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EXPERIMENTAL ANALYSIS OF A SOLAR WATER HEATER WITH A THERMOSIPHONE FOR DOMESTIC APPLICATIONS IN THE SOUTH-EAST OF KAZAKHSTAN

In this study, a flat solar collector with a thermosiphon was tested in the laboratory of the Institute of Information and Computing Technologies of the Ministry of Education and Science of the Republic of Kazakhstan, located in Almaty (77 degrees east longitude and 43 degrees north latitude). Experimental data were concentrated on many sunny and cloudy days. The dynamic reaction of the system to changes in cloudless insolation was studied and analyzed. It has been found that such systems can guarantee sufficient energy to meet the needs of hot water, contrary to the false opinion of residents. The design functions using six meters (temperature sensor, water flow converter, pressure converter, cooling water temperature converter in the heater tank, cooling water temperature converter in the heat exchanger, and external air temperature sensor). Six counters are controlled using a programmable logistics integrated circuit (FPGA) STM32, designed to monitor the entire solar system, and serviceable mechanisms connect power relays. The temperature data is sent to the ESP 32 device. The ESP 32 device is synchronized with six sensors connected to the STM32 FPGA, supported by six galvanic wires programmed in C, which, after processing the provided information about temperature, date, and time, work according to the clock of the current time. After all the work is completed, all the counter data is sent to the ESP 32 module, from where the information is sent to the database. During the experiment, due to the control signal in the controller, a significant impact on the service life of the equipment was shown.

Key words: Solar Water Heaters, Thermosiphon, Flat Collector, STM32 platform, controller, ESP 32.

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Қазақстанның оңтүстік-шығысында тұрмыстық қолдануға арналған термосифоны бар күн су жылытқышын эксперименттік талдау

Бұл зерттеуде Термосифоны бар жазық күн коллекторы Алматыда орналасқан Қазақстан Республикасы Білім және ғылым министрлігінің ақпараттық және есептеуіш технологиялары институтының зертханасында (77 градус шығыс бойлық және 43 градус солтүстік ендік) сыналды. Эксперименттік деректер көптеген шуақты және бұлтты күндерде шоғырланған.

Бұлтсыз инсоляцияның згеруіне жүйенің динамикалық реакциясы зерттелді және талданды. Мұндай жүйелер Тұрғындардың жалған пікіріне қайшы, ыстық суға деген қажеттілікті қанағаттандыру үшін жеткілікті энергияға кепілдік бере алатындығы анықталды. Дизайналты есептегішті (температура сенсоры, су ағынының түрлендіргіші, қысым түрлендіргіші, жылытқыш ыдысындағы салқындатқыш су температурасының түрлендіргіші, жылу алмастырғыштағы салқындатқыш су температурасының түрлендіргіші және сыртқы ауа температурасының сенсоры) пайдалану арқылы жұмыс істейді. Алты есептегіш бүкіл Күн жүйесін бақылауға арналған бағдарламаланатын логистикалық интегралды схема (FPGA) STM32 арқылы басқарылады, ал жұмыс істейтін механизмдер қуат релелерін қосады. Температура деректері ESP 32 құрылғысына жіберіледі. ESP 32 құрылғысы берілген температура, күн және уақыт туралы ақпаратты өңдегеннен кейін ағымдағы уақыт сағаттарына сәйкес жұмыс істейтін алты сыммен бағдарламаланған алты гальваникалық сыммен қолдау көрсетілетін STM32 plis-ке қосылған алты сенсормен синхрондалады. Барлық жұмыс аяқталғаннан кейін есептегіштің барлық деректері ESP 32 модуліне жіберіледі, сол жерден ақпарат дерекқорға жіберіледі. Эксперимент контроллердегі басқару сигналының жабдықтың қызмететумерзімінеайтарлықтай әсерін көрсетті.

Түйін сөздер:: Күн су жылытқыштары, Термосифон, жазық коллектор, STM32 платформасы, контроллер, ESP 32.

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Экспериментальный анализ солнечного водонагревателя с термосифоном для бытового применения на юго-востоке Казахстана

В данном исследовании плоский солнечный коллектор с термосифоном был протестирован в лаборатории Института информационных и вычислительных технологий Министерства образования и науки Республики Казахстан, расположенного в Алматы (77 градусов восточной долготы и 43 градуса северной широты). Экспериментальные данные были сосредоточены во многих солнечных и пасмурных днях. Была изучена и проанализирована динамическая реакция системы на изменения безоблачной инсоляции. Было установлено, что такие системы могут гарантировать достаточное количество энергии для удовлетворения потребностей в горячей воде, вопреки ложному мнению жителей. Конструкция функционирует с использованием шести счетчиков (датчик температуры, преобразователь расхода воды, преобразователь давления, преобразователь температуры охлаждающей воды в баке нагревателя, преобразователь температуры охлаждающей воды в теплообменнике и датчик температуры внешнего воздуха). Шесть счетчиков управляются с помощью программируемой логистической интегральной схемы (FPGA) STM32, предназначенной для мониторинга всей солнечной системы, а исправные механизмы подключают силовые реле. Данные о температуре передаются на устройство ESP 32. Устройство ESP 32 синхронизировано с шестью датчиками, подключенными к ПЛИС STM32, поддерживаемыми шестью гальваническими проводами, запрограммированными на С, которые после обработки предоставленной информации о температуре, дате и времени работают в соответствии с часами текущего времени. После завершения всей работы все данные счетчика отправляются в модуль ESP 32, откуда информация отправляется в базу данных. В ходе эксперимента было показано значительное влияние управляющего сигнала в контроллере на срок службы оборудования.
Ключевые слова: Солнечные водонагреватели, Термосифон, Плоский коллектор, платформа STM32, контроллер, ESP 32.

1 Introduction

When using traditional energy, which requires the production of fossil fuels or coal, this leads to pollution and harms the environment. The article [1] presents a few varieties of alternative energy, however, the most impressive alternative energy comes from solar energy. In the article [2], a system for heating water with a thermosiphon effect has been developed. In [3], a numerical study of computational fluid dynamics was developed to compare conventional and spiral models to improve thermal characteristics using a spiral standing pipe. In the article [4], a numerical analysis of the heat transfer process of a ribbed tube was developed and investigated, which showed an increase in heat transfer. In [5], a solar water heater with a cross-section of an absorption pipe was developed. It was recorded that the absorption pipes absorb compared to another absorber pipe, in which the efficiency of the absorption pipe increased by 10-12 %. An article [6] was developed in which the fluid flow and heat transfer in a solar heating device was experimentally analyzed. In [7], the effect of a transverse section of a thermal pipe was experimentally examined. In the article [8], an experimental study was conducted to improve the absorption of heat by a solar collector. In [9], the characteristics of heat transfer and flow of a device for collecting solar energy using CFD modeling are studied. In the article [10], the effect of using coils of wires in absorber tubes to improve heat transfer. In [11], the characteristics of various configurations in the solar water heating device were calculated and the output data were compared. An experimental study of the thermodynamics of solar collectors was carried out in [12]. In the article [13], experimental work was carried out to increase the heat transfer of a device for collecting solar energy in the climatic conditions of Iraq. In [14], the thermal characteristics were experimentally verified. Thermosyphon is one of the most "successful"solar heating systems. Compared to a conventional system using fossil fuels, a thermosiphon system saves up to 70% of fossil fuel consumption [15]. While compared to a solar heating system with forced circulation, the thermosiphon system does not rely on a circulation pump, but on the thermal buoyancy of the flow [16].

Figure 1: Single-circuit solar water heater with thermosiphon.

Figure 1 shows a single-circuit solar water heater with a thermosyphon on the campus of Yunnan University, where two sets of single-circuit solar water heaters with a thermosyphon were designed and tested. Each consists of 18 tubes (diameter of the inner tube/lid 47/58 mm, length 1.8 m) and one horizontal cylindrical water tank (volume 140 l) (Fig. 1). Both systems were identical in all aspects, except for the angle of inclination of the collector: one tilted 22PIвЂ”B from the horizon (SWH-22), and the other at 46PIвЂ”B (SWH-46). Two experiments have been developed: the PïB-$\Delta rstisaimedtostudythenighttimeperformancecharacteristicsofasingle - circuitsolarwaterheaterwit$

Figure 2: Single-circuit solar water heaters.

Theoretical flow forecasts in thermosiphon solar collectors are compared with experimental measurements. Modifications of the usual method of analysis to improve the accuracy of forecasts are proposed. The results are compared with flow forecasts and measurements in other studies [18]. In [19], experimental comparisons were made of two sets, each of which consists of a collector with a flat plate (1000 P“вЂ” 2000 mm in size) with an aluminum absorber painted in matte black. For both systems, the collectors, an electrical resistance of 2 kW was fixed. A backup water tank was installed, inside of which a floating ball valve was equipped to control the water level in the storage tank. One was positioned vertically with a vertical distance of 0.7 m between the collector circuit connections in the tank, but for another system, the storage tank was positioned horizontally with a vertical distance of 0.35 m between the collector circuit connections in the tank.The upper connecting pipe of both systems was insulated with 30 mm thick tubular polystyrene. Figure 3 shows a single-circuit solar water heater. The main components of a thermosiphon solar heating system are a solar collector, a water tank, connecting pipes. Fig. 4, in this work the solar collector is selected as a horizontal solar collector with a vacuum tube "water in glass"because of its low cost and high efficiency. The collector, which uses water as a working fluid, is directly connected to the new variable volume water tank, which is equipped with three outlets. The dynamic switch of the working outlet of the tank is automatically switched on by electric valves installed in each outlet. The heat exchanger that transfers the accumulated heat to the reservoir for use is a submerged flat coil. The submerged coil is connected to the heating terminal.

The submerged coil is connected to the heating terminal. Supplied to the heating terminals is called the supply temperature, and the temperature returning from the terminals is the return temperature. The pipe connects the outlet inlet of the reservoir, called the upper

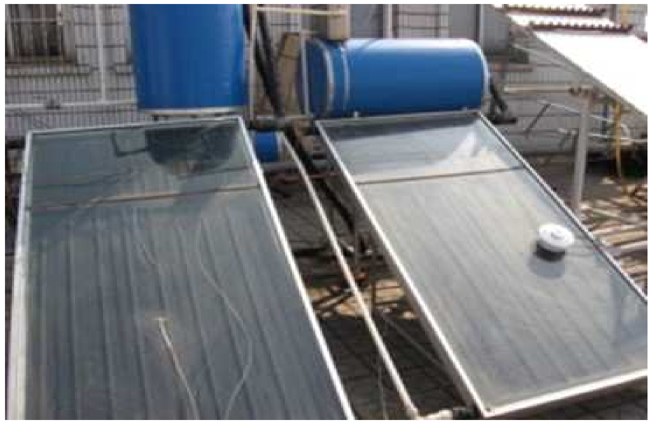

Figure 3: Single-circuit solar water heaters.

connecting pipe. The water in the upper connecting pipe is water heated by the collector. The pipe connects the outlet of the reservoir and the inlet of connecting pipe. The water in the lower connecting pipe is water flowing out of the tank and waiting for heating. The water temperature in the upper and lower connecting pipes and the design of the pipes largely depend on the speed of the natural circulation flow [20].

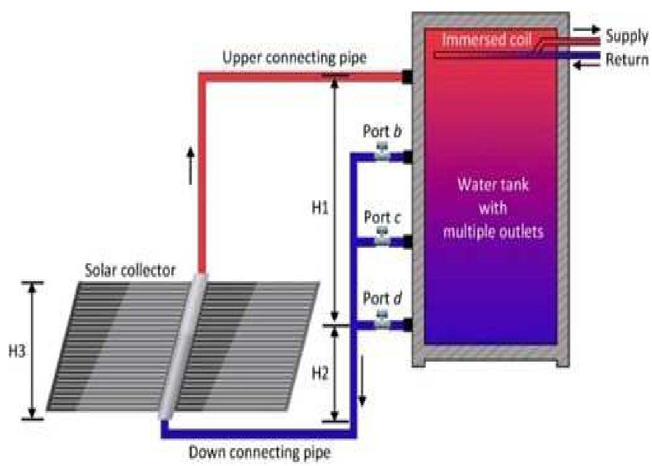

Figure 4: Installation of hot water supply

There are many examples of electronic monitoring used in hospitals and medical centers [21], with the Arduino platform. An efficiency control system for managing a photovoltaic solar power plant was developed [22].

Figure 6 shows view 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 thermal gain of the collector to the solar heating system [23]. A new water flow controller based on the Arduino open hardware platform has been designed, built, installed and tested in an experimental prototype in two solar installations.This work is aimed to study the experimental analysis of a solar water heater with a thermosyphon for domestic

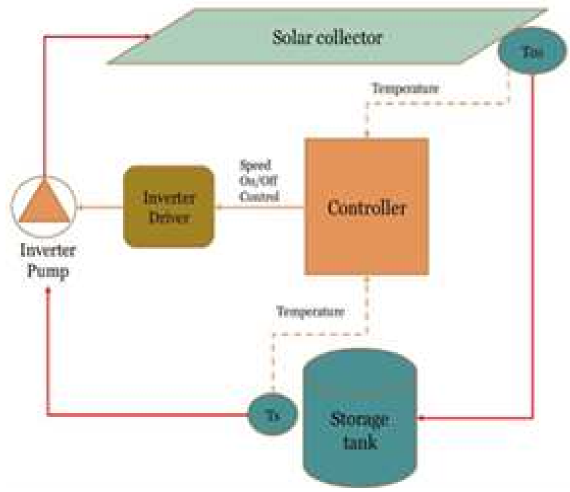

Figure 5: Automated solar heating system with an inverter collector pump in the collector circuit

Figure 6: View of the front of the automatic controller.

applications in the south-east of Kazakhstan.

The proposed controller is capable of performing continuous tasks of monitoring solar installations, controlling an experimental prototype of the installation without any manual intervention. It measures several parameters and performs the actions necessary to control the system in accordance with the programmed algorithm. Therefore, the controller is offered as an inexpensive, easily programmable and expandable electronic platform for solar building research. In [24], an electric multiplex design was invented using the Arduino platform to control and record temperature profile information.

In [25] discusses the consequences of experimental measurements, performance comparison, and control system of the master controller of a flat solar collector with thermosiphon circulation and a flat solar collector with a special chemical coating. The master controllers control device has been designed, which perceives the initial temperature and light sensors acquired during operation. In [26], a successful design of ambient temperature control

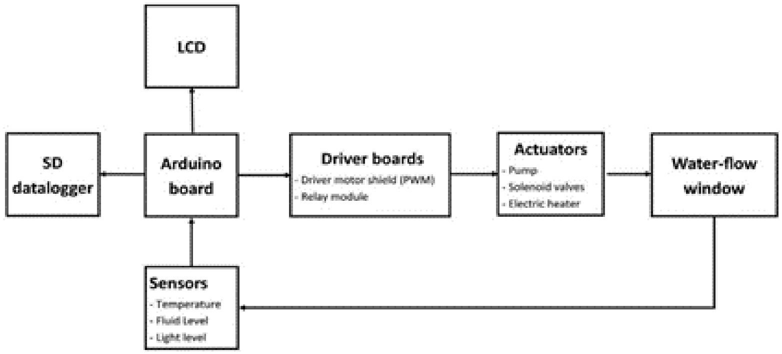

Figure 7: Block diagram of the control system.

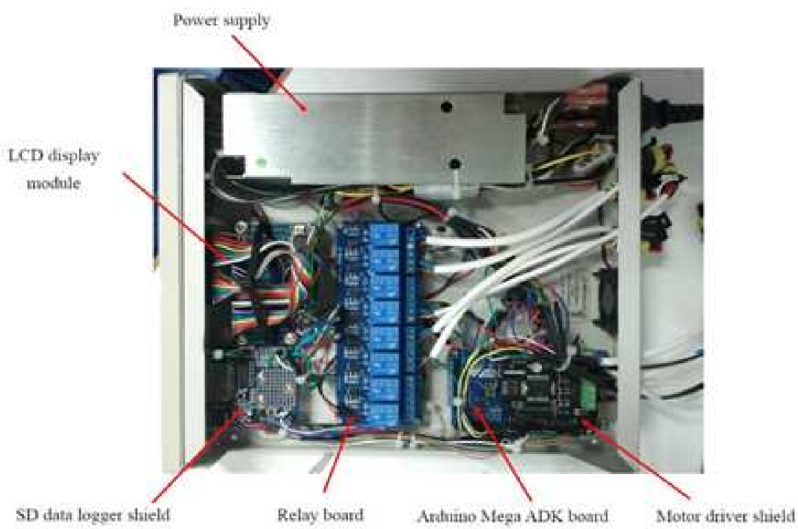

Figure 8: Prototype of the third version – detailed view.

for houses and buildings was invented. This work is aimed at experimental study for domestic use of solar water heating installations in the south-east of Kazakhstan.

2 Research methodology

The experimental station was manufactured and tested in the laboratory of the Institute of Information and Computing Technologies of the Ministry of Education and Science of the Republic of Kazakhstan. Figure 1 shows a modification of a flat solar collector. The meaning and innovation of the proposed one lie in the fact that, unlike the well-known design principle, the collection includes a colorless window 2, as well as a frame 1. The lower part 7 is made of plywood and a thermal insulation shell 5 is glued to it. An elastic thin-walled wavy stainless steel tube with a diameter is placed in the gap formed between the double-glazed windows and the lower part of the frame. The edges of the tube are fixed on the input and output protruding posts 6.

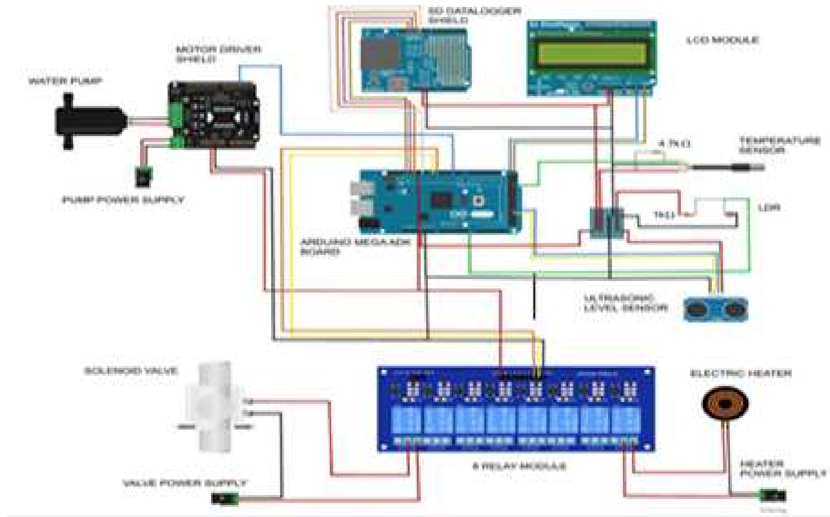

Figure 9: Connection diagram of the proposed controller variant.

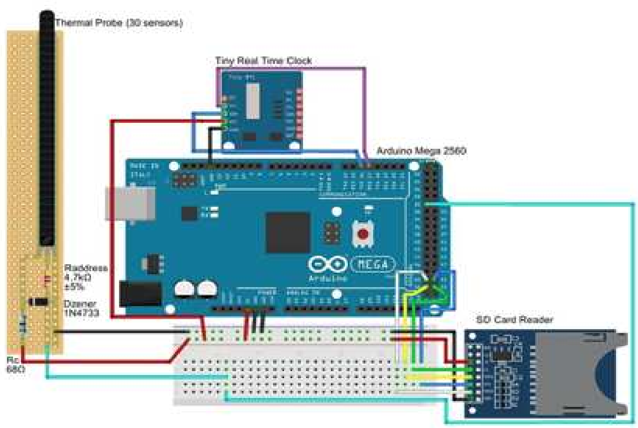

Figure 10: Arduino connections with the specified sensors.

Figure 11, solar energy hits the top of the glass and hits the absorber plate, which heats up, converting solar energy into thermal energy. Heat is supplied to the working fluid, which will flow through pipes welded to the absorber plate.

Figure 12 shows a full-scale modification of a flat solar collector. The solar collector appears to be the key heat-generating apparatus of a solar installation. To achieve this mission, we have consciously developed a newly invented flat solar collector, based on which all kinds of solar systems will be formed, both in size and design, used for water heating and indoor heating. 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°
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

The novelty of the study provided is the development of a flat solar collector, which is a heat-insulating clean double-glazed window with reduced pressure, and the coolant is made of thin-walled wavy stainless pipe. The heat received from the solar flux heats the solution in the coils, which is prevented from the collector, continuous thermal circulation comes out, which increases the efficiency of heat transfer, eliminating additional transition walls between the panel and thermal insulation. In addition, there is a non-flowing weightless gap, the temperature of which achieves more high values than the ambient temperature, due to the loss of heat from the upper glass. The higher the temperature discrepancy between the sluggish weightless opening and the environment, the greater the internal wind speed. In the case of continuous ambient temperature, the temperature discrepancy between the sluggish weightless opening and the environment increases with increasing operating temperature, which leads to an increase in the overall loss coefficient. Taking into account that with a spontaneous gradation change in ambient temperature, the speed of the internal wind decreases, and vice versa. The performance provided by the investigated flat solar collector is achieved through the development of an experimental model. In [14], concrete results were obtained earlier on the development of an automated control controller. A Mojo V3 board was built with sensors to control the temperature data. The built Mojo V3 chamber provides a flexible architecture for expanding the solar collector control system with thermosiphon circulation. Using the Mojo v3 board. you can quickly determine, which indicate that the Mojo V3 board is highly accurate and the data transmission reception rate via the ETHERNET module interface is up to 1 GB per second. The high-speed interface Mojo v3. allows you to automatically build temperature dependencies in any region of Kazakhstan.

STM32 is a platform based on STMicroelectronics microcontrollers based on an ARM processor, various modules and peripherals, as well as software solutions (IDE) for working with hardware. STM-based solutions are actively used due to the performance of the microcontroller, its successful architecture, low power consumption, and low price. 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.

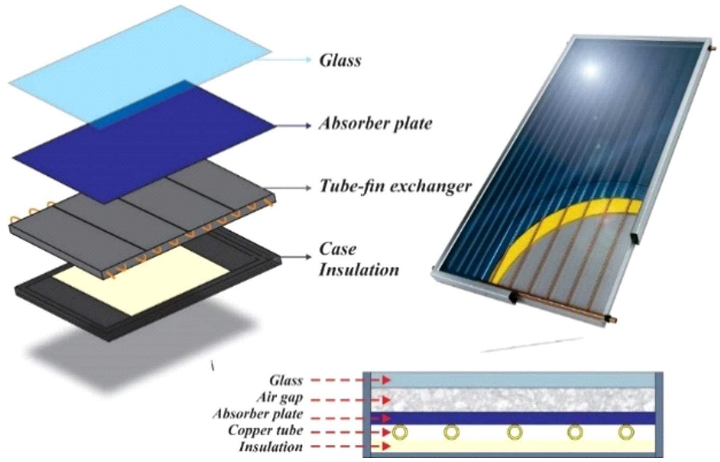

Figure 11: P C' modification of a flat solar collector.

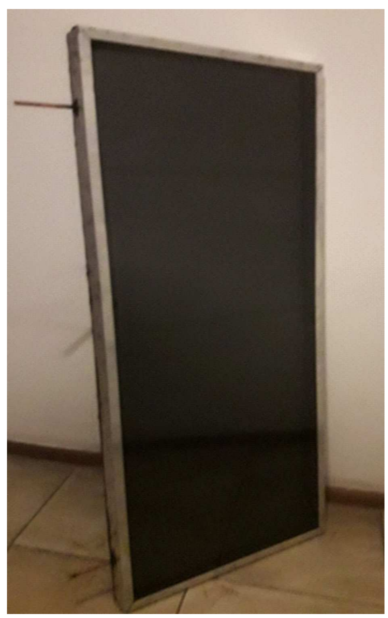

Figure 12: Industrial type of collector.

ESP32-WROOM is a module with an ESP32PIP,вЂќD0WDQ6 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.

Figure 17 shows the block diagram of the control controller.

The design functions using six meters (temperature sensor, water flow converter, pressure converter, cooling water temperature converter in the heater tank, cooling water temperature converter in the heat exchanger, and external air temperature sensor). Six counters are controlled using a programmable logistics integrated circuit (FPGA) STM32, designed to monitor the entire solar system, and serviceable mechanisms connect power relays. The

Figure 13: Test bench.

Figure 14: Solar water heater with thermosiphon.

temperature data is sent to the ESP 32 device. The ESP 32 device is synchronized with six sensors connected to the STM32 FPGA, supported by six galvanic wires programmed in C, which, after processing the provided information about temperature, date, and time, work according to the clock of the current time. After all the work is completed, all the counter data is sent to the ESP 32 module, from where the information is sent to the database. During the experiment, due to the control signal in the controller, a significant impact on the service life of the equipment was shown.

3 Results and discussion

The experimental site conducted for the study of the city of Almaty has 77 degrees east longitude and 43 degrees north latitude. To study the distribution of temperature and water flow is carried out by a dispenser. The testing period for each launch is from 8.00 am to 22 pm. Figure 18 shows various locations along the absorber plate on a sunny day. Judging by Figure 18, a one-hour delay was detected at 13:30. At this time, the absorption plane is 1000

Figure 15: STM32.

Figure 16: ESP32-WROOM.

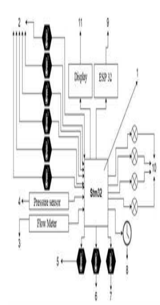

Figure 17: Block diagram for the control controller.

W/m2. After 19:00, the radiation begins to fall, the temperature of the absorber continues to rise for another two hours.

Figure 20 shows the temperatures in the air gap between the absorber plate and the colorless collector cover. As can be seen from the picture, at noon a thermal gradient is

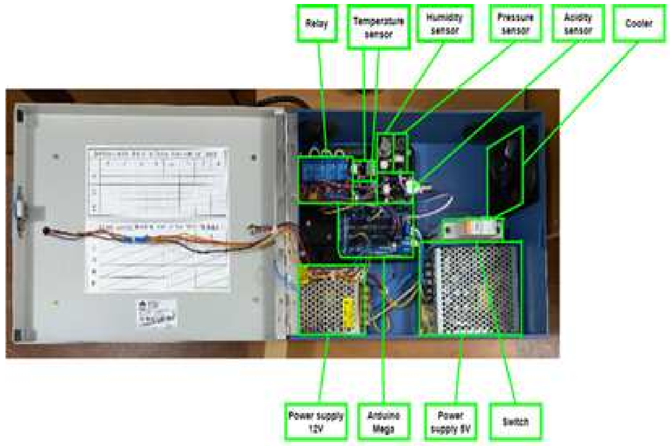

Figure 18: Controller in full-scale form.

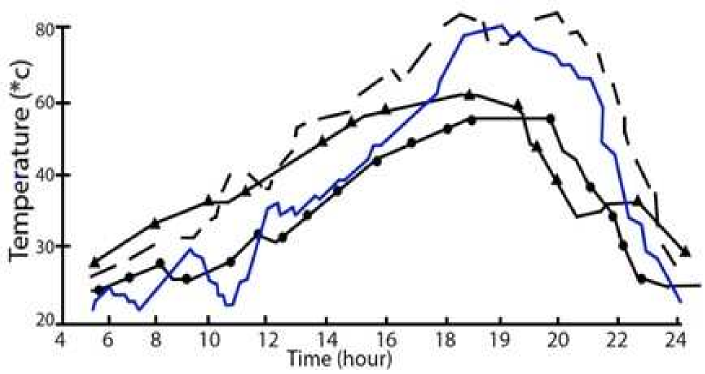

Figure 19: Dependence of time on a sunny day

noticed here on the site. The discrepancy between the temperature of the plate and the temperature in the air opening is maximum at 2: 30 p.m., which is 17 P'B°C.

Figure 21 shows the temperature dynamics we see in marriage with a thermosiphon. We see that in marriage with the thermosiphon, the water began to heat up first and first reaches the threshold value of 55 P'B° C for the tank, at which the pump turns on and supplies cold water recharge. This measure was taken in order to avoid exposure to extreme temperatures on the equipment.

4 Conclusion

In this paper, a tank equipped with a vertical dispenser with a solar water heater for the southern region of Kazakhstan has been experimentally investigated. In summer, the collector reaches 75 P'B°C, and the time to reach the maximum temperature was about 1.5 hours of

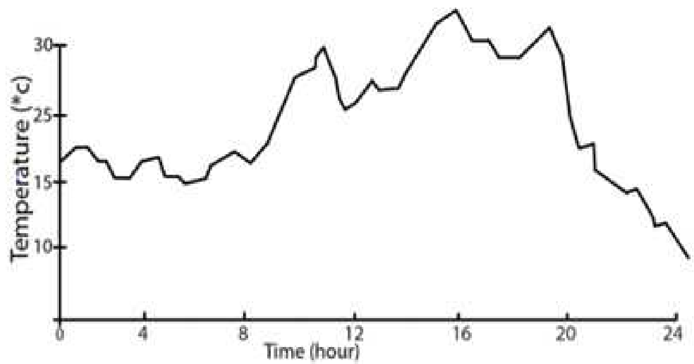

Figure 20: The temperature change over time for a sunny day.

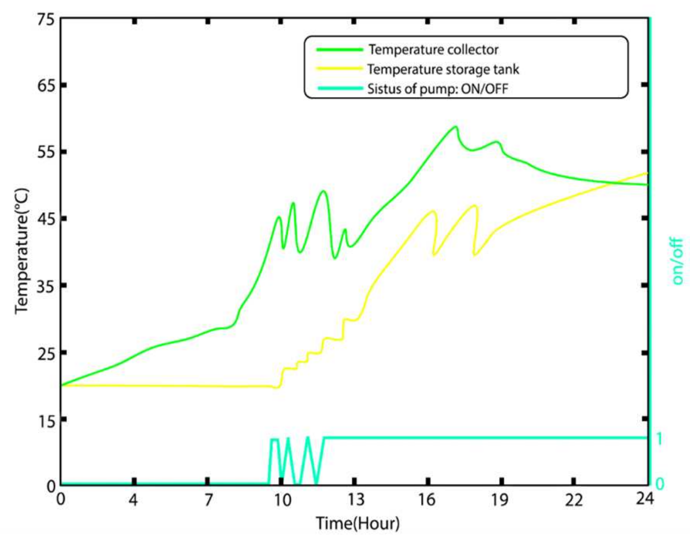

Figure 21: Temperature dynamics in marriage with a thermosiphon.

radiation flux. In the study, the norms were fully observed when using the installation, and the temperature of the upper water layer on a sunny day was 60 P'B°C. The measured thermal characteristics of the installation are in good agreement with other researchers' data. The controller is specialized for controlling solar thermal installations, mainly characterized by a modular structure. This allows you to restore the operability of the controller by the measure of the future formation of the structure. A model of the layout of a modular solar controller based on a widely programmable platform was presented. The developed control controller collects data and monitors the current temperature.

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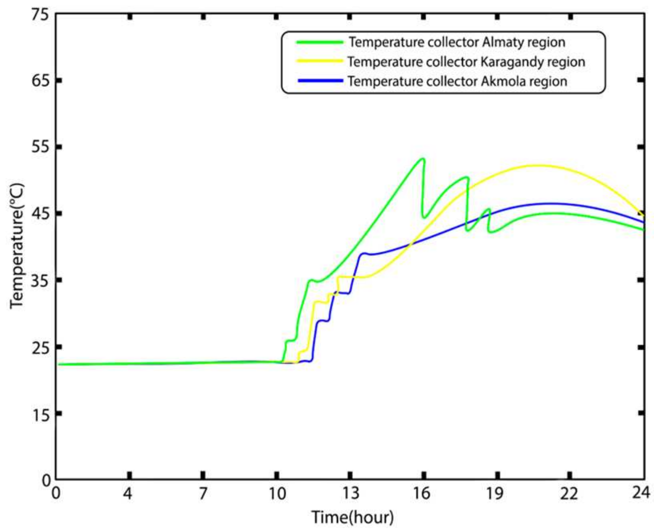

Figure 22: Temperature change in the installation

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