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Calculation of temperature data from an automatic solar heat supply system

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ABSTRACT

This paper calculates the temperature in an automated solar heat supply system. The study used an automatic controller to monitor the temperature data of the entire system. The developed solar heat supply system has a flat solar collector, heat-insulating translucent glass, and double glazing with reduced pressure. The coolant is made of thin-walled corrugated stainless pipe. The heat from the solar flow heats the liquid removed from the collector, and cold water from the siphon enters its place. There is a constant circulation of heat, which increases heat transfer efficiency by eliminating additional partitions between the panel and thermal insulation. The controller has sensors that register using field-programmable gate array (FPGA) STM32, designed to monitor the entire solar system, and the actuators include power relays. During the experiment, it was found that temperature sensors save energy by 2% due to the use of power relays, which has a significant impact on the service life of the equipment.

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1. INTRODUCTION

In [1], [2], a thermal system was developed by a thermal accumulating tank, which was studied using the method of thermal stratification. The collected data, according to the thermosiphon principle, were stored in the form of thermal energy. The thermal efficiency of photovoltaic air heating using fins attached to the collector was also investigated. Rosen and Kumar [3], the method of stationary effect on a photovoltaic/thermal solar air heater was investigated. Temperature, efficiency, and other parameters were calculated. Sugathan *et al.* [4], an automated solar heating system with an inverter collector pump in a collector circuit was investigated.

Figure 1 shows a schematic diagram of an automated solar heating system with an inverter collector pump in a collector circuit. A new design of the inverter collector pump with a new control controller has been developed, which allows collecting data on the parameters of the solar heat supply system, as well as monitoring the entire system.

Figure 2 shows a view of the front of the automatic controller. This paper considers the stability and accuracy of an automatic regulator with an inverter collector pump for variable mass flow in the collector circuit, as well as the contribution of the useful collector gain to solar energy [5]. Benammar *et al*. [6], was developed profile in a heat storage device for a solar collector.

Figure 3 shows a block diagram of data storage on an SD card. In the block diagram, the temperature parameters are recorded in the Arduino board. The algorithm written in C++ saves them in XML format (extensible mark-up language) on an SD memory card. Berahim *et al*. [7], an automated temperature controller of a hybrid nanofluid in a vacuumed tubular solar collector was developed. The system consists of a mechanical part and an electrical part. The mechanical part includes an outer frame, a base made of metallic iron, as shown in Figure 4. The electrical part consists of a power source in addition to a microcontroller (Arduino). Figure 5 shows the control board of the electrical part.

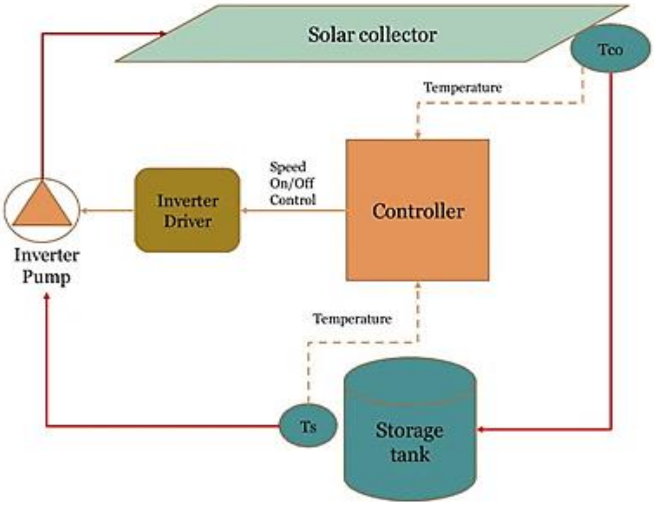

Figure 1. Schematic diagram of an automated solar heating system with an inverter collector pump in the collector circuit

Figure 2. View of the front of the automatic controller

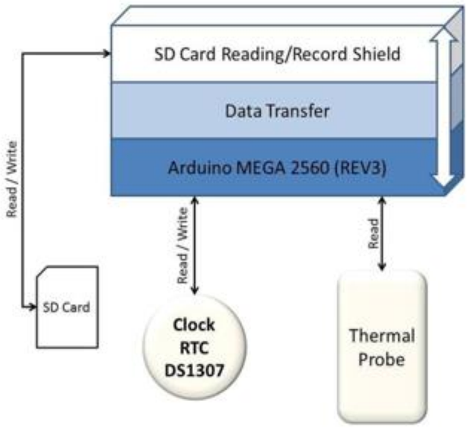

Figure 3. Block diagram of data storage on an SD card

Figure 4. Tubular solar collector

Figure 5. Automated solar collector controller

In the article [8], the program design was developed, which was based on the Arduino programming language manual. Figure 6 shows an automatic controller with protective housing. Communication and initialization of the device are carried out using room [9]. The purpose of this work is to develop and calculate temperature data from the control controller.

Figure 6. Automated controller with protective housing

2. METHOD

The control controller was built in Almaty, Kazakhstan. The device was developed using a wireless data transmission and reception system, in which solutions are available to avoid problems with both devices and remotes. Designed to measure the temperature of dispersion inside the tank, to determine the excess of fixed values for selected operating modes. The methodology of this study is to develop an automated circulation system and a control controller for this installation [10]-[13]. Flat solar collectors with thermosiphon circulation convert accumulate tangible energy in rooms and heat water. Figure 7 shows an automated solar thermal system [10], [12].

In Figure 7, 1 is a flat solar collector; 2, a translucent insulating transparent double-glazed window; 3, a coil; 4, the bottom of a flat solar collector; 5, inlet and outlet pipes; 6, a heat insulating film; 7, a siphon dispenser tank; 8, a pipeline with a valve for cold water; 9, a dispenser tank; 10, a circulation pipe; 11, a heat pump; 12, an evaporator; 13, a compressor; 14, a valve; 15, a condenser; 16, a heat exchanger of the heating system; 17, an electric drive; 18, a backup electric heater; 19, a heat exchanger of the heating system; and 20 and 21, circulation pumps.

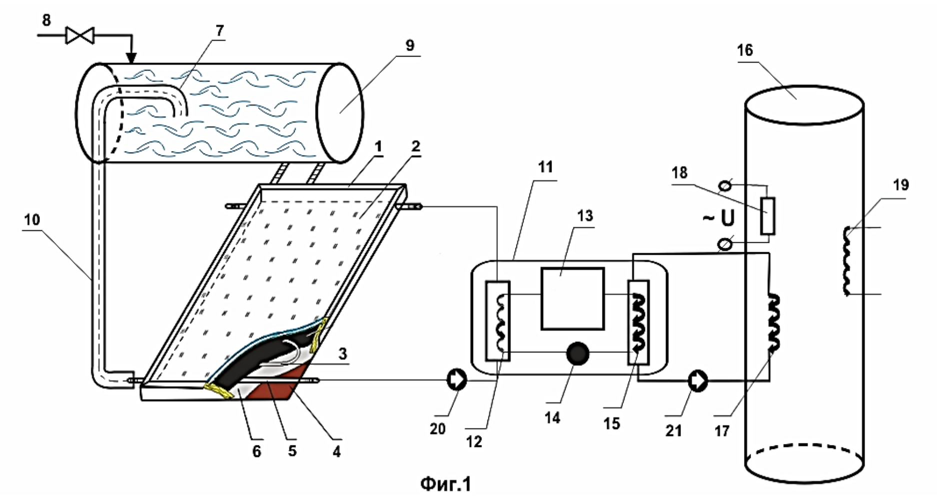

Figure 7. Automated solar thermal system with thermosiphon [10], [12]

The novelty of this research is the development of an automated two-circuit solar system, which is a transparent glazed window into which heat enters, which increases the efficiency of the intermediate walls of the heat pump, which are made of a condenser [10], [12]. Belic *et al*. [13], some methods for the management of solar heat supply systems are investigated. Fontes *et al*. [14], new control algorithms in automated solar heat supply systems were investigated. Rekstad *et al*. [15] shows the newest aspect of temperature control and energy calculation in solar heating systems. Chinnakani et *al*. [16], several types of control schemes are considered for regulating the main parameters in the premises, as well as new energy-saving methodologies. Wang *et al*. [17] a new mathematical model was made for controls in solar heating systems. Ali *et al*. [18] demonstrated a new monitoring and control system using a new algorithm. Dounis and Caraiscos [19] show an analysis of current management concepts in buildings. This improved management concept is formed together with the use of new algorithms for monitoring solar heating systems. Serrano and Chmielewski [20] show a method for designing a new controller by optimizing temperature data in a solar heat supply system. A new computer model is demonstrated in article [21]. The developed [new model explores new control algorithms for energy saving in homes and premises. Son and Hyogon [22], the installation of a heating system was developed and investigated using neural networks. Chao *et al*. [23], a new simulation of a control controller for a greenhouse was presented. Xu *et al*. [24], an algorithm was made for a new controller for controlling the temperature in the greenhouse, as well as a new method of simulation modeling. Mohamed and Hameed [25], a neural network was developed, which was located in the controller and a new simulation model was made in MATLAB Simulink. Atia and El-madany [26], a new approach to a dynamic model of a solar heating system using a controller in a greenhouse is considered. Gruber *et al*. [27], a new control controller was investigated in which the main parameters of solar heat supply systems were substantiated. New technical solutions and optimization problems have been developed in [28]-[30], as well as new methods of the approach of intelligent control of the main parameters in the room.

The power supply management system with an autonomous power source, which transmits data to the collector, manages the complex, and monitors. For rational measurement of heat from heat-dissipating solar collectors and simplification of the operation of the solar system, it is obvious that it is advantageous for this system to work with thermosiphon circulation. Therefore, in order to determine the thermal modes of the solar installation. The temperature readings of the new circuit are transmitted to the ESP 32 module. The ESP32 module is a synchronized FPGA that synchronizes the clock. After the entire process is completed, the entire ESP 32 sensor module is sent to the database.

3. RESULTS AND DISCUSSION

The scientific development in this article was obtained by STM32 and ESP32. Figure 8 shows STM32. STM32 is a platform based on STMicroelectronics microcontrollers based on an ARM processor, various modules and peripherals, as well as software solutions integrated development environment (IDE) for working with hardware. Currently, the STM32 already consists of several lines for a variety of purposes. The ARM core design has many customizable options, and ST chooses an individual configuration for each microcontroller, while adding its own peripherals to the microcontroller core before converting the design into a semiconductor wafer. The following table shows the main series of microcontrollers of the STM32 family.

Figure 9 shows ESP32-WROOM. ESP32-WROOM is a module with an ESP32—D0WDQ6 chip, 4 MB Flash memory and all the necessary strapping, which are hidden under a metal casing. Next to the casing is a miniature antenna from the track on the top layer of the printed circuit board. The metal casing shields the module components and thereby improves the electromagnetic properties. In this study, a new intelligent control controller for an automated solar heat supply system has been developed. The controller has sensors that register the temperature of a flat solar collector in which data is collected and the entire system is monitored.

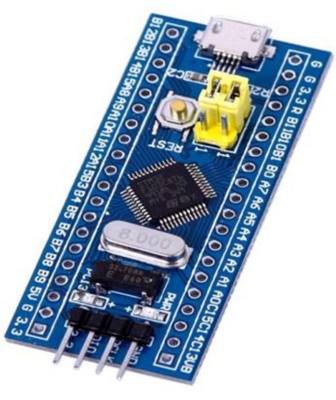

Figure 8. STM32

Figure 9. ESP32-WROOM

Figure 10 shows a schematic diagram of the controller. The sensors measure the output of the solar heater T1, the heat exchanger T2 and the ambient temperature T3. The measurement results are processed, used for indication, and stored. Also, according to these measurements, control actions are formed on the circulation pump and the alarm of the emergency mode. The circulation pump is switched on if the temperature in the water heater tank is 5 °C above the temperature of the heat exchanger. If the temperatures are equal, the pump stops working. When the temperature at both points rises to +95 °C or decreases to +4 ° C, an audible signal is activated in the heat exchanger. The controller provides for the possibility of manual pump control mode.

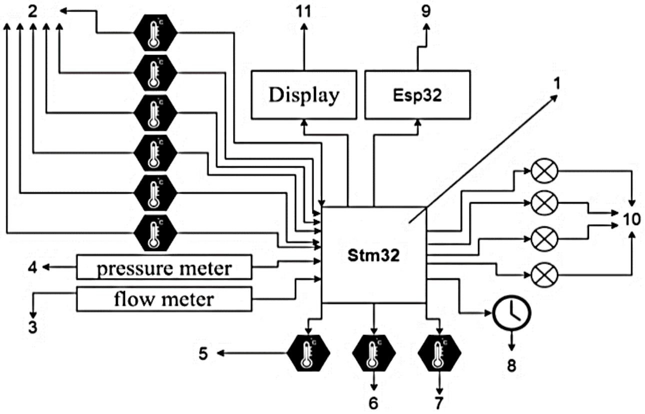

Figure 10. Block diagram for the control controller

Figure 11 shows the controller with the lid removed. The main components of the circuit, the supply wires, and the power supply are visible. The temperature readings are transmitted to the ESP 32 module. The ESP 32 module is synchronized with the FPGA, which is the clock frequency. After the entire process is completed, the data is sent to the database.

A real-time clock allows you to attach timestamps to values and events. It is possible to build charts and trends. Currently, there is an accumulation of real data. Experimentally, it was found that it is most expedient to use the data received every 5-10 minutes. The air temperature sensor is located in the shade. The value of the external temperature T3 allows you to evaluate the efficiency of the heater – heating the coolant relative to the environment by the rays of the sun.

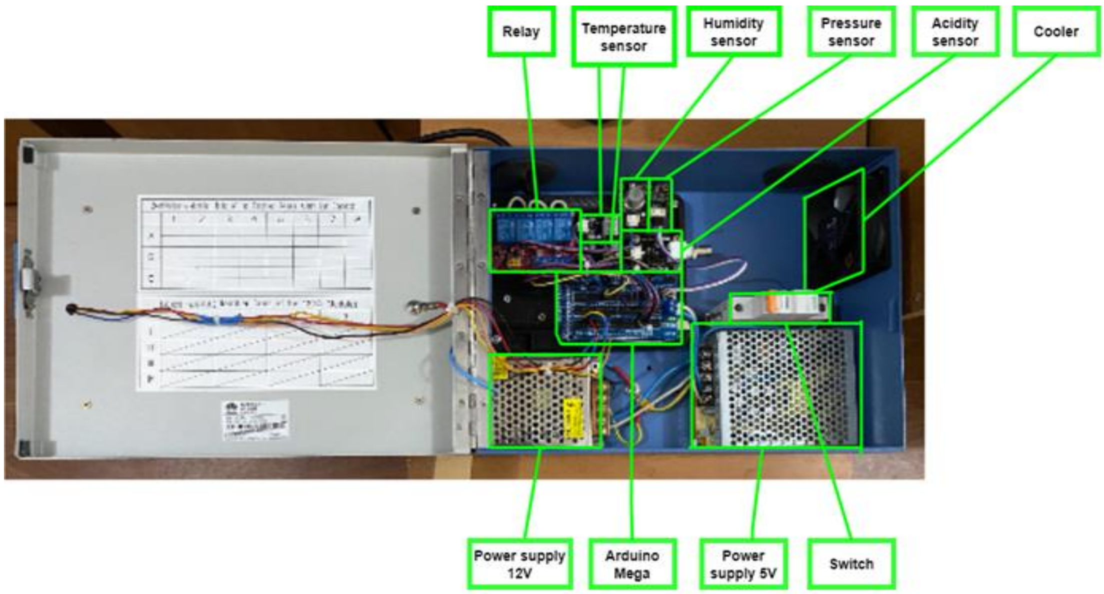

Figure 11. Controller design

The Figure 12 shows the control controller, In addition to data collection, the controller has additional control and protection functions. These include: control of the hot water circulation pump, protection against freezing or periodic overheating of the hot water tank. Figure 13 shows temperature trends from sensors in the tanks of the panel and heat exchanger, the data was accumulated by the controller for 4 days – from June 21 to June 24, 2021. Based on the constructed trends, we can draw the following conclusions; the coolant in the heat exchanger can be heated to a temperature of 64 °C, which is a good result and can be used in the household; there is a temperature discrepancy in the collector and in the heat exchanger without heat extraction 3-5 °C. The discrepancies are insignificant and indicate that the design is made qualitatively, and there are no significant heat losses from the collector to the heat exchanger.

Figure 14 presents the temperature accuracy assessment Dallas DS18B20. A controller can operate in the range of temperatures from −30 °C to +100 °C and maintain relative humidity from 10% to 90%. Sensor T1 shows values in the range from 35 to 55 °C. Temperature sensor T2 shows temperature values from 45 °C to 85 °C. Temperature sensors T3 and T4 have the value 85 °C. Figure 14 shows the various options for using the correction. The equations were included in the Arduino tabular code installed inside the control and monitoring unit. As a result of the study, we can note a safe high level that deviates with an increase. Figure 15 shows different range temperature change in the period from April 19 to June 9, 2021. As it is seen from the Figure 15, indications, observed on April 19 from 07:30 to 09:00, are similar, though with less number of switching on / switching off cycles and with higher temperatures, comparing to June 9.

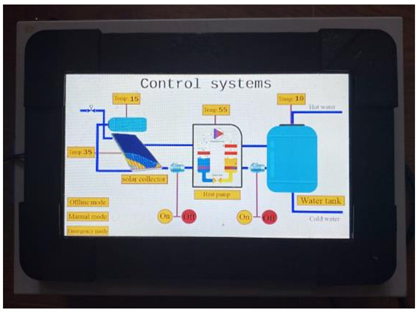

Figure 12. Control controller

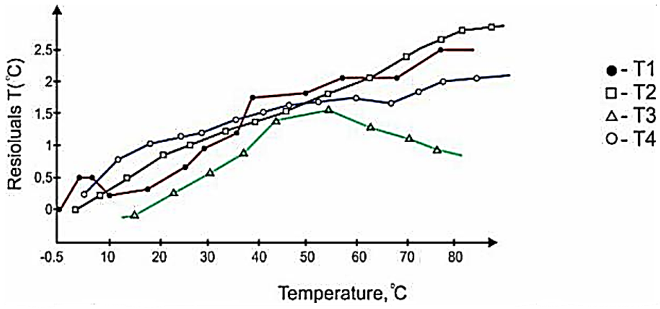

Figure 13. Assessment of temperature external control unit accuracy

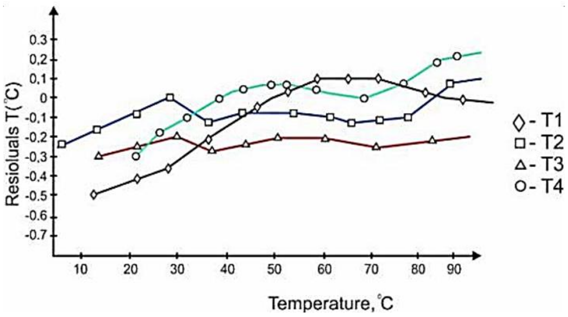

Figure 14. Corrections for various temperature ranges

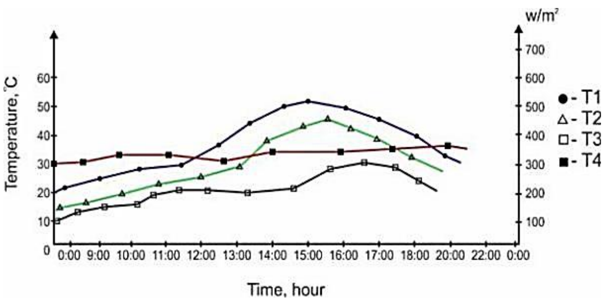

Figure 15. Temperature change of sensors

4. CONCLUSION

In this study, a new automated solar heat supply system was developed and investigated. A new design of an intelligent control controller was developed, which recorded the temperature for the entire installation. During the experimental work, the work of the controller was compared with other indications for a month of operation of the installation. The controller operated in the temperature range from -30°C to +100°C and maintained a relative humidity of 10% to 90%. The T1 sensor shows values in the range of 35 to 55°C. The temperature sensor T2 shows temperature values from 45 °C to 85 °C. The temperature sensors T3 and T4 have a value of 85°C. The readings observed in April from 07:30 to 09:00 are similar to other readings, although with fewer on/off cycles and with higher temperatures compared to June 9. The developed intelligent controller can work in any weather conditions, and also has a low cost, which proves the advantage and cost-effectiveness of work.

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