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Study of the Efficiency of the Traction Electric Drive System of Operating Electric Trains of the Tashkent Metro

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Abstract. *The purpose of this study is to determine the most effective and cost-effective options for the traction electric drive system for the Tashkent metro. The work examines factors such as energy efficiency, reliability, availability, technical characteristics, economic aspects and environmental sustainability. The study is conducted by comparing different electric traction drive systems based on their energy efficiency, reliability, technical parameters, costs and environmental sustainability. The results obtained will allow us to identify the most optimal solutions for the Tashkent metro, taking into account its features and requirements.*

Keywords: *Traction electric drive system, Tashkent metro, energy efficiency, reliability, accessibility, economic aspects, operating costs, modernization.*

Introduction. The increase in the number of cars on the roads of large cities, including Tashkent, leads to serious problems in urban passenger transportation. This situation reinforces the need to expand the metro network in the public transport system. In Tashkent, for example, from 160 to 220 thousand cars enter daily, which is twice the capacity of the road infrastructure. Traffic jams are becoming so intense that drivers spend up to five days a year stuck in them, the equivalent of 120 hours - more than half the average monthly working time. This circumstance, together with its other obvious consequences, leads to large unproductive material losses, which forces us to intensively increase the share of metro electric trains in urban passenger transportation, even if they are unprofitable due to the high cost of sales in relation to traditional urban vehicles - buses. The inevitability of such a solution to the problem of providing urban passenger transportation in large cities was predicted in the USSR at the very beginning of the development of the metro. In particular, the Tashkent metro was opened on November 6, 1977, and today its share in the transportation of passengers among urban passenger transport enterprises in the capital exceeds 20% [1]. According to the website Daryo.uz [1], "on average, more than 630 thousand use its services daily. passengers, and on weekdays this figure exceeds 1 million passengers."

At the same time, current plans provide for a sharp increase in the pace and volume of construction of new lines of the Tashkent metro. In particular, Construction from the "Buyuk ipak yulli" station to the "Tashkent Tractor Plant" station of the Chilanzar line, with a length of 8.2 km, with 4 stations. Construction from the Beruni station to the Karakamysh residential area of the Uzbekistan metro line, 3.2 km long, with 2 stations.

Despite the intensive development of subways, their load quickly reaches its maximum. In particular, in Tashkent during peak hours on many lines the traffic intensity reaches 20 pairs of trains per hour. At the same time, the interval between trains on the Chilanzar line is 90 seconds. and is the smallest in the world. This traffic intensity places increased demands on the reliability of subway cars. To assess the technical and economic efficiency and reliability of the operation of subway cars, it is necessary to consider the traction electric drive system used on them.

The history of the development of traction electric drives for electric rolling stock has been going on for several decades and is always accompanied by competition between two systems - direct and alternating current drives.

Operating experience and practice show that there are many supporters and opponents of various traction electric drive systems, and each side has its own compelling arguments in favor of the system they have chosen. Of course, both the DC drive system and the AC drive system have their advantages and disadvantages.

To determine the most promising and efficient traction electric drive system, it is necessary to analyze and evaluate the systems used by subway cars. The results of such analysis can be useful in the development and modernization of existing and future electric traction drive systems.

Analysis of the study. With the development of semiconductor converter technology, many opportunities have emerged for improving the traction electric drive. Some of these include the use of traditional traction machines with pulse control for DC power supply, and variable voltage control and regenerative braking for AC power supply. In addition, it is possible to use commutator traction machines with independent excitation on both electric rolling stock with direct current and alternating current. Another option is to use brushless traction machines, such as asynchronous, valve and inductor. These new technologies and capabilities provide a wide range of options for improving electric traction drive technology.

On metro cars in Tashkent, existing traction electric drive systems with DC traction machines and asynchronous traction machines are shown in Fig. 1.

Traction electric drive system with discrete rheostat control.

The traction electric drive system with discrete rheostat control includes several main devices. One of them is the position switch, which is used to switch between driving and braking modes, as well as to change the connection of traction machines (from series to parallel). Another device is a rheostatic controller, which serves to regulate the resistance in the circuit of traction machines during starting and braking.

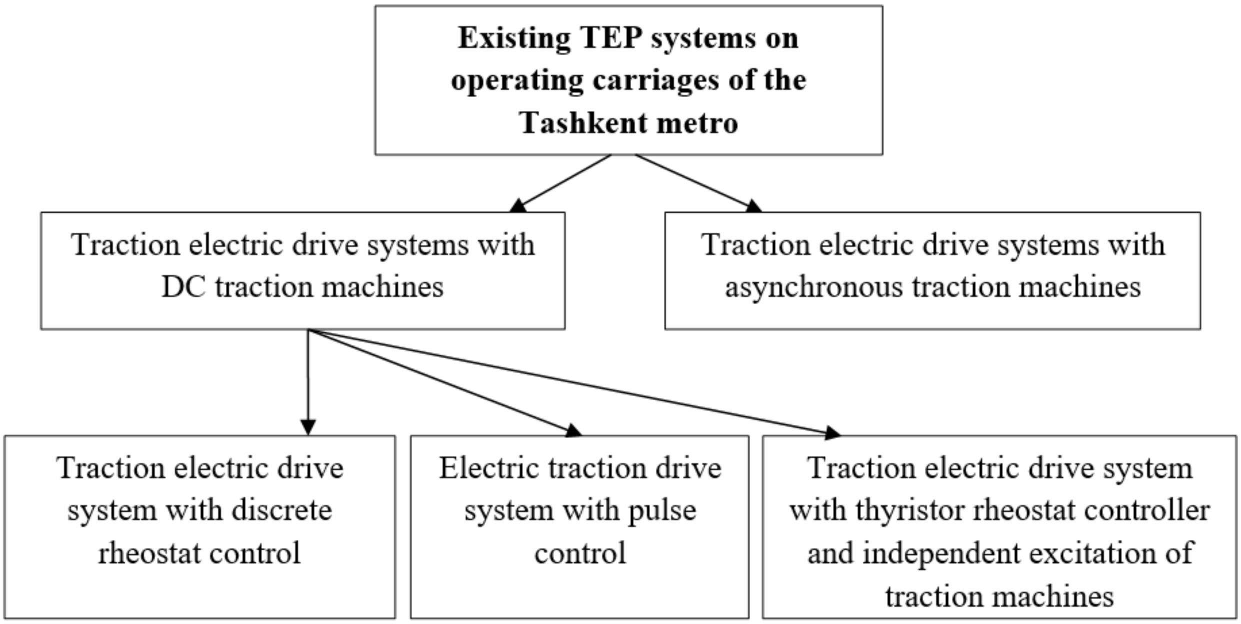

Fig. 1. Existing traction electric drive systems on operating cars of the Tashkent metro

Thyristor control systems for DC electric rolling stock.

We will take into account only the main DC voltage conversion systems on electric rolling stock in order to avoid unnecessary detail and focus on key aspects.

It is necessary first of all to distinguish between conversion systems based on static DC conversions on electric rolling stock. An important factor is the choice of traction machines, which can be either direct current or brushless multiphase alternating current [2].

Advantages of thyristor control

During the first attempts to develop a pulse control system, it was assumed that the transition from rheostat-contactor control to contactless thyristor control would significantly change the operating conditions of electrical equipment and the control of direct current electric rolling stock (ERS), significantly improving its traction and operational characteristics and increasing the economic efficiency of electric traction. Comparing a DC system with thyristor control and an existing DC system with rheostat-contactor control (RKU), we can highlight the following main advantages of a thyristor-controlled system:

• increasing the reliability of electrical equipment due to the elimination of contact switching equipment;

• non-resistance soft start, which allows, along with eliminating losses in starting resistance, to increase the average starting acceleration;

• smooth, lossless speed control throughout the entire range of its change;

• smooth regenerative braking over a wide speed range without special exciters or parallel excitation windings of the traction motor;

• elimination of switching of traction motors for speed control;

• the possibility of using a permanent parallel connection of traction motors, which improves the use of adhesion weight;

• the possibility of increasing by 10-20% the average voltage supplied to the engines, and a corresponding increase in their power, and, consequently, the speed of movement;

• protection of the traction motor from the effects of voltage fluctuations and overvoltages in the traction network (implied constant switching on of the pulse converter);

• ease of automation of EPS management operations.

In DC multiphase current systems, in addition to most of the hypothetical advantages mentioned, it becomes possible to use reliable, lightweight and relatively inexpensive brushless traction motors with frequency regulation. However, compared to direct current systems, converter installations on electric rolling stock are becoming more complex and expensive.

DC-polyphase systems require conversion of DC to AC using a frequency converter. This converter consists of a power module, a control system and a cooling system. The power module includes power semiconductor switches (for example, thyristors or IGBT modules) [3], which are controlled by signals from the control system to create the required polyphase alternating current. A cooling system is necessary to remove the heat generated during the operation of power semiconductor switches.

Converter installations on electric rolling stock in direct-multiphase current systems usually have a more complex structure and require a higher degree of integration and automation. This may increase the cost and complexity of system maintenance.

However, despite these additional costs and complexities, DC systems with brushless traction motors and frequency control offer significant advantages in terms of efficiency, reliability and control of the traction drive.

One of the important advantages of a direct current electric rolling stock (EPS) system using static converters is the ability to increase the voltage in the contact network. Increasing the voltage significantly reduces the cost of the power supply system and also reduces power losses. In addition, this makes it possible to reduce the required number of traction substations and the total consumption of non-ferrous metals for the equipment of the traction electric drive system [10].

An increase in voltage in the contact network leads to a decrease in the current required to transmit a certain power, which in turn makes it possible to reduce the cross-section of wires and use cheaper materials for their manufacture. This significantly reduces the cost of the power supply system and reduces electricity losses in transmission lines [5].

In addition, increasing the voltage makes it possible to reduce the required number of traction substations, since at a higher voltage it is possible to transmit more power over longer distances without significant losses. This reduces the cost of construction and operation of traction substations, which also reduces the overall cost of the system [4].

Higher voltage DC systems also require less equipment made from non-ferrous metals such as copper or aluminum. This leads to saving non-ferrous metals and reducing the cost of equipment for the traction electric drive system.

Thus, increasing the voltage in the contact network in a DC electric rolling stock system using static converters is an important advantage that can reduce the cost of the power supply system, reduce electricity losses and reduce equipment costs [6].

The economic efficiency of thyristor control of an electric rolling stock system is determined by the balance between the increase in the cost of rolling stock and the reduction in operating costs caused by an increase in speed and a reduction in electricity consumption by eliminating losses in starting resistance and reducing braking losses. In addition, increasing the reliability of EPS electrical equipment should reduce the cost of its repair. If higher voltage is used in the contact network, the cost of construction and operation of the power supply system will also be significantly reduced. In already electrified areas operating on direct current, increasing the voltage in the traction network leads to an increase in the throughput of the power supply and makes it possible to abandon other more expensive methods of increasing throughput, such as the construction of additional traction substations [7].

Thus, the use of thyristor control in an EPS system can lead to economic benefits associated with a reduction in operation and maintenance costs, as well as a reduction in the cost of construction and operation of the power supply system. Increasing overhead voltage can also lead to increased capacity and improved power conditions at existing sites, avoiding costly capacity expansion methods.

Conclusions

Based on the comparison of the efficiency of the traction electric drive system of electric trains in operation in the Tashkent metro, the following conclusions can be drawn:

The studied electric traction drive systems differ in energy efficiency. Some systems exhibit higher energy efficiency, which can lead to lower energy consumption and operating costs.

Important characteristics of an electric traction drive system are reliability and availability. Some systems can provide more reliable and affordable operation, which affects the reliability and punctuality of the metro.

Different electric traction drive systems have different technical characteristics such as speed, acceleration, traction force, etc. These characteristics can affect the performance and comfort of transportation.

When choosing an electric traction drive system, it is important to consider economic aspects such as the costs of construction, maintenance and operation of the system. The optimal solution must strike a balance between efficiency and economic benefit.

Electric traction drive systems can have different levels of environmental sustainability. Choosing a system that provides lower levels of emissions and pollution helps improve the environmental situation in the city.

Based on the comparison, we can conclude that for the Tashkent metro it is recommended to choose a traction electric drive system that has high energy efficiency, reliability, availability, appropriate technical characteristics and economic benefits. Consideration should also be given to the environmental sustainability of the system to reduce the negative impact on the environment. These conclusions can be used when making decisions on the modernization and development of the Tashkent metro.

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