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Improve operational efficiency of regulated conveyor installation of the mining industry

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ABSTRACT: The article describes the requirements for electric drives and control systems for conveyor systems. The conditions of energy efficient operation of conveyor systems that determine the basic requirements for electric drives and control systems, taking into account the features of their static and dynamic properties, are considered. The justification and choice of the electric drive system for conveyor systems are given. The main rules for selecting a frequency converter are determined. Functional and structural schemes of an electromechanical system of a belt conveyor with an open control system, taking into account the elastic mechanical properties of the conveyor belt, one and two-loop systems of the frequency-controlled electric drive of the belt conveyor to control the cargo flow are constructed. The results of simulation calculations for the system "frequency-controlled asynchronous motor-conveyor" are obtained in the effective mode in MATLAB environment.

KEYWORDS: belt conveyor, frequency-controlled electric drive, energy efficiency, mathematical model, structural diagrams, control systems of conveyor

I.INTRODUCTION

Energy saving has become in recent years one of the main priority areas of technical policy in all developed countries of the world. Energy saving in any field is reduced to a reduction in useless losses. Analysis of the structure of losses in the production, distribution and consumption of electricity shows that determines the losses (up to 90%) falls on the sphere of consumption [6].

The high energy intensity of the technological equipment of the mining industry determines the use of energy-saving technologies in the processing of mineral and raw materials [4]. To ensure efficient operation of the most energy-intensive equipment - mill blocks, it is necessary to coordinate the conveyor systems, which are the connecting link of the continuous technological process of the mining industry and one of the energy-intensive equipment [9].

On open mining, conveyor systems are widely used on continuous-action complexes, with conveyor transport in concentrating factories. At the enterprises of the mineral and raw materials complex, belt conveyors and scraper conveyors are mainly used. The performance and operating conditions of such units may be different, which affects the choice of their electric drive systems [1, 8]. Modes of operation of conveyor plants are due to continuous operation over a long period of time due to loading, transportation and unloading in a continuous mode. This circumstance affects the choice of the drive motor and its components.

II. RESEARCH PROBLEM AND METHOD

For electric drives of conveyor plants, a relatively important start-up process is of great importance. This is due to the start-up of the conveyor under load due to the presence of a load on the traction body after an emergency stop. Significant starting currents for a long time make it necessary to use special drive motors with large overload capacity for conveyor systems [1].

The uneven loading of the load bearing conveyor branch affects the static load of the electric drive. The loading of the main belt conveyors installed in the capital excavations depends on the unevenness of the cargo flows from the mining faces and from the place where the cargo flows flow to it. As a result, the conveyor, selected for the maximum receiving capacity, is significantly under loaded during operation. Reducing the static load negatively affects the power characteristics of the electric drive. There is a redistribution of the share of energy between the costs of moving the traction organ and payload. Most of the energy is spent on moving the traction organ while increasing the energy consumption for moving the payload [10].

Improving the energy properties of the electrical drive of the conveyor system is possible by adjusting the speed of the traction body in the function of the cargo flow in such a way as to ensure a full load of the conveyor belt. Providing this mode of operation of the conveyor system is possible only at the expense of a regulated electric drive [3].

III. REQUIREMENTS FOR ELECTRIC DRIVES AND CONTROL SYSTEMS FOR CONVEYOR SYSTEMS

Consideration of working conditions of conveyor plants allows determining the basic requirements for electric drives and control systems, taking into account the features of their static and dynamic properties [10]. The electric drives of the conveyor systems must provide operation in a continuous mode with variable load without reversing the direction of travel. In some cases, for example, when the conveyor system is sloping, the electric drive must work both in the motor and in the braking modes. In the case of sequential installation of several conveyors working with transshipment of transported material from one conveyor to another in the general technological chain, the order of their switching on and off must be ensured. The inclusion of conveyors should occur in the direction of the counter-flow, and the trip-in the direction of the traffic flow to eliminate blockages at the points of congestion.

For main conveyors operating with variable loads for long periods of time, it is considered advisable to regulate the speed of the traction body to ensure a constant load of the load-bearing branch of the conveyor. This makes it possible to increase the energy efficiency of the use of conveyor plants, to shorten the travel of the traction organ, and consequently to increase the resource of an expensive conveyor belt.
For multi-drive conveyors, the electric drive must ensure that the loads are equalized between the motors and that the slip of the belt relative to the drums is eliminated.
In order to limit dynamic loads, ensure reliable adhesion of the tape to the drum and the transported load with the belt, the electric drive of conveyor systems, especially with their long length, should limit the acceleration at start-up by the permissible value and eliminate the oscillating dynamic loads.
In the case of the use of adjustable electric drives providing soft start, speed control, conveyor belt systems, limiting dynamic loads and load balancing between the drive motors, the minimum speed control range must be 10: 1.

IV. ELECTRIC DRIVE SYSTEMS FOR CONVEYOR SYSTEMS

When justifying and choosing the electric drive system for conveyor systems, one should take into account that the greatest application is the AC drive based on asynchronous motors. For short conveyors of low capacity, asynchronous motors with a deep-sealed squirrel-cage rotor or a double squirrel cage type rotor having an increased starting torque are usually used.

A. Unregulated electric drive of conveyor systems

At present, soft starter devices (SS) are becoming more common, and a number of modifications have also included braking functions. The application of soft starter provides: smooth start-up of an asynchronous motor with limitation of starting current and angular acceleration, protection from mechanical impacts of the actuator, allows regulating the acceleration and deceleration time.

The soft starter represents a semiconductor voltage regulator at the motor stator terminals. The voltage is changed by adjusting the angle of unlocking the thyristors, switched on the counter-parallel connection scheme in each phase of the stator winding of the engine. The functional diagram of the SS is shown in Fig. 1, where the following designations are adopted: TS - thyristor switch; AM - asynchronous electric motor; CS - control system, which includes the driver of control pulses; FI - drivers serving to control thyristors, as well as galvanic separation of power circuits and control circuits; MC - microcontroller; IOD - input-output device; CP - control panel; PS - power supply; SC1, SC2, SC3 - current sensors designed for monitoring, starting current control and protection against over current and short circuit currents; SV1, SV2 - voltage sensors designed to protect against unacceptable excess and voltage reduction and voltage regulation at the stator terminals of an asynchronous motor.

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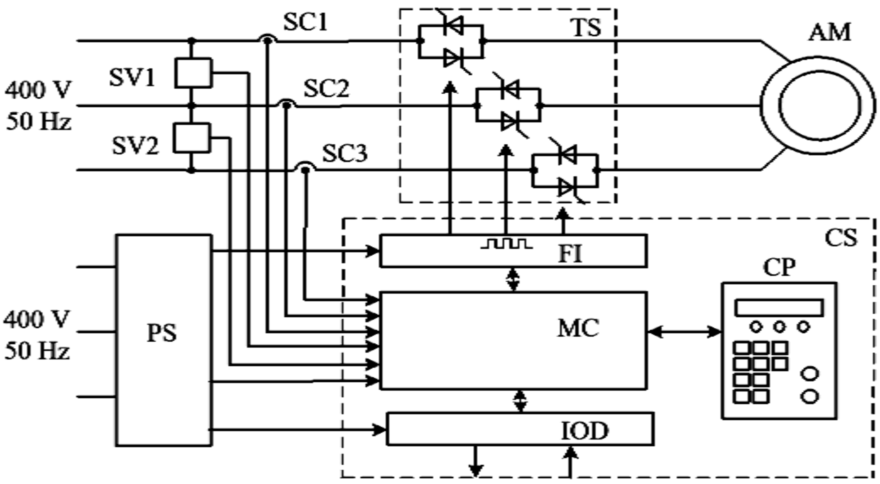

Fig. 1. Functional diagram of the soft starter

Voltage control ensures smooth start-up of the motor, however, the current and torque of the motor are not controlled during start-up n(Fig. 2, a). This control method is not suitable for electric drives with heavy starting.The current control provides for start-up current limitation. The voltage variation at the stator terminals is such that during the most part of the starting time the motor current is kept constant (Fig. 2, b). Torque control is the most perfect way to start. In this case, the SCP monitors the required torque value, ensuring start-up with the lowest possible current value (Fig. 2, c). The application of the control system with the monitoring of the motor torque provides a linear graph of the change in speed in time.

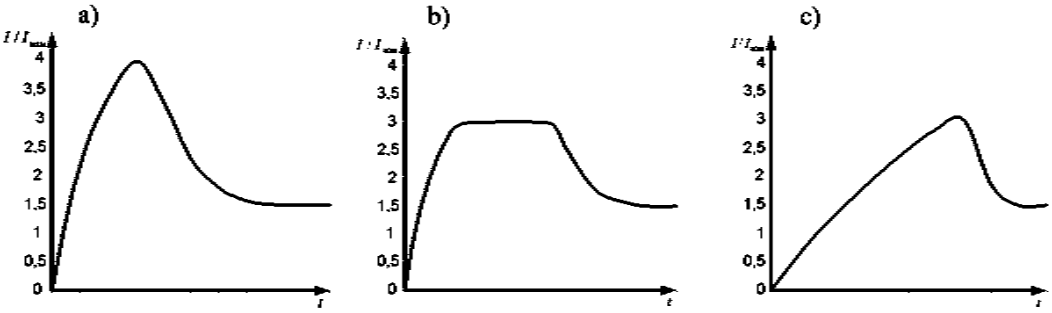

Fig. 2. Graphs of the time variation of the current when the motor is started from the soft starter under the control methods: a) - voltage at the stator terminals; b) - current; c) - moment of the engine

B. Adjustable electric drive of conveyor systems

The application of relay-contactor circuits and soft starters solves the problems of providing starting processes for conveyor systems. To implement other requirements for conveyor systems, such as regulating the speed of the belt as a function of the cargo flow or limiting dynamic loads, the use of an adjustable electric drive is required. In modern conditions, frequency-regulated electric drives with asynchronous and synchronous motors have the greatest prospects [5].

In Fig. 3 shows a typical scheme of a low-voltage asynchronous frequency-controlled electric drive with an autonomous voltage inverter based on IGBT transistors. Frequency converters are built on the basis of semiconductor power electronics: intelligent power modules (IGBT-module), representing a constructive unity of power keys and drivers for managing them; Built-in security elements and interface with a microcontroller control system [7].

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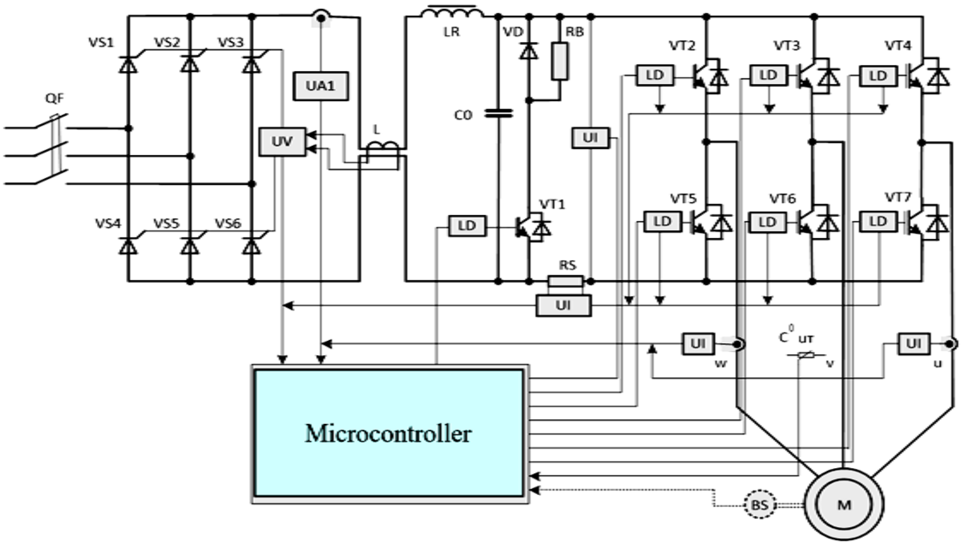

Fig. 3. Typical scheme of a low-voltage asynchronous frequency-controlled electric drive with an autonomous voltage inverter

A high-voltage frequency converter with a voltage inverter based on IGBT transistors contains a multiphase input transformer, power units and microcontroller control, protection and control system. The functional diagram is shown in Fig. 4.

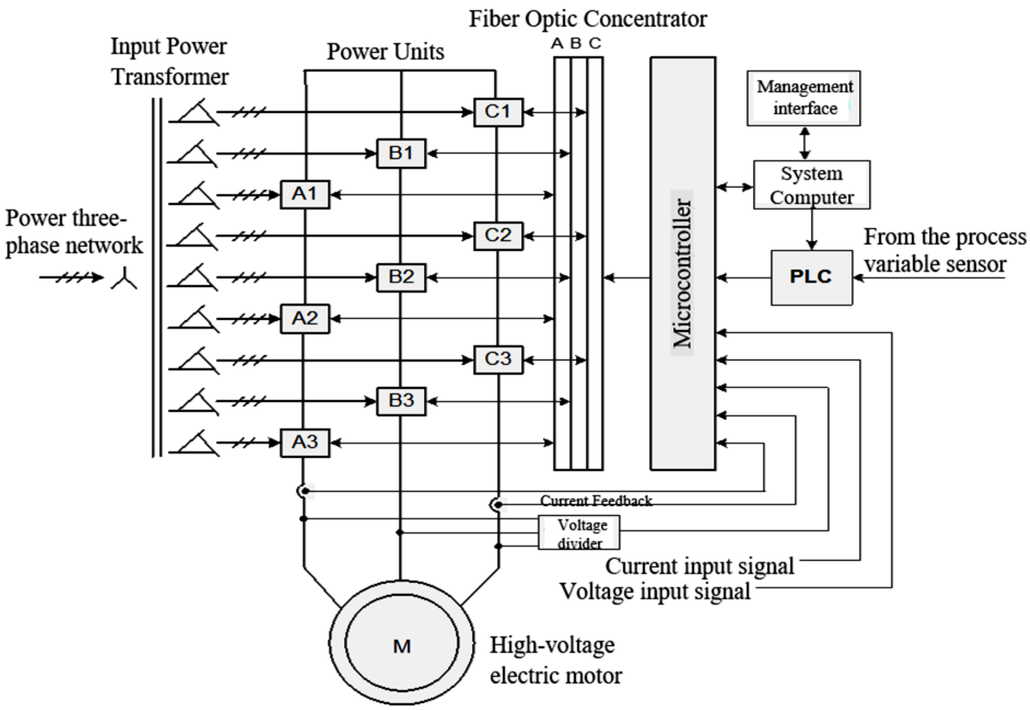

Fig. 4. Functional diagram of high-voltage frequency-controlled electric drive with voltage inverter

A significant disadvantage of high-voltage frequency converters with an autonomous voltage inverter is the use in its composition of a complex multiwinding transformer. Because of this, such converters have significant weight and size indicators. Therefore, in the present conditions are spreading transformers of inverters.

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Vol. 5, Issue 3 , March 2018

C. Selecting a frequency converter

An analysis of the existing fleet of frequency converters shows that when selecting frequency converters to regulate the speed of the traction body of the conveyor system, the following rules should be followed:

- the rated voltage of the drive motor must correspond to the rated voltage of the frequency converter;
- the rated power (current) of the frequency converter must correspond to the rated power (current) of the frequency converter;
- parallel connection of several motors is allowed only to frequency converters with a voltage inverter. Such connection of motors is allowed within the power (current) of the frequency converter (the total rated power of the connected motors must be equal to or less than the rated power of the frequency converter);
- frequency converter with a current inverter is designed to work with an individual electric drive, i.e. only one drive motor of the conveyor system can be connected to it. A number of conveyor systems have several drive motors, for which several frequency converters with a current inverter are required, the number of which corresponds to the number of motors.

V. MATHEMATICAL MODELS AND STRUCTURAL DIAGRAMS OF THE ELECTROMECHANICAL BELT CONVEYOR SYSTEM

A. Mathematical description of electromechanical belt conveyor system with open control system

To study and analyze the dynamic properties of the electromechanical system of the belt conveyor, its mathematical description is necessary. Depending on the tasks to be solved, mathematical models can be different. With reference to the problems solved by means of an adjustable electric drive of conveyor plants, it is possible to obtain the following mathematical models: 1. To solve the energy saving problem and increase the energy efficiency of the technology of transportation of minerals, a mathematical model of the electromechanical system can be obtained on the basis of parallel or sequential correction of coordinates. In this case, the electromechanical system is considered as a single-mass system, without taking into account the elastic properties of the traction organ. 2. To solve the problem of limiting dynamic loads in the kinematic circuits of the electromechanical system of the conveyor system, the mathematical model must be multi-mass. The control structure in the model can be either with parallel or sequential correction of coordinates.

These models are based on a mathematical description of the electromechanical system of a belt conveyor with an open control system. A modern adjustable electric drive of conveyor systems with an asynchronous drive motor uses frequency converters with autonomous voltage or current inverters. Mathematical models of frequency-regulated electric drives are rather complex and unsuitable for solving the tasks set for energy saving and limiting dynamic loads. To solve the energy saving problems, the static and energy properties of the electromechanical system of the conveyor system are important. The problems of limiting dynamic loads in the traction organ are associated with low-frequency mechanical vibrations of the masses being moved, which prevail over high-frequency electromagnetic oscillations in the system "frequency converter - motor".

On the basis of the dependences obtained, we have a mathematical description of the single-mass electromechanical system of a conveyor belt with an electric drive according to the scheme "frequency converter - asynchronous motor" in the form of a structural diagram, shown in Fig. 5.

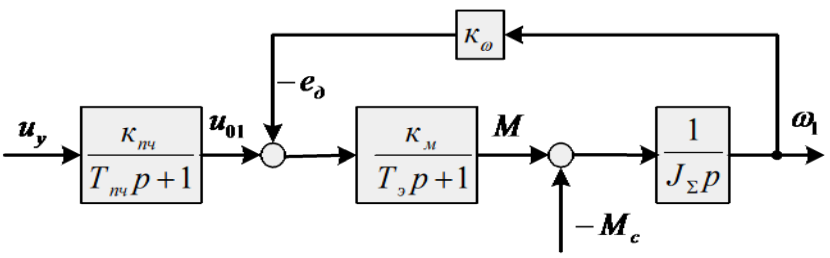

Fig. 5. Structural diagram of frequency-controlled electric drive

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B. Single-circuit system of frequency-controlled electric drive of a belt conveyor for controlling the cargo flow

The control system is designed to regulate the speed of the traction body of the conveyor unit as a function of the incoming cargo flow. Since the cargo flow is not always the maximum, most of the time the conveyor belt moves at a reduced speed, ensuring the maximum cross-section of the load throughout the entire length of the belt. This provides energy saving in the system of an adjustable electric drive and resource saving of an expensive conveyor belt, as its mileage is reduced [2].
For speed control as a function of the cargo flow, the electronic conveyor scales are used as a traffic sensor, which are installed in the path of the cargo flow before it arrives on the assembled main belt conveyor. Since the control signal is generated by the load sensor, a servo system is implemented which sets the control signal for speed, depending on the weight of the load passing through the electronic conveyor scales.
The structural diagram of a single-loop control system for cargo traffic is shown in Fig. 6.

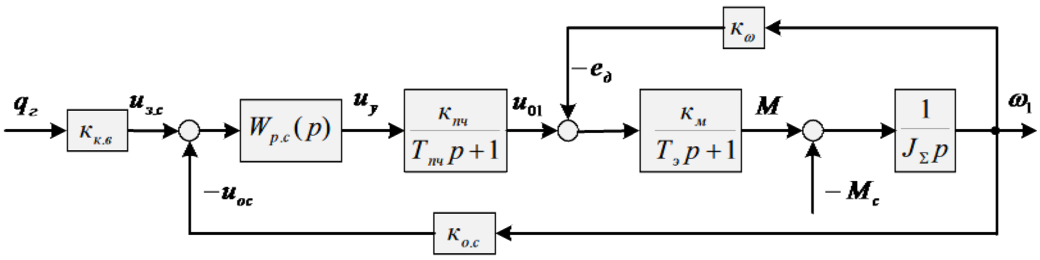

Fig. 6. Structural scheme of a single-loop regulating system for the conveyance of a belt conveyor

The following symbols are used in the structural scheme: $q_г$ – running weight of cargo on the belt, kg / m; $k_{кв}$ – transmission coefficient of conveyor scales, V·m / kg; $u_{з.с}$ – speed reference signal (voltage), V; $k_{o.c}$ – speed feedback coefficient, V·s; $u_{o.c}$ – speed feedback signal (voltage), V; $W_{pc}(p)$ – transfer function of the speed controller.

C. Two-circuit system of frequency-controlled electric drive of belt conveyor for cargo traffic control

The management of the freight flow in a single-loop control system has a significant drawback due to the lack of the ability to monitor the current of the stator circuit of the motor. Therefore, along with a single-loop system, the system with a two-loop system of subordinate regulation became widespread. In such a system, the internal loop is the current (torque) control loop, and the external circuit is the speed control loop. The block diagram of a two-loop subordinate control system for controlling the cargo flow of a belt conveyor with a frequency-controlled electric drive is shown in Fig. 7.

In comparison with the single-loop control system on the structural diagram of Fig. 6 there are additional symbols: $u_{з.m}$ – current reference signal (voltage), V; k_{om} – current feedback coefficient, V/A; $u_{o.m}$ –current feedback signal (voltage), V; $W_{p.m}(p)$ – transfer function of the current regulator; $c_м$ – coefficient of proportionality between the electromagnetic moment of the motor and the stator current, Nm / A.

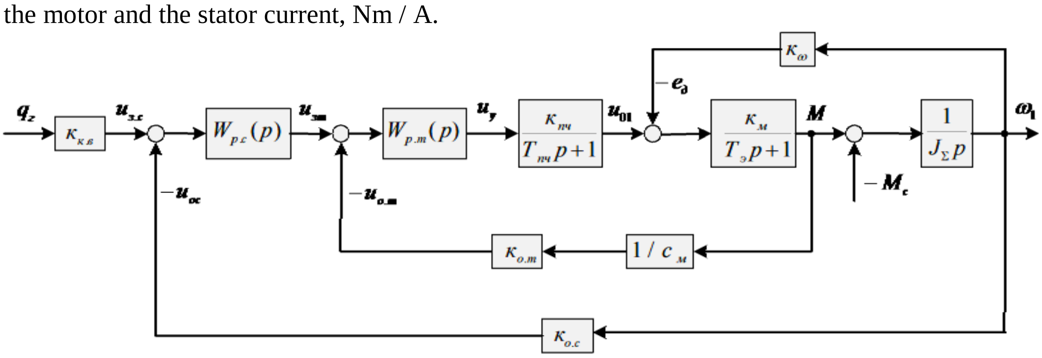

Fig. 7. Structural scheme of a two-loop subordinate regulation system for the conveyance of a belt conveyor

ISSN: 2350-0328
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Vol. 5, Issue 3 , March 2018

Calculations were carried out for a belt conveyor type *KLS-800* with the following passport data: motor power P = 15 kW; rotation speed n = 1460 rpm; belt width B = 800 mm; productivity Q = 70 tons / hour; the speed of the tape υ = 1,53 m/s; distance between the centers of the drums L_{conv} = 54.53 m.

The results of simulation calculations for the "frequency-controlled asynchronous motor-conveyor system" obtained in the MATLAB environment are shown in Figure 8.

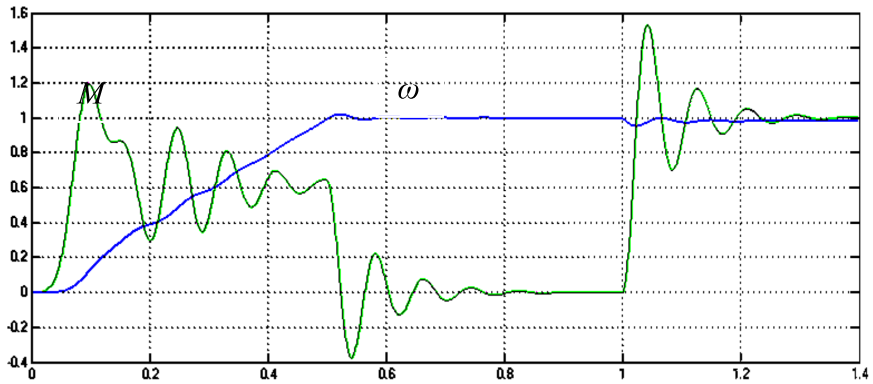

Fig. 8. The electromagnetic moment M and the rotation frequency ω under the dynamic regime of the frequency-controlled electric drive of the conveyor

D. Mathematical description of the electromechanical system taking into account the elastic mechanical properties of the conveyor belt

The propagation of elastic oscillations in these bars is described by second-order partial differential equations. In the mathematical description, the following generally accepted assumptions are used: viscous friction forces are not taken into account; the conveyor belt has only an elastic deformation; the center of the second mass is located in the middle of sum of the translationally moving masses. The mechanical part of the two-mass system of the conveyor system is described by a system of differential equations [8] in the operator form:

$$J_1 p\omega_1 = M - M_{y1} + M_{y2};\ pM_{y1} = c_1(\omega_1 - \omega_2);$$
$$J_2 p\omega_2 = M_{y1} - M_{y2} - M_c;\ pM_{y2} = c_2(\omega_2 - \omega_1), \quad (1)$$

In the system of differential equations (1), the difference in the moments of the elastic forces in the oncoming and running branches of conveyor is represented as the moment of elastic loading.

$$M_{y.нг} = M_{y1} - M_{y2}, \text{ Nm.} \quad (2)$$

We represent the system of differential equations (1) with the complement (2) in the form of the structural scheme of Fig. 9.

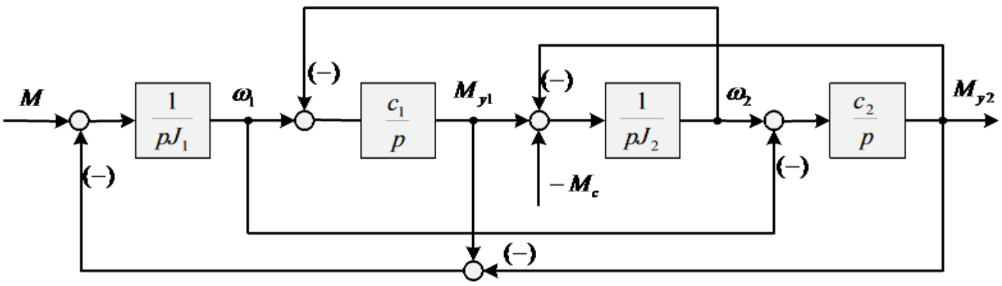

Fig. 9. Structural scheme of the mechanical part of the belt conveyor drive

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Vol. 5, Issue 3 , March 2018

VI. CONCLUSION

Based on the analysis of the results obtained, the following was established:

- in the course of work on the project, a control system for the belt conveyor motor was designed and calculated using the IF-AD system. A functional and structural scheme was constructed, with the help of which the parameters for constructing a mathematical model in the MatLab environment were calculated. The study of the obtained virtual model made it possible to study the dynamic and static characteristics of the control system of the electric drive using the IF-AD system under load and during idling;
- application of frequency-controlled electric drive of the conveyor system reduces the dynamic processes occurring in the tape during the start-up. During frequency start-up, the speed of propagation of the stress wave in the belt decreases;
- frequency-controlled electric drive of conveyors of the mining industry will allow to ensure the operation of the "electric drive-conveyor" system in an economical mode;
- control of the productivity of the conveyor system will ensure the full loading and operation efficiency of the mill blocks and crushers, which will prevent their idle mode of operation and will reduce the wasteful use of energy-intensive equipment, which will lead to significant energy savings by mill blocks and crushers.

REFERENCES

[1] Belov M.P., Novikov V.A., Rassudov L.N.: Automated electric drive of standard production mechanisms and technological complexes. Academy, 576 p, 2007.
[2] Babokin G.I.: Energy saving in the electric drive of the conveyor. Mining Journal, Moscow, no1, p 122-125, 2002.
[3] Bose, Bimal K.: Modern power electronics and AC drives. USA, Prentice Hal, 711p, 2002.
[4] Kalukiewicz A., Romanovič A.S.: The requirement for an energy-efficient Tangential cutter used for the development of mining of potassium ore. Journal of Mining Industry, no 1, p 52–54, 2015.
[5] Kamalov T.S, Toirov O.Z: Control of operating modes of conveyor systems based on frequency-controlled electric drive in the mining industry. Journal of "Problems of energy and resource saving", no 3, p 17-22, 2015.
[6] Kamalov T.S., Toirov O.Z.: The current state of belt conveyor systems and the issues of their energy and resource saving. “Problems of Informatics and Energetics”, no 1-2, p 53-62, 2013.
[7] Kamalov T.S., Toirov O.Z.: Modern condition and possibilities of program management of frequency-adjustable electric drives. Scientific Journal «European research», London, no 6(17), p 18-20, 2016.
[8] Kostyuk V.S., Volkova L.P., Fashilenko V.N.: Adjustable electric drive of shaft installations. Textbook, 65 p, 1984.
[9] Kulinowski P., Kasza P., Zarzycki J., Płonka M.: Comparative studies of the effectiveness of the belt tensioning devices. Industrial Transport, no 1, p 6–11, 2015.
[10] Pertin A.Yu .: Conveyor systems. Professional, 507 p, 2008.

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