STUDY OF THE INFLUENCE OF OPERATIONAL FACTORS ON LOAD PARAMETERS POWER ELECTRICAL EQUIPMENT OF TROLLEY BUSES AND SAFETY OF PASSENGER TRANSPORTATION

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Abstract

The question of ensuring the appropriate level of electrical safety by controlling the technical condition of the insulation of traction motors is considered. Mathematical models of changing the parameters of electric machines and their resource on different routes of the corresponding trolleybus have been developed, which is confirmed experimentally, ie according to the operating data. The issues of the influence of the length of the haul on the temperature conditions of the power electrical equipment of trolleybuses, in particular traction electric motors, are considered.

Keywords: trolleybus, electric motor, insulation, electrical safety, reliability, parameters, technical condition. temperature conditions, loading factors, insulation.

Formulation of the problem. Trolleybus transport, along with significant advantages, has several disadvantages. First of all, this refers to the need to address the issue of electrical safety, because in violation of the insulation of high-voltage electrical equipment may cause electric shock to passengers. Therefore, during the operation of trolleybuses, the technical condition of isolation of high-voltage circuits is constantly monitored. With high-voltage electrical equipment, traction motors are the least protected against the effects of weather conditions because they are located under the floor.

In case of high humidity or dew due to changes in the motor temperatures, it is possible to reduce the electrical insulation resistance and the potential to appear on the trolley body relative to the road surface. Since the traction motor is also engaged in the braking modes, a malfunction in its operation is directly related to the safety of movement.

Therefore, the issue of monitoring the technical condition of traction motors in terms of ensuring the appropriate level of electrical safety and braking modes is urgent [1].

Analysis of publications. Research findings [2–5] and experience in operating trolleybuses indicate that there is currently no effective automatic control of the isolation status, in particular during operation, which will significantly improve the electrical safety status of trolleybuses on routes. A considerable number of publications are devoted to the identification of faults in electric machines and their control [6–11].

An analysis of the operating conditions of electric motors in recent years shows that the reliability of the electric drives has not only reached the desired level, but on the contrary, decreased.

Thus, monitoring the technical condition of the insulation in order to improve the reliability of traction electric motors during operation for trolleybuses is an urgent task.

The purpose of the work is to increase the reliability of traction electric motors and to organize the control of the technical condition of the insulation to increase the safe transportation of passengers.

Main part. The rolling stock of urban electric transport typically uses DC electric motors. Depending on the excitation systems, they are classified into machines with parallel, sequential and mixed excitation.

In the process of traction electric motor degradation of the parameters of a number of its elements occurs, which leads to the following significant negative consequences:

– disability of the traction electric motor;

– the presence on the body of the engine (body trolleybus) is dangerous for passengers and staff voltage;

– increased against the natural rate of wear of the individual elements of the traction electric motor;

– high vibrations with a negative impact on the comfort of the trip and the trouble-free operation of other elements of the trolley that are damaged by the vibration of the engine.

The process of changing the parameters of an electric motor can be mathematically described by a power function: $y = ax^{\alpha} + в.$

Considering the change of the parameters P of the technical condition of the electric motor we have:

$$\Pi = V_c l^{\alpha} + \Delta\Pi, \qquad (1)$$

where V_c – the rate of change of the parameter;

$l -$ mileage of the moving unit, km;

$\Delta\Pi -$ admission to development;

$\alpha -$ the exponent of the approximation function.

In general, the transport company operates several types of trolleybuses $j_{m\acute{o}}=1,2,...,J_{m\acute{o}}$ on different routes $i_{m\acute{o}}=1,2,...,I_{m\acute{o}}$, which, for known reasons, have different indicators of the cost of resources and the volume of transport services provided. There fore, given (1) relative to the trolleybus ($m\acute{o}$) by types and units change the parameter of electric machines $\Delta\Pi$ and identifying their resource $r_{j_{m\acute{o}}}$ can be represented as a mathematical model (2):

$$r_{j_{m\acute{o}}}=\begin{cases}\dfrac{\Delta\Pi_{1_{e\text{м}}}^{(j=1m\acute{o})}}{\sum l_i}=\dfrac{V_c l^{\alpha_1(j=1m\acute{o})}}{\sum l_i};\\ \dfrac{\Delta\Pi_{2_{e\text{м}}}^{(j=2m\acute{o})}}{\sum l_i}=\dfrac{V_c l^{\alpha_2(j=2m\acute{o})}}{\sum l_i}\\ \text{..............................};\\ \dfrac{\Delta\Pi_{n_{e\text{м}}}^{(j=Jm\acute{o})}}{\sum l_i}=\dfrac{V_c l^{\alpha_n(j=Jm\acute{o})}}{\sum l_i}\end{cases} \quad (2)$$

Change the parameter $\Delta\Pi$ electric machines and their resource on different routes $r_{i_{m\acute{o}}}$ the corresponding trolleybus can be represented as a mathematical model (3):

$$r_{i_{m\acute{o}}}=\begin{cases}\dfrac{\Delta\Pi_{1_{e\text{м}}}^{(j=1m\acute{o})}}{\sum l_{i_{\text{м}}}^{(i=1m\acute{o})}}=\dfrac{V_c l^{\alpha_1(j=1m\acute{o})}}{\sum l_{i_{\text{м}}}^{(i=1m\acute{o})}};\\ \dfrac{\Delta\Pi_{2_{e\text{м}}}^{(j=2m\acute{o})}}{\sum l_{i_{\text{м}}}^{(i=2m\acute{o})}}=\dfrac{V_c l^{\alpha_2(j=2m\acute{o})}}{\sum l_{i_{\text{м}}}^{(i=2m\acute{o})}}\\ \text{..............................};\\ \dfrac{\Delta\Pi_{n_{e\text{м}}}^{(j=Jm\acute{o})}}{\sum l_{i_{\text{м}}}^{(i=Im\acute{o})}}=\dfrac{V_c l^{\alpha_n(j=Jm\acute{o})}}{\sum l_{i_{\text{м}}}^{(i=Im\acute{o})}}\end{cases} \quad (3)$$

$\Delta\Pi_{e\text{м}}$ – depends on a number of factors, such as the distance of the moving unit, the insulation heating temperature, the operating conditions, the operating time, or aging [4,5].

Loading modes of power electrical equipment of electric vehicles are determined by the operating conditions of the traction unit (TU). A comprehensive, systematic study of the main operational factors is an important task, the solution of which will increase the level of adequacy of the developed methodology to real conditions.

To analyze the operating conditions of rolling stock (RS), studies were carried out on the route systems of large cities in Ukraine. At the same time, methods of probability theory and mathematical statistics were widely used [1,2], which made it possible to determine with a sufficient degree of accuracy the laws of distribution of various motion parameters for trolleybuses of various modifications and the level of technical condition.

Experimental studies made it possible to identify the influence of many factors on the operating modes of the power drive. Among them, the main ones can be identified [3]:

– length of hauls;
– travel speed or travel time along the stretch;
– vehicle speed restrictions;
– contact line voltage;
– qualifications and experience of the driver;
– technical condition of the substation.

The influence of each factor individually and all of them together determines the complex processes of loading the power electrical equipment (PEE) of trolleybuses. Identification of the main statistical characteristics, laws of distribution of the operating factors under study, their correlation with the value of specific power consumption allows us to consider in more detail the process of formation of loading modes of the power drive,

The length of the haul also affects the temperature conditions of power electrical equipment. Increasing the length of the haul increases the duration of the traction mode, and therefore the duration of operation of the traction electric motor (TEM) under current. The permissible duration of operation of power electrical equipment (PEE) at a given load is determined by heating its parts above safe temperature values regulated by relevant standards.

Figure 1 shows the motion curve of a traction unit on a stretch of length L with a single switching on of the power circuit, with the curve of the current consumed by the traction motor plotted on it.

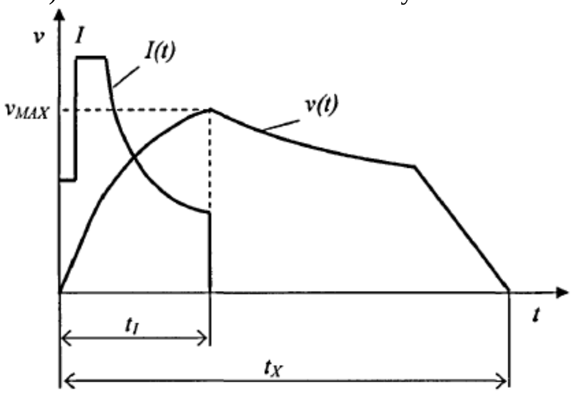

Figure 1 – Curves V(t) and I(t) for a single switching on of the electric motor at stage L

The operating conditions of urban electric transport are characterized by repeated and short-term loading modes of the traction motor. Then, under the assumption that the thermal energy released by the TEM is determined by the expression:

$$\Delta P = I^2 r, \tag{4}$$

where *r* is the resistance of the TEM windings, the heat balance equation, when averaging the values included in it [4,5]:

$$\frac{1}{t_x}\int_0^{t_x} \Delta P dt = \frac{1}{t_x}\int_0^{t_x} I^2 r dt = \frac{r}{t_x}\int_0^{t_x} I^2 dt = I_э^2 r \tag{5}$$

where Ie is the mean square current during the stroke time t_x.

Obviously, the value of the root mean square current depends on the duration of the mode or modes of movement under current. Which, in the absence of additional obstacles, is clearly determined by the length of the stretch (Fig. 2).

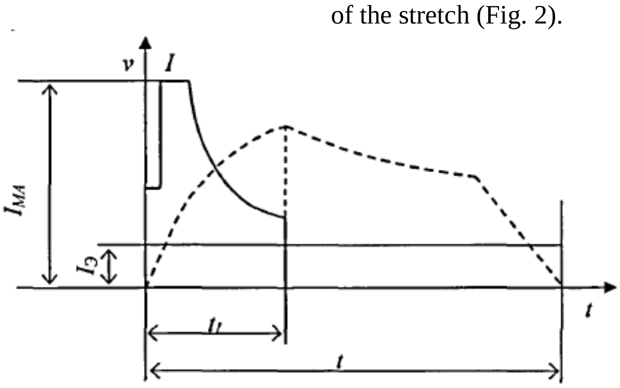

Figure 2 – Curves V(t) and I(t) for I_e movement under current on section L.

An area of increased attention is the insulation of the TEM windings. The service life of the insulation, and therefore the TEM, is inversely proportional to the temperature to the third power.

The magnitude of the temperature rise of the TEM over the ambient temperature is estimated using the heating equation for a homogeneous body [4,5]:

$$\tau = \tau_\infty \left(1 - e^{-1/T}\right) + \tau_0 e^{-1/T}, \tag{6}$$

where τ_∞ is the steady increase in the heating temperature of the windings at a given load above the ambient temperature (at);

τ_0 – initial temperature rise of the windings above the ambient temperature;

T – thermal time constant for traction motor windings;

t – heating time of the traction motor windings.

Expression (6) contains the sum of two exponentials: heating (Fig. 3, curve 1) and cooling with the initial coordinate (Fig. 3, curve 2).

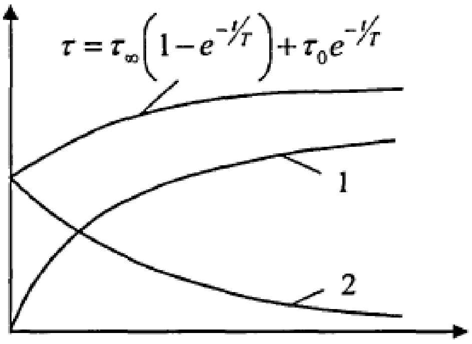

Figure 3 – Heating and cooling curves of trolleybus TEM

Expression (6) contains the heating time t of the TEM windings, which is determined by the duration of movement of the substation in traction mode or under current, which is realized during the acceleration mode or when the power circuit is additionally turned on during the haul.

In the course of experimental studies, it was established that in real operating modes, the implemented load modes of the power electrical equipment (PEE) not only do not lead to overheating of the windings, but also in some cases do not contribute to the drying out of the electric motor, which significantly increases the probability of insulation breakdown, and therefore shortens the operating time power drive of the traction unit.

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Conclusions. In the course of experimental studies, it was found that in real operating modes, the implemented loading modes of the PEE not only do not lead to overheating of the windings, but also in some cases do not contribute to the drying of the electric motor, which significantly increases the likelihood of insulation breakdown, and therefore reduces the operating time of the power drive of the traction unit.

Today, in such difficult economic conditions, scientific research in Ukraine should be directed to the development and implementation of technologies of the most efficient use of well-known equipment, its modernization, increase of reliability and prolongation of the resource of work.

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