

# Developing the System of Collecting, Storing and Processing Information from Solar Collectors

Waldemar Wojcik, Yedilhan Amirgaliyev, Murat Kunelbayev, Aliya Kalizhanova, Ainur Kozbakova, Talgat Sundetov, and Didar Yedilkhan

**Abstract**—The article herein presents a new technique of controlling the system of collecting, storing and processing the information from the solar collectors, which might be applied to heating the industrial and domestic compartments for hot water supply. The most profitable usage of the solar collectors in the industry is replacement of a human interference with wireless sensor nets. The solar collector standard system consumes in average 30% of the heat due to poor control and configuration. Our monitoring and control system allows upgrade the performance of heating the industrial and domestic premises by means of solar collector for hot water supply.

**Keywords**—solar collector, master controller, ESP-WROOM-32, monitoring

## I. INTRODUCTION

RENEWABLE energy sources are sustainable and able to meet the current and future predicted global demands for energy without affecting the environment. For sustainable satisfying the global need in the energy the power renewable sources, such as solar energy, wind, hydropower and biogas are applicable alternatives. The best alternative to meet the growing demand for energy is the solar energy. Solar radiation transformation into heat is one of the simplest and direct means of its capacity usage.

In the works [1-3] there have been developed electronic equipment for controlling the solar power installation operation through specifying the physical parameters and controlling the executive systems for opening/shutting the electric valves and switching on/switching off the heating supporting systems. Moreover, the control block can monitor the set of visual/audio signals of the feedback for communicating the troubles and maintenance request.

The developed monitoring system is accessible via personal computer through the serial cable RS232 and mobile devices on the Android base, connected to the Internet for remote monitoring. In the work [4] the researches have presented an intelligence system for controlling the energy consumption at home with the devices on the base of ZigBee, as well, with programmable logic controller modules for monitoring the renewable energy generation.

Pasamontes et al. [5] have developed the dynamic hybrid model for solar energy installations, consisting of solar thermal

flat collector field. With the aim to maximize the efficiency of using / generating the energy, programmable monitoring systems for power production objects acquire the growing importance in case of fail [6]. The researches in the work [7] have elaborated an approach, which consists in designing and developing the reliable, effective in real time and flexible, cost-effective, in real time and feasible sensor nets for smart building system. The article [8] presents some of the recent tendencies in the field of developing the multithreaded direct current converters. There have been studied the methods of synthesis of multiport transformers, their operation principles, advantages and disadvantages. In the work [9] there has been developed and researched a smart home system with built-in sensors for controlling by means of GSM, which is necessary for safety. In the research [10] there has been developed the system of recording, visualizing and controlling the smart home system, which uses the solar and wind power resources, as well, registers and controls each devices energy consumption.

The work [11] has researched introducing the power intelligence systems for remote monitoring, controlling and planning the energy sources by means of mobile devices on the Android base. Several researches have confirmed the compressor's speed effect at the output [12]. The work [13] considers studying the convective heat exchange in flat solar collectors. The dependences of the Nusselt criterion on round and flat pipes of the solar collector are obtained. In [14], the graph analytical method of the energy and optical characteristics of a flat solar collector is considered. The total solar radiation of the solar collector tilt is calculated. Optical characteristics coefficient has amounted to 66%. It confirms correctness of solar collector's parameters selection. In [15] there has been developed the solar system master controller, able to monitor the current temperatures of solar heat system. For that purpose, in the offered system the measurements are executed from 6 digital sensors (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 sufficiently raises the effectiveness of control over the system and increases data processing rate. We have considered the possibilities of configuring the sensors for Arduino platform, as well, the scheme of solar collector controlling.

This work is supported by grant from the Ministry of Education and Science of the Republic of Kazakhstan within the framework of the Project «BR05236693 "Mathematical and computer models, hardware and software tools and experimental development on creation of network combined effective dual-circuit solar collectors with thermosiphon circulation and monitoring of their functioning»

Waldemar Wojcik Lublin Technical University, Poland (waldemar.wojcik@pollub.pl).

Yedilhan Amirgaliyev, Murat Kunelbayev, Aliya Kalizhanova, Ainur Kozbakova, are with Institute of Information and Computational Technologies CS MES RK, Al-Farabi Kazakh National University (e-mail: amir\_ed@mail.ru, kalizhanova\_aliya@mail.ru, ainur79@mail.ru).

Didar Yedilkhan are with Institute of Information and Computational Technologies CS MES RK, Astana IT University (e-mail: yedilkhan@gmail.com)



## II. METHOD

The system of solar heat supply with a controller has been constructed at the Institute of information and computational technologies in Almaty, Republic of Kazakhstan (latitude  $45^{\circ} 24'5''\text{N}$ , longitude  $9^{\circ} 14'58''\text{E}$ ).

The installation has been developed without wire routing, which is cheaper, than available solution and easier in implementation, which permits to avoid the problems of communication with a device inside the building, far from the solar panel. The system anticipates installation of external heat

exchanger for simulating the hot water consumption or heat dissipation at temperature inside the boiler, exceeding the specified value, established as the maximum threshold. Control system consists of outer wireless and solar power source with autonomous power supply, which transmits the data on the solar panel temperature ( $T_1$ ) in the inner control unit, which receives the data and control the system, monitoring the temperature magnitudes and two electric pumps condition. Figure 1 shows the scheme of the solar heat supply system with a controller.

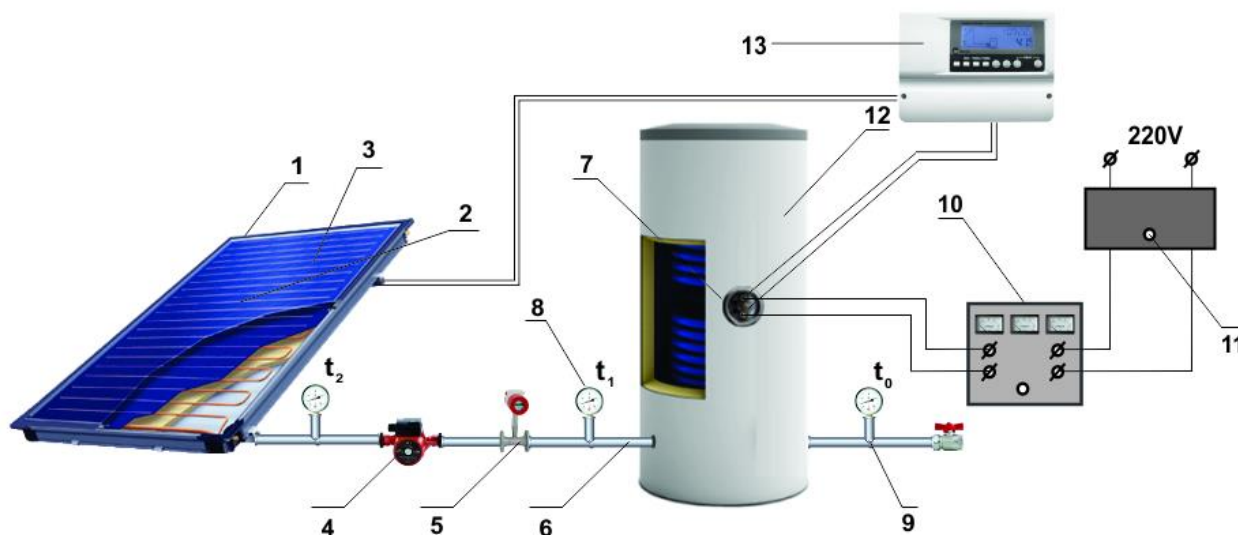


Fig.1. Principle system of solar heat supply with controller

1 – heat-sealed body; 2 – translucent cover; 3 – absorber tank; 4 – circulating pump; 5 – flowmeter; 6 – pipeline; 7 – THE 8, 9 – temperature meters for water temperature measuring at absorber tank inlet and outlet and environment; 10 – set of electric meters K 501; 11 – autotransformer; 12 – storage tank; 13 – controller

Scheme of laboratory stand consists of heat-sealed body 1, translucent cover 2, absorber tank 3 and circulating pump 4, flowmeter 5, pipelines 6, thermo-electric heater with heat controller 7, temperature meters 8, 9, for measuring water temperature at inlet ( $t_1$ ) and outlet ( $t_2$ ) of the tank and environment ( $t_0$ ), metering device K 501 and autotransformer 11, as well, controller for monitoring system. For rational heat removal from heat transmitting solar collectors and solar system operation simplification it is obviously profitable, that the system thereof operates with thermosiphon circulation. Therefore, to determine the solar installations thermal modes it is necessary to define the dependence of productivity on the regime characteristics of solar radiation density, heat removal factor, ambient temperature, temperature difference, etc.

### Prototype model of modular controller for solar thermal system

Controllers, designed for controlling the solar thermal installations, in particular, shall be characterized with modular structure. It allows upgrade controller's functionality with further installation development. The chapter herein presents an example of prototype model of modular solar controller, based on freely programmable platform.

For creating and researching the thermal system monitoring platform for controlling the solar installation, based on using the platform ESP-WROOM-32, there has been described the

operation principle of each element, the net controlling and monitoring controller will be constructed of.

Built-in strain regulator can withstand  $4,8\text{ V} - 12\text{ V}$ . And it consists of a microcontroller (ATmega32U4), used for adjusting FPGA, USB-communications and reading analog outputs. There is built - in a concurrent loader ESP-WROOM-32, permitting easy programming and microcontroller.

Figure 6 demonstrates a digital temperature meter DS18B20, the feature of which is, that it has transformation resolution of 9 - 12 discharges and function of temperature control alarm. Control parameters might be prescribed by a user and stored in sensor's non-volatile memory.

DS18B20 shares the data with a microcontroller along a single-wire line, using 1-wire interface protocol.

A sensor receives power supply directly from the data line without using an external source. In that regime the sensor gets the power from the energy, stored in parasitic capacitance.

Temperature measuring range is from  $-55$  to  $+125\text{ }^{\circ}\text{C}$ . For the range from  $-10$  to  $+85\text{ }^{\circ}\text{C}$  the error does not exceed  $0,5\text{ }^{\circ}\text{C}$ .

Each microsystem of DS18B20 has a unique serial code of 64 discharge length, which permits several sensors to be connected to one common communication line. That is, it is possible through one microcontroller port to exchange the data with several sensors, located at considerable distance. The regime is extremely comfortable to be used in ecological control systems, for temperature control in buildings, equipment modules.

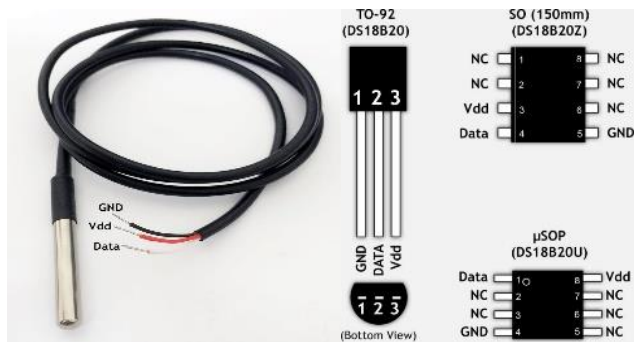


Fig. 2. Digital temperature meter DS18B20

A tiny module RTC for Arduino contains a real time clock DS1307 IC-it is a low-powered, full bidecimal clock /calendar (BCD) plus 56 byte SRAM. Clock / calendar submits the information about seconds, minutes, hours, day, date, month and year. It is one of the simplest in usage RTCs, with Arduino and other libraries or just with usage of I2C command for setting and resetting time and date. It is very easy in usage and with our textbook you will be ready for Arduino and be able to run it in the shortest time.

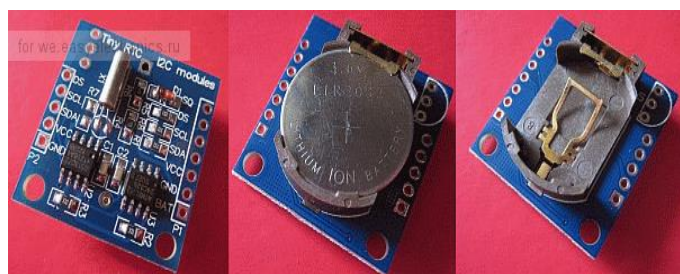


Fig.3. Real Time Clock module with a battery (DS1307)

Along with real time clock DS1307 the module also has a chip Atmel 24C32 EEPROM, which is convenient for data storage, not worrying about the power supply loss. There is also a space on the plate for soldering your own temperature sensor DS18B20.

S108T02 and S208t02 series solid-state relays (SSR) represent the integration of infra-red irradiant diode (IRED), Photovoltaic detector and main output triac. Those devices are quite appropriate for controlling high voltage loads of alternating current with solid-state reliability upon maintaining insulation of 3,0 kv (Viso(rms)) from inlet to outlet/

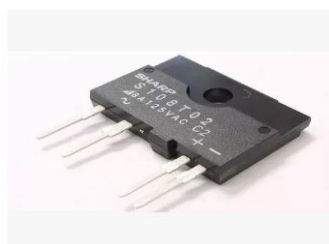


Fig. 4. S108T02 series solid-state relay

ESP-WROOM-32, containing binuclear 32-discharge microprocessor Tensilica Xtensa ® LX6. That processor is like the ESP8266, but has two nucleus of the processor (might be controlled individually), it operates on regulated timing frequency from 80 to 240 MHz and executes up to 600 Dhrystone Million instructions per second.

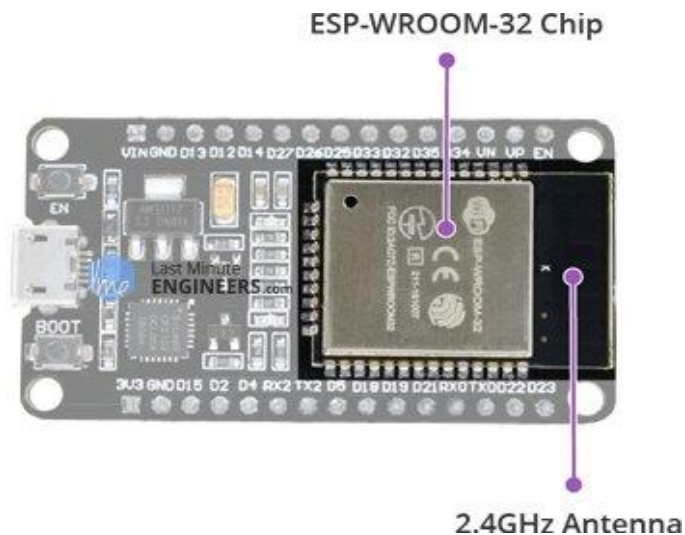


Fig. 5. ESP-WROOM-32, containing binuclear 32-dicharge microprocessor

There is also the 448 KB ROM, 520 KB SRAM and 4 MB flash memory (for storing programs and data) quite enough to cope with big rows, which present web pages, JSON/XML data and everything we throw on the devices of Things internet currently.

ESP32 integrates transmitter/receiver unit 802.11 b/g/n HT40 Wi-Fi, hence it can be not only connected to the Wi-Fi network and interact with the internet, but also create the own network, permitting other devices to be switched on directly to it. ESP32, as well, supports Wi-Fi Direct, which is an appropriate version for peer-to-peer connection without an access point. Wi-Fi Direct is easier to adjust, and data transmission rate is much higher, then that of Bluetooth. The chip also has bimodal Bluetooth potentials, which means, that it supports both Bluetooth 4.0 (BLE/Bluetooth Smart) and Bluetooth Classic (BT), which makes it more match-all.

As ESP32 working voltages range amounts to 2,2 V - 3,6 V, a plate is delivered with LDO voltage regulator to maintain constant voltage at the level of 3,3 V. It can reliably supply up to 600 mA, which shall be more than sufficient, when ESP32 drives off up to 250 mA during radio frequency transmission. Regulator's output is also broken down to one of plate sides and denoted as 3V3. That pin contact can be used for supplying power to external components.

### III. RESULTS

In the current research six digital temperature sensors (Dallas DS18B20) 2,3,4,5,6,7 register the thermosiphon flat solar collector temperature. Sensors are controlled with programmable logistic integral scheme 1 ESP-WROOM-32, containing binuclear 32-discharge microprocessor. Temperature showings recordings, which are stored at ETHERNET module 9, which every 5 seconds sends temperature data states of valves 10. Real time clock (RTC) 8 records the data and time of temperatures measuring data, sending it to programmable logistic integral scheme ESP-WROOM-32. Six sensors are connected to the plate ESP-WROOM-32, with six electric wires, programmed in the language VHDL after temperature data processing, specifying date and time. Received from real time clock 8, accordingly, the data is saved in XML.

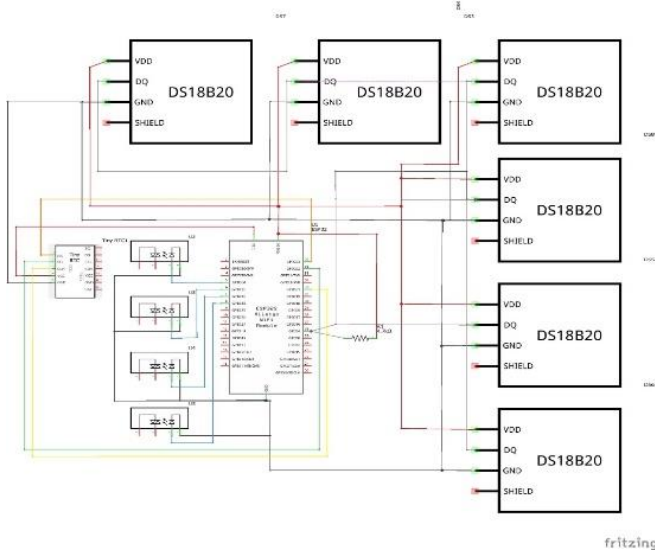


Fig.6. Principal scheme of connecting ESP-WROOM-32 to sensors of controller monitoring system

Language XML makes easier processing that data by means of automatic or manual interpreting the programs of data electronic tables. Temperature data, date, time and states of valves of the installation operation system are imaged on the display 11.

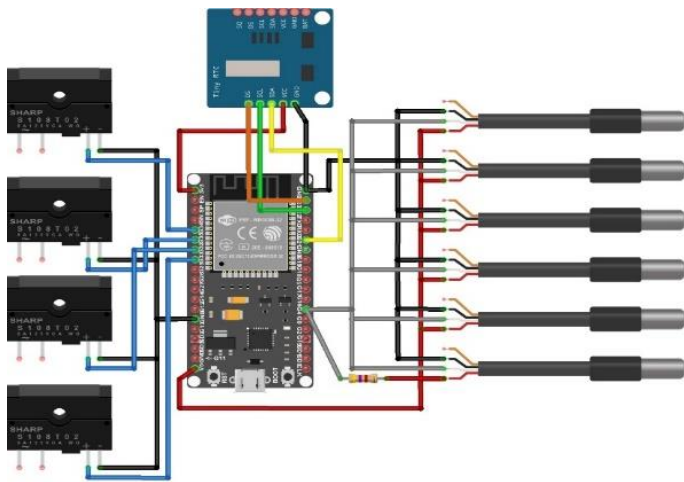


Fig. 7. Principal scheme of controller on the platform ESP-WROOM-32



Fig. 8. Solar system monitoring controller

TABLE I

Technical specifications of solar system monitoring controller

Dimensions, (mm)	120x120x23
Power supply, (V)	AC110 / AC220
Consumption, (Wt)	< 3
Temperature measuring accuracy, (°C)	-/+2
Collector's temperature metering range,(°C)	-10...220
Tank temperature metering range, (°C)	0...+110
Pump maximum capacity, (Wt)	3 units < 300
Inlets	1 unit pt1000, 2 units ntc10k
Outlets (relay for pump, valve, THE)	10 A
Working temperatures, (°C)	-10 +50
Water - proof class	IP40

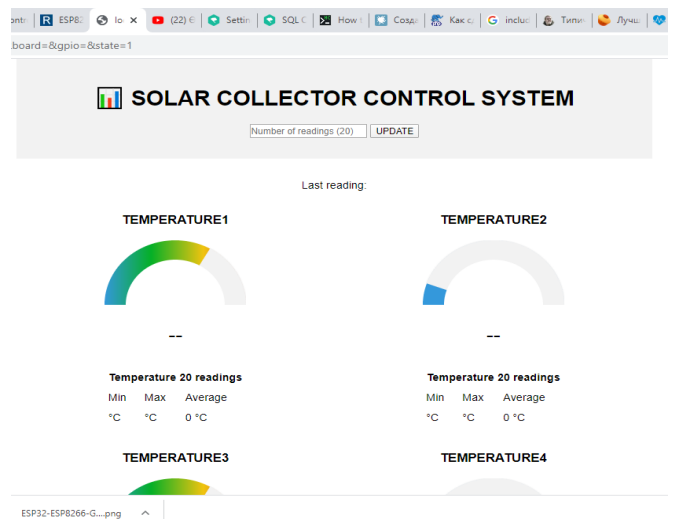


Fig.9. System of net collecting, storing and processing information from solar collectors

The solar collector monitoring controller has the processor ESP 32 1, which initializes and starts the solar collector 2 temperature data assembling and controls valves relays states in the master controller 3. After the above mentioned process, the processor ESP 32 starts connection with Wi-Fi and switches on to the Internet 4. Having switched on to the Internet the ESP 32-1 connects to URL-domain address with the hypertext transfer protocol (HTTP) 5. Temperature data and master controller valves relays states are sent to the database 6. From the database 6 the data is extracted by means of PHP script. Extracted data is stored in the database 8. The stored data is interpreted in the web interface for users 9. Web interface operates for a mobile version and personal computer

Link between a client and server is fulfilled by means of the hypertext transfer protocol (HTTP). In that protocol a client initializes the link, requesting the definite web page with the help of HTTP. One of the main features of ESP 32 consists in the fact, that it can both be switched on to the Wi-Fi network and acts as a web-server, and can adjust the own network, permitting other devices to be connected directly to it and receive an access to the web pages. It is possible, because ESP32 can operate in free different regimes: station regime, soft access point regime and both simultaneously. It provides the possibility to construct grid networks.

Link between a client and server is fulfilled by means of the hypertext transfer protocol (HTTP). In that protocol a client initializes the link, requesting the definite web page with the help of HTTP. One of the main features of ESP 32 consists in the fact, that it can both be switched on to the Wi-Fi network and acts as a web-server, and can adjust the own network, permitting other devices to be connected directly to it and receive an access to the web pages. It is possible, because ESP32 can operate in free different regimes: station regime, soft access point regime and both simultaneously. It provides the possibility to construct grid networks.

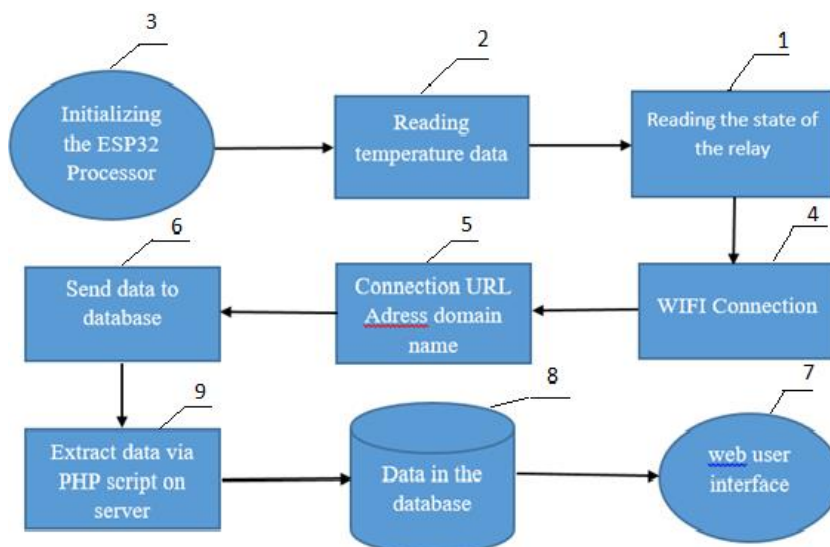


Fig. 10. Scheme of solar collector remote monitoring

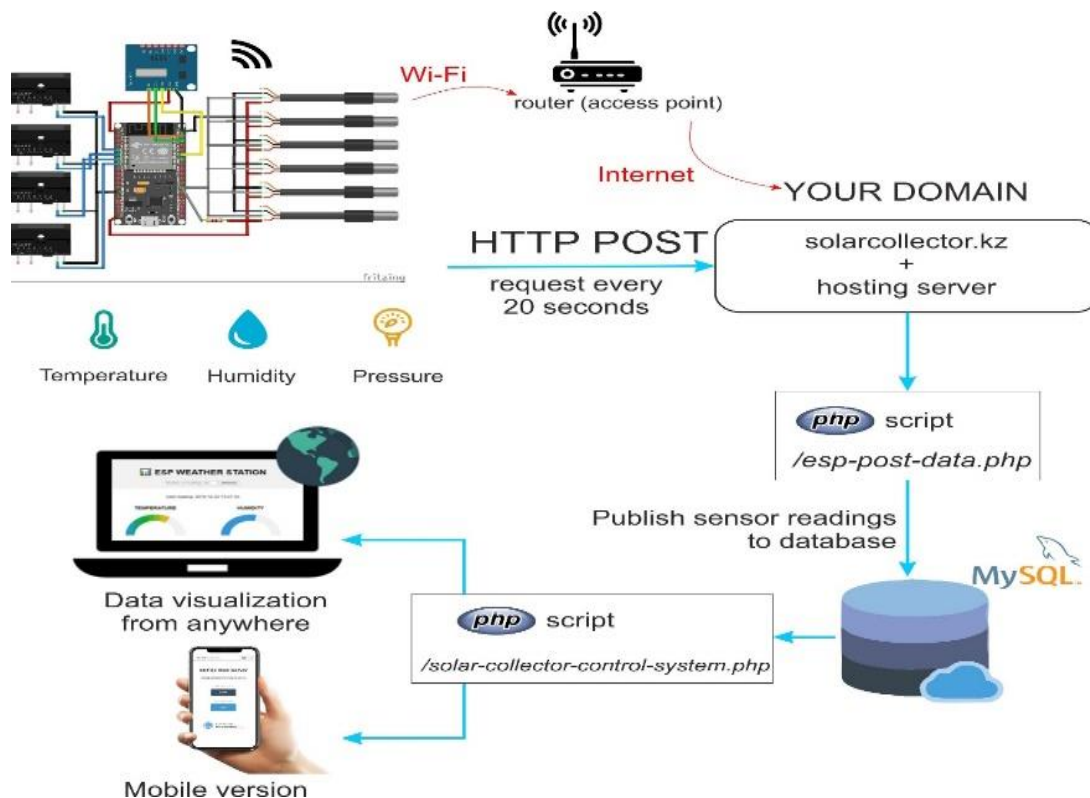


Fig. 9. Stationary system of solar collector remote monitoring

Link between a client and server is fulfilled by means of the hypertext transfer protocol (HTTP). In that protocol a client initializes the link, requesting the definite web page with the help of HTTP. One of the main features of ESP 32 consists in the fact, that it can both be switched on to the Wi-Fi network and acts as a web-server, and can adjust the own network, permitting other devices to be connected directly to it and receive an access to the web pages. It is possible, because ESP32 can operate in free different regimes: station regime, soft access point regime and both simultaneously. It provides the possibility to construct grid networks.

#### CONCLUSION

The article herein presents development of the system of collecting, storing and processing the information from the solar collectors with the aim of creating the reliable system for the solar energy data collection in the real time to optimize the operation of solar heat and hot water supply system. The article demonstrates hardware and software outcomes of real case implementation in industrial and domestic premises during longer time period.

System of remote monitoring with fixed solar collector has a smart structure and can effectively fulfill automation control and management over the solar collector network, image monitoring interface in place, database, dynamic data, historical data, dynamic curve and solar collector monitoring information in the real time mode, as well, remotely regulate the working condition and establish the solar collector's working parameters.

#### REFERENCES

[1] P. Visconti, A. Lay-Ekuakille, P. Primiceri, and G. Cavalera: Wireless Energy Monitoring System of Photovoltaic Plants with Smart Anti-Theft solution integrated with Household International Journal on Smart Sensing and Intelligent Systems, ISSN 1178-5608, Vol. 9 (Issue 2), pp. 681–708, Web-site: <http://s2is.org/Issues/v9/n2/papers/paper15.pdf> (June 2016).

[2] S. Viswanath, M. Belcastro, J. Barton, B. O'Flynn, N. Holmes, P. Dixon: Low-Power Wireless Liquid Monitoring System Using Ultrasonic Sensors. International Journal On Smart Sensing And Intelligent Systems, Vol. 8, No. 1, pp 26-44, Web-site: <http://s2is.org/Issues/v8/n1/papers/paper2.pdf>. (2015).

[3] M. A. Sanz-Bobi: Use, Operation and Maintenance of Renewable Energy Systems, Green Energy and Technology: Experiences and Future Approaches. (Book) Springer Int. Publishing (2014).

[4] J. Han, C.S. Choi, W.K. Park, I. Lee, and S.H. Kim: Smart Home Energy Management System Including Renewable Energy Based on ZigBee and PLC. IEEE Transactions on Consumer Electronics, Vol. 60 n.2, pp 198-202 (2014).

[5] M. Pasamontes, D.J. Alvarez, J.L. Guzman, M. Berenguel, E.F. Camacho: Hybrid modeling of a solar-thermal heating facility. Solar Energy, Vol. 97, pp. 577-590 (2013).

[6] H. Ghayvat, J. Liu, A. Babu, E. Alahi, X. Gui, S. C. Mukhopadhyay: Internet of Things for smart homes and buildings: Opportunities and Challenges. Published on Australian Journal of Telecommunications and the Digital Economy; Vol. 3(Issue 4), pp. 33-47, DOI: <http://dx.doi.org/10.18080/ajtde.v3n4.23> (2015).

[7] H. Ghayvat, S. Mukhopadhyay, X. Gui, N. Suryadevara: WSN- and IOT-based smart homes and their extension to smart buildings. Sensors Journal (Switzerland), Vol. 15 (Issue 5), pp. 10350-10379, DOI:10.3390/s150510350 (2015).

[8] Z. Rehman, I. Al-Bahadly, S. Mukhopadhyay: Multiinput DC-DC converters in renewable energy applications - An overview. Renewable and Sustainable Energy Reviews, Vol. 41, pp. 521-539, DOI:10.1016/j.rser.2014.08.033 (2015).

[9] X. Zhenghua, C. Guolong, H. Li, Q. Song, L. Hu, C. Lei, M. Youwen, X. Yexiang: The Smart Home System based on the IAP 15F2K61S2 and GSM. International Journal On Smart Sensing and Intelligent Systems, Vol. 7, No. 4, pp 1789-1806, Web-site: <http://s2is.org/Issues/v7/n4/papers/paper19.pdf>. (2014).

[10] K. Jiju, P. Brijesh, P. Ramesh, B. Sreekmari: Development of Android based on-line monitoring and control system for Renewable Energy Sources. IEEE Proceeding of Int. Conf. on Computer, Communication and Control Technology (I4CT 2014), pp 372-375 (2014).

[11] A.S. Pattanayak, B.S. Pattnaik, B.N. Panda: Implementation of a smart grid system to remotely monitor, control and schedule energy sources using Android based mobile devices. IEEE Proceeding of 9th Int. Conf. on Industrial and Information Systems (ICIIS), pp 1-5 (2014).

[12] Amirgaliyev Y., Kunelbayev M., Kalizhanova A., Amirgaliyev B, Kozbakova A, Auelbekov, O., Kataev, N. Study of convective heat transfer in flat plate solar collectors. WSEAS Transactions on Systems and Control, Volume 14, 2019, Pages 129-137