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Elaboration of the Load-Equalization System of the Electric Drive of the Main Hoist of a Bridge Crane

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Abstract—Simulation of the operation of the electric drive of the main hoist mechanism of a bridge ladle crane has been performed for two modes: emergency lifting and lowering of a loaded bucket. Experimental investigation has been carried out at a laboratory setup with indication of static and dynamic parameters of the synthesized and calculated control system. The results satisfy the requirements; the values of qualitative parameters do not exceed the allowed values. Implementation of the elaborated load-equalization system of the electric drive of the main hoist of the bridge crane KMEML 210+63/20 t exploited under the conditions of steel production of the joint-stock company "Ural Steel" will make it possible to reduce by 4.6% the current time-outs, which will lead to an increase in its lifetime and a reduction of the expenses on purchasing of the electric drive elements with an increase by 0.8% in the profit of the steel-making plant.

Keywords: electric drive, bridge crane, load equalization, controller, mechanism of the main hoist, control system, simulation

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INTRODUCTION

Mineral resource and metallurgy industries are the parts of the overall technological cycle, where crane systems and carrying and lifting equipment must have a maximal reliability [1, 2]. A weak point of the cranes of back issue, especially the bridge cranes, is their relay-contactor control system and, as a consequence, the failures of the ladle cranes are mostly related to the electrical equipment [3]. This problem can be solved by implementing up-to-date frequency converters and induction motors [4, 5].

The majority of the main and auxiliary mechanisms of the bridge crane are usually driven by two or, sometimes, a larger number of motors [6, 7]. The two-motor electric drive has some advantages over the one-motor drive [8–10]: a reduced total moment of inertia of the driving system, the possibility of creating high-power systems when using quantity produced machines, a higher reliability, etc.

The bridge ladle crane KMEML 210+63/20 t chosen as the object was produced in 1979 and was exploited with a rated load-lifting capacity of the main hoist of 180 t until 2005. After reconstruction carried out in 2006, the load-lifting capacity of the crane was increased up to 210 t. The increase in the load-lifting capacity was required in connection with partial changes in the steel-making technology.

Considering the technological mode of operation of the main hoist mechanism of the bridge crane and the peculiarities typical of all metallurgical cranes [11–15], we can formulate the technological requirements for electrical equipment of the electric steel-making bridge cranes [16], including the possibility of speed control in a wide range (1 : 100) [17] and providing smooth transient processes at a control accuracy of up to 3% [18].

The aim of this work is modernization of the bridge ladle crane owing to implementation of the elaborated load-equalization system of the two-motor electric drive of the main hoist of the bridge ladle crane KMEML 210+63/20 t operating under the conditions of the steel-making production. The scientific novelty consist in elaboration of the load equalization device based on comparison of the moments (currents) that differs from the known devices by the algorithm of equalization of the moments obtained, which will make it possible to increase the speed of operation of the bridge ladle crane.

LOAD-EQUALIZATION SYSTEM OF THE ELECTRIC DRIVE

The force diagram of the bridge crane control is shown in Fig. 1. The presented solution has a significant shortcoming which consists in discrepancy

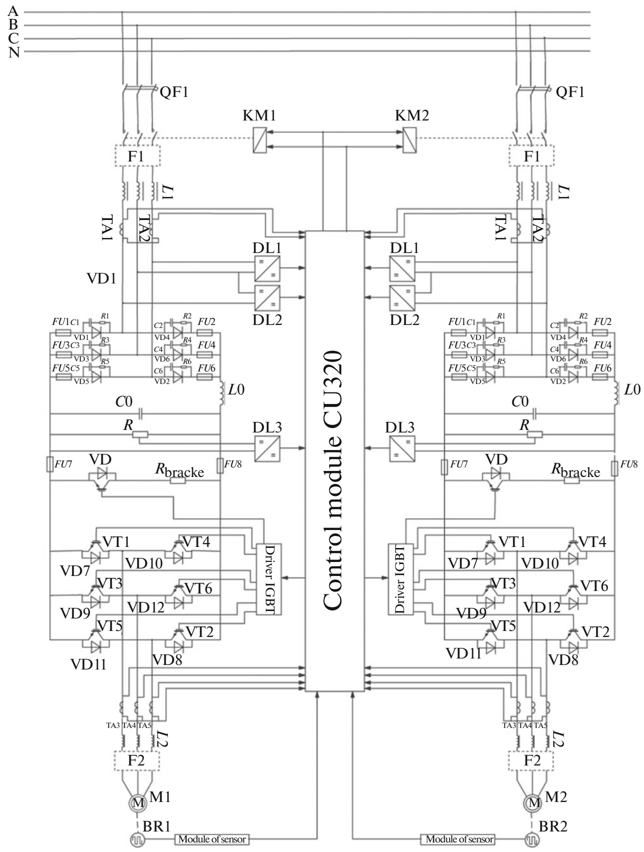

Fig. 1. Force diagram of the two-motor electric drive.

between mechanical parameters of induction motors, even under the condition of one type of their use [19]. Therefore, in the two-motor system, a mismatch in the load distribution will occur at any (static or dynamic) mode of operation [20].

The proposed load-equalization system is based on operation with the use of proportional integral (PI) controllers with no "driving-driven" separation of the system elements. With the purpose of implementation of the proposed load-equalization system, the model of two-motor system was worked out in Matlab Simulink, which is presented in Fig. 2. The model consists of the automatic control systems (ACS) of the first and second electric motors based on their frequency control. The subsystem "mechanical connection" considers the moment of inertia of electric drive, making it possible to correct the moment of inertia at the instant of load lowering and lifting. The "intensity selector" (IS) blocks are intended to provide a correct control of bridge-crane electric motors that receive a task from the common control block.

Load distribution is realized with the help of the DLD block (Fig. 3). The task signals are formed according to the following algorithm: currents (moments) from the motors are compared between each other, obtaining the value of mismatch. The efficiency of the moment equalization is performed owing to the proportional coefficient *K* and the integral coefficient, which are summarized and form the coefficients of the PI controller. The comparison process is carried out according to the following algorithm:

equality of currents (moments)—the value of coefficient K is zero;

the current (moment) of the first motor exceeds that of the second motor $M_1 > M_2$ leads to formation of a positive coefficient $K(M_1 - M_2) > 0$;

the current (moment) of the second motor exceeds that of the first motor $M_1 < M_2$ leads to formation of a negative coefficient $K(M_1 - M_2) < 0$.

To verify the adequacy of the proposed solution for load equalization, we use the Matlab Simulink soft-

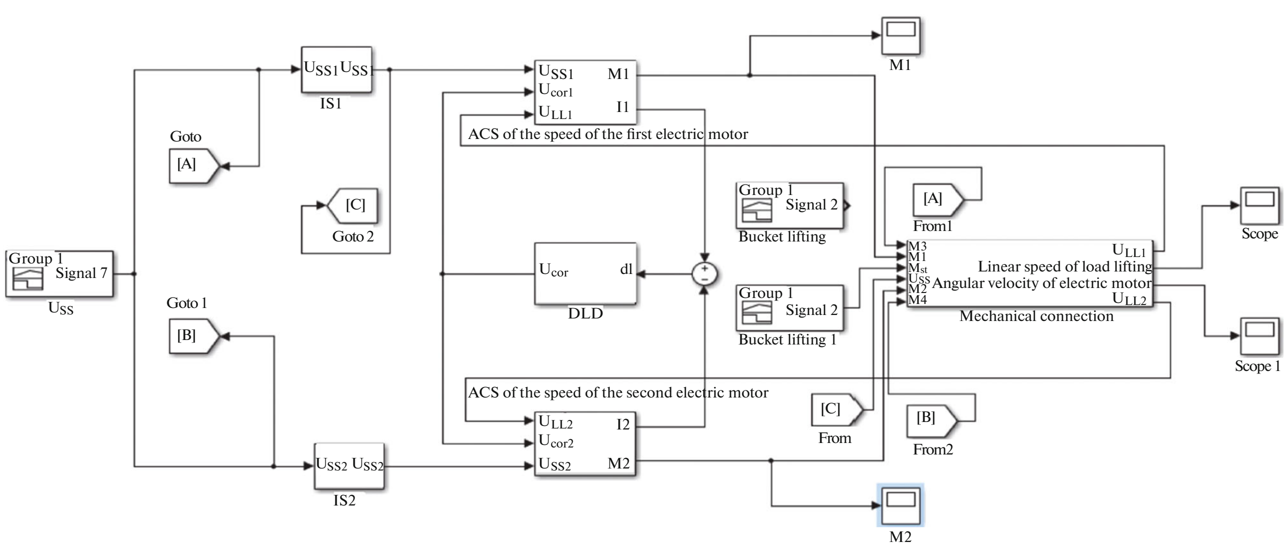

Fig. 2. Mathematical model of the two-motor system of the main electric drive of the bridge crane.

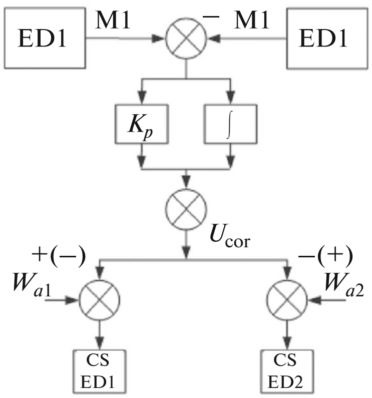

Fig. 3. Structure scheme of load-equalization control.

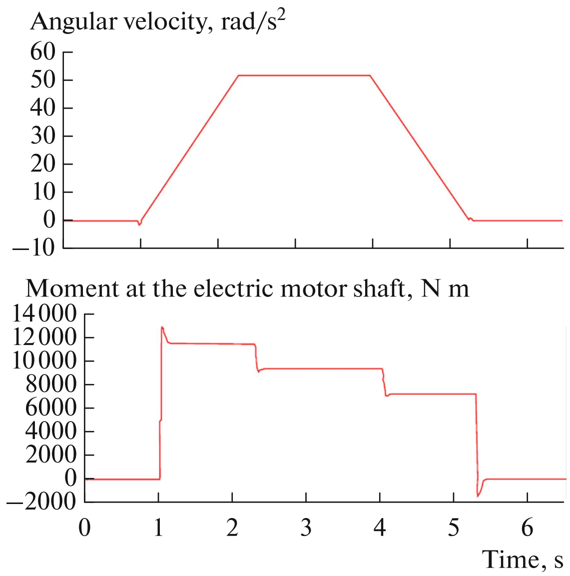

Fig. 4. Transient processes of the speed and moment in the mode of emergency lifting and lowering of the loaded bucket.

ware that allows realizing the model of a two-motor electric drive with the elaborated load-equalization system. Figure 4 shows the transient processes of speed and moments in the mode of emergency lifting and lowering of a load under the conditions of operation at a rated speed.

The experimental investigations were carried out based on the laboratory bench "BoomBox Imperix" whose software is based on Matlab Simulink and the force part consists of a set of necessary elements. Formation of the force part of the laboratory bench was performed according to Fig. 1.

CONCLUSIONS

The results of simulation and experimental verification of the synthesized and calculated control system show that the processes passing in it completely reflect the main theoretical and practical ideas concerning the systems of subordinate control of electrical-motor parameters. A moderate speed overshoot is conditioned by the control of the rate of acceleration by means of the intensity selector. The deviation of the set value of speed from the steady speed does not exceed 3%. Implementation of the elaborated load-equalization system of the electric drive of the main hoist of the bridge crane KMEML 210+63/20 t exploited under the conditions of the joint-stock company "Ural Steel" will make it possible to reduce by 4.6% the current time-outs, which will lead to an increase its lifetime and a reduction of the expenses on purchasing of the electric drive elements with an increase by 0.8% in the profit of the steel-making plant.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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