Implementation of the control algorithm of the traction electric equipment

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Abstract. Currently, in various fields of science and technology, there is a fairly large number of methods for predicting reliability indicators, which differ in the set of tasks to be solved and the features of the mathematical apparatus used. When developing a methodology for calculating the reliability of an electric machine, one of the main stages is the development of a mathematical model, in which it is possible to take into account the factors, the impact of which directly affects the technical condition and the level of operational safety. Taking into account the disturbing influences during the implementation of the technological process is possible provided that the means of automation are used. The performed analysis of statistical data on traction motor failures made it possible to substantiate the advisability of warming up, since a significant number of electrical part failures occur in the autumn - winter - spring periods of time. This feature of the distribution of failures is to a certain extent due to the direct wetting of the insulation and a decrease in its dielectric strength. This process is associated with a sharp drop in external and internal temperatures when placing the locomotive at the depot, which contributes to the appearance of condensate on the insulation, its further destruction. The measure proposed in the article for warming up traction electrical equipment is aimed at an integer reduction in the failures of the electrical part of the electric motors under consideration.

1. Introduction

In order to maintain the required level of insulation resistance of traction motors (TED), prevent moisture release and frost formation on collectors, brushes, electric locomotives that arrived at the depot and when they are put into operation, blowing is carried out by turning on motor-fans to equalize the temperature of the anchors and the surrounding air. The presented technology allows you to remove moisture only from the upper layers of insulation, which is a fundamental factor in the low efficiency of this method.

During the period of difficult weather and climatic conditions (blizzard and snowfall), along with the issues of infrastructure reliability [1-5], in order to prevent snow from entering the traction electric motor and other electrical equipment of electric locomotives, the following measures are implemented:

• filter circles are installed on the suction openings of the sockets of the fans of electric locomotives with a corresponding entry in the log of the established form;
• motor-fans are switched on;
• curtains in the prechambers are straightened.

When the outside air temperature is below -8 °C, each opening of the locomotive depot gates must be accompanied by the inclusion of thermal air curtains. The fastening of the rolling stock at the repair positions of the depot sludge is carried out with brake shoes, using the brake means of the locomotive in accordance with the existing instructions.

2. Problems of operational reliability of traction electric machines of an electric locomotive

The problems of reliability of electrical machines are conventionally subdivided into structural, technological and operational [6-8].

The structural reliability of any electrical machine as a whole depends on the active and structural materials used in it, the quality of manufacture of its main parts and parts.

Environmental parameters are the main factor that affects the operational reliability of electrical machines, which emphasizes the relevance of the article presented for consideration.

Improving the operational reliability of electrical machines is a multifaceted problem and requires a comprehensive solution, which is implemented in the following areas:

• improvement of the design of electrical machines;
• modernization of existing electrical machines;
• improvement of protection devices in emergency modes;
• use of modern means, methods and equipment for the implementation of scheduled preventive repair and maintenance.

Based on the analysis of statistical data on TED failures, it was revealed that most of them occur in the autumn - winter - spring periods of time (Figure 1). This feature of the distribution of failures is to a certain extent due to the direct wetting of the insulation and a decrease in its dielectric strength [9, 10]. This process can be associated with a sharp temperature drop when placing the locomotive at the depot, which directly leads to the appearance of condensation on the insulation, its further destruction. The proposed measure for warming up traction electrical equipment is focused on an integer reduction in the failures of the electrical part of the electric motors under consideration.

![Figure 1. Failures of traction motors in 2019 – 2020.](image)

According to the presented statistical data, it follows that a large share is accounted for by failures of the electrical part of the considered electrical machines (Figure 2).
3. Algorithm of control of the automated system for heating traction electrical equipment of an electric locomotive

Taking into account the advantages and disadvantages of the existing methods for restoring the TED insulation made it possible to substantiate the structure of the proposed heating technology [11, 12]. The implementation of starting the motor-fans of an electric locomotive at a reduced speed is possible using a semiconductor frequency converter [13-17], which is implemented in a mathematical model using a multi-position key MK1 (Figure 3). It should be noted that the operation of cooling electric motors at maximum speed is possible taking into account the standard circuit. This decision will favorably affect not only the weight and dimensions of the proposed system during its practical implementation, but also the feasibility study [18-21].

Setting the proposed value of the current of traction electrical equipment will make it possible to displace moisture from the inner layers of insulation to the outside. Temperature control is carried out using a temperature sensor Dt, the signal of which realizes the switching of the motor-fans to the maximum speed in order to easily remove moisture from the surface of the insulating materials for 10 minutes (Figures 4, 5, 6). The end of the above operation algorithm, taking into account the environmental parameters, will allow setting the required current value for the favourable maintenance of the TED temperature for placing the locomotive in repair positions (Table 1).

### Table 1. Recommended current values taking into account environmental parameters.

| $T_{\text{amb. air}}$ °C | 5   | 0  | -10 | -20 | -30 | -40 |
|---------------------------|-----|----|-----|-----|-----|-----|
| $I_{\text{te}}$, A        | 200 | 200| 250 | 300 | 350 | 400 |

In order to take into account the parameters of the ambient air in the presented mathematical model, a multi-position key MK2 is used, with the help of which switching to different levels of not only positive, but also negative temperatures is realized. This contour is used to assess the adequacy of the presented model for real physical processes.

In a similar way, the circuit for modeling the current value in traction electrical equipment using MK3 is presented (Figure 3).
Figure 3. Mathematical model of the proposed automated heating system.

Transients for different ambient air parameters are shown in Figures 4-6.

Figure 4. Transient heating processes at an ambient temperature of 5 °C.
4. Conclusion
With the aim of practical implementation of the proposed automated system, it is necessary to focus on the series of electric locomotives and the purpose of cooling machines. Guided by the developed mathematical model, it is necessary to justify the practical use of additional equipment, taking into account the weight and size and technical and economic aspects. The main advantage of the implementation of this system is not only a reduction in the warm-up time, but also an increase in the reliability of traction electric motors, the repair of which is laborious and economically costly.
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