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THE PRINCIPLE OF CONSTRUCTION OF THE BOILER CONTROL SYSTEM WITH EFFICIENT USE OF THE SOLID FUEL

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***Abstract*: The system for controlling the economic operation of a solid fuel boiler is a device that controls and monitors the processes that occur during fuel combustion and water circulation in a solid fuel boiler. The system describes the combination of two main components: software and hardware. Based on these components, this article presents the method of building a system of economic operation of a solid fuel boiler, describes the development environment with its functions and capabilities, provides a detailed description for the user with explanations of key points in the operation of the system. This system is aimed at improving the quality of room heating and optimizing this process in order to regulate the desired temperature for the user with minimal error. All software tools interact with each other according to clearly defined protocols, so there are no system failures.**

***Index Terms*: solid fuel boiler, algorithm, functional blocks, industrial controller.**

I. INTRODUCTION

A smart control system for a solid fuel boiler is an important element that allows you to optimize the efficiency of the boiler and ensure economic benefit. Recent years have witnessed the active development of various smart control systems for solid fuel boilers, after all, it is necessary for each person to rest [1]. This article reviews the experience of using smart control systems for solid fuel boilers, which are based on intelligent technologies such as smart control algorithms.

The [2] controller is an important component of a smart solid fuel boiler control system. This controller, produced by the company, works on the basis of a microprocessor and provides automatic regulation of boiler operation taking into account external conditions and consumer needs. In addition, the [2] controller displays the state of the boiler on the indicator and provides the possibility of programming the work schedule to ensure the efficient use of solid fuel [2].

The [3] controller is another innovative device that can be used to implement a smart solid fuel boiler control system. This controller has a large number of settings, which allows you to fine-tune the parameters of the boiler according to the user's requirements [3].

The controller provides a wide adjustment range, which allows you to adjust the boiler's operating mode depending on changes in weather conditions. In addition, it has a built-in interface for communication with other devices, which allows expanding the functionality of the control system [3].

Thus, the [3] controller is an important component of a smart solid fuel boiler management system, which provides accurate regulation of the boiler's operating parameters and the ability to communicate with other devices to expand the system's functionality. A reference to this device can be found in [3].

A Polish company [4] specializes in the production of innovative solutions in the field of heating and ventilation. The company produces a wide range of products, including thermostats, pump groups, controllers and sensors. One of the company's products is thermostats for heating systems, which allow you to effectively control the temperature in the room.

In particular, among [4] thermostats, the [4] 2000 model can be singled out, which allows you to control the temperature in the house and ensure the optimal level of comfort and energy efficiency. This thermostat has a wide range of functions and capabilities, in particular it provides the ability to program the schedule of the heating system for a week, it has a "holiday" function that allows you to lower the temperature in the house during the vacation period, and it also has a presence sensor in the room that allows you to automatically turn off the system heating when the room is empty.

In general, [4] products are a good example of the use of modern technologies in heating and ventilation systems, which allows to reduce energy costs and increase the comfort of life for users [4].

II. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The article [5] is important in terms of intelligent control systems for solid fuel boilers, because it proposes a new neural network-based control method that can provide efficient and accurate temperature control in industrial processes. This resource can be used to demonstrate the advantages of a control system based on neural networks over traditional control systems, as well as to study specific methods of designing and modeling neural network control systems.

A research paper devoted to the research and development of a control system for a solid fuel boiler using fuzzy logic to solve the problem of uncertainty and vagueness of input data is given in [6]. The article [6] describes in detail the structure and operation of the control system, which includes sensors, data collection devices, a control unit, as well as software that provides data processing and control of boiler processes. The authors of the article [6] suggest using fuzzy logic to increase the accuracy and efficiency of the control system.

This article [6] contains important information about the development of a solid fuel boiler control system using fuzzy logic. Its results can be useful for researchers and engineers working on the development of similar control systems.

A research paper from [7] presents an intelligent model for predictive residential heating control based on an improved comfort index and an online learning approach. The article examines the need to improve the methods of managing the heating of residential buildings in order to increase the comfort of residents and reduce heating costs.

The authors proposed a new method of improving the quality of heating management in residential buildings, in particular, the use of an improved index of system management comfort. To achieve this goal, the authors proposed to use predictive control models based on neural networks, which make it possible to make predictions for future heating control based on historical data of heating systems and other input data. The article also considers the application of online learning to improve the quality of forecasting.

Therefore, the description provides additional ideas on how to increase comfort and reduce heating costs with the help of intelligent control of heating systems. This can be useful for our article, as it demonstrates the possibilities of using intelligent methods of optimizing the operation of heating systems [7].

The article [8] describes the development and implementation of an intelligent control system for the operation of a solid fuel boiler, which is based on the integration of a system for monitoring boiler parameters and automatic control of fuel combustion parameters. The authors of the study developed software for collecting data from sensors installed on the boiler and software for managing fuel combustion parameters.

Research conducted by the authors showed that a smart control system allows maintaining a stable temperature level in the room. The results of the study indicate that a smart control system can be an effective solution for increasing the efficiency of solid fuel boilers.

The general approach used in this work is based on the use of sensors, data collection and control of the fuel combustion process. This approach is fairly standard for intelligent control systems for solid fuel boilers. The authors offer their solution, which, according to them, allows improving the operation of the boiler. However, the article [8] does not provide a detailed comparison with other developments and research in this field, so it is difficult to assess the uniqueness of the proposed approach [8].

The article [9] is devoted to the application of various methods and algorithms for intelligent control of solid fuel boilers. The article describes the application of a control algorithm based on neural networks, which allows optimizing the operation of the boiler and reducing electricity consumption. The article also discusses the use of a control algorithm based on genetic algorithms, which also allow optimizing the operation of the boiler.

The authors of the article [9] conducted a study of the effectiveness of each algorithm and compared their results. According to the results of the study, the control algorithm based on neural networks gave better results compared to other algorithms. Also, the authors of the article indicate that the use of an intelligent control system for a solid fuel boiler can lead to significant economic benefits, reducing energy consumption and increasing the durability of the boiler.

In general, the article [9] is an interesting study that demonstrates the possibilities of applying various algorithms for intelligent control of solid fuel boilers. The results of the study confirm the effectiveness of using a control algorithm based on neural networks and indicate that the use of intelligent control systems for solid fuel boilers can lead to important economic and environmental benefits [9].

After conducting an analysis of already completed projects and mining companies that provide their services in this field, the following results were obtained. Some projects are amateur, that is, they fall into the relatively cheap price category because they consist of cheap controllers (processors), sensors, control nodes and other equipment. Therefore, such projects can be called not very reliable. The projects of several leading companies that offer their control system for solid fuel boilers were also analyzed.

At the moment, in Ukraine, unlike the European market, there is a small number of companies that offer their services in this field, especially national products. Several leading foreign companies were selected and their management systems were analyzed.

III. REVIEW OF AVAILABLE METHODS FOR SOLVING THE PROBLEM

Today, their niche in the field of radio electronics and circuit engineering is occupied by microcontrollers and software platforms. They greatly simplify the implementation of tasks for developers and allow the creation of new devices with extended functionality, allowing combining several devices into one functional unit.

This property was used to develop a system for managing the economic operation of a solid fuel boiler, which will allow automating the management of the boiler plant, reducing the costs of the enterprise or the user.

The control unit for a solid fuel boiler is based on a board Arduino Uno Rev3.

Arduino is a hardware computing platform for amateur's construction, the main components of which are a microcontroller board with input/output elements and the Processing/Wiring development environment in the language programming, which is a simplified subset of C/C++. Arduino can be used to create autonomous interactive objects, and connect to the software that runs on computer. Information about the board (drawing of the printed circuit board, specifications elements, software) is in the public domain and may be used by those who prefer to create boards with their own hands.

Arduino and Arduino-compatible boards are designed so that they can it was necessary to expand by adding new components to the device ("shields"). These expansion boards connect to the Arduino using pin connectors installed on them.

There are a number of unified boards that allow a structurally rigid connection processor board and expansion boards in a stack through pin lines. In addition, boards with reduced (for example, Nano, Lilypad) and special (for tasks of robotics) form factor.

Third-party manufacturers produce a large number of all kinds of sensors and of executive devices, which to one degree or another are compatible with each other and with Arduino processor boards. Third-party manufacturers also produce electromechanical sets elements aimed at working together with Arduino boards (as a rule, through special boards-"drivers") - engines, electromagnets, etc.

Arduino Uno is a widely used microcontroller board with open source based on ATmega328P microcontroller. It includes everything necessary for convenient work with the microcontroller: 14 digital inputs/outputs (from 6 of them can be used as PWM outputs), 126 analog inputs, 16 MHz crystal resonator, USB connector, power connector, an In-Circuit Programming (ICSP) connector and a reset button.

To start working with the device, it is enough to simply supply power from an AC/DC adapter or battery, or connect it to a computer using a USB cable.

A solid fuel boiler is a device for generating and transferring heat carrier energy for the purpose of its further use for heating purposes.

The fuel for solid fuel boilers is firewood, coal or fuels granules (pellets) are an inexpensive alternative to gas and oil. Burning of this kind fuel (sawdust, wood chips, sunflower husks) also allows you to solve the problem of disposal of woodworking and agricultural production waste.

Modern solid fuel boilers provide high-quality, environmentally friendly combustion and a high degree of automation. In conditions of constant growth in prices for gas in Ukraine began to be in great demand.

A solid fuel boiler transfers heat generated as a result of fuel combustion coolant, which gives it to the internal environment through heating radiators rooms. The storage tank adds inertia to the system, accumulates heat at the peak productivity of the boiler and gives it to the heating and water supply system in case necessity. This stabilizes the operation of the solid fuel boiler and enables the system function even after burning out the fuel in the boiler (the time can vary from 6 hours to several days, depending on the volume).

It is also possible to install an indirect heating tank inside the storage device of hot water, which makes it possible to obtain hot water in quantity stably necessary to provide several hot water distribution points.

It is also an integral part of the heating system based on solid fuel the boiler has thermostatic mixers – they ensure a stable temperature in boilers, hot water supply and heating system.

The operation of solid fuel boilers (especially cast iron) requires stable coolant temperature – the temperature difference between the supply line and reverse should not exceed 5-10° C. It serves to achieve this goal thermostatic valve near the boiler in connection with the circulation pump. Following the thermostatic valve is located on the hot water supply line and stabilizes it temperature at the set value — usually from 55 to 65° C. The last valve in connection with the circulation pump ensures a stable temperature of the coolant in heating system.

Solid fuel boilers are currently on the Ukrainian heating equipment market needed more than ever. In terms of functionality, they are at least slightly inferior to gas ones, electric analogues, but significantly surpass them due to availability and relatively low cost of fuel. To achieve the maximum productivity of the equipment it is possible using automation for solid fuel boiler. It allows optimizing the combustion process and increasing its efficiency by an average of 20-30 %. At the same time primordial the programmed boiler can function almost without human intervention, guaranteeing the user comfort and complete safety.

The program part in the bachelor's qualification work is designed so that it allows you to connect the following devices to the board: a pump (for water circulation), a motor air injection (fan) and boiler temperature sensor. The pump and fan will be connected to the controller using auxiliary relays, and the temperature sensor directly.

Also, for displaying the graphical interface and convenient interaction user with the control unit, a simple and clear display was selected and 6 buttons to control the system.

The user can set the desired value independently in manual mode water temperature in the solid fuel boiler, and accordingly in the home heating system or any other premises. The system will be in automatic mode maintained the selected temperature until the fuel runs out solid fuel boiler.

The Arduino Uno Rev3 board is used as the basis of the control unit for the solid fuel boiler. Also, during the creation of the system, a four-channel relay, a high-precision sensor for measuring the water temperature in the heating system was used. The software part is de-

signed to allow the following devices to be connected to the board: pump (for water circulation), air injection engine (fan) and boiler temperature sensor.

The user can manually set the desired water temperature in the solid fuel boiler, and accordingly in the heating system of the house or any other room. The system in automatic mode will maintain the selected temperature until the fuel in the solid fuel boiler runs out. Also, in the proposed method, the accuracy of temperature measurement should be improved and the sensor data should be reduced to a minimum error.

IV. THE PURPOSE OF THE ARTICLE

Any of the energy carriers listed above are loaded into a special compartment of the boiler - the furnace, and set on fire. The heat produced in the combustion process heats the water, which, in turn, heats the house, circulating through the pipes.

Sometimes it was believed that the use of firewood as fuel for such boilers ineffective, since the burning period in this case is very short, low.

It is efficient to constantly add new portions of fuel and remove ash. To solve these problems, modern solid fuel boilers were developed, as well as pyrolysis boilers and top combustion boilers.

Regulators for solid fuel boilers differ in operational capabilities and the number of functions (additional options). There are many models on the market, from the most functional to the simplest. Currently, boiler manufacturers offer to buy a solid fuel boiler with automation for adjustment.

The purpose of the article is the principle method of building a system for managing the economic operation of a solid fuel boiler, where the user can manually set the desired water temperature in the solid fuel boiler, and accordingly in the heating system of the house or any other room. The system in automatic mode will maintain the selected temperature until the fuel in the solid fuel boiler runs out.

Also, in the proposed method, the performance of the system will be improved by 12.6%.

On the basis of this technique, the author's system for managing the economic operation of a solid fuel boiler was developed.

V. DEVELOPMENT OF THE SYSTEM STRUCTURE

A. HARDWARE SELECTION

When developing your own control system, you need to pay a lot of attention to the choice of technology that can be used in its construction. You need to review popular programs for development, modern controllers for programming and select sensors with high reliability. Based on this analysis, choose those components that will be able to satisfy the requirements of the system.

Based on the analysis and research, Arduino Uno Rev3 was chosen as the controller. In Fig. 1 the algorithm of the program is shown.

Features and capabilities of the controller:

- Microcontroller type: AVGA328P;
- Stabilizer output current: 3.3 V, 50 mA;
- Flash memory volume: 32 kB;
- SRAM memory volume: 2 kB;
- EPROM memory volume: 1 kB;
- Clock frequency 16 MHz;
- Analog inputs: 6 pcs.;
- Digital inputs-outputs: 14 pcs.;
- Compatibility with Win7 and Win8;
- Dimensions: 68 x 53 x 15 mm.

B. SOFTWARE SELECTION

To implement the software part of the project, we use:

1. "Arduino IDE" configuration software.
2. Configuration software "FLProg".

Arduino IDE is software for users of the Windows operating system that allows you to write your own programs (sketches) for the Arduino platform. This platform is primarily aimed at amateur designers who use Arduino to build simple automation and robotics systems. However, sometimes serious projects were created on the basis of Arduino.

The Arduino IDE consists of a fairly simple text code editor, a project manager, a compiler, and a module for uploading firmware to the microcontroller. This integrated environment is written in Java and is based on Processing and other open source software. Unlike the online version of the code editor (Arduino Web Editor), the desktop version can be used in the absence of the Internet.

The Arduino programming language is standard C++ (using the AVR-GCC compiler) with some features.

Advantages of Arduino IDE:

- availability of tools necessary for work;
- several options of programming languages;
- built-in set of program examples;
- functions of saving, exporting, checking.

For Windows, it is possible to download the archive and the installer (.EXE file). The archive can be used as a portable version. If you install the Arduino development environment at your permanent workplace, it is better to choose Windows Installer.

FLProg is a program created on the basis of visual programming languages FBD and Ladder, used for programming almost all logic relays and parts of industrial controllers around the world.

C. CREATING THE HARDWARE PART OF THE SYSTEM

On The electrical connection diagram consists of the following components:

- Arduino Uno Rev3 microcontroller;
- Power supply unit for the microcontroller;
- Temperature sensor DS18B20;
- Four-channel relay SRD-05VDC-SL-C;
- LCD1602 Keypad SHIELD indicator module.

Powering the Arduino Uno Rev3 controller can be done simply by connecting it to a computer with a USB cable or by connecting an external power source to the board. To power the device, you can use a 7-12 V source using the VIN and GND contacts, or directly using the +5V and GND contacts, but in this case you need to use only the current that passed through the 5 V voltage stabilizer, otherwise you can burn the board, yes it does not have a built-in stabilizer.

In this work, an external power source will be connected to the controller, which will use an ordinary phone power supply called Power Adapter MDY-11-EZ with the following characteristics:

- Input voltage: 220 – 240 V;
- Output voltage: 5 V;
- Power 10 W.
- Output current: 1 A.

The characteristics of this power supply unit are quite sufficient, since the control system consumes 300 mA.

Thus, from a 220 V network through a power supply unit connected via a USB cable of type A/B to the VIN and GND contacts, we will receive a stable 5 V power supply to the Arduino Uno Rev3 board. The diagram of power connection to the controller is shown in Fig. 1.

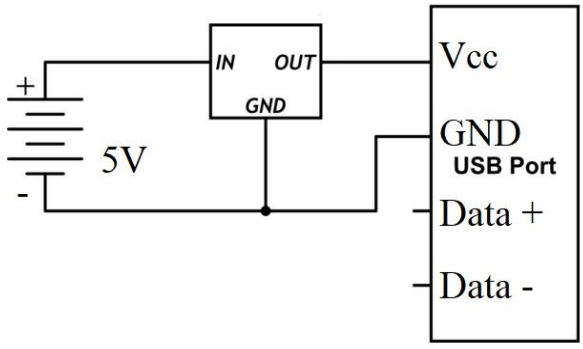

Fig. 1. Diagram of power connection to the controller

The DS18B20 temperature sensor is used in this system for controlling the economic operation of a solid fuel boiler.

Two methods of connection are possible: using only two of the three outgoing conductors (in this case, power will be supplied through the data contact), or using all three outputs. In this work, the connection is made according to the second option. Data is transmitted from the sensor to the board through the yellow wire, which is connected to the D2 output. Consumed voltage for the DS18B20 is possible in the range from 3.0 to 5.5 V. In the case of this system, a five-volt connector (5V) is used on the board, to which the red wire of the temperature sensor is connected, through which power is supplied. The third (black wire) is "ground", connected to the GND output on the board. It should be noted that there is a 4.7 kΩ resistor between the red and yellow wires (power and data).

The relay is controlled from the controller outputs. With the help of a relay, control is implemented by executive mechanisms, such as: a pump (for water circulation in the heating system) and a fan (for oxygen saturation of the fuel in the boiler). The system uses a module designed on the basis of four SRD-05VDC-SL-C relays. The VCC output of the relay module is connected to the 5V line on the Arduino Uno Rev3 controller, similarly, GND is connected to GND on the boards. Outputs IN1, IN2 of the relay module are connected to D3 and D4 on the controller, respectively.

Connection of the LCD1602 Keypad SHIELD board, which acts as both a display and control of the entire system with the help of built-in buttons, is carried out by hinged mounting. When connecting the display module to the controller, most of the outputs of the Arduino Uno are duplicated on the LCD1602 Keypad SHIELD board, because the display and control module is connected only to the outputs: D5, D6, D7, D8, D9, the five-volt line 5V, GND and the analog output A0, which are on the microcontroller. The scheme of the electric functional system of controlling the economic operation of a solid fuel boiler is shown in Fig. 2.

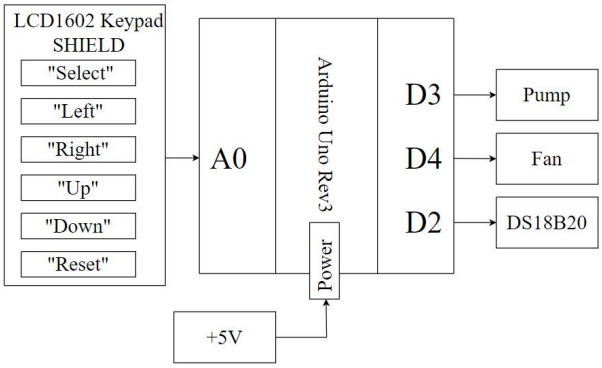

Fig. 2. Scheme of the electric functional system of controlling the economic operation of a solid fuel boiler

For an example of use, let's take a solid fuel boiler that produces power (P_1) = 12 kW when heating water to t_1 = 90 degrees. The type of fuel is dry oak firewood. Combustion chamber volume (V) = 33 liters = (0.033 m^3). The efficiency (η) of this wood boiler is 70 %.

Density of dry oak (ρ) = 650 kg/m^3. Accordingly, with a volume of 0.033 m^3, the theoretically possible capacity of the firebox (m) = ρ * V = 650 kg/m^3 * 0.033 m^3 = 21 kg of firewood. However, we understand that the actual volume of filling will be an order of magnitude smaller, since the loaded firewood will have a certain number of gaps between it and the walls of the firebox.

Therefore, for wood, such an indicator as the stacking coefficient (k) is used. This parameter is quite conditional and can vary within 0.35 - 0.45. For this example, we will take the average value (k) = 0.4.

Thus, taking into account the stacking factor, the actual amount of oak firewood:

$$(m\_fact) = m * k = 21 \text{ kg} * 0.4 = 8 \text{ kg}.$$

Next, we calculate the calorific value of the bookmark (Q) = m fact * 4200 kJ/kg = 8 kg * 4200 kJ/kg = = 33600 kJ or 39 kW. Taking into account the efficiency of the boiler, the tab will produce effective power:

$$(P\ eff) = Q * \eta = 39 \text{ kW} * 0.7 = 27.3 \text{ kW}.$$

Now we calculate the time (T_1) of the tab's burning duration:

$$T_1 = P\_eff / P_1 = 27.3 \text{ kW} / 12 \text{ kW} = 2.275 \text{ hours}.$$

Using automation for a solid fuel boiler, you can increase the burning time of the same amount of firewood in the same boiler.

For example, if the user considers it appropriate to heat water to $t_2 = 80$ degrees, the following results can be achieved with the help of automation:

boiler power becomes:

$$P_2 = t_2 * P_1 / t_1 = 80 * 12 \text{ kW} / 90 = 10.6667 \text{ kW}.$$

Burning time of the bookmark with an automatic control system (T_2) at this power:

$$T_2 = P\ eff / P_2 = 27.3 \text{ kW} / 10.6667 \text{ kW} = 2.5625 \text{ hours}.$$

System performance improvement in usage time according to the formula:

$$\Delta T = (T_2 / T_1 - 1) * 100\ \% =$$
$$= (2.5625 \text{ hours} / 2.275 \text{ hours} - 1) * 100\ \% = 12.6\ \%.$$

VI. THE DECISION TREE DESIGN PROCESS

The FLProg program was used in the development of the software. Immediately before the preparation of the development of the entire system, it was decided that it should perform:

- Water circulation in the system;
- Fuel saturation with oxygen.

The algorithm of the program is shown in Fig. 3.

To begin with, you need to understand how a solid fuel boiler works there are pros and cons when operating this unit. This device can be compared with a boiler operating on natural gas, automatic control of which is already, as a rule, built into the unit itself.

When heating a room (house), the consumer sets the desired temperature water to which the boiler, using natural gas combustion, heats the water, and the pump, that is installed in the device constantly circulates it. This happens until water in the entire heating system will not acquire the desired value of the consumer.

Further water circulation continues even without gas burning, while the water in the system is not will cool by, as a rule, 2-3 degrees. What happens in the gas boiler ignition and subsequent heating of water to previous temperatures, so the consumer can get a comfortable temperature in the room, once after configuring the device.

The mechanical regulator for solid fuel boilers is one of the main components that allow you to control the temperature in the water heater. This device allows you to automatically adjust the supply of air and fuel to the boiler, ensuring the optimal level of heat generation and maintaining a stable water temperature.

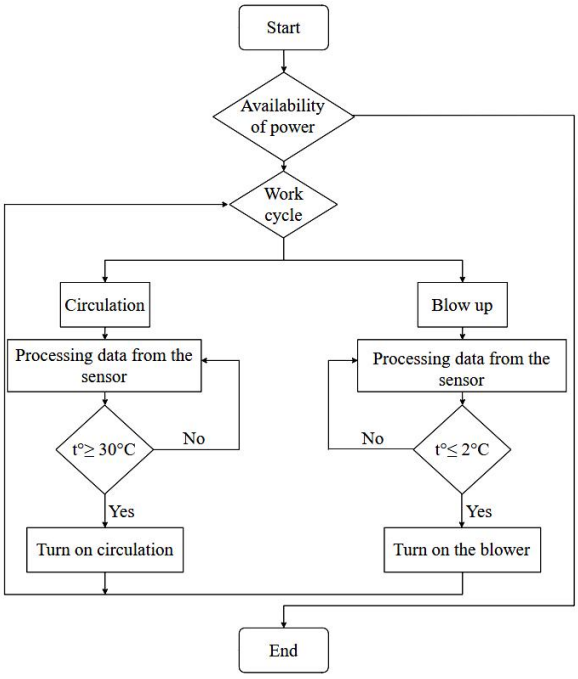

Fig. 3. Algorithm of the program

The regulator consists of various elements that ensure the efficient operation of the device. One of the most important elements is the thermostat, which is responsible for measuring the water temperature and sending a signal to adjust the fuel. In addition, the mechanical regulator includes a mechanism for adjusting the air supply, which allows you to maintain the optimal concentration of oxygen in the boiler.

One of the advantages of the mechanical regulator is its reliability and ease of operation. It does not require complex settings and does not require special knowledge to install it. In addition, the mechanical regulator can work without an additional energy source, which makes it economical and environmentally friendly compared to electronic regulators.

There are many different models of mechanical regulators for solid fuel boilers. Some of them have additional functions, which allow you to reduce heating costs. Some models also have the ability to connect to heating control systems using sensors or other devices.

In general, a mechanical regulator for solid fuel boilers is an important element of the heating system, which helps to reduce heating costs and save energy. With proper selection and installation, it ensures efficient and reliable operation of the boiler for a long time.

The functionality of the mechanical is limited to the possibility of opening and closing the air in the combustion chamber fuel. The rate of fuel combustion will depend on this parameter and the temperature of the coolant in the boiler. Such a device is a brass sleeve with a plastic handle, as well as a chain that regulates the air supply to the furnace.

The movement of the sleeve will be regulated by the temperature of the water in the system. It makes this regulator completely independent of the power grid, but

it does not work a significant plus, since it is still required for the full operation of the system electricity for water circulation by the pump.

When combining a reliable microcontroller with circulation systems and oxygen enrichment – as a result, we will get an automatic and economical system control of a solid fuel boiler with the necessary basic functions for full, serviceable and high-quality operation of the unit.

The received necessary information will be shown on the display monitoring, control, as well as correction by the user necessary for him values and making corrections to the temperature regime, which is necessary for the owner.

A reliable and high-precision sensor should also be added to the whole system temperature, for the correct reading by the microcontroller of the water at the exit from boiler.

The entire automatic control system will work according to the principle a combination of the theory of operation of a boiler operating on natural gas and a mechanical one regulator for a solid fuel boiler. After turning on the control system, the user will have to choose the desired temperature of the water at the outlet and set fire to firewood, coal, sawdust, etc.

The temperature sensor that will be attached to the required heating pipe home, immediately sends data to the microcontroller. After that, when detected the temperature on the pipe is lower than the one set by the user by more than 2°C the system will automatically start the operation of the fan to saturate the fuel with oxygen.

In this way, active burning of firewood, coal or other will take place before those until the pipe to which the temperature sensor is attached begins to flow water with a temperature set by the user. After reaching the desired temperature, the device in offline mode will turn off the oxygen supply to the combustion chamber and waiting for a decrease of 2° C will begin, after which the process will be repeated again and again.

In addition, the circulation pump of the entire system, which will also be connected to the microcontroller and will only work when the temperature sensor is on water whose degree is greater than or equal to 30° C. This is done in order to automation did not circulate cold water in the heating system through the radiators.

Finally, everything needs to be securely fastened, including the temperature sensor set as close as possible to the pipe at the outlet, for correct data that will be transmitted from it to the microcontroller. Also, the whole system automatic control must be carefully isolated from moisture.

Let's start with the implementation of the connection of the display module and the control system of the economic operation of the solid fuel boiler.

LCD1602 Keypad SHIELD, acting as a display, has built-in six buttons, which are quite enough for control. Moreover, control is carried out only through one analog output, since each button has its own individual signal. When pressing a certain button, the microcontroller "understands" which key was pressed by the user.

Features and capabilities of the LCD1602 Keypad SHIELD keyboard:

- Right – allows the user to move through the menu on the display to the right;
- Left – allows the user to move through the menu on the display to the left;
- Up – allows the user to increase the desired temperature at which water circulation will occur or air blowing will be turned on;
- Down – allows the user to lower the desired temperature at which water circulation will occur or air blowing will be turned on;
- Select – is responsible for entering one or another variable, the value of which the user intends to change; is responsible for exiting this or that variable whose value the user has changed;
- RST (Reset) – is responsible for rebooting the system, after updating the values required by the user.

Next, we will connect and configure the DS18B20 temperature sensor. It will play a major role in the further correct operation of the entire control device. In particular, the real-time temperature will be updated every 1 second and displayed in the lower right corner of the display with the sign "°C" after the value.

The pump for water circulation in the system works as follows. It uses a relay that is in one of two positions. The first position – the pump (water circulation in the system) is turned off, the second is turned on, because the signal from the controller reaches the relay and switches it to the working position.

As for switching on, it happens according to certain logic, namely when the controller reads the value from the DS18B20 sensor and detects a temperature ≥ 30°C.

If the water in the heating system is ≤ 29°C, the controller turns off the relay to which the circulation pump is connected.

The fan, which is designed to saturate the fuel with oxygen, works on almost the same principle as the pump for water circulation in the heating system. It also uses a relay that is in one of two positions. The first position – the fan (air blowing) is turned off, the second is turned on, because the signal from the controller reaches the relay and switches it to the working position.

As for the inclusion, the logic is slightly different from that by which the pump works.

The user himself sets the desired value using the buttons on the LCD1602 Keypad SHIELD, after which the controller reads data from the DS18B20 sensor and compares them not with a constant, but with the data specified by the user.

Thus, if the temperature value sent by the DS18B20 sensor to the controller is < 1°C from the temperature specified by the user, the controller turns on the relay to which the fan is connected, which in turn starts saturating the fuel with oxygen. This happens until the values from the DS18B20 sensor and the user are the same.

The LCD1602 Keypad SHIELD interface is both intuitive and simple to use that the user can deal with everything he needs immediately and without problems.

On the second line of the screen on the right, by default, the temperature currently sent by the DS18B20 sensor to the controller (water temperature in the heating system) is displayed.

In the first line on the left is the constant V (fan) and the temperature value set by the user from the keyboard.

In the second row on the left is the constant N (pump) and the temperature value at which the circulation pump goes into operation.

Also, both in the first and in the second line there are variables "on" and "off", which show whether the fan and the pump are on or off, respectively.

VII. CONCLUSIONS

The proposed methodology stated how a 12.6% improvement in the system was achieved.

Modern systems of automatic control of the economic operation of a solid fuel boiler were analyzed in the article.

The main components of the control system were also described. Necessary calculations were made. The main points of system management were presented, the elements that performed the main functions and actions were reasonably selected.

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