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Optimization of collector area for solar heating

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Abstract

The objective of this work is to size for four different configurations in the December installation of solar water heaters for industrial use to heat a capacity of 4500 liters at 60 ° C on the site Cheraga with an overall thermal study each field capture. Taking into account the implementation of these plans on a defined sensors terrace. In order to choose the optimum configuration according to the desired conditions.

Keywords: *Solar System – Solar Sensor – Collector Area – Desire Temperature – Solar Fraction*

1. INTRODUCTION

The performance of solar water heating is strongly affected by its orientation, its optical and geometrical proprieties and climatic and geographic parameters. It is also influenced by operational factors such as temperature and operation duration.

The present paper experimentally investigates the thermal performance of solar water heating under Algerian climate. Various configurations have been evaluated including parallel concept and series concepts.

2. MODELING OF THE SYSTEM:

Solar radiation:

Due to the lack of data and in order to predict solar radiation intensity at the selected site, the Perrin de Brichambaut model has been used.

The Perrin de Brichambaut recommends the following formulation to estimate the direct and diffuse components of solar radiation [1]:

$$I_b = A \times \sin h \times exp\{-\left[C \times \sin\left(h + 4 \times \frac{\pi}{180}\right)\right]^{-1}\} \quad (1)$$

$$I_d = B \times (\sin h)^{0.4} \quad (2)$$

The global component is then deduced from the following equation. It can also be obtained via summing the above components.

$$I_g = D \times (\sin h)^E$$

Energy balance

The energy balance of the system can be given by [2]:

$$(\mathrm{Mcp})_s \frac{\mathrm{d}T_s}{\mathrm{dt}} = Q_u{}' + \mathrm{Q_{aux}} - (\mathrm{Q_s} + \mathrm{Q_l}) \quad (3)$$

$$\mathrm{Q_u} = \mathrm{A_c F_r}\left[(\tau\alpha)_e \mathrm{I_g} - \mathrm{U_g}(\mathrm{T_i} - \mathrm{T_a})\right]^+ \quad (4)$$

After solving the above equation, the variation of storage temperature as a function of time is [3]:

$$\mathrm{T_s}^+ = \mathrm{T_s} + \frac{\mathrm{dt}}{(\mathrm{Mcp})_s}\left\{\mathrm{A_c F_r}'\left[(\tau\alpha)_e \mathrm{I_g} - \mathrm{U_g}(\mathrm{T_i} - \mathrm{T_a})\right]^+ - (\mathrm{UA})_s(\mathrm{T_s} - \mathrm{T_a}) - \varepsilon(\dot{m}\mathrm{cp})_s(\mathrm{T_s} - \mathrm{T_r})\right\}$$

(5) The ratio of meeting Customer needs can be calculated from the following formula [3]:

$$f = \frac{1}{L}\int_{\Delta t} A Fr\left[(\tau\alpha)_e I_g - U_g(T_e - T_a)\right]^+ dt \quad (6)$$

This equation can be divided into two non dimensional parts [4]:

$$Y = \frac{A Fr}{L}\int_{\Delta t} (\tau\alpha)_e I_\beta \, dt = \frac{A Fr}{L}\overline{(\tau\alpha)}_e H_\beta N$$

$$X = \frac{A Fr}{L}\int_{\Delta t} U_g\left(T_{ref} - T_a\right)dt = \frac{A Fr}{L}U_g\left(T_{ref} - \overline{T_a}\right)\Delta t \quad (7)$$

Under the following operation conditions:

- Mass flow : 0.015 kg $m^{-2}s^{-1}$
- Storage capacity : 50 à 100 kg/m^2 of collector surface (a capacity of 75 kg/m^2 has been chosen in this study)

- Heat exchanger efficiency : $1 < \frac{\varepsilon\, C_{min}}{U\, A} < 5$

Therefore, the coverage solar is obtained using the equation below [2]:

$$f = 1.029\, Y - 0.065\, X - 0.245\, Y^2 + 0.0018\, X^2 + 0.0215\, Y^3 \quad (8)$$

With:

$0 < Y < 3$ et $0 < X < 18$

The need in hot water is usually stable though a year. To take into consideration this fact, a correlation for the variable X has been introduced [32]:

$$\frac{X_c}{X} = \frac{11.6 + 1.18 T_s + 3.86 T_r - 2.32 \overline{T}_d}{100 - \overline{T}_d} \quad (9)$$

With : T_r : grid temperature,

T_s : Storage temperature,

T_d : mean daily temperature.

3. RESULTS AND DISCUSIONS

Solar radiation under clear sky:

In figure1, it is represented the predicted and measured solar radiation in a typical day in December. It has been observed high accuracy of the selected model, in red color compared to measured data (blue color). The small difference is related to measurement uncertainty and to climatic conditions. Note that the solar radiation intensity can reach up to 900 W/m2 at the site under investigation.

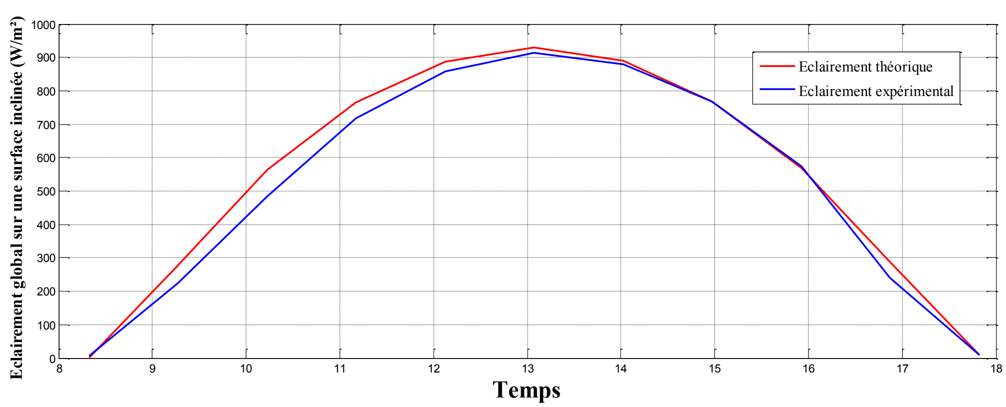

Figure 1. *Solar radiation in a clear sky day in December predicted using Brichambaut.*

The design concept of the installation considered in this investigation is mainly based on collector configuration. The results have been highlighted in the following sections:

Parallels configuration :

The larger the collector the greater the energy collection and the higher is the satisfaction factor. The variation of energy collection as function of collector size is illustrated in figure 2 . It has been observed lower solar ratio in December, in the order of 0.4, compared with the mean yearly value that reach 0.7. This latter reflects the importance of the selected location in this study which has higher solar ratio.

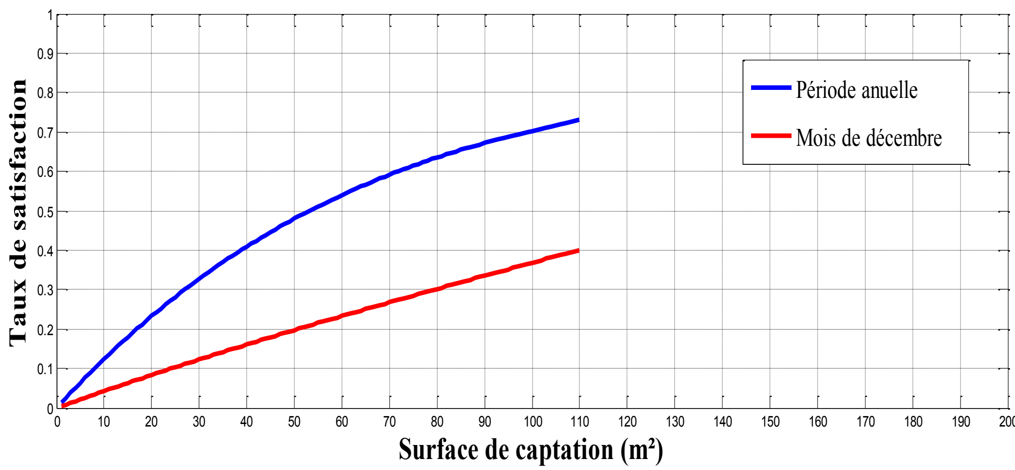

Figure 2. *Effect of collector surface in the case of parallel configuration*

Configuration that include two collectors in series:

Figure 3 shows the solar fraction desired in the month of December. We have observed that this configuration allows reaching a collection surface of about 120 m^2, larger than that obtained using parallel concept (110m2).

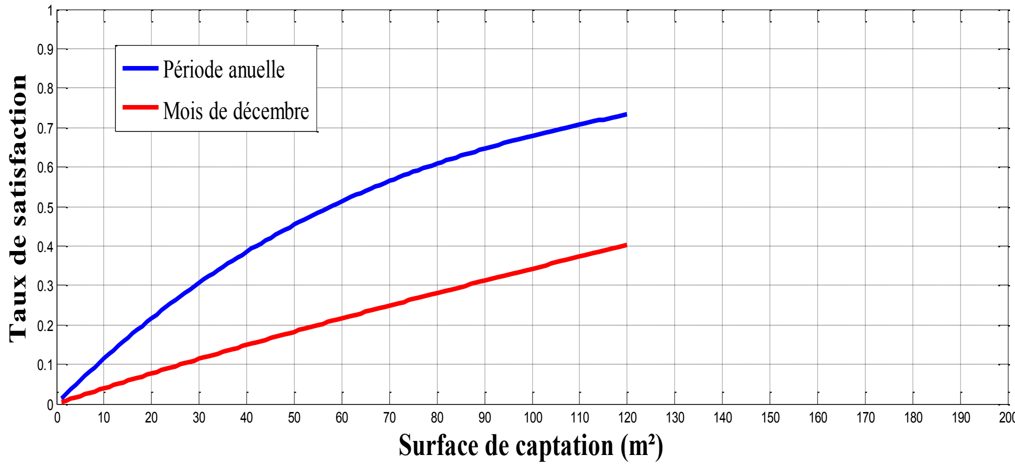

Figure 3. *Effect of collection surface in the case of two collectors in series.*

Configuration that includes three collectors in series:

This configuration allows reaching 154 m² collection surface. The monthly and yearly satisfaction fraction (taux de satisfaction) is presented in the figure bellow. It has been observed parallel allure between these two fractions for surfaces larger than of 90 m^2 (see figure 4).

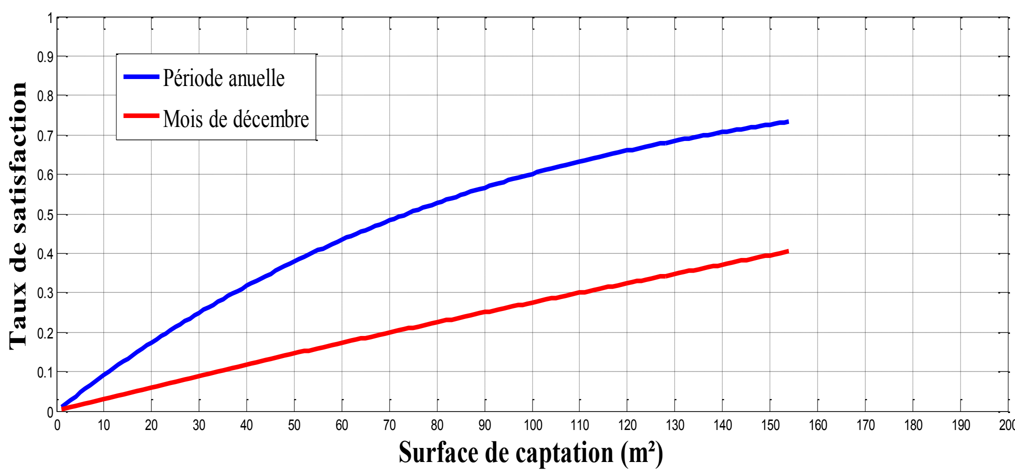

Figure 4. *Effect of collection surface in the case of three collector in series.*

Configuration that includes four collectors in series:

Figure 5 demonstrates the results when using four collectors in series. This concept requires larger collection surface than the previous design. It has been shown that this configuration offers larger surface that can be two times larger than that given by the parallel configuration.

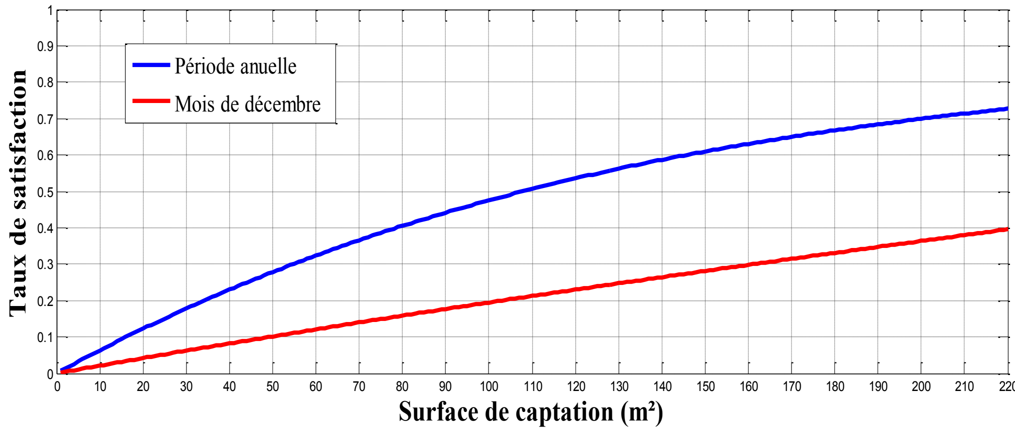

Figure 5. *Effect of collection surface in the case of four collectors in series.*

Comparison of the four configurations

As it is shown in Figure 6 the concept of collectors in series decreases the satisfaction of the system .From economic point of view, parallel configuration offers the best choice. However, four collectors in series concept provide many advantages from the energetic point of view, i.e., higher water temperature. Therefore, the selection of the optimum configuration that saves money and offers higher thermal performance requires thechnico-ecomonic assessment.

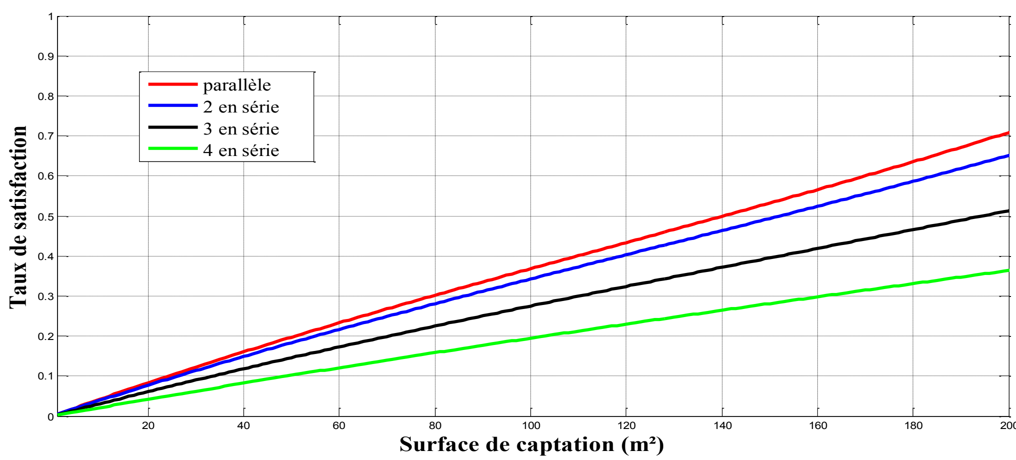

Figure 6. *Variation of the satisfaction fraction as function of collection surface.*

4. CONCLUSION:

The thermal performance of solar water heating system been presented in this paper whereby the effect of collector configuration is analyzed. The results have shown that efficiencies between 30 to 60% are feasible. Furthermore, the investigation has also indicated that the selection of the best configuration of flat plat collector is strongly related to storage temperature and to mass flow.

The thermal analysis has pointed out that parallel concept offers better performance in terms of efficiency and collection surface, whereas, four collectors in series design increases storage temperatures.

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