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ALGORITHM OF A SOLAR INSTALLATION FOR HOT WATER PROVISION IN AN AGRITOURIST HOSTEL

Sebastian BLAJ-BREZEANU [1]
Gheorghe BRĂTUCU[1]

Abstract: *This paper presents the algorithm used for calculating the choice and the dimensions of an installation of solar panels used for heating the water necessary for an agritourist hostel. The starting point was the establishment of the daily water consumption, in accordance with the regulations in force, of the surface for capturing the solar energy and of the number of necessary panels. Useful remarks are made regarding the ideal way of placing the solar panels, after which the algorithm is continued with the necessary capacity for the heater, the necessary time for heating the water from the heater, the necessary power of heating the water, the surface of the heat exchanger and the medium efficiency of the collector.*

Key words: *agritourist hostel, hot water, solar panels, algorithm.*

1. Introduction

Solar energy has proven to be an alternative source of energy. Today solar power is used worldwide to produce various types of energy, lighting energy, photovoltaic modules, domestic hot water, solar collectors. Lately, on the background of reducing energy consumption from conventional sources, it has been speculated that an alternative might be solar energy, more specifically solar energy.

The availability of this energy depends on the day-night cycle, the latitude of the place where it is captured, the seasons, and the degree of cloudiness. Against the backdrop of reducing gas emissions and pollution a viable alternative may be the use of technologies that work with solar energy. In thermal processes, solar energy is used to heat gas or liquid, which is then stored or distributed.

2. Material and Method

2.1. The Calculation of Daily Water and Heat Requirements

The daily water requirement G_T in the considered agritourist hostel, with a maximum capacity of 30 *pers./day*; the following relation is established [1]:

[1] Faculty of Food and Tourism, *Transilvania* University of Braşov;
Correspondence: Gheorghe Brătucu; email: gh.bratucu@unitbv.ro.

$$G_T = 1{,}1 \cdot n_p \cdot q_p = 1{,}1 \cdot 30 \cdot 80 = 2640 \ [l/day] \quad (1)$$

in which:

q_p is the daily quantity of water for a person, in *l*; according to STAS 1478- this quantity is of 70 *l /per person in a day*;

n_p – number of persons (n_p= 30 persons).

The heat requirements in order to ensure hot water in the questhouse are [2]:

$$Q_z = n_p \cdot (t_e - t_i) = 30 \cdot 70 \cdot (50 - 20) = 63000 \ [kcal/day] \quad (2)$$

in which:

Q_z is the daily necessary heat, in k*cal/per day*;

t_i – the temperature of hot water when entering the installation (t_i = 10°C);

t_e – the temperature of hot water when leaving the installation (t_e = 50°C).

2.2. Calculating the Surface of Captured Solar Energy

The surface of the captured solar energy S_p, which can ensure the necessary specific heat can be calculated with the following equation [3]:

$$S = \frac{Q}{q \cdot \eta \cdot \eta} = \frac{63000}{90000{,}5 \cdot 0{,}8} = 17{,}5 \left[m^2\right] \quad (3)$$

in which:

Q_z is the necessary heat in a day expressed, in k*cal/per day*;

q_r – mass density of the daily solar irradiance,

$$q_r = 6000 Kcal/day \cdot m^2;$$

η – efficiency of the installation ($\eta = 0{,}5$);

η_s – efficiency of the technical transmission storage cell ($\eta_s = 0{,}8$).

The capture area is chosen: $S_p = 17{,}5 m^2$.

The solar panels specified in table no 1, are chosen their characteristics being in accordance with the test reports No. 2003-17 of Fraunhofer Institute fuel Energie systeme, conf. EN 12975-1, 2. The conclusion is that ten solar panels are needed.

2.3. Setting up the Solar Panels

When setting up the solar panels, the following requirements should be taken into consideration:

- the collector should always be oriented southwards;
- the angle of inclination of the collector, in relation to the horizontal is chosen by - the geographical latitude of the location and the environmental conditions (the degree of pollution, the degree of shading with vegetation and constructions, etc).;
- the collector can be placed on the roof of the houses or on a metal frame when it comes to terraced roofs.

According to the studies made by INCERC regarding the climatic conditions from Romania, the following inclination angles are recommended:

- angle $\alpha = 45^0$, for solar installation with permanent operation (winter-summer);

– angle α = 26-32 ^{0}, for solar installation functioning during certain seasons, between April and September.

In Figure 1 there is represented the ideal placement of the angle in order for them to have the previously mentioned performance is represented.

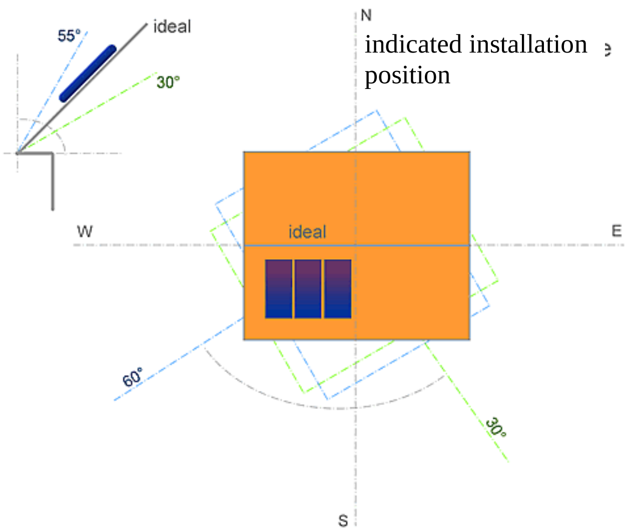

Fig. 1. *The ideal angle for the setting up of the solar panels*

Technical characteristics of the chosen solar panels in order to heat the water Table 1

Gross floor area	2,03 m^2
Absorbent surface	1,78 m^2
Overall dimensions	1040 x 2040 mm
Glass	Solar glass 4 mm
Connection	Flanges Φ 6mm
Carcass	Made by stamping, it is made of alloy sheet metal Al-Mg
Sensor sheath	For a sensor of Φ 6mm
Thermal insulation	Mineral wool
Volume of the thermal agent	1,57 l
Total mass	37 kg
Absorbent	Extruded copper sheet with one layer Ni-Al_2O_3
Solar absorption $\alpha_{M1.5}$	Min. 0,95
Thermal emissivity $\varepsilon_{82°C}$	Max. 0,16
Optical efficiency	81%
Working temperature	Under 100ºC
Stagnation temperature at the radiation of 1000 W/m^2 and the ambient temperature 25ºC	170ºC
Maximum pressure of the thermal agent	600 kPa
Recommended AT flow	30 – 100 l/h / collector
Captured energy on the collector*	Until 1000 kWh/an

2.4. Calculation of the Required Boiler Capacity

The *V* capacity of the boiler which should ensure the supply of hot water for the consumers who are accommodated in the hostel, the following relation is established:

$$V = \frac{860 \cdot \sum (n \cdot Q_{h\max}) \cdot \varphi_n \cdot \varphi_2 \cdot Z_A}{(Z_A + Z_B) \cdot (T_a - T_e) \cdot a} \; [l] \quad (4)$$

in which:

$Q_{h\max}$ is the necessary heat for in ensuring hot water at any point of the consumption period, in *kWh;*

n – the number of rooms with the same water consumption requirement (Table 2) the coefficient of simultaneity of hot water use (φ_n = 1 from Table 2);

Z_A – the heating time, in *h* ;

Z_B – the time of peak consumption of hot water;

T_a – the hot water temperature in the heater;

T_e – the temperature of hot water when entering the heater;

α - the coefficient that takes into account the workload of the heater (α = 0,8);

φ_2 – category coefficient, in terms of comfort (φ_2 = 1 from Table 3).

Table 2

The value of the simultaneity coefficient for hot water use φ_n

Number of rooms	1.....15	16.....36	35......75
φ_n	1	0,9...0,7	0,7....0,6

Table 3

The value of the category coefficient φ_2 *, in terms of comfort*

Housing type	Average	High comfort	Luxury comfort
φ_2	1,0	1,1	1,2

For average comfort the $\varphi_2 = 1{,}0$ is chosen. With these data the *V* volume of the necessary heater will be:

$$V = \frac{860 \cdot \sum (n \cdot Q_{h\max}) \cdot \varphi_n \cdot \varphi_2 \cdot Z_A}{(Z_A + Z_B) \cdot (T_a - T_e) \cdot a} [l];$$

$$V = \frac{860 \cdot 90 \cdot 1 \cdot 1 \cdot 1{,}5}{(1{,}5 + 1{,}5) \cdot (60 - 10) \cdot 0{,}8} = 967{,}5 \; [l] \quad (5)$$

A heater with a volume of 1000 *l*, is chosen and its technical characteristics are represented in the Table 4.

2.4. Determining the *Z* Time Interval Needed to Heat the Water from the Heater

The following relation is realized:

$$Z = \frac{n_b \cdot V \cdot N_h}{G_T} \quad (6)$$

in which:

n_b – the number of heaters;

V – the quantity of heated water (V=1000 *l*);

N_h – the number of hours of usable sunlight (N_h=9h);

G_T – the daily water consumption (G_T=2640 *l*), meaning:

$$Z = \frac{n_b \cdot V \cdot N_h}{G_T} = \frac{1 \cdot 1000 \cdot 9}{2640} = 3{,}4[h].$$

2.5. Determining the Necessary Power for Heating the Water

$$Q_A = \Phi_A = \frac{c \cdot V \cdot \Delta_{TA}}{Z_A} \quad [KW] \quad (7)$$

in which:

Q_A – the minimum power for heating the water from the heater, in *KW*;

V – storage capacity, *in m²*;

Z_A – heating time, in *h*;

Δ_{TA} – the difference of temperature between the output and the input agent [Δ_{TA} = (60-10) ^0C =50 ^0C];

c – the caloric capacity of the heating agent .

$$Q_A = \Phi_A = \frac{c \cdot V \cdot \Delta_{TA}}{Z_A};$$
$$Q_A = \frac{1 \cdot 1000 \cdot 50}{860 \cdot 3{,}4} = 17[KW]. \quad (8)$$

The technical characteristics of the heater with a volume of 1000 l Table 4

Type	U.M	1000NTR
Tank volume	l	958
Diameter	mm	1010
Weight	kg	323
ACM working pressure	MPa	1
AT working pressure	MPa	1
Maximum temperature of AT	ºC	110
Temperature ACM	ºC	95
Heating surface of the upper coil	M2	1,12
Heating surface of the lower coil	M2	2,45
Power of the upper/lower coil	KW	76/32
Power coefficient of upper coil, according to DIN 4708	NL	71
Power coefficient of inferior coil, according to DIN 4708	NL	26
ACM upper coil flow rate	l/h	1200
ACM lower coil flow rate	l/h	776
Heat loss	KW/24h	2,1

2.6. Determining the Surface of the Heat Exchanger

The surface of the heat exchanger is calculated using the following relation:

$$S_{sch} = \frac{Q_h}{\varphi \cdot k \cdot \Delta_{tmed}} \qquad (9)$$

in which:

S_{sch-} – the surface of the heat exchanger , in m^2 ;

$\varphi-$ the utilization coefficient of the heat exchanger;

K – total coefficient of thermal transfer;

Δ_{tmed} – the medium temperature difference, $^{\circ}C$;

Q_h – the quantity of heat needed for the heating, in *Kcal*, meaning:

$$Q_h = G_p \cdot (t_{TP} - t_{RP}) \qquad (10)$$

G_p – primary agent flow ;

t_{TP} – thermal agent temperature from the primary circuit to the input of the heat exchanger ;

t_{RP} – temperature of the thermal agent at the output of the heat exchanger. For the specified heat exchanger, the following are taken into consideration:

$$Q_h = G_p \cdot (t_{TP} - t_{RP})$$

$$Q_h = 1200 \cdot (59 - 44) = 18000 [Kcal / h].$$

Determining the coefficient of the k thermal agent:

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}} \qquad (11)$$

in which:

α_1 – the partial heat transfer coefficient from the hot fluid to the wall;

α_2 – the partial heat transfer from the wall to the cold fluid;

δ – the thickness of the pipe's wall;

λ – thermal conductivity of the material the pipes are made of:

$$k = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}};$$

$$k = \frac{1}{\frac{1}{2500} + 0{,}000261 + \frac{1}{1760}}; \qquad (12)$$

$$k = 819 Kcal / m^2 \cdot h \cdot {}^0C$$

$$S_{sch} = \frac{Q_h}{\varphi \cdot k \cdot \Delta_{tmed}} = \frac{18000}{0{,}87 \cdot 819 \cdot 10} \Rightarrow S_{sch} = 2{,}52 m^2$$

$$\Delta_{tmed} = \frac{(t_{RP} - t_{RS}) - (t_{TP} - t_{TS})}{2{,}3 \cdot \ln \cdot \frac{(t_{RP} - t_{RS})}{(t_{TP} - t_{TS})}};$$

$$\Delta_{tmed} = \frac{(35{,}26 - 10) - (59{,}26 - 45)}{2{,}3 \cdot \ln \cdot \frac{35{,}5 - 10}{59{,}26 - 45}} = 10^{\circ}C \qquad (13)$$

in which:

t_{TP} – the temperature of the thermal agent from the primary circuit when entering the exchanger;

t_{RP} – the temperature of the thermal agent of the primary circuit when exiting the exchanger;

t_{RS} – the temperature of the thermal agent when entering the heater;

t_{TS} – the temperature of the thermal agent when exiting the heater.

2.7. Determining the Medium Efficiency of the Collector: $\eta_p^{(0)}$

$$\eta_p^{(0)} = \frac{b \cdot c_p \cdot (t_{bf} - t_{bi})}{\eta_{iz} \cdot g \cdot N_h} \qquad (14)$$

in which:

c_p – the specific heat;

η_{iz} – the efficiency of the thermal insulation (η_{iz} =0,9);

N_h – the number of hours of functioning (N_h =9h);

g – intensity of the solar irradiance (g = 600W/m^2);

b = 75 $l/m^2 \cdot day$, meaning:

$$\eta_p^{(0)} = \frac{b \cdot c_p \cdot (t_{bf} - t_{bi})}{\eta_{iz} \cdot g \cdot N_h};$$

$$\eta_p^{(0)} = \frac{75 \cdot 1{,}16 \cdot (50 - 15)}{0{,}9 \cdot 600 \cdot 9} = 0{,}62 \qquad (15)$$

3. Conclusions

1. The use of the solar panels in heating the domestic hot water and the living spaces can bring a very important contribution to the energy independence of the agritourist hostels.
2. The use of an algorithm to calculate the element of the specialised water heating installation at least for a feasibility calculation it is very helpful for the designers of agritourist hostels.
3. It is useful to know the efficiency of the installation in order to compare different technical solutions.

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