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Software for designing solar water heating systems

Carlos Eduardo Camargo Nogueira*, Magno Luiz Vidotto, Fernando Toniazzo, Gilson Debastiani

College of Post-Graduation Program of Energy Engineering in Agriculture (PPGEA), from State University of Western Paraná (UNIOESTE), Cascavel, PR, Brazil

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ABSTRACT

This paper presents a complete development of software for sizing small solar water heating systems. The application framework was developed using the MATLAB platform, and its algorithm was structured to minimize the user intervention. The software was developed using consolidated methodologies and practices relationships, aiming at the technical and economical project optimization. The used project methodologies were the F-Chart and Brazilian Technical Standards (NBR-15569), together with an economic analysis. All of them are detailed in this work. The database was built using commercial equipment performance data, from the official tests of the Brazilian Labeling Program, and meteorological data, from the Brazilian Solarimetric Atlas and Agronomic Institute of Paraná. The developed software allows the sizing of natural and forced circulation systems, composed of flat plate collectors or evacuated collectors type U, horizontal thermal storage tank and auxiliary power supply (electric or gas). It also allows the user to modify the input parameters at any time, making possible to simulate different situations and find the best technical and economical solution. An example of the solar system design is also presented and discussed.

Contents

* Corresponding author. Tel.: +55 45 3220 3151.
E-mail address: carlos.nogueira@unioeste.br (C.E. Camargo Nogueira).

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1. Introduction

Currently the global demand for energy reaches worrying levels. Increasingly unbridled energy dependence and consumption are tied to population growth and modernization of production processes. In this context, the growing global demand for energy and efforts to reduce the availability of non-renewable fuels become a means of encouraging research into alternative technologies for power generation as well as for more efficient applications.

In several countries, various alternative energy sources are now available and being applied: wind, biomass, small hydroelectric generators, solar thermal and photovoltaic [1]. Among those, solar thermal energy to heat water has been highlighted due to its important social, technological, economic and environmental, as well as being abundant on the surface of the planet Earth [2,3].

The application of solar thermal energy for water heating is accomplished through solar collectors. These devices are responsible for the capture of solar radiation and transferring the thermal energy to a fluid. Solar water heating systems are usually composed of: solar collector, accumulator (hot water tank), auxiliary source (electrical resistance or gas heater) and pipes for distribution of heated fluid [4,5]. Among several applications of such systems, the most common use (85%) is for domestic hot water [6].

In Brazil, the electricity consumption related to water heating in residential sector is approximately 26%, but this percentage can reach 35% of total demand of low-income families [7]. According to Passos et al. [8] showerheads consumption accounts represent 43% of the high consumption peak between 6 and 9 p.m. on the Brazilian residential sector demand profile. Many studies [8–15] have suggested that solar energy could reduce part of this demand, since Brazil has a relatively high average annual global radiation throughout its territory. Global daily radiation rates showed values ranging from 4.25 kW h/m² on the northern coast of Santa Catarina to 6.5 kW h/m² at the border of Bahia with Piauí [16].

However, one of the obstacles in Brazil for the spread of solar water heating systems has been the high initial investment compared to conventional systems [14]. Another factor is the careless projects adopted by manufacturers and national sellers. These methods are summarized in design recommendations on the number of plates (installed area) depending on the number of users and/or consumption points. This procedure may produce good results in family projects, but when it comes to a specific design or installation in different climates, they fail and compromise the reliability of solar technology [17,18]. The use of computer tools specialized in the design of solar systems can be a great option to mitigate this problem, provided that these tools do not require an advanced knowledge of the user.

In this context, the present study aimed to develop a software application to assist in the design of small water solar heating systems. With the development of this tool, the design of these systems will be more accurate, taking into account the particularities of hot water consumption of the facility, the climatic characteristics of the site, the performance data of the equipment, the orientation of the collectors, alternatives and cost of the complementary energy system.

2. Solar water heating systems

The simplest installation to use solar energy for hot water supply in small systems is basically composed by solar collectors, hot water tank, insulated pipes and an auxiliary power source. These systems can be classified as active systems or passive systems [19]. Active systems use a flow pump to force the fluid flow, and passive systems are characterized by not using an external power source for fluid flow, because this action is performed by natural means (thermosyphon) [20].

Solar heating systems can be further classified into direct and indirect. In direct systems the fluid stored in the thermal tank is the same that circulates in the solar collectors. In the indirect system, the collectors heat a coolant (oil, ethylene glycol or propylene glycol) that transfers heat to the water through a heat exchanger. The latter, being very expensive, are best used in areas of severe weather to prevent the occurrence of water freezing and it is uncommon in Brazil [5,21].

Currently, the most used collectors for water heating in residential sector are flat plate collectors and evacuated tube collectors (which are on the rise in the market due to excellent performance in cold climates) [6,22]. The flat solar collector (Fig. 1a)

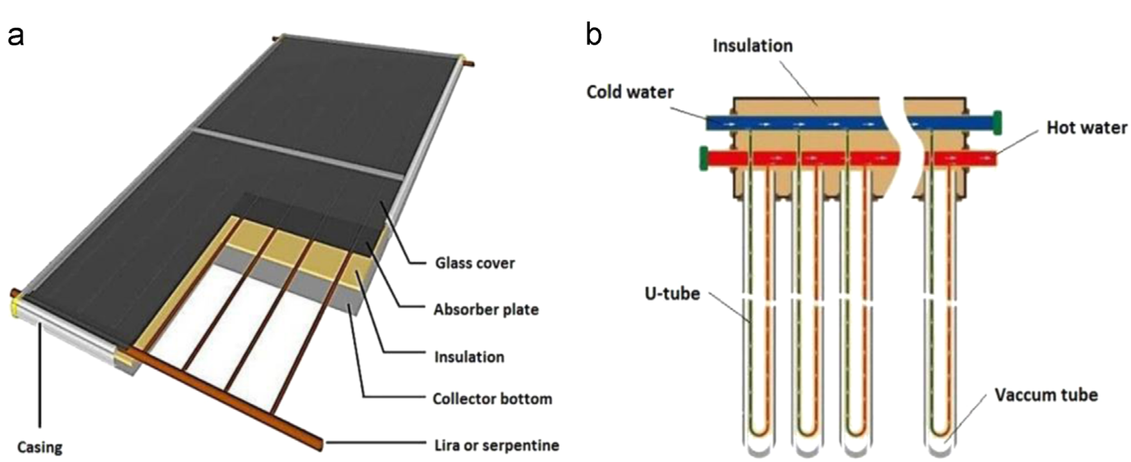

Fig. 1. (a) Flat plate solar collector; (b) "U" type vaccum solar collector.
Source: [24].