DEVELOPMENT OF AN ADAPTIVE BELT CONVEYOR CONTROL SYSTEM

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Abstract. *Continuous transport machines, in particular belt conveyors, are used in a wide variety of industries. Such machines are especially effective when used in mechanical engineering, in warehouses, and in the logistics system. In the process of intensifying production, a number of requirements are placed on conveyors in terms of their productivity and the accuracy of cargo positioning. These requirements can only be achieved by adjusting the speed of the electromechanical conveyor system. In turn, the regulation will necessarily cause uneven movement of the conveyor belt and oscillation of the load relative to its equilibrium position. Due to wear and tear of technological equipment, as well as changes in loading patterns, the conveyor is a significantly unstable object, the properties of which change significantly over time. In addition, the electromechanical system of the conveyor is influenced by external disturbances, the nature of which varies from smooth and continuous to sharp and intermittent. All this allows us to conclude that the electromechanical belt conveyor system, from a control point of view, is a non-stationary object. On the other hand, operating experience shows that we get the greatest effect from the operation of cargo transportation systems when regulating the speed of the belt conveyor. For example, energy savings of up to 30%, while increasing the stability of conveyor systems by 10%. Therefore, today the urgent task is to develop a model of an adaptive automatic control system for EMC conveyor belts, taking into account the influence of external disturbing factors, which will limit load fluctuations in combination with high productivity. The article uses materials from a project to automate the conveyor belt system used for transporting air conditioners and refrigerators produced at the enterprises of ARTEL, Tashkent*

Keywords: *belt conveyor, Unsteady mode, Adaptive control, External interference, optimal control model, Magnetization curve, Variable frequency drive, Relay protection and automation systems, Fiber-optic current converter.*

Introduction. The article discusses an adaptive automatic control system for the electric drive of a conveyor, which allows minimizing fluctuations of loads relative to the equilibrium position, regardless of the nature of their non-stationary nature and the influence of external disturbing factors. To improve the accuracy of assessing the criterion of external disturbing factors, an adaptive system for regulating the operation of a conveyor electric drive using a fiber-optic measuring current transformer as a sensor of random control signals is considered. The article proposes to use a fiber-optic current transformer as a signal sensor for protection and control systems of a belt conveyor. This transformer is widely used in the field of automation of control systems and protection of electric drives and as a source of operational information. The technical result is to increase the reliability and stability of measurements during long-term operation under all types of changes in the current electrical voltage, mechanical loads and various environmental factors.

I. MAIN CONTENTS.

A preliminary production analysis showed:

a) conveyor systems used in the production of air conditioners and refrigerators are flat belt systems with magnetization and roughness (18 - 23)%.

b) Conveyor systems need automation based on the introduction of modern control systems for the operation of electric drives.

c) Conveyor systems must be adapted to changing external factors, in particular to sudden changes in current and voltage in the supply network

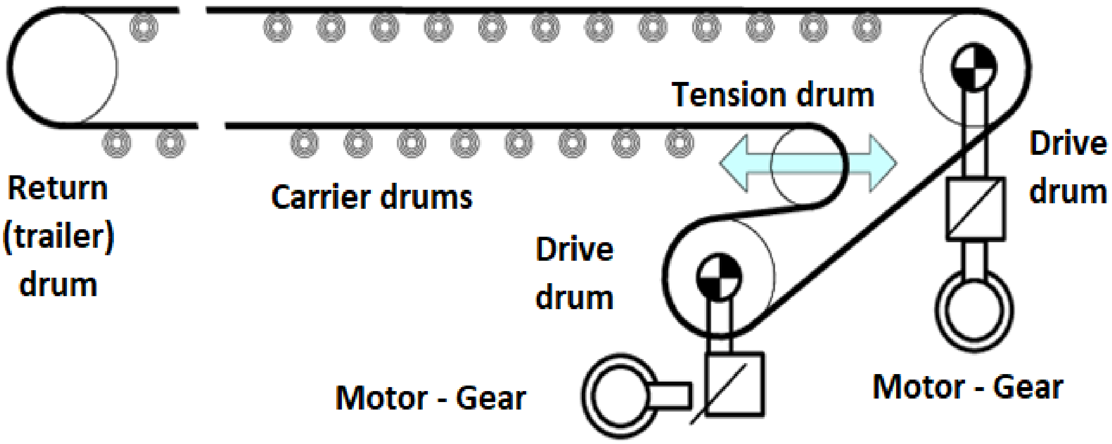


Fig 1. Basic operating diagram of a belt conveyor

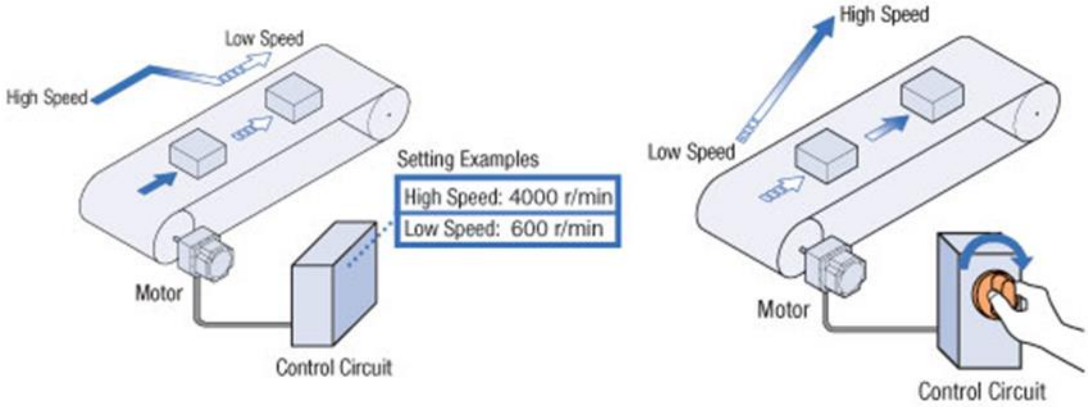


Fig 2. Controlled electric drive of the conveyor belt

We studied the possible options for electric drives offered by the company, a global manufacturer of conveyor systems ORIENT MOTOR, and settled on 2 SEMs based on a Direct Current Motor (DCM) and based on an Asynchronous Motor (AM). In terms of regulation, the option with DPT is better, but in terms of economic indicators, a frequency-controlled system is better and we choose it. This is a Modbus ACA610-1385-6 (RTU) control system. Figure 3 shows a schematic diagram of this system.

To determine the control range, as well as to check the stability of the selected system, the dynamic characteristics of the Electro Mechanical System (EMS) were calculated taking into account real operating conditions. As a result, a variant of the conveyor belt type ACA631-2600-6 was proposed; 2176 A with three 500LR6 type asynchronous motors and VF ACA610-1385-6 1156A control system as the drive system.

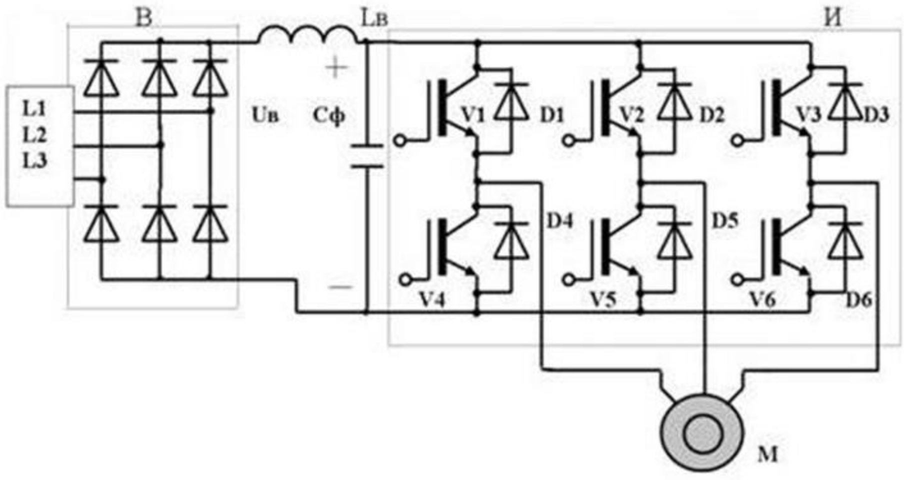


Fig.3. Schematic diagram for controlling the operation of the Modbus ACA610-1385-6 (RTU) belt conveyor drive.

1.1 Development of a system for regulating the operation of the electric drive of a belt conveyor

The intensification of production processes inevitably leads to increased requirements for the quality of transient processes and comprehensive automation of production. Therefore, conveyor systems must be adapted to changes in external factors, in particular, to sudden changes in current and voltage in the electrical network. If the desired characteristics cannot be achieved over the entire range of possible parameter changes, it is necessary to consider adaptive control to improve the reliability of the belt conveyor control system. The reasons for applying the principles of adaptation can be combined into two groups: 1) Variability of the characteristics of the control object and the influence of the external environment. Environmental factors include: climatic; mechanical – cargo; changes in the energy system; 2) Requirements for increasing the accuracy and technical and economic characteristics of systems. When developing an adaptive conveyor belt model, two types of information are needed: initial information, which gives a mathematical description of the process of the conveyor system, and current information received during the operation of the system. The introduction of adaptation elements complicates the system, and therefore reduces its reliability, so the application of adaptation principles requires an analysis of efficiency. 1. Partial indicators characterize the quality of the process with fixed characteristics of the control device (OY), control unit (YY) and specified noise characteristics. They are indicated by:

$$\beta\ (\text{ОУ},\text{УУ}) \Rightarrow Q\ (\beta)\ (1)$$

β is the totality of all process parameters.

3 generalized criteria characterizing the range of changes in individual indicators with possible changes in the characteristics of the control object and disturbing influences

$$\text{Ϫ}\beta(\text{ОУ}\ ,\text{УУ})\Rightarrow Q(\text{Ϫ}\beta) \Leftrightarrow \Delta Q/|\text{Ϫ}\beta|\ (2)$$

Thus, the VF-Inverter + AD circuit operates with known parameters (taking into account belt speed, load weight, tension force), but in addition to these parameters, in order to adapt the system to possible external interference, general information about the EMC structure and its characteristics for given operating conditions is required. As a base model, we use the classic automatic control system of the self-propelled guns, shown in Fig. 4.

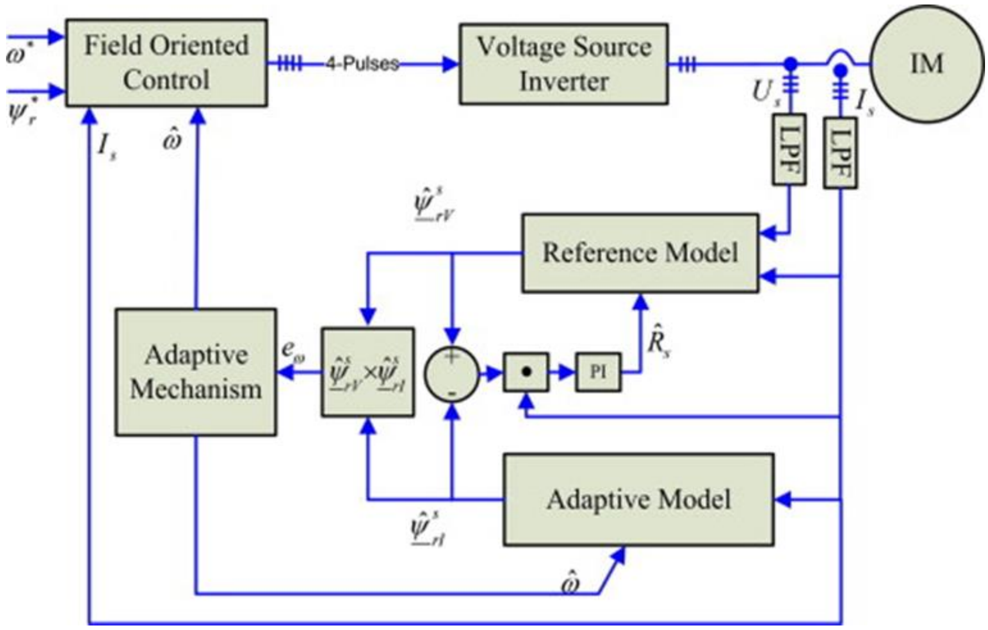
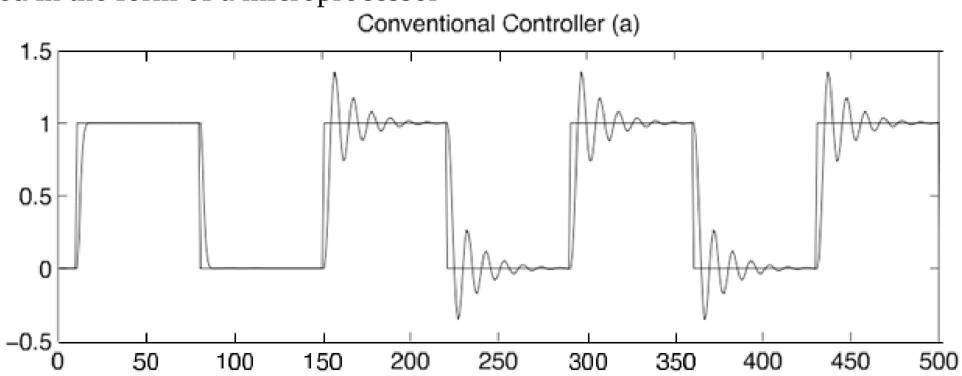


Fig 4. Classic adaptive control system of automatic control system for belt conveyor

In Fig. 4. 2 control systems are shown: a) ACS I without adaptation consists of a low-voltage inverter control system Field Oriento Control (SPWM) - VF-Inverter-Induction Motor with speed feedback from the LPF sensor. All ACS I are controlled by a reference model. Due to possible changes in technology (load weight, belt speed, belt tension), as well as external influences (changes in current and voltage in the network), we create a mechanism for adapting to changes (Adaptation Mechanism); c) ACS II with adaptation consists of an Adaptive Model, which receives information from sensors LPF1 and LPF2, is compared with the data of the Reference Model and the result is transmitted to the Adaptation Mechanism, and then to SPWM according to Figure 4. The Adaptive Model is the main element of ACS II, technically implemented in the form of a microprocessor. In Fig. 4. 2 control systems are shown: a) ACS I without adaptation consists of a low-voltage inverter control system Field Oriento Control (SPWM) - VF-Inverter-Induction Motor with speed feedback from the LPF sensor. All ACS I are controlled by a reference model. Due to possible changes in technology (load weight, belt speed, belt tension), as well as external influences (changes in current and voltage in the network), we create a mechanism for adapting to changes (Adaptation Mechanism); c) ACS II with adaptation consists of an Adaptive Model, which receives information from sensors LPF1 and LPF2, is compared with the data of the Reference Model and the result is transmitted to the Adaptation Mechanism, and then to SPWM according to Figure 4. The Adaptive Model is the main element of ACS II, technically implemented in the form of a microprocessor



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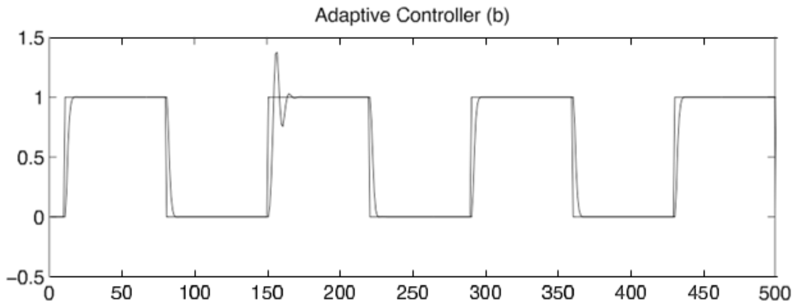


b

Fig 5. Oscillograms of currents and voltages a - the usual control model of ACS-I; b- adaptive model of the conveyor belt ACS II

It can be seen that the system with the adaptive ACS II model smooths out current and voltage peaks and adapts them. The same effect can be seen in the graphs for starting the IM with load and at idle.

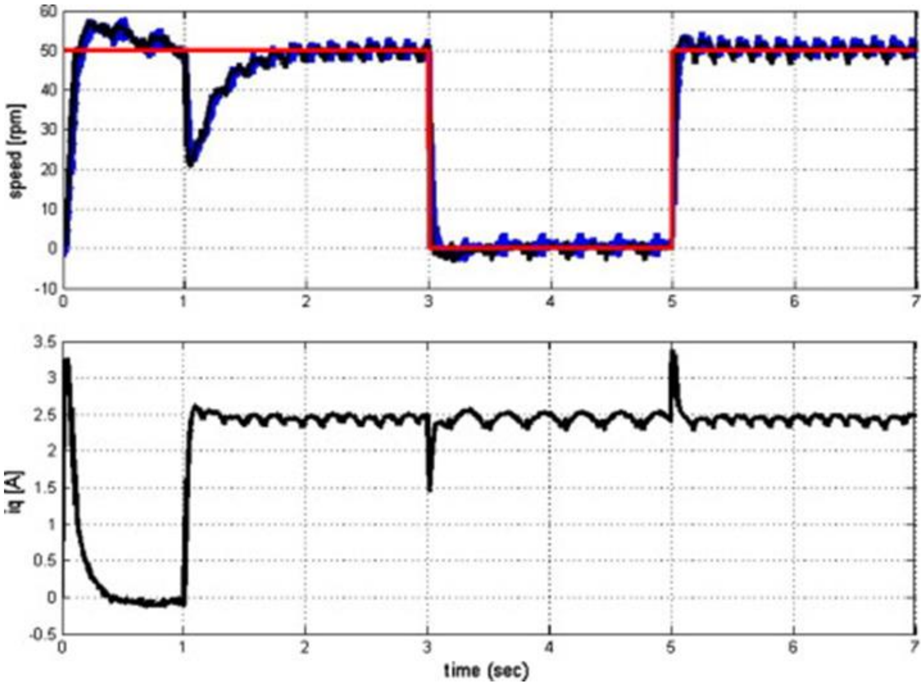


Fig.6. Top: Reference speed (red), estimated speed (blue) and actual speed (black) in rpm. Lower: torque current iq (A).

1.2 Using an optoelectronic current transformer as an external noise sensor.

In Figure 4, standard electromagnetic measuring current transformers are used as current sensors. Due to the nonlinearity of the magnetic core magnetization process, transformers of this type cannot provide an objective signal. For an adaptive belt conveyor control system, sensors based on electromagnetic current transformers are not suitable. For an adaptive system, this is a very important indicator, so the article proposes to use a fiber-optic current transformer that is devoid of these disadvantages.

A fundamentally different approach is implemented in optoelectronic current transformers, used in combination with modern technologies of digital signal processing and data transmission [12].

The fiber-optic current transformer includes a current-carrying circuit covered by a magneto-optical sensor in the form of a coil of optical fiber, means for inputting a polarized light signal into the fiber, and means for dividing the polarized light signal into mutually orthogonal ones. linearly polarized components, as well as a block for converting components into electrical signals normalized by intensity and a block for generating a measuring signal and determining the measured value from it [14].

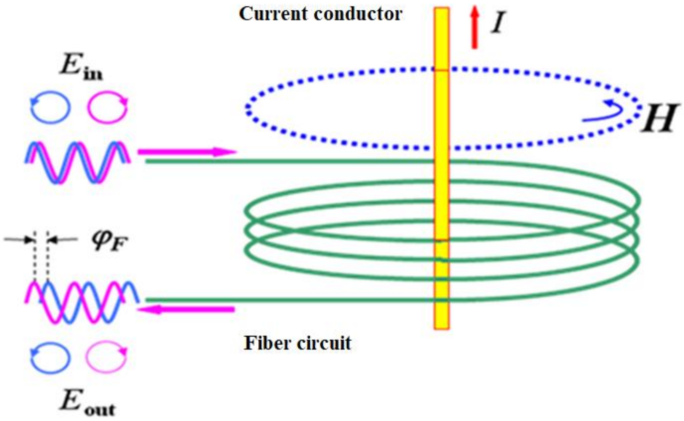
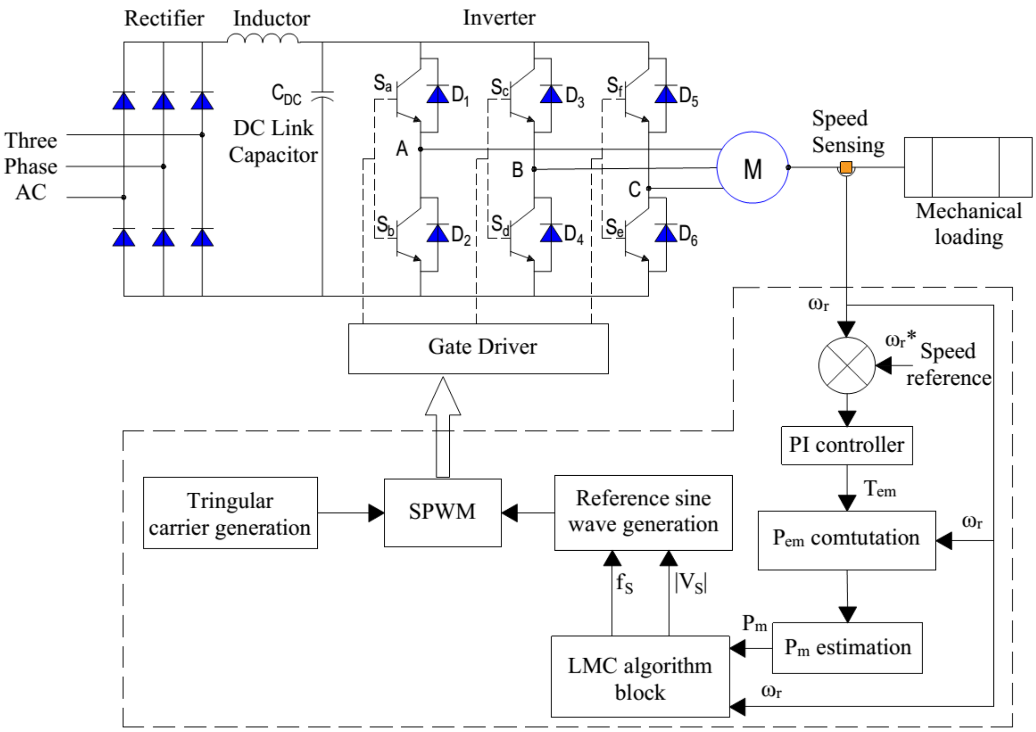


Fig. 7. Schematic diagram of a fiber optic current transformer

Obtained results and their discussion

Thus, in all respects, a fiber-optic current transformer can be used as a random signal sensor in a model of adaptive control of a belt conveyor. This was tested on an adaptive controller that controls the speed of an induction motor (AD) drive with imprecise models.

The proposed controller consists of an adaptive feed-forward control loop that compensates for nonlinear and uncertain factors, and a feedback control loop that guarantees system stability. An optoelectronic current transformer was used as a signal sensor for random factors. In Fig. 8 shows a diagram of an adaptive control model for a conveyor belt drive based on an RS-485/Modbus (RTU) frequency controller [2].



Rice. 9. Block diagram of the adaptive control model of the belt conveyor drive

The proposed scheme is not only simple and convenient to operate, but also guarantees accurate and fast speed tracking [9,4]. Experiments carried out on an asynchronous electric drive with a rated motor power P = 4 kW confirmed good control characteristics (better stability, lower root-mean-square and maximum absolute errors), especially in the case of a serious discrepancy between the parameters of the real drive and the model used to develop the control system.

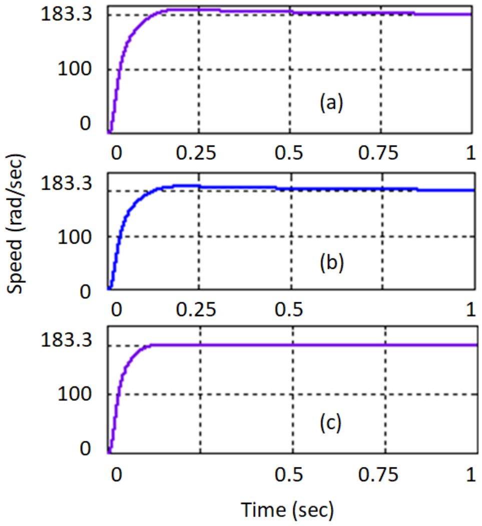


Fig 9. Starting characteristics of the IM drive of the conveyor belt

In Figure 9 shows the starting characteristics of an asynchronous conveyor drive using an adaptive control system: a, b – starting without taking into account current fluctuations in the supply network; c – taking into account the network factor and using an optoelectronic current transformer as a sensor. [9,16]

Fig.10. Adaptive conveyor control system RS-485/Modbus (RTU)

Conclusion

1. A preliminary analysis of production showed: a) the conveyor systems used in the technological process are flat-belt systems with magnetization and roughness (18-23) %.

2. For conveyors where the speed needs to be controlled or varied during operation, Oriental Motor offers easy-to-use variable speed AC motors as well as brushless DC motors and gear heads (BLDC motors),

3. Analysis of the catalog data of the world manufacturer of conveyor systems, ORIENT MOTOR, showed that for the transportation of air conditioners and refrigerators manufactured by ARTEL, the 3-belt conveyor RDC 02/001 with an ABB Automation drive type ACA631-2600-6 is most suitable; 2176A or ACA635-1710-6 1320A. Taking into account the planned increase in production volumes, we choose ACA631-2600-6; 2176 A with three asynchronous motors type 500LR6 and VF system type ACA610-1385-6 1156A

4. Experience in operating adjustable conveyor belts shows that they are non-stationary and stochastic objects and the EMC characteristics we need can be obtained using adaptive control methods.

5. It is assumed that the EMC model of the conveyor belt is linear, and the control systems under consideration are also linear. Therefore, the task of the adaptation cycle is exclusively to search for “good” values of the control system parameters.

6. The use of adaptive control methods involves increasing the accuracy of sensors that detect external interference affecting the operation of the control system. Taking this into account, optoelectronic current transformers have been proposed as voltage level sensors for powering the conveyor belt.

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