



SYSTEM OF LIFTING AND ROTATION OF RAILWAY CARS

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ABSTRACT

This article represents the results of development of the railway car lifting-rotation system that is adaptive to the variables of inertia moment and resistance moment. The given system is based on multimotor electric drive with asynchronous motors. Equal load distribution is fulfilled through motor speed control using frequency converters according to the developed control algorithm. This algorithm was implemented in MATLAB by means of vector control. The article shows the simulation predictions and experimental setup of the system of lifting-rotation of railway cars.

Keywords: lifting-rotation of multi-ton objects, multimotor electric drive, railway car, adaptive system.

INTRODUCTION

Currently, many innovations in equipment and infrastructure have led to increased use of railways [1]. This in turn gave fresh impetus to the production and repair of railway cars. Due to the large weight and size, there appear a number of tasks involving lifting and rotation of railway cars. Such systems must enable efficient but safe and reliable running and mitigate the risks of people injury and damage to property.

So far there already exists a large number of different control systems of lifting and rotation of railway cars, and a huge variety of approaches to their design has been proposed [2]. The latest designs focus on multimotor electric drives [3, 4]. This allows using the drive that is light in weight, has less stiffness and developed torque, what in the end decreases frictional moment and inertia moment of the system. The above-mentioned reduces size and cost of the lifting-rotation system and increases reliability of the equipment. However, alongside with positive points of using of multimotor electric drive systems, there exists an acute problem in parallel operation of electric motors when they are equally loaded in multimotor electric drive [5, 6].

Most of the known multimotor electric drive systems use asynchronous electric drive with vector torque control [7]. They differ only in the control device. Present-day developments in the field of information systems and electronics, in particular in the field of mathematical modeling of systems and processes, allow to study and design considerably complex nonlinear automatic control systems, including systems of lifting-rotation of multiton objects.

This article shows the results of research and development of railway car lifting-rotation system (RCLRS) on the basis of multimotor electric drive. Distinctive feature of the developed system is the adaptability to variables of inertia and resistance moment.

DESCRIPTION OF THE RAILWAY CAR LIFTING-ROTATION SYSTEM

When designing the system of lifting-rotation of railway cars, it is sufficient to study the subsystem of railway car rotation. This is due to the fact that the subsystem of railway car lifting has much in common with

the rotation system from structural and functional point of view, while quality requirements to the lifting system are less strict than those to the rotation system. This comes from the reason that motor load in this case is almost steady. Due to this fact we can further study the rotation control system while the obtained results may be fully applied to the system of lifting control.

Figure-1 shows a flow chart of railway car rotation system that consists of hardware and software components. The hardware includes the control system and the power block consisting of AM1 and AM2 asynchronous motors, R1 and R2 reduction gear units, and FC1 and FC2 frequency converters. Each of the gear units has S1 and S2 RPM sensors which send the signal to the control system.

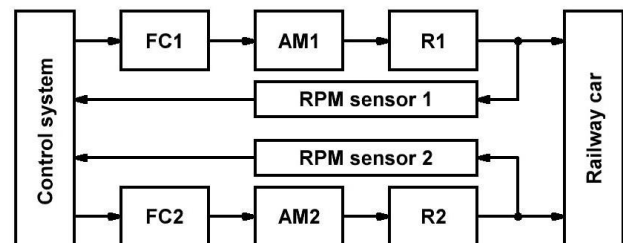


Figure-1. Flow chart of the railway car lifting-rotation system.

For the purposes of the study we assembled a model set of the railway car lifting-rotation system consisting of the given units and a physical model of the control system at a scale of 1 in 10 (Figure-2). The set is a platform with 4AX80A4V3 asynchronous motors installed on the both sides. The motors are coupled to ДРБ20-T reduction gear units with a gear ratio of 1500 and to ЛІР-362 RPM sensors. Reduction gear units are connected through the brackets to a platform that simulates car frame. Asynchronous motor (ASM) speed is controlled through frequency converters.

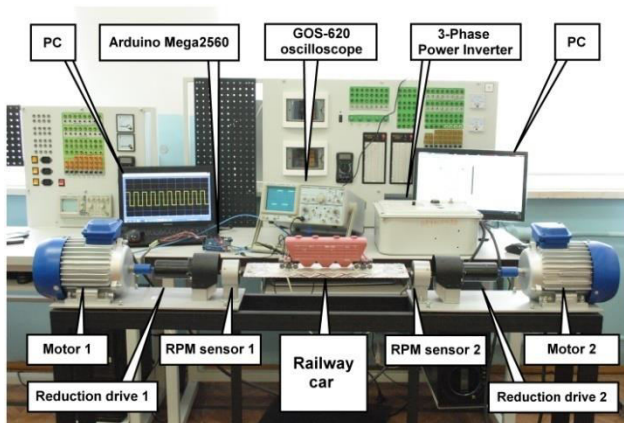


Figure-2. Photograph of the experimental unit.

A PC with PCI-1710HGU I/O card or a control unit based on the Arduino Mega2560 platform can be used as a control system. The control algorithm is implemented in MATLAB. Thus the software should include a speed controller, a space vector modulator, an inverse back integrating coupling, a converter and a Simulink.

CONTROL SYSTEM BASED ON MATLAB

Figure-3 shows the diagram of one drive that was constructed in accordance with the described structuring principle of structural division.

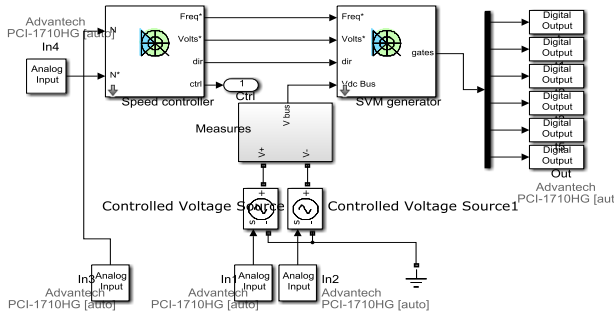


Figure 3. The software part of the system.

Rotation speed control of a rotor shaft in three-phase asynchronous motors with squirrel-cage rotor is performed through using vector control. One of the key elements in this diagram is the space vector modulator. In1 and In2 analog inputs apply the generated constant voltage through the meter to the space vector modulator. The signal from the encoder (RPM sensor) goes through In3 analog input to the speed controller. In4 analog input connects the RPM sensor to the speed controller. Depending on the input signal, space-vector modulator generates pulses that are transmitted to the six digital outputs. Then these signals go to the three-phase inverter [8], where the three-phase voltage is already produced to supply the asynchronous motor.

Figure-4 is the flow chart that shows the operation of the modulator. The modulator has seven blocks. Three-phase generator generates three sine waves with changing frequency and amplitude. Each sine wave is

shifted by 120° relative to another. The unit of $\alpha\beta$ -sector vectors is used for modulating algorithm of the space vector that defines the sector for the required spatial vector of the output voltage by finding the necessary angle. Then the required space vector is divided into state vector components which can be obtained at the output stage during switching. The output voltage vector is limited by the size of the circle inscribed in the hexagon formed by the active state vectors.

Then information on the rotation angle of the basic vector of the output voltage goes to the switching time calculator together with Km modulation factor. Ramp generator is used to create PWM-modulation and determine the time of switching of combinations sequence in a three-phase inverter. The low-pass bus filter is used to filter emissions at the input of the measured DC voltage.

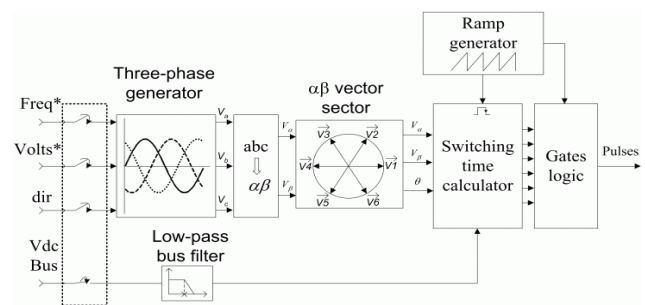


Figure-4. Space-vector modulator.

Gates logic receives the temporal sequence from the switching time calculator and the ramp generator. This unit compares the two voltages and generates a signal to activate inverter codes at a certain time. The inverter is a hardware part of the system made as a bridge circuit.

Thus, the three outputs of the inverter generate the PWM pulses which are different combinations of on and off transistors. However, due to the fact that asynchronous electric motor which receives these pulses is a low-pass filter, it can be assumed that ASM winding shall detect the pulses as sine waves. Besides, the waveform of control voltage can be achieved by the method specified in [9].

Figure-5 shows the results of the mixed simulation in Simulink (Figure-3) and the live operation of RCLRS hardware. The solid line shows the given rotation speed. This line also corresponds to the rotation speed of the first electric drive shaft. Since the shaft of the second electric drive suffers increased load torque, the rotation speed of the second drive (dotted line) lags at a certain point of 900 RPM behind the set speed. Compensating feedback eliminates the speed error within 1.2 seconds, and the numbers of rpm of the both drives are reduced to the safe level defined from the point of view of energy consumption.

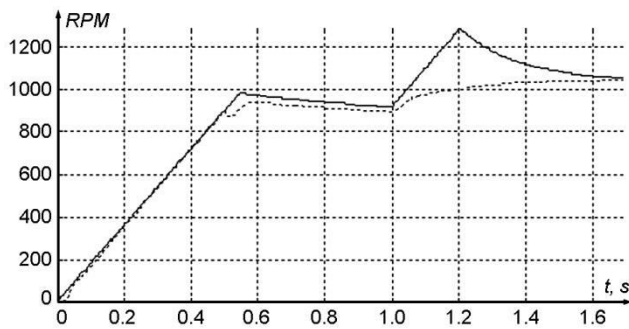


Figure-5. Simulation results of the real-virtual two-motor system.

The review of the chart shows that the transient motion lasts more than 1.2 seconds, i.e. the eliminating of the speed mismatch at the shafts of both motors is quite slow. This owes to the reason that the MATLAB system fails to execute quite complicated control algorithm in a real-time, since the principles of programming in MATLAB are based on continuously accesses to the various system libraries, so this method of sectional execution of the algorithm greatly delays the whole control process. Therefore when designing the RCLRS we considered the possibility of replacing the program-visual control in MATLAB by program control using Arduino Mega2560.

ARDUINO BASED CONTROL SYSTEM

The process of a program recorded to the microcontroller of AtMega2560 is described in detail in [10]. The control unit of a single drive based on an independent Arduino platform is shown in Figure 6.

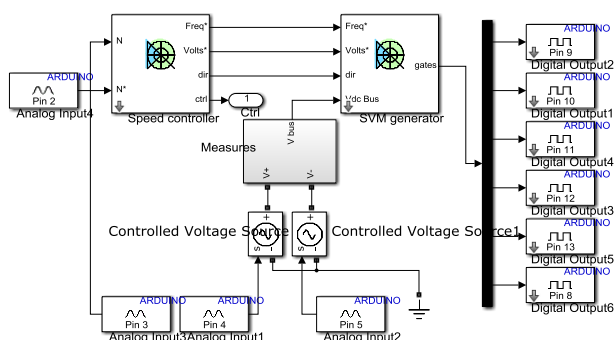


Figure-6. Flow chart of the control unit based on Mega2560 Arduino.

After connecting inputs and outputs of the given control unit to the power executive part of RCLRS we have autonomous model of rotation or turning of railway cars. Yet, it is still necessary to uphold the communication interface between the speed sensors and the computer on the basis of PCI-1710 to record deviations of rotation speeds of both drives to the waveform chart. In order to start the turning, the Arduino plate shall be powered on and three-phase power voltage shall be connected to the RCLRS hardware. The result of the first test with load moments used in previous experiments are presented in

Figure-7. It should be highlighted that the load moments on the shafts of both drives were created with the help of electromagnetic clutches.

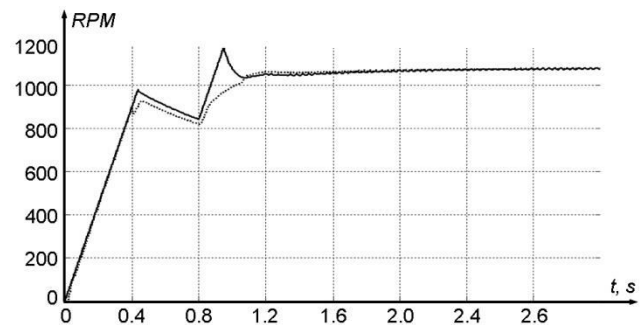


Figure-7. Simulation results of the real model of two-motor system in the Arduino Mega2560

On analyzing the chart (Figure 7) and comparing its shape with shape of the chart (Figure 5) we can clearly see that the transient motion on the latter chart decreased significantly.

CONCLUSIONS

The results of simulation and experimental studies of multidrive system of railway car lifting and rotation showed that the most effective means of synchronized rotation of the two interconnected drives at a higher load torque on one of the drives is simultaneous reduction of speed to the value at which an increased load torque does not affect this speed. It is necessary to synchronize not only the speed but also the absolute number of revolutions of both motors. In this connection we used an integrating unit for feedback that led to the conversion of the angular rotation into rpm. At the same time transients are much shorter when using Arduino platform.

The developed system can be used in electromechanical systems during the work of several current-shared electric motors in high-speed controlled electric drives of conveyers, lifting cranes and other equipment which should meet strict requirements for weight, size and performance specifications.

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