The impact of the passage of long-distance trains on the required electrical capacity of the transport infrastructure facilities of the Eastern polygon of Railways

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Abstract. Increasing the profitability and profitability of railways can be achieved through a phased study, identifying the most problematic areas and a competent, well-planned and economically sound solution to these problems. To do this, the road management structures of individual departments must constantly analyze and develop design solutions for the development and reconstruction of railway transport. Particular attention in terms of increasing freight turnover should be paid to ensuring the required electrical capacities of all transport infrastructure facilities of the Eastern Railway Range, which is currently the most strategically significant in the Holding. In order to optimize the transport service of the eastern direction, increase the cargo turnover of the Baikal-Amur and Trans-Siberian Railways, first of all, it is necessary to provide the required electric capacities of transport infrastructure facilities. It is possible to achieve efficient and reliable power supply for the railways of the Eastern Range, to exclude the possibility of non-export of all categories of cargo, provided that a coordinated integrated approach to the development of the power grid sector of Siberia and the Far East is developed. Such an approach should provide for a phased strengthening of the power system of facilities.

1. Introduction

According to the planned indicators for the organization of freight work as part of the operation of Russian Railways OJSC (RZD OJSC), for 2022, the plan for the network amounted to 1.4 billion tons, which exceeds the freight turnover in 2021 by 2.5%. The increase in loading volumes is expected at the level of 30.5 million tons compared to last year for all categories of transported cargo, except for timber cargo, in the second half of this year, only for grain, the increase will be 3.5% against the background of the main indicators of a successful sowing campaign and favorable weather - climatic conditions in
the regions. Also not a bad forecast for the increase in the volume of loading of oil and oil products in general for the holding - 1.7%, i.e. 4 million tons higher than in 2021, currently export transportation of this category of cargo is at the level of more than 270 thousand tons per day, within the country - 350 thousand tons, which is associated with rising prices and consistently high demand [1, 2].

In January 2022, compared to the previous year, an increase is observed in the following types of cargo: coal by 3.2%, oil cargo by 8.4%, construction cargo by 6.7%. Due to the introduction of a ban on the export of unprocessed or roughly processed wood from the Russian Federation from January 1 of this year, the volume of transportation of timber and timber products decreased by 13% [2, 3].

According to the forecast values, the export loading volume of JSC Russian Railways in 2022 has an increase of 505 million tons, this indicator is a new record for the Holding. Thus, it is planned to increase loading at Russian ports by 4.6%, which will amount to almost 370 million tons, according to China, the plan has reached 100 million tons of cargo. Good indicators of the organization of cargo work were achieved due to the completion of a number of investment projects in the transport industry: the capacities for transport approaches and the infrastructure of the ports of the Azov-Black Sea basin were increased to 125.1 million tons; period to achieve a carrying capacity of 158 million tons, an increase by 14 million tons compared to last year [1-3].

Based on these factors, in the presented scientific publication, the authors analyzed the technology of operation of section C, which ensures the safe and uninterrupted operation of one of the sections of the railway line of the Eastern Railway Range, the procedure for processing transit train flows and maintenance of non-traction rolling stock, the established procedure for traction service for train traffic in this direction. The analysis made it possible to develop and justify a technical solution aimed at improving the performance of transport infrastructure facilities by increasing its required electrical capacities [4].

2. Ensuring efficient energy supply to the railways of the Eastern range

The relevance of the chosen topic lies in the fact that the problem of lack of capacity of railway transport infrastructure facilities is complex, to a greater extent, the causes of its occurrence and possible solutions lie not only within the area under consideration, but also go beyond it, which indicates the possible risks of functioning transport system as a whole. The high level of traffic intensity, the lack of reserves for the passage of trains, technical and organizational disruptions that occurred in one place automatically lead to the appearance and increase in unproductive idle time of the rolling stock throughout the Eastern range.

The limiting indicator is the maximum volume of trains (pairs of trains) passing per unit of time that can be passed through a section of the railway line according to the existing technology of operation and the existing infrastructure equipment - throughput and transport infrastructure [4-6]. In order to improve the values of this indicator, the holding network widely uses technologies for the formation of trains with an increase in weight, heavy-weight and connected trains. Carrying out such activities leads to a decrease in the number of pairs of trains that have passed through the section under consideration according to the predicted size of the car traffic, which allows to significantly increase the percentage of passes, thereby improving the throughput and carrying capacity of the selected directions. Such an approach to organizing the passage of trains on the section leads to an improvement in such an indicator as the performance of a train locomotive, however, it increases the idle time of freight trains at amplification stations, provided there are no restrictions on traction power supply [4-6].

In order to optimize the work of the railways of the Eastern range, in order to increase the throughput of the facilities of the Baikal-Amur and Trans-Siberian Railways in the context of a planned increase in freight turnover, the required electrical capacities of transport infrastructure facilities must be almost doubled. It is possible to achieve efficient and reliable power supply for the railways of the Eastern Range, to exclude the possibility of non-export of all categories of cargo, provided that a coordinated integrated approach to the development of the power grid sector of Siberia and the Far East is developed. Such an approach should provide for a phased strengthening of the energy system of the BAM and Trans-Siberian facilities. The choice of the order of modernization should be carried out on the basis of
a detailed analysis of the quality indicators of work and the level of throughput of transport infrastructure facilities, as well as the systematization of influencing factors.

The technology of power supply of transport infrastructure facilities operating today on the network of JSC Russian Railways is a complexly structured dynamic system that includes a complex of power and information subsystems actively interacting with each other. The purpose of this system is to provide an economical, reliable and safe power supply to traction and non-traction consumers, to ensure a stable design level of traction power supply capacity without overloading the main elements while ensuring the standard quality of electricity [7].

3. Influence of the passage of long trains on the required electric power of transport infrastructure facilities

Consider the impact of long trains on the quality performance and throughput of transport infrastructure facilities using the example of railway station C. According to the technology of operation of railway station C of section 1 of the railway line of the Eastern Railway Range, trains weighing more than the established regulatory limits, if their length is not more than useful the length of the station receiving and departing tracks are accepted, processed and disbanded in the usual manner in accordance with the current road order "On the establishment of norms for the weight and length of passenger and freight trains" [8-11]. At station C, freight container trains are combined with the trailer of an operating train locomotive, one at the head of the train, the second in the middle of the train, provided that it is connected by a brake line. The procedure for passing, receiving and departing freight trains of increased length, long trains and trains that do not fit into the useful length of the railway track is regulated and carried out in the manner prescribed in the annex to the regulatory document characterizing the operation of the railway station "Technical and administrative act of the railway station C" - "Instruction for the reception, departure, passage of trains and shunting work with trains of increased length, connected, long trains and trains exceeding the capacity of the receiving and departing tracks of the station" [10, 11].

The analysis of the organization of the work of station C for the passage of odd long trains from 116 to 138 conditional wagons showed that when a train arrives at the station and the pushing locomotive is placed at the head of the train, a change in the cab of the locomotive is required by the locomotive crew in order to further put the freight train at the head. These shunting movements are carried out behind the shunting signals No. M96, M48 and M98, all of the listed signals are located along the first main track of station C, through which odd trains pass through to station C2.

To develop a design solution, a photograph of the production process was taken, station siding No. 43 was chosen as the object of study, the area of contact network junction for setting locomotives for pushing and supplying locomotives under trains for the smooth organization of passenger traffic at station C. Based on the results of photographing the production process, it was revealed that that upon the arrival of odd trains, freight trains do not fit into the useful length of the receiving-departure track of the railway station C, which makes it difficult to install the pushing locomotive “on the go”, shunting movements are carried out with prohibitive indications of the shunting traffic light, since trains arrive along tracks No. 31, 33, 35, 37, 39 to track 23, where the speed is not more than 15 km/h. The next train, arriving at station C according to the train schedule, on the first main track, makes a forced stop, due to the arrival of the push locomotive on track 23. Also, according to the order on the norms of weight and length of trains calculated on the basis of a series of locomotives, a pushing locomotive is installed on trains [12-14].

During a practical study of station C, the possibility of electrifying dead end No. 43 was revealed, which showed the possibility of setting up a pushing locomotive from signal No. M82, without leaving the main track of the station. Electrification of this siding will allow pushing locomotives and passenger traffic locomotives to be set up in advance for timely placement under trains. The proposed reconstruction of the track will reduce the idle time of trains on the neighboring tracks of station C waiting for departure, provided that there are no restrictions on traction power supply.
According to the presented technical solutions, the construction of possible options for daily schedules of the work of station C was carried out, the values of the throughput of the object of study were determined, table 1.

**Table 1. Summary table of station throughput values**

| Throughput rate               | Unit | Value          | current chart | alternative solution |
|-------------------------------|------|----------------|---------------|----------------------|
| Total occupation time         | min  | 8562.01        | 9566.8        |
| Track utilization rate        | -    | 0.89           | 0.81          |
| Path power                    | train| 101/111        | 169/200       |
| Throat utilization ratio      | -    | 0.91           | 0.87          |
| Throat capacity               | train| 99/109         | 150/178       |

Throughput capacity of the considered neck: for the reception of odd transit freight trains: \( n = \frac{137}{0.87} = 150 \) trains; for the departure of even transit freight trains: \( n = \frac{162}{0.87} = 178 \) trains. The effectiveness of the event is 16067.28 million rubles per year.

The main purpose of using this technology for passing freight trains is to reduce the inter-train interval on section 1 of the railway line and significantly increase its capacity, without the need to build new tracks, as well as the optimal use of the existing tracks of station C, provided there are no restrictions on traction power supply.

The level of throughput of a railway section or facility determines the maximum value of trains of a certain weight that can be passed on a given line for a specified time interval, taking into account the technical equipment of its infrastructure. Accordingly, the value of the throughput in the considered section 1 is determined by the current power supply system, which makes it necessary to check its operability and uninterrupted operation in the conditions of an increase in freight traffic up to 150/178 trains, since the passage of long trains will have a significant load on all objects of the transport infrastructure of the section under consideration. We will carry out this check using traction calculations.

The traction load in the power supply system of the object under consideration is determined by traction calculations, which were carried out by the authors using the KORTES software package, designed to solve multi-level technical problems on personal computers in the Windows 98/Me/2000/XP environment, aimed at choosing the optimal operating modes and establishing uninterrupted parameters functioning, determining the characteristics of the modes and the load capacity of traction power supply systems and their individual elements [15, 16].

It is advisable to present the available capacity of the traction power supply infrastructure of the object under consideration as the maximum number of trains passed in even and odd directions of movement based on the following indicators of the load capacity of these devices:
- the power of power equipment of traction substations - step-down transformers of converter transformers and rectifier converters of the DC system, as well as autotransformers of the AC system 2x25 kV;
- voltage on current collectors of electromotive traction means;
- the value of the indicator of temperature heating of the wires of the contact network.

The established values of the above indicators of the operation of the traction power supply transport infrastructure facility must be taken in accordance with the regulatory and technical documentation approved by Russian Railways. The main criterion for the passage of freight trains exceeding the established weight during the maximum loaded periods of operation of the section under consideration, as well as during periods of possible planned technological breaks intended for various types of repair of infrastructure facilities, is the minimum value of the inter-train interval, which is permissible according to the above indicators of the load capacity of traction power supply devices [15-17].
Traction calculations and calculations of possible allowable modes of loading the AC system of section 1 of the railway line of the Eastern Railway Range, in the conditions of the passage of long trains when introducing the option of increasing the level of efficiency of the railway station, are shown in Figure 1 and Table 2.

**Figure 1.** Traction calculations when passing a freight train with a maximum weight.

**Table 2.** Report on traction calculation using the KORTES software package when passing a freight train with a maximum weight of 6300 tons

| Stage                           | Length, km | Travel time, min | Energy consumption |
|---------------------------------|------------|------------------|--------------------|
|                                 | total      | under current    | Wh                 | V-A-h              |
| GONCHAROVO - BOLSHOY LUG        | 18,0       | 15,9             | 8,8               | 1823,1             | 2163,1            |
| BOLSHOY LUG - PODKAMENNAYA      | 26,0       | 23,0             | 21,4              | 6125,7             | 7280,4            |
| PODKAMENNAYA – GLUBOKAYA        | 12,0       | 10,6             | 10,6              | 3103,9             | 3689,4            |
| GLUBOKAYA – ANDRIANOVSKAYA      | 12,0       | 10,3             | 8,2               | 1320,4             | 1566,8            |
| ANDRIANOVSKAYA – ANGASOLKA      | 12,0       | 13,2             | 1,1               | 295,3              | 346,6             |
| ANGASOLKA – SLYUDYANKA 2        | 21,0       | 22,9             | 0,0               | 368,3              | 430,3             |
| SLYUDYANKA 2 – SLYUDYANKA 1     | 6,0        | 6,7              | 1,1               | 222,7              | 262,6             |
| GONCHAROVO – SLYUDYANKA 1       | 107,0      | 102,7            | 51,2              | 13259,7            | 15739,4           |

KORTES - Traction calculations. Trip report. 02.02.2022. 9:40:06 am. Option 2
Road: East Siberian;
Section: GONCHAROVO - SLYUDYANKA-1 / odd 6300 tons, even 6300 tons;
Path type: link;
Structure: cargo, 85% loading;
Train: freight, weight 6780 tons, length 1279 meters, locomotive 2.5-2ES5K Yermak;
Energy consumption: 13259.7 kWh; recovery 0.0 kWh;
Specific consumption: active, 18.3 Wh/t-km; total 21.7 V-A-h / t-km;
Technical speed: 62.5 km/h;
Maximum train current: 1107 A per km 5238.49
Maximum overheating of the motor windings 990 (permissible 1300) per km 5260.20
Based on the analysis of the operating modes of section 1 of the railway line of the Eastern Railway Range, it can be concluded that the limiting load factor for the two types of freight trains does not go beyond the allowable limits, which have a standard value of 2.0. In this case, the temperature of the transformer oil is 65 °C, which also does not exceed the permissible set value of 95 °C. The voltage is within the allowable value. The temperature in the contact network and the suction line is low and does not exceed the maximum allowable value of 90°C.

4. The impact of the passage of long trains on the quality indicators of work and the throughput of transport infrastructure facilities

Reconstruction of the 43rd dead end of station C will allow non-stop passage of odd transit trains to station C2, circulating on this section, when performing shunting movements without leaving the pushing locomotives on the main track of the station. To implement the electrification project of the 43rd dead end of station C, it is necessary to build a 200-meter contact network in order to perform shunting work on setting push locomotives at the “head” of odd freight trains from 116 to 138 conditional wagons, as well as traction locomotives for tourist trains. This measure provides for an increase in the capacity of station C in an odd direction; at the moment, shunting work is carried out on the main running track of the station [16, 17].

Figure 2 shows the dependence of the throughput and carrying capacity of the infrastructure depending on various weight norms.

![Figure 2](image)

**Figure 2.** Graphical dependence of the throughput and carrying capacity of the infrastructure depending on various weight norms.

The estimated value of capital investments will be 1595.42 thousand rubles. At the same time, the additional construction of 200 meters of a contact network does not require a change in the staff of the power supply section, the costs are for maintenance and service. The costs of maintaining additional fixed assets will increase by 76.24 thousand rubles a year. [18].

The economic effect from the modernization of dead end No. 43 will be determined on the basis of the calculated performance of station C and the construction of a daily schedule of its work, will be obtained by reducing the downtime of freight trains waiting for departure, reducing the downtime of local cars and shunting operations. Savings from reducing the idle time of Eprost cars, thousand rubles / year, determined by the formula (1)
\[ E_{\text{prost}} = e_{\text{prost}} \cdot (\sum nt^0 - \sum nt^1) \cdot 365, \]

where \( e_{\text{prost}} \) - cost of wagon-hours of wagon downtime, rub;
\( \sum nt^0 \) - the sum of car-hours of downtime of the transit car before the reconstruction measures;
\( \sum nt^1 \) - the sum of car-hours of downtime of the transit car after the reconstruction measures.

\[ E_{\text{prost}} = 21,32 \cdot (6090,71 - 5666,25) \cdot 365 = 3303,06 \text{ thousand rubles/year}. \]

The value of the coefficient of economic efficiency will be 2.02. Estimated payback period is one year.

5. Conclusion
According to the study conducted by the authors, it can be concluded that with the current size of train traffic, the economic effect of improving the performance of station C amounted to 3303.06 thousand rubles/year. In the future, with an increase in train traffic, the economic effect will increase without requiring capital investments, and, accordingly, bringing additional profit due to an increase in freight turnover.

Having considered the effectiveness of the proposed design solution and calculated the payback period, which was one year, we can conclude that the project for the reconstruction of the contact network presented by the authors is acceptable for this station and the railway as a whole. The construction of a contact network in the 43rd dead end entails an improvement in the quality indicators of the station.

The traction calculations and calculations of the load modes of the AC system of section 1 of the railway line of the Eastern Railway Range, in the conditions of the passage of long trains when introducing the option of increasing the level of efficiency of the railway station C, proved the feasibility of electrifying the receiving and departing track.

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