Analytical Study of the Power Parameters of Electric Traction Drive for Modern Vehicles

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Abstract. The development of electric freight transport is becoming increasingly important against the backdrop of growing environmental problems, especially in megacities. The selection of the actual parameters of the power plant for electric freight vehicle is important here. This article analyzes the implemented projects in the world. The information gains particular relevance against the background of the absence of industrial production of power plants in the Russian Federation. The paper presents data on freight vehicles with a traction electric drive and deduces patterns in the value of the power of the used electric motors relative to the mass of the car in order to clarify the most popular standard-size series. This study was carried out with the aim of a feasibility study of models of electric motors for commercial vehicles proposed for launch into serial production.

Keywords: Electric vehicle · Hybrid vehicle · Ecology · Energy efficiency · Electric drive · Electric machines · Electric truck

1 Introduction

The prospect of electric-powered commercial vehicles in Russia has often been discussed, despite the slow growth, demand for each year. The level of demand for the growth curve in the world [1, 2].

Despite the fact that the prices for hydrocarbons in Russia are relatively low, the development of commercial vehicles on electric traction is developing rapidly [3, 4]. Currently, there are about 450 electric buses in use on public roads in Moscow, and trends are outlined for an increase in the fleet by 300 units annually. A further increase in the dynamics of development is impossible without the local production of electric motors.

The electric vehicle market is constantly evolving. For example, sales of passenger electric vehicles increased from 450 thousand units in 2015 to 2.1 million in 2019.

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According to forecasts of the research service Bloomberg NEF, their sales will decrease to 1.7 million electric vehicles in 2020 due to the coronavirus but will increase to 8.5 million by 2025, 36 million by 2030, and 54 million by 2040 [5].

Currently, there are a large number of trucks with electric transmissions of various carrying capacities [6] and the electric drive manufacturer needs to determine which characteristics will be most in demand. This requires an analysis of existing vehicles and their characteristics.

In Russia, despite the clearly insufficient number of electric stations, the lack of service for quickly replacing discharged batteries with charged ones by analogy with the Gogoro Network [7, 8], and other restrictions, the electric vehicle market is also gradually developing.

If we assume that even an electric vehicle for commercial cargo transportation will not be so popular, then the operation of buses with hydrogen fuel cells looks quite promising since hydrogen can significantly increase the range, thus, the electric transmission remains relevant and does not depend on the scenario of generating electricity [9].

All of the above facts once again emphasize the relevance of the topic raised by the author of the article.

The main purpose of the study was to determine the power parameters of the power plant of an electric freight vehicle, depending on the class.

The data of the analysis of the parameters of the power plant can be used in the design of electric trucks, for the selection of primary power values for the purpose of further calculations on the mathematical model, as well as for the development of technical specifications for the creation of a power plant.

2 Methods

During the research, the method of systematic analysis of the data on the parameters of the power plants of electric freight transport was used. Each selected component was analyzed as part of the problem, to identify positive and negative features. An empirical scientific approach is used, consisting of data collection, scientific analysis, hypothesis formulation, and theory development.

3 Research and Discussion

3.1 Data Collection

Collection of statistical data on the parameters of trucks of world manufacturers. The main parameters of electric trucks produced, as well as ready for production and denominated since 2017 [5–11] are summarized in Table 1.
Table 1. Characteristics of electric trucks.

| Name, features                  | Manufacturer              | Full weight, tons | Characteristics of the electric motor, kW |
|---------------------------------|---------------------------|-------------------|-------------------------------------------|
| Model 520, Transpower ElecTruck, 8 load class | Peterbilt | 36,00 | 280 |
| BYD 8R                          | BYD                       | 26,00             | 2 × 148                                   |
| LDV EV80                        | SAIC                      | 3,50              | 92                                        |
| ZRD                             | ZRD Auto                  | 2,00              | 18                                        |
| BYD BYD5071XXYBEV               | BYD                       | 7,49              | 125                                       |
| BYD BYD5030XXYBEV1              | BYD                       | 2,78              | 80                                        |
| BYD BYD5070XXYBEV               | BYD                       | 7,32              | 150                                       |
| BYD BYD5031XXYBEV               | BYD                       | 3,50              | 160                                       |
| BYD BYD5070XXYBEV1              | BYD                       | 7,32              | 125                                       |
| BYD BYD5110XXYBEV               | BYD                       | 10,70             | 150                                       |
| BYD BYD1070A7BBEV               | BYD                       | 7,32              | 110                                       |
| BYD BYD5070XXYBEV               | BYD                       | 7,32              | 150                                       |
| BYD1180D8DBEVD (T8C)            | BYD                       | 18,00             | 270                                       |
| BYD BYD3250EEFBEVD              | BYD                       | 25,00             | 180                                       |
| BYD BYD5160GSSBEVD              | BYD                       | 16,00             | 270                                       |
| BYD BYD1030K77BEVD              | BYD                       | 3,50              | 80                                        |
| BYD1071A7BBEVD                  | BYD                       | 7,50              | 125                                       |
| BYD1070A7BBEVD1                 | BYD                       | 7,32              | 90                                        |
| Jiefang J6F electric            | FAW                       | 4,50              | 50/100                                    |
| GINAF Dura Truck E2121,         | GINAF                     | 12,00             | 280                                       |
| Renault Trucks D                | Renault Trucks            | 13,00             | 103                                       |
| Emoss,                          | Emoss Mobile Systems B.V. |                   | 350                                       |
| VDL                             | VDL Bus & Coach           | 37,00             | 240                                       |
| Iveco Eforce E44                | E-FORCE ONE AG            | 44,00             | 350/550                                   |
| Cummins AEOS, 4 × 2,            | Cummins                   | 34,00             | 276                                       |
| Thor ET-One                     | Thor Trucks               | 36,00             | 224/522                                   |
| Toyota Fuel Cell Truck Semi,     | Toyota Motor North America Inc | 36,00       | 2 × 250                                   |
| RENAULT MASTER ZE               | RENAULT                   | 3,10              | 57                                        |
| RENAULT TRUCKS D ZE             | RENAULT                   | 16,00             | 130/185                                   |
| RENAULT TRUCKS D WIDE ZE        | RENAULT                   | 26,00             | 260/370                                   |
| Volvo FL Electric,              | Volvo                     | 27,00             | 400/330                                   |
| Futuricum 26E (Volvo FM),       | Designwerk Products AG    |                   | 4 × 560                                    |
| Freightliner eCascadia,         | Daimler Trucks            |                   | 545                                       |
| Freightliner eM2 106            | Daimler Trucks            |                   | 358                                       |
| Tesla Semi.                     | Tesla                     | 36,00             | 750                                       |
| Nikola One                      | Nikola                    |                   | 746                                       |
| Mercedes-Benz Sprinter, Orten ET35M | ORTEN Electric-Trucks    | 5,5, 4,2          | 81                                        |
3.2 The Type of Power Plants Used

By the type of electric machines used, electric trucks are no exception and, like all-electric vehicles, they mainly use three-phase brushless DC motors with neodymium magnets, i.e. BLDC or PMSM motors (valve motor according to the Soviet abbreviation), which have significant advantages:

The advantages of BLDC motors:

1) Lack of a brush assembly (as well as the lack of regular replacement of brushes, cleaning).
2) Simplicity of design and no excitation losses.
3) Higher specific power (kW/kg) in comparison with asynchronous motors (asynchronous motors of comparable power are noticeably heavier).
4) Low inertia with significant torque.
5) Maintaining the torque on the shaft, regardless of the rotor speed.
6) Higher starting torque than induction motors or brush motors of the same power. For electric vehicles, the moment of starting at the start is of great importance in order to move the vehicle from a state of rest.
7) High efficiency in the entire range of rotor speeds, including at reduced speeds.
8) Small dimensions. For example, an asynchronous machine of the same power and energy efficiency class is 2 times larger than an asynchronous motor.
9) Less cost of the controller in comparison with induction motors of comparable power.
10) More technological and cheaper in serial production.

3.3 The Choice of the Power Plant

The use of one or another electric vehicle on trucks is primarily associated with the basic requirements for a truck:

A) Gross vehicle mass.
B) Maximum speed of movement.
C) Dynamics of movement.
D) The cost of a pair of motor + controller

When choosing a power plant, they are guided by the following criteria:

A) Engine power, nominal - maximum - peak
B) Moment on the shaft, nominal - maximum - peak
C) Motor weight
D) Cooling type.

The type of transmission used and the gear ratio of the gearbox, which affect the torque and power characteristics of the selected power unit, are important when choosing. Trucks use various transmissions from the direct drive (through a gearbox) to a 6-speed automatic.

The operation of the selected power plant is checked on a mathematical model, depending on the operating conditions.
The power characteristics of the power plant are associated primarily with the total weight of the electric truck. Having analyzed this dependence, we build a power diagram versus the total mass of implemented electric truck projects (see Fig. 1), based on research data (see Table 1).

![Power of electric motor versus the total mass of implemented electric truck](image1)

**Fig. 1.** Power of electric motor versus the total mass of implemented electric truck

It is not difficult to notice points with overestimated power characteristics, falling out of the general picture. Since products with overestimated characteristics are prototypes, we delete these points and build an approximating line showing us the average dependence of power on the total mass of an electric truck (see Fig. 2).

![The dependence of average power of electric motor on the total mass of electric truck](image2)

**Fig. 2.** The dependence of average power of electric motor on the total mass of electric truck
This line can serve as a starting point for choosing the initial power of the power machine, with a known total mass, with further miscalculation and correction on a mathematical model.

3.4 The Range of Powers of the Applied Power Plants by Classes

The most effective classification of electric trucks should be considered the classification by gross weight, due to the fact that the weight of the supply battery assembly is quite significant and has a strong influence on the choice of the power plant [10].

The classification of trucks by gross weight is regulated by the standard UN 025 270-66. It is convenient to represent the designation system of automobile rolling stock in the form of a table (Table 2).

Table 2. Vehicle types by purpose (operation).

| Weight, t | Flatbed | Tractor | Dump Truck | Tanker | Van | Special |
|----------|---------|---------|------------|--------|-----|---------|
| to 1,2   | 13      | 14      | 15         | 16     | 17  | 19      |
| 1,2–2,0  | 23      | 24      | 25         | 26     | 27  | 29      |
| 2,0–8,0  | 33      | 34      | 35         | 36     | 37  | 39      |
| 8,0–14,0 | 43      | 44      | 45         | 46     | 47  | 49      |
| 14,0–20,0| 53      | 54      | 55         | 56     | 57  | 59      |
| 20,0–40,0| 63      | 64      | 65         | 66     | 67  | 69      |
| up 40,0  | 73      | 74      | 75         | 76     | 77  | 79      |

Some classes from 18 to 78 are missing from indexing, this is a reserve. The designations are as follows:

digit “1” - truck class (gross weight);
digit “2” - type of automatic telephone exchange:
3 - A flatbed truck or pickup;
4 - Truck tractor;
5 - Dump truck;
6 - Tanks;
7 - Van;
8 - Reserve digit;
9 - Special vehicle.
numbers “3” and “4” - serial number of the model;
digit “5” - car modification;
digit “6” - type of execution:
1 - Cold climate;
6 - Moderate;
7 - Tropical.

We sort the data in Table 1 for compliance with the total mass and power, taking into account the points out of the sequence (clause 3) From the sample of the digital
sequence, we obtain the range of powers of the power plants used in the corresponding weight class and enter it in Table 3. A similar classification of trucks is used in the United States [11].

In our case, it is necessary to obtain a range of applied capacities, therefore, the initial data is clearly insufficient for an assessment in this way. More objective data can be obtained from the graph of the correspondence of the total mass and power by means of mathematical operations. Create the upper and lower border of the averaged values (Fig. 3).

According to the classification, we find the values of the power spreads in the corresponding range from the lower to the upper approximation line and the average value. Result in Table 4.

| Correspondence of total weight (tons) and power (kW) | Type | Power (kW) |
|-----------------------------------------------------|------|------------|
| 2                                                   | 18   | 1.2–2.0    | 18     |
| 2,78                                                | 80   | 2.0–8.0    | 50–150 |
| 3,5                                                 | 80   |            |        |
| 4,5                                                 | 50   |            |        |
| 7,32                                                | 150  |            |        |
| 7,32                                                | 125  |            |        |
| 7,32                                                | 110  |            |        |
| 7,32                                                | 150  |            |        |
| 7,32                                                | 90   |            |        |
| 7,5                                                 | 125  |            |        |
| 7,5                                                 | 125  |            |        |
| 10,7                                                | 150  | 8.0–14.0   | 103-150|
| 13                                                  | 103  |            |        |
| 16                                                  | 150  | 14.0–20.0  | 150    |
| 18                                                  | 150  |            |        |
| 25                                                  | 180  | 20.0–40.0  | 180–300|
| 34                                                  | 276  |            |        |
| 36                                                  | 280  |            |        |
| 36                                                  | 300  |            |        |
| 37                                                  | 240  |            |        |
| 44                                                  | 350  | up 40      | 350    |
A significant spread in capacities is due to:

1. The use of transmissions with different gear ratios.
2. Different requirements for speed modes and dynamics.

Example: If you set the task of determining the optimal characteristics of the power plant for electric trucks of category 5 (gross weight 14–20 tons), then 3 trucks can be safely included in this category based on Table 1:

- RENAULT TRUCKS D ZE (van 16t) rated power 130 kW
- BYD1180D8DBEVD (chassis 18t) rated power 150 kW
- BYD BYD5160GSSBEVD (chassis 16t) rated power 150 kW

| Type | Power range, kW | Average value, kW |
|------|----------------|-------------------|
| 1    | to 1.2         | to 50             | 25                |
| 2    | 1.2–2.0        | 10–70             | 40                |
| 3    | 2.0–8.0        | 18–145            | 82                |
| 4    | 8.0–14.0       | 65–195            | 130               |
| 5    | 14.0–20.0      | 110–235           | 173               |
| 6    | 20.0–40.0      | 150–340           | 245               |
| 7    | Up 40          | Up 255            | 310               |

Table 4. Vehicle types by purpose (operation).
Thus, for the 5th category of electric trucks (gross weight 14–20 tons), the initial choice of the power plant with the following parameters will be optimal:

- type: permanent magnet synchronous motor.
- rated power 150 kW
- peak power 200 kW.

4 Conclusion

After analyzing existing vehicles and their electric motors, it is possible to identify the most optimal power ranges for each specific type of truck. Knowing the market capacity of certain types of trucks, you can calculate the number of electric motors that will be in demand. This information can be used for technical and economic calculations when preparing an electric motor for production. The authors of the work are aware that for each vehicle it is necessary to do a power calculation, but most of this calculation depends on the transmission. Therefore, the initial choice of the engine can be carried out based on the classification carried out and the ratio of truck sizes with the power of the electric motor.

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