Evaluation of the compatibility of the power traction supply system in the field of implementing the train traffic interval regulation with a use of a "virtual coupling" technology

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Abstract. This article will propose the practical use of the interval control technology that will reduce the interval of passing trains and will increase the capacity of railway lines. In general, the effectiveness of implementing the train traffic interval regulation with a use of a "virtual coupling" technology is presented in the works of many authors; however, the issues of the use of the existing infrastructure of the traction power supply system are not considered in the works. Comparing the "virtual coupling" technology with connected trains driving consists of the capacity reserve and train schedules evaluation. The use of modern software tools for mathematical modeling will allow you to solve not only the tasks set, but also to evaluate the compatibility of the currently used traction power supply system. According to the results of authors meant below, it can be seen that the temperature in the contact system and the suction line, the load limiting factor and the energy losses of the traction network trains movement in the "virtual coupling" are lower than those during the movement of the united train. When using trains with a virtual coupling, the voltage in the contact network is significantly higher than when using connected trains. Based on the above, it can be concluded that the virtual coupling trains use on the section under consideration is more appropriate than the use of the connected trains.

1. Introduction

In accordance with the scientific basis of the railway transport development strategy accepted for the period up to 2030, the tasks of industry main costs minimization are brought to the fore and are aimed at the technological equipment operation and repair [1]. Development of the transportation processes optimization policy is possible when we take into account such moments as the use of modern technical means and technological processes, which are compatible with operational conditions of electrical equipment and with power supply systems.

Today the use of new technologies in the transportation process is a necessity due to the sharp increase in cargo traffic towards the Far East. Over the past 15 years, the volume of freight traffic in this direction has increased more than 2.5 times, while the railway transport infrastructure in operation has not changed for the most part. Since the new railway lines construction is not economically justified, it...
is necessary to find alternative ways to meet the growing demands of local businesses and industrial enterprises, one of which is the "virtual coupling" technology, which can potentially increase the maximum of the possible cargo delivery volume more than five times [2, 3, 4].

Nowadays one of the main directions in the field of the transportation process improvement is the development of interval control technology, the use of which will allow one to determine the distance between trains not by free block sections, but by focusing on the current location of the rolling stock. The practical use of this technology will reduce the interval of passing trains and will increase the capacity of railway lines and other transport infrastructure. The technology is primarily aimed at solving the problem of the railway lines sections carrying capacity increase without upgrading the existing infrastructure, which is especially important in modern conditions with the growth of traffic volumes on the entire railway network [5, 6].

2. Traction calculation of freight trains on the Achinsk – Mariinsk section
Reliable power supply provision for train traction and non-traction power consumers, maintenance of the specified capacity and carrying capacity of railway sections without main elements overload, ensuring the standard quality of electricity [7-10], taking into account the use of the considered (in the article) system, will allow us to justify the expediency of its practical application.

When calculating acceptable inter-train intervals, we used a conditional parallel traffic schedule with an average distribution of the largest and average trains mass on each track along the entire section. Taking into account that only certain inter-station zones and tracks are the busiest at different time periods, calculations based on the specified schedules provide an acceptable margin of the capacity utilization degree to compensate for intra-day fluctuations in the traffic size [11, 12, 13].

On the basis of the mode maps, the article considers the calculated section of the Mariinsk – Achinsk railway, which track profile is presented in the "KORTES" program (Figure 1).

![Figure 1. Longitudinal profile of the Mariinsk – Achinsk section.](image)

Taking into account the speed limits of the presented section, which are 80 km/h in both even and odd directions, determines the current consumption of the train. The presented calculations are focused on a series of electric locomotives 2(3)ES5K, due to their use in the considered area. The forecast values of freight train weight standards and the freight train traffic value for 2025 are shown in Table 1.

| Table 1. Freight train traffic sizes up to 2025 |
|-----------------------------------------------|
| Section name | Weight standards of freight trains, tons | Size of freight trains, trains/day back |
|---------------|------------------------------------------|----------------------------------------|
| Mariinsk – Achinsk | 7100                                      | 7                                      |
|                | 6000-6300                                 | 14                                     |
|                | 4000-4200                                 | 19                                     |
|                | 3000                                      | 10                                     |
|                | 3000                                      | 1                                      |
|                | 1500-1700                                 | -                                      |
|                | Total                                     | 51                                     |
The traction calculations results with a use of the LVI-table in the program complex "KORTES", were acquired total current variation graphs from the train coordinates for the considered types of trains in the odd and even directions, see figure 2. These relationships indicate a possible omission of the all freight trains categories within the existing power supply system parameters and class insulation of the electric locomotive traction equipment [14, 15, 16, 17].

![Graph](image1.png)

Figure 2. The total current dependences graphs on the coordinates of odd (a) and even (b) trains of different masses on the Achinsk – Mariinsk section.

According to the conducted scientific research, traction calculations were performed for the presented section in order to determine the value of the traction load in the power supply system [18-21]. The calculations consider high and medium weight freight trains in even and odd directions and
simulate the movement of a connected train with a weight norm of 12,600 tons. On the basis of the data in table 1, the average freight trains weight is calculated for the specified weight standards without taking into account the number of trains with increased weight. The calculated value for the railway line sections is:

- odd direction of the Mariinsk – Achinsk section:

\[
m_{\text{mid}} = \frac{4200 \cdot 19 + 3000 \cdot 10 + 3000 \cdot 1 + 1700 \cdot 10}{19 + 10 + 1 + 10} = 3245 \text{ tons;}
\]

(1)

- even direction of the Mariinsk – Achinsk section:

\[
m_{\text{mid}} = \frac{4200 \cdot 19 + 3000 \cdot 10 + 3000 \cdot 1}{19 + 10 + 1} = 3760 \text{ tons}
\]

(2)

The parameters shown in table 3 indicate that the load limiting factor for the two types of trains does not exceed the permissible value, and the transformer oil temperature does not exceed the permissible value.

3. Conclusion

On the basis of the obtained results, it is proved that it is reasonable to move trains in the "virtual coupling" mode, since the energy consumption, losses in the traction network, the limiting load factor, the temperature in the contact network and the suction line are lower than when the connected train technology is used. When trains are used in the «virtual coupling» mode the voltage in the contact network is also significantly higher than when using connected trains.

The "virtual coupling" technology assumes that radio modems installed on the electric locomotives maintain communication between the master and slave trains via a secure digital channel and transmit energy-optimal driving modes for locomotives that also ensure the minimum safe interval between trains. As a result, the section capacity increases: the inter-train interval with the new technology will be 5 minutes, and the distance between trains will be reduced to the required stopping distance.

References

[1] Development strategy of the Russian Railways Holding for the period up to 2030 2013 (Moscow: JSC Russian Railways)
[2] Official website of Russian Railways: http://rzd.ru
[3] Taranets I 2019 Digital technologies will reduce the time of registration of transportation by five times Newspaper "Gudok"
[4] Klimova E V, Pilipushka L E, Ryabov V S 2019 The technology of "virtual coupling" of trains as a tool for increasing the carrying and carrying capacity of the line Transport infrastructure of the Siberian region Vol. 1 (Irkutsk: IrGUPS) pp 60-64
[5] Rosentals E M, Buinova N V 2019 Interval regulation: innovations and development prospects: a thematic selection (Krasnoyarsk: KrTsNTIB) p 232
[6] Cherpanov A V, Kutsy A P, Esaulenko A S 2020 Application of virtual coupling technology for high-mass trains Young Science of Siberia: electron. scientific. zhurn 2
[7] Belogolov Yu I, Olentsevich V A, Astashkov N P 2018 Improving the operational management of transport processes in railway transport Proceedings of 6th International Symposium on Innovation and Sustainability of Modern Railway ISMR 2018 (Irkutsk: ISTU) pp 602-609
[8] Olentsevich V A, Belogolov Yu I, Kramynina G N 2019 Set of organizational, technical and reconstructive measures aimed at improvement of section performance indicators based on the study of systemic relations and regularities of functioning of railway transport system IOP Conf. Series: Materials Science and Engineering 832 012038
[9] Olentsevich V A, Upyr R Yu, Gladkikh A M 2020 Computational procedure for preparing the technical conditions for stowage and securing cargo in rail cars and containers Journal of Physics: Conference Series 1615 012029
[10] Olentsevich V A, Gozbenko V E, Kargapol'tsev S K, Kramynina G N 2019 Complex of
organizational, technical and reconstructive measures aimed at improving the performance of the section based on the study of system connections and regularities of the functioning of the railway transport system. Modern technologies. System analysis. Modeling. Vol. 62 3 (63) pp 171-179

[11] Tumanin A S 2019 Technological process of the traffic control center of the Krasnoyarsk traffic control directorate - a branch of Russian Railways p 94

[12] Arkhangelsky E V, Vorobiev N A, Drozdov N A, Miroshnichenko R I, Segal L G 1997 Calculation of the throughput of railways (Moscow: Transport)

[13] Gromyshova S S, Astashkov N P, Olentsevich V A, Lobanov O V 2019 Assessment of the level of security of complex-structured transport systems in order to increase the level of their competitiveness in the market of transport services. Modern technologies. System analysis. Modeling. Vol. 62 2 pp 250-259

[14] Astrakhantsev L A, Astrakhantseva N M, Astashkov N P 2012 Development of resource-saving electrified technological processes. Bulletin of KrasGAU 8 (71) 166-169

[15] Astrakhantsev L A, Astashkov N P, Ryabchenok N L, Alekseeva T L, Astrakhantseva N M 2012 Increasing the electromagnetic compatibility of rolling stock. Safety of regions - the basis of sustainable development 1-2 92-94

[16] Ryabchenok N, Alekseeva T, Astrakhanchev L, Astashkov N, Tikhomirov V 2020 Energy-saving driving of heavy trains. Advances in Intelligent Systems and Computing 982 491-508

[17] Upyr’ R Yu, Goncharova N Yu, Eremenko M N 2020 Heavy traffic - a reserve for increasing the carrying capacity. Railway transport 7 10-13

[18] Nazarychev S A, Akhmetshin A R and Gaponenko S O 2019 Full compensation of reactive power in electric networks 0.4-10kV. Journal of Physics: Conference Series, XI Scientific Technical Conference on Low Temperature Plasma during the Deposition of Functional Coatings. 1588 012036 DOI: 10.1088/1742-6596/1588/1/012036

[19] Suslov K V, Solonina N N, Smirnov A S 2014 Distributed power quality monitoring. Proceedings of International Conference on Harmonics and Quality of Power, ICHQP pp 517-520 DOI: 10.1109/ICHQP.2014.6842882

[20] Akhmetshin A, Marin G and Mendeleev D 2020 Modeling of asynchronous motor operation modes for the correct selection of voltage regulation devices. 2020 High Speed Turbomachines and Electrical Drives Conference (HSTED 2020) E3S Web of Conferences 178 01015 DOI: 10.1051/e3sconf/202017801015

[21] Suslov K, Piskunova V, Gerasimov D, Ukolova E, Akhmetshin A, Lombardi P, Komarnicki P 2019 Development of the methodological basis of the simulation modelling of the multi-energy systems. In Proc. International Scientific and Technical Conference Smart Energy Systems 2019 (SES-2019) E3S Web of Conferences 124 01049 DOI: 10.1051/e3sconf/201912401049