WATER HEATING THROUGH A SOLAR COLLECTION SYSTEM: A CASE STUDY

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Abstract. This paper presents a case study of the transformation of solar radiation into heat and the transfer of this heat to water. The purpose of the case study is to provide technical measures to improve the energy consumption of buildings, according to the technical specification and the current regulations. The use of solar collectors is applied to help heat hot water and, at the same time, helps to protect the environment. It is necessary to develop and implement ecological and highly efficient solutions for heating and domestic hot water, which will make a significant contribution to the protection of nature and the improvement of living conditions. The system under consideration gives us a good example of the benefits of using solar energy.

Keywords: energy efficiency, domestic hot water, solar collectors.

1. INTRODUCTION

Solar collectors collect [1-3] and receive heat energy from the sun, using it for heating and warm water that is stored in a special water tank-boiler. Collectors are gaining more and more popularity and are increasingly widely used in many buildings and households. With the help of a solar collector, hot water is constantly available and at the same time helps to protect the environment [4-6]. Heating costs are significantly reduced for hot water compared to a conventional boiler type. It is necessary to develop and implement ecological and highly efficient solutions for heating and domestic hot water, which will contribute significantly to the conservation of nature and improve living conditions.

Solar collectors are an efficient and inexpensive way to heat water used for domestic, rural needs, farm even small industrial enterprises. Households have an almost constant need for hot water to meet different needs [7-18]. The solar collectors are usually used in conjunction with a traditional water heater, as the weather conditions

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affect the hot water production efficiency. When choosing such a system, the traditional water heater complements the solar one heater. The addition of solar collectors with a water heating jacket can reduce electricity bills and corresponding carbon dioxide emissions in half, sometimes even more.

Along with ultramodern technologies, there are also simple solutions that bring exceptional benefits to society and the environment on a global scale. Such are solar systems for hot water production. Every day, this technology saves millions of euros and tons of carbon emissions for humanity. European policies for clean energy and energy security have made the Old Continent a leader in the field of RES technologies, in particular solar thermal ones. In the last decade, leading EU countries have created powerful instruments in support of green technologies, and this motivates millions of households and businesses to invest in these solutions [2].

Each system is built from complementary and working synchronous elements. This is also the case with thermal systems for hot water, which are composed of:

- Solar collector(s) for hot water;
- Control, monitoring, and controlling the operation of the installation with a digital display for visualizing the functions and the possibility of individual settings;
- Solar pumping station, consisting of a circulation pump, stopcocks, thermometer, flow meter, pressure gauge, safety valve, etc.;
- Pipeline, transferring heat - collector heat exchanger of a boiler - collector, built, most often, of copper or flexible stainless steel pipes;
- Boiler with one or two heat exchangers, so-called coils.

Principle of operation of solar thermal systems:

The principle of operation of solar thermal systems is based on the capture and conversion of solar energy into thermal energy by means of solar collectors. These collectors, usually with a black surface to maximize the absorption of solar rays, are located on roofs or other open areas where they can receive the maximum amount of sunlight. When the sun's rays hit the collector surface, they are converted into heat, which is transferred to a heat carrier – usually water or a special liquid, circulating through pipes inside or on the surface of the collector. This liquid is heated and then pumped to storage tanks or heating systems. Depending on the type of system, the heat can be used directly to heat buildings, domestic water, or industrial processes. Systems can be passive or active; active systems include pumps and control devices to manage the circulation, while passive systems use natural convection. The use of solar thermal systems is environmentally friendly, energy-efficient, and allows for a significant reduction in heating costs, while also contributing to reducing the carbon footprint.

It is recommended that the collector be oriented to the south. In case it is impossible to comply with this condition, it is advisable to orient the collector to the southeast or southwest with an inclination of several degrees. The optimal inclination of the solar collectors is in the range from 30 to 60°, with an inclination of 45° being considered optimal. It is believed that with this orientation and inclination, the total daily transformation of energy has a maximum. Application and return on investment. [2-5].

Solar hot water systems are applicable both in residential buildings and villas as well as in tourist complexes (hotels, guest houses, spa centers, swimming pool complexes); public buildings (hospitals, schools, kindergartens, etc.); shopping centers; industrial enterprises; and agricultural sites (farms, greenhouses, dryers). [1-7].

2. PROJECT DESCRIPTION

Solar hot water systems benefit from the sun's radiant energy (so-called radiation), converting it into thermal energy for domestic, public, and business needs, most often for sanitary and hygienic needs: washing, bathing, low-temperature heating, but sometimes also for heating water for providing industrial and agricultural processes.

The basic principle in the functioning of solar thermal systems is the cyclicity of the performed thermal transmission. This process starts when a certain difference is detected (individually set, most often 5-7ºC) between the water temperature in the boiler and the fluid in the manifold.

For example, if the temperature of the solar collector is 5ºC higher, this is recognized by the electronic control, which signals the pump station to start cooling of the solar collector and parallel heating of the heat exchanger, by circulating a heat-carrying fluid from the manifold to the water heater. The cycle continues until equalization at both temperatures. Temperatures are reported through thermal sensors mounted in special "sockets" in these two components. The solar system itself is protected from overheating, as by default the electronics cut out the heat transfer when the water heater reaches a temperature of 60-70ºC. In this system, the pressure in the pipe network is assumed from an expansion vessel with precisely dimensioned individual volume, which accommodates the expansion of the heat transfer fluid to the coming of night when the system self-cools.

An optimal place for mounting the solar collectors is the roof of the relevant building or site on a supporting metal construction. An important condition is that the collector is put in an open and unshaded place. Another good solution for the installation of the solar collectors is their integration in structures – roof, wall, incl. as an enclosing element, which turns them into an element of the architecture of the given building. For this purpose, special collectors have been developed, which function even when mounted at 90 or 180º.

Figure 1 illustrates a solar energy collection system that includes solar collectors located outdoors, on the roof of an open-air building, oriented towards the sun to maximize solar radiation capture. The collectors are connected to pipelines through which the heat carrier (a special fluid) is circulated, which is heated by solar energy and then transfers the heat to storage tanks or to heating systems. Figure 2 shows the schematic layout of the buildings on the site, emphasizing the position of the solar collectors relative to the buildings and areas for optimal solar energy capture. This figure illustrates the strategic placement of the buildings and solar systems to maximize solar collection efficiency and minimize shadows and losses, thus optimizing the use of solar energy for heating and hot water.

When the building was photographed, it was found that thermal insulation was not laid correctly on the hot water pipes for domestic needs.

There is no thermal insulation on the pipes and in the technical premises, already at the exit from the boilers.

In the boiler room, the insulation is old and burnt; in places, it is even missing.

This is a prerequisite for large energy losses already at the outlet, as well as along the entire pipe network.

Proposed energy saving measure 1:

The measure includes the installation of thermal insulation from microporous rubber with a thickness of 13 mm on all tubes piping for hot water transfer in the building, and on thermal insulation from microporous rubber with a thickness of 19 mm, sheathing with galvanized sheet metal on pipe distributions located outdoors.

Energy saving measure 2:

Construction of a domestic water heating installation needs harnessing solar energy.

Existing position.

The building has a central supply system.

Hot water. It was built independently for each case boiler room in which water containers are located, produced in 2001. With electric heaters as follows:

ZONE 1 – MIDDLE FOREST BUILDING 1;

Two boilers are installed in the boiler room, each with a capacity of 4m3, and each is equipped with an electric heater of 60kW.

ZONE 2 – MIDLAND FOREST BUILDING 2

Three boilers are installed in the boiler room, each with a capacity of 4m3, and each is equipped with an electric heater of 60kW.

AREA 5 – GALLEON HULL

Four boilers are installed in the boiler room, each with a capacity of 4m3, and each is equipped with an electric heater of 60kW.

ZONE 3 and ZONE 4 – CENTRAL BODY

For the supply of hot water for the domestic needs of Central case, the system is tied directly to a speeder water-to-water heat exchanger.

Fig. 1. Solar Collection System.

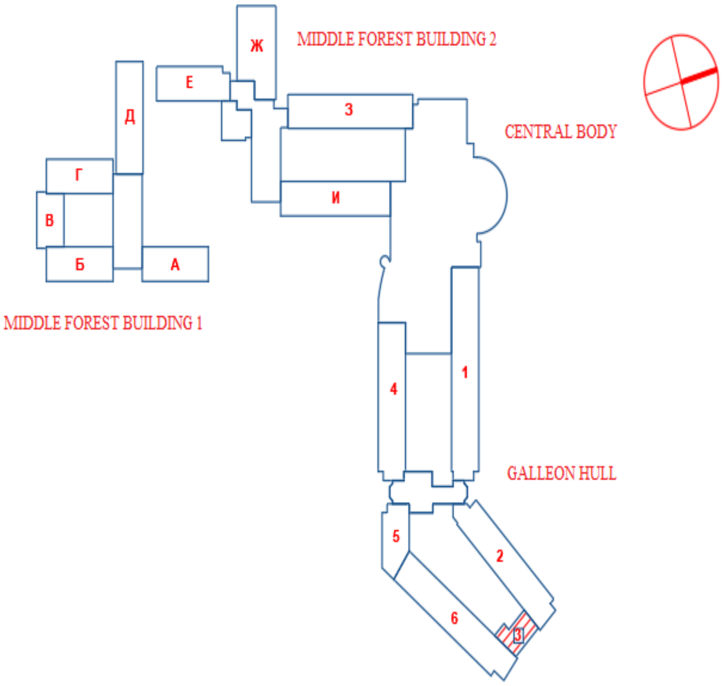

Fig. 2. Location of the buildings on the site

The main source of heat for heating water for household needs for all households is a water-heating gas boiler with a power of 350- 380kW working on propane-butane, installed in a boiler room located next to.

Central body. The heat carrier obtained from the gas boiler by means of a "water-to-water" speed heat exchanger heats up water for domestic needs. The heated water enters the water containers in the boiler rooms of the individual cases. The electric heaters for the boilers heat the water in case of a power shortage or in emergency situations.

This is how the domestic water heating scheme was built, which is a prerequisite for losses already at the exit from the heat source because the heat carrier does not enter directly into the volume to be heated (boilers are not used with the coil), and losses are already present in the high-speed heat exchanger.

The scheme also implies more frequent heating of the water by means of the installed electric heaters at increased consumption.

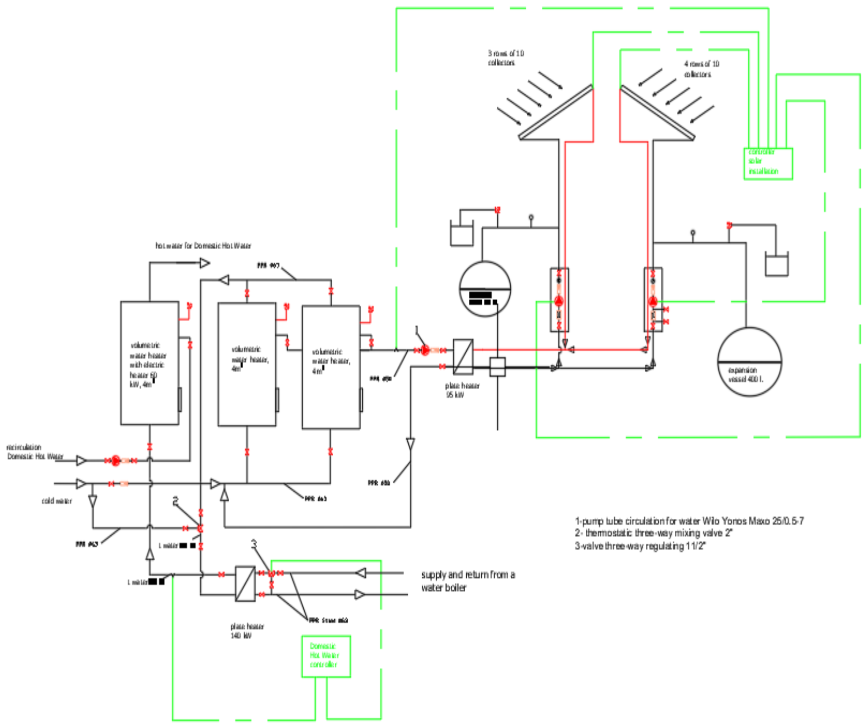

Fig. 3. Solar Collection System MIDDLE FOREST BUILDING 1.

Figure 3 shows the schematic layout of the collectors and the management of the domestic hot water heating system for the building MIDDLE FOREST 1.

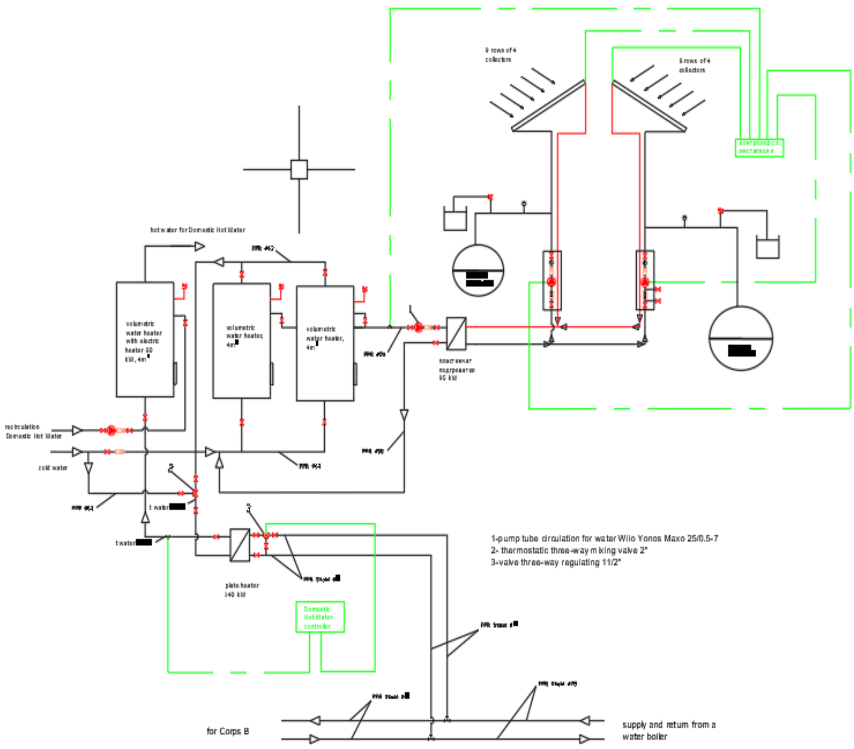

Fig. 4. Solar Collection System MIDLAND FOREST BUILDING 2

Figure 4 schematically shows the arrangement of the collectors and the management of the domestic hot water heating system for the SREDNA GORA 2 building. The difference with Fig. 2 is in the number of collectors and, accordingly, the expansion vessel.

Figure 5 shows – 5 rows of 6 collectors are placed in this housing Galleon Hull.

The location and number of collectors are tailored to the area of the roofs of each building, and the volume of the boilers and expansion vessels.

The planned energy-saving measure does not contradict the current regulations for environmental protection.

Their implementation leads to a reduction in CO_2 emissions. The equipment is state-of-the-art and therefore does not pose a danger to the environment.

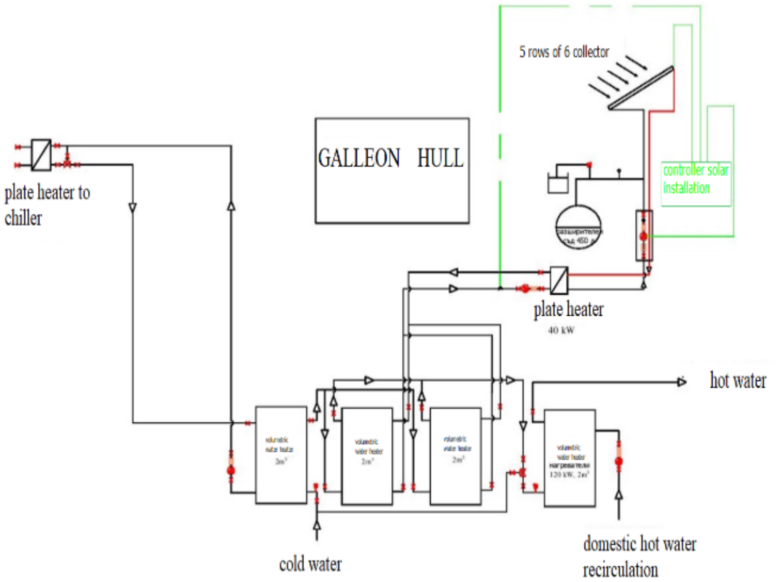

Fig. 5. Solar Collection System GALLEON HULL

3. SOLAR COLLECTION SYSTEM

Along with ultra-modern technologies, there are also simple solutions that bring extraordinary benefits to society and the environment worldwide. That's exactly what solar hot water systems are like. Every day, this technology saves millions of euros and tons of carbon emissions for humanity. European policies for clean energy and energy security have turned the Old Continent into a leader in the field of RES technologies, in particular solar thermal [7-18].

In the last decade, leading EU countries have created powerful tools to support green technologies, which have motivated millions of households and businesses to invest in these solutions.

Solar hot water systems are applicable both in homes and villas as well as in tourist complexes (hotels, guest houses, spa centers, complexes with swimming pools); public buildings (hospitals, schools, kindergartens, etc.); shopping centers; industrial enterprises; and agricultural facilities (farms, greenhouses, drying facilities).

4. CONCLUSION

An installation for heating water for household needs using solar energy was built in a hotel complex.

After the implementation of such a system, with proper maintenance and operation, water heating savings when using a gas boiler are reported as follows: propane-butane up to 45% and electricity up to 8%, which shows the cost reduction and positive side of implementing such integrated systems.

REFERENCES

[1] B. WINTHER-JENSEN AND F. KREBS, High-Conductivity Large-Area Semi-Transparent Electrodes for Polymer Photovoltaics by Silk Screen Printing and Vapour-Phase Deposition (2006) *Solar Energy Materials and Solar Cells* **90** (2) 123–132, online: https://doi.org/10.1016/j.solmat.2005.02.004.

[2] C. LUNGENSCHMIED, G. DENNLER, H. NEUGEBAUER AND ET. AL., Flexible, Long-Lived, Large-Area, Organic Solar Cells (2007) *Solar Energy Materials and Solar Cells* **91** (5) 379–384, online: https://doi.org/10.1016/j.solmat.2006.10.013.

[3] G. LI, R. ZHU AND Y. YANG, Polymer Solar Cells (2012) *Nature Photonics* **6** (3) 153–161, online: https://www.nature.com/articles/nphoton.2012.11.

[4] W. WONG AND A. SALLEO, Flexible Electronics: Materials and Applications (2009) Springer Science & Business Media, online: DOI 10.1007/978-0-387-74363-9.

[5] J. HAMBRICK AND D. NARANG, High-Penetration PV Deployment in the Arizona Public Service System, Phase 1 update (2012) 38th IEEE Photovoltaic Specialists Conference, Austin, TX, USA pp. 1-4, online: https://doi.org/10.1109/PVSC.2012.6317555.

[6] M. PRIMORAC, D. ŠLJIVAC, Z. KLAIĆ, AND ET. AL., Microgrid Energy Management System in a Public Building (2016) International Conference on Smart Systems and Technologies (SST) pp. 103-108.

[7] L. MARTIRANO, S. ROTONDO, M. MANGANELLI AND M. KERMANI, A Smart Microgrid for Buildings of the Public Administration (2020) IEEE Industry Applications Society Annual Meeting, Detroit, MI, USA, pp. 1-4, online: https://doi.org/10.1109/IAS44978.2020.9334918.

[8] A. MARTYANOV, D. KOROBATOV AND E. SOLOMIN, Simulation Model of Public Street Lighting Provided by a Photovoltaic Converter and Battery Storage (2017) International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM), St. Petersburg, Russia, pp. 1-5, online: https://doi.org/10.1109/ICIEAM.2017.8076213.

[9] J. OVIEDO-CEPEDA, F. AMARA AND A. ATHIENITIS, Model Predictive Control Horizon Impact Over the Flexibility of a Net Zero Energy Building (2021) IECON 2021 – 47th Annual Conference of the IEEE Industrial Electronics Society, Toronto, ON, Canada, pp. 1-6, online: https://doi.org/10.1109/IECON48115.2021.9589828.

[10] D. JIMENEZ, L. CARRASCO, R. EYRAS AND ET.AL., Architectural Integration of Grid Connected Photovoltaic Systems for Schools in Coslada (2003) 3rd World Conference on Photovoltaic Energy Conversion, Proceedings of, Osaka, Japan, pp. 2370-2374, online: https://ieeexplore.ieee.org/document/1305066?arnumber=1305066.

[11] M. YOUNG, The Technical Writer's Handbook (1989) Mill Valley, CA: University Science.
[12] LUXOR SOLAR GMB, Photovoltaic Panel Luxor 540W Mono Eco Line Half Cell LX-540M/182-144+, 2020.
[13] D. MALAMOV, I. HADZHIEV, V. ZLATANOVA AND ET.AL., Analysis of a Wind Farm with SCIG Integrated into a High-Power System (2020) *Compel – The International Journal for Computation and Mathematics in Electrical and Electronic Engineering*, **39** (3) 637 – 645, online: https://doi.org/10.1108/COMPEL-10-2019-0383.
[14] I. HADZHIEV, D. MALAMOV AND A. GEORGIEV, Analysis of Earth Faults in a Wind Farm Integrated into the Electric Power System (2015) IOP Conference Series: Materials Science and Engineering, Plovdiv, Bulgaria, **878** (1)1-8, online: http://dx.doi.org/10.1088/1757-899X/878/1/012015.
[15] A. NOURI, S. KHADEM, A. MUTULE AND ET.AL., Identification of Gaps and Barriers in Regulations, Standards, and Network Codes to Energy Citizen Participation in the Energy Transition (2022) *Energies* **15** (3) 856, online: https://doi.org/10.3390/en15030856.
[16] R. STANEV AND P. NAKOV, Power System Stabilizers for Inverter-Dominated Future Power Systems (2020) 21st International Symposium on Electrical Apparatus & Technologies (SIELA), Bourgas, Bulgaria, online: https://doi.org/10.1109/SIELA49118.2020.9167134.
[17] K. HADZHIYSKA AND D. STOILOV, Multi-Criteria Analysis Approaches for Energy System Development Scenario — Review (2023) 18th Conference on Electrical Machines, Drives and Power Systems (ELMA), Varna, Bulgaria, pp. 1-9, online: https://doi.org/10.1109/ELMA58392.2023.10202557.
[18] D. STOILOV, D. TONEV, K. ANGUELOV AND K. HADZHIYSKA, Energy Planning in Bulgaria (2022) V International Conference on High Technology for Sustainable Development (HiTech), Sofia, Bulgaria, pp. 1-6, online: https://doi.org/10.1109/HiTech56937.2022.10145524.

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