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DIRECT SOLAR ENERGY USE FOR GREENHOUSES AND SMALL CONSUMERS

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Abstract: The paper presents our on-going research in the domain of the renewable, clean energies. A direct solar thermal energy system was installed for domestic use in Arad. Its main characteristics and functioning principle are described. Measurements are performed since October 2006 twice a week, for an entire day interval. The illumination is correlated with the temperatures reached by the water heated, and thus a discussion on the energetic efficiency of the system may be performed. The conclusions reached through the optimization allows for the next step of the research, which will start September 2007, when the system will be transferred to a greenhouse where, with the expertise gained, it has to prove its efficiency.

1. Introduction

The energy issue is an increasing problem throughout the word. Alternative sources are researched in order to prepare for a possible future shortage of fossil and nuclear fuels [4,10] and in order to increase the energetic sustainability of the different nations – highly dependent nowadays of rather unstable, mostly oil, suppliers, in an interaction that makes the hidden agenda of many of the word's problems today.

The European Union, like the other centers of economic power, has strategic program that aims at solving the above issues both by economic and political strategies and by a focused scientific and technological effort concerning the alternative, renewable, preferably clean energy sources [12]. Solar, wind, geothermal and ocean wave energy are by far the most promising ones; together with other solutions, like biomass and hydropower, they are expected to cover some 12% of the EU energetic necessities by 2010, already.

The efforts concerning the use of the solar energy are concentrated both on photovoltaics and on direct thermal solar installations [3,6,7]. The latest are recommended to be used mainly in high-power, costly energy facilities (). In this direction we have considered, however, a different approach, which involves small-power installations, affordable by the domestic consumer and/or by small companies. This approach supposes, like all solar systems, a high initial investment (some 50% of the total costs), but one that is expected to be attractive for the domestic users, as well as for greenhouses, by example, for which our project was initially designed.

2. The project

Our research was initiated under the European Project FP6 GREENENERGY, contract COLL CT-2005-012566: "Energy optimisation in European greenhouses". The main objective of our part is to optimize the functioning of an Alphabit direct thermal solar system [13], in order to use it for a greenhouse at S.C. Agronim S.R.L. Curtici, Arad County, company with which an agreement was set in this direction [5].

The solar system will be installed in this facility starting august 2007, and it is expected to be fully operational by september. Until then, since september 2006, it performs real-life testing in a domestic house in Arad, in actually the same solar radiation conditions as in Curtici, which is 20 km west of Arad.

The very first step of the study concerned the analyse of the solar radiation in the area, as well as throughout Romania. The conclusion is that the areas situated in the Western Plain and Banat, characterized by an average energetic solar flux (1350-1450 kWh/m^2 per year), like the Romanian Plain and a part of the Transylvania and Moldavia high plains [14], are in the B (average) radiation area of Europe. Thus, the solar system we propose for the water heating is expected to assure 25-35% of the total energetic amount necessary for a greenhouse or for a domestic user through the year [5,10].

A calculus has also been done with regard to the economic efficiency of the use of the solar installation at S.C. Agronim S.R.L. Curtici. We expect that at least the green salad, which has small heating requirements (6-8^{0}C in the first 10 days, then 16-18^{0}C), will be possible throughtout the entire year – thus, even in the cold season. This has to be demonstrated experimentally. Another aspect is that, now, the heating of the existing greenhouses is done with geothermal water of 55°C, obtained from two sources situated at 1 km distance from the faro, using two 30 kW pumps. A major disadvantage is that the geothermal water is quit costly, both because of the transport costs and of the gas elimination neccasary process. Using the solar energy, these costs will be lowered, as the geothermal will become but an auxiliary source. The economic efficiency is, of course, even better when we are speaking about greenhouses that work not on geothermal, which is a cheaper energy, but with conventional ones, about 4 times more expensive than the geothermal.

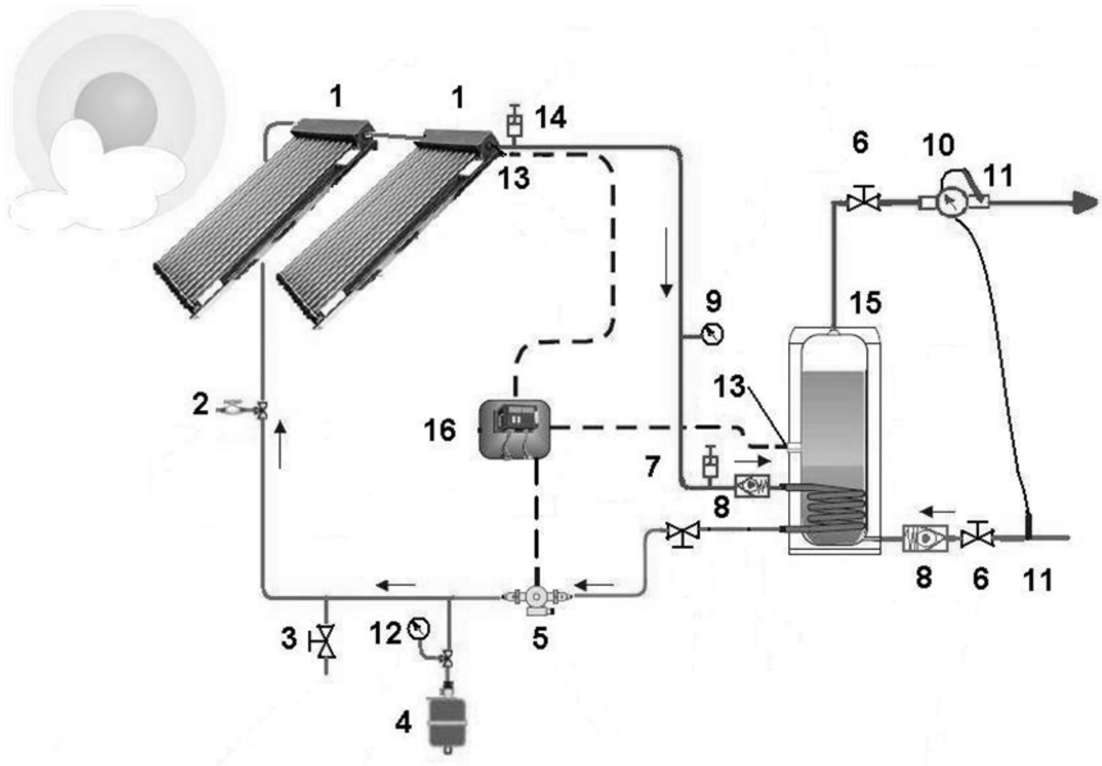


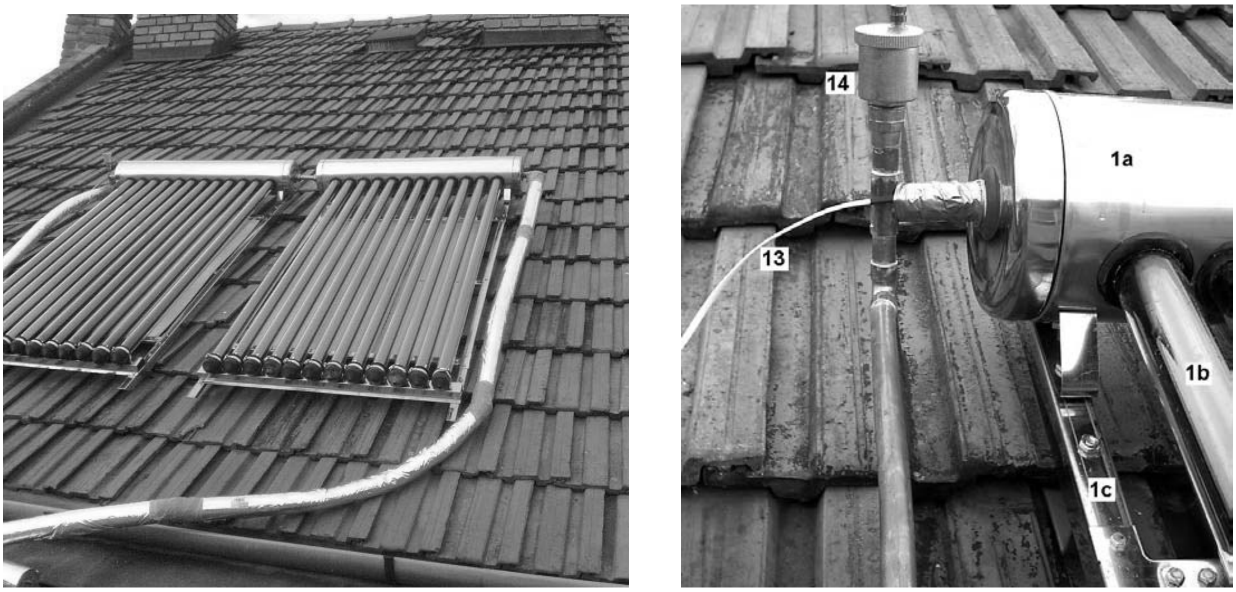
Fig.1. Direct solar thermal installation – principle scheme

3. The solar installation

The principle scheme of the installation is presented in figure 1, while in the following figures (2-8), the photos of the system installed in Arad point out the main components and mearuring apparatuses.

The main components and subsystems of the solar installations are (Fig.1): 1. two solar panels, Beta 47/1500-12 (diameter/length of the tube - number of tubes per panel); 2. safety device; 3. filling pipe; 4. expansion tank; 5. pump; 6. input pipe; 7., 14. air-evacuation device; 8. one-way water circulation device; 9. thermometer; 10. thermal energy meter; 11. hot water; 12. manometer; 13. probe 1 (exit of panel) and 2 (tank); 15. 120l tank; 16. X2 microcontroller.

The solar panels are presented in figure 2a, installed on the roof of the house. The tubes are manufactured from Jena type glass, double walls with vacuum in between, covered with Tinox light absorbent. At the lower part, they have a barium substrate that preserves the vacuum between the walls of the tube. Inside each glas tube, there is a copper one (filled with a mixture of 4g water and etilenglicol, vaporized because of the vacuum) linked to a condensor-colllector. The individual tubes construction makes the system safe, while the vacuum provides a good thermal isolation, with almost no losses.



a) *b)*

Fig.2. Solar panels: a) the assembly; b) detail (same notations as in Fig.1)

The thermal agent from the collector receives from the mixture of water and etilenglicol the termal energy and, in the tank (15), passes it to the water to be heated. The pump (5) is started only when the termal agent from the collector of the panel has a temperatura higher than the one in the tank. It is started and stopped by the microcontroller (16), which receives the temperatures from the sensors (13), calculates the temperature difference T1-T2 and, taking into account the lower (L1) or higher (H1) limit set by the user, commands the shutter.

The condensor –collector (1, Fig.2b) is a recipient in which all the tubes are introduced (3, Fig.2b) and in which is produced the heat transfer with the copper tube, through which the thermal agent used for the heating circulates (antigel with 40% propitilena). We therefore have an indirect thermal contact, that allows for the rotation or the replacement of the tubes, even if there is a liquid under pressure in the installation. The temperatura in the collector- condensor may reach a value of 130^0C. The flow of the thermal agent is 270 l/h, the maximum pressure is 6 bar, while the energetic flux received is about 784 kWh/m^2/an [13].

The thermal agent from the collector circulates through the installation, reaching the solar tank where it transfers the heat to the cold water. From the tank, the hot water produced is circulated to the consumer (shower, heating circuit of the house, greenhouse and so on).

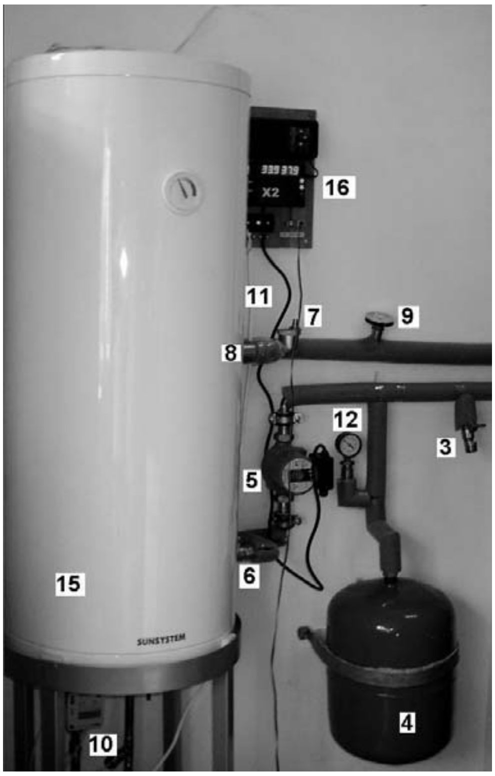


Fig.3. Solar reservoir (left), pump and expansion tank (down right) - same notations as in Fig.1

The recirculation pump (5, Fig.1, Fig.3, Fig.4) functions only when the thermal agent from the solar panel has a temperature higher than the one in the tank. The start and the stop of the pump is provided by a process computer, the X2 microcontroller (16, Fig.1, Fig.3, Fig.5), to which the two temperatures sensors (13, Fig.1) are connected. The first three digits (Fig.5) indicate the temperature provided by the first sensor (S1: at the tank), while the next three digits, the temperature provided by the second sensor (S2: at the solar panel).

The X2 microcontroller (Fig.5 – with different notations from figure 1) has two modes of functioning:

- *Mode 01:* the apparatus receives the temperature signals from the sensors S1 and S2, calculates the difference of temperature $\Delta T = T2 - T1$ and, with regard to the minimum and the maximum values L1 and H1, respectevely, adjusted for ΔT, commands through a shutter (R1), the connection or the disconection of the water pump;
- *Mode 02:* the apparatus works as an assembly of two independent termostats. The first one consists of the sensor S1 and the shutter R1, while the second, of the sensor S2 and the shutter R2. In this case the limits L1 and H1 are set for the first termostat, while different limits may be set for the second one.

Remark: L1 (low)= 2 ^{0}C is the minimum value a lui ΔT; while H1 (high)= 8 ^{0} C is maximum value of ΔT.

When the controller is started, the sensors measure the temperatures in the solar installation (T2) and in the water tank (T1). A comparison is made: if $\Delta T = T2 - T1 > H1$, the water pump is started; if $\Delta T < L1$, the pump is stopped. When the temperature in the solar installation, T2, increases, ΔT increases and when it surpasses H1, the controller comands the pump to start. When T2 decreases (or T1 increases), ΔT goes down and when it reaches the value L1, the pump is stopped. Thus, the pump works only when the temperature in the solar installation is higher (with the ΔT difference) than the temperature in the tank: the heat transfer is one-way only – from the panel to the tank.

The expansion tank (4, Fig.1, Fig.3) has 10l volume, is inox with double walls, termal isolated and allows for the pressure to be mantained when the temperatura increases and the water in exceso needs to be collected. the pipes are copper, d=18 mm in diameter, g=1 mm in thickness. The thermal isolation of the pipes situated in the exterior of the house is triple.

The measuring apparatuses used for monitoring the system are: the Extech 401036 luxmeter for the illumination (Fig.8), the manometer (12, Fig.1), the thermometers (9, Fig.1, Fig.6) and the thermal energy meter G20, Kundo type (10, Fig.1, Fig.7).

Fig.4. Pump

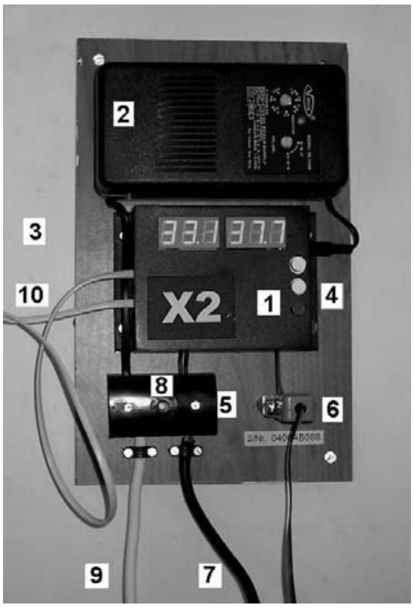


Fig.5. Micro-controller X2

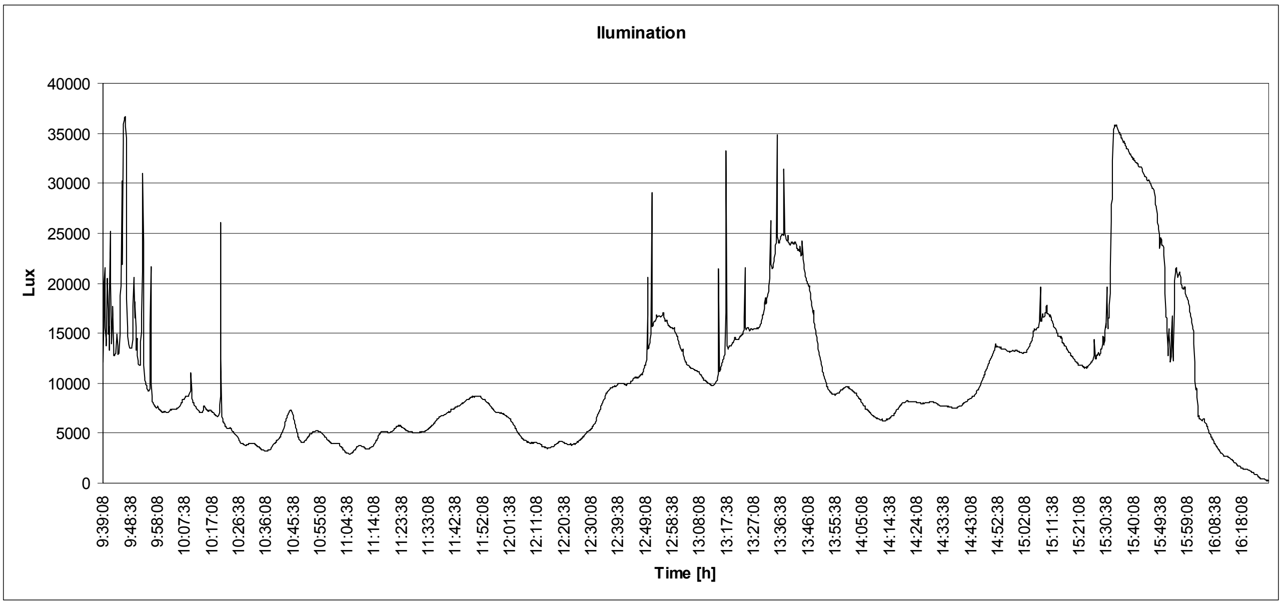
Fig.6. Thermometers

Fig.7. Thermal energy meter

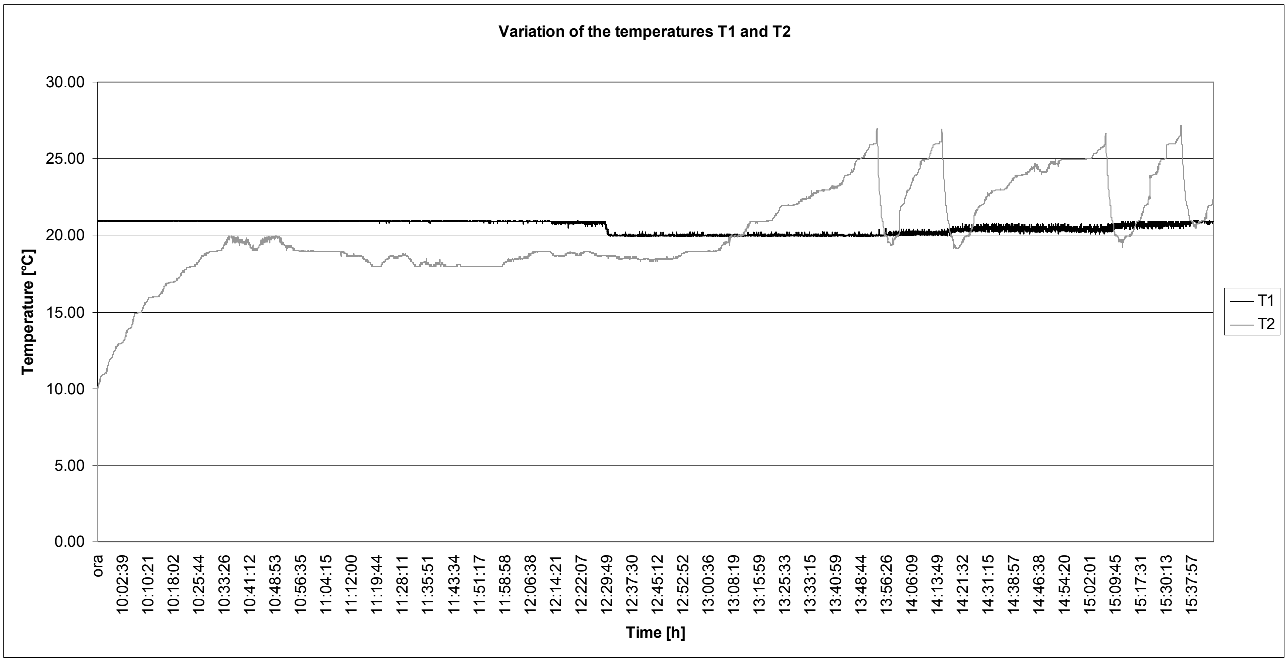
Fig.8. Extech 401036 luxmeter

The thermal energy meter consists of a flowmeter, the thermo-resistance 1, placed inside it (and on the hot water pipe, of small diameter D_n =15 mm), the thermoresistance 2 (placed on the cold water pipe) and the calculus modulus. The parameters provided by the energy meter are automatically listed or at request: the thermal energy (MWh or GJ), the hot water volume (m^3), the instantaneus hot water flow (m^3/h), the difference between the hot and the cold water (output and input from the tank) (^0C), the temperatures of the cold and hot water, the instantaneus thermal water (kW), the current time, the pressure of the thermal agent (bar). The energy meter also also signals the possible malfunctioning of the system.

4. Examples of experimental results



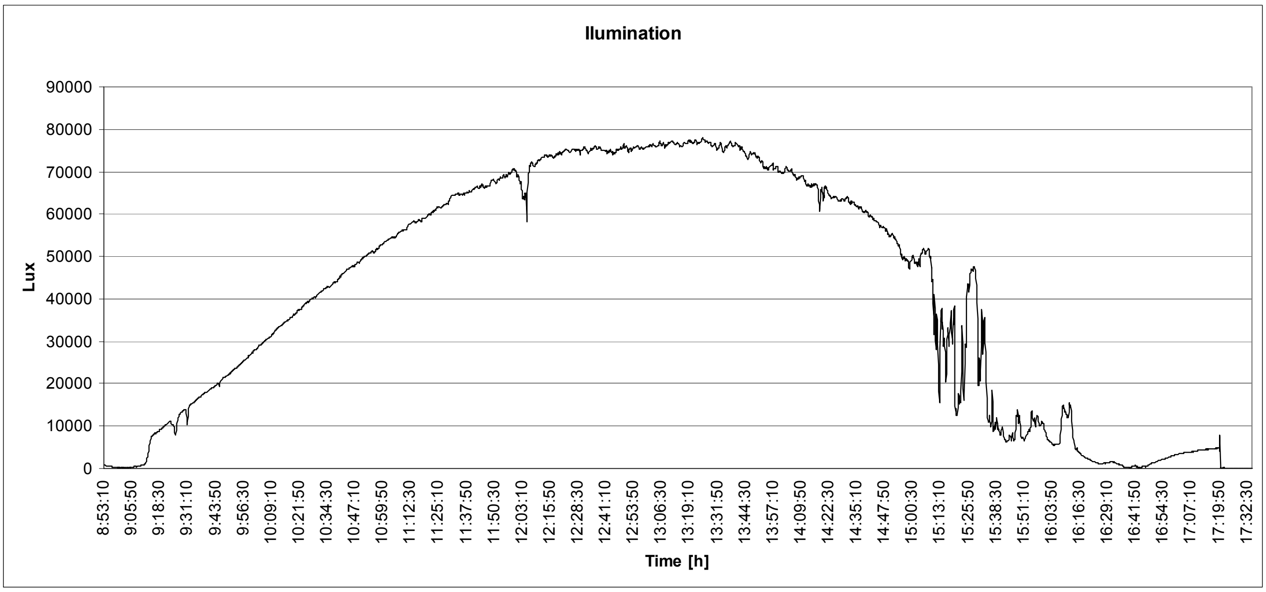
a)



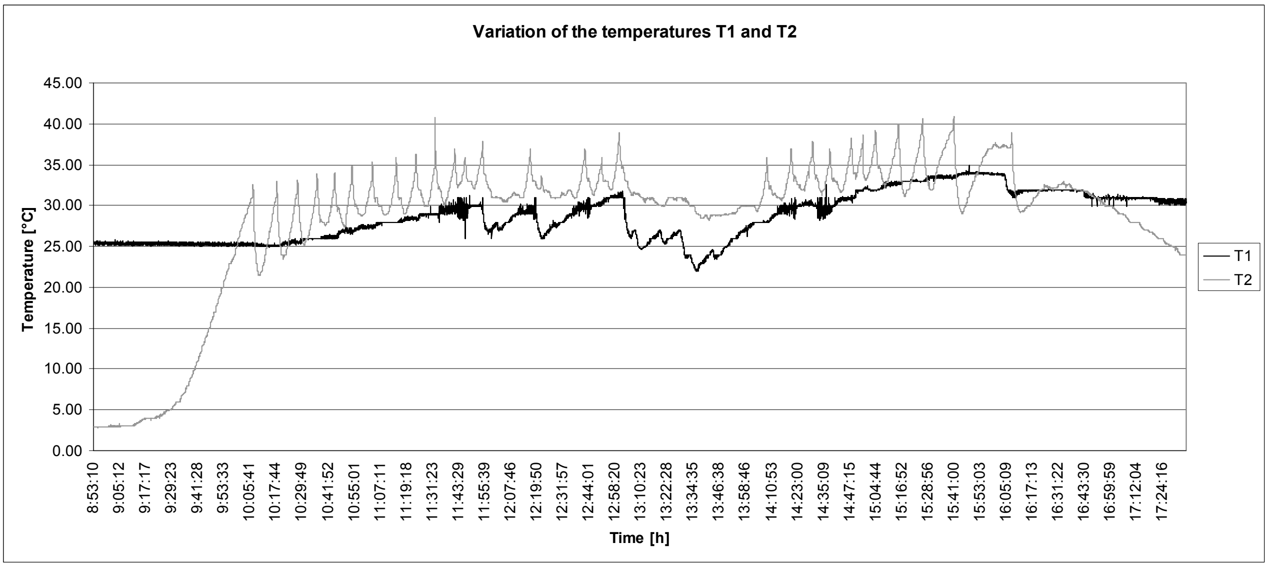
b)

Fig.9. Measurements in a clouded day, cold season (21 Jan. 2007):
a) illumination [lx]; b) T1 and T2 temperatures [C]

Two examples of the measurements, each for the duration of a day, are presented in figures 9 and 10. The solar illumination is measured with the Extech 401036 luxmeter (Fig.8), with a very small time increment. From the software of the device, measurements with a larger, more useful, time increment are selected and the illumination diagram is obtained (Figures 9a and 10a). The measurements are performed twice a week, but in days that are different from the point of view of the solar radiation, in order to be able to make a relevant comparative study of the functioning of the system.



a)



b)

Fig.10. Measurements in a sunny day, cold season (14 Jan. 2007):
a) illumination [lx]; b) T1 and T2 temperatures [C]

In parallel with the illumination measurements, the two temperatures (T1 and T2) are obtained from the S1 and S2 transducers (13, Fig.1) and the thermal energy obtained is indicated by the meter (10, Fig.1). This thermal energy is then compared with the solar one, in order to evaluate the efficiency of the installation in certain functioning conditions.

One may see from figures 9b and 10b the way the X2 microcontroller starts the water pump, as soon as the difference between the two temperatures reaches the imposed value. In a sunny day (Fig.10), with a considerable amunt of illumination, the microcontroller starts the pump many times and the thermal heat provided by the system is high. In a clouded day, by the contrary, the pump starts only after a proper sunny period (around noon), while the system does not prove efficient at low illuminations, unless the low and high limits are set in relation with the illumination. From these measurements, in figures 9 and 10, one can see the difference between the results obtained in two different days, a sunny and a rather clouded one (where the same settings of L1 and H1 have been preserved – no feed-back of these limits, with regard to the illumination, being yet considered).

The measurements performed also prove that, because of the very construction of the system, the environment parameters (temperature and pressure) have no influence; only the solar illumination is important. The parameters for which the installation itself is set, that is the low and the high limits of temperature, as well as the flow of the water pump, are relevant, and their adjustment represents the way to optimise the functioning of the system.

5. Conclusions

The paper presents our on-going project concerning the optimization of the use of a direct thermal solar energy system. The construction and the characteristics of the system are presented. Its functioning is discussed and some examples of the measured performed are given. The project is halfway of completing its first phase: the expertise gaining, in order to pass to the second phase, in the greenhouse nearby Arad.

Acknowledgements

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