

PARAMETERS ANALYSIS OF A THERMAL INSTALLATION WITH HEAT PIPE VACUUM TUBE SOLAR COLLECTOR

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ABSTRACT: This paper deals with a major technical problem, namely the use of solar energy to produce thermal energy. In this sence has been studied the behaviour of a thermal installations with heat pipe vacuum tube solar collector, being analyzed the behaviour of the system depending on climatic parameters, thus determining the operating parameters of the centralized system.
KEY WORDS: Energy conversion, solar heating, renewable energy sources, thermal variables measurement, thermal variable control

1. INTRODUCTION

Vacuum heat-conducting tubes contain a small amount of liquid evaporated through the action of solar radiation, vapour rising to the top where it is condensed by contact with the heat exchanger and transfers the heat to the heat transfer fluid. The main advantage of the system consist in the fact that a broken tube can be replaced without removing the entire heat collector together with high temperature (over 100 C degrees) inside the heat tube. In order to have maximum efficiency, these collectors must be installed to an angle of 30 to 45 degrees [1]. The radiation sent to the solar panel is not all converted into thermal energy because of the thermal losses that occur (release heat by convection and radiation to the environment is inversely proportional to the ambient temperature) and optical (because of the glass used as "mirror” for radiations). In the case of vacuum collectors the heat loss are reduced by up to 50% than the planar collectors [2], [4].

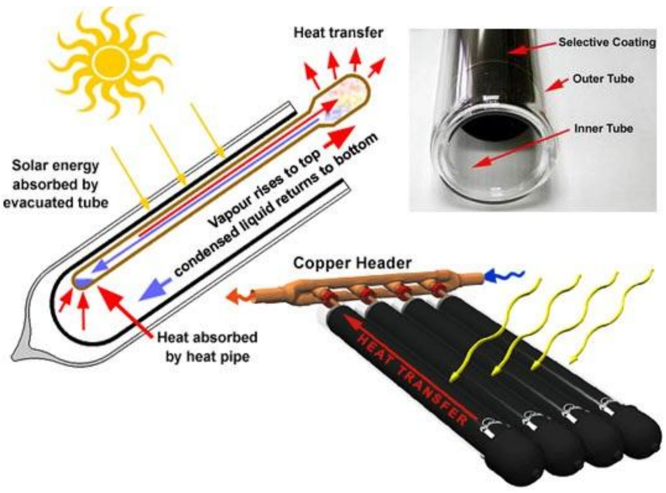

Figure 1. Vacuum collectors tube-in-tube system with dry connection

2. THE DOMESTIC HOT WATER PRODUCTION AND THE HOME HEATING

A solar hot water producing system works in two phases. In the first phase, the sunlight is captured by solar panel and converted into heat. Thermal fluid is pumped into the panel where it absorbs heat and transports it to the tank battery. The second stage occurs in the reservoir (tank), which, with the role of a heat exchanger heats the water in the plumbing system. We can say that a system that provides hot water produced by solar energy consists of 5 sub-elements:

- sub-collector system
- sub-system energy transfer
- sub-storage system
- auxiliary power sub-system
- sub-distribution system

The most usually used solar installation system is the forced circulation solar heating system which comprise its main elements: solar panel, water tank with heat exchanger, recirculation pumps controlled by a control system which circulates heat-transfer fluid through the pipes when there is a 5 to 8 C degrees temperature difference between the fluid in the solar collector and the water from reservoir.

Home heating is based on the same principle as that of producing hot water. The panel captures the sun's energy, warming the primary heating which is led to reservoir "tank in tank". The energy produced by the solar panel is distributed in the heating system of the building through the existing coil placed in the reservoir. The main reservoir (tank) for heating contains the small domestic hot water reservoir where the water is heated by absorbing heat created in large tank. The pump group and the automatic control system ensure the recirculation of primary heating from the panel and heating radiators.

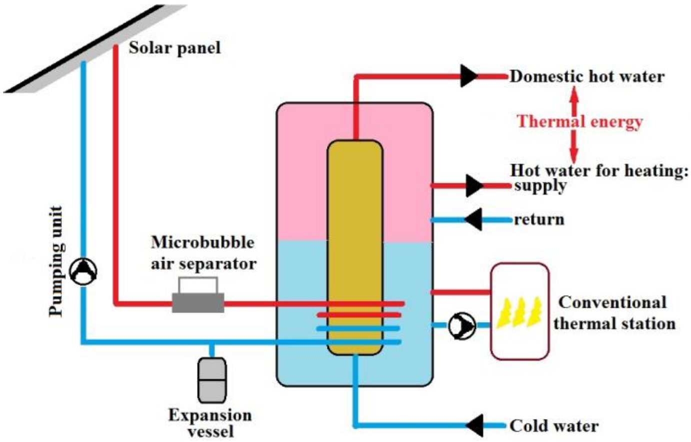

Figure 2. Forced-circulation solar thermal systems

Because during winter the sunlight is very weak, solar panels cannot cover all the necessary heat required by a house, so as we need extra energy to compensate it [2]. This compensation can be realized through a double exchanger tank with solar energy, tank which contains the heat exchanger of the solar panel. In addition to the heat exchanger from the solar panel, this tank contain also another heat exchanger at the top, supplied from an electrical resistor, or gas, wood, coal or pellets burner. It has the advantage of low cost but hasn't a very high efficiency [5].

3. SOLAR SYSTEM PRESENTATION AND ITS OPERATION

3.1 The solar collector

Solar collectors (solar panels) used in this study are the vacuum tube type heat-pipe technology, substantially reducing losses by conduction and convection. Operation at high temperatures and very low losses, make these vacuum tube collectors to be ideal for heating and domestic hot water [3].

Figure 3.a. Solar collectors Webstech WT-B58-30 with 3x30pc vacuum pipes

Figure 3.b. Solar reservoir „tank in tank Siss 900/200"

The latent heat of vaporization is transferred through a water-based liquid in the inlet region of the evaporator and condenser of solar heat in the discharge region. The heat source is the absorbent plate, which is continuously connected to the heat pipe. The condenser is in direct contact with a collector that serves as a heat exchanger, with the heat transfer always in one direction - from the absorber to the collector. The vacuum tube can bring the liquid in the heat pipe up to 300 C degrees. Webstech WT-B58-30 panels are produced in Germany and have an efficiency of 730 kW/h/year (Figure 3.a.).

3.2 The storage tank and the heat exchanger

In the analyzed system, the storage reservoir is type of tank in tank, thereby in the main boiler used for heating is introduced a smaller boiler used to heat domestic hot water.

The main reservoir has insulation with thickness of 100 mm ECO SKIN, ensuring minimum heat loss 0.2 kW/h. It has two longitudinal grooves designed for mounting sensors of "Pt 1000". The boiler can be linked not only to solar installations but also to other types of heat generators such as gas boiler. The working temperature of the tank goes up to 95 C degrees, with the dimensions of 2150 mm length and 990 mm overall diameter (Figure 3.b.). The pressure inside the small tank is limited to 6 bar, and for the large tank to 3 bar.

The heat exchanger consists of a single coil of copper having a corrosion protection with the total area of 3 square meters, with a capacity of 19.3 liters of water, designed for pressures up to 10 bar and a maximum temperature of 110 C degrees. As auxiliary facilities, the solar system uses a 6 kW/h electrical resistor with adjustable thermostat, feed from a tripled phase system and a gas boiler.

The "FV TACOSOL ZR 70" solar station fulfill the functions of recirculation for the analyzed solar system. This station consists mainly of circulation pump "Wilo ST 25/3", regulator and ventilation system, through this being able to adjust water flow and bleed facility of the installation (Figure 4.a).

Figure 4.a. Solar station „FV 70 TACOSOL ZR”

Figure 4.b. Solar controller ”Steca TR A502 TT”

3.3 Recirculation system

The "Setter" device incorporated in the station, allows adjusting the amount of water in the primary circuit.

3.4 Control and metering system

The "Steca TR A502 TT" controller is a control system for the circulation pump of the heating agent and metering of the heat produced by the solar collectors (Figure 4.b).

The solar controller has 5 inputs for the temperatures aquisition and 2 outputs. It can be used for controlling high-efficiency pumps. Together with an external pulse decoder, integrated into the system, allows the acquisition of numerical information from the solar system field.

For each solar scheme of the controller, the external components (pumps, valves, temperature sensors) must be connected to the terminals of each component. From the 11 solar schemes, the analized instalation is set to scheme 1, which consists of a single solar panel, a single tank (puffer) with one temperature sensor and a circulation pump. All operations are automatically controlled with settings preset but operational changes may be submitted manually by the user for the outputs, pumps and temperature sensors.

3.5 Security systems

As a first solar protection system of the instalation is used the 24 liters expansion tank; with maximum working pressure of 8 bar and 4.7 Kg weight (Figure 5). The expansion tank will take the amount of water in case of high-pressure but it can also compensate the thermal expansion of the fluid in the system. It can sustain, without the need for a large increase in pressure in the plant, all liquid contents of collectors field, when the condensate due to excessive temperature will empty collectors.

Figure 5. Expansion tank

Other protection system used is the safety valve, in order to avoid excess pressure in the piping system. There are several safety valves installed in certain parts of the system for protection. The valves have maximum pressure of 3 bar and maximum temperature permitted of 160 C degrees. In addition, automatic air vents are fitted, resistant up to 180 C degrees.

4. EXPERIMENTAL RESULTS AND THE PARAMETERS ANALYSIS OF THE SOLAR INSTALLATION

In order to examine the thermal energy diagram depending on weather data for the solar system was necesary the climate data record during March 16 to March 31 and 11aprilie - 16th. The thermal energy produced by the solar system was analyzed and recorded every day in this period [6].

The climate graphs were introduced to notice how many hours of sun are in each calendar day and also to observe the concerned temperatures during the day, because for the solar panels are the most important hours of sunshine (hours of operation) than the ambient temperature [7].

In Figure 6 are presented the four important parameters of the solar installations. The data used for this graph but also to the following graphs from this work, were taken every day as accurately as possible. As shown, the first parameter is the energy produced by solar panels, which has a maximum of 46 kW/h of heat in the day March 19 when the maximum ambient temperature was 10 C degrees. The highest ambient temperature was reached in March 31, when the solar panels produced 20 kW/h of energy. We can say that the panels have produced less energy, compared to other days when we had not an outside temperature so high, but about the same energy output.

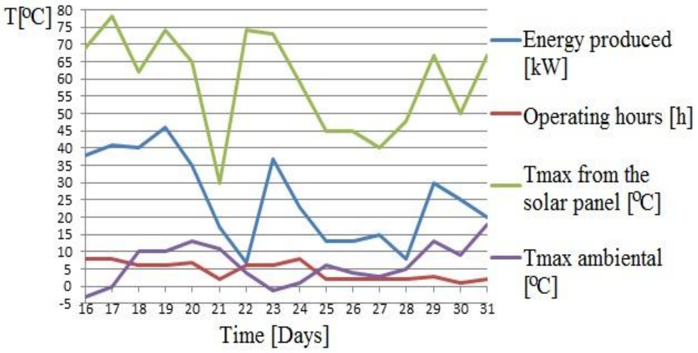

Figure 6. Variation of solar thermal power versus time and temperature for March 2015

It is interesting the fact that in the March 16 solar panels have produced 38 kW/h of heat even if the outside temperature was -3 C degrees, because during that day were 9 hours of sunshine, fact that demonstrates that solar radiation is very important for the solar panels. With only 9 hours of sunshine even if the outside temperature was negative, the solar panels had produced heat for 8 hours, with a maximum operating temperature of 68 C degrees, the temperature being maintained at a minimum of 55 C degree by the boiler. Also can be noticed that we had a minimal power of 7 kW/h in March 22 even if the temperature in the solar panels reached 74 C degrees and worked for 6 hours. From the meteorological data, was noticed the fact that during the day we had no even one hour of sun radiation. This amount of energy is due to the fact that this month of the year we had an additional energy from the gas boiler. Large amounts of heat produced in March by the solar panels were made possible because of the energy supplement provided by gas boiler. Since gas boiler heated the water tank can say that solar panels have a very small contribution to water heating from the tank thus we have high temperatures in the solar collectors, because the recirculation pump starts when temperature exceeds with + 5 C degrees the temperature from the puffer. This makes the Steca system, data collection, record significant amounts of energy.

Supplementation with heat from the gas boiler took place also in April. Analysing the heat produced in Figure 7, in April can be observed many fluctuations. We start from an average power, from 11 to 15 April, when we record a minimum power of 15 kW/h thermal energy.

This minimum from the 12th day, is because the outdoor temperature was not very high and also because the panels had not solar radiation. Also we note the fact that we only had 5 hours of operation of the solar system.

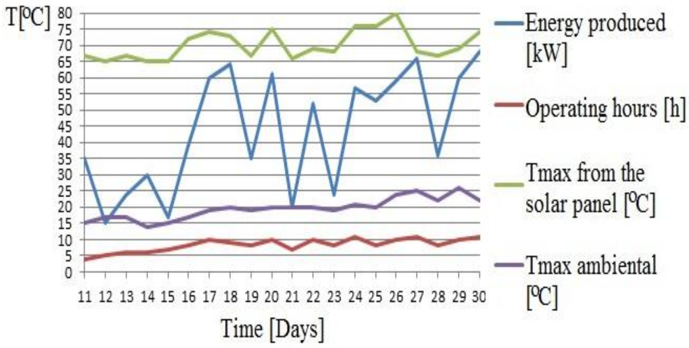

Figure 7. Variation of solar thermal power versus time and temperature for April 2015

Maximum power occurred on the last day of the month, being 68 kW/h. Analysing the weather data from this day, is noticed that we had only 6 hours of sun radiation and a maximum temperature of 22 C degrees. Because in the previous day was produced a quantity of energy quite close to that of the last day, the amount of energy produced by the solar colectors was maximized. Water from the tank was heated to a high enough temperature in the previous day, so as was not necessary so much energy to heat water because the fact that the tank has a very low rate of heat loss. Hence the energy produced on the day preceding the day in question is very important. Temperature fluctuations from the solar panels are not very high, given the fact that temperatures have steadily increased in April compared to March when there were quite a few fluctuations in outside temperature.

In Figure 8 is presented that during May we have two peaks of energy produced in the day 7th and 16th, maximum power reached being 85 kW/h.. On the 7th day the solar panel temperature it was 80 C degrees, which was the maximum temperature of 16 days to solar panels, while on May 16 to 69 C degrees, but with equality in operating hours. The external temperatures are approximately equal, 26 C degrees on day 7 and 25 C degrees on the 16th day.

Given that we have the same energy produced in the two days but we have a difference of 11 C degrees even if in the solar panels are roughly equals, remain to analyse the parameters of sun radiation during every day to realize where it comes from this difference. We note that on May 16 were more hours of sun radiation than May 7, and this clarify the issue with the temperature difference of solar panels.

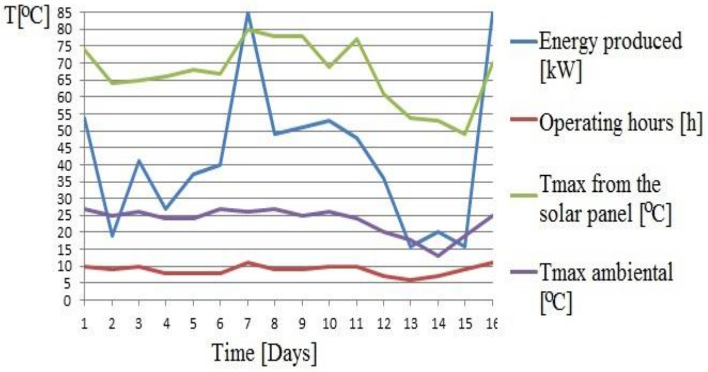

Figure 8. Variation of solar thermal power versus time and temperature for May 2015

Minimum energy produced, the most important parameter, was done in two days, same as the maximum of this month.It was 16 kW/h heat in the 13th and 15th day. In this case we have not equality of any parameter. On May 13, the system worked for 6 hours with a maximum temperature of 54 C degrees, while the solar panels on the May 15th, worked for 9 hours at a maximum temperature of less than solar panels, only 49 C degrees. The ambient temperature was about 18 C degrees on both days, but the amount of solar radiation was higher on day 15th. Minimum outdoor temperature has not been recorded in these two days, but it was reached in the day between them, on 14, when the temperature was only 13 C degrees. The energy produced in this day of 14 was slightly higher than the minimum energy produced 20 kW/h. This month we gave up to the supplement energy from the gas boiler, so the solar system brought the whole household energy demand.

5. CONCLUSIONS

A first conclusion: in order to get maximum efficiency of the panels the solar radiation must be present for a long period of time at high intensity. It was noticed that at low temperatures the solar panels produce heat but it needs sunlight. The solar collector system brings forth the heat and the cold season but it is below 5% of the heat for heating. The panels will begin to operate with increased intake from March / April when we have more hours of sun radiation per day. Was also noticed that the accumulated thermal energy in the storage tank (puffer) can be stored for several days if is not used, because it has very low thermal losses (about 2 C degrees in 24 hours).

For a family of 4 people is required on average quantity 200 liters of hot water per day. If the water temperature is 10 C degrees and it needs to warm to 55 C degrees, the maximum recomanded temperature for the condensing gas boiler to operate at maximum efficiency, the energy requirement is approximately 11 kWh / day. From the experimental measurements made in perimeter we noticed that the water temperature to be heated is 13-14 C degrees, so as thermal energy needs will therefore be up to 10 kwh / day.

Gas bill for the building in which it works and solar panels have an average of about 400 lei / month (125 kWh/day) during the 6 months of the year with low temperatures. In warmer months of the year, the gas bill is around 10 lei / month (3.1 kWh/day) with a total 2860 Ron/year. The time period used to determine the total cost includes also the functioning of solar collectors. During the summer months the panels contributed 100% and in the cold months contributed between 0 and 5% to domestic hot water production and heating.

The gas bill without the contribution of solar panels would have an average cost on colder months of approximately 480 lei/month (150 kWh/day). In warmer months because it only needs hot water gas bill would be about 40 lei (12.5 kW/h/day). The calculation of the invoice for the cost of thermal power without the contribution of the solar installation is around Ron 3,600 per year.

The gain recorded using solar thermal plant is around 740 euro/year. Total cost of the solar system with associated piping and other components is approximately 18,000 Ron. The payback period of the investment will be approximately 24.5 years. Since the summer the panels produce more heat than necessary requirement, we can use thermal energy "left" for other purposes, such as heating water from a pool, so as the payback period would decrease.

It remains to be seen who will be the period of operation of the installations with solar panels, because the guarantee provided by the manufacturing firms is for the 25 years operating. Regarding the maintenance costs they are relatively small, vacuum tubes should be kept clean, aiding thermal fluid changed at a period set by the supplier.

Regarding the environmental aspect we can say that this systems and all solar facilities are 100% ecologic without negative influence on sorounding environment. Solar panels are recyclable due to the materials they are made, and through the heat produced will reduce consumption of natural gas or electricity for home heating and domestic hot water.

6. ACKNOWLEDGEMENTS

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