

Modelling and control algorithms of the cross conveyors line with multiengine variable speed drives

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Abstract. The paper deals with the actual problem of developing the control algorithm that meets the technical requirements of the mine belt conveyors, and enables energy and resource savings taking into account a random sort of traffic. The most effective method of solution of these tasks is the construction of control systems with the use of variable speed drives for asynchronous motors. The authors designed the mathematical model of the system 'variable speed multiengine drive – conveyor – control system of conveyors' that takes into account the dynamic processes occurring in the elements of the transport system, provides an assessment of the energy efficiency of application the developed algorithms, which allows one to reduce the dynamic overload in the belt to 15-20%.

1. Introduction

One of the most productive types of machines for continuous transport are belt conveyors, because they are able to move minerals to considerable distances with minimal operating and energy costs, can be integrated in conveyor lines of the great length and performance, and are also used in the complexes of cyclic-flow technology.

Operating conditions of the conveyor electric drive has a number of specific features that set additional requirements for the choice of a control algorithm: provision of the soft start with restrictions of short-time accelerations; the requirement for creating the starting torque (several times higher than nominal); minimization of the time of starting and braking with no slipping and the restriction of dynamic tension in the belt [1].

2. The proposed model of the cross conveyors line

On the basis of the chosen scheme of conveyors location, in the line with several cross conveyors (Figure 1) in the application 'Simulink MatLab', the model 'conveyor – multiengine electric drive' has been developed. It was created in the form of separate blocks, the inputs of which represent the control and disturbance variables for a given element of the system, and outputs are state variables that are the subject of research or can be used as inputs to other blocks [2].

The object model was provided with the following components:

1. The subsystem 'drive – conveyor' (conv1-conv4) consisting of a mechanical (belt pulley, belt, etc.) and electrical part of the conveyor (multiengine variable speed electric drive).
2. The block which generates the load of the conveyor (loading1, loading2).
3. The block of the control system for the cross conveyors line (Control).



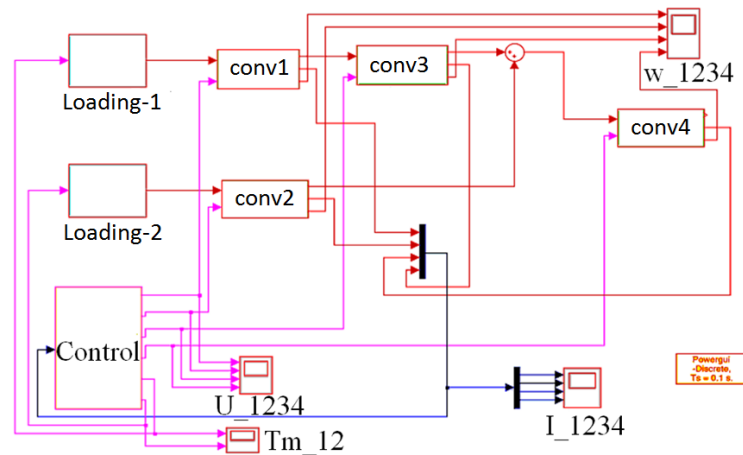


Figure 1. The continuous transport system consisting of four cross conveyors.

The mathematical model of this continuous transport system is a model of four cross conveyors, three of the conveyors are connected in series (conv 1, 3 and 4) and one — parallel (conv 2). In addition to the subsystems, containing models of conveyors (conv 1, 2, 3, 4, Figure 2), are also shown in figure 1: blocks Loading-1,2 (Figure 6) simulating the load and taking into account the random type of traffic; the control block of the transport system (CONTROL) the input of which receives signals (I_s) from the conveyors simulating their load, and the outputs are control actions (U_1 - U_4) over the conveyors, and signals Tm_1 and Tm_2 enter blocks Loading1,2, which allows taking into account the current load on the continuous transport system.

Digital implementation of the continuous transport system was created with the use of the C language in the program 'Matlab'. Using the model of the continuous transport system, it is possible to analyze operating modes of conveyors start-up in a predetermined order with the rated torque up to the rated speed, deceleration, the adjustment of conveyors to the predetermined load, and to obtain functions (monitors w -1234, I _1234, Tm _12) determining the workload of individual conveyors in the system and showing the speed change of the conveyor depending on the load.

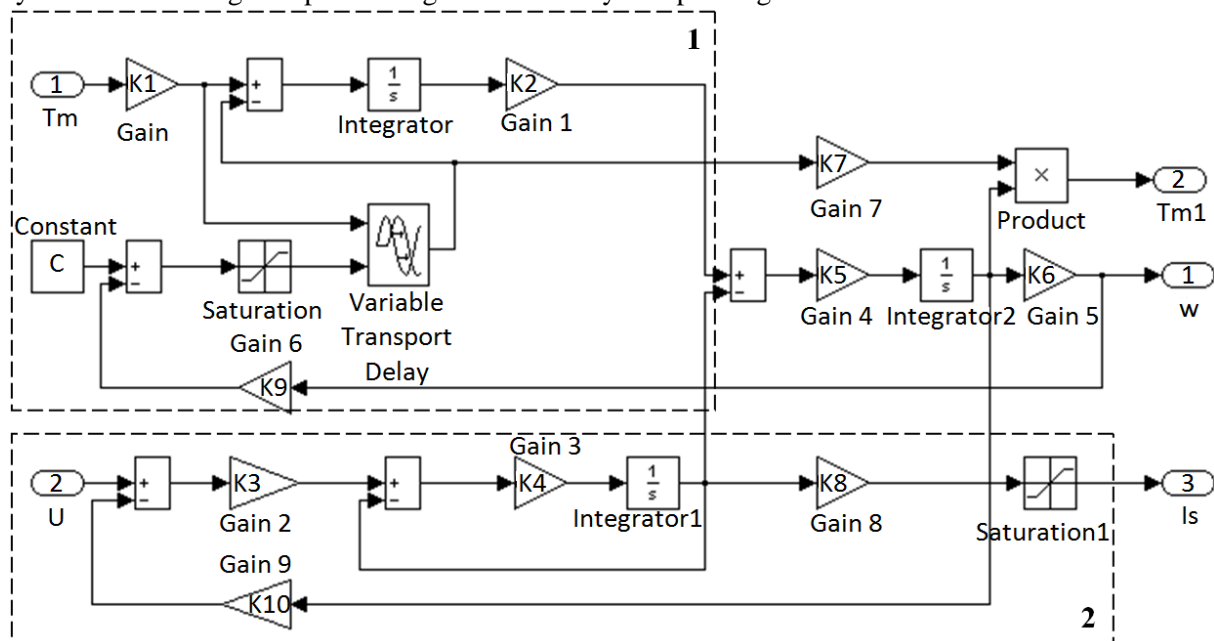


Figure 2. The model of the conveyor in Simulink Matlab.

Unit 1 simulates the variation of the load on the conveyor. The input signals 'Tm' from the block 'Loading' (Figure 1), taking into account the random type of traffic, and a constant value of load 'Constant'. Unit 2 determines the response of the conveyor to input signal U (the control action from the control system of the continuous transport system depending on the conveyors load). The output of the model 'Tm1' is the load supplied to the next belt conveyor (Figure 1, blocks 'conv1-conv4'), 'w' (Figure 2) is the speed of the movement of the belt of the conveyor, which is displayed on the monitor (Figure 1, monitor w1234), Is - stator current that determines the load level of the conveyor (Figure1, monitor I-1234).

To determine the accuracy of the mathematical model of the conveyor drive in the laboratory of the Department of electrical engineering and electromechanics (Mining University), the model of the multiengine variable speed drive for asynchronous electric motors was mounted (Figures 3,4), the parameters of which were incorporated in the computer model.

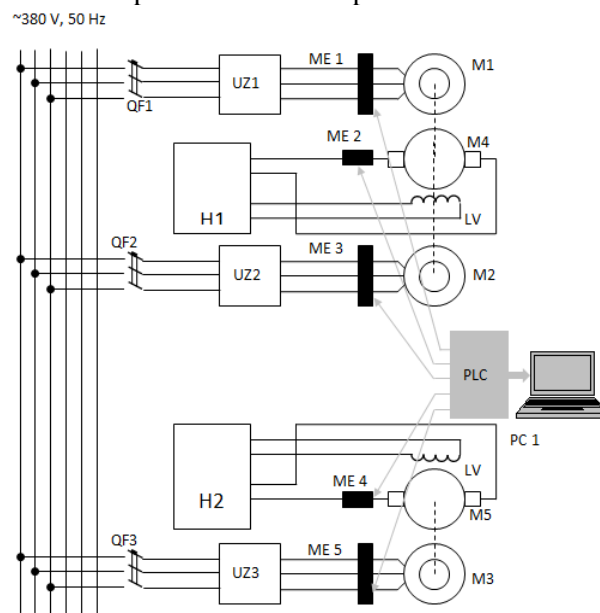


Figure 3. The functional diagram of the laboratory installation.

UZ1, UZ2, UZ3 – variable speed drives; H1, H2 – load (block of resistors); QF1..3 – circuit breakers; M1, M2, M3 – asynchronous motors; M4, M5 – loading machines; LV – excitation winding; ME1..5 – measuring equipment; PLC – controller; PC – personal computer.

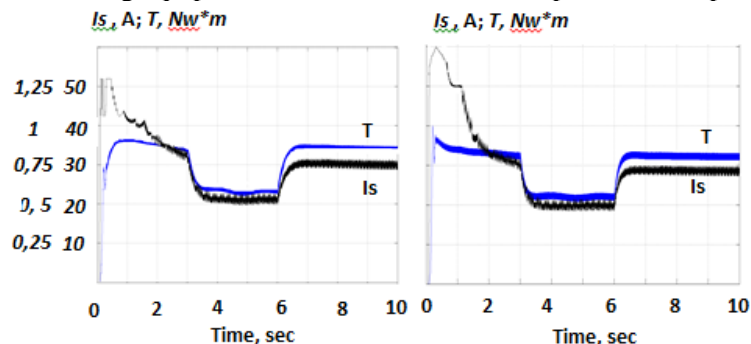


Figure 4. Stator current and torque characteristics (left – experimental, right – simulation).

The comparison of simulation results and experimental data showed that the maximum variation of the estimated and actual characteristics (motor currents and voltages, currents of the load

machines in the simulation mode of conveyor acceleration up to full speed and subsequent stop) does not exceed $\pm 11\%$. This fact allows us to make a conclusion about the sufficient convergence of the results, and consequently, the relevance of the mathematical model to the real object [3].

Figure 5 presents characteristics of motor current and torque when load is applied. The load is set by adjustment of the current of load motors M3 and M4. The comparison of the simulation results showed that the mismatch between the calculated and experimental curves is not more than 10%.

With the presented mathematical model, the system of direct torque control (DTC) for the multiengine asynchronous electric drive of the conveyor was adjusted.

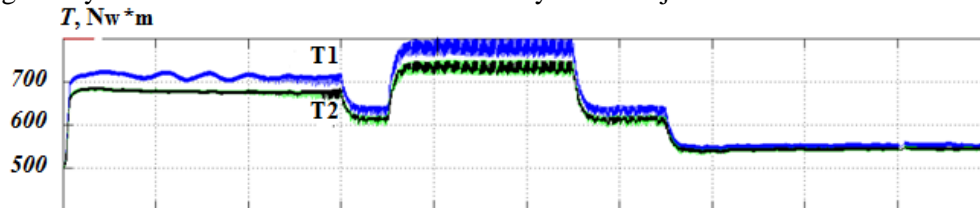


Figure 5. Characteristics of the torque at start-up, load-off and load-on (blue – the existing system of drive control of conveyors; black - direct torque control (DTC)).

Figure 5 presents the curves of moment change at start-up under the rated load, load-off and load-on, illustrating the decrease in the dynamic moment (15-20)% compared to the existing control systems for conveyor drives.

3. The designed control algorithm

The reference signals generation algorithm in the control system of the multiengine asynchronous electric drive allows one to take into account the probabilistic type of traffic, to improve the uniformity of load transfer between the drive motors to 90% and to eliminate slippage of the belt with the change of conveyor operating conditions [4]. The algorithm of direct torque control (DTC) which provides maximum performance in the current (torque) loop and a maximum value of the current (up to the rated torque) was used as a local control algorithm for the multiengine electric drive.

One of the main features of the conveyor transport as a technological system is the random incoming of traffic from the interconnected process equipment [5]. The model of load was created in Simulink Matlab (Figure 6), simulating random traffic arriving on the conveyor.

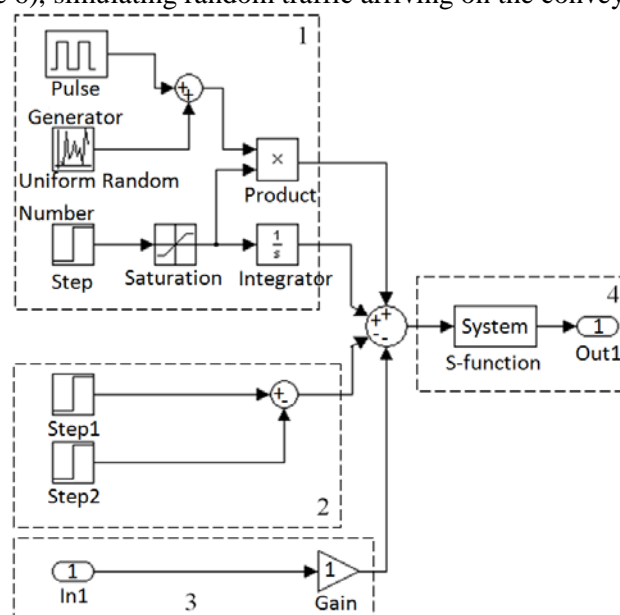


Figure 6. The model of load traffic.

Block 1 simulates the traffic as a discrete sequence of pulses with random duration of incoming load and with random intervals of its absence. Within the duration of impulses, the traffic is described as a continuous random process [6].

Block 2 simulates the load-off mode of the conveyor.

Block 3 simulates the incoming of load from other cross conveyors.

Block 4 is written in the Matlab language s-function that describes the distribution of traffic.

The reference signals generation algorithm in the control system of the multiengine asynchronous electric drive, taking into account the random type of the load, is: the value of load mismatch (actual current of semiconductor converters) is used to adjust the speed of the individual drives [7].

The algorithm of reference signals adjustment is shown in Figure 7.

1. If $T_1 = T_2$, then $K \times (T_1 - T_2) = 0$, a corrective signal is equal to 0.
2. If $T_1 > T_2$, then $K \times (T_1 - T_2) > 0$. The speed controller assignment (PC1) is reduced, and PC2 increases.
3. If $T_1 < T_2$, then $K \times (T_1 - T_2) < 0$. The speed controller assignment (PC1) is increased and PC2 decreases.

Coefficient K regulates the performance of torque adjustment [8].

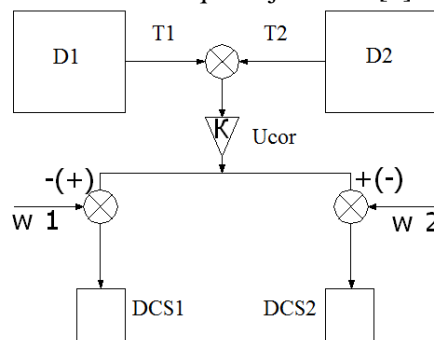


Figure 7. The algorithm of reference signals adjustment (D1,2 – drives, Ucor – correction signal, w1,2 – speed assignment, DCS1,2 – drive control systems).

Figure 8 demonstrates the curves of torque and the speed of the AC drive with the random load from the start-up mode to full speed and subsequent deceleration to a complete stop and stepped load-on. From these curves we can see that the use of the developed algorithm reduces the overshoot and torque oscillations, and therefore speed [9].

Researches of the drive operating modes showed that the implementation of the speed adjustment algorithm of the individual drives has provided increased uniformity of load distribution between drive motors (mismatch is not more than 10%), limiting the overshoot of the engine torque (up to 15%), and therefore, the restriction of dynamic loads on the conveyor drive with the use of the direct torque control algorithm and elimination of the belt slippage when changing the conveyor operating conditions [10].

4. Conclusion

Improving energy and resource savings of conveyor transport requires the installation of the regulated asynchronous electric drive with semiconductor frequency converters and control of operating modes of the cross conveyors line in consideration with the technological requirements and a random type of traffic.

The mathematical model of the electromechanical system of the conveyor – multiengine variable speed drive with implementation in Simulink Matlab allows one to perform researches of the conveyor operating modes taking into account the specifics of the mechanism operation at different control algorithms of electric drives.

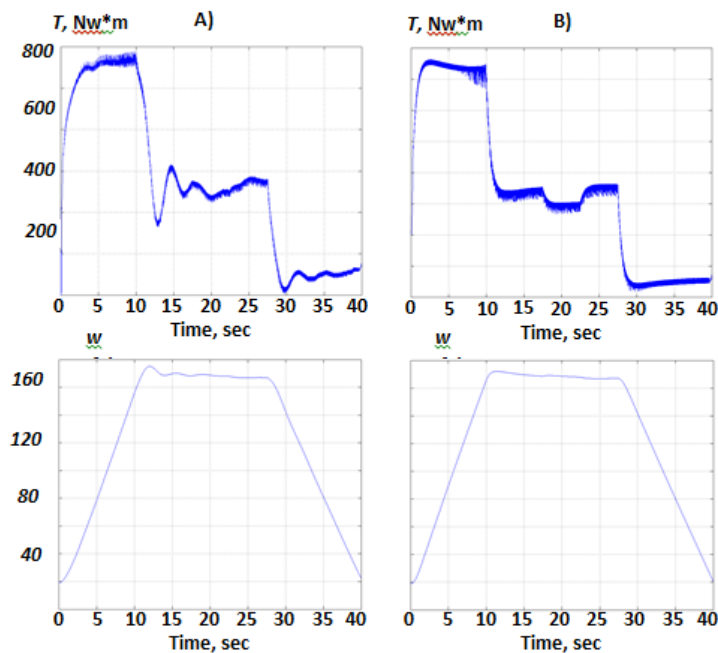


Figure 8.Curves of the drive torque and speed without adjusting the signals (A) and with the developed algorithm (B).

We demonstrated the expediency of applying the algorithm of local digital torque control of the induction motor together with the developed algorithm of reference signals adjustment, providing increased uniformity of load distribution between drive motors and elimination of belt dynamic loads (over-regulation until 15%).

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