Development of Commercial Electric Vehicles Platforms Adapted for the Use of Self-Driving Systems

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Abstract. One way to improve commercial vehicle safety and environmental protection is the application of modern technology, using electricity as a main power source. Electric vehicles have undeniable environmental advantages over cars with internal combustion engines. Scientific team of the NNSTU, with the support of engineers from the Joint GAZ Group Engineering Center and specialists from PJSC "GAZ", is developing a line-up of electrical platforms for commercial vehicles with autonomous power sources. The article presents an analytical review of existing prototypes of electrical platforms. The authors performed an assessment of the possibilities of usage an auxiliary power plant based on fuel cells (including the membrane type) as part of the electrical platforms. In addition, the work touches upon the problem of using traditional energy sources for electric platforms - traction batteries, because the consumer appeal of electrical platforms largely depends on the batteries. The authors propose the configuration of the chassis for the platforms. The configuration provides wide opportunities for the integration of automated and unmanned traffic control systems in commercial vehicles. The article presents a prototype of the electric platform, equipped with the developed systems of automated traffic control. In conclusion, the results of experimental studies, based on the running tests, are given.

1. Introduction
Vehicles are one of the main sources of environmental pollution. At this point, about 1 billion cars have been registered and analysts forecast that this value will be doubled by 2030. [1]. Vehicles with internal combustion engines (ICE) occupy a large part of the automotive market. And the same time such vehicles have the greatest impact on environmental pollution. The world's automakers, including manufacturers in the Russian Federation, must comply with a number of environmental safety requirements in the UNECE Regulations (No. 49, 83, 96) [2].

The commercial transport has a significant impact on the environment, because of constant operation with minimal downtime. The GAZ Group is the leader on Russian market of commercial vehicles and holds about 70% in the LCV category and 65% in the LDT category. [3]. A number of methods were considered to improve the environmental safety of the products of this manufacturer.

Comparatively cheap reserves of the environmental safety improvement of ICE are becoming exhausted and the development of new systems that meet the new standards and UNECE requirements leads to complication and increase of the vehicles' cost. It is established that the transition from Euro III to Euro IV on average increases the cost of a vehicle by 1000$. [4].
The environmental safety increasing of ICE is also possible due to the introduction of automation systems for vehicle traffic control, including the automation of engine control. [5]. In work [6] it is noted that autonomous vehicles will have higher environmental performance than similar man-operated vehicle due to the motion with optimal speed, smooth acceleration and braking, and also more efficiently chosen routes. According to the study mentioned in [7], the increase of the environmental performance will be up to 15%.

Almost every major vehicle manufacturer, supplier and technology company has announced projects or collaborations around the autonomous vehicles [8]. Studies by Json & Partners Company show that the market of self-driving cars will grow up to 30.4 million cars per year by 2035 [9].

Currently, the barriers of the self-driving vehicles distribution are the high cost of an unmanned traffic control system, many times greater than the cost of the car itself; unpreparedness of the infrastructure; problems of the information security. In addition, the key barrier is the existing regulatory framework, which prohibits the distribution in many states.

Usage an electric drive is the most promising way to improve the environmental friendliness of vehicles. The electrification of the road transport is currently one of the main trends in the development of the world automotive industry [10]. Despite the fact that in 2015 the share of electric vehicles in the global fleet was insignificant - about 0.1%, the share is projected to grow rapidly and will be around 10% by 2030 and around 40% by 2050 [11].

As well, the use of the electric drive allows the most effective implementation of traffic automation systems. This is due to the simpler control (in comparison with ICE) of the main units of the vehicle due to the high degree of electrification. The absence of additional actuators leads to the increase of the fault tolerance of the system, the increase in speed, simplification of the control system, and the reduction in the final price. Thus, the combination of the above technologies will have a positive social and economic effect, which come to the environmental impact reduction and the road safety improvement of commercial vehicles [12, 13], produced by the GAZ Group.

2. Development of commercial electric vehicles platforms

To implement the mentioned technologies, employees of the NNSTU, with the support of engineers from the Joint Engineering Center of the GAZ Group and specialists from United Engineering Centre of CAZ Group, carry out the works of the creation of an electric platform with autonomous power sources for commercial vehicles (Figure. 1).

![Figure 1. GAZ Group LCV lineup.](image_url)

At the first stage of the study, the analytical review of the existing electric LCV-platforms, available on the market, was made. Table 1 shows the main technical characteristics of the considered electrical platforms.
Table 1. Characteristics of electrical LCV-platforms.

| Model/Picture          | Power kWt (h.p.) | Range with GVW, km | Battery type, Power capacity | Full charging time, hours | Payload, kg |
|------------------------|------------------|--------------------|------------------------------|---------------------------|-------------|
| Ford Transit Connect Electric [14] | 50 (68)          | 130                | Li-ion, 28 kWh               | 4                         | 410         |
| Renault Master Z.E. [15]             | 57 (77)          | 200                | Li-ion, 33 kWh               | 6                         | 1000        |
| Volkswagen e-Crafter [16]         | 100 (135)        | 208                | Li-ion, 35.8 kWh             | -                         | 1700        |
| Workhorse N-Gen Electric Van [17]  | 160 (218)        | 160                | LFP, 60 kWh                  | -                         |             |
| EMOSS E-Bus [18]                | 158 (214)        | 200                | Li-ion                       | 3                         | -           |
| Iveco New Daily Electric [19]     | 60 (81)          | 130                | NaNiCl2, 85 kWh              | 2                         | 1500        |

The results of the analysis allow to conclude that the maximum range of electrical platforms is significantly less than the range for a similar car with ICE. This disadvantage can be eliminated by developing a city network of charging stations. However, the development of the network has limitations related to the contradiction between the development of electric transport and energy infrastructure. Generating electricity is an established technology, and the laws of energy transfer are likely to remain largely unchanged. Generally, the use of electric transport is being considered as a measure of reducing the environmental load in large cities, but the existing electric grids of the large cities operate at the limit that does not allow increasing of the electric power transmission.

At the same time, the way to increase the capacity of batteries to achieve the range without refueling about 300-400 km is seen as ambiguous. The energy intensity of the best lithium-ion batteries is today about 250 Wh/kg. With an energy consumption of 300 Wh/km for LCV, the mass of the batteries can be up to half of the car curb weight. It will significantly increase the energy consumption for traffic, and for commercial transport will reduce the payload.

Therefore, as an alternative version of the energy source for the developed electric platform, the application of fuel cells was considered.

Fuel cells with a proton exchange membrane are one of the most common types of fuel cells for generating vehicle power [20]. The comparative analysis of existing commercial vehicles with fuel cells was carried out. The main technical characteristics of the vehicles are presented in Table 2.
Table 2. Characteristics of vehicles with fuel cell.

| Model | NISSAN e-Bio Fuel-Cell | Hyundai H350 | Mercedes-Benz Sprinter fuel cell van | Mercedes-Benz Citaro | Toyota «Project Portal» |
|-------|------------------------|--------------|-------------------------------------|----------------------|------------------------|
| Picture | ![Picture](image1) | ![Picture](image2) | ![Picture](image3) | ![Picture](image4) | ![Picture](image5) |
| Fuel type | Ethanol | Hydrogen | Hydrogen | Hydrogen | Hydrogen |
| Power | - | 100 kW / 134 hp | 75 kW / 102 hp | 250 kW / 340 hp | 493 kW / 670 hp |
| Battery capacity | 24 kWh | 24 kWh | - | - | 12 kWh |
| Range | 600 km | 422 km | 150 km | 200 km | 320 km |
| Top speed | - | 150 km/h | 120 km/h | 80 km/h | - |
| Fuel mass / Tanks amount | 24 kg/1 | 7.05 kg /4 | - | 35 kg / 9 or 7 | - / 4 |

From Table 2, we can conclude that the most common alternative source of energy is hydrogen. The limiting factor for the distribution of vehicles with fuel cells is the lack of the hydrogen infrastructure. There is also a problem of obtaining and storing hydrogen [26]. First, the hydrogen must be clean, so that there is no quick depletion of the catalyst, and secondly, cheap, so that its cost is profitable for the end user. There are many ways to produce hydrogen, but about 50% of the hydrogen produced around the world is derived from natural gas. All other methods, at present, have high cost [27].

Based on the results of the analysis, it was decided to use batteries as a source of energy, because this technology is currently the most accessible, has significant accumulated experience of application and, despite the limitations, ensures the achievement of acceptable consumer properties of electrical platforms.

The next stage of the LCV electric platform creation, adapted for self-driving systems, was the formation of the structure of the electrical platform, design work and installation of components on the platform. Based on the results of the analysis, technical requirements for the electrical platform were developed. It is determined that for the creation of a competitive product, the key characteristics of the platform should be within the following limits: range is 120-200 km; payload is 1400-1600 kg; charging time is less than 7 hours. For the electric platform with the wheel arrangement 4x2, the electrical transmission scheme is selected. The scheme consists of a drive to the rear axle via thru the gear unit. This scheme is easy to implement and provides high indicators of consumer properties. The general view of the electric platform is shown in figure 2.

![Figure 2. The electrical platform.](image6)
The structure of the electrical platform is presented in figure 3. The power plant uses the Siemens 1PV5135 motor, which has a rated power of 61 kW and a nominal torque of 160 Nm. The platform with this motor in its traction and speed characteristics is not inferior to a similar vehicle with ICE.

![Figure 3. The structure of the electrical platform.](image)

The 48 kWh traction battery was selected as a power source. It provides the range of at least 100 km with a full load of the vehicle. The traction battery is equipped with battery management system (BMS). This system provides control of voltages and temperatures on each cell, the current strength, balances the cells. As well, the battery is equipped with heating system for operation during winter. The charger NGL 664 was used for the traction battery charging. The charger allows to fully charge the battery in less than 3 hours from the charging stations of the European standard IEC 62196-2. It is also possible to charge the battery using a typical household electrical outlet. The control unit of the electrical platform has an external control, which provides wide opportunities for the integration of automated and unmanned traffic control systems into commercial vehicles.

3. Development of the self-driving system

Automation of the developed electrical platform is one of the important tasks enabling in the near future to implement various driver assistance systems that reduce driver fatigue and improve road safety by warning the driver of potential hazards, as well as by actively influencing the driving of the electrical platform. Within the framework of this work, the driver assistance system is presented, the functional of which is aimed at recognizing the road scene, traffic objects and warning of the emergence of a critical situation. The hardware of the system consists of the Nvidia Jetson TX2 computing module and the Basler video camera. The fragment of the system's work is shown in figure 4. The main barrier of the development of these systems is the absence of Russian databases of signs and traffic lights. In view of this, the team of NNSTU has been working on collecting video data from the roads of Nizhny Novgorod and forming own database. The learning of the neural networks for the recognition of vehicles, traffic lights and traffic signs was carried out based on the collected data.
The tests were carried out at the GAZ Group test site and on public roads. The tests showed that the quality of the system in terms of vehicle recognition is around 85%. With regard to the recognition of road signs and traffic lights, additional work is required for collection of a wide range of data for further neural networks learning and improvement of the system quality.

At the next stage of system development, it is planned to introduce active sensors, such as short-range and long-range radars. Determining the type of object using a combination of a camera and a radar will alert the driver of potential hazards such as frontal and lateral collision with road users, and also control the electrical platform to prevent a critical situation.

4. Conclusions

The possibilities of the safety and ecological performance increase of commercial vehicles through the use of modern technologies that ensure the use of electricity as the main source of energy were considered in the work. The article presents an analytical review of existing prototypes of electrical platforms that have a number of environmental advantages over vehicles with ICE. The estimation of the possibilities of using an auxiliary power plant based on fuel elements of the membrane type in the structure of the electrical platform is considered. Based on the results of the analytical review and calculations, technical requirements for the key parameters of the electrical platform were developed. The hardware composition is proposed and the chassis of the electrical platform is developed. According to its technical characteristics, the platform is not inferior to the mass-produced analog with ICE. It is worth noting that on the basis of the developed electrical platform will be implemented a line-up of commercial vehicles (cargo and passenger types) of the GAZ Group.

The self-driving system, planned to be introduced into commercial electric vehicles, is presented. Results of the GAZ Group test site and road tests are given. The quality of the system in terms of vehicle recognition was 85%. The results of experimental studies in the conditions of the test site are presented. In the future, additional tests of the electrical platform, equipped with self-driving system, will be carried out.

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