Identification of electric traction in the urban electric transport system

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Abstract. The article presents the results of a systematic review of the basis of formation and implementation of electric traction in the urban electric transport system. Its complexity is determined by the fact that various technical, technological, industrial and other subsystems and complexes are included in it, whose main purpose is to satisfy the needs of the population in transportation. Determining the basis for the formation and implementation of electric traction in the system of urban electric transport is a condition for finding methods and means of improving its efficiency, including the energetic one. Based on the proposed approach, urban electric transport was interpreted as a complex production and technical system, which allowed identifying electric traction as an electrical engineering complex, and at the same time as a technological system, and as a technological process of functioning of this system. The results of the study should be interpreted from the standpoint of synergistic ideas that will contribute to the development of the general theory of electric traction in the context of modern scientific methodology.

1. Introduction
Currently, creation and introduction of new modern technologies aimed at improving the efficiency of electric traction (ET) as the major energy-intensive component of the transport process are the promising directions for improving the efficiency of urban electric transport (UET). Systematic consideration of principles of ET formation and implementation is a condition for the scientific inquiry for methods and means of improving its efficiency in the UET system and the methodological basis for the development of the general theory of electric traction in the context of the modern scientific synergistic world outlook [12].

The complexity of the UET system is determined by the fact that various technical, technological, industrial and other subsystems and complexes are included in it, whose main purpose is to satisfy the needs of the population in transportation [3, 4]. For further investigation of the “electric traction” we will consider the UET as a production-technical system.

2. Theoretical study
The UET system uses many technical facilities and tools that can be functionally combined into subsystems: electric rolling stock (ERS); track facilities and roads (TFR); plants and depot (D); energy supply devices (ES); communication and blocking devices (CB); means of traffic organization and management (TOM). Together, these subsystems form the technical part of the production and technical system of UET (Figure 1, a).
We detach some part of the technical component of the UET system, which is a set of elements for the conversion, accumulation, transmission and use of electrical energy and electrical information for the motion of the traction unit, i.e. including the subsystem "ES" and "ERS" (and in the case of rail transport it also includes "R"). This subsystem "ES-ERS-R" forms the electrical complex of electric traction [3, 4]. The structure and parameters of this electrical complex will be definitely determined by the electric traction system used for this type of transport. So, for example, 3 kV DC systems and 25 kV AC single-phase current are commonly used at the railways of Russia, and only the DC system of 550 V (tram and trolleybus), and of 750 V (metro) are used at the UET [1, 2, 5].

To determine the differences between the concepts of "electrical complex of electric traction" and "electric traction system" we consider the production component of the UET system.

Transport production can be structurally divided into two subsystems, the control one and that being controlled [6]. The first has the integrative “managerial function”, the second one implements the process of transport production (Figure 1, b). The subsystem being controlled is a higher-level system for the technical, technological and organizational production systems of UET, which are also complex.

The "electrical complex of electric traction" previously allocated in the technical component of the UET system, together with the instructions, regulations, operating rules, etc. forms a technological system or simply the technology of electric traction, which in the scientific literature is called the "electric traction system" used on a particular type of transport.

According to the Russian State Standard GOST 27.004–85, a technological system is “a set of functionally related means of technological equipment, items of production and performers in the regulated conditions of production, for the given technological processes or operations” [7].

The technical and technological systems of electric traction are interconnected and their interaction is crucial for achieving the main goal of the UET, i.e. implementation of the process of moving...
passengers and goods by electrically driven vehicles through the use of controlled electric traction. Thus, electric traction is also identified as a “process.” In [8], this process as motion by rail using electric rolling stock, i.e. as a transport process, in [5] it is defined as a production process of converting electricity to the motion of goods.

To further identify the “electric traction process”, we consider the features of transport production as a whole.

Transport is a branch of material production, namely the transport industry, which meets the vital requirements of society for the motion of people and goods [9].

Transport is characterized by all three elements, which are intrinsic for any branch of material production, namely: the means of labor, i.e. means of transport; objects of labor, i.e. transportation facilities (cargo and passengers); appropriate activity of people, i.e. their work. It is known that transport does not make any transformations with objects of labor (if not to take into account the loss of their quantity and quality during the process of transportation), it provides the necessary motion of objects in the production cycle and in the sphere of their circulation (from production sites to consumption sites). From this point of view, transport represents a more complex industry than any other material production.

At the same time, transport has some peculiarities that distinguish it from other sectors of the national economy.

First, transport does not produce new material products, but continues the production process in the sphere of circulation. The end result of production is realized at the consumer, therefore the transport is the continuation of the production process. Manufacturers are interested in the quality of the transport process, improving the use of rolling stock and saving transport costs.

Secondly, transport production is inseparable from the process of transport manufacturing. It cannot be accumulated, or one cannot create its reserves. The problem of reserves on transport is not connected with creation of stocks of transport products, but it consists in creation of reserves of carrying and working capacity. It is almost impossible to maneuver with reserves, therefore reserves of carrying and working capacity must be created first on routes with fast-growing traffic volumes.

Thirdly, transport products do not contain raw materials. The share of wages in its cost is twice as high as in industry. The cost of depreciation, fuel and electricity account for almost half the operating costs of transport. Cost reduction can be achieved primarily by increasing productivity, improving rolling stock utilization, reducing fuel and electricity consumption per unit of transport work.

Fourthly, the circulation of funds in transport takes place in a special way: not the goods in the form of a new thing are sold on the transport market, but the production process of the transport industry itself. The quality of transport products is determined not only by the quality of the final product, but also by the quality of the transport production process. Of particular importance are the speed of delivery and uninterruptedness of the transport process, the safety of goods during transportation, the reliability of all parts of the transport conveyor, the quality of work of each employee, the company and the system as a whole.

The literature analysis [5, 8, 9] shows that the concepts of “production process” and “transport process” taking into account the specifics of transport are very close and intersect according to various authors.

So, for example, A.V. Velmozhin and V.A. Gudkov [10] present the transport process as a certain technology, in accordance with which a certain cargo moves from the place of its production to the place of its consumption. When transporting passengers, the transport process is associated with the motion of passengers, including the sale of tickets and the formation of passenger traffic, the boarding and disembarking of passengers, as well as the supply of vehicles. Turevskiy I.S. [11] relates the transport process exclusively to the motion of goods and passengers, including all preparatory and final operations: preparation of goods, their loading and unloading, embarkation and disembarkation of passengers, acceptance of goods, supply of vehicles and other operations. Another definition is given by S.I. Tereshko [12]: transport process is a combination of engineering preparation of the transportation process and itself.

The authors [13-15] define the production process as a set of interrelated labor and natural processes, under the purposeful influence of which the raw materials are transformed into finished products.
According to GOST 12.3.002-2014, the production process is a set of technological and other processes necessary for the production, working (manufacturing) operations, including labor activity and labor functions of workers [16].

The concept of "production process" is much more comprehensive than the concept of "transport process" and it is obvious that the transport process is part of the production. The similar situation takes place with ET implementation - the transport process is only a part of this process, which characterizes only controlled mechanical motion, i.e. transportation process. The ET includes the formation of controlled ERS traction, by converting electrical energy into mechanical energy and vice versa, the interaction of the traction unit with the elements of the track, with the traction power supply system and the environment.

The identification of electric traction as a production process of converting electric energy to the motion of passengers and goods [5] is also not entirely true, as in this definition the electric power has the meaning of “raw materials”, from which the production product is received, namely motion of goods and passengers. And as it was said above, there is no raw materials in transport production, but there are only costs for the production process, which can be defined as consumed resources. These resources can generally include energy resources, as well as material, human, financial, information.

The production process according to [15] is a combination of all the actions of people and means of production, carried out at the enterprise, aimed at manufacturing products; and in the case of transport production it is aimed at implementing the transportation process.

The production process consists of the following processes [17]:

- The main ones are technological processes, during which the main actions related to the products manufacturing take place;
- The auxiliary ones, which ensure the uninterrupted flow of the main processes (manufacturing and repair of equipment; provision of all types of energy (electrical, heat, water, etc.);
- Servicing ones, associated with servicing both main and auxiliary processes, but as a result of which products are not created (storage, transportation, technical control, etc.).

According to the Russian State Standard GOST 3.1109-82, a technological process is a part of the production process that contains targeted actions to change and (or) determine the state of the subject of labor [18].

With this in mind, electric traction can also be identified as the “main technological process of the UET production process”, during which an ordered sequence of interrelated actions takes place aimed at providing the transport process with traction units using electric traction drive (Figure 2).
3. Conclusion

In the course of the study it was theoretically justified that the electric traction can be identified both as an “electrical complex”, and as a “technological system”, and as a “technological process” in the UET system.

The main feature of technical systems is the close relationship between their structure and the process being implemented [19]. In this regard, the construction of the “electrical engineering complex” of the ET and the implementation of the traction technology, which forms the “technological system” of the ET, are uniquely determined by the structure of the UET system and are rather deeply theoretically worked out by applied industry sciences. The methodological foundations of the construction of the "technological process" of the ET are not yet fully developed because the general theory of electric traction considers ET only in the context of the implementation of a mechanical motion, and in the theory of transport management, ET is interpreted only from the perspective of the formation of the production process.

For the development of methodological ideas about the implementation of electric traction as a "technological process", it is advisable to consider its structural and functional features in the context of the operation of an open complexly organized production and technical system UET [20], which will contribute to the development of a general theory of electric traction based on a modern scientific synergistic world view.

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