Solar Thermal System – Practical Case Study

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Abstract

This paper focuses on supplying the technical data of a forced-circulation solar thermal system located in Covilhã, Portugal. This is an area of the Portugal with an excellent solar resource. It is followed by a description of the major components of the system. Also, the results of energy balance estimation are duly presented.

Key Words: solar thermal system; forced-circulation; energy balance

1. Introduction

The solar systems for domestic use are an alternative to traditional water heating equipment. Thus, for temperatures between 40 and 70°C, it is necessary to use flat plate collectors that have a coating, usually glass, causing a greenhouse effect inside. This type of collector consists of an insulated aluminum frame where the absorber (copper tubes, welded to a thin copper sheet painted black, where water circulates). It also contains a specific high transmission glass sealed to the frame, and to increase the efficiency of the absorber, selective plates are used (alloys of various metals with special treatment to the surface) [1].

There are two different solar systems for domestic use: 1) thermosyphon; 2) forced circulation (Figure 1).

![Thermosyphon and forced-circulation solar thermal systems](http://www.painelsolartermico.com/sistemas-solares-termicos/)

The operation of both is basically the same, i.e., a collector captures the sun's rays and then transfers heat to the water [2]

The thermosyphon system is used in hot climates where there is no risk of freezing, being the most commonly used in homes because of their ease and operation independence, since the circulation of water between the collector and the tank occurs by gravity. As for its operation, the collector captures the direct and diffuse solar radiation. Through the thermosiphon effect, the hot water rises to the tank and the cooler (higher density) goes down to the collector to be heated. The tank is insulated, with minimal loss of heat during the night period [2,3].
For the forced solar system is essential to install the collector(s) on the cover and the bottom tank, requiring a force - recirculation pump - to transport water from the tank to the collector to be heated, and vice versa. It is a more aesthetic system than the previous one. However, it requires more material and, consequently, the costs are higher. As for its operation, the thermodifferential regulator, using two sensors, one located in the warmest area of the collector and the other in the coldest zone of the tank, lights a recirculating pump light so that the collector sensor measures the temperature warmer than in the tank. The pump takes the cooler water of the tank to the collector to be heated, to then return to the tank. If the collector temperature is equal to the tank, the regulator shuts-off the pump. Thus, water has minimal heat losses in the tank, as this is properly insulated to its consumption, which may be the next day [4,5]. From the economic point of view, solar systems for hotels have a shorter repayment period, compared to a home system, because they need the same elements. There are other types of applications where solar thermal technology could be used, such as solar dryers, agricultural procedures, solar kitchens, industrial applications and power generation [6,7]. One of the problems associated with solar thermal technology is its high initial cost. However, equipments used in solar home systems for heating water, especially those constituting the collectors, have a time span of 30 years or more. The tanks have a lifetime of 5 to 15 years depending on water quality and the inner lining (black iron or stainless steel) [1].

2. Case study

The case study in question is that of a forced-circulation solar thermal system, in which the collector is installed separately from the solar panels. This is placed vertically, which results in a better stratification of temperature levels and, consequently, a greater use of solar energy. This means that the support system runs during smaller time, which translates into greater energy savings. Thus, if the collector is placed in a protected location, there is a significant reduction of thermal losses of the deposit. Another advantage of this system relates to its aesthetic, since the collector does not need to be placed on the roof (Figure 2).
The solar thermal system in question is installed in Covilhã, Portugal, and was placed under the Measure "Solar Thermal 2009". The facility has been designed taking into account the constituents of the household and its usage profile. In this particular case, the aggregate consists of four users of hot water.

3. Solar thermal system components

3.1 Collector

They are installed outdoors, typically on roofs whose location is not affected by shading, generally facing south and with the proper slope to the latitude of the place. The collectors can be installed vertically or horizontally, having a high degree of effectiveness. Other important features are: high life span, robust construction, weather and temperature resistant, reduced heat loss, high levels of insulation (Figure 3 and Table 1).

![Collectors installed on the roof](image)

Figure 3 - Collectors installed on the roof

3.2. Hot water tank

This equipment has the function of storing hot water. The main requirements to be considered are: high heat capacity, reduced deposit volume, operating temperature according to energy requirements, rapid response to consumer, good integration in the building, low cost, security and long-term duration (Table 2). Typically these devices are arranged vertically, to facilitate the stratification of the water, and through this provision ensure that the water is warmer at the top of the deposit, which is precisely from where the water is extracted for its sanitary use.

3.3. Primary circuit circulation pump

The movement of the heat transfer fluid in the primary circuit is realized with the help of circulator pumps, which provide the fluid with the necessary energy for its transport at a certain pressure. This energy must overcome the resistance that opposes the fluid passing through the tube and the increase in height to keep the working pressure at any point of the installation. The circulation pump is placed in the return of the primary circuit, i.e., the pipe going to the collectors and the lower part of the installation to work with the appropriate height gauge. Generally, these devices are of the centrifugal type, quiet and of low maintenance.
3.4. Differential thermostat with automatic control

The pumps must operate only when the collector may have a useful gain and should stop when income is negative, i.e., when the temperature at the collector’s exit is lower than the temperature of the deposit. This occurs either when the radiation is low or when the tank is already hot, through the differential thermostat and temperature probes. The probes are placed either in storage or in the collector. The thermostat compares the corresponding temperature activating the pump when necessary.

3.5. Other system equipment

Previously, the most important equipments of the system were specified, but there are others who are required to operate the system:
- Closed expansion vessel which serves to accommodate the spreading of the warming waters;
- Air traps, in charge of evacuating the air in the heat transfer fluid;
- Safety valves that act as pressure limiting components of the circuits and are essential to protect the elements of the facility;
- Thermostatic mixing valves that allow a rational use of water and energy.
4. Performance of the solar thermal system

In this type of systems is difficult to make a comparison between the actual and estimated values. Thus, it is always necessary to have a feedback of information on the performance of the system by users of the same. That said, a usage profile was outlined with the following characteristics (Figure 4):

- Temperature rating of drinking water: 50 °C.
- Temperature of supply deposit: +/- 12 °C.
- Consumption profiles in liters.

![Figure 4 - Usage Profile](image-url)
Considering the usage profile, the monthly energy balance was obtained, presented in Figure 5. After analyzing the results, it can be seen that in this system:
- The solar fraction is 64% with an overall annual yield of 43%.
- The solar system itself can provide a total output of 3459 kWh, to a total required level of 5401 kWh.

![Figure 5 - Monthly energy balance of the installation](image)

However, after contacting with the users themselves, it was found that the system itself has never needed any support for the hot water consumption from the month of April. This means that the estimated value does not represent reality, being higher than anticipated, which is always positive for the ultimate goal.

This type of analysis is highly important, to enable a rational and appropriate use of the system, maximizing its usage. On the downside, we present the high initial investment cost, as mentioned earlier, which is about 3000 €. However, for high hot water consumption needs, the turnaround time is greatly reduced.

References


