of investment of system or energy equipment, that it is in photovoltaic solar energy or conventional energy (diesel or others) [1-2].

The economic study of the production cost per kWh showed that it varied greatly and that the best system was the one which could achieve a kWh at the lowest price [3]
The reference [4], carried out a test bench of a solar heating water. This bench set up allowed the recovery of several experimental parameters which will be used to validate the theoretical results and that allowed the determination of the instantaneous performance of the plane solar collector and its characteristics.

In this present study we intend to evaluate the optimal parameters which influence the performances of a solar heating water for the domestic use.

II. THEORETICAL STUDY OF SOLAR COLLECTOR

The objective of this study, is to determine all the allowed and exchanged heat transfer rates, as well as the factors which characterize the operation of the solar collector, in order to be able to establish the specific mathematical model to this device.

A. Solar gains

Solar gains are made by

- The direct radiation.
- The diffuse radiation, where this last will be subsequently considered as a direct radiation with an angle of incidence of 60°.

A.1. The solar flux received by the surface collector.

The solar flux received by the surface of one meter area of a solar collector tilted an angle 'β' is the sum of two fluxes: direct and diffuse.

$$P_g = P_{dif} + P_{dir} \qquad (W/m^2) \qquad (1)$$

A.2. The energy recovered by the coolant

The energy recovered by the collector, is given by:

$$P_u = F_R\left((\tau\alpha)p_g - U_g(T_w - T_a)\right) \qquad (2)$$

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B. The study of solar water heater

The cost per kilowatt-hour produced by a production system with hot water storage can be evaluated using the method of calculating the rate of recovery of the charge by solar energy (solar fraction) [6]. This method calculates, on a monthly basis, the amount of energy provided by a solar heating system with storage, based on monthly values of solar irradiance incident (Pg) and energy requirements (L), knowing the average ambient temperature ((t_A) ̅) and the temperature of the cold water (taken Tm = Ta). To calculate the fraction of solar energy, two no-dimensional numbers X and Y are defined:

$$X = \frac{A_c U_g \acute{F}_R \left(11.6 + (1.18\, T_w) + (3.86\, T_m) - (2.23\, \overline{T}_a)\right)}{L} \cdot \frac{X_c}{X} \quad (3)$$

$$Y = \frac{A_c\, Ht\, N\, U_g \acute{F}_R (\overline{\tau\alpha})}{L} \quad (4)$$

Avec :

$U_g, \acute{F}_R$: Representing the overall heat loss coefficient (W/m^2·K). Exchange and absorber efficiency given by the manufacturer.

$\overline{\tau\alpha}$: The monthly average of the product of the transmission coefficient due to absorption sensor.

T_w : is the temperature of the hot-water ($°C$).

The energy requirements are defined by the following equation:

$$L = Cp\, n\, M_L (T_{bes} - T_m) \quad (5)$$

Où :

M_L : is the mass of water consumed (kg).

n : is the number of days of the month.

T_{bes} : is the temperature of the water for consumption ($°C$).

The rate of coverage is given by the following equation [6]:

$$F = \frac{\sum_{i=1}^{12} f_i\, L_i}{\sum L_i} \quad (\%) \quad (6)$$

with :

f_i : is the monthly coverage of the month (i).

L_i : represents the energy requirement of the Month (i), in (J).

III. MATHEMATICAL RESOLUTION SYSTEM (COLLECTOR)

By analogy between thermal and electrical quantities sizes, we can apply the laws of Ohm's and Kirchhoff. Consider any section of the system at time t.

The balance sheet at node (i) gives:

$$\frac{M_I}{S_i} Cp_i \frac{\partial T_I}{\partial t} = \sum_{j=1}^{N} h_{ij}(T_j - T_i) + P_i \quad (7)$$

M_I: the mass at the medium i of the system (kg).

Cp_i : is the specific h eat (J / kg. K).

S_i : is the section (m^2).

N : is the set of nodes j for which T_j is connected to a potential T_i.

P_i : factor is the well or source (W/m^2).

∂t : variation with respect to time.

The energy balance in the coolant give us the following equation:

$$\frac{GCp_f}{S_f}(T_f - T_{f^*}) = \left(\frac{S_f}{S_t} H_{vtf}(T_t - T_f) + SifSiHvif(Tii - Tf) \quad (8)$$

After discretization there was a system of seven unknown equations: Tve, Tvi, Tp, Tt, Tf, Tii, Tie are respectively the temperatures of: the external and internal faces of the glass, plate, the tube, the fluid, the internal face of insulator and the external face of insulator.

- For the resolution of the system of equation, one used of Gauss-Seidel iterative method. We supposed known, the temperatures of the various nodes at the initial moment and with the calculation algorithm, we can evaluate the various coefficients of the thermal transfers. Thus, for each step of time and each mesh, we obtain a system of equations whose resolution would enable to calculate the unknown factors.

IV. INTERPRETATION OF RESULTS

Calculation derived from the numerical simulation in MATLAB language in 2010 Allowed us to obtained the results, taking into account meteorological data for the region of JIJEL as we chose April 15 as a day of calculation:

- Latitude = 36°48' N.
- Longitude = 5°53' E.
- Albédo = 0.2.

A. Variation in power

fig.1,shows the evolution of global solar radiation received by a square meter of surface of the solar sensor and the power absorbed by the absorber so that the power output and the overall losses, versus time. Note that the power output has the same shape as that of other powers, where the output power reaches its maximum when the power absorbed by the absorber is at maximum. But the values of the useful power received by the coolant is lower than the power absorbed by the absorber, which is due to losses in the absorber, but the difference is still small due to the isolation. This leads to conclude that the increase of the power absorbed by the absorber directly affects the power to the heat transfer fluid.

B. Variation in temperatures

According to the fig.2, we note that the highest temperature is that of the absorber, resulting in significant power it has absorbed. A small difference between the temperature of the absorber

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tube and coolant, this is mainly due to the convection coefficient between them that has significant and thermal conductivity values of the absorber.

C. Variation in thermal efficiency of the solar collector.

La fig.3, represents the change in thermal efficiency of the sensor as a function of the temperature of the absorber. It shows that when the temperature of the absorber increases, there are increased at the same time the amount of heat transmitted to the fluid and the loss heat, despite this evidence, the performance continues to increase with the temperature of the absorber.

D. Change Instant thermal efficiency with insulation thickness

Figure.4, represents the change in thermal efficiency of the solar collector According to the thickness of the insulation. The presence of a small thickness from 0.001 to 0 .04 m insulation sufficient to improve performance very much because of the reduced heat loss back, ie thicknesses beyond influence of increasingly weak as the rest of the losses before.

E. Change the storage temperature

From fig.5, we note that the temperature of the hot water rises to the local time to reach its maximum value at 14 h due to increased solar radiation and the temperature of the coolant. After this, the reduction is very low due to the insulation. The decrease in temperature after 19h is due to the nocturnal losses.

F. Storage performance variation depending on the thickness of the insulating

The fig.6 shows that the performance of storage is very poor in the absence of insulation. Very thin insulation between 0.001-0.0[illegible] causes a very significant increase due to the reduction of heat loss. The influence of additional thickness of the insulation on the storage efficiency is very low.

G. Change in annual coverage

In the fig.7, the annual rate of coverage increases with the increase of the collector surface due to the growth of the energy production. Indicating that the last square meters 6-30 m^2 sensor produces less energy than the first [0.5-6m^2], this is due to shutdown during the summer months when the coverage reaches its maximum value (100%) .

In fig.8, growth of the hot water consumption leads to a decrease in the rate of coverage, this is due to the increased energy needs.

IV. CONCLUSION

Energy balance has been established in the various parts of solar water heater, through the study of the collection system (sensor) and the storage system. Secondly, a numerical code written in the programming language MATLAB 2010, to simulate the operation of a solar water heater and its performance.

The results obtained by simulation allowed us to find the best sensor surface (3,5 m²) for a constant consumption on the one hand and the best hot water consumption (300 liters) for a constant surface other.

The rate of coverage is important when consumption is very low [50-300 liters]. Changes in the consumption of hot water have little influence beyond 500 liters, it means by the small decrease in coverage during the summer and stop the decline of the approximately zero percent during the winter period.

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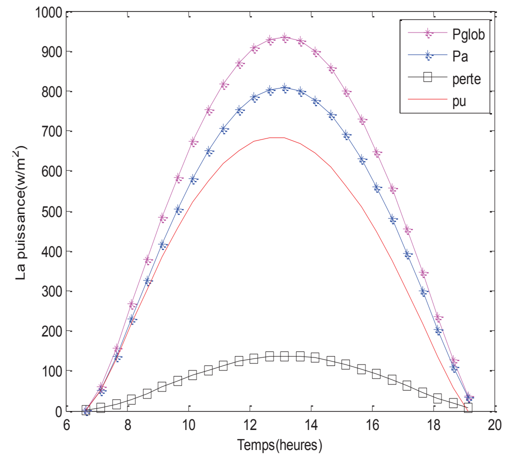

Fig.1. Change in global radiation (P_g) and power absorbed by the absorber (pa), the useful power (PU) and the overall losses with time.

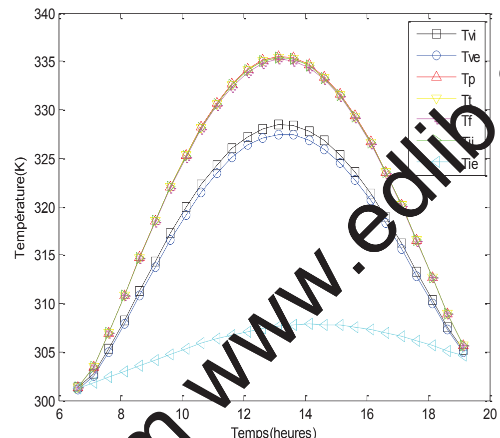

Fig. 2. Temporal variation of each temperature sensor element

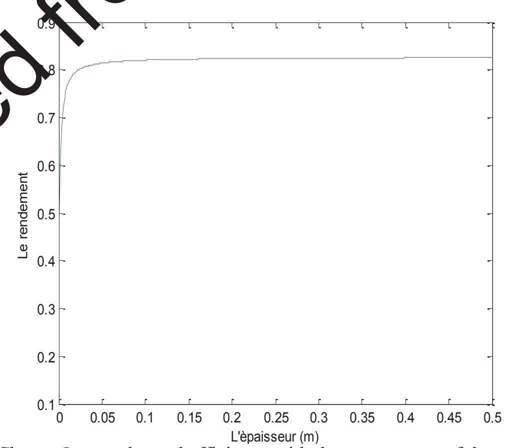

Fig.3. Change Instant thermal efficiency with the temperature of the absorber.

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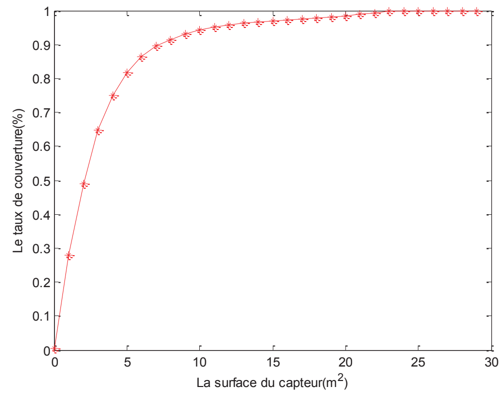

Fig.4. Change Instant thermal efficiency with insulation thickness.

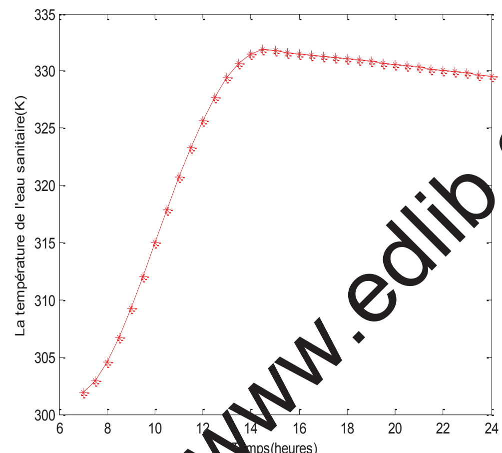

Fig.5. The temporal variation of the temperature of the hot water.

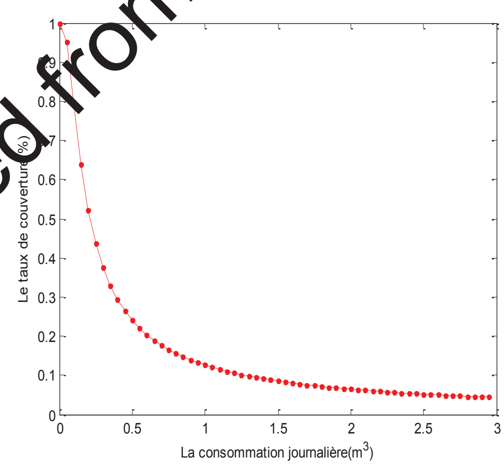

Fig.6. Storage performance variation depending on the thickness of the insulation.

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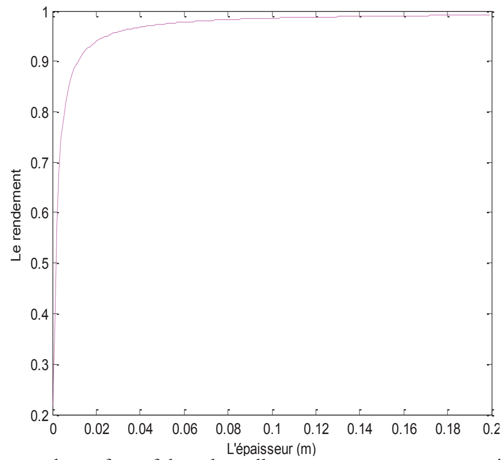

Fig.7. Change in coverage depending on the surface of the solar collector to a constant consumption (300 l / d) of hot water at 50 ° C.

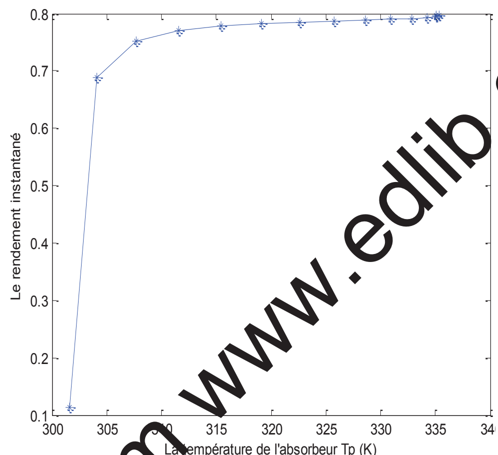

Fig.8. Change in coverage depending on the consumption of hot water at 50 ° C for a collecting area of 3 m^2

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