Increased efficiency of tests of electric machines of various types

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Abstract. The paper describes the issues of operation of electric machines of various types. A wide adoption of asynchronous electric drives in various fields is noted. The relevance of the issue of embedding test complexes at companies conducting repairs, both asynchronous motors and direct current machines with different excitation types, is justified. The importance of the application modern power-saving technologies in the process of repair of electric machines is noted. One such technology is the method of mutual loading. Proposed scheme makes it possible to carry out tests by means of method of mutual loading such as induction motors, and direct-current machines with serial and independent (parallel) excitation. The effect is that the proposed scheme has a much lower cost compared to the total cost of schemes designed for testing of electric machines of the same types.

1. Introduction
Asynchronous electric drives are currently being widely used in various fields of engineering [1-7]. This fact determines the urgency of the task of ensuring their timely maintenance and repair. After completion of the repair of the electric machine according to the guidelines, it is necessary to carry out loading tests requiring a considerable amount of electric energy. For the purpose of energy saving, in the performance tests of electric machines, a number of circuits have been developed, which are based on the method of mutual loading [8-12]. Different schemes have different features and their associated fields of application [13].

A significant obstacle in the embedding of new production facilities at the enterprises is often their high cost. From this point of view, the task of embedding test complexes at enterprises is of particular importance, conducting repair of simultaneously asynchronous motors and dc machines, which may be of different type of excitation. In such cases, a considerably larger list of equipment is required than when testing machines of one type. Reduction of cost of test equipment makes it possible to optimise its list by excluding elements of duplicating each other. This idea is used in the development of test circuits of asynchronous motors and direct-current machines with independent (parallel) excitation and testing of asynchronous motors and direct-current machines with serial excitation [14, 15]. However, these technical solutions did not allow to combine into a common circuit equipment for testing DC machines with different types of excitation. Fragments of these test circuits, including equipment for testing DC machines, are shown in Figures 1 and 2.
In this paper, we consider the option of combining circuits (Figure 1, 2) that provide mutual load testing of electrical machines of various types – asynchronous machines and DC machines with serial and independent (parallel) excitation [16].

2. Description of the new test scheme

Circuit testing of asynchronous machines and direct-current machines with serial and independent (parallel) excitation is illustrated in figure 3.

The circuit is provided with two frequency converters 1 and 2, supplied from the three-phase alternating current network and performing the double transformation of the kind of current [17-22]. The first frequency converter comprises an uncontrolled rectifier 1.1, DC link 1.2 and controlled inverter 1.3. The second frequency converter includes an uncontrolled rectifier 2.1, DC link 2.2 and controlled inverter 2.3. DC links 1.2 and 2.2 are connected electrically by a common bus 3. Shafts of asynchronous machines 8 and 9 are rigidly connected by clutch 10. Stator windings of asynchronous machines 8 and 9 are connected to frequency converters 1 and 2 by means of contactors 5 and 6. Shafts of DC machines 14 and 15 are connected to outputs of non-controlled rectifiers 11 and 12 by means of commutator 13. Contactors 4 and 7 make it possible to connect uncontrolled rectifiers 11 and 12 to outputs of frequency converters 1 and 2.

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**Figure 1.** A fragment of the test circuit of DC machines with serial excitation by the method of mutual loading

**Figure 2.** A fragment of the test circuit of DC machines with independent (parallel) excitation by the method of mutual loading
3. Principle of operation of the test scheme

The proposed scheme of testing of electric machines by the method of mutual loading works as follows. The frequency converters are powered by a three-phase network. Alternating voltage is converted to constant voltage by rectifiers. Then constant voltage is supplied to the input of controlled inverters which convert it to an alternating voltage having the required effective value and frequency.

In carrying out tests of asynchronous motors, power is not supplied to the windings of DC machines, and windings of asynchronous machines are connected through contactors to outputs of frequency converters. Asynchronous machines are triggered at the same frequency of supply voltage. Further, the frequency of the voltage fed to one of the asynchronous machines is reduced to provide...
When testing direct-current machines, asynchronous machines are switched off from frequency converters. Power is supplied by contactors to uncontrolled rectifiers 11 and 12 (Figure 3).

When testing direct-current machines with serial excitation, the electric switches 13 are shifted to the left (Figure 3). Excitation windings of both DC machines are connected in series with one of armature windings. The value of the direct current supplied to the DC machines from the output of the uncontrolled rectifier is determined by the parameters of the alternating voltage at the output of its frequency converter. To provide load to DC machines, it is necessary to increase the voltage in the armature circuit of only one machine. This is done by the voltage supplied from the output of the uncontrolled rectifier 12 (Figure 3), which in this case serves as a booster converter. The machine, in the armature circuit of which the voltage has turned above goes into the mode of the engine, and the other machine goes into the mode of the generator. DC voltage at the output of boost converter 12 (Figure 3) is determined by the parameters of the alternating voltage at its input, which is controlled by the corresponding frequency converter.

When testing direct-current machines with parallel (independent) excitation, the electric switches 13 are shifted to the right (Figure 3). Two armature windings and one excitation winding are connected in parallel into the first electric circuit. Second excitation winding is switched into second electric circuit. DC voltage is supplied to the first electric circuit from the output of uncontrolled rectifier 11 (Figure 3) and is determined by the parameters of the alternating voltage at the output of the corresponding frequency converter. The DC voltage in the second electrical circuit is similarly determined by the alternating voltage parameters at the output of the other frequency converter. To create the load, the machines must first be raised to a nominal value of the supply voltage. Further, by means of the second frequency converter, it is necessary to loosen the excitation winding of one of the machines. As a result, the electromotive force of the armature winding in this machine will also decrease, and this machine will enter the engine mode, while the second machine will enter the generator mode.

4. Conclusions and recommendations

The proposed scheme solution allows to cover basic types of electric machines used in railway transport as traction ones. Introduction of this test scheme in designing new test complexes makes it possible to reduce capital costs for their production, and thus reduce the payback period of the introduction of new equipment.

The application of the presented scheme allows to increase the economic efficiency of test complexes based on the method of mutual loading, which has a high energy efficiency of the test process.

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