Intelligent Thermal Accumulator Operation Control System based on Renewable Energy Sources

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Abstract: In this paper, we consider the software and hardware implementation of an intelligent control system for optimal use of solar thermal energy and geothermal energy accumulator for heating and hot water supply of residential areas, multi-storey buildings, greenhouses with the highest possible efficiency. To achieve maximum results, the system complies with the Industry 4.0 concept and uses a multi-level management and monitoring structure such as Web dispatching, local and global system management and monitoring, cloud and local data storage, cloud and local management and monitoring, emergency notification and changes in the system via web technologies.

1 INTRODUCTION

Currently, for heating and hot water supply, energy is used from coal-fired thermal power plants with outdated low-efficiency systems. The sun is a huge, inexhaustible, absolutely safe source of energy. Of all the types of renewable energy sources known to us, geothermal energy is the most attractive in terms of continuous operation. It does not depend on the weather in a given area, the sun (Tverskoy, 2021) is shining or not, the wind is blowing or not. The advantages of such systems include inexhaustibility, stability, compactness and convenience for difficult areas, environmental friendliness, the possibility of parallel mining. In view of the fact that there is a decrease in hydrocarbon reserves in the world with a simultaneous increase in the rate of energy consumption, solar energy (Spitsyn, 2022) should be considered not only as a win-win, but also in the long term as an uncontested choice for humanity.

The technology of seasonal accumulation of solar thermal energy is intended for storing large quantities of solar thermal energy in an underground heat accumulator and in accumulators for further use of the accumulated thermal energy in space heating and hot water supply systems. The developed technology solves the problems associated with daily and seasonal changes (Kuznetsov, 2017) in the intensity of solar radiation, which allows the technology to function as a heat supply system all year round, regardless of time and weather conditions. The purpose of the automated control system is to maintain the established modes of the technological process by monitoring technological parameters, influencing and changing them, issuing commands to execution mechanisms and visually displaying data on the state of the production process and technological equipment, execution tools. The functions of the automated control system TP include Emergency Prevention, analysis of controlled values, remote control, stabilization of mode parameters and technological indicators. Automation helps to achieve the main goals of the company's policy in internal and quality issues. The principle of operation (Phillips-Wren, 2008) of automation systems is based on measuring the parameters of the technological process using intelligent measuring instruments and subsequent control of the technological process, its changing effects.

2 DESCRIPTION OF THE GENERAL SYSTEM

The system is a software and hardware complex for optimal adjustment of the temperature mode. Intelligent control unit system depending on temperature, water level and pressure received from sensors; flow meters; shut-off valves and signal pumps can remotely control shut-off valves, control the flow rate of heat carriers in heat exchangers, turn

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on or off solar collectors, pumps, or change the direction of flow in pipes.

Small circuit - circuit from solar collector to heat storage. The inlet and outlet are equipped with temperature sensors and solenoid valves. There is a circulation pump for each individual circuit. Large circuit - circuit from accumulator heat to consumption terminal. On the way to the terminal there is a connection with solenoid valves and a distribution system (Averkin, 2020).

3 DATA COLLECTING MODULE

To transfer data from the actuators to the upper level, the ModBus TCP protocol is organized over TCP / IP. The structure of client-server relationships is used. On the client side, port 502 is specified. Older automated systems used RS-485 serial communication lines. Since today ModBus TCP is more reliable and advanced, this technology is used in the system. The

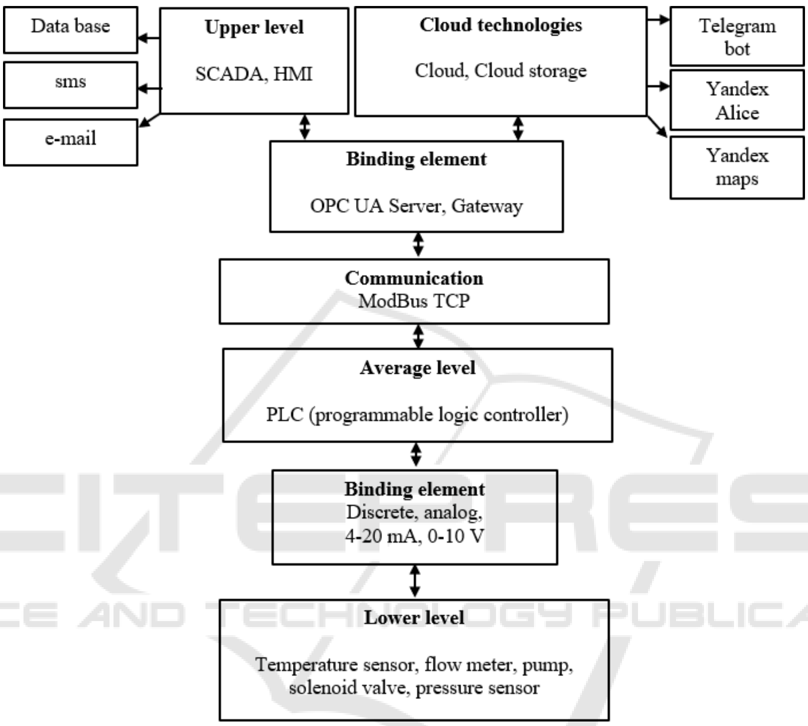

Figure 1: System architecture.

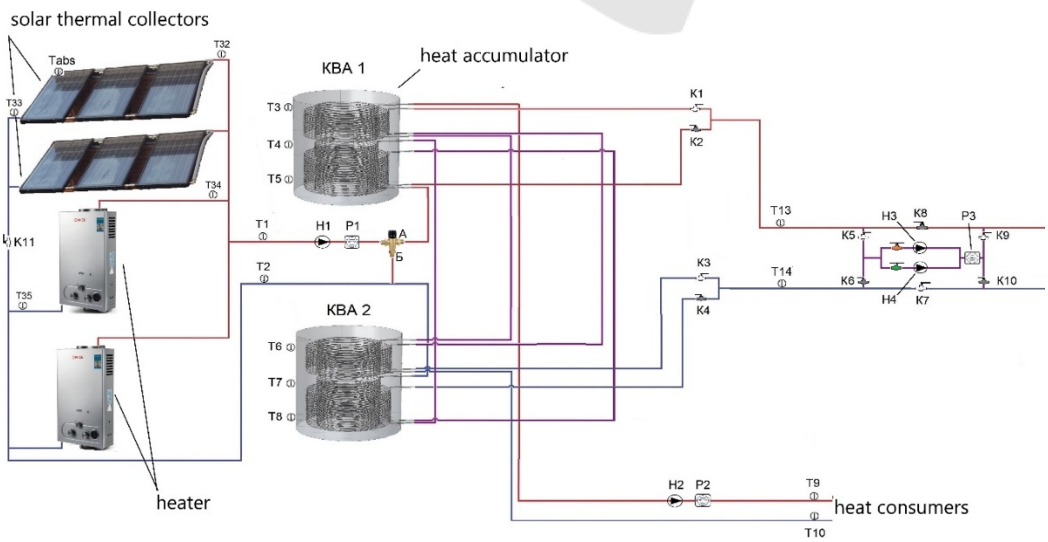

Figure 2: Scheme of layer 1 part 1.

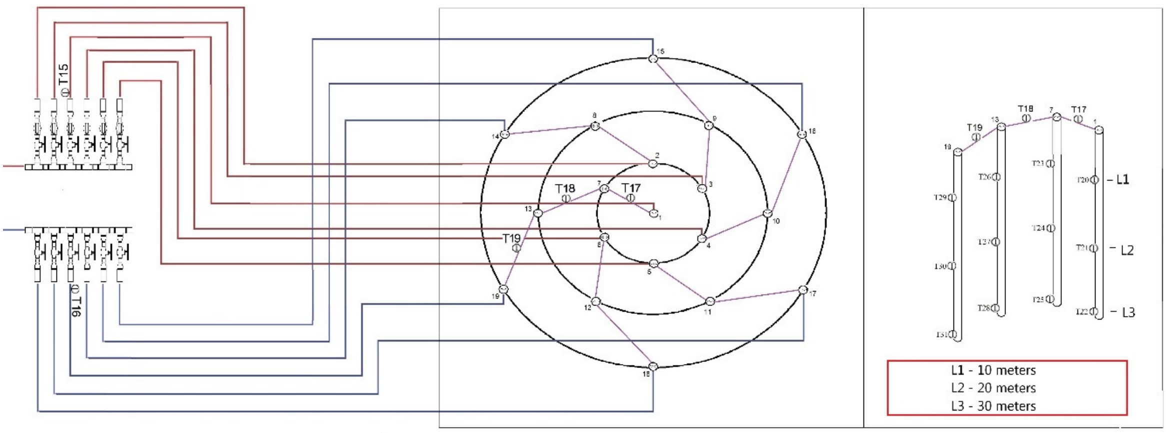

Figure 3: Scheme of layer 1 part 2.

ModBus protocol reads data from the PLC registers for certain functions. Read and write functions are specified from the PLC and OPC server side. The data from the PLC via the ModBus TCP protocol is received by the OPC server. In the OPC server the IP address is specified and a data collection node with certain read and write functions has been created (Duarte, 2021).

4 CONTROL MODULE

Regardless of the PLC logic, the SCADA (Chuan, 2021; Wertani, 2008) system has its own error handling logic, a system for alerting about accidents and warnings, sending a message to a specific addressee, sending an SMS message, archiving and storing an event in a database.

Data from the PLC and all internal processes of the system are stored in the server database. MySQL is selected as the DBMS. Specified Port 3306, login and password.

With the help of SCADA (Aydin, 2020) system scripts, a table is directly created and the database columns are filled. The script supports SQL commands.

The intellectual component of the system consists of two modules: an analysis module and a decision-making module.

It is possible to view the selected data in the form of graphs and tables and in the form of a report with a choice of period and device (Dubolazova, 2019).

Changes in the system, accidents of certain degrees, warnings are notified through the Telegram bot, Yandex Alice. The connection with the Telegram bot is created using tokens. The link to Yandex Alice was created using the UID. All notification properties of the event and trigger are configured and specified in the cloud (Aleio, 2018).

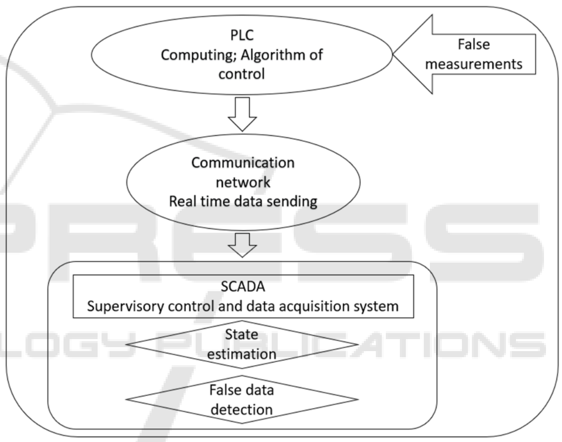

Figure 4: Input data structure.

The interface allows direct control of fieldbuses and actuators in real time.

The implementation of a SCADA system gives the enterprise the following advantages:

- A continuous real-time data exchange system is established through special drivers.
- All incoming information is processed in real time.
- Obtaining an easy-to-use human-machine interface
- Availability of a database with data on the progress of all technological operations of the enterprise.

In a SCADA system, data is read from the OPC server and assigned to specific variables. When read, specific OPC servers with a specific address are indicated.

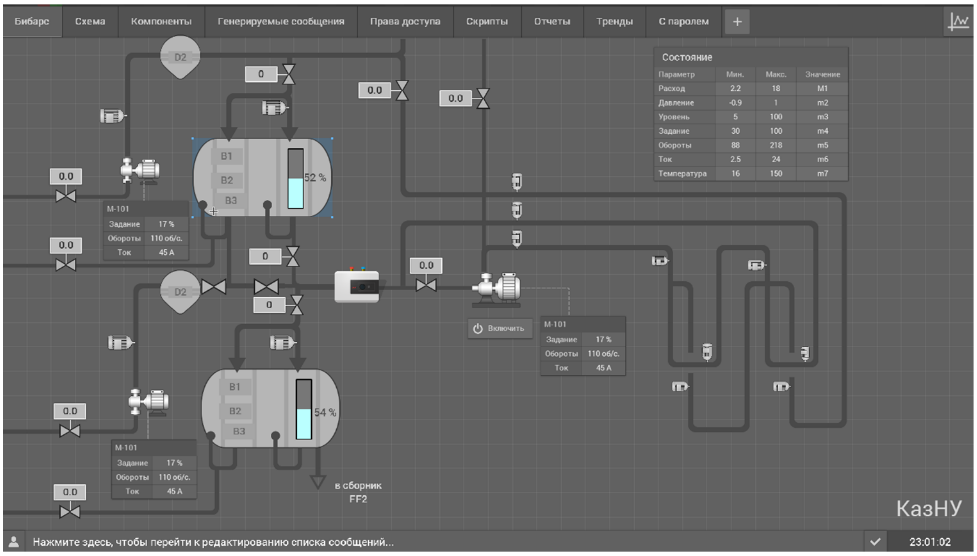

Figure 5: SCADA system.

The following main parts of the SCADA system can be distinguished:

- base of tags;
- graphic display module;
- script processor.

5 RESULTS

There is an architecture of automated process control system. In this scheme we will go from down to up. There are actuators and sensors in the lower level. We took 2 types of sensors in this project. We have PT100 and PT1000. These sensors are designed to measure temperature. They are submerged and they are invasive. Invasive is because they are screwed into the inside of pipes with hot water supply, and they describe the temperature according to the principle of changing the resistance in the network. It turns out that the more, for example, resistive resistances or less, they change the data.

About 10 temperature sensors (PT100, PT1000) are used in this project. They connect to our PLC, they feed data in the form of analog signals and connect to analog and PLC paths, as a PLC controller we used Segnetics SMH2G controllers and from this controller we sent via Ethernet module to our Cloud OPC server. We used the Oven OPC server as an OPC server, it is free and we can use it to store our data or process our data. As a SCADA system, we took the Simple SCADA program.

Next, we have a PC ARM smartphone, ARM is an automated workplace and an ARM smartphone, they serve to output data from sensors, from the system for the user so that he can see and understand it, even a user far from this sphere could understand what is described and shown here. This is the architecture of this system.

Figure 6: The control panel.

Control box dimensions 800mm in length, 650mm in width and 250mm in height. The SMH2G controller has an Ethernet port that support ModBus protocol and it has a display, it shows data from temperature sensors. Here we have data from the PT100 and PT1000 sensors connected, and they are connected to our controller. They are powered by a 24V power supply and they are connected to the analog paths of our controller. This is our FMR extension module. Our controller has very few inputs and outputs, and this module is designed to increase input and output cells. These are our control relays, they are needed to control the valves. We have 10 valves and 10 pumps located there. The relay is needed to control valves and pumps with a controller control signal. The controller sends a signal to the relay, and the supply voltage comes to the relay and the relay closes, as it were, and the valve or pump stops working. And as soon as the controller sends a working signal, these valves operate at a voltage of 250V, and the control signal is 24V without a controller. The controller sends a 24V signal to the relay, the relay closes and blocks the 250V voltage that flows through it and feeds our pumps and valves. This is our 24V power supply, it is designed to power our controller, which is powered by 24V and expansion modules and Ethernet data transfer modules. The Ethernet module is needed in order to transfer data to the OPIS server and the cloud. And also on the control panel there are control switches for entering into automatic and manual mode and completely shutting down the system during emergencies.

Figure 7: Implemented intelligent control system in the mosque «Koksay».

Here we have PT100, PT1000 sensors, valves, control pumps and the SMH2G controller, which is programmed in FBD (function block diagram). Each of devices has a ModBus IP address. This system is located in the Koksay Mosque. It is fully operational and has already been put into operation. It is designed to manage excess energy from the solar collector for heating the system which is in the form of hot water supply and floor heating. All logic is based on this control panel. It controls the actuators of this system.

6 CONCLUSIONS

The paper considers an approach to the software and hardware implementation of an intelligent control system. The technical result has an increase in the optimization factor and functionality due to the structure of management and monitoring and the model of an intelligent system.

The functionality of the system with the help of an intelligent automated system allows you to minimize human influence, increase the efficiency of the system, manage and monitor all states in the system locally and remotely, analyse and investigate data in a certain period of time, identify violations and failures of elements and sections of the system, optimize all workers processes (Kozadaev, 2021).

The developed intelligent automated system solves the problems associated with daily and seasonal fluctuations in the intensity of solar radiation, which allows the developed technology to function as a centralized heat supply system all year round, regardless of the time of day and weather conditions.

Using green energy and storing thermal energy in underground batteries is a conceptually new approach to energy supply. The advantages of the technology are its environmental friendliness and versatility. This technology can replace thermal power plants operating on fossil fuels such as coal or gas, heat power plants operating on environmentally hazardous ones. The system is easily scaled and can operate for many years without interruption and is safe for the environment. In addition, the developed model of an intelligent work automation system can be applied not only in heat power engineering, but also in other industries and automation, such as Smart City, work line automation in production, food industry, chemical industry.

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