Schemes analysis of solar plants with automatic regulation

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Abstract. This article discusses the main fundamental options for circuit designs of solar heat supply systems (SHS) with integrated automation elements. The subject of these elements' study in this work is the degree of their influence on the operating parameters of the mentioned systems, in order to find the most versatile and effective way to optimize and increase the solar plants productivity. At the same time, the main focus was the achievement of such a result, in which the successful implementation of the renewable energy and solar heat supply systems development trend, in particular, is possible. In order to achieve the final result of the study, the analysis for the technical and economic feasibility of the considered circuit designs of solar power plants and individual parametric values from the number of these systems' operating characteristics has been carried out.

1 Introduction

The existing construction projects, whether they are residential, public or industrial buildings, along with their other functions, are also characterized by the consumption of certain resources, in particular, thermal energy. The provision of buildings and structures of the latter is carried out from various sources, which traditionally are boilers or boiler installations on gaseous, liquid or solid fuels. For energy production, one way or another, they consume any fossil fuel [1], which in turn is accompanied by the emission of pollutants into the atmosphere, and also causes an increase in the raw materials extraction level, the existing methods of which now similarly entail environmental pollution. In this regard, any methods suitable for reducing the volume of processing and extraction of fossil fuels, with the concomitant preservation of the security level, are currently extremely relevant [2]. One of such substitution methods is the use of renewable energy sources (RES) [3], among which solar energy supply is one of the leading in terms of universality and application in the world. At the same time, this direction, among other things, is characterized by the fact that it is able to provide the supply of both thermal and electrical energy without the concomitant need to convert one type of energy into another. This, for example, is not able to boast of wind energy, bioenergy and a number of other energy types.

At the same time, solar heat supply, which, under certain conditions, can effectively replace the load on the entire buildings' heat supply, in addition to environmental

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friendliness [4], is also characterized by such characteristics as low cost of energy, self - sufficiency of systems and availability in comparison with other methods, such as, for example, geothermal and bioenergy.

The introduction of a solar heat supply installation for a particular construction object does not lead to a decrease in the consumption level, but is characterized by the building or structure main heat supply system productivity replacement [5]. At the same time, it is important to understand that the solar plant itself, in general, is not a fully-fledged separate system. It is directly connected to the heating and / or hot water supply system of the facility, in order to ensure load replacement, the degree of which is expressed as a percentage of the building total consumption and varies from 1 to 100% - in general, in the range of 40-60% (regardless of the operation seasonality, redundant energy sources, type of substituted load and connection scheme) [6, 7].

One of the main goals of introducing solar heat supply installations, like any other systems based on the use of renewable energy sources, is to reduce the pollutants emission level into the atmosphere from the operation of traditional power generating installations, which is achieved by replacing the volumes of heat and electricity they produce. In this case, the indicator of the technical and economic feasibility of introducing a solar plant in a particular case plays a fundamental role. This value is dimensionless and is expressed as a coefficient, which is based on the main indicators of the selected solar heat supply system, as well as the normative data obtained through the empirical long-term research on the economic indicators of construction projects that have solar installations in the engineering systems that replace part or all of the heat load by heating and / or hot water supply [8].

2 Relevance

First of all, in order to be able to achieve the goal described earlier, it is worth paying attention to the main, basic aspects of engineering systems using alternative energy sources. So, analyzing the level of feasibility of introducing a particular solar heat supply system, it is worth considering the principle of its operation, which is based on basic thermophysical aspects.

At the same time, it should be understood that any solar plant, like any engineering system, is a complex organism consisting of various, constantly interacting, main and secondary elements. The schematic diagram of the solar heating system has the configuration shown in Fig. 1 [9].

To the same extent, an important and integral part of the solar power plants main and secondary elements' set is their operating principle, based on the flow of a number of heat and mass transfer and hydraulic processes [10]. The fundamental and comprehensive process in this case is accumulation - the process of absorption, transformation and accumulation of energy. Through this phenomenon, the solar energy entering the surface of the solar collector aperture is absorbed by it and, due to heat exchange, is transferred to the coolant flowing through the pipes, which heats up and enters the storage tank, where heat energy is accumulated and stored in the form of heated water. It is also important to understand that there is no direct mixing of the coolant circulating through the pipelines of the solar heat supply system and heating or hot water supply systems. Separate circulation circuits are arranged in such way, that the heat exchange between which takes place in the storage tank through a dividing wall that looks like one or a plurality of coils.

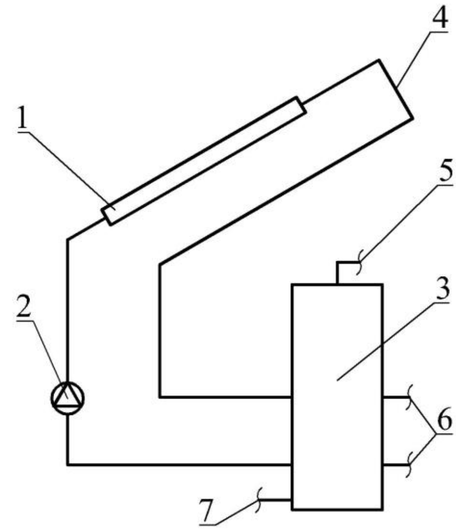

Fig. 1. Schematic diagram of a solar heating system: 1– solar collector; 2 - pump (pump group); 3– storage tank (storage capacity); 4 - pipelines (supply and invert); 5 - selection for hot water supply; 6 - connection of the heating system; 7 - water supply pipeline.

Along with other things, storage tanks, like any heat storage tanks, are largely insulated in order to avoid unnecessary losses of thermal energy. Nevertheless, one way or another, these measures are often insufficient, which periods is accompanied by a loss of heat energy, sometimes in the amount of up to 100% of its amount accumulated per day during cooling [11]. This, in turn, affects such indicators of a solar plant as the efficiency involved in calculating the technical and economic feasibility of introducing a solar heat supply system to a particular construction object.

There are many traditional ways to reduce heat loss in solar thermal systems. The insulation of the system elements' main heat-conducting parts: pipelines and a storage tank are traditional as already discussed earlier. However, even this is characterized by colossal losses and a decrease in system performance. To increase the efficiency indicators and efficiency of solar plants, and, consequently, the technical and economic feasibility of their implementation, other, more adapted, universal and, equally important, suitable for a joint device in one system, methods of reducing heat losses have been developed, as in periods of cooling and heating [12]. Nevertheless, even these methods are not characterized by high efficiency, despite the comparative increase in the SHS efficiency indicators. In other words, solar power plants, in their current configuration, often do not have sufficient efficiency indicators, which leads to a low technical and economic feasibility of their implementation, and often, moreover, gives rise to the lack of the possibility of using them in the northern regions.

At the same time, the described problem does not have sufficient illumination in the periodical literature. Despite the fact that the problem of environmental deterioration is extremely significant and relevant, all existing ways of implementing the development concept in this area, in particular, increasing the efficiency of solar heat supply systems, are characterized by triviality. There are practically no fundamentally new technical solutions aimed at achieving the global result. Basically, development is carried out using one of two main ways of moving technical progress, namely the existing technologies' improvement.

3 Problem statement

So, one of the solutions to the problem described above is, for example, the development of solar energy receivers for intensified heat exchange, the basis for the implementation of which is primarily an analysis of the efficiency and economic feasibility of technically improved structural elements of a flat solar collector. At the same time, the actual side of the stated concept is the study of the thermal energy accumulation process by solar plants. The purpose of this study is to improve the main performance characteristics in solar heat supply systems and to intensify the process of solar collectors' heat exchange. The formulation of the problem is to optimize the operation of solar collectors directly, which not only ensures its efficient generation, but also to some extent increases the overall efficiency of the system.

However, what has been described does not exclude and does not even reduce the level of heat energy losses, but directly only increases it - an increase in the productivity level, with the same thermal protection indicators, causes an increase in natural heat losses [15] of the solar plant. Consequently, the achievement of the main goal - increasing the technical and economic feasibility of introducing solar plants, by increasing their productivity, has significant limitations, in particular, they do not solve such a problem as the possibility of arranging solar heat supply systems in northern latitudes. In particular, the probability of the system complete cooling during periods of solar radiation low intensity (for example, at night or with high clouds) is not excluded.

Thus, in order to achieve the previously described global goal, which is the possibility of using solar power plants instead of traditional heating systems for buildings and structures, with the concomitant leveling of pollutant emissions from fossil fuels combustion, as well as with a decrease in demand and, therefore, the need to extract the latter, a different approach should be chosen in principle. For this, first of all, a comparative analysis of the already existing variants of circuit solutions for solar installations should be carried out, which will allow choosing a universal device for a solar heat supply system and developing a further research concept that meets the outlined plans.

4 Theoretical part

So, the thermal energy absorption and conservation intensification concept implementation during the operation of solar power plants is feasible, first of all, due to the conduct of analytical research work aimed at identifying existing conceptual methods for the active SHS device. Based on the results of the described actions, it is possible to determine the most appropriate option for achieving the set task, while being suitable for modernization and improvement [16]. Thus, the active SHS device is possible in one of the following ways:

1) Traditional - combination with a water (radiator or other) heating system, where SHS acts as an additional source of thermal energy, providing hot water with a higher temperature in the area in front of the heating system boiler (Fig. 2). In this case, a higher efficiency of the building heating system is provided by reducing the energy consumption of the boiler for heating the coolant. However, such a solution requires the introduction of an automation system that links the indicators of both systems and provides the function of shutting off the water supply from the SHS during the periods when the water temperature in the solar heat supply system is lower than the temperature of the coolant in the return pipe of the heating system, as well as during periods when the water temperature in SHS is higher than the temperature of the heating medium in the supply pipe of the heating system. To do this, without fail, a temperature sensor and a shut-off valve on this pipeline from the

SHS are placed on the return line in the place before connecting the feed pipeline, as shown in Fig. 2.

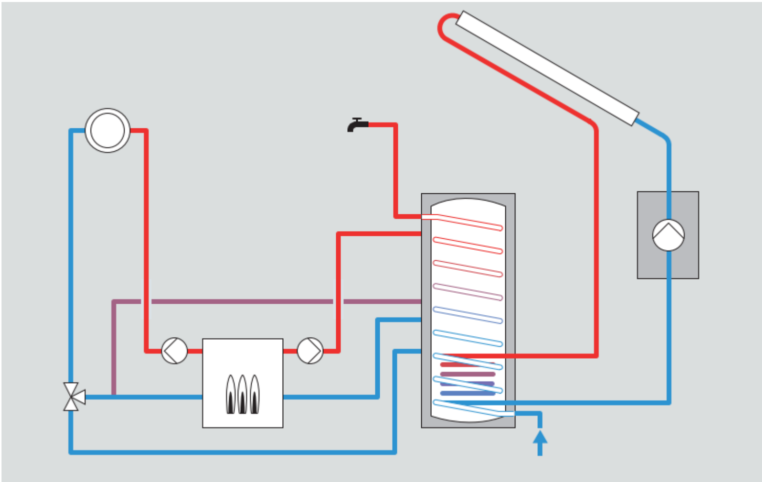

Fig. 2. SHS combining with water heating system

2) The introduction of thermoelectric heaters into the SHS storage tank [17] with a calculated power sufficient to maintain a constant temperature of the coolant required to ensure a given flow rate, both for the hot water supply system and the building heating system (Fig. 3), which eliminates the need for a duplicate heat source energy.

3) The device of a powerful solar collector field (Fig. 4), providing 100% of the annual load, taking into account cooling and possible consumption at night and in the morning, which is achievable through the use of vacuum collectors. This solution has an extremely low technical and economic feasibility, due to high capital investments and high operating costs for maintenance and repair, as well as the need to ensure the conditions for this solar collector field location. But the actual possibility of providing thermal energy for the needs of heating and hot water supply without the use of redundant systems, gives a possibility to achieve higher energy efficiency and environmental security. It is also possible to introduce thermoelectric heaters into the storage tank (Fig. 3).

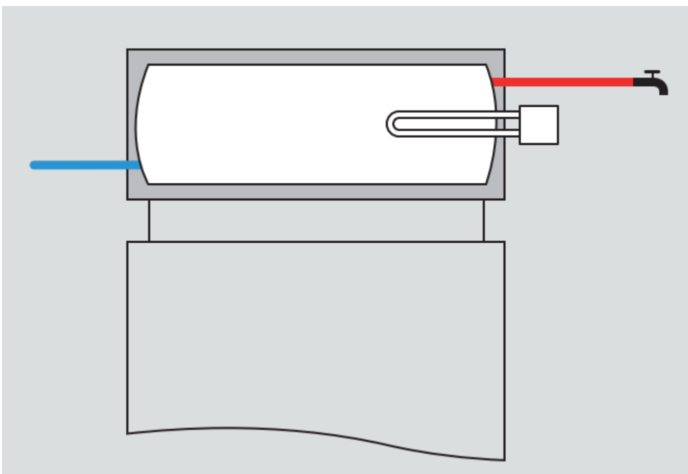

Fig. 3. Introduction of heating elements into the SHS battery tank

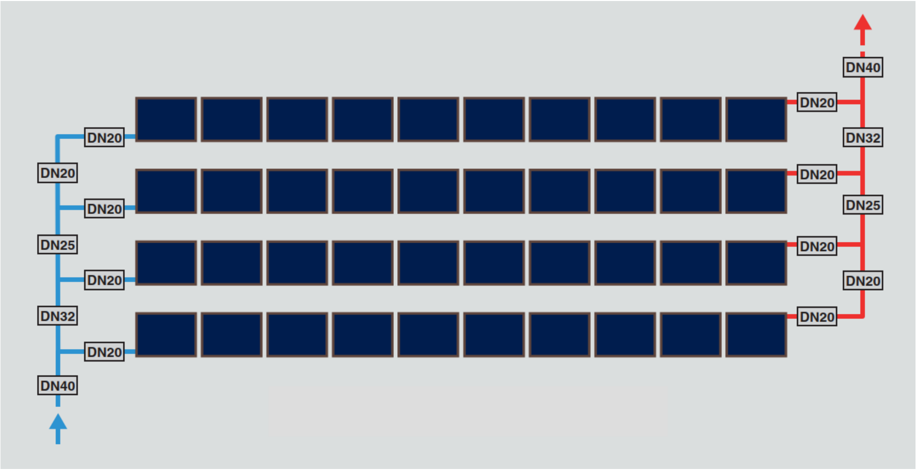

Fig. 4. Heliopolis

5 Practical significance

Based on the above-said, we can conclude the following.

Without fail, for any chosen solution from those discussed above, it is necessary to provide for automatic regulation of the thermal energy flow into the SHS. In the first case (Fig. 2), this aspect is achieved by arranging a set of instrumentation and a controller, which form a single automation system that analyses the coolant indicators at various points of the solar heat supply system and controls shut-off and control valves relative to specific conditions. At the same time, the parameters of the internal and external environment are taken into account directly by the heating system of the building, the regulation of the coolant temperature and flow rates in which a change in the amount of heat energy taken from the heat storage capacity of the SHS is provoked. In view of this, there is no need to link the control and regulatory and reading the heating systems' data, solar heat supply and hot water supply directly. Each system is equipped with a set of instrumentation and shut-off and control valves within the limits of its operation, while each of the systems also conventionally has its own energy source and its consumer, where solar energy and a collector act as a source for SHS, and heating and hot water systems are used as consumers of water supply; for the heating system and hot water supply, the source is the solar plant, the consumer is a person (conditionally). Thus, a cascade control of the system complex is formed, in which, depending on the section and stage of the coolant circulation, the principle of the operating mode regulation is subdivided: natural, due to thermophysical and hydraulic characteristics, or mechanical, through the operation of elements that read, process and transmit signals to the shut-off -regulatory fittings and other elements (heaters, etc.).

In the second case (Fig. 3), automatic regulation of the heat energy flow into SHS is achieved by installing a heating element in it, which acts as an additional source of energy that maintains the temperature of the coolant in the heat storage tank in a given range (usually about 55 ° C). In this case, an automation system similar to the first (Fig. 2) is installed, which takes into account the temperature of the coolant at the inlet and outlet of the collector, at the inlet to the storage tank and directly integrated in the tank itself, for which the corresponding sections are equipped with temperature sensors. The readings from the mentioned devices are transmitted to the controller, which processes the received signals about the coolant parameters in each section of the network, and, according to a given algorithm, transmits control commands to shut-off-regulating and other SHS devices.

In the third case (Fig. 4), the automation systems' elements arrangement is in many respects similar to the first, in one only difference, which consists in the need to install a set of series or parallel connected heat storage tanks [18]. At the same time, the separation of the solar collector field itself into separate circulation circuits is also often performed, which are subsequently connected in the mains. The described, in turn, requires the installation of additional control and measuring devices, namely the temperature sensors in the input sections of each separate heat storage tank and sensors identical to the first directly on each separate section of the solar collector field.

Summarizing and structuring the above-said, we can conclude that the most universal and most technically and economically feasible implementation method will be one that combines the three previously described, since the disadvantages inherent in certain types of solar power plants in it will be leveled by the advantages of others, and the advantages the latter are multiplied by the prevailing characteristics of analogs. This will ultimately make it possible to implement a symbiosis of the existing traditional circuit solutions for the solar heat supply systems within the framework of the fundamental concept of intensifying the efficiency indicators of solar power plants and increasing the technical and economic indicators when implemented in any possible conditions [19].

6 Conclusion

The development of technologies for the renewable energy sources use, in particular solar energy, is one of the prevailing ways of implementing the environmental security concept and, in general, achieving the fundamental goal of techno spheric safety [20]. Along with this, the above-mentioned is one of the factor-forming aspects of the construction industry development and the implementation of the tendency to increase the technical and economic indicators of the energy policy in the whole world [21]. In continuation of the topic considered in this work, the authors of the article plan to carry out further research aimed at finding a solution to the problem of thermal energy losses during the solar plants operation.

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