Control of electric locomotives with asynchronous electric motors under asymmetric operating conditions in Uzbekistan

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Abstract. The control of energy conversion processes in an alternating current electric traction drive with asynchronous (induction) motors under asymmetric operating conditions are considered in the paper and the ways to improve their efficiency are proposed. It was stated that asymmetric modes create asymmetry of currents in the AM phases, which negatively affects both the electrical and mechanical parts of electric traction drives. The analysis of electromagnetic processes in the complex asymmetry of currents and voltage in the circuits of electric traction drives allows creating an adaptive algorithm for electric locomotives control which allows increasing electric power indices and the system reliability.

1. Introduction

Given the difficult operating conditions on the railways of Uzbekistan and the ongoing annual increase in freight traffic, the most promising type of locomotives are the electric locomotives with an asynchronous traction drive (ATD). In this regard, the “Uzbekistan” freight-and-passenger electric locomotives and the “Uzbekistan–Y” passenger electric locomotives manufactured at the Chjudzhou Electric Locomotive Plant, North Korea, have proven themselves well. Due to the low specific consumption of active materials, ATD in comparison with commutator motors, have better mass and size parameters and require less maintenance costs; high rigidity of electromechanical characteristics allows realizing high values of adhesion coefficient. The combination of these factors allows increasing the axial power of electric locomotive provides the best traction characteristics, makes it possible to reduce the maintenance costs and obtain a number of other most important operational advantages.

A necessary condition for the maximum use of adhesion weight of the rolling stock is the uniform load distribution between its traction motors. At the same time, high rigidity of electromechanical characteristics of the ATD and their non-identical nature, as well as the uneven wear of tires during the locomotive operation, cause different loading of the traction motors. Modern traction systems, currently used, eliminate the resulting difference in ATD loads. Such systems are based on the use of voltages of different frequencies for the power supply of each engine; they require the presence of an individual frequency converter and the number of phases for each motor [1, 2].

A very promising direction in the development of electric traction drives is the drive based on asynchronous motors, more reliable and unpretentious in operation, smaller in size and cost, with rigid characteristic that guarantees high anti-wheel spin properties of the locomotive.
2. Methods
At present in the Republic of Uzbekistan, targeted measures are taken to further develop the transport potential, which contributes to the strengthening of political and economic independence of the country, ensures its active integration into the world community.
In particular, the construction of new railway lines within the country is underway; the reconstruction and electrification of the main transit railway lines, the organization of new routes and the formation of container trains are realized to open customer-oriented, short and convenient transportation routes. Railway transport of the country carries more cargo than all other transport services. Especially great is its importance in the export and import of goods.
In order to ensure a continuous and safe transportation process, the projects are underway to update and modernize the rolling stock, at the expense of the company’s own funds and the credit funds from international financial institutions.
The department of locomotive operation is one of the important divisions of “Uzbekistan Temir Yo’llari” JSC and has a powerful fleet of traction forces at its disposal: diesel locomotives, electric locomotives; it provides all types of passenger, commuter and cargo transportation, shunting operations. In the depot at the disposal of the management, the maintenance and repair works are carried out.
Electric locomotives “Uzbekistan” and “Uzbekistan-Yulovchi” with the alternating current drives were created according to the contract requirements for the conditions of Uzbekistan. The technical specifications used in the design and manufacture of these electric locomotives are the standards that correspond to ISO, IEC, UIC, GOCT and GB, etc. The characteristics of these electric locomotives differ from the ones used in Uzbekistan.
In the field of electric traction drives with asynchronous (induction) motors, there are scientific justifications confirming its effectiveness. However, there are still a number of unresolved issues that allow more efficient use of energy-economic capabilities of this type of electric traction drives. This is due to the fact that the operating conditions of electric traction drives of electric locomotives are very specific and influenced by a number of factors [3], such as:
- severe restrictions on mass and size dimensions;
- type of electrical equipment performance;
- the impossibility of transferring the results of studies obtained and tested for trunk transport.
The main reason from which the consequences follow is the type of electrical equipment performance, since in our region the ambient temperature exceeds the nominal temperature and, thus, minimizes the process of heat removal from power electrical elements with natural additional losses of electrical energy and, consequently, with the heating of elements in the system as a whole [3, 4]. It is proposed to use IGBT (Insulated Gate Bipolar Transistor) inverters for the frequency control of the ATD, where almost all contactor equipment is excluded from the power circuit with the exception of the running (linear) contactor, which switches in no-voltage condition. Despite the higher cost of inverters compared to pulse converters, the total cost of AC electrical equipment is expected to be less than constant current equipment [2]. However, the question arises of creating control algorithms for a pulse converter in the event of emergency of the ATD modes due to:
- distortion of voltage symmetry of mains supply;
- asymmetry of resistances in the rotor and stator circuits;
- asymmetry in connection chart of motor windings.

3. Results and discussions
Asymmetric modes create current asymmetry in the AM phases, which negatively affects both the electrical and mechanical parts of the electric traction drive (ETD). This is the reason for hidden mechanical damage to the ETD, itself, in which the electromagnetic processes change, and the
negative impact on the processes on the whole system of electric traction drives. Unfortunately, the part of these modes in the total work of electric traction drives can be very significant. As studies have shown, all electric locomotives with the ATD can function in such modes from the beginning of their operation [5, 3]. It is important to know not only the dynamics of energy conversion processes, but also to assess the degree of influence of the terms causing abnormal modes on quantitative assessment in a given type of electric drive, i.e. the control algorithm of the ATD converter should adaptively compensate for the asymmetric modes, the possibility of electric locomotive traction occurrence is very high in mountain conditions [4, 6-18].

Figure 1. Control algorithm for the search for the modes of asymmetry compensation of ATD parameters

Figure 2. Variable component of the moment of ATD at 20% asymmetry of stator resistance at a load of 0.25 Mₜ: 1 - at symmetrical power supply; 2 - at asymmetry compensation
The research results reflect the change in electromagnetic moment and power consumption during the start-up of an “asymmetric” AM and with preventive compensation for the asymmetry. In the steady-state condition with a nominal load on the axle, the asymmetry of stator resistances leads to the appearance of a variable component of the moment and power (Figure 2, curve 1). The use of compensation equations in the control system of a pulse converter makes it possible to virtually eliminate the variable component of the moment and power (Figure 2, curve 2). Figures 3 and 4 show, as an example, the corresponding changes in the values of phase currents and voltages.

Figure 3. Phase voltages in the ATD stator at 5% asymmetry of the stator inductance at a load of 1.0Mₘ: a - before compensation; b - after compensation

Figure 4. Phased currents in the ATD at 5% asymmetry of the stator inductance at a load of 0.1 Mₘ: a - before compensation; b - after compensation
4. Conclusions
Thus, the analysis of electromagnetic processes at complex asymmetry of currents and voltages in the circuits of electric traction drives and the compensation equation obtained allow creating an adaptive control algorithm for the pulse converter, which improves electric power performance and the reliability of the pulse converter system – the asynchronous (induction) traction motor.

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