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FORECASTING RESIDUAL RESOURCE AND PROLONGATION OF SERVICE LIFE OF ELECTRICAL INSTALLATIONS OF RAILWAY SERVICE CARS AND RAY MOTOR TROLLEYS

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Abstract: The issues of forecasting residual resource and prolongation of service life of electrical installations of special self-propelled rolling stock are described in the paper. Examples of solving the probability of their failure-free state are considered based on changes in statistical data of quantitative reliability indicators, such as mathematical expectation and variance with further determination of optimal periodicity of current repairs taking into account actual operational conditions.

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Railway service cars and ray motor trolleys are one of the main types of special self-propelled rolling stock SSRS widely used in the areas of energy supply, overhead lines, track distances, communications, as well as in the emergency recovery of rail transport. The operation of railway service cars and ray motor trolleys, which have malfunctions that threaten traffic safety, is not allowed.

The complex of SSRS test activities conducted by the operating department of JSC "Uzbekistan Temir Yullari" to identify the adaptability of units and parts of electrical installations for maintenance and repair, the ability to detect, prevent and eliminate failures in the work of the SSRS, assess the resource of its electrical installations, identify positive qualities, and constructive and technological shortcomings for technical diagnosis, allowed in the design, manufacture and placement of equipment.

The SSRS as an object for reliability research is a complex multi-element dynamic system whose operation is characterized by heavy operating conditions. Under these conditions, the state of the object continuously changes depending on the time and mode of operation.

The change in the state of such complex systems, as a rule, is described by a random process, which is an alternation of the time intervals of the object's working capacity and the recovery time after failures.

It is known that the technical state of the elements and units of devices in operation are sudden or gradual in nature and they relate to the statistical model "parameter - admission field" and depends in the finished form on the quality of manufacturing and repair systems. Sudden failures like the burning of relay coils, wire breakage, switching faults of elements lead the object to unplanned repairs, and gradual failures, for example, the state of electrical insulation, change in the electromechanical characteristics of control systems, and determine the timing of maintenance and repair.

During the exploitation of the SSRS, the deterministic signal s(t) continuously changing from time and load is acting on it, resulting from damage to the electrical or mechanical part of the SSRS, and the random process n(t)

$$\sum_{i=1}^{m} x_i(t) = \sum_{j=1}^{n} S_j(t) + \sum_{r=1}^{m} n_k(t) \quad (1)$$

Under the action of which the parameters of the object are transformed and the output forms the realization of the process-irreversible change in the parameters of the technical state (electrical strength, wear of gear teeth, etc.) in time

$$\sum_{i=1}^{m} y_i(t) = \sum_{j=1}^{n} z_j(t) + \sum_{k=1}^{p} p(t) \quad (2)$$

The reliability indices of SSRS, such as the time to failure *ti*, the recovery time, the average service life *tк*, the average intensity λ(t) and the failure flow ω(t), the probability of failure-free operation P(*tp*) for the calculated time tp, coefficient factor (Kг) show that their quantitative characteristics are described by a Markov random process for which *i*=1,2, ... with sufficient confidence, the principle of independence of negatively acting processes on the object is observed, and with identically distributed random variables with an exponential distribution function

$$P(n)(z) = 1 - \sum_{j=0}^{n-1} \frac{(\omega s_j)}{j!} \; e^{-\omega s_j(t)}, n = 1,2,\ldots \quad (3)$$

Where $\omega_j(t) = \int_{i=1}^{n} \lambda_i(t)\,dt, \lambda_i(t)$ - are the flow parameter and the failure rate, respectively, 1 / year.

Analysis of the data on the quantitative assessment of reliability indicators carried out in the operational department of the SSRS

JSC "Uzbekistan Temir Yullari", in the amount of 27 railway service car of the type ADM-1 and other analogues conducted in 2010-2018 shows that there are their failures in electrical installations 57, hydraulic installation 45 and mechanical part-33. At the same time, it was revealed that failures have an incremental character and arise due to the growth of operational loads, which are increased in comparison with the permissible technical characteristics, in particular for electric motors and their contact control system; there were defective elements due to imperfect control in the manufacturing process and low qualification in the staff.

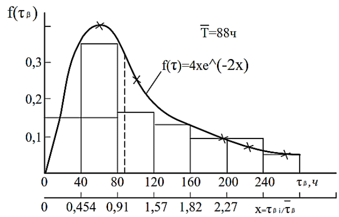
Typical failures of electrical installation of the SSRS are thermal electric breakdown and interterm closures of the stator windings of an asynchronous motor making up more than 72.0%, failures of control panels of relays - 13.5%, breakage of wire line terminals - 7.2%, etc.

Based on the analysis of the recovery time Tв, depending on the nature of the failure, the maintainability of the electrical installations of the railway service car and the preparedness of the maintenance personnel, a characteristic asymmetrical distribution of the probability density of the recovery time of the electric motors and auxiliary electric control circuits (Fig. 1, a), hydraulic (Figure 1, b)) and the mechanical part (Figure 1, c) of the railway service cars, their proximity to their mode of distribution.

This character of the distribution law is mathematically determined by Erlang's law [1]:

$$f(T_в) = \frac{4T_в}{\overline{T}_в}\exp[-\frac{2T_в}{\overline{T}_в}] \quad (4)$$

а)



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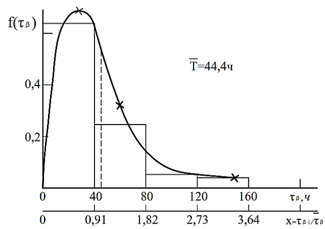

в)

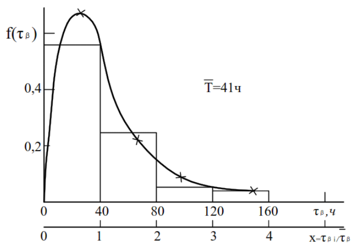

Fig.1. the probability density of the recovery time:

a) Electric, b) hydraulic, c) mechanical installation of railway service cars

On the other hand, the same analysis shows that the recovery time of a railway service car corresponding to the mode of distributions amounts to 88, 44, 4 and 41 hours according to the electrical installation, the hydraulic installation and the mechanical part, which speaks about the advisability of more advanced technological service and maintenance (fig .1).

The basic performance characteristics of all the main parts of the SSRS should correspond to the continuous increased operational loads.

Various nodes and installations of railway service cars, determined by heavy operating conditions, are naturally characterized by several quantitative parameters of reliability. Therefore, it is important to establish a predictive parameter that unambiguously and rapidly changes in operating conditions and further determine the residual life of the SSRS.

To the component of the predictor parameter of the *i*-element, which reaches its critical value $\alpha_{\text{кр}}$, its mathematical expectation $M_i(t)$and dispersion $D_i(t)$, which vary continuously slowly, smoothly, monotonically with intensity η_i. can be assigned. The equations for changing parameters in time can be approximated in the following form:

$$\begin{cases} M_i(t) = M_{io} \pm M_{\eta i}(t)t; \\ D_i(t) = D_{io} \pm D_{\eta i}(t)t^2; \end{cases} \quad (5)$$

where $M_{io}; D_{io}$- respectively, the mathematical expectation and variance of the i-element at the initial instant of time; $M_{\eta i}, D_{\eta i}$- mathematical expectation and variance of the intensity of change in the predictor parameter.

It is known that the continuity and monotonicity of the change in the predictive parameters causes the asymptotic independence of its random process, leading ultimately to the law of probability distribution without refusal work according to Bernstein [2]

$$P_n = 1 - \Phi \left| \frac{t - \frac{a_{i\text{кр}} - M_{io}}{M_{\eta i}(t)}}{\sqrt{\frac{D_{\eta i}(t)t^2 + D_{io}}{M^2_{\eta i}(t)}}} \right|, \quad (6)$$

where Φ- is the Laplace function.

For a three-phase asynchronous motor of a railway service car, the predictor parameter is the insulation resistance of the stator windings relative to the housing, the phase-to-phase resistances, as well as the rotor's extensionality, determined by the spectrum of the modulated stator windings, as well as the thermal state of the stator winding when the multiplicity of its currents changes.

One of the main factors affecting the performance of asynchronous motors (AD) is the overheating of the stator windings with the subsequent determination of the electrical isolation resource from the change in the multiplicity of its current. The measurements taken during the repair tests showed that the decrease in the electrical insulation of the stator windings relative to the hull was $M_{\eta\ \text{об.ст.}} = 0{,}22 * 10^6\ \frac{МоМ}{год}$

$D_{\eta\ \text{об.ст.}} = 0{,}0083 * 10^6\ \frac{МоМ}{год}$.

substituting these data in equations. (6), taking into account the allowable thermal data of the AD, we obtain the probability of the stopping resource of the stator winding of a three-phase asynchronous MTF-112-6-type motor, 5.0 kVT, with a rated stator current of 14.5 A used in the ADM-1 .

$$P_{\text{б об.ст.}} = 1 - \Phi \left| \frac{t - 3{,}74 * 10^3}{\sqrt{0{,}0081\ t^2}} \right| \quad (7)$$

The dependence of the probability of failure-free operation time of the blood pressure, calculated from (7), is shown in Fig. 2.

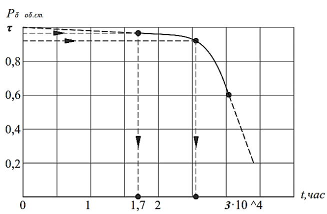

Fig.2. Dependence of the probability of failure-free operation time of an induction motor of a railway service car

From Fig. 2 that the dependence of the lifetime of an induction motor with a probability P = 0, 925 is t = 2.96 years, and for P = 0.95-t = 1.73 years.

Since the operability of electric hydro- and mechanical installations of railway service cars is determined by the initial and operational characteristics, the exploitation of the resource is not equal.

Consequently, it is advisable to determine the predictive parameter of each installation that is most rapidly changing under adverse operating conditions, and accordingly determine it separately for each installation taking into account the cost.

It should be noted that if the cost of preventive maintenance is less than the total cost of emergency repairs and losses from the cessation of movement of electric rolling stock, then preventive maintenance is economically justified [3]. As a result, an optimization task is set according to the criterion of minimum annual costs, including losses due to "windows" for the termination of rolling stock movement:

$$З = \sum_{i=1}^{n} C_{ab_i} \lambda_i + \sum_{i=1}^{m} C_{плi} \lambda_{плi} \to min \quad (8)$$

Conditions (8) correspond to a critical minimum of unit costs:

$$з = \frac{З}{\sum_{i=1}^{n} C_{abi}} = \lambda_{ср} = \left(\sum_{i=1}^{m} C_{плi} / \sum_{i=n}^{n} C_{abi} \right) \lambda_{пл} \to min, \quad (9)$$

Where

$$\lambda_{плi} = \frac{1}{T_{плi}};\ \lambda_{ср} = \frac{1}{T_{пл} \int_0^{T_{пл}} \omega(t) dt}.$$

Taking the last notation into account, we rewrite (9) in the form of equality.

$$з = 1/T_{пл}\left[\int_0^{T_{пл}} \omega(t)dt + \sum_{i=1}^{m} C_{пл i} / \sum_{i}^{n} C_{abi}\right] \quad (10)$$

The failure statistics of electrical installations of the SSRS show that they have a wear-out exponential character and their frequency increases with time [2,4]. Accordingly, this increase in failure rates can be approximated by the expression [4]:

$$\omega(t) = 0{,}01t \quad (11)$$

Differentiating (10) with respect to and equating the derivative to zero, taking into account (11) we obtain the conditions of the optimum as:

$$0{,}005T_{пл}^2 + \sum_{i=1}^{m} C_{пл i} / \sum_{i=1}^{n} C_{abi} = 0{,}01\, T_{пл} \quad (12)$$

From (12) we obtain the optimal periodicity

$$T_{пл.опт} = \sqrt{\left(\sum_{i=1}^{m} C_{пл;} / \sum_{i=1}^{n} C_{abi}\right) 0{,}005}$$

on separate current repair of the main functional devices of self-propelled rolling stock [5].

Conclusions. The forecasting of the residual life and the continuation of the life of the main functional devices of railway service cars and auto drainers subjected to wear, erasure and reduction of electric strength associated with loss of stability of performance characteristics requires periodic complex control, statistical analysis of failures of its electric, hydraulic and mechanical devices, generalized indicators of their reliability with subsequent calculations of the probabilities of failure-free operation of in relative time of operation and to determine the optimal frequency of the current repairs, taking into account the failure rate of each device.

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