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The Principle of the Complex Systems of Container Pneumatic Transport Using Multi-Purpose Switch Throwers

Yuriy Genrihovich Lobotskiy[1], Valerii Vasilievich Khmara[1], Alexandr Mihailovich Kabyshev[1] & Albert Gageevich Dedegkaev[1]

[1] The North Caucusing Institute of Mining and Metallurgy (state technological universiny), Vladikavkaz, Russia

Correspondence: Valerii Vasilievich Khmara, The North Caucusing Institute of Mining and Metallurgy (state technological universiny), st. Nikolaeva, 44, Vladikavkaz, 362021, Russia. Tel: 7-928-488-6913. E-mail: khmaraval@yandex.ru

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Abstract

This article discusses issues related to the testing process automation of the technological processes in enterprises involved in concentrating, metallurgical and other processing industries and the construction of complex distributed systems of container pneumatic transportation. The structure of such systems includes automatic loading and unloading devices for the transport containers and automatic switch throwers for directional changing the routes of laden and empty transport containers. All these devices belong to the class of robotic mechanisms, automatic control of which is usually provided by the microprocessor control system. The implementation of optimal control of such devices in the microprocessor control system is performed by consistent receiving the information signals, based on which and taking into account the previous state, the control system generates the control commands. In this regard, the control system shall be able to process in real time a large amount of input data and have an internal memory of sufficient depth. It is shown that the construction of complex systems, pneumatic transport of container is possible based on various combinations of universal switch throwers built on the modular basis.

Keywords: testing of technology products, automated analytical control systems, container pneumatic transportation system, automatic switch throwers, transport container, robotic mechanism, microprocessor control system, control command, control algorithm

1. Introduction

Production efficiency is largely determined by the degree of automation of technological processes, which is especially important for enterprises of concentrating, metallurgy, and many other process industries.

Almost all of these enterprises are equipped with modern efficient equipment and have reasonably complex technological processes. Under these conditions, obtaining high technological parameters depends on the perfection of the organization of the quality control process of processed products at each stage of the process. The necessary information about the raw material, intermediate products and finished products and dump products is produced by sampling, i.e. by representative sampling, which reliably characterise the whole amount of the original flow of the controlled product. The selected single sample can be immediately directed to the chemical laboratory for analysis. However, in most cases the selected single samples is sent for reduction and then, the sequentially selected within a certain time reduced single samples get averaged, and the required amount of the average sample is delivered to the analysis in the laboratory. As a rule, the average sample is identical in composition throughout sampled batch of the controlled product. The number of private single samples that make up the average sample determines the probability of drawing quite representative average samples with any desired accuracy.

Due to the high demands on accuracy and speed of obtaining analytical information on the composition of processed products, the information is usually produced in the automated systems of analytical monitoring (**ASAM**), major subsystems of which are the subsystems of automatic selection and delivery of samples for analysis and the analytical subsystem.

2. Literature Review

The process timely obtaining of the analytical information in the required extent and with the required accuracy can be viewed as a process in which the quality of the process functioning is determined by the quality of the resulting analytical data, i.e., completeness, timeliness and reliability of measurement results (Khmara, 2006; Lobotskiy, 2013). Object for control and the information source for ASAM of the concentrating and metallurgical production is a sample, which is represented by the pulp, liquid and free-flowing products. Transfer of the consumer-required information contained in the sample into available for its further use form is carried out after numerous conversions. Typical algorithmic chain of the selection of representative single samples, compiling an average sample, high-speed container delivery to the place of the centralized control and preliminary preparation for instrumental analysis of samples of pulp, liquid and free flowing products is shown in Figure 1.

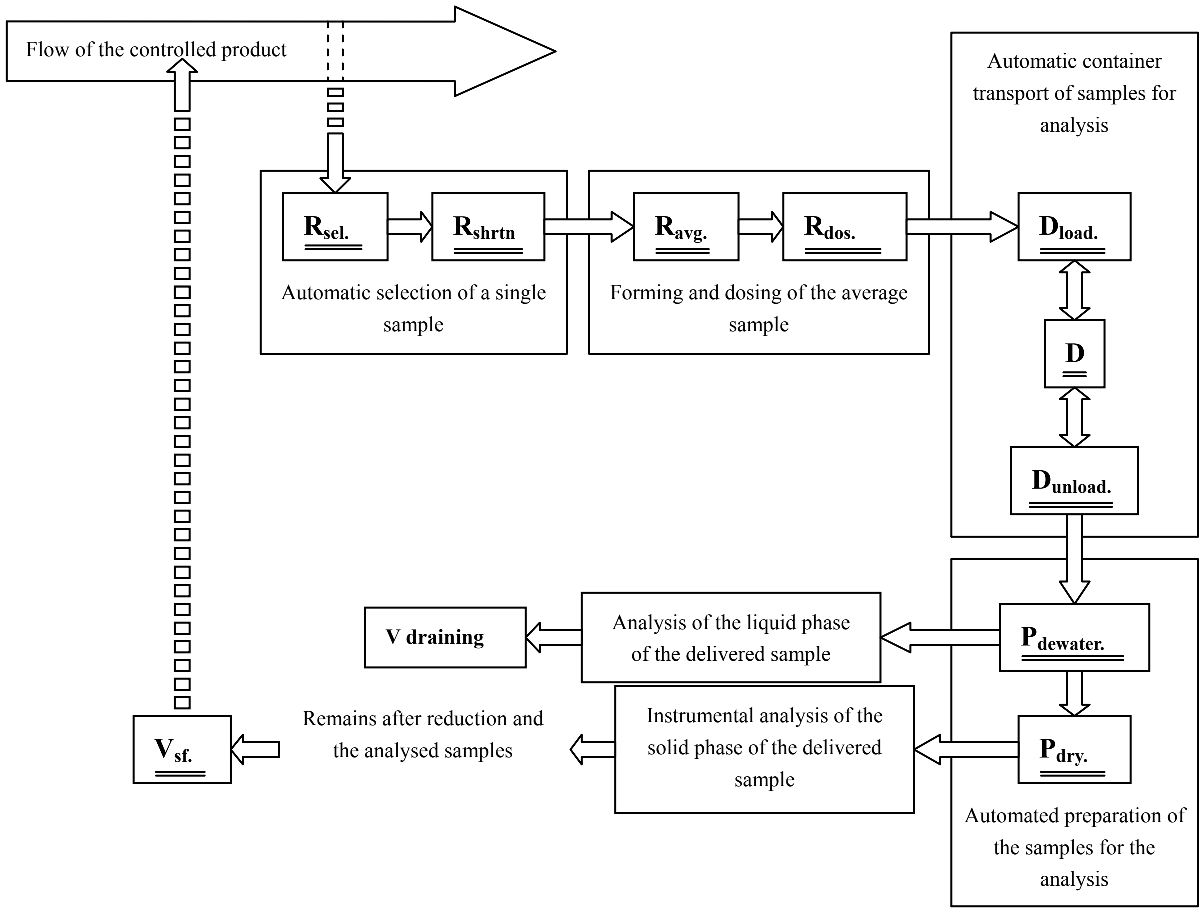

Figure 1. Algorithmic chain for taking representative single samples, compiling an average sample, rapid delivery of samples to the place of centralized control and preparation for instrumental analysis of the delivered samples

All operations performed in ASAM are interrelated and constitute algorithmic chain, built to optimize all processes for online analytical information.

The Figure has the following notation:

$\underline{\underline{P_{отб.}}}$ – Operator for selecting a single sample;

$\underline{\underline{P_{сокр.}}}$ – Operator for reducing a single sample;

$\underline{\underline{P_{уср.}}}$ – Operator for averaging of a number of single samples;

$\underline{\underline{P_{доз.}}}$ – Operator for dosing the average sample;

$\underline{\underline{Д_{загр.}}}$ – Operator for loading average samples into the transport container;

$\underline{\underline{Д}}-$ Operator for delivering the averaged samples for analysis;

$\overline{\overline{Д_{разгр.}}}-$ Operator for unloading the delivered for the analysis samples from the transport container;

$\overline{\overline{П_{обезвож.}}}-$ Operator for dehydration of the delivered for the analysis sample;

$\overline{\overline{П_{суш.}}}-$ Operator for drying and additional preparation of the delivered for the analysis samples;

$\overline{\overline{В_{тф}}}-$ Operator for returning of the delivered for the analysis samples into the process of solid phase.

It is found theoretically and experimentally that the optimal solution to the problem of analytical control of technological products, continuous or discrete, - for the continuous processes, can be carried out using an automated system for container transporting of samples for analysis (Liu, H. 2006, Terzini, R. 2011) , which is provided by the technical means (Bregman, 1984; Khmara, 2012):

- Periodic selection of representative single samples and, if necessary, their proportional reduction;
- Preparation of averaged sample from single samples for a certain period of time (hour, shift, day);
- Reducing the average sample to the desired volume or weight;
- Loading the dosed amount of the average sample into the transport container;
- Pneumatic container transport of the sample for analysis;
- Unloading of the delivered average sample from the transport container;
- Return the empty transport container.

The structure of such systems includes the following devices: for automatic selection of representative single samples; automatic proportional reduction of the selected single samples; production of the average sample for a predetermined period of time; for volumetric dosing of average sample; for automatic loading the average sample into the transport container and send the loaded sample of the transport container into the express-laboratory; system of transport pipelines connecting point of the selecting process samples to analytical laboratories; automatic unloading devices of the delivered for the analysis process samples from the transport container and the automatic return of the empty transport container to the place of sampling; automatic switch throwers of the movement direction of laden and empty transport containers; automatic bypass valves ensuring smooth (no impact) reception of the delivered laden or empty transport container and some other auxiliary devices (Bregman, 1989; Plekhanov, 2003; Cox, 2008; Chenglin, 2014).

Discreteness of the selecting single samples may not change, but in some cases it shall be adaptive, i.e. vary depending on the specific technological factors (Khmara, 2009).

To optimize delivery routes samples for analysis (in terms of the total length of transmission pipelines) these systems are best constructed using turnouts (Khmara, 2012).

Automatic switch throwers have universal design and implement the two functions: transport container transfer from several pipelines into one transport pipeline and transfer of the transport container from one transport pipeline to one of the multiple transport pipelines. Typically, the container delivery systems for samples to be analysed, the switch throwers ST 2 are used providing transfer of the moving transport container via one of the two transport pipelines to one transport pipeline and transfer of the transport containers moving over one transfer pipeline to one of the two transport pipelines.

3. Methodology

In industrial practice, quite often there are situations when it is necessary and appropriate to transfer the transport container from a larger number of transmission pipelines (3 or 4) into one transport pipeline. In this situation, the series connection of transport pipelines is usually used with multiple (2 or 3) switch throwers ST 2, which inevitably leads to an increase in the number of used technical equipment and reduce the reliability of the system as a whole. Therefore, there was the task for design automatic switch throwers ST 4, providing transfer of a moving transport container according to one of four transport pipelines into a single transport pipeline.

When using automatic switch throwers ST 4 in the "**From 4 into 1**" mode (see Figure 2), the moving transport container comes from the transport pipeline 1, 2, 3 or 4, and leaves the transport pipeline 5. When using automatic switch throwers ST 4 in the "**From the 1-st into 4**" mode, the transport container arrives over the transport pipeline 5 and goes out via the transport pipeline 1, 2, 3 or 4.

Automatic switch thrower in the "**From 4 into 1**" mode performs the following functions:

- Automatic vertical transfer of the swirl pot to the "**Receiving transport container**" position from the corresponding transport pipeline;

- Automatic reception of the transport container;

- Automatic vertical transfer of the swirl pot with the delivered transport container to the "**Horizontal movement**" position;

- Automatic horizontal gauge carriage return for sending the delivered transport container via the transport pipeline 5;

- Automatic vertical transfer of the swirl pot with the container to the "**Sending container**" position;

- Automatic sending of the transport container by applying the transporting compressed air through **EPV 5**.

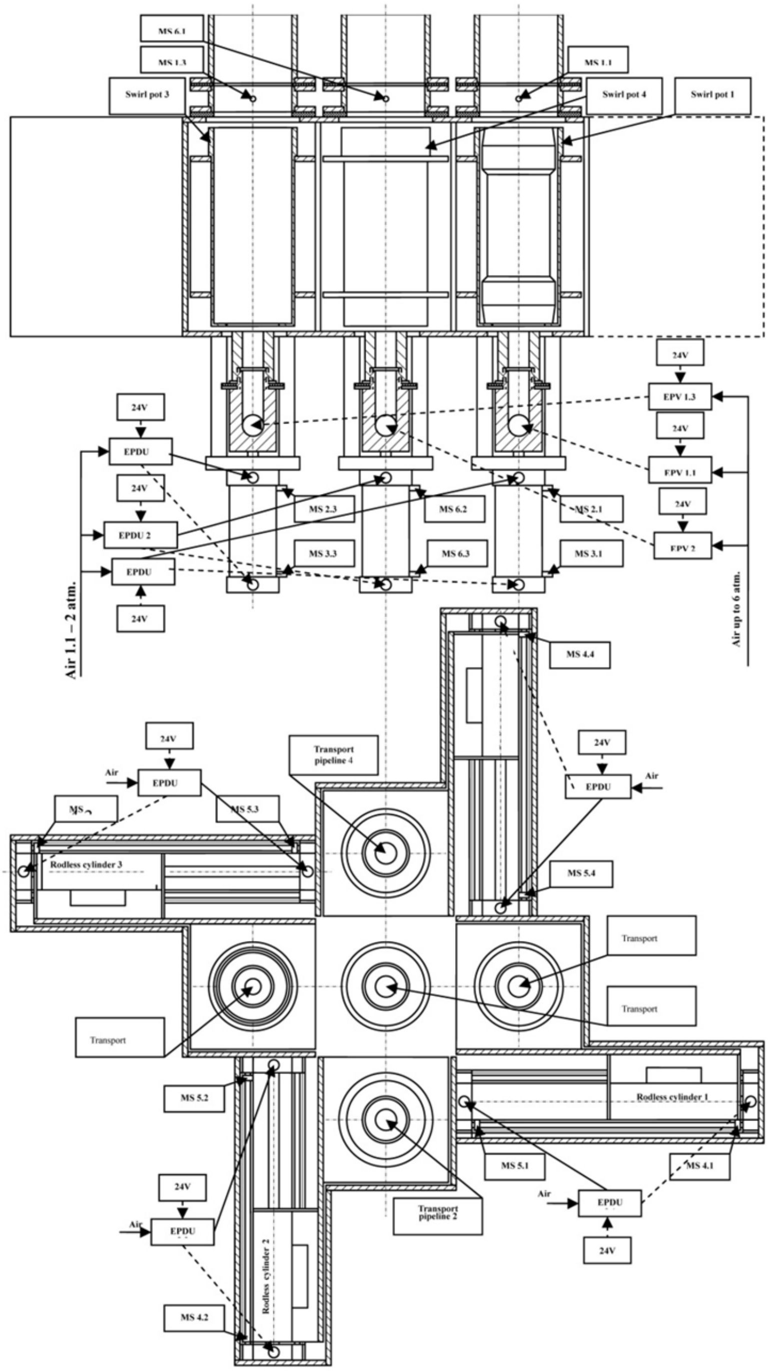

Figure 2. Automatic switch thrower "From 4 into 1". Initial position

Automatic switch thrower in the "**From the 1-st into 4**" mode performs the following functions:

- Automatic transfer of the swirl pot of the transport pipeline that shall be used for further sending the transport container under the transport pipeline 5;

- Automatic vertical transfer of the swirl pot to the "**Receiving container**" position;

- Automatic reception of the delivered transport container to the swirl pot via transfer pipeline 5;

- Automatic vertical transfer of the swirl pot with the delivered transport container to the "**Horizontal movement**" position;

- Automatic horizontal gauge carriage return with a container for sending the transport container over the appropriate transport pipeline;

- Automatic transfer of the swirl pot with the transport container to the "**Sending container**" position;

- Sending the transport container by supplying the transporting compressed air through the appropriate **EPV**;

- Disabling of the transporting compressed air supply and automatic vertical transfer of the swirl pot to its original position.

Pneumatic cylinders by Camozzi with magnetic position sensors (MS) perform these functions in ST 4. Electro-pneumatic distribution units (EPDU) perform airflow control in the pneumatic cylinders; electro-pneumatic valves (EPV) by Camozzi control transporting compressed air supply. **EPDU** and **EPV** are controlled by feeding and removing a 24V DC voltage. Power consumption of **EPDU** and **EPV** is 1W.

Automatic switch thrower ST 4 is connected to 18 flexible pneumatic tubes with an internal diameter of 4 mm for supplying compressed air from **EPDU** with air pressure of 2 kg/cm^2 and five hoses with an inner diameter 1/2" for feeding transporting compressed air from **EPV**. The control cabinet has 23 low-voltage lines from magnetic position sensors **MS** from the loading station of samples loading.

Containers are send using compressed air with pressure up to 6 kg/cm^2 (depending on the length of the route for container delivery).

4. Results

The studies demonstrated that when creating automated systems of analytical monitoring, it is necessary to pay special attention to the error-free design and manufacturing process of automatic selection and delivery of samples for analysis and parametric modelling (Lobotskiy, 2014).

The basis for the design of automatic switch throwers are the four mobile gauge carriages (free to move in the horizontal directions) with swirl pots in them able to move freely in the vertical direction. Swirl pots are used for automatic reception of the transport container and ensure the necessary conditions for receiving and sending the transport container to the destination point.

Work of the automatic switch thrower ST 4 is as follows:

In the initial state: all four gauge carriages are at the extreme positions (under the transport pipelines 1, 2, 3 and 4); transporting air supply units are in the lowest position; all controls are de-energized; compressed air is supplied to all of **EPDU** and **EPV**.

Upon receiving the command for preparing the delivery route of another average sample for analysis (e.g., through pipeline No. 1), the local automatic control system for switch thrower connects the controls to the power supply and generates a command to **EPDU 1** for vertical movement of the gauge carriage while the swirl pot is in the "**Before accepting container**" position (see Figure 3).

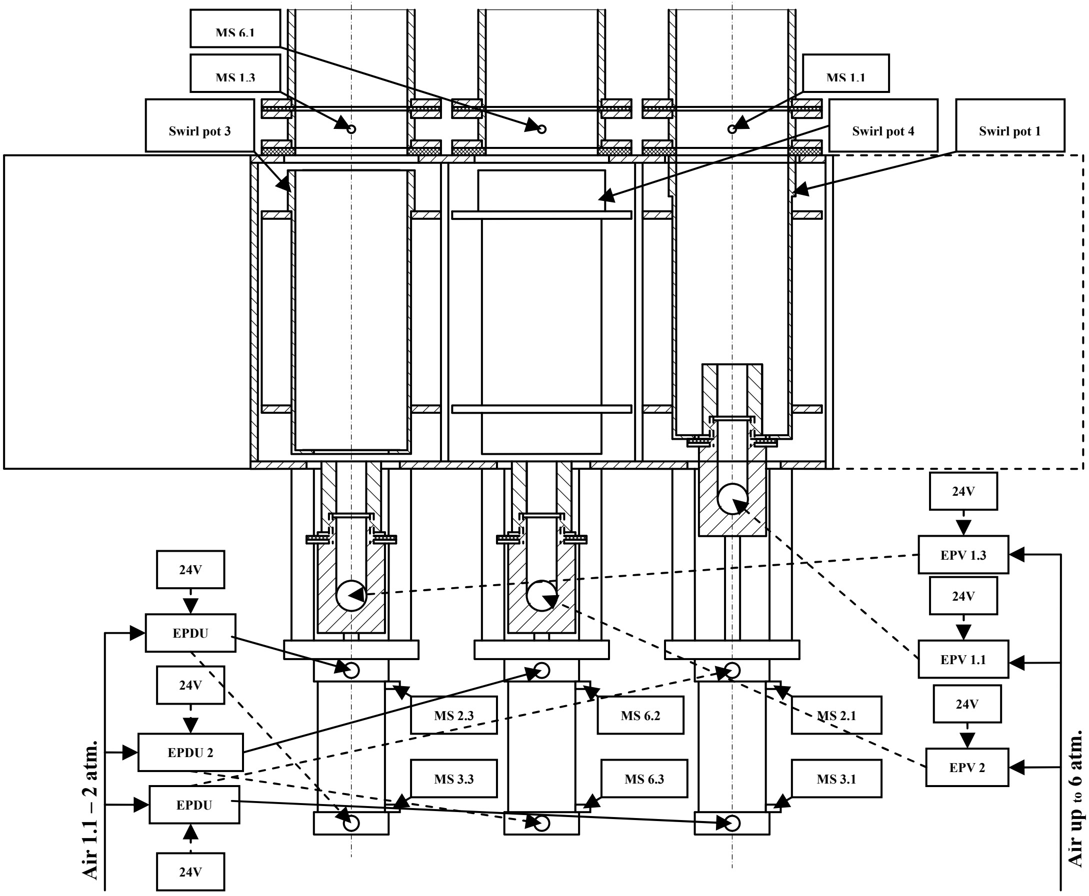

Figure 3. Position "Before taking the container"

After receiving the delivered container (see Figure 4), the information signal comes from the magnetic sensor **MS 1.1**, which forms the information signal to turn off the transport of compressed air and remove the command from **EPDU 1.1** resulting in lowering of the swirl pot and transport container to the "**Horizontal movement**" position (see Figure 5).

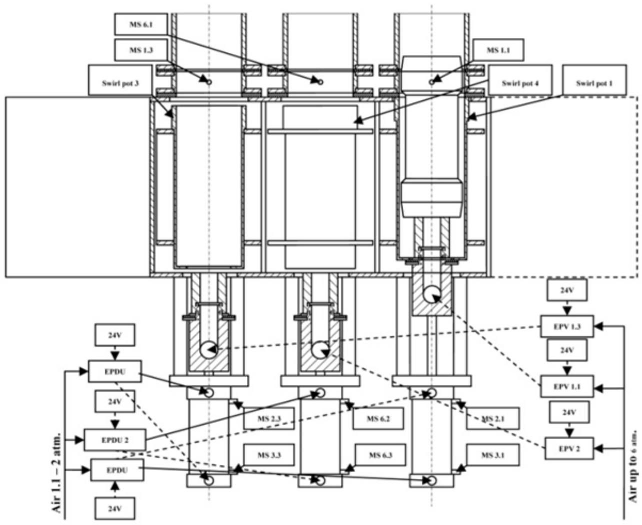

Figure 4. Position "Taking the container"

After the appearance of the information signal from the magnetic sensor **MS 1.1**, command is issued to **EPDU 3.1** whereby container moves horizontally and appears under the transport line 5 in position "Before sending the container" (see Figure 6).

When the information signal from the magnetic sensor **MS 5.1** appears, the command is issued to **EPDU 2**, whereby the pot with transport container rises to **"Sending container"** position and run of further delivery of the transport container is formed (see Figure 7).

Upon receiving the information signal from the magnetic sensor **MS 6.2** , the command to **EPV 2** is sent for feeding transporting compressed air, whereby the transport container is sent to the next device.

After receiving the information signal on delivering the container to the next device of the system, the control command from **EPV 2** is removed, and switch thrower ST 4 is turned into the standby mode waiting for the return of the empty transport container.

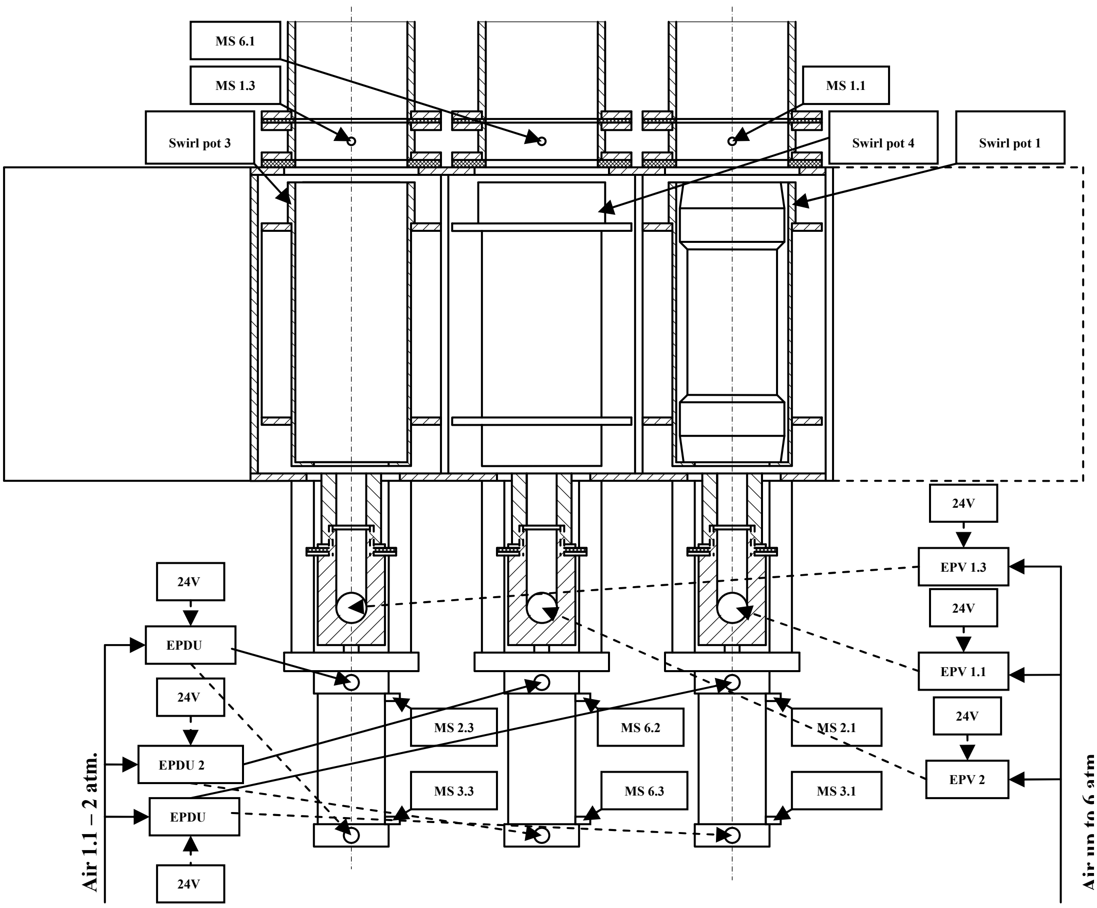

Figure 5. Position "Horizontal movement"

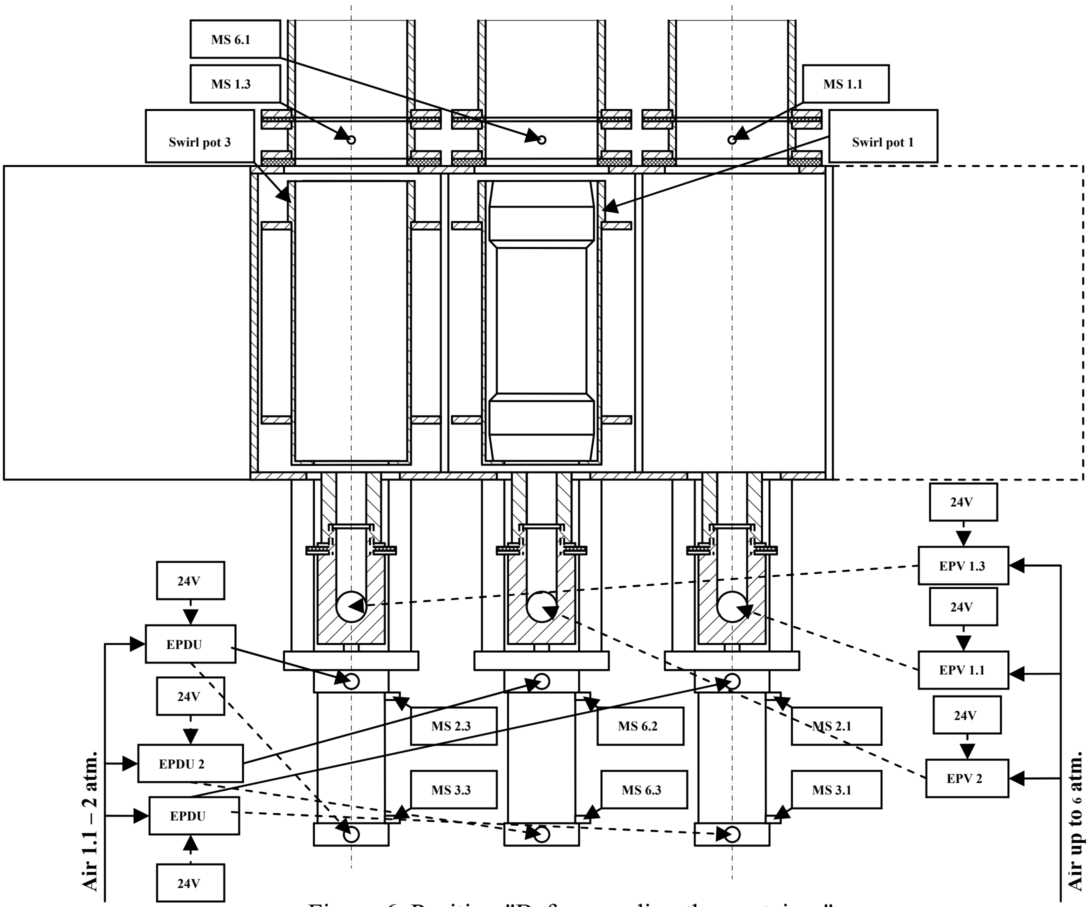

Figure 6. Position "Before sending the container"

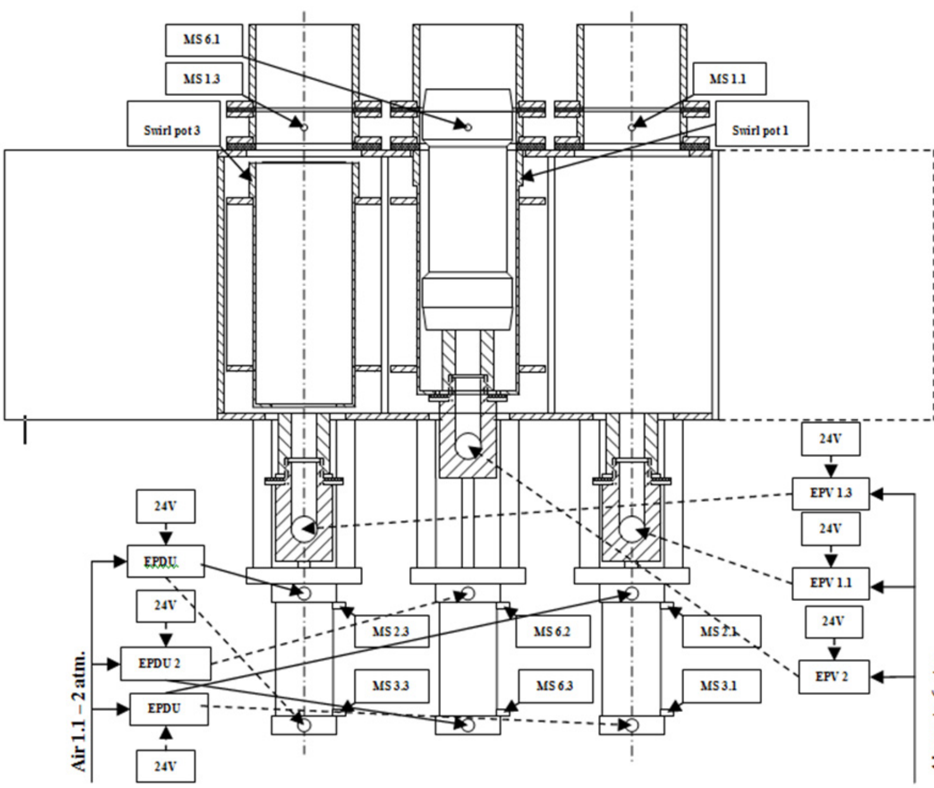

Figure 7. Position "Sending the container"

When returning the empty transport container, the swirl pot 1 of the switch thrower is sealed to the transport pipeline 5. These results into gentle lowering of the delivered empty transport container into the swirl pot (see Figure 7).

Based on the information signal from the magnetic sensor **MS 6.1**, the control system provides information signal on delivering of the transport container to turn off the transporting compressed air supply and removes the control command from **EPDU 2**, whereby the container is lowered to the "**Horizontal movement**" position (see Figure 6) and when the information signal from **MS 6.3** appears, it removes the control command from **EPDU 3.1** resulting in horizontal movement of the gauge carriage to the "**Before sending the container**" position (see Figure 5).

Upon receiving the information signal from the magnetic sensor **MS 4.1**, **EPDU 1.1** receives a command resulting in rising of the swirl pot, pressurizing the container delivery route and when receiving the information signal from the magnetic sensor **MS 2.1**, **EPV 1.1** receives a command to supply compressed air to transport the container (see Figure 4).

After the delivery of the empty transport container to the next device of the system, the commands are removed from **EPV 1.1** and **EPDU 1.1** of the switch thrower ST 4 resulting in the interrupted compressed air supply. The swirl pot falls to the starting position (see Figure 2).

Consider the structure for the control and organization of the automatic control system for switch throwers ST 4 shown in Figure 8 (Dedegkaev, 2014).

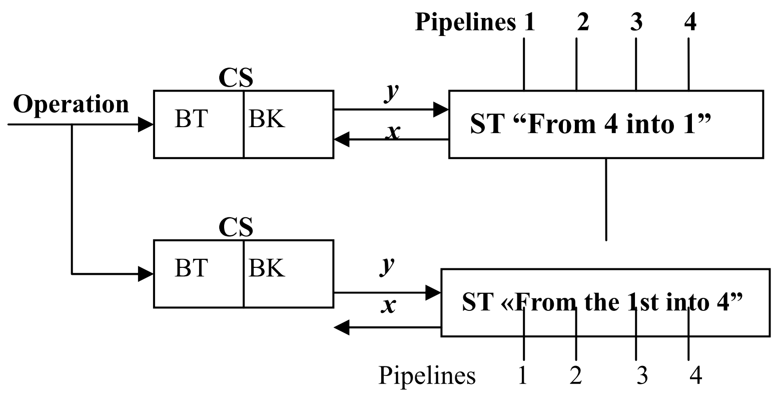

Figure 8. Structural scheme of automatic control for switch throwers ST 4

Structurally, the switch throwers ST 4 working modes "From 4 into 1" and "From the 1st into 4" are absolutely identical and differ only in the operation algorithm. Switch thrower "From 4 into 1" is set in the optimal location for sampling, while switch thrower "From the 1st into 4" - in an optimal location of the control of the samples. Switch throwers are connected to each other by one common transport pipeline 5.

The Figure has the following notation: 1, 2, 3, 4 or 5- transport pipelines; CS - control system for switch thrower consisting of the selecting block for a transport pipeline (PB) and the control block of distribution units and valves (BK); Y - control commands; X - information signals from magnetic sensors (MS). External signal "Work" takes the CS from the "Stand-by" to "Work" mode. In addition to the signals from the magnetic sensors, the CS receives the following information signals: "Pipeline No. i", where i is the number of the pipeline (1,2,3,4), which is used for delivery of the transport container; "The container is delivered" is a message from the device receiving the transport container; "The container is returned" is a message to the device that sent the shipping container.

Location of the magnetic sensors (MS) and the kinematic scheme of the switch thrower ST 4 are shown in Figure 2.

Magnetic sensors MS generate information signals:

MS 1.i - on delivery the transport container on the corresponding pipeline;

MS 2.i - on ST 4 readiness to take or send the transport container over the pipeline i;

MS 3.i - on readiness of horizontal movement of the gauge carriages of ST 4;

MS 4.i - on finding the gauge carriage in the initial position;

MS 5.i - on finding the gauge carriage in position before receiving or sending the transport container on pipeline 5;

MS 6.i - on delivery the transport container on the pipeline 5;

MS 6.2 - on readiness of sending or receiving the transport container over pipeline 5;

MS 6.3 - on readiness for horizontal movement of the gauge carriage.

The commands, generated by the control system, used for turning on and off of:

- Electro-pneumatic distribution units EPDU 1.i, EPDU 2 and EPDU 3.i, used for controlling the vertical and horizontal movement of the gauge carriage and swirl pots;

- Electro-pneumatic valves EPV 1.i and EPV 2, used to feed and turn off the supply of the transporting compressed air.

The above signals are used for working of the control system which block diagram is shown in Figure 9.

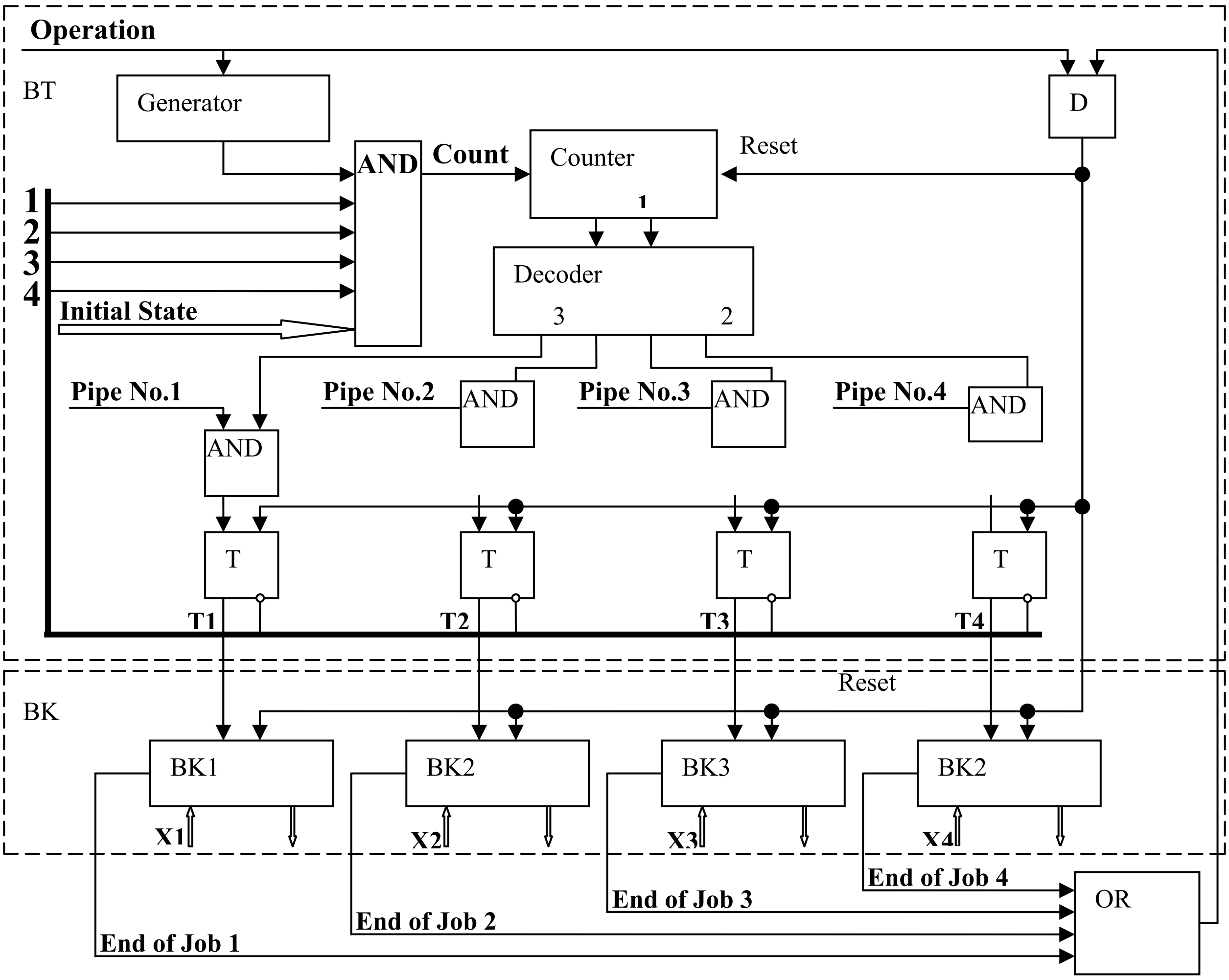

Figure 9. Functional scheme of automatic control for switch throwers ST 4

Figure 9 has the following notation: D - shaper signal "Reset" (differentiating circuit); AND - logical element "AND"; OR - logical element "OR"; T - memory element (trigger).

The control block for distribution units and valves (BK) consists of four blocks (BK1, BK2, BK3, BK4) controlling the relevant transport pipelines. These blocks receive signals (X) generated by the magnetic sensors installed on the pipes. Signals (Y) are output and are used to control distributor units and valves.

Each unit generates a signal "End of job", which brings the system to its original state. Working state of the blocks (BK1, BK2, BK3, BK4) is returned by signals T1, T2, T3, T4 coming from the selection block of the transmission pipeline (PB).

When the control signal "Work" comes to the control system, the pulse generator work is allowed. The generator is part of PB. Then the signal

"Reset" is generated, taking the system to working condition, while if the signals "Initial state" are received, then the passage of the pulses from generator to the count input of the binary counter are allowed, the outputs to the counter are connected to the inputs of the decoder. Signals "Initial state" are formed by sensors: MS 3.1, MS 3.2, MS 3.3, MS 3.4, MS 4.1, MS 4.2, MS 4.3; MS 4.4 and MS 6.3.

The counter outputs state makes active only one output of the decoder. The decoder determines the sequence of status polling for transport pipelines. At receipt of one or more signals "Pipe No. i" (sensors MS 1.i), one of the trigger (T) is switching, at that passage of oscillator pulses to the counter input is blocked, block BK i comes into operation and i^{th} transport pipeline is served.

Blocks of the control system (BK1, BK2, BK3, BK4) generate signals that determine the state of the switch thrower. Switch thrower "From 4 in 1" is characterized by the following conditions (a_i) that are initiated by the control commands (y_i), coming from the control system:

a_0 – starting position - ST 4 is supplied with no electrical power and compressed air, all the swirl pots are in extreme positions under the same pipelines, transport container in the device is absent, all magnetic sensors (MS) send no information signals to the control system;

a_{1i} -electric power and compressed air supply is turned on, the control system receives the information signal from the switching ST 4 into "Operation" mode and information signals come only from MS 3.1, MS 3.2, MS 3.3, MS 3.4, MS 4.1, MS 4.2, MS 4.3; MS 4.4 and MS 6.3. Subject to the conditions, the control system issues the command "Enable EPDU 1.i";

a_{2i} – under the transfer line i, the swirl pot i is raised to the "Receiving the transport container". If the control system receives a signal from the MS 2.i, then the signal "Ready" is generated.

a_{3i} – when the signal comes from the MS 1.i (corresponds to the delivery of the transport container), the control system sends the signal "Container accepted" to the "Sender".

a_{4i} – Upon receiving from the sender of the information signal "Compressed air 1 off", the control system sends the command "Ready to Remove", "Disable EPDU 1.i" and remove the signal "Container accepted."

a_{5i} - swirl pot i with transport container falls to the "horizontal movement" position. If the signal comes from MS 3.i, then the command "Enable EPDU 3.i" is generated.

a_{6i} - swirl pot i with transport case is horizontally moving to the position "Under the transfer line No. 5". If the signal comes from MS 5.i, then the control command "Enable EPDU 2" is generated by the system.

a_7 - swirl pot i with transport container goes up vertically to the "Sending container" position. If the information signal comes from MS 6.2, then the command "Enable EPV 2" is generated.

a_8 - delivery of the transport container is carried out by pipeline No. 5. If the signal "Container delivered" comes from the recipient, then the control system receives a control command "Disable EPV 2".

a_9 - ST 4 does not change its state. If the signal comes from MS 6.1, then the control system sends the information signal "Container delivered" to the sender.

a_{10} - ST 4 does not change its state. If the recipient of the container sends the "Compressed air 2 disabled" signal, then the command "Disable EPDU 2.i" is formed.

a_{11} - swirl pot i with transport container falls vertically to the "horizontal movement" position. If the signal comes from MS 6.3, then the command "Disable EPDU 3.i" is generated.

a_{12} - swirl pot i with transport case is horizontally moving to the position "Under the transfer line i". If the signal comes from MS 4.i, then the control command "Enable EPDU 1.i" is generated.

a_{13i} - swirl pot i with transport container goes up vertically to the "Sending container" position. If the signal comes from the sensor MS 2.i, then the command "Enable EPV 1.i" is generated.

a_{14i} - transport container is returned to the "Sender". If the supplied informational signal comes from the sender "Container is returned", then the control system sends control commands "Disable EPV 1.i" and "Disable EPDU 1.i";

a_{15i} – swirl pot falls to the "horizontal movement" position. If the information signal comes from MS 3.i, command "End Job i" is generated in the block BK i. The result is ST 4 taking its initial position.

ST 4 switch thrower while performing its functions ***generates*** and receives from the outside the following information signals, which are used to generate control commands Y_i:

x_0 - "Work" - signal switching ST 4 in the "Operation" mode.

x_{1i} - signals from the magnetic sensors MS 1.1 MS 1.2, MS 1.3, MS 1.4;

x_{2i} - signals from the magnetic sensors MS 2.1 MS 2.2, MS 2.3, MS 2.4;

x_{3i} - signals from the magnetic sensors MS 3.1 MS 3.2, MS 3.3, MS 3.4;

x_{4i} - signals from the magnetic sensors MS 4.1 MS 4.2, MS 4.3, MS 4.4;

x_{5i} - signals from the magnetic sensors MS 5.1 MS 5.2, MS 5.3, MS 5.4;

x_6 – signal from the magnetic sensor MS 6.1;

x_7 – signal from the magnetic sensor MS 6.2;

x_8 – signal from the magnetic sensor MS 6.3;

x_{9i} - signal to the sender "Ready";

x_{10i} - signal to the sender "Container is taken";

x_{11} - signal to the sender "Container is delivered";

x_{12i} - signal from the sender "Container is returned".

x_{13i} - signal from the sender "Compressed air 1 disabled";

x_{14} - signal from the sender "Compressed air 2 disabled";

Depending on these input signals and its previous state, the system controller (state machine) generates internal signals U_i, which are applied to inputs of memory elements T_i causing state change of a memory element displayed by symbol Z_i in accordance with Table 1.

As seen from the table, input signal x_0 is present in all four transitions of ST 4 and at generating control commands by the control device. Therefore, at processing of the input signals x_i, information signal x_0 can be ignored. Based on this position control commands and outgoing information signals Y are generated at the following combinations of input signals x_i:

$Y_0 = x_0 \overline{x_{1i} x_{2i} x_{3i} x_{4i} x_{5i} x_6 x_7 x_8 x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – Initial position;

$Y_{1i} = x_0 \overline{x_{1i}}\, \overline{x_{2i}} x_{3i} x_{4i} \overline{x_{5i}}\, \overline{x_6}\, \overline{x_7} x_8 \overline{x_{9i}}\, \overline{x_{10i}}\, \overline{x_{11}}\, \overline{x_{12i}}\, \overline{x_{13i}}\, \overline{x_{14}}$ – "Turn on EPDU 1.i";

$Y_{2i} = x_0 \overline{x_{1i}} x_{2i} \overline{x_{3i}} x_{4i} \overline{x_{5i}}\, \overline{x_6}\, \overline{x_7} x_8 \overline{x_{9i}}\, \overline{x_{10i}}\, \overline{x_{11}}\, \overline{x_{12i}}\, \overline{x_{13i}}\, \overline{x_{14}}$ – Send "Ready".

$Y_{3i} = x_0 x_{1i} x_{2i} \overline{x_{3i}} x_{4i} \overline{x_{5i}}\, \overline{x_6}\, \overline{x_7} x_8 x_{9i} \overline{x_{10i}}\, \overline{x_{11}}\, \overline{x_{12i}}\, \overline{x_{13i}}\, \overline{x_{14}}$ – Send "Container accepted".

Table 1. Table of transitions a_i, generation of signals z_i and output control commands Y_i of the sequential control system for switch thrower ST 4

x \ a	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}
x_0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
x_{1i}	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
x_{2i}	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
x_{3i}	0	1	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0
x_{4i}	0	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0
x_{5i}	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0
x_6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
x_7	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0
x_8	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0
x_{9i}	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
x_{10i}	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
x_{11}	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
x_{12i}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
x_{13i}	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
x_{14}	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
z	z_0	z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	z_9	z_{10}	z_{11}	z_{12}	z_{13}	z_{14}	z_{15}	z_{16}
Y	Y_0	Y_{1i}	Y_{2i}	Y_{3i}	Y_{4i}	Y_{5i}	Y_{6i}	Y_{7i}	Y_8	Y_9	Y_{10}	Y_{11}	Y_{12}	Y_{13i}	Y_{14i}	Y_{15i}	

$Y_{4i} = x_0 x_{1i} x_{2i} \overline{x_{3i}} x_{4i} \overline{x_{5i} x_6 x_7} x_8 x_{9i} x_{10i} \overline{x_{11} x_{12i} x_{13i} x_{14}}$ – Remove "Ready" and "Container accepted". "Turn off EPDU 1.i".

$Y_{5i} = x_0 \overline{x_{1i} x_{2i}} x_{3i} x_{4i} \overline{x_{5i} x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11} x_{12i}} x_{13i} \overline{x_{14}}$ – "Turn on EPDU 3.i".

$Y_6 = x_0 \overline{x_{1i} x_{2i}} x_{3i} \overline{x_{4i}} x_{5i} \overline{x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – "Turn on EPDU 2".

$Y_7 = x_0 \overline{x_{1i} x_{2i}} x_{3i} \overline{x_{4i}} x_{5i} \overline{x_6} x_7 \overline{x_8 x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – "Turn on EPDU 2".

$Y_8 = x_0 \overline{x_{1i} x_{2i}} x_{3i} \overline{x_{4i}} x_{5i} \overline{x_6} x_7 \overline{x_8 x_{9i} x_{10i}} x_{11} \overline{x_{12i} x_{13i} x_{14}}$ – "Turn off EPV 2".

$Y_9 = x_0 \overline{x_{1i} x_{2i}} x_{3i} \overline{x_{4i}} x_{5i} x_6 x_7 \overline{x_8 x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – Send "Container delivered".

$Y_{10} = x_0 \overline{x_{1i} x_{2i}} x_{3i} \overline{x_{4i}} x_{5i} \overline{x_6} x_7 \overline{x_8 x_{9i} x_{10i} x_{11} x_{12i} x_{13i}} x_{14}$ – "Turn off EPV 2" and remove "Container delivered".

$Y_{11i} = x_0 \overline{x_{1i} x_{2i}} x_{3i} \overline{x_{4i}} x_{5i} \overline{x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – "Turn off EPDU 3.i".

$Y_{12i} = x_0 \overline{x_{1i} x_{2i}} x_{3i} x_{4i} \overline{x_{5i} x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – "Turn on EPDU 1.i".

$Y_{13i} = x_0 \overline{x_{1i}} x_{2i} \overline{x_{3i}} x_{4i} \overline{x_{5i} x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ – "Turn on EPV 1.i".

$Y_{14i} = x_0 \overline{x_{1i}} x_{2i} \overline{x_{3i}} x_{4i} \overline{x_{5i} x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11}} x_{12i} \overline{x_{13i} x_{14}}$ – "Turn off EPV 1.i".

$Y_{15i} = x_0 \overline{x_{1i} x_{2i}} x_{3i} x_{4i} \overline{x_{5i} x_6 x_7} x_8 \overline{x_{9i} x_{10i} x_{11} x_{12i} x_{13i} x_{14}}$ –End of job. Transition to initial state.

Since the control of real positional systems before applying any control command Y_i, only one new information signal appears, then control of all information signals is necessary only in the initial state. In all other states, it is enough to control the generation of this "new" information signal. I.e. input signal is characterized by the generation of new (compared with the previous state) of the information signal:

$Y_0 \rightarrow$ information signals are absent;

$Y_{1i} \rightarrow x_{3i}$;

$Y_{2i} \rightarrow x_{2i}$;

$Y_{3i} \rightarrow x_{9i}$;

$Y_{4i} \rightarrow x_{10i}$;

$Y_{5i} \rightarrow x_{13i}$;

$Y_{6i} \rightarrow x_{5i}$;

$Y_{7i} \rightarrow x_7$;

$Y_8 \rightarrow x_{11}$;

$Y_9 \rightarrow x_6$;

$Y_{10} \rightarrow x_{14}$;

$Y_{11} \rightarrow x_8$;

$Y_{12} \rightarrow x_{4i}$;

$Y_{13i} \rightarrow x_{2i}$;

$Y_{14i} \rightarrow x_{12i}$;

$Y_{15i} \rightarrow x_{3i}$; End of job.

In view of this, terminal automatic device in such an option may be described by automate grafoid shown in Figure 10.

Vertices of the graph S_i corresponds to the states of ST, and arcs - to transitions. Arcs of the graph are marked with signs of the transition and output functions.

Symbol S_0 denotes the initial and final vertices. All other vertices are denoted by symbols S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}.

Input signals X_{0i} represent the following vectors:

$X_{01} = x_0 \overline{x_{1.1} x_{2.1}} x_{3.1} x_{4.1} \overline{x_{5.1} x_6 x_7} x_8 \overline{x_{9.1} x_{10.1} x_{11.1}}$;

$X_{02} = x_0 \overline{x_{1.2} x_{2.2}} x_{3.2} x_{4.2} \overline{x_{5.2} x_6 x_7} x_8 \overline{x_{9.2} x_{10.2} x_{11.2}}$;

$X_{03} = x_0 \overline{x_{1.3} x_{2.3}} x_{3.3} x_{4.3} \overline{x_{5.3} x_6 x_7} x_8 \overline{x_{9.3} x_{10.3} x_{11.3}}$;

$X_{04} = x_0\overline{x_{1.4}x_{2.4}}x_{3.4}x_{4.4}\overline{x_{5.4}x_6x_7}x_8\overline{x_{9.4}x_{10.4}x_{11.4}}$.

The output signals Y_i, providing transitions of the terminal automatic device, are indicated at the end of the arcs (since they depend on both the inputs and the states) and determined as a function of the transition between the operator vertices.

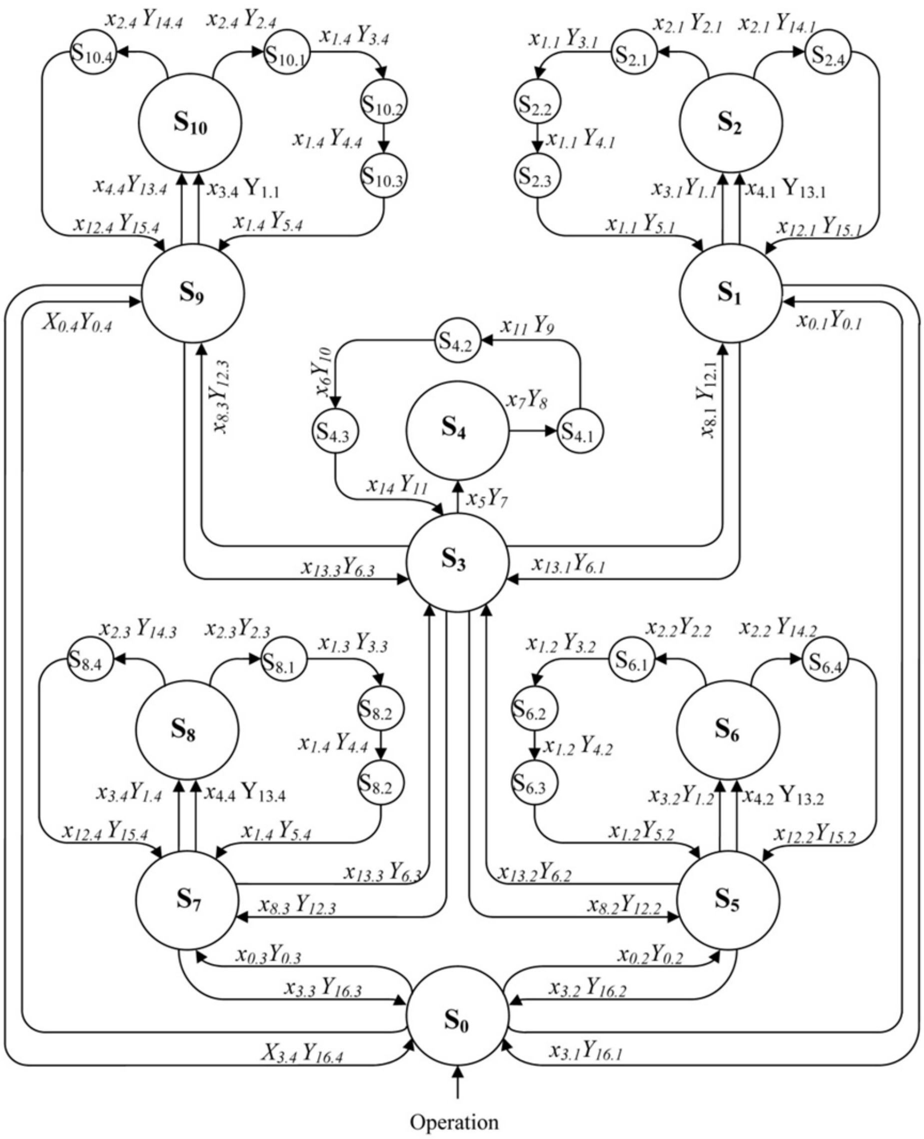

Figure 10. Automate grafoid of the control model for switch thrower "Of the 4 into 1"

The scheme generates control signals to the actuators based on information received from the magnetic sensor. Installation signals of memory elements (T) in the state of "zero" are formed on the outputs of the elements "OR" or directly by the signal "Reset".

Signal Ti, coming from the block BT of the control system, translates the scheme into operation.

The system shown in Figure 8 and 9 is based on a modular principle of functionally complete modules ST 4 and CS.

The modular principle enables creating complex transport systems and manages them using only those modules.

Figure 11 shows one of the possible options of such a system.

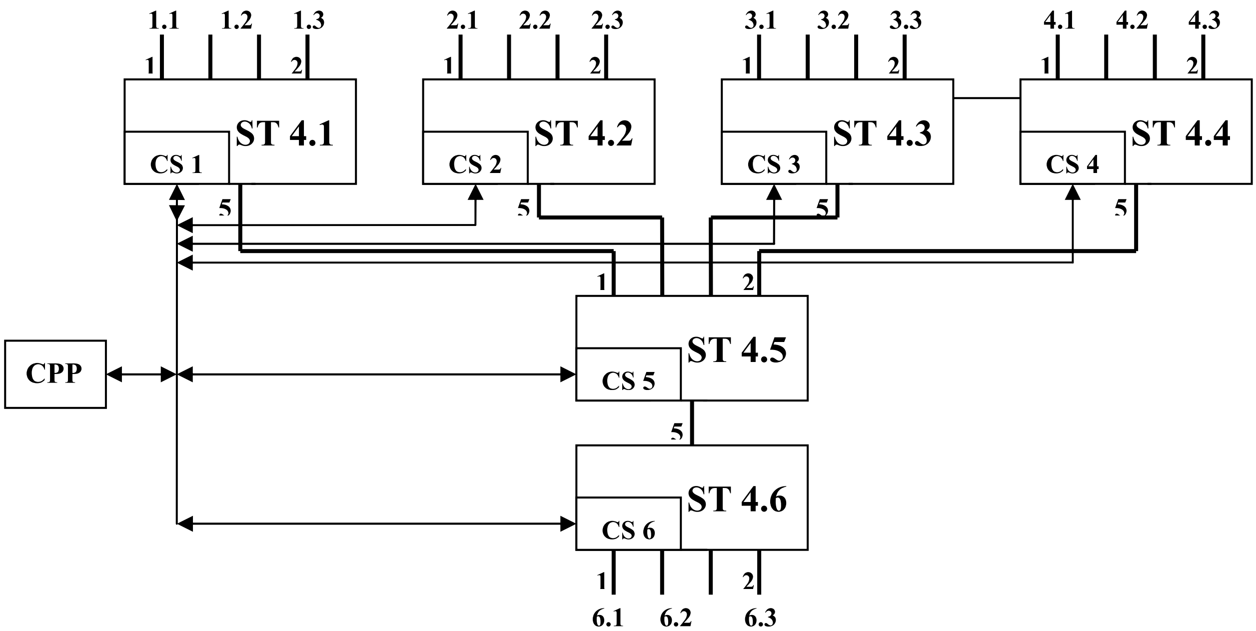

Figure 11. Block diagram of a complex transportation system

Here, CPP is the central control panel (a PC). CPP and control systems CS i of switch throwers ST 4i have bidirectional communication in between that allows monitoring and controlling the system. The use of microcontrollers in the CS of the switch throwers allows building systems that are adapted to the different routes of transporting containers using software microcontrollers that implement the desired functioning of the algorithm.

Figure 12 shows a block diagram of a microprocessor control system ST 4.

The Figure has the following notation: MC - microcontroller; M - multiplexer; DB - data bus; AB - address bus; X - input data signals; Y - output control signals for actuators ST 4; DU - display unit.

When controlling the operation of switch throwers ST 4, a large number of control and information signals are used that requires from the microcontroller to have a large number of ports for receiving and transmitting information. To address these microcontroller to coordinate the work with a large number of sensors and actuators ST 4, which allows the use of this scheme with almost any modern microcontroller. Information between the MC and multiplexer is transmitted via DB. The microcontroller to transmit the address of the multiplexer, which should start work, will use address bus (AB). AB and DB are implemented using the MC ports. The display unit (DU) is used to display information and control signals, which allow for technical troubleshooting of switch thrower ST 4.

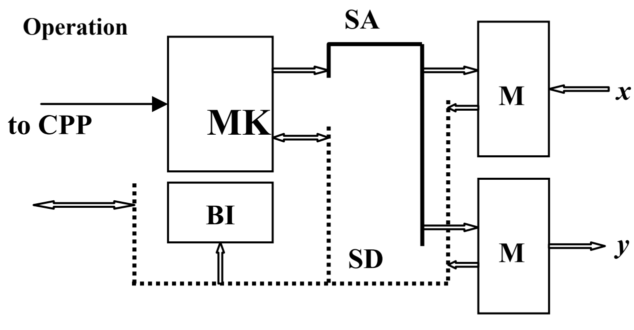

Figure 12. Block diagram of the microprocessor control system

Control of functioning devices of the transport system is supplied from a central control panel (PC) by drawing the route of delivering laden container to the customer and returning the empty transport container to the sender. Such an organization of movement for laden and empty transport container minimizes the number of transport containers used by the system - one for each sender. Source and destination addresses of the laden container are formed by CPP and taken into account when drawing up the route of delivery for laden container.

Delivery route for laden containers is to include the work of relevant control system for switch thrower ST 4i. All switch throwers ST 4 involved the delivery of laden container from source to destination, are included in the work of both on and off from work after returning empty transport container to the sender.

Let us consider the complete algorithms of control system functioning (see. Figure 13 and Figure 14) of the devices of the sophisticated transport system shown in Figure 12. Suppose it is needed to send a laden container via the transfer line 3.2 and deliver it to the recipient via the transfer line 6.3.

Having received this task, the central control panel CPP issues a command "Work" on the control system CS 4.3, CS 4.5 and CS 4.6. Control systems of switch throwers ST 4.3, ST 4.5 and ST 4.6 and check the initial state of switch throwers and develop the control algorithms presented in Figures 13 and 14.

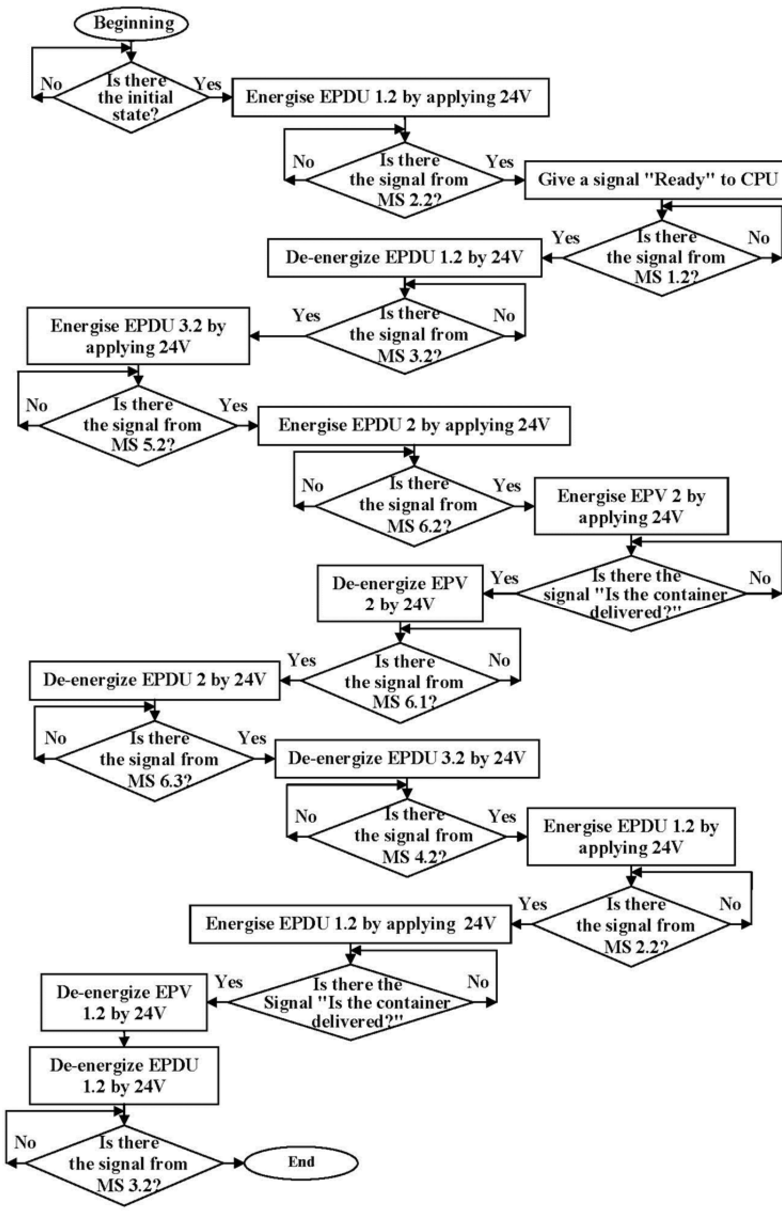

Figure 13. Block-diagram for controlling the operation of ST 4.3 and ST 4.5

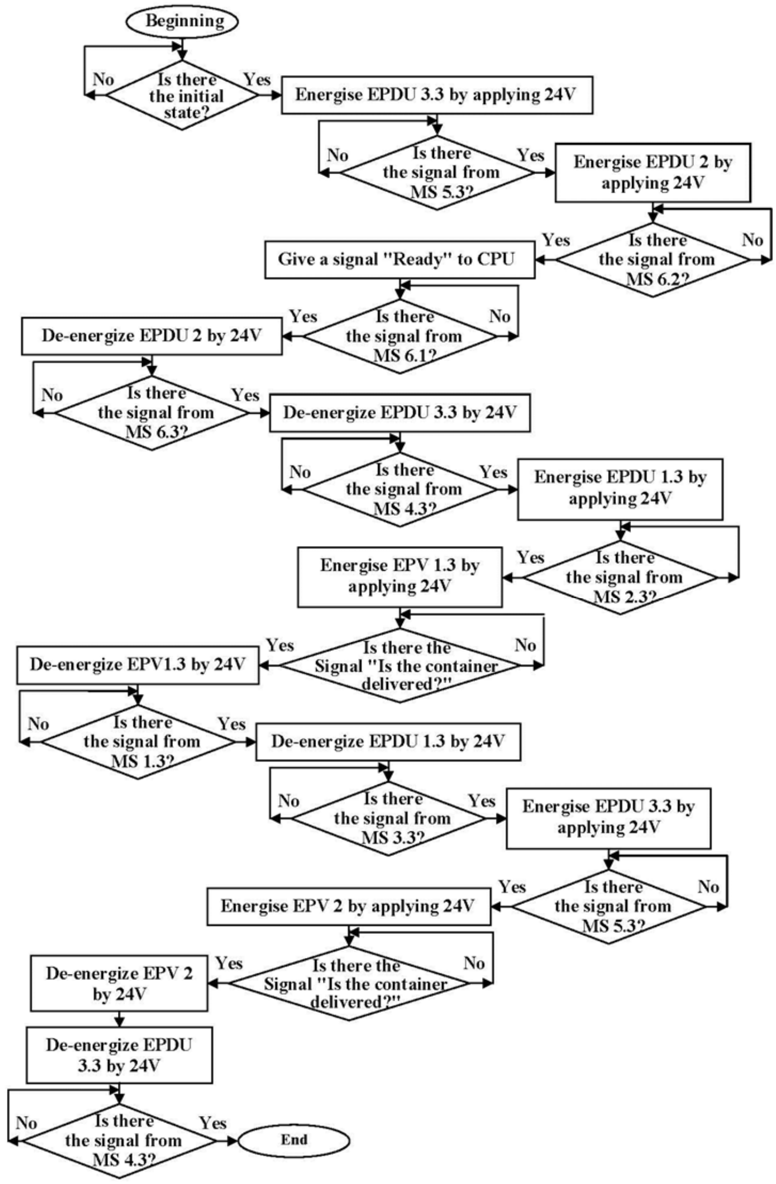

Figure14. Block-diagram for controlling the operation of ST 4.6

Upon receiving the "Work" command, CS 4.3, CS 4.5 and CS 4.6 work under the commands of the algorithms and at issuance of control signals "Ready" to the central control panel, the CPP gives permission to send the laden container. Further work is performed automatically in sequence in ST 4.3, then ST 4.5 and in ST 4.6. Having performed the operations of delivery of laden container, switch throwers expect the return of empty transport container and subsequently automatically perform all necessary operations in the reverse order, i.e., in ST 4.6, then ST 4.5 and ST 4.3.

After the delivery of the empty container to the sender, CPP performs the necessary switching to deliver laden container on a different route or goes into standby mode.

Information on the status of sensors and actuators, ST 4 is transmitted to the CPP in real time mode, allowing the operator to monitor the status of the entire system, quickly identify potential problems, and thereby increase the operational reliability of the system.

5. Conclusion

The paper summarizes the results of research in the theory and practice of automatic selection and container transport process samples for analysis in a laboratory express companies processing and metallurgical production. Ongoing research by the authors developed the original design of organizational compatibility of technical means for the selection of representative grab samples, averaged sample preparation, dispensing and automatic loading of samples averaged into a transport container, high-speed pneumatic delivery composite samples for analysis and the return of empty transport container to the place of sampling.

The results of the research showed that the developed modular design for universal switch thrower ST 4 and automatic microprocessor control system for positional devices allow creating a system of automatic pneumatic transport container of any conFigureuration. Made parametric modelling of assemblies and parts of the automatic device selection and delivery of samples for analysis allow designing of all devices out of the system of a finite set of standard devices with a minimum number of developed original parts. The proposed methods and technologies of unmistakable design and manufacturing allow using computer-aided design of complex systems of pneumatic containers transportation. The results of the research will be useful for scientific and engineering - technical workers at enterprises, scientific-research, design, and start-up companies.

References

Bregman, I., Khmara, V., Golant, Y., Nefediev, Yu., & Ogol A. (1984). Automated system of analytical control (ASAC) for iron and steel companies of non-ferrous metallurgy. M: Tsvetmetinformatsyia, 60.

Bregman, I., & Khmara, V. (1989). Set of standard hardware for ASAC of metallurgical production. M. Tsvetmetinformatsyia, 44.

Cox, B. (2008). Pneumatic Powder Transport System». U.S. Patent № 7464733 B2.

Chenglin, M., Haijun, M., Xuechun, Y., Jingfeng, D., Chao, M., & Lihua, A. (2014). Study on the Development Mode of Urban Underground Logistics System. *Service Science and Management Research (SSMR), 3*(1).

Dedegkaiev, A. G., Kabyshev, A. M., Lobotskiy, Yu. G., & Khmara, V. V. (2014). Optimization of the structure and organization for functioning of the organization of a universal system for sequential positional control of devices (pp. 45-67). International Scientific and Practical Conference "Engineering sciences: Theory, methodology and practice", RSCI. Moscow.

Liu, H. (2006). Transporting Freight Containers by Pneumatic Capsule Pipeline (PCP): Port Security and Other Issues. Invited presentation at Summer Meeting of U. S. Transportation Research Board (TRB) LaJolla, California, July 10.

Lobotskiy, Yu., & Khmara, V. (2013). Automated system of analytical control as the basis for technological process control (pp. 146-151). Collection "VII International Scientific and Practical Conference "The new word in the science and practice: Hypothesis and testing of the researches results", RSCI, Novosibirsk.

Lobotskiy, Yu., & Khmara, V. (2014). Technological design of systems for selection and delivery of samples to be analysed. Lambert Academic Publishing. ISBN: 978 – 3 - 659 – 28785 – 5. 69 pgs.

Plekhanov, Yu. V., & Khmara, V. V. (2003). The modern concept of creating automated systems for analytical control of enriching factories (pp. 38-40). Proceedings of the IV Congress of enrichers of the CIS countries, Volume II, M,: Alteks.

Terzini, R. (2011). Container for use in pneumatic transport system». U.S. Patent № 0142554 A1.

Khmara, V. V. (2006). Fundamentals of the theory and practice of creating automated systems of analytical control of non-ferrous metallurgy products. Doctoral dissertation. Specialty 05.13.06. The city of Vladikavkaz. P. 316.

Khmara, V. V. (2009). Optimization of sampling interval at discrete control of a changing value (pp. 97-99). Tsvetnyie Metally, M., No. 2.

Khmara, V. (2012). Universal container system of pneumatic transport of samples to be analysed. Fundamentals, principles of construction, design, and operation algorithms. Lambert Academic Publishing. ISBN: 978 – 3 - 8433 – 6602 – 1. 89.

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