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STUDIES OF TRANSMISSION OF INFORMATION AND CONTROL SIGNALS OF TREATMENT PLANTS

DINARA KOZHAKHMETOVA*[1], DMITRIY MYASSOYEDOV[2], RASHID NAZAROV[3], DANAR BEKKASSIMOVA[4], DINARA KURUSHBAYEVA[5]

[1,2,3,4,5]Department of automation and information technology, Semey State University Named after Shakarim, Semey, Kazakhstan

E-mail: [1]dinara_kozhahmetova@mail.ru(D.K.), [2]dmitriy880@mail.ru(D.M.); [3]naz-2009@yandex.ru(R.N.); [4]beccasimova@mail.ru(D.B.), [5]sh_din097@mail.ru(D.K)
*****corresponding author: dinara_kozhahmetova@mail.ru

ABSTRACT

This article is devoted to the development of an automated control system for process parameters, which allows transmitting controlled parameters to the computer of the central dispatch control room in order to increase the efficiency of the sewage treatment facilities in Semey due to the possibility of making operational decisions on the control of the process of wastewater treatment based on the monitoring of equipment. The article is aimed at substantiation and development of centralized automated system of control of technological parameters (ASC TP) of treatment facilities of g. Semey, including a microcontroller information system for the main sewer pumping station and blower pumping station and designed for continuous monitoring of operating and limit (emergency) parameters of equipment operation, They are presented in the form of discrete potential and continuous current signals, with the possibility of graphical and sound display of the current information on the panel of controllers and computer monitor with the possibility of saving.

Keywords: *Wastewater Treatment, Sewage Treatment Facilities, Mechanical Treatment, Biological Treatment, Control Systems, Dispatch Control, Sewage Pumping Station, Signal Frequency.*

1. INTRODUCTION

Currently, an important scientific and technical problem is the environmental protection of the natural environment from pollution by industrial waste and municipal waste water. The main tasks of protecting the water basin include both the rational use of water resources and the treatment of effluents to the level of requirements for their discharge into water bodies.

In the general problem of protecting the environment from natural and anthropogenic impacts, rational use and reproduction of natural resources, the fight against pollution of reservoirs by domestic and industrial wastewater is extremely urgent. The socio-ecological side of the problem is often successfully combined with the purely economic side, since a huge amount of irretrievably lost valuable substances can, with their optimal extraction and use, significantly replenish the country's raw materials [1].

Wastewater, or waste liquid, is water used for domestic or industrial needs and has received contaminants that change its original chemical composition or physical properties [2,3,4].

Wastewater is a product of human physiological activity, as well as its domestic and production activities. Depending on the nature of the formation, wastewater is divided into domestic and industrial. In terms of composition and nature, domestic wastewater is quite constant, industrial wastewater is very diverse. Wastewater is a complex heterogeneous system contaminated with substances that can be in all states - soluble, colloidal and insoluble. Colloidal and insoluble substances form coarse and finely dispersed suspensions, emulsions and foam. Both organic and inorganic contaminants are always present in the wastewater. Organic substances in domestic effluents are in the form of proteins, carbohydrates, fats, physiological processing products, in addition, domestic effluents contain large impurities - paper, waste of plant origin, as well as synthetic surface-active substance (SSAS). Of the inorganic components in this category of effluents, potassium, sodium, calcium, magnesium, chlorine, carbonates, sulfates are always present. Domestic effluents, in addition, necessarily include biological contaminants.

Following legislative instructions on the need to further strengthen environmental protection, policymakers decided to strengthen work on the study, design and construction of high-efficiency water treatment facilities and devices. The increased requirements for the quality of their operation thus made it necessary to significantly expand the range of tasks solved from the standpoint of a system approach based on the achievements of management theory, modeling methods and optimization of engineering and environmental processes and systems [5].

The ingress of organic and mineral contaminants into water and soil basins occurs during the discharge of municipal and industrial wastewater generated during the implementation of technological processes of production and processing of products and in the process of human life. Such water is commonly called wastewater. The peculiarity of wastewater discharged to treatment facilities is that they are largely contaminated with substances of organic and mineral origin, which are in dispersed, colloidal and soluble forms. Wastewater contains a wide range of organic carbon-, nitrogen- and phosphorus-containing contaminants, requiring the use of various physicochemical and microbiological methods for their removal from wastewater. The need to equip the water management systems of cities and industrial enterprises with modern complexes of gravity and head pipelines and other special facilities that implement the removal, treatment, neutralization and use of water and the resulting precipitation is obvious.

Improvement of management efficiency of treatment facilities operation can be achieved due to automation of control at the stages of observation, collection, processing and analysis of information by means of packages of mathematical analysis of data, implementation of automated process control systems (APCS).

New data collection techniques combined with low-cost storage applications have facilitated the collection and analysis of massive datasets to holistically describe natural and artificial environments. However, the area of integration of energy, water and agriculture management through developing remote sensing technologies is still in its infancy. We believe that remote sensing technologies are increasingly being used for resource management, but there is still great scope for implementing these technologies to achieve the goals of integrated resource management [6].

2.PROBLEM DEFINITION.

The modern development of scientific studies and technology for the treatment of natural and wastewater goes mainly in two directions:

1) development of fundamentally new techniques of deep treatment using physicochemical methods and their combination with biological treatment;

2) development of methods of so-called post-treatment of wastewater, ensuring improvement of efficiency of existing methods of pollution removal [7,8].

Improvement of efficiency of management of operation of treatment facilities can be achieved due to automation of control at the stages of observation, collection, processing and analysis of information by means of packages of mathematical analysis of data, implementation of automated process control systems (APCS).

The structure of the control system has at least two components - hardware and software system.

When developing conceptual issues, at least two global tasks must be solved: the technical modernization of equipment and the definition of tactical and strategic goals for the management of these equipment. Thus, the conceptual issues of technical modernization of APCS water disposal are not only the replacement of the old process equipment with a new one, but also the selection and application of new technical means of controlling these equipment, allowing to manage all treatment facilities in accordance with the general goal - wastewater disposal from consumers and their treatment at minimum energy costs.

The concept of modernization of the control system should lead to the creation of such a structure of APCS, which will allow to have complete and timely information about all events taking place at water disposal facilities, including the number of domestic and industrial effluents withdrawn from consumers and treated, on the state of the process equipment at any moment, on the readiness of the equipment for operation in the planned periods of time, on the state of the network and the quality of its operation and on the basis of this information, perform related management of all objects included in the structure of the water disposal system.

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The research hypothesis suggests the possibility of improving the efficiency of wastewater treatment facilities by using modern methods of collecting and transferring technological parameters to the dispatcher's control panel in order to make operational decisions on the control of the wastewater treatment process based on monitoring equipment operation. Due to the complexity of the entire complex of treatment facilities, the main sewage pump station and blower pump station were chosen as facilities for the development of the automated process parameter control system (APPCS).

The development and implementation of an automated monitoring and control system for water supply and water disposal (sewerage) is appropriate when the most important decisions affecting the management strategy or goals, development and improvement of the system are based on the experience of a person, his intuition, which cannot be formalized and therefore cannot be programmed; partially or completely (depending on the type of automated control system (ACS) and the type of information), the processes of collecting, recording, storing and processing information are automated, that is, processes that can be performed automatically without compromising the functioning of the system.

The design and implementation of an automated control and management system for water supply and sanitation (sewerage) is appropriate where critical decisions affecting the management strategy or objectives, the development and improvement of the system, based on the human experience, his intuition, which is not susceptible to formalization and therefore cannot be programmed; the collection processes are partially or completely (depending on the type of automated control system and the type of information) automated, Recording, storage and processing of information, i.e. processes that can be performed automatically without affecting the functioning of the system.

As the transition from the automation of individual processes and apparatuses of natural and wastewater treatment to the operational management of treatment complexes with the help of an automated system of process control, the managed objects become more and more complex, and their operation requires taking into account the specifics of each specific class of technological processes of water treatment. In addition, the specificity of the formulation and solution of the tasks of operational automated management of treatment plant systems is due to many similar features of hardware and technological schemes and methods of control over their work.

Intelligent energy networks consist of devices capable of performing their functions in an energy-efficient method and capable of interlinking and remote control. Therefore, some of these devices, such as intelligent energy meters, become attractive for use in energy generation and distribution, realizing the concept of intelligent networks. However, to create a fully functional and secure intelligent network, many problems must be overcome. Providing measurement, control, interlinking, power, display, and synchronization capabilities will be challenging for intelligent meters [9,10]

The layout plan of wastewater treatment facilities is given in Figure 1.

1 – suction chamber; 2 – bar screen building; 3a – aerated detritus chamber; 3б – pavilion and detritus chambers; 4 – biological treatment unit; 5 – chamber of post-treatment and UV-sanitization; 6 – pumping station №2; 7 – reservoir of biologically clean drains with the volume of 3000 m^3; 8 – reservoir of untreated washwater with the volume of 2000 m^3; 9 – filter bowl; 10 – sludge pumping station; 11 – work section of precipitation mechanical dehydration; 12 – pump and air blower house; 13 – laboratory; 14 – accommodation module; 15 – garage; 16 – distributing gear 6 kV; 17 – inventory and equipment subsurface warehouse; 18 – sand sites (7 maps); 19 – drainage pumping station; 20 – pumping station of technical and wash water; 21 – administrative and production building; 22 – laboratory warehouse.

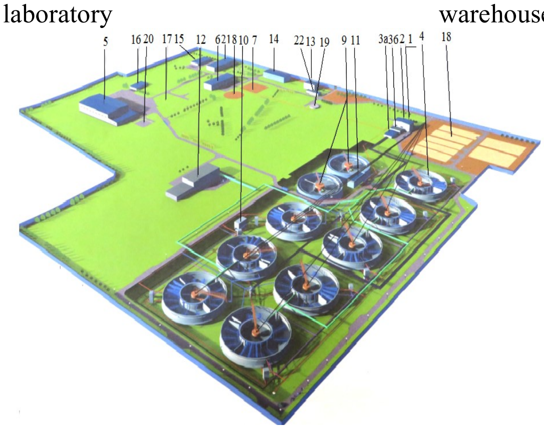

Fig. 1 Plan Of Sewage Treatment Facilities.

In most cases, the treatment facilities are equipped with pump units with electric motors with a voltage of 6.0-10 kV and a capacity of 315-2500 kW. Traditionally, water supply parameters are controlled by throttling. As a result, the

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unproductive costs of electricity in some cases are up to 30-40%.

Their significant reduction is achieved by replacing throttling control with frequency control.

The classical control method of pump units involves throttling of head lines (installation of control valves), according to the level in the tank. Pump units in this case are selected based on certain design characteristics (as a rule, with a productiveness supply) and constantly operate at a constant circular frequency, without taking into account changing costs. That is, at a minimum flow rate, the pumps continue to operate at a constant nominal (maximum) circular frequency, creating excess head in the network, while a significant amount of electricity is useless.

Let's look at the operation of the process, from the point of view of changing the flow rate in the network - Q. To do this, we will use the known Q-H characteristics for pumping units and the network (Figure 2).

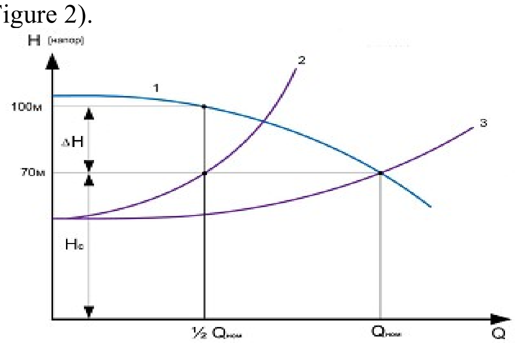

Fig. 2 Characteristics Of Pump Unit And System With Throttling Control.

Curve 1 corresponds to the head characteristic of the pump unit, curve 2 corresponds to the hydraulic characteristic of the throttling network, and curve 3 corresponds to the natural hydraulic characteristic of the network (without throttling). The point of intersection of the pump head characteristic and the natural hydraulic characteristic of the network is the ideal design point of joint operation of the pump unit and the network (without throttling), and corresponds to the flow rate Qnom.

The classic control of the flow rate of the target component is the installation of a control valve (throttling control) in the pipeline section, after the pump.

This valve creates additional hydraulic resistance, and allows to ensure the required flow rate in the network pipeline. When using control valves, the head is distributed on the system elements. This head distribution is shown in Figure 2, where ΔH is the head drop on the throttling element.

To maintain a given flow rate in the network pipeline, the hydraulic resistance of the control element must be changed. At the same time, the overall hydraulic characteristic will have an abrupt appearance. The ΔH value with this adjustment is steadily increased. Thus, if the throttling by the control element is deeper performed, the entire process has more energy losses.

The amount of losses during throttling is influenced not only by the control element: most often, at the design stage, a pump unit with a certain head flow rate is selected, and when replacing pump units, the new equipment may have somewhat overstated head characteristics. In addition, the range of change in input heads (upstream of foot pipe of the pump unit) affects the head value downstream of the pump unit. All these circumstances lead to the fact that the energy losses during the process become quite large, reaching 45% or more of the pump rating.

To solve the problem of minimizing losses related to network head control, it is necessary to exclude additional hydraulic resistances in the section from the pump unit to the network pipeline, that is, it is necessary to fully open the whole valves and piping.

This can be done if the flow rate control process is transferred to the pump unit. The theory of superchargers operation (pumps and ventilators) proves that the change in the circular frequency of the supercharger drive changes its head characteristics. In addition, the head created by the supercharger is proportional to the square of the unit circular frequency. Change of head characteristics of pump unit at change of circular frequency is shown in Figure 3, in which curve 1 corresponds to nominal (at nominal circular frequency of drive) head characteristic, and curves 2-4 - to head characteristics at reduced circular frequency.

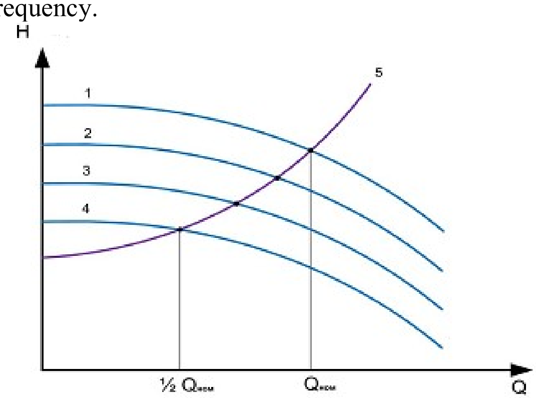

Fig. 3 Characteristics Of Pump Unit And Network With Frequency Adjustment

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In this case, the pump unit and the network operate at an ideal joint nominal design point. Thus, there is no additional hydraulic loss.

By organizing the operation of the pump unit drive so that it changes the circular frequency when the process parameters change, it is possible to control the consumption of the target component without significant energy losses. With such a control method, head losses (no throttling elements) are excluded, and therefore hydraulic energy losses.

The method of controlling the flow rate in the network by changing the circular frequency of the pump unit drive reduces energy consumption for another reason. Actually, the pump, as an energy conversion device, has its own efficiency - the ratio of the mechanical energy applied to the shaft to the hydraulic energy received in the head pipeline of the pump unit. The nature of the change in the efficiency **η** of a pump depending on the flow rate of liquid **Q** at different circular frequencies is shown in Figure 4.

Research hypothesis suggests the possibility of increasing the efficiency of wastewater treatment plants by using modern methods of collection and transfer of technological parameters to the control panel of the dispatcher in order to be able to take operational solutions to control the process of wastewater treatment on the basis of equipment operation monitoring [2]

Analysis of required change of pump unit frequency at change of flow rate in the network shows that decrease of rotation speed is required as flow rate decreases. If you consider the pump operation for the flow rate less than the nominal (1/3 Qnom and 1/2 Qnom), then for these modes it is rational to operate at a reduced circular frequency. In this case, the efficiency of the pump is higher than when operating at a nominal circular frequency.

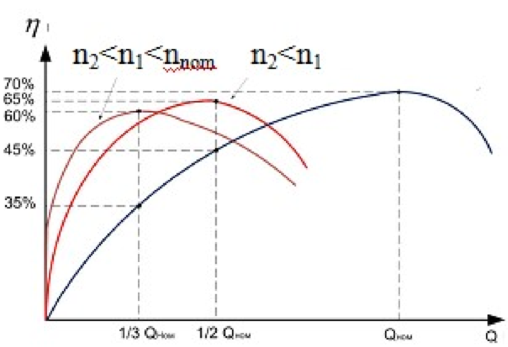

Fig. 4 Change Of Efficiency Of The Pump Unit With Frequency Adjustment At Capacity Change

Thus, the reduction of the circular frequency, in accordance with the process load, allows not only to save energy consumed by eliminating hydraulic losses, but also to obtain an economic effect by increasing the efficiency of the pump - the conversion of mechanical energy to hydraulic [11,12,13].

3. RESULTS AND ANALYSIS.

Automated Process Parameters Control System (APPCS)

In developing conceptual issues, at least two global challenges need to be addressed: the technical upgrade of equipment and the definition of tactical and strategic objectives for the management of that equipment. Thus, the conceptual issues of technical modernization of automated systems of technological processes of water disposal consist not only in replacement of old technological equipment with new, but also in the choice and use of new technical means of control of this equipment, allowing to manage all facilities of treatment facilities in accordance with the common goal - to remove from consumers wastewater and its treatment at a minimum energy cost [7,8].

Stage 1. Since the distance between the main sewage pump station and the central dispatch control room is 1200 meters, the flow line should be examined to determine the line's capability to transmit information signals.

A 1200 m long UTP 5e cable coil was taken as the flow line. Before the experiments, the flow line characteristics shown in Table 1 were determined. Measurement of parameters was carried out using a bridge RLC-meter MS5308, designed to measure inductance, capacity, resistance (Figure 5).

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Fig. 5 RLC-Meter MS5308

Table 1 - Flow Line Parameters

Line characteristic	Value of physical quantity
line resistance (R_{line})	950 Ohm
line capacity (C_{line})	51 nF
line inductance (L_{line})	140 H

Physical investigations were carried out at an experimental facility consisting of a signal generator (Figure 6), an oscillograph C1-67 (Figure 7), a digital multimeter Sanwa PC500a (Figure 8).

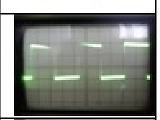
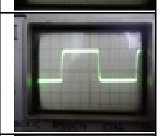
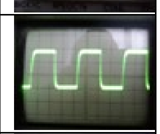
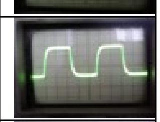
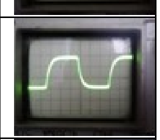
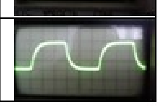
Fig. 6 Functional Generator

Fig. 7 Oscillograph C1-67

Fig. 8 Digital Multimeter Sanwa PC500a

In a series of experiments, rectangular waveforms of different frequencies were transmitted through a transmission line to the oscillograph input to detect changes in the parameters of the signals passing through the line. The amplitude of the input signal was adjusted at 5V, the amplitude of the output signal was measured by multimeter. The results of the experiment are shown in Table 2.

Table 2 - Results Of Physical Investigation Of Signal Transmission On Transmission Line

Input signal frequency, Hz	Output voltage, V	Difference between input and output voltages of flow line, V	Waveform from the oscillograph at the output of the flow line
1	2	3	4
30	5	0	
50	5	0	
100	4,945	0,055	
250	4,880	0,120	
500	4,769	0,231	
750	4,661	0,339	
1000	4,550	0,450	
1250	4,444	0,556	
1500	4,334	0,666	
1750	4,293	0,707	

As seen from the experiment (Table 2), the waveform changes with increasing signal frequency

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and the amplitude of the output signal decreases, which questions the possibility of transmitting data at a distance of 1200 m over the selected flow line. To verify this assumption, a circuit based on the MAX 232 microchip was assembled, converting the signals of serial port RS-232 into signals of the TTL level (Figure 9). This microchip allows to connect microcontrollers through the UART serial port to the COM port of the computer by matching the voltage level. The connection diagram of MAX 232 microchip is given in Figure 9.

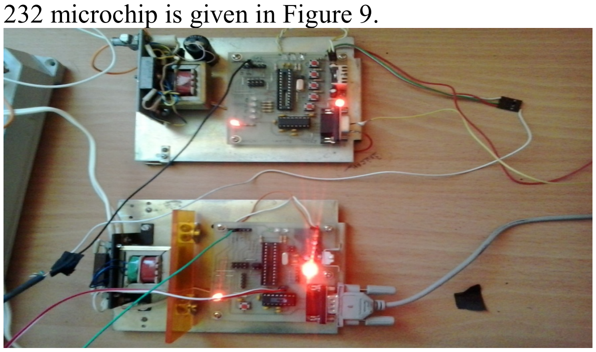

Fig. 9 Experimental Facility To Test The Possibility Of Data Transmission Via Serial Port RS-232

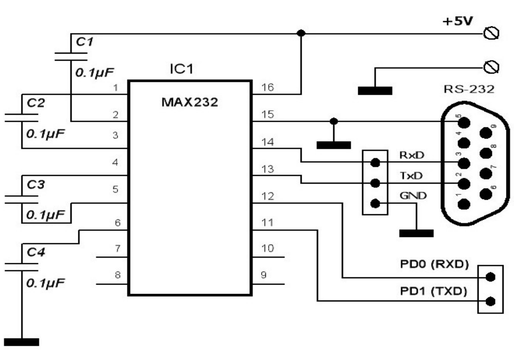

Fig. 10 Diagram Of Microcontroller Interlinking With Computer Via COM Port (RS-232)

Stage 2. The purpose of the experiment is to test the possibility of data transmission between two computers through the serial port RS-232 on the selected flow line. Control over the transmitted information will be carried out using the Terminal 1.9b program installed on computers, which allows to work with the COM port of the computer.

Experiment 1. To begin with, it is possible to transmit data over the flow line of 0.3 m long at a transmission rate of 9600 baud in order to check the operability of the assembled device. To do this, from the computer transmitting information, we send the phrase "Verification of information transmission at a transmission line length of 30 centimeters." Figure 11 shows the program window on the computer side receiving the information messages (the program windows on the receiving computer side will also be shown further).

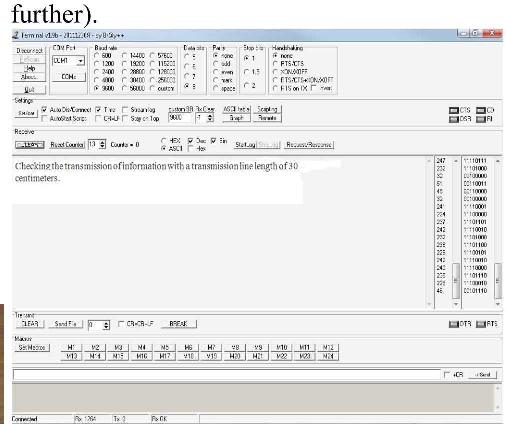

Fig. 11 Result Of Experiment 1

As shown in Figure 11, the transmission of information was successful.

Further studies have shown that increasing or decreasing the transmission rate does not lead to a positive result, hence it can be concluded that the accepted potential method of transmitting information at these flow line parameters is not suitable for interlinking of the microcontroller information system with the computer of the central dispatcher station in the structure of the developing automated process parameter control system.

Stage 3. We replace the potential method of transmitting information with the method of transmitting information using measured values of electric current strength. Currently, this method is more common in engineering practice than the use of voltage for this purpose. A generally controlled current source is used to set the measured current values.

Advantages of current loop interface:

- - accuracy does not depend on the length and resistance of the transmission line, since the controlled current source will automatically maintain the required current in the line;
- long range (up to several kilometers);
- ability to power the sensor directly from the transmission line;
- high noise resistance;
- simplicity of implementation, no need to coordinate the line;
-ability to combine multiple sensors in a single interface.

All these advantages allowed this interface to be successfully used in APCS systems. The digital current loop standard uses the absence of current as the value of SPACE (low level, logical zero) and the presence of a signal as the value of MARK (high level, logical one). The absence of a signal for a long time is interpreted as a BREAK state (line break). The data is transmitted by the start-stop method, the send format coincides with RS-232, for example 8-N-1: 8 bits, without parity, 1 stop - bit. The current loop can be used at considerable distances (up to several kilometers).

To protect the equipment, galvanic isolation on optoelectronic devices is used. Realization principle f digital "current loop" is given in Figure 12 [14,15].

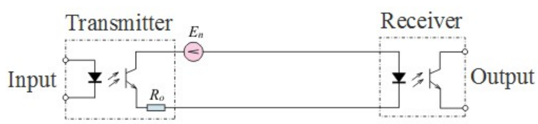

Fig. 12 Realization Principle Of Digital "Current Loop"

To carry out the 1200 m data transmission experiment, a circuit (Figure 13) was assembled, allowing data to be transmitted over the selected flow line in a "current loop" method.

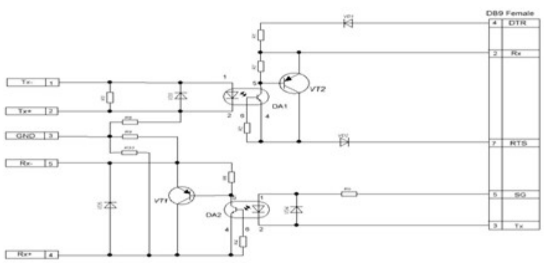

Fig. 13 Schematic Diagram Of Adapter RS-232C - "Current Loop"

Since a cable of category 5 UTP type of 1200 meters long is used between the main sewage pump station and the central dispatch control room, that transmission of information in standard digital form is impossible, therefore, transmission of information between objects should be carried out in the form of current parcels (via the "current loop" interface), which is justified by the type, length and quality of the flow line between objects.

The reliable and uninterrupted operation of wastewater treatment systems requires clear coordination and mutual integration of the work of its individual elements, which can be achieved through the introduction of a single centralized management and control. Centralized management of the sewage treatment plant system by the dispatch service.

The concentration of the control data by high-speed automatic devices and the use of this information for the operational management of the production process allows it to be carried out in optimal mode, t. e. with maximum productivity with increased product quality and minimum cost. Dispatching covers not only control and management of the production process, but also operational planning of its conduct, distribution of energy, transport and material resources to achieve optimal performance of production.

The task of operational collection and complex monitoring of technological parameters of the process of operation of treatment facilities with the possibility of storing them (to identify the causes of equipment deviation from the set parameters) is an integral part of ensuring the quality of wastewater treatment [2,7,8,16].

4. CONCLUSION

The problem of improving the energy efficiency of technological equipment that consumes electricity has always been urgent. In most cases, the treatment facilities are equipped with pump units with electric motors with a voltage of 6.0-10 kV and a capacity of 315-2500 kW. Traditionally, water supply parameters are controlled by throttling. As a result, the unproductive costs of electricity in some cases are up to 30-40%. Their significant reduction is achieved by replacing throttling control with frequency control.

As a result of the study, schemes for switching on high-voltage stations of frequency control of pump units were analyzed and their comparative characteristics were given, the features of parallel operation of pump units with frequency control and without frequency control were considered.

An effective means of achieving a high quality of operation of sewage treatment plants is the use of the Automated System of Autonomous Wastewater Control - it allows to conduct on-line reduced chemical analysis. The system works by varying the sensor equipment can both increase and reduce the number of controlled parameters, thus bringing the control parameters closer to the parameters of the treatment plants.

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