DEVELOPMENT AND PRACTICAL APPLICATION OF A CONTROL UNIT FOR A TWO-CIRCUIT SOLAR SYSTEM WITH THERMOSIPHON CIRCULATION LOCATED IN THE CITY OF ALMATY (KAZAKHSTAN)

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ABSTRACT

An article describes the development and practical application of control unit of the solar plant, located in Almaty city (Kazakhstan). Such system envisages using an electrical pump for circulation in the transfer medium, connecting a flat plate solar collector with a tank. There has been developed a controller for solar system management, able to control the solar thermal system's current temperature. With the aim thereof in the proposed system the measurements are carried out from 6 digitizers (DS18B20 Dallas), using 16 wires. Using Dallas sensors and corresponding software it is possible to control the temperature level and heat amount. Usage of 4 digital sensors substantially increase the system control performance and raises data processing speed. There have been considered the possibilities of the configuration of the senstors for Arduino platforms, as well, the solar collector management scheme. This paper scientifically analyzes the work of the new controller for controlling the solar thermal system using 6 digital temperature sensors using the Arduino platform to determine the control of the entire solar thermal system.

Keywords: *solar collector, master controller, Arduino, monitoring*

INTRODUCTION

Renewable energy sources usage promotes constant demand increase on the energy and on ecologically friendly technologies outspread. Photothermal conversion in solar thermal systems is one of the most widespread means of that energy using [1], [2]. The necessity to submit the system's corresponding operating parameters maintains the usage of properly selected and adjusted controllers. Solar controllers are produced by many companies and firms [3], [4], [5], [6]. Despite the accessible solutions' wide spectrum, controllers are still the devices with a closed structure and practically they do not have extension flexibility. On the other hand, flexible solutions, based on the programmable controllers (PLC Programmable Logic Controller), are applicable only in large-scale systems due to very high cost of PLC [7]. However, currently there is the growing interest in modular controllers, completely programmable, which allow integrating several systems into a common operational system. Not of less importance for users is the implementation of several additional functions. The article [8] presents an exemplary prototype of a modular solar controller based on the freely programmable Arduino platform. For instance, the system of management and control via the Internet [9] or using the power supply source with photoelectric panels [10], [11]. In [12] there was elaborated mathematical model for hybrid power supply system, based on photo-solar-bioenergetics installation, permitting to cut power consumption by agricultural production. There have been submitted experimental outcomes of the researches on the performance of offered dilution hydraulic system. The research [13] considers the computation of heat amount in thermal pump in the combined solar heating unit. To compute the equalizing of thermal pump thermal balance in the solar heating integrated system there was developed technique of calculation, applying the above mentioned methodologies, defining equalizing of thermal and energy balance amount. The compressor is located in the evaporator impact zone. Key performance indicator (KPI) constitutes from 2,5 to 4,5 units.

The aim of the work herein is the development and practical application of the control management system of the solar plant, located in Almaty city (Kazakhstan).

METHOD OF RESEARCH

The solar heat supply system with a controller has been constructed at the Institute of information and computer technologies in Almaty city, Republic of Kazakhstan.

In 2019 there was developed the system of solar heating, the solar energy E with temperature t0 is absorbed by solar collector 1, with temperature t1, heating solar energy flow, goes through semitransparent insulation glass 2. The heat, received from the solar flow, heats the liquid in coils 3, which is removed from the collector, and cold water occupies its place from the pipeline with cold water tap 8, and from distributor tank siphon 7 there takes place constant circulation of thermal siphon by the usage of circulation pipe 10. Further, the liquid enters the thermal pump 11, which consists of condenser-evaporator 12 with temperature т2, in which a heat exchanger is fabricated in spiral form, absorbing the transfer medium heat, lowering its temperature below ambient temperature (Q2), by means of throttling valve 14, thereby promoting additional absorbing the heat from atmospheric air. The diagram also shows the solar irradiation, reflected from semitransparent coating (Q0) and absorbing panel surface (Q1). Transfer medium, having a relatively low temperature of condencer transfer medium 15 in the spiral form with higher temperature t2, increases square and speed of heat exchange. To fulfill such cycle there is used a compressor 13 with temperature т3 with electric drive 17. Further with the help condencer heat exchanger 15 with temperature t4 heat from the thermal pump (Q5) is transferred to the tank from heat exchanger Q6 with temperature t6 of heating 18. As the installation has two circuits, it is equipped with automatic circulation pumps 19 and 20 for liquid circulation between solar collector and evaporator, condencer and storage reservoir. Water temperature is adjusted up to the required technological level and supplied to a customer for hot water supply and heating.

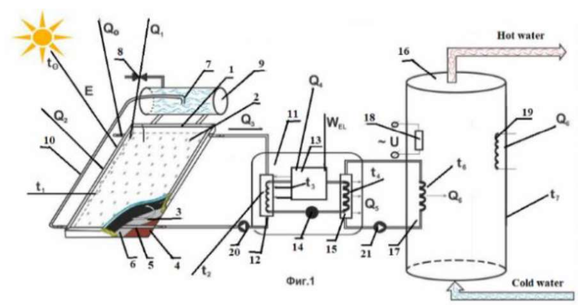

Fig.1. *Principal diagram of double circuit solar installation with thermosiphon circulation*

The given research originality is development of double circuit solar system with thermosiphon circulation, which has flat solar collector, representing heat insulating traansparent double-glazing unit with lower pressure, and transfer medium is made of a thin-walled corrugated stainless tube. Heat, obtained from solar flow, heats the liquid in colis, which is removed from the collector, and its place is occupied with cold water from the siphon and there occurs constant thermal circulation, which upgrades heat transfer efficiency, at the expense of eliminating additional webs between a panel and heat insulation. There exists also a thermal pump, where cindencer and evaporator are made in the form of heat exchanger of "spiral in spiral" type, heat exchanger pipelines are located one over another, increasig the square and heat exchange intensity.

As mentioned above, a double-circuit solar system with thermosiphon circulation can absorb heat from a solar source.

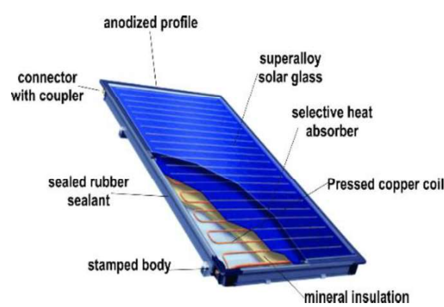

Fig.2. *Principal diagram of flat solar collector*

Figure 2 shows a model of a flat solar collector. The essence and novelty of the proposed one is that, unlike the well-known design principle, the collector contains a transparent double-glazed window 2 with double glass and with reduced pressure, as well as a perimeter frame 1. The bottom of the wooden frame 7 is made of 8 mm thickness plywood. and heat-insulating film 5 with foil is glued to it. In the gap, formed between the double-glazed window and the bottom of the frame, a flexible thin-walled stainless corrugated tube of 4-16 mm is laid in the coil form. The edges of the tube are attached to the inlet and outlet protruding pipes 6.

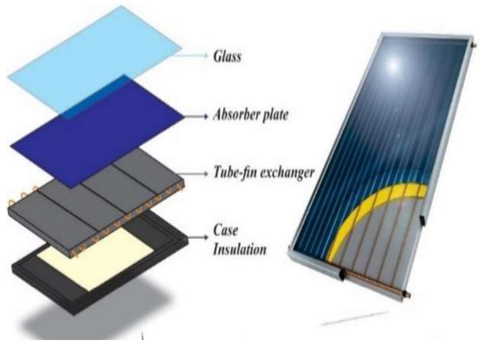

Fig.3. *Principal diagram of flat solar collector in parts*

As shown in Figure 3, the solar energy passes through the glass and hits the absorber plate, which heats up, converting solar energy into thermal energy. Heat is transferred to the working fluid, which passes through tubes, attached to the absorber plate.

Fig.4*. Flat solar collector mockup*

Figure 4 shows a full-scale model of a flat solar collector. The solar collector is the main heat-generating unit of the solar installation. To achieve this goal, we have developed a fundamentally new flat solar collector, on the basis of which various types of solar systems will be created, both according to sizes and design, applied to water heating and premises heating.

Table 1. *Selected performance capabilities of flat solar collector*

Parameters	Value
Absorbing plate material	copper
Absorber plate dimensions	2 m×1 m
Plate thickness	0.4 mm
Glazing material	Hardened glass
Glazing sizes	2 m×1 m
Glazing thickness	4 mm
Insulation	Foam plex (foam polyurethane)
Collector tilt	45^0
Absorber heat conductivity	401 W/(m K)
Insulation heat conductivity	0.04 W/(m K)
Transmittance-absorption factor	0.855
Apparent sun temperature	4350 K
Environmental temperature	303 K
Irradiation intensity	1000 W/m^2

COUNTERPART OF MODULAR CONTROLLER FOR SOLAR THERMAL SYSTEM

Controllers, designed for the solar thermal plants monitoring shall have a modular structure. It provides upgrading controller's functionality with the device further development. A chapter herein presents a modular solar controller counterpart, based on freely programmable platform. The controller block-diagram is shown on Figure 5. The controller prototype consists of a central module, uniting all main controlling functions and three principle extension modules: system monitoring, reserve electric power supply and meteorological station.

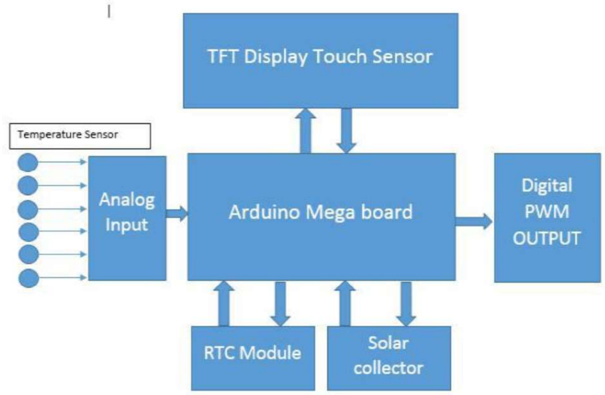

Fig. 5. *Block-diagram of managing controller of double circuit solar plant with thermosiphon circulation*

The control unit body has been designed as appropriate and implemented using 3D-printer, so that it can be easily assembled and disassembled.

Fig.6. *The solar system management controller*

Table 2. *Technical specifications of the solar system management controller*

Dimensions, (mm)	120x120x23
supply, (V)	AC110 / AC220
Consumption, (Wt.)	< 3
Temperature measuring accuracy, (°C)	-/+2
Collector temperature measuring range, (°C)	-10…220
Tank temperature measuring range, (°C)	0…+110
Tank maximum capacity, (Wt.)	3 pieces < 300
Inlets	1 piece pt1000, 2 pieces ntc10k
Outlets (relay for pump, valve, THE)	10 A
Working temperature, (°C)	-10 +50
Waterproof class	IP40

***Fig.** 7. Assessment of temperature external control unit accuracy*

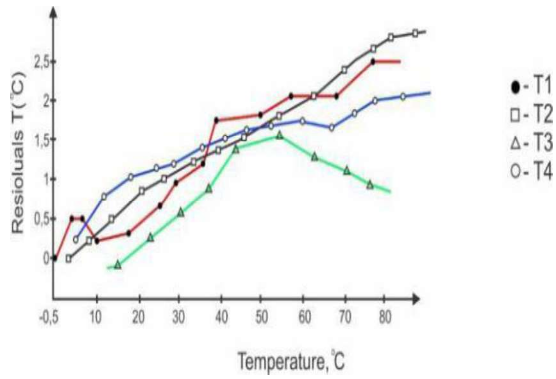

Figure 7 presents temperature external control unit accuracy assessment T1 and four sensors Dallas DS18B20 (T2 – T4). The controller can operate in the range of temperatures from −30 ° C to +100 ° C and maintain relative humidity from 10% to 90%. Sensor T1 shows values in the range from 35 to 55 ° C. Temperature sensor T2 shows temperature values from 45 ° C to 85 ° C. Temperature sensors T3 and T4 have the value 85 ° C.

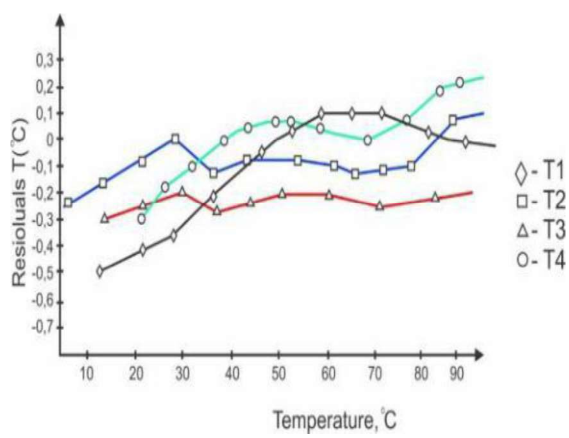

***Fig. 8.** Corrections for various temperature ranges*

Figure 8 shows the correction of temperatures for various ranges, necessary for using in a monitoring system. Each sensor has a linear equation. Equations have been included in the plate code of Arduino, installed inside the control and monitoring unit. In the result of research, we can note, that the sensors secure high accuracy along with the range, correcting, in particular, deviant behavior upon temperature rise.

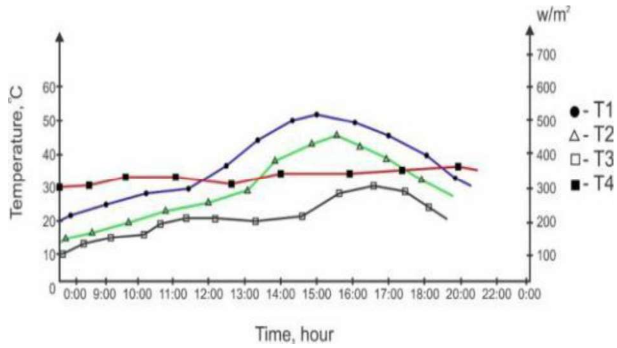

Fig.9. The temperature change of sensors and heat pump according to the time

Figure 9 shows different range temperature changes in the period from April 19 to June 9, 2021. As it is seen from Figure 14, 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.

CONCLUSION

In the present work, we have developed the stages of designing and practical application of the solar plant control management system (Almaty city, Kazakhstan). To create and research the solar plant thermal system monitoring platform, based on using the platform Arduino Mega, we have described every element operation, on the basis of which the network controller control and monitoring has been executed. We have carried out assessing the accuracy of the controller, which can operate in the temperature range from −30°C to +100°C and maintain relative humidity from 10% to 90%. Sensor T1 shows indications in the range from 35 to 55°C. Temperature sensor T2 presents temperature values from 45°C to 85°C. Temperature sensors T3 and T4 have the value 85°C. As a result of research, we can note, that the sensors provide high accuracy along with an overall range, correcting, in particular, deviant behavior upon temperature raise. The control and monitoring system is implemented in the VHDL and VERILOG languages. The system found that the thermal efficiency of water in a thermosiphon tank for a flat solar collector increased by 5%. Solar radiation, depending on the thermal power of the installation and the time of heating the water, has achieved the greatest efficiency in the circulation of water in the metering tank.

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