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JUSTIFICATION OF HEAT-TECHNICAL PARAMETERS OF HYBRID HEAT AND HOT WATER SUPPLY SYSTEM

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ABOUT ARTICLE

Key words: Hybrid heat supply system, vacuum solar collector, a heat pump device, working body, heating coefficient, cooling coefficient.

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Abstract: In the article, a heating scheme of a hybrid heat and hot water supply system based on vacuum solar collectors and heat pump devices for country houses and model houses is proposed. The operating procedure of the hybrid heat and hot water supply system is presented. The hybrid heat and hot water supply system is connected to a vacuum solar collector and a heat pump device connected to an underground heat source (sewage well) through a tank accumulator. Heat-technical calculation of tank-accumulator and heat pump device is given. The energy consumption of the heat pump device used in the hybrid heat supply system is 2.5 kW, and the heat and hot water supply system produces 22, 65 kW of heat energy for the tank accumulator, which is 20÷25 more than boiler devices and electric heating devices in traditional heat and hot water supply systems. It is based on the fact that it has up to 25 times energy efficiency.

Taking into account the meteorological climate parameters of the Kashkadarya region, the heating season is 135 days, in the hybrid autonomous heat supply system of the proposed rural houses and model houses, it is possible to save 73,386 kW of electricity or use 30÷40 tons of conventional fuel due to the use of only a 2.5 kW heat pump device. It is scientifically proven that savings can be made.

INTRODUCTION

Today, mankind is faced with the problem of environmental crisis related to habitat destruction. Energy and industry have given humans unprecedented power, but it has also threatened their existence and peace. Renewable "GREEN" energy sources such as solar and wind energy are free of toxic emissions and environmentally friendly [1-5].

However, at present, almost all spheres of human activity, including the modern economy and social sphere, are based on the use of energy resources that are depleting and non-renewable. As a result, environmental air pollution, energy shortages for consumers, health risks, climate change, price volatility in hydrocarbon markets, and problems in the population's fossil fuel-based energy supply systems are becoming acute and global with the development of urbanization [4-8].

Modern methods of energy production cause irreparable damage to nature and humanity. Natural fuels: Burning oil, coal, and gas releases pollution, carbon dioxide (CO2), and other greenhouse gases into the atmosphere. Atmospheric pollution caused by the use of non-renewable energy sources leads to climate change, resulting in the melting of polar ice caps and rising sea levels. The reduction of natural ecosystems leads to a decrease in the stability of the environment and the deterioration of its quality of life [9-12].

Several decades ago, it became known that the amount of greenhouse effect substances (carbon dioxide, methane, nitrogen oxides, etc.) in the atmosphere has increased dramatically over the past 250 years. This is primarily due to the burning of fossil fuels, deforestation, and the expansion of agricultural land, which have been built up on the earth over millions of years. In the last half-century, there has been an increase in the planetary greenhouse effect. The amount of carbon dioxide in the atmosphere is constantly increasing. Today, there are reasons to believe that human activity has had a significant impact on changes in the Earth's climate system.

According to climate change, by 2030-2050, the temperature increase in Central Asia will be +1°C to +3°C. If measures are not taken to stabilize CO2 levels, reduce emissions, restore forest ecosystems, and continue to accumulate greenhouse gases in the atmosphere, the temperature increase by the end of the century may be + 3°C + 6°C [12-15].

Therefore, the need for an energy supply system based on renewable and alternative energy sources is increasing, which, in turn, requires the implementation of integrated energy supply systems based on renewable energy sources, and the rapid resolution of priority tasks for achieving energy production indicators based on renewable energy sources.

Methods and materials: The widespread use of energy complexes with a number of renewable energy sources to provide energy to rural houses and model houses, located far from energy supply systems, is the basis for the formation of new approaches to the fundamental, theoretical, and practical development of renewable energy.

Modern energy is characterized by the increasing trends of diversification of energy sources based on the development of new technologies, improvement of security systems, and acquisition of new composite materials and remote control devices [12-18].

In rural areas, in particular, in residential model houses, the heating system in the winter season is carried out by means of a water heating boiler that works on coal or natural gas, and at the same time, in most cases, an autonomous air conditioner that works on electricity. An autonomous hot water supply is organized by using an electric water heater (Ariston) or using coal or natural gas. Such systems do not work during power outages or emergency situations, and in most cases, the air conditioner, boiler heating system, and autonomous electric heaters work together and lead to high electricity consumption.

In particular, there is no integrated system that optimally combines the conventional heat supply system with solar water heating collectors, which are being installed a lot now, technologically, technically, and economically. This issue will be of great importance, especially in the transition of facilities in rural areas from natural gas to coal.

In the developed countries of the world, scientific and research work is also being carried out on the development of the concept of management of integrated intelligent energy supply systems, Smart Grid and smart metering.

In this article, the authors proposed a method of transferring rural facilities, i.e. consumers with decentralized energy supply (decentralization), to integrated energy supply based on solar collectors, heat pump devices, and a warm floor heating system, which increases savings, increases reliability, and reduces CO_2 emissions into the atmosphere (improved technological schemes of autonomous heat supply for decarbonization) and their technological solutions based on thermal-technical, thermal-heliotechnical calculation methods are proposed.

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The proposed combined autonomous hybrid heat and hot water supply system allows for providing high-quality and stable energy to the heating and hot water supply systems of the building using direct solar energy a heat pump, and a tank accumulator.

According to the proposed scheme, the heat and hot water supply system of rural houses and model houses is implemented on the basis of vacuum solar collectors, heat pump devices, water warm floor system, and their combination. The vacuum solar collector is designed for the production of hot water or hot air, the heat pump unit is connected to a low-potential underground heat source (sewer well), and the system consists of a vacuum solar collector, a heat pump unit, a tank-accumulator, a water-based warm floor system, and heat exchangers. and includes pipes and fittings. An important condition for the use of the proposed hybrid heat supply system is the uninterrupted and reliable operation of heat and hot water supply, regardless of time, heating season, or meteorological characteristics of the local climate (weather conditions). consists of transmission through the hot water supply system. On cloudy, evening, and low-temperature days, it is provided by a heat pump device connected to a low-potential heat source.

The most efficient thermal scheme of a hybrid heat and hot water supply system is shown in Figure 1 below.

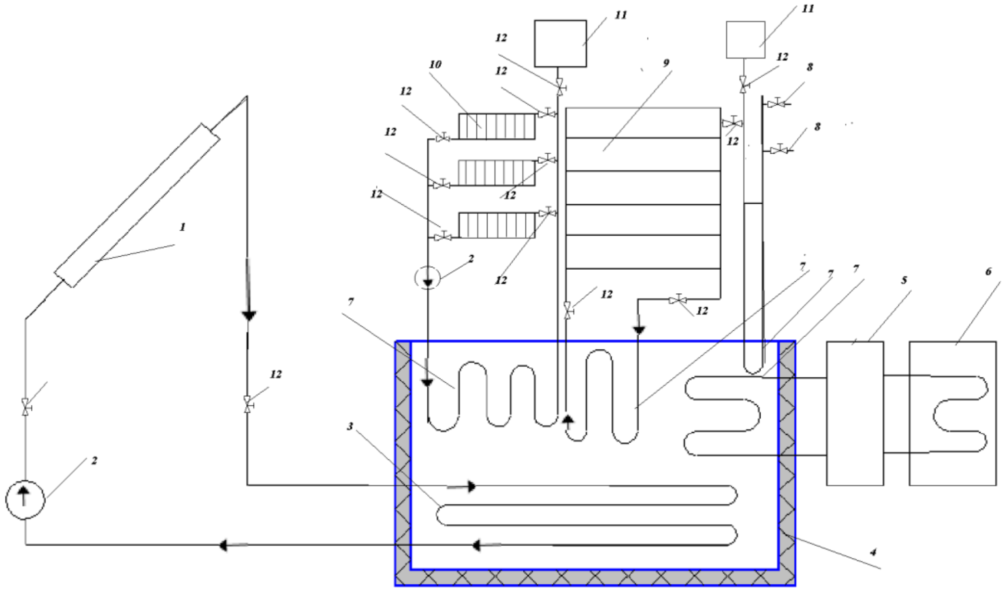

Figure 1. The principal scheme of the hybrid heat supply system.

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1-vacuum solar collector; 2-circulation pump, 3-spiral heat exchanger; 4-tank-accumulator; 5-heat pump device; 6- underground heat source (sewage well); 7- spiral heat exchanger; 8-hot water supply system; 9-water heated floor system; 10-heat supply system; 11-cold water tank; 12- valves.

The hybrid heat supply system proposed by the authors works in the following order:

Heat supply system: The heat supply system consists of the following elements. Heat supply system 10, circulation pump 2, cold water tank 11, valves 12, spiral heat exchanger 7, and tank-accumulator 4. Open the valve 12 and fill the heat supply system 12 with reserve water in the cold water tank 11. The circulation pump 2 circulates the water in the system, as a result, the cold water circulates through the spiral heat exchanger 7 located in the tank-accumulator 4, heats up due to convective heat exchange, and circulates in the heating system through the valve 12 based on forced convection and keeps the temperature of the building air moderate.

Water-based warm floor system: The water-warm floor system consists of the following elements: spiral heat exchanger 7; tank-accumulator 4, water-warm floor system 9, 11-cold water tank, 12-valves. By opening valve 12, the water warm floor system 9 is filled with reserve water in the cold water tank 11, the water is heated by free convection due to convective heat exchange through the spiral heat exchanger device 7 located in the tank-accumulator 4, and the room is additionally heated through the water warm floor system 9, which in turn prevents heat loss through the floor of the room.

Hot water supply system: The hot water supply system consists of the following elements: Tank-accumulator 4, spiral heat exchanger 7, hot water supply system 8; cold water tank 11, valves 12.

By opening valve 12, the hot water supply system 8 is filled with reserve water in the cold water tank 11, the water is heated by convective heat exchange through the spiral heat exchanger device 7 located in the tank-accumulator 4 and is transferred to the consumer through the hot water supply system 8. The hot water moves through the cold water tank due to the pressure generated.

Heat accumulation occurs due to the inconsistency between the duration of solar energy during the day and year, the amount of radiation, the metrological climate parameters of the area, the level of air pollution, as well as the schedule of consumption of heat production and heat supply systems of solar devices. The maximum level of solar radiation occurs at noon and the minimum in the evening and at night, but the need for thermal energy for heating and hot water supply continues throughout the day. So is the seasonal difference between solar energy production and use. Therefore, when energy production exceeds consumption, its surplus is stored in storage tanks.

Tank batteries are surrounded by insulating materials to prevent heat loss through heat exchange devices. Their use is carried out in two stages: the first is to charge the tank accumulator with thermal energy and the second is to discharge it, that is, the efficient use of thermal energy in the heat and hot water supply system. Depending on the duration of the cycle, hourly, daily, and seasonal tank accumulators differ, and according to the temperature range: operating temperature of tank accumulator for air heating systems - 28÷30°C, hot water supply - 45÷60°C, for water heating system up to 80÷85°C.

Charging of the tank battery with thermal energy is carried out in two stages.

The first. A spiral heat exchanger 3 is installed in the tank accumulator 4 and is connected to the vacuum solar collector through a pipe system. Under the influence of solar energy, the working body in the vacuum solar collector, water is heated in the temperature range of 90÷95°C and is circulated in the spiral heat exchanger 3 through the circulation pump 2. Due to the temperature difference of the working body in the tank battery, heat is exchanged and the tank heats up the temperature of the working body in the battery in the temperature range of 80÷85°C. And the process works depending on the duration of the sun.

The second: a spiral heat exchanger 7 is installed in the tank accumulator 4 and connected to the heat pump device 5 through a pipe system. The heat pump device is connected to the underground heat source (sewage well) 6 and converts the low-temperature source temperature to the high temperature of the working body. As a result, the tank charges the battery with additional heat energy during cloudy, evening, and cold seasons.

The amount of heat of the tank-accumulator is determined using the following formula [19-23].

$$Q_{ac.} = M_{ac.} \cdot C_{ac} (t_{1ac.} - t_{2ac.})$$

The ratio of the heat amount of the tank-accumulator $Q_{ac.}$ to the volume of the tank-accumulator is called the specific heat amount of $V_{ac.}$ m³: $q_{v.} = \frac{Q_{ac.}}{V_{ac.}}$.

Charging the tank battery with thermal energy $\tau_{char.}$ depends on the structural structure and size of the tank battery, as well as the thermal efficiency of the vacuum solar collector $Q_{h.}$:

The charging of the tank battery with thermal energy is calculated by the following expression:

$$\tau_{char.} = \frac{Q_{ac.}}{Q_{h.} \cdot Q_{h.lost.v.c.} \cdot Q_{h.lost.ac.} \cdot Q_{h.lost.tube}}$$

Here, $Q_{h.lost.v.c.}$ - Heat loss in the vacuum solar collector, W, $Q_{h.lost.ac.}$ - heat loss in the storage tank, $Q_{h.lost.tube}$ - heat loss in the pipes of the heat supply system, W.

A heat pump device uses the environment's natural renewable low-potential heat energy (ground heat, heat from a sewage well) and raises the potential of the primary cooling water to a high level while consuming several times less primary energy or natural energy. The heat pump device works according to the thermodynamic Carnot cycle, in which low-temperature fluids (ammonia, freon, etc.) act as the working fluid. The transfer of heat from a low potential source to a high-temperature level is carried out in a compressor with mechanical energy (steam compression) or additional heat supply (absorption).

For the heat pump device, we choose R22 refrigerant, its parameters are as follows: refrigerant consumption $G = 0{,}06, kg/s$, boiling temperature $t_0 = 3,$ °C, condensation temperature $t_c = 62,$ °C, coolant temperature at the inlet to the evaporator from a low-potential source (underground heat), $t_{en} = 15,$ °C, water at the outlet of the condenser temperature $t_o = 57,$ °C, temperature difference of cooling water in the condenser $\Delta t = 22$ °C, consumption of water in the condenser $G_w = 0{,}3, kg/s$, power of the compressor $N_c = 2{,}5, kW$, heat production capacity of the heat pump device $Q_{HP} = 22{,}65, kW$, heating coefficient of the heat pump device is equal to $\varphi = 5$.

We calculate the heating coefficient φ of the heat pump device as follows.

$$\varphi = \frac{q_1 + l}{l} = \frac{T_c}{T_c - T_o} = \frac{335}{335 - 276} = 5{,}7$$

q_1-condensation heat, kDj/kg, l-compression work, kDj/kg, T_c and T_0-condensation and boiling temperature, K.

In an ideal heat pump cycle, the amount of heat removed from the low-potential source is equal to the heat of vaporization of the refrigerant entering the evaporator: $q_{ev} = r(x_1 - x_0)$ kDJ/kg, where r is the heat of vaporization. The cooling coefficient of this cycle is calculated as follows:

$$\varepsilon_{HP} = \frac{q_i + l}{l} = \frac{T_0}{T_c - T_o} = \frac{276}{335 - 276} = 4{,}6$$

For an ideal cycle of a heat pump device and without considering heat losses, the following relationship is appropriate: $\varphi = \varepsilon_{HP} + 1$.

The amount of useful heat transferred to the consumer or the heat production capacity of the heat pump device depends on the cooling water flow rate G_w, kg/s, the average isobaric heat capacity Cp kDj/(kg·K) and the temperature difference Δt. Based on this, we perform the following calculation [24-28].

$$Q_w = G_w \cdot C_p \cdot \Delta t = 0{,}3 \cdot 4{,}19 \cdot 22 = 27{,}65 kW$$

Therefore, if 1 kW of electrical energy is consumed for the mechanical operation of the compressor, then 9 kW of heat is transferred to the heat supply system, transferring pure electrical energy to thermal energy through a heat pump device will transfer 7÷10 times more thermal energy to the heat and hot water supply system allows to transfer.

In the conditions of a real market economy, heat pumps make it possible to provide heat and energy supply systems with stable and reliable energy units in the main areas of the economy: in the housing and communal economy, in industrial enterprises, in health and sports complexes, in agricultural production.

The following conclusion can be made about the proposed hybrid heat supply system:

The choice of heat pump devices for hybrid heat and hot water supply systems is based on the characteristics of the low-temperature heat source, taking into account the structure of the high-pressure unit equipped with vacuum solar collectors and a daily (or seasonal) tank accumulator.

For the heat pump device used in the proposed system, R22-refrigerant is selected, the refrigerant consumption is $G = 0{,}06, kg/s$, the boiling temperature is $t_0 = 3,$ °C, the condensation temperature is $t_c = 62,$ °C, the coolant temperature at the inlet to the evaporator from the low-potential source (underground heat) is $t_{en} = 15,$ °C, and the water temperature at the outlet of the condenser is $t_o = 57,$ °C, the temperature difference of the cooling water in the condenser is $G_w = 0{,}3, kg/s$ °C, the consumption of water in the condenser $G_w = 0{,}3, kg/s$, the capacity of the compressor is $N_c = 2{,}5, kW$, the heat production capacity of the heat pump device is $Q_{HP} = 22{,}65, kW$, and the heating coefficient of the heat pump device is equal to $\varphi = 5$, based on the results of heat technical calculations. The energy consumption of the heat pump device used in the hybrid heat supply system is 2.5 kW, and it produces 22.65 kW of heat energy for the tank accumulator of the heat and hot water supply system. As a result, boiler devices in traditional heat and hot water supply systems are 20÷25 times more energy efficient than electric heating devices. Considering the meteorological climate parameters of the Kashkadarya region, the heating season is 135 days, taking into account the operation of only a 2.5 kW heat pump device in the proposed heat supply system, it is possible to save 73 386 kW of electricity or save 30÷40 tons of conventional fuel.

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