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SEASONAL STORAGE OF HEAT AS A FACTOR IN IMPROVING THE ENERGY BALANCE OF A DETACHED HOUSE

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Abstract: The problem of accumulation of solar energy is undertaken fairly widely in the world. Mostly they realized they are large power installations for residential or larger enterprises and institutions. Publications describing the solution in a small scale (eg. The use of detached houses) is much less. The paper presents an analysis of the operating parameters of the battery using solar energy to heat a single-family home and water heating. The analyzed magazine uses the heat capacity of gravel of different water saturation.

Introduction

Considering the energy balance of a residential building in our geographical area is easy to see that the maximum heat demand occurs during the months of late autumn, winter and early spring. In the era of searching for the possibility of using RES (Renewable Energy), the easiest way is to use solar energy.

However, solar energy reaches the Earth's surface with the highest power in the year in which it is least needed, ie. In the summer. In contrast, during the heating season when demand for heat is the greatest intensity of solar radiation is minimal. To compensate for fluctuations in the required heat-streams are used in the heat storage.

Storage of thermal energy are being built all over the world. Research is also conducted experimental and simulation. Storage may be short-term (eg. Warehouses and power plants in order to improve the balance of the daily or the use of large trays – heated hot water solar collectors) and long term (seasonal) STES (Seasonal Thermal Energy Storage) decomposing downloaded heat flux for the whole heating season.

For the storage of heat energy use of different solutions for construction, the use of the media, physical and chemical processes. The most commonly used are magazines ground with holes hollow in the ground type BTES (Borehole Thermal Energy Storage). The holes are inserted heat exchangers U - tube. Founded over openings is lagging and vapor check. Magazines heat may be low temperature (0 to 20°C) with an additional heat pumps and high-temperature (50 to 10°C). Construction of underground storage type BTES makes sense for investments in large scale. It heat loss by penetration into the ground (the lower the ratio of heat exchange surface to the volume of fluid in a smaller flow losses). In the work [1], [2] and [3] provides a solution storage BTES used on a large scale in Germany, Sweden and Canada.

Another widely used solution in the world is a magazine-type HWTES (Heat Water Thermal Energy Storage) in which the medium accumulating heat is hot water. Magazines of this type are built on a large scale (residential institutions) – for example, work [4] or small (houses) – work [5] or [6] and [7] of simulation studies on the subject. They are used also other interesting solutions like ATES (Aquifer Thermal Energy Storage), using aquifer GWTS or type batteries (Gravel-Water Thermal Storage) in which the heat storage medium is a mixture of gravel and water.

In addition to the heat storage solutions utilizing thermal capacity of various media are used methods based on different physical and chemical phenomena. Research is being conducted experimental and simulation in which factor is the change heat storage phase, reversible chemical reaction. The use of phase-changing material of heat accumulation is shown in operation [8], dehydration-hydration process is used for storing solar heat and then used for the heating of a detached house shown in operation [9] and [10]. Design solutions using energy storage facilities are diverse. They may be isolated steel or concrete tanks. Also, the location of the tanks can be different, eg. under the building, outside the building, aeration, partially or entirely underground. There are also known solutions in which the installation of a steel storage tank is placed inside a residential building. Heat accumulator can also be concrete blocks (eg. foundations) equipped with heating coils.

Simulations

The paper presents a program of simulation process of thermal energy storage with solar collectors then used for heating residential building and domestic hot water systems. The thermal load dwelling unit was established as an annual heating energy consumption for heating per square meter, while the heat flow into the DHW calculated based on the consumption of hot water by one person.

Structure calculations

Building loads Q can calculate as:

$$Q = Fd \times q_j [kWh/a] \quad (1)$$

where:

Fd – usable home $[m^2]$
q_j – specific heat energy consumption $[kWh/m^2, a]$.

The average flux thermal load as during the heating season:

$$N_{gsr.a} = \frac{q}{I_d \times 24} [kW] \quad (2)$$

where:

I_d – the number of days during the heating season (months X to the mid-IV).

The average flow of heat load which in the considered month:

$$N_{gsr.m} = N_{gsr.a} \times \frac{\Delta t_{sr.m}}{\Delta t_{sr.msg}} [kW] \quad (3)$$

where:

$\Delta t_{sr.m}$ – the temperature difference between the temperature inside the rooms tp residential and the average ambient temperature of the month in question $t_{sr.m}$

$\Delta t_{r.m} = t_p - t_{r.m} [K]$

$\Delta t_{sr.msg}$ – the average temperature difference between the temperature inside the living quarters and the average ambient temperature of each month of the heating season.

$$\Delta t_{sr.msg} = t_p - t_{sr.msg} [K] \quad (4)$$

$$t = \frac{t_{sr.mI} + t_{sr.mII} + t_{sr.mIII} + t_{sr.mIII} + 0,5}{6,5} \times \frac{t_{sr.mIV} + t_{sr.mX} + t_{sr.mXI} + t_{sr.mXII}}{6,5} [^\circ C] \quad (5)$$

The stream of heat loss by penetration overhead storage in a given month calculated by:

$$N_{str.m} = \frac{KSB \times F_{wcs} \times \Delta t_{zsr.m}}{1000} + \frac{k_p \times F_{wcp} \times \Delta t_{psr.m}}{1000} [kW] \quad (6)$$

where:

KSB – heat transfer coefficient of walls and magazine covers heat $[W/m^2, K]$ (calculated for the accepted scheme insulated walls),

$\Delta t_{zsr.m} = t_{wm} - t_{sr.m} [K]$,

k_p – heat transfer coefficient base heat storage $[W/m^2, K]$,
F_{wcs} – heat exchange surface of the side walls and heat magazine cover $[m^2]$,

$\Delta t_{psr.m} = t_{wm} - t_g [K]$,

F_{wcp} – heat exchange surface heat storage base $[m^2]$,
t_{wm} – the temperature inside the heat storage $[^\circ C]$,
$t_{sr.m}$ – ambient temperature, the average monthly $[^\circ C]$,
t_g – the ground temperature $[^\circ C]$.

The temperature rise inside the warehouse medium heat in a given month calculated by:

$$\Delta t_m = (N_k - N_{str.m} - N_{cwu} - N_{gsr.m}) \times I_{dm} \times 24 \times \frac{3600}{c_{pm}} \times M_m \quad (7)$$

where:

$$N_k = \frac{F_k \times E_{km} \times 1000}{I_{dm} \times 24 \times 3600} [kW]$$

– stream thermal energy from the solar collectors in individual months,

F_k – solar collector area $[m^2]$,
I_{dm} – the number of days in a given month,
E_{km} – a stream of solar thermal in a given month,
c_{pm} – heat of the filling medium heat magazine,
M_m – weight Fill a medium heat magazine.

The temperature of the heat storage medium determined by adding the designated temperature rise above the temperature of the medium in the previous month.

The efficiency of the system – collector, installation of heating, heat storage (do not include losses installation):

$$\eta_{sm} = \frac{Q_{neta}}{Q_{kaa}} = \frac{Q_{kaa} - Q_{stra}}{Q_{kaa}} \quad (8)$$

where:

Q_{kaa} – heat generated by solar collectors during the year,
Q_{stra} – the total heat loss in a tank storage during the year.

Description of simulation studies

The study model chosen residential building with a usable area of $150m^2$ and a fairly well-insulated walls (the demand for thermal energy for heating is assumed to be $30[kWh/m^2a]$). The thermal energy for hot water preparation are based on the standards adopted by per capita consumption (in the house live 4 people).

Magazine is an isolated reinforced concrete, heat tank filled with gravel of varying water saturation. Insulation thickness of 40 cm is made of expanded polystyrene having a coefficient of thermal conductivity $\lambda = 0.04[W/mK]$. For calculation of solar energy flux in different months of the year were selected on the basis of information the Institute of Meteorology for the region Polish North-East.

The results of calculations adopted model.

A detailed description of the assumptions and the method of calculation described in the work ().

The results of calculations performed in this work are presented in graphs (Fig. 1 - 4). According to Fig. 1 solar collector surface increases with increasing water content in the bed.

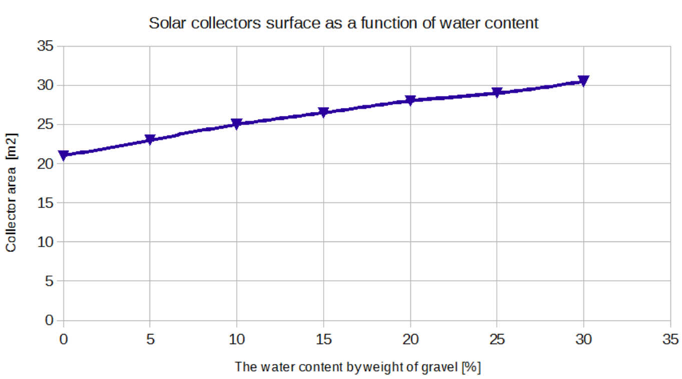

Fig. 1: Adopted the surface of solar panels depending on the water content in the deposit

This is due to increasing the heat storage capacity (higher water content is larger heat capacity and also increases the density of the bed). The surface of the collector was chosen as the maximum, however, so as not to exceed the boiling point of water.

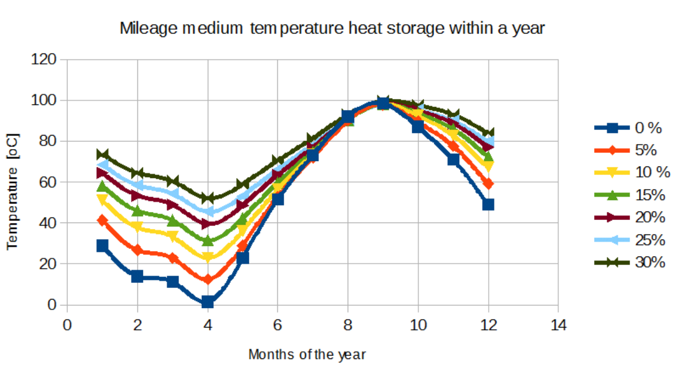

Fig. 2: The curve of the temperature of the bed of gravel throughout the year for different values of water content in the heat storage medium

In Fig. 2 shows the medium temperature stabilized mileage accumulation per year (after the 5-year period of stabilization) for assumed water content in the bed. In analyzing these graphs can be seen that the lower water content (dry gravel) there is large temperature fluctuations during the year. These are the months in which the magazine does not accomplish its purpose (temperature lower than the temperature of heating water for radiant heating up). Limit on the water (the temperature of heating water for heating the wall) in the bed can be estimated at 20%. These diagrams show that the highest temperature stability of the bed is in the month of September, while the largest dispersion in the month of April. This is confirmed by graphs shown in Fig. 3.

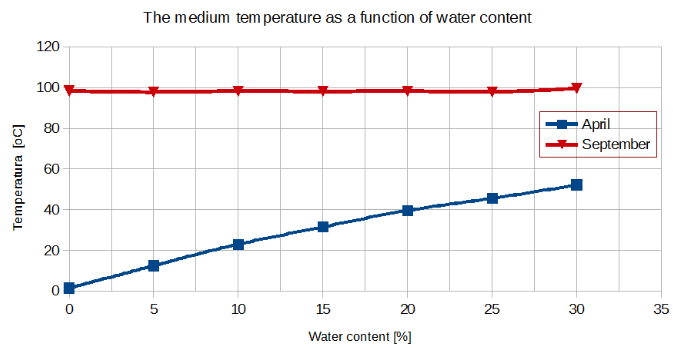

Fig. 3: Extreme temperatures medium depending on the content of water in months (the minimum in April maximum in September)

The effect of water content in the deposit on system efficiency of solar batteries - Heat magazine shown in Fig. 4. In the course of the graph shows that the system efficiency is defined as the ratio of solar heat gain, net (stored and less heat loss through the tank wall penetration) to the total energy collected from the sun decreases with increasing water content of the reservoir. This is due to the increased area of solar collectors at constant volume heat accumulator.

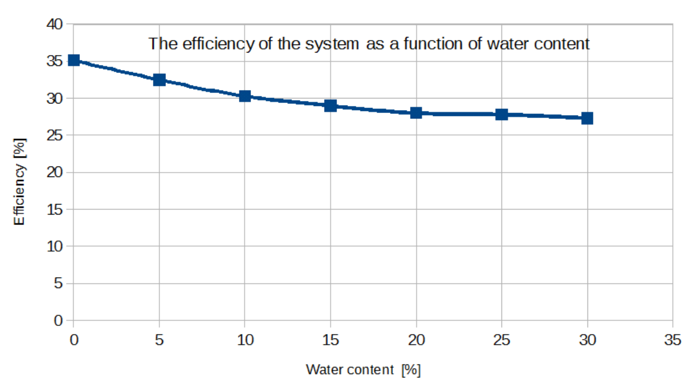

Fig. 4: Chart efficiency of the system (battery solar collectors - Heat magazine) depending on the bones of water contained in the deposit accumulation)

Summary

Analyzing the results of calculations adopted model of storing solar energy can be seen that using other media than water (eg. Gravel) should take into account the humidity. The water content in the bed of gravel decisively affect the course of his temperature throughout the year. Higher water content is greater storage capacity but in turn reduces the efficiency of the system.

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