Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Presentation and experimental validation of a solar DHW installation sizing control tool

Taoufik Mezni [a], *Mohamed Amine Zainine* [a,b,*], *Mohamed Ali Dakhlaoui* [a,c], *Ali Zghal* [a]

[a] *Université de Tunis, Ecole Nationale Supérieure d'Ingénieurs de Tunis, U.R. MSSDT 99/UR/11-46, 5, Av. Taha Hussein, 1008, Tunis, Tunisia*

[b] *Université de Tunis el Manar, Ecole Nationale d'Ingénieurs de Tunis (ENIT), B.P. 37, 1002, Tunis-Belvédère, Tunisia*

[c] *Université de Tunis el Manar, Faculté des Sciences de Tunis, Campus Universitaire 2092 — El Manar Tunis, Tunisia*

ARTICLE INFO

Article history:
Received 28 March 2017
Accepted 19 April 2017
Available online xxx

Keywords:
Solar hot water system
Sizing control
Measurement uncertainty
Fouling effect
Experimental validation
Operating parameters

ABSTRACT

A knowledge-based model aiming to check the correct sizing of an active indirect solar water heating system with an external heat exchanger is presented. This model has been subjected to an experimental validation trial where the effect of input data measurement uncertainties on each simulated variable was exposed. It was noted that each input data measurement error has a different effect depending on the time and the simulated variable. After the experimental validation, in order to take into account the fouling effect when controlling a solar installation sizing, its impact on solar installation energetic performance was studied. The results show that it can cause the decrease of the solar installation energy intake and of the storage tank outlet temperature to load, respectively by a value of 9.06% and 1.68 °C. It can also cause the increase of the collector outlet temperature by a value of 1.3 °C. Finally, the presented tool was used to control solar installation sizing. The sanitary, energetic and longevity aspects were examined. These latters were respectively checked by evaluating the storage tank outlet temperature to load, the energy produced by the solar installation and the collector outlet temperature.

Introduction

Solar thermal systems for hot water production are certainly the most developed solar systems in the market. However, through the analysis of the existing facilities, it has been noticed that many of them show a dimensioning defect. This can lead to economic losses and/or sanitary problems such as legionella. Moreover, with the collaboration of several Tunisian design offices and installation companies, it was found that during the design of a solar thermal system, it would be better to have an interface allowing to control the design of such installation, by displaying its various operating parameters. Indeed, some software used by design offices during dimensioning stage (for

* *Corresponding author*. 5 Av. Taha Hussein, 1008, Tunis, Tunisia.
E-mail addresses: mezni.taoufik@planet.tn (T. Mezni), zainine.amine@hotmail.com (M.A. Zainine), dakhlawimedali@yahoo.fr (M.A. Dakhlaoui), Ali.Zghal@gmail.com (A. Zghal).

http://dx.doi.org/10.1016/j.ijhydene.2017.04.129
0360-3199/

example SOLO) remain fairly reliable if handled in a proper way, and if their increasing error margin for large flow rates (20% in the case of SOLO) is taken into account [1]. Nevertheless, this type of software can quickly lead to error if not appropriately used, and appears less helpful for junior engineers.

Many studies have been conducted on such installation concerning their design optimization [2], their classification [3] and fault detection [4]. The first two may help engineer for design optimization purpose and for choosing best product. The last one may serve to check the correct functioning of the installation. Unfortunately, this fault detection takes place at functioning stage. This may detect installation or manufacturing problem. But, concerning dimensioning defect, it seems without any advantage as control take place after investment are made. Our proposal is to perform solar installation sizing control at design stage.

Therefore, it will be presented in this paper a knowledge-based model serving at controlling the proper sizing of an active indirect solar water heating system with an external heat exchanger. Thermal models of the three main components of the solar thermal system (solar collector, storage tank, heat exchanger) will be chosen based on three parameters: minimum computation time, simple and readily available inputs and most encountered installations (large flow installations). Thus, the thermal model of the flat-plate solar collector presented by J.A. Duffie and W.A. Beckman [5] will be adopted and modified by replacing the correlations used to calculate the heat exchange coefficient. Similarly, the finite volume method was adopted for the heat exchanger modeling, as it is known for both its good results in simulating the heat exchangers thermal performance and its maneuverability that allow the local physical correlations use [6]. Finally, concerning the storage tank, many thermal models are available, most of which taking into account the stratification phenomenon [7,8]. Since it usually does not greatly influence the performance of high-flow solar thermal systems (as it has been demonstrated by K. Johannes [7] and C. Cristofari et al. [9]), which are the most targeted by this work, the choice of the storage tank thermal model has been oriented towards the one developed by O. Morisot and S. Roujol [10]. This model moderately takes into account the stratification effect but it has the advantage of being simple and fast.

The presented tool will be subjected to an experimental validation trial on a solar installation localized at a hotel in southern Tunisia and part of the "PROSOL-TUNISIA" program. The effect of input data measurement uncertainties on each simulated variable will be exposed.

After the experimental validation, this tool will be used to study the fouling effect on the solar installation energetic performance.

Finally, it will be presented a case study serving as an example of the use of the exposed tool to control solar installation sizing.

Modeling of the solar installation

Modeling of the solar collector

The modeled system is a single or multiple glazing flat-plate solar collector. Fig. 1 shows a special case of the modeled system (case of double glazing). The used model is the one developed by J. A. Duffie and W. A. Beckman [5]. Some correlations used to calculate the heat exchange coefficients by the latter have been replaced. Since this model is well-known by the scientific community, only the relationships used to calculate the variables exchanged with other components of the solar installation (as the collector outlet temperature) and the correlations used for determining the heat exchange coefficients will be presented.

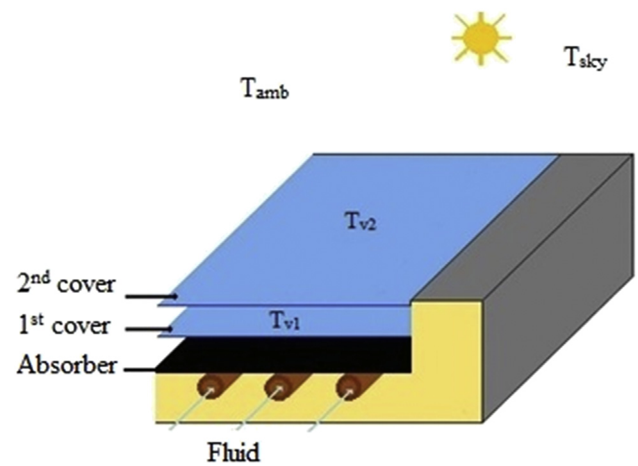

Fig. 1 – Schematic of a flat-plate solar collector.

- In order to model this system the following simplifying assumptions were made:
  - The absorber and the covers are considered as gray, infinite and parallel surfaces.
  - The covers are opaque to infrared radiation.
  - The headers can be neglected as they cover a small area of the collector.
  - Uniform flow is provided to tubes by the headers.
  - The temperature gradients in the direction of flow and between the tubes can be treated independently.
  - Loss through front and back are to the same ambient temperature.
  - Shading of the collector absorber plate is negligible.
  - The regime is steady state.
  - The thermo-physical properties of the components are independent from the temperature.
  - The sky can be likened to a black body.
  - Temperature gradients around tubes can be neglected.
  - Temperature drop through a cover is negligible.
  - All covers have the same emittance.
  - The effect of dust and dirt on the collector performance is neglected.
  - The heat losses by radiation from bottom and lateral sides of the collector are neglected.
  - The heat flow through a cover is one-dimensional.
  - The heat flow through back and lateral insulation is one-dimensional.
  - The heat transfer fluid does not undergo a change of state.

Please cite this article in press as: Mezni T, et al., Presentation and experimental validation of a solar DHW installation sizing control tool, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.04.129