Efficiency of dual hot water systems with the use of solar evacuated tube collectors in the Northern territories

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Abstract. This research is aimed at studying efficiency of using solar energy in dual hot water systems with the use of solar evacuated tube collectors and central heating network in Siberian climatic conditions. The paper includes results of actual implementation of dual hot water systems with solar evacuated tube collectors and water heat up till the required temperature with the help of a gas boiler for 3-storey residential buildings or a central heating network (for “Vasilyok” kindergarten) in Zhatay city district in Yakutia. The research demonstrates that the amount of heat energy produced by solar collectors makes up over 50 % of the total consumption of hot water system of “Vasilyok” kindergarten.

1. Introduction

Over the recent years, in the framework of socio-economic development program many Russian regions, particularly northern ones, have planned partial replacement of conventional heat energy sources with renewable ones, which is caused by significant fuel transportation costs. Yakutia is in the list of Russian regions with the highest electricity tariffs. In 2018, the price was 5.68 ruble/kW-h, with the average price in Russia being 3.71 ruble/kW-h. Hot water supply tariff for residents of Yakutsk is 200.75 rubles per 1 m³. And in districts nearby Yakutsk it reaches from 400 to 700 rubles per 1 m³. In some districts of Yakutia prices even go as high as 2000 rubles per 1 m³. For most part of Siberia, including Yakutia, the average annual solar radiation values are 4.0 – 4.5 kW-h/m². Hence, application of technologies related to solar batteries and solar collectors are intensively tested in all Siberian and Far East regions, mostly in the form of pilot projects.

In spite of the fact that Western European countries started using solar heat units earlier than Russia, today the entire global academic community is deeply involved in related studies and search of the most efficient solar energy technologies [1-17].

This study is based on the pilot project of construction of an energy efficient district with the use of solar energy in hot water supply system in the framework of Yakutsk municipal targeted program “Rehousing of Zhatay district residents from dilapidated housing stock with the account of the need for low-rise housing construction in 2013-2017”.

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This is the most large-scale and successful case of dual hot water systems application in Russia with the use of solar evacuated tube collectors with heat up till the required temperature using a gas boiler (for all 3-storey buildings) or central heating network (for “Vasilyok” kindergarten).

2. Methods of Research
This study is aimed at analyzing efficiency of solar energy application in dual hot water systems with the use of solar collectors and central heating network.

Figure 1 presents a mnemonic scheme of hot water system of “Vasilyok” kindergarten. The scheme illustrates real-time operation of all the system’s parameters.

Using such mnemonic scheme in remote access mode (for instance, being located in Tomsk) one can control the level of heat energy production and consumption and perform emergencies management. The dual hot water system is supplied from the cold water metering system installed on the connection of the external water supply line to the kindergarten building. Circulation of water in hot water system is provided. Two groups of solar panels equipped with solar evacuated tube collectors serve as a source of heat for the hot water system. Bringing water temperature in the feed pipe to the required level of 50-55 °С is done by an independent gas heating station located in the territory of the kindergarten. Regulation of output and consumption of heat and electric energy, as well as control of operation and emergency safety of equipment and pipelines of the hot water system is performed using the developed automation tools. Propylene glycol-based low-freezing liquid is used as a heat transfer fluid for solar panel contours. Heat transfer fluid circulation in the panel contours is induced by three-speed pumps powered by four solar panels. Membrane pressure vessels are provided in the hot water systems to compensate for thermal expansion of heat transfer fluid. Booster pump is applied to maintain the required pressure in the contours.
The system is equipped with safety valves to ensure high pressure protection. Heat transfer fluid is discharged from the contours through drain pipes to the fluid vessel.

Reports for various operation periods of the hot water system (cumulative daily and hourly reports, interval daily and hourly reports) are generated using the main menu of the experimental complex (Fig. 2).

3. Results and Discussion
Figure 3 demonstrates a temperature graph in the feed and circulation pipelines on the hourly basis (March 1, 2019) for “Vasilyok” kindergarten.

It should be noted that the temperature in feed hot water system pipeline does not exceed 45 °C, which is lower than the required value. Analysis of annual data set showed that such situation occurs in the system in spring and fall seasons. As a result of heating system and hot water system analysis it was found that heat transfer fluid for heat up of water for hot water supply comes from the heating system of the building. Having studied temperatures of heat transfer fluid of central heating system at the entrance to the building it was found that one cannot provide the required water temperature in the feed pipeline of hot water system in the specified periods due to low heat transfer fluid temperature in the central heating system and low heat energy output by solar collectors. Radical solution to the problem is the use of electric power for water heat up in the feed pipeline of hot water system.

Figure 4 shows the graph of hot water consumption in the feed and circulation pipelines and the graph of heat energy consumption by the hot water system (March 1, 2019).
Figure 3. Temperature graph in feed and circulation pipelines by hours (March 1, 2019).

Figure 4. Consumption of hot water in feed and circulation pipelines and heat energy (March 1, 2019).

Based on the data presented in Figure 4 hourly volume of consumed hot water and heat energy can be drawn.

Figure 5 demonstrates the percentage graph for heat energy output by solar collectors and consumed heat energy from the heating network in a dual hot water system for April 2019.
Figure 5 indicates that heat energy output by solar collectors makes up more than 50% of the hot water system consumption.

4. Conclusion
The implemented dual hot water system with the use of solar evacuated tube collectors and central heating system allows saving up to 50% of heat energy, and its dispatch system enables control heating equipment and fast response to occurring emergencies. At the same time it should be mentioned that the main drawback of this object is low water temperature in the feed pipeline of hot water system in spring and fall seasons. Radical solution to this issue is using electric power for heating up water in the feed pipeline of the hot water system.

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